

[IN THE KING'S BENCH DIVISION AND IN THE COURT OF APPEAL.]

K. B. D.

PAYZU, LIMITED *v.* SAUNDERS.

1919

May 6, 7, 8.

[1918 P. 658.]

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June 26, 27.

*Sale of Goods—Delivery by Instalments—Failure to make punctual Payment—
No Inference of Repudiation—Refusal of Seller to make further Deliveries
under Contract—Mitigation of Damages—Alternative Offer by Seller—
Duty of Buyer to accept.*

A contract for the sale of goods by the defendant to the plaintiffs provided that delivery should be as required during a period of nine months, and that payment should be made for each instalment within one month of delivery less $2\frac{1}{2}$ per cent. discount. The plaintiffs failed to make punctual payment for the first instalment, and the defendant, in the erroneous belief that the plaintiffs' failure to pay was due to their lack of means, refused to deliver any more of the goods under the contract, but offered to deliver the goods at the contract price if the plaintiffs would agree to pay cash at the time of the orders. The plaintiffs did not accept this offer, and, the market price of the goods having risen, brought an action against the defendant for breach of contract, claiming as damages the difference between the market price and the contract price:—

Held, by McCardie J., that the plaintiffs' failure to make punctual payment for the first instalment did not in the circumstances show an intention to repudiate the whole contract, and that the defendant was liable for damages; but that the plaintiffs should have mitigated their loss by accepting the defendant's offer, and that the damages recoverable were, not the difference between the market price and the contract price, but only such loss as the plaintiffs would have suffered if they had accepted that offer.

Brace v. Calder [1895] 2 Q. B. 253 followed and applied.

Held, by the Court of Appeal, that the question what steps a plaintiff in an action for breach of contract should take towards mitigating the damage is a question of fact and not of law; and that the Court below had come to a proper conclusion on this question.

ACTION tried by McCardie J. without a jury.

By a contract in writing dated November 9, 1917, the defendant, who was a dealer in silk, agreed to sell to the plaintiffs 200 pieces of crêpe de chine at 4s. 6d. a yard and 200 pieces at 5s. 11d. a yard, "delivery as required January to September, 1918; conditions, $2\frac{1}{2}$ per cent. 1 month," which meant that payment for goods delivered up to the

C. A. twentieth day of any month should be made on the twentieth
1919 day of the following month, subject to $2\frac{1}{2}$ per cent. discount.
PAYZU, At the request of the plaintiffs the defendant delivered, in
LD. November, 1917, a certain quantity of the goods under the
v. contract, the price of which amounted to 76*l.*, less $2\frac{1}{2}$ per cent.
SAUNDERS. discount. On December 21 the plaintiffs drew a cheque in
favour of the defendant in payment of these goods, but the
cheque was never received by the defendant. Early in
January, 1918, the defendant telephoned to the plaintiffs
asking why she had not received a cheque. The plaintiffs
then drew another cheque, but owing to a delay in obtaining
the signature of one of the plaintiffs' directors, this cheque
was not sent to the defendant until January 16. On that day
the plaintiffs gave an order by telephone for further deliveries
under the contract. The defendant in the belief, which was
in fact erroneous, that the plaintiffs' financial position was such
that they could not have met the cheque which they alleged had
been drawn in December, wrote to the plaintiffs on January 16
refusing to make any further deliveries under the contract
unless the plaintiffs paid cash with each order. The plaintiffs
refused to do this, and after some further correspondence
brought this action claiming damages for breach of contract.
The damages claimed were the difference between the market
prices in the middle of February, 1918, and the contract prices
of the two classes of goods, the difference alleged being
respectively 1*s.* 3*d.* and 1*s.* 4*d.* a yard.

Compston K.C. and *R. J. Willis* for the defendant. The failure of the plaintiffs to make punctual payment for the first instalment of the goods justified the defendant in drawing the inference that the plaintiffs were intending to repudiate the whole contract, and the defendant was therefore not bound to make any further deliveries under the contract: *Freeth v. Burr* (1); *Mersey Steel and Iron Co. v. Naylor, Benzon & Co.* (2) But assuming that the defendant has committed a breach of the contract, it was the duty of the plaintiffs to mitigate their loss so far as possible, and they should have

(1) (1874) L. R. 9 C. P. 208.

(2) (1884) 9 App. Cas. 434.

accepted the offer of the defendant to deliver the goods against cash.

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J. B. Matthews K.C. and *Turrell* for the plaintiffs. The defendant, not the plaintiffs, repudiated the contract. The doctrine of the mitigation of damages must be applied in a reasonable manner, and should not be made a fetish. It is not reasonable to expect a business man to enter into fresh contractual relations with a party who has just committed a breach of his contract. [They referred to ss. 10 and 31, sub-s. 2, of the Sale of Goods Act, 1893.]

[McCARDIE J. referred to *Brace v. Calder*. (1)]

Cur. adv. vult.

May 8. McCARDIE J., after stating the facts, said: It has been contended on behalf of the defendant that the failure of the plaintiffs to pay on or about December 20 for the goods delivered in November constituted in the circumstances such a breach of contract as amounted to a repudiation of the whole contract, and reliance was placed on *Mersey Steel and Iron Co. v. Naylor, Benzon & Co.* (2) It is not necessary to recapitulate the facts of that well-known case. In my opinion the decision so far from being in favour of the present defendant is distinctly against her. It is sufficient to refer to the following passage from the opinion of Lord Selborne (3): "I am content to take the rule as stated by Lord Coleridge in *Freeth v. Burr* (4), which is in substance, as I understand it, that you must look at the actual circumstances of the case in order to see whether the one party to the contract is relieved from its future performance by the conduct of the other; you must examine what that conduct is, so as to see whether it amounts to a renunciation, to an absolute refusal to perform the contract, such as would amount to a rescission if he had the power to rescind, and whether the other party may accept it as a reason for not performing his part; and I think that nothing more is necessary in the present case than to look at

(1) [1895] 2 Q. B. 253.

(2) 9 App. Cas. 434.

(3) Ibid. 438, 439.

(4) L. R. 9 C. P. 208.

C. A. the conduct of the parties, and see whether anything of that
1919 kind has taken place here."

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It is essential to remember in the present case that by s. 10 of the Sale of Goods Act, 1893, it is provided that unless a different intention appears from the terms of the contract, stipulations as to time of payment are not deemed to be of the essence of a contract of sale, and by s. 31 where there is a sale of goods to be delivered by stated instalments which are to be separately paid for, and the buyer refuses to pay for one or more instalments, "it is a question in each case depending on the terms of the contract and the circumstances of the case, whether the breach of contract is a repudiation of the whole contract or whether it is a severable breach giving rise to a claim for compensation but not to a right to treat the whole contract as repudiated." It is to be observed that in the present case the contract did not provide for delivery in any particular number of instalments. The deliveries were to be extended over the period from January to September, and it was contemplated that there would be an unspecified number of deliveries and a corresponding number of payments. I may, with diffidence, refer to my own judgment in *In re Rubel Bronze and Metal Co. and Vos* (5), where I referred to the leading authorities. I recognized that in certain circumstances a single breach of a contract may amount to a repudiation of the whole contract. I adhere to what I said in that case, but in the present case I entertain no doubt whatever that the plaintiffs' failure to make punctual payment for the November delivery did not amount to a repudiation of the contract, nor did it go to the root of the contract; on the other hand, in my opinion, the defendant's letter of January 16 did in fact and in law amount to an unjustifiable refusal by her to carry out her contractual obligations, for she announced in clear terms that she would thenceforth deliver no further goods to the plaintiffs under the contract unless the plaintiffs paid cash to cover each invoice. The market price of these goods was rising from the beginning of January and continued to rise up to the middle of February. The plaintiffs claim to

be entitled to damages based on the market price at that date. I find as a fact that the market prices in February were respectively 6*d.* and 7*d.* per yard in excess of the contract prices. The plaintiffs did not in fact purchase goods as against their contract with the defendant. They asserted that the market was so bare of goods as to render purchases impracticable.

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Now a serious question of law arises on the question of damages. I find as a fact that the defendant was ready and willing to supply the goods to the plaintiffs at the times and prices specified in the contract, provided the plaintiffs paid cash on delivery. Mr. Matthews argued with characteristic vigour and ability that the plaintiffs were entitled to ignore that offer on the ground that a person who has repudiated a contract cannot place the other party to the contract under an obligation to diminish his loss by accepting a new offer made by the party in default.

The question is one of juristic importance. What is the rule of law as to the duty to mitigate damages? I will first refer to the judgment of Cockburn C. J. in *Frost v. Knight*, (1) where he said: "In assessing the damages for breach of performance, a jury will of course take into account whatever the plaintiff has done, or has had the means of doing, and, as a prudent man, ought in reason to have done, whereby his loss has been, or would have been, diminished." This rule is strikingly exemplified in *Brace v. Calder*. (2) There the plaintiff claimed damages for wrongful dismissal. He had been employed as manager of a business carried on by four persons in partnership. In the course of his employment two of the partners retired, and the business continued to be carried on by the two remaining partners. The plaintiff resented his technical dismissal which resulted from the dissolution of the partnership, and declined to serve the two remaining partners; and he brought an action against the original firm claiming damages for wrongful dismissal. There was a difference of opinion in the Court of Appeal as to whether the plaintiff had been wrongly dismissed, but the members of

(1) (1872) L. R. 7 Ex. 111, 115.

(2) [1895] 2 Q. B. 253.

C. A. the Court were unanimously of opinion that the plaintiff as a
1919 prudent, reasonable man should have accepted the offer of
PAYZU, the two remaining partners to retain him in their service, and
LD. that he was therefore entitled to nominal damages only. I
v. think that the substance of the rule which I have indicated
SAUNDERS. was also laid down by the House of Lords in *British Westing-*
McCardie J. *house Electric and Manufacturing Co. v. Underground Electric*
Railways Co. of London (1), where Lord Haldane said :
“ The fundamental basis is thus compensation for pecuniary
loss naturally flowing from the breach ; but this first principle
is qualified by a second, which imposes on a plaintiff the duty
of taking all reasonable steps to mitigate the loss consequent
on the breach, and debars him from claiming any part of the
damage which is due to his neglect to take such steps.”

The question, therefore, is what a prudent person ought reasonably to do in order to mitigate his loss arising from a breach of contract. I feel no inclination to allow in a mercantile dispute an unhappy indulgence in far-fetched resentment or an undue sensitiveness to slights or unfortunately worded letters. Business often gives rise to certain asperities. But I agree that the plaintiffs in deciding whether to accept the defendant's offer were fully entitled to consider the terms in which the offer was made, its bona fides or otherwise, its relation to their own business methods and financial position, and all the circumstances of the case ; and it must be remembered that an acceptance of the offer would not preclude an action for damages for the actual loss sustained. Many illustrations might be given of the extraordinary results which would follow if the plaintiffs were entitled to reject the defendant's offer and incur a substantial measure of loss which would have been avoided by their acceptance of the offer. The plaintiffs were in fact in a position to pay cash for the goods, but instead of accepting the defendant's offer, which was made perfectly bona fide, the plaintiffs permitted themselves to sustain a large measure of loss which as prudent and reasonable people they ought to have avoided. But the fact that the plaintiffs have claimed damages on an erroneous

principle does not preclude me from awarding to them such damages as they have in fact suffered, calculated upon the correct basis. See *Cory v. Thames Ironworks and Ship-building Co.* (1) They have suffered serious and substantial business inconvenience, and I conceive that I am entitled to award them damages for that. The authorities are conveniently collected in *Arnold on Damages* at p. 13. Moreover, even if the plaintiffs had accepted the defendant's offer, they would nevertheless have lost the very useful period of credit which the contract gave them. Taking into consideration all the circumstances of the case I have come to the conclusion that the right sum to award as damages is 50*l.* I give judgment for the plaintiffs for that amount, and in view of the important points involved I give costs on the High C courtscale.

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Judgment for plaintiffs.

F. O. R.

The plaintiffs appealed on the question of damages.

June 26, 27. *J. B. Matthews K.C.* and *Turrell* for the appellants cited *Wilson v. Hicks* (2) and *Brace v. Calder*. (3)

Compston K.C. and *R. J. Willis* for the respondent were not called on.

BANKES L.J. At the trial of this case the defendant, the present respondent, raised two points: first, that she had committed no breach of the contract of sale, and secondly that, if there was a breach, yet she had offered and was always ready and willing to supply the pieces of silk, the subject of the contract, at the contract price for cash; that it was unreasonable on the part of the appellants not to accept that offer, and that therefore they cannot claim damages beyond what they would have lost by paying cash with each order instead of having a month's credit and a discount of 2½ per cent. We must take it that this was the offer made by the respondent. The case was fought and the learned

(1) (1868) L. R. 3 Q. B. 181.

(2) (1857) 26 L. J. (Ex.) 242.

(3) [1895] 2 Q. B. 253.

C. A. judge has given judgment upon that footing. It is true
1919 that the correspondence suggests that the respondent was at
PAYZU, one time claiming an increased price. But in this Court
LD. it must be taken that the offer was to supply the contract
v. goods at the contract price except that payment was to be
SAUNDERS. by cash instead of being on credit.
Banks L.J.

In these circumstances the only question is whether the appellants can establish that as matter of law they were not bound to consider any offer made by the respondent because of the attitude she had taken up. Upon this point McCardie J. referred to *British Westinghouse Electric and Manufacturing Co. v. Underground Electric Railways Co. of London* (1), where Lord Haldane L.C. said: "The fundamental basis is thus compensation for pecuniary loss naturally flowing from the breach; but this first principle is qualified by a second, which imposes on a plaintiff the duty of taking all reasonable steps to mitigate the loss consequent on the breach, and debars him from claiming any part of the damage which is due to his neglect to take such steps. In the words of James L.J. in *Dunkirk Colliery Co. v. Lever* (2): 'What the plaintiffs are entitled to is the full amount of the damage which they have really sustained by a breach of the contract. The person who has broken the contract not being exposed to additional cost by reason of the plaintiffs not doing what they ought to have done as reasonable men, and the plaintiffs not being under any obligation to do anything otherwise than in the ordinary course of business.' " It is plain that the question what is reasonable for a person to do in mitigation of his damages cannot be a question of law but must be one of fact in the circumstances of each particular case. There may be cases where as matter of fact it would be unreasonable to expect a plaintiff to consider any offer made in view of the treatment he has received from the defendant. If he had been rendering personal services and had been dismissed after being accused in presence of others of being a thief, and if after that his employer had offered to take him back into his service, most persons would think he was justified in refusing the offer,

(1) [1912] A. C. 673, 689.

(2) (1878) 9 Ch. D. 20, 25.

and that it would be unreasonable to ask him in this way to mitigate the damages in an action of wrongful dismissal. But that is not to state a principle of law, but a conclusion of fact to be arrived at on a consideration of all the circumstances of the case. Mr. Matthews complained that the respondent had treated his clients so badly that it would be unreasonable to expect them to listen to any proposition she might make. I do not agree. In my view each party was ready to accuse the other of conduct unworthy of a high commercial reputation, and there was nothing to justify the appellants in refusing to consider the respondent's offer. I think the learned judge came to a proper conclusion on the facts, and that the appeal must be dismissed.

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SCRUTTON L.J. I am of the same opinion. Whether it be more correct to say that a plaintiff must minimize his damages, or to say that he can recover no more than he would have suffered if he had acted reasonably, because any further damages do not reasonably follow from the defendant's breach, the result is the same. The plaintiff must take "all reasonable steps to mitigate the loss consequent on the breach," and this principle "debars him from claiming any part of the damage which is due to his neglect to take such steps": *British Westinghouse Electric and Manufacturing Co. v. Underground Electric Railways Co. of London*, per Lord Haldane L.C. (1) Mr. Matthews has contended that in considering what steps should be taken to mitigate the damage all contractual relations with the party in default must be excluded. That is contrary to my experience. In certain cases of personal service it may be unreasonable to expect a plaintiff to consider an offer from the other party who has grossly injured him; but in commercial contracts it is generally reasonable to accept an offer from the party in default. However, it is always a question of fact. About the law there is no difficulty.

EVE J. I agree. But for the difficulty introduced by the respondent's demand for a higher price than that named in

(1) [1912] A. C. 673, 689.

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the contract, I think this is a plain case. That difficulty is more apparent than real. It was not raised in the Court below, and there is not enough evidence to enable us to give effect to it, assuming it to be a matter of substance.

Appeal dismissed.

Solicitors for appellants: *W. H. Martin & Co.*
 Solicitors for respondent: *S. Myers & Son.*

W. H. G.

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[IN THE COURT OF APPEAL.]

THIRKELL v. CAMBI.

[1919 T. 58.]

Contract—Memorandum in Writing—Sale of Goods—Letter repudiating Contract—Solicitor—"Agent in that behalf"—Sale of Goods Act, 1893 (56 & 57 Vict. c. 71), s. 4.

By s. 4, sub-s. 1, of the Sale of Goods Act, 1893, a contract for the sale of any goods of the value of ten pounds or upwards shall not be enforceable by action unless, failing other alternatives, "some note or memorandum in writing of the contract be made and signed by the party to be charged or his agent in that behalf":—

Held, by the Court (Bankes and Scrutton L.JJ., and Eve J.), that a letter signed by the party to be charged or his agent in that behalf, and referring to other letters as containing the terms of a contract may, although it repudiates liability on the contract, be a sufficient note or memorandum in writing; but if, while referring to other letters, it refuses to admit that they contain the terms of the contract, it is not a sufficient note or memorandum.

Bailey v. Sweeting (1861) 9 C. B. (N.S.) 843; *Wilkinson v. Evans* (1866) L. R. 1 C. P. 407; *Buxton v. Rust* (1871), L. R. 7 Ex. 1, distinguished.

Held, further, by Scrutton L.J., that the letters in question omitted a material term of the contract.

Held, by Bankes L.J. and Eve J., that a solicitor instructed to deny a contract with which his client is charged is not the client's agent to make or sign a note or memorandum in writing of the contract for the purposes of the statute.

APPEAL from the judgment of Bailhache J. in an action tried before the learned judge without a jury.

[HOUSE OF LORDS.]

STEELE	APPELLANT ;	H. L. (N. I.)*
	AND	1942
ROBERT GEORGE AND COMPANY } (1937), LIMITED	RESPONDENTS.	Jan. 14, 15 ; Mar. 4.

Workmen's compensation—Incapacity resulting from injury—Workman's refusal to undergo operation—Reasonableness—Question of fact—Burden of proof—Workman's doctor against operation—Workmen's Compensation Act, 1925 (15 & 16 Geo. 5, c. 84), s. 9, sub-s. 1.

The question whether a workman is unreasonable in refusing to undergo a surgical operation with the object of diminishing an incapacity resulting from an accident is a question of fact to be decided by the judge of fact on the evidence. The onus of proving that the workman's refusal to undergo the operation is unreasonable is on the employer. Where the workman has been advised against the operation by a skilled medical man in whom he has confidence the employer can only discharge that onus by bringing home to the workman an extremely strong body of expert advice in favour of the operation.

Decision of the Court of Appeal in Northern Ireland [1941] N. I. 133, reversed.

APPEAL from the Court of Appeal in Northern Ireland.

The facts were stated by Viscount Simon L.C. as follows : The appellant was a joiner and on February 4, 1938, while working for the respondents, he fell from a height, landing on his feet on a tiled floor, and as a result his left ankle joint sustained a comminuted fracture which completely incapacitated him. He received weekly payments on this basis until September 3, 1940, when the respondents terminated the payments, alleging that his condition thenceforward was due to his unreasonable refusal to undergo a surgical operation. The appellant requested an arbitration. The case was heard by the recorder of Belfast and the evidence disclosed a conflict in the medical opinions tendered to the disabled appellant. Mr. Irwin, the surgeon who attended him in hospital after the accident and saw him on many occasions during the next two years, advised an operation, which, by making the injured joint stiff, would relieve the pain suffered from standing and

* *Present* : VISCOUNT SIMON L.C., LORD ATKIN, LORD WRIGHT, LORD ROMER, and LORD PORTER.

H. L. (N. I.) would, as Mr. Irwin confidently expected, give him a "strong stable limb." Mr. Irwin described the operation as a reasonable one, without extra risk beyond that attending any operation, and one which in his own practice had produced excellent results. Another surgeon, Major Fraser, who had also examined the appellant's injury, confirmed Mr. Irwin's view. The appellant, however, consulted a third surgeon to whom he was sent by his trade union, and this gentleman advised against the operation. The findings of the recorder, who ordered the respondents to pay the appellant a weekly sum of compensation, were as follows: "On this evidence I find that the applicant suffered a very severe and intractable injury as a result of which in his present condition he cannot bear weight on his foot without pain, and, therefore, cannot do joinery work, and no other work was suggested which he could do. I summarized the evidence on both sides and said one might consider the applicant in two capacities: (1.) as a patient when the question would be 'On balance of evidence, is operation a reasonable one?'; and (2.) as a claimant under the Workmen's Compensation Acts, when the question would be: 'Has the employer proved that his incapacity is due to unreasonable refusal to undergo operation?' Sometimes these points of view clash, as here, where the man seemed more anxious to establish his right under workmen's compensation than to get well. On balance of evidence I would hold operation one which a man might reasonably undergo. It affords a reasonable chance of relief from pain and ability to do some work, and the alternative is a lifetime of pain and idleness. There is no other remedy. But the real question for me is No. 2 and on this I find that: (a) a competent surgeon advises against the operation; (b) there is evidence that, even if the operation were successful, the man could not work or earn wages. As to (b), I do not accept the contention that a joiner with a stiff ankle can earn no money; but I cannot hold the claimant unreasonable in following the advice of a competent surgeon in the present case." The respondents having appealed, the Court of Appeal in Northern Ireland (Andrews C.J., Babington and Murphy L.JJ.) allowed the appeal, holding that the appellant was unreasonable in refusing to undergo the operation and that he was not entitled to an award of compensation. The appellant appealed to the House of Lords.

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Thomas Campbell K.C. (of the English Bar, K.C. of the H. L. (N. I.) Irish Bar) and *John Agnew* (of the Irish Bar) for the appellant.

Paull K.C. and *Goldie* (of the Irish Bar) for the respondents.

The arguments appear sufficiently from the opinions delivered.

The House took time for consideration.

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VISCOUNT SIMON L.C. My Lords, the Workmen's Compensation Acts do not contain any express provision that the weekly payment during incapacity shall come to an end or be reduced if the workman unreasonably refuses to undergo a surgical operation or other medical treatment for the purpose of ending, or diminishing, the incapacity. This ground of relief to the employer is based on the view that, if the proximate cause of the continuing incapacity is the unreasonable refusal of a workman to avail himself of surgical or medical skill, it can no longer be said that the incapacity "results from 'the injury' within the meaning of s. 9 of the Act of 1925, after the time when the rejected remedy might be confidently expected to bring about a cure. As *Fletcher Moulton L.J.* put it in *Warncken v. R. Moreland & Son, Ltd.* (1), "a workman must behave reasonably, and if the incapacity, or the 'continuance of the incapacity after a certain time, is due 'to the fact that he has not behaved reasonably, then the 'continuing incapacity is not a consequence of the accident, 'but a consequence of his own unreasonableness." This view of the matter has been recognized by this House in *Fife Coal Co., Ltd. v. Cant* (2), and in *Fyfe v. Fife Coal Co., Ltd.* (3), as well as in many cases in the Court of Appeal in England and in the Court of Session in Scotland. *Andrews C.J.*, in dealing with the present case in the Court of Appeal in Northern Ireland, admirably stated some of the considerations involved as follows (4): "If he [the workman] refuses to submit to 'an operation from defect of moral courage or because he is 'content to put up with the disablement and is willing to live 'on a pittance under the Workmen's Compensation Act he 'is not entitled to compensation. To borrow the language 'of the Lord Justice Clerk" [*Lord Macdonald in Donnelly v. Baird & Co., Ltd.* (5)], "the workman should do what a man 'of ordinary manly character would undergo for his own good,

(1) [1909] 1 K. B. 184, 189.

(2) 1921 S. C. (H. L.) 15.

(3) 1927 S. C. (H. L.) 103.

(4) [1941] N. I. 133, 136.

(5) 1908 S. C. 536, 540.

H. L. (N. I.) "in a case when no question of compensation being due by
"another existed."

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The principle is, therefore, established, though I may observe that cases might arise in which there would be some difficulty in working out the quantitative result of applying it. For example, if the proposed operation can at best only work a partial cure, it does not appear to be an easy matter to fix what the reduced figure of compensation should be. And a converse case may be imagined. Supposing that a workman who is partially incapacitated undergoes an operation which is recommended as likely to cure him, but the operation fails and reduces him to total incapacity—is the compensation due from the employer thereby increased?

In the present appeal, however, we are not troubled with these conundrums. Mr. Paull, in his candid and ingenious argument for the respondents, examined the grounds advanced for the opinion of the appellant's surgeon with a view to showing that the reasoning of the two experts who advised an operation should be preferred. This, however, is not the immediately relevant issue. The relevant question is whether the appellant was unreasonable in refusing to submit himself to the operation. It may in some cases be quite reasonable for a man to decide not to undergo an operation if his own doctor advises against it, for it is the conclusion reached by his doctor which governs his decision much more than the logic by which his doctor has reached the conclusion. In 1915, Lord Strathclyde, then Lord President of the Court of Session, went so far as to say in *Gracie v. Clyde Spinning Co., Ld.* (1), that he was prepared to hold "that, save in very "special circumstances, the proximate cause of incapacity "never can be the unreasonable refusal of a workman to "undergo an operation if his own medical adviser advises him "against undergoing that operation." The Lord President regarded this as the result of the decision of the Court of Session in *Sweeney v. Pumpherston Oil Co., Ld.* (2). It is not necessary to adopt a proposition which goes so far as this, and, indeed, Lord Birkenhead L.C., in *Fife Coal Co., Ld. v. Cant* (3), insisted that in each case the circumstances must be considered and that there was no general rule excusing the workman from undergoing a reasonable operation because his medical adviser advised against it. It is enough to say that

(1) 1915 S. C. 906, 910.

(3) 1921 S. C. (H. L.) 15, 22.

(2) (1903) 5 F. 972.

the question whether the workman is unreasonable in refusing to undergo an operation is a question of fact to be decided by the judge of fact on the evidence, and that where the workman has been advised against the operation by a skilled medical man in whom he has confidence, it would be necessary to bring home to the workman an extremely strong body of expert advice to the contrary before the onus which rests on the employer of proving that the refusal was unreasonable should be regarded as discharged.

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The recorder considered it to be proved that the operation was one which a man in the appellant's condition might reasonably undergo, and that it afforded a reasonable chance of relief from pain and of ability to do some work, while the alternative was a lifetime of pain and idleness. But he went on to say: "But I cannot hold the claimant unreasonable in following the advice of a competent surgeon in the present case." The Court of Appeal has interpreted this last sentence as a ruling in point of law. If the recorder should be understood as having asserted as matter of law that as long as an injured workman follows the advice of his own doctor in refusing to undergo the operation, the employer's case must fail, whatever the other circumstances are, he would have misdirected himself. But I do not so understand the sentence. The last four words of it show that no abstract doctrine was being enunciated, and when the recorder said: "I cannot hold," he did not, in my opinion, mean that the law constrained him to decide as he did, but that on a review of all the circumstances of the particular case, he felt unable to decide as a matter of fact that the appellant had acted unreasonably. There was evidence to support this conclusion of fact, and it cannot be upset on appeal. If the recorder, as the final judge of fact, had decided otherwise, his decision would have been equally unassailable. The appeal must, therefore, be allowed. I must add that, even if the recorder had been open to correction in point of law, I do not see how the Court of Appeal could itself properly undertake to determine the question of fact which would then arise. It would still be for the recorder to decide on the evidence to what conclusion of fact he himself would arrive. I move that the appeal be allowed with costs here and in the Court of Appeal.

LORD ATKIN. My Lords, I agree with the opinion which has just been given by the Lord Chancellor and only add a

H. L. (N. I.) few words as we are differing from the decision of the Court of Appeal. The appeal turns on the true view to be taken of the judgment of the learned recorder on a pure question of fact. The Court of Appeal appear to have considered that the recorder had found as a fact that the employers had proved that the workman was unreasonable in not submitting to the operation, but had held as a matter of law that the advice of the workman's doctor compelled a decision in his favour. I do not think that such a view does justice to the learned recorder. It appears to me that he rightly considered all the facts, including the important fact of the advice of the workman's doctor, and came to the conclusion in fact that the employers had not discharged the onus which lay on them to prove that the refusal of the workman to undergo the operation in the circumstances was unreasonable. As that decision was one of fact to support which there was ample evidence it is unassailable. I agree with the proposed motion.

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Lord Atkin.

LORD WRIGHT. My Lords, the appellant is appealing against an order of the Court of Appeal, discharging an award made by the recorder of Belfast in favour of the appellant for compensation under the Workmen's Compensation Act. The Court of Appeal held that, though the appellant had received an injury by accident arising out of and in the course of his employment, it had been established to the satisfaction of the court that he had been unreasonable in refusing to undergo an operation by which the incapacity resulting from the accident might be removed or reduced. The court ordered that the arbitration should stand adjourned with liberty to either party to apply.

The decision of the Court of Appeal presupposes, as I understand it, either that the recorder has made no finding of fact on the relevant issue, which is whether there has been an unreasonable refusal on the part of the man, or that his finding of fact is unsupported by evidence or involves a misdirection in law and, therefore, cannot stand. It is clear that the question whether a refusal to undergo an operation in cases of this character is reasonable or unreasonable "is an absolute matter of fact" as Lord Dunedin said in this House in *Fyfe v. Fife Coal Co., Ltd.* (1). If the arbitrator decided that the refusal was not unreasonable there is an end of the matter unless there was no evidence to support his finding or

(1) 1927 S. C. (H. L.) 103, 106.

he misdirected himself. In the present case, the recorder's words were: "I cannot hold the claimant unreasonable in following the advice of a competent surgeon in the present case." The words which precede or follow in the award are merely argumentative. The precise words of decision which I have quoted correctly approach the problem as being one the solution of which depends on the facts of the case. The recorder expressly limits his decision to the present case. The recorder also treats the problem as being one in which the precise issue is whether the employers have discharged the burden of proof which rests on them of showing that the man was unreasonable in his refusal to undergo the operation, and refuses to hold that they have. That is how I construe the award, and, in my opinion, the result is that the decision is final. It is not based on any principle as to what does or does not in law constitute unreasonableness in these matters. Indeed, I do not see that any legal rule can be stated to determine the decision of the arbitrator. As Lord Birkenhead explained in *Fife Coal Co. v. Cant* (1), the circumstances must be considered in each case. A good many decisions have been reported on this question, but once it is appreciated that the question is one of fact, decisions in other cases are more likely to mislead than to guide, though perhaps sometimes it may help to know what was decided on more or less similar facts.

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The rule as to the effect of an unreasonable refusal by a workman to undergo an operation, which has been approved by the two decisions of this House which I have quoted, was a piece of judicial legislation adopted by the Court of Appeal as long ago as 1903, but it has not been disavowed or qualified by the legislature in the subsequent revisions or re-enactments of the Act. It must be taken to have commended itself to the general sense of the community, but it is not easy to understand or apply. It is rather a penalty provision than anything else. I find it not very logical to say that the workman's refusal breaks the chain of causality between the accident and the incapacity. On the contrary, effects of the accident still remain. The operation, furthermore, may not be successful, even if it is not refused. Quite apart from the surgical evidence in the particular case, which may be conflicting, the workman's own physical or mental idiosyncrasy cannot in general be excluded. I believe that arbitrators

H. L. (N. I.) have approached these questions in a humane and liberal spirit, realizing that the question cannot be decided save on a sympathetic estimate of the workman's personality and the special circumstances of the particular case.

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With the greatest respect to the Court of Appeal, I cannot agree with their conclusion. In any event they were not entitled to usurp the function of the recorder as the judge of fact. For the reasons stated by my noble and learned friend the Lord Chancellor I concur in the motion proposed.

LORD ROMER (read by LORD PORTER). My Lords, it appears to have been decided by authorities that are binding on this House that where an incapacitated workman unreasonably refuses to submit himself to an operation which, if successful, would restore his capacity in whole or in part, his right to compensation on the footing of his existing incapacity ceases as from the date on which the capacity might reasonably be expected to have been so restored had the operation been successfully performed. The question whether in any particular case the workman has unreasonably refused to undergo an operation is purely a question of fact, and is, therefore, one on which the finding of the arbitrator is conclusive unless there is no evidence on which his finding can properly be based or unless he has misdirected himself in law. In the present case the arbitrator was the learned recorder of Belfast, and he plainly decided the question of fact in favour of the appellant, for he said: "I cannot hold the claimant unreasonable in following the advice of a competent surgeon in the present case," and he made an award in the appellant's favour. It cannot be denied that there was ample evidence on which this finding of fact could be based. The Court of Appeal, however, set aside the award of the arbitrator on the ground that he had misdirected himself in law. Looking at the award as a whole, they came to the conclusion that the arbitrator himself was of opinion on the evidence that the appellant was unreasonable in refusing to undergo the operation, but that he, the arbitrator, considered himself bound as a matter of law to decide in the appellant's favour merely by reason of the fact that the appellant's own surgeon had advised against it, and without the arbitrator forming any conclusion as to the weight that ought to be attached to the surgeon's opinion or as to the grounds on which that opinion was based. The Lord Chief Justice, after referring to the finding which I

cited a few moments ago, said this (1): "In this finding, at H. L. (N. I.) "which he appears to have arrived without considering the "grounds or the sufficiency of the reasons advanced by the "surgeon in support of his opinion, the learned recorder was, "in my opinion, in error on the authorities to which I have "referred, and on this vital issue he accordingly misdirected "himself." Babington L.J. said (2): "The recorder's award "as I read it finds that the applicant was unreasonable in "not submitting to the operation in fact, but that he was not "unreasonable in law because his refusal was based on the "advice of his own doctor." Murphy L.J., after referring to the opinion of the surgeon in question, said (3) that the recorder did not appear to have agreed with it, and that in treating that opinion as conclusive on the question of the reasonableness of the appellant the recorder had misdirected himself.

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Lord Romer.

My Lords, if the Court of Appeal were right in the construction which they put on the award, they were unquestionably right in allowing the appeal. With all respect to the learned recorder, it must be confessed that his award is not so clear as could have been wished. I have, nevertheless, come to the conclusion, after giving it my careful consideration, that it does not bear the meaning attributed to it by the Court of Appeal. A perusal of the judgments of that court makes it clear that the conclusion to which they came was largely if not wholly based on a finding in the award that comes a little earlier than the one which I have already cited. It is in these words: "On balance of evidence I would hold "operation one which a man might reasonably undergo. It "affords a reasonable chance of relief from pain and ability "to do some work, and the alternative is a lifetime of pain "and idleness. There is no other remedy." This was understood by the Court of Appeal to be a finding by the learned recorder that in his opinion the refusal of the appellant to undergo the operation was unreasonable. I do not so read it. It is no more than a finding that there was nothing unreasonable in asking a man—i.e., any man suffering from the same physical disabilities as the appellant's—to undergo the operation. Had the finding been the other way, there would have been no more to be said. The award would necessarily have been in the appellant's favour. As it was, it was necessary for the

(1) [1941] N. I. 133, 142.

(2) Ibid. 143.

(3) Ibid. 146.

H. L. (N. I.) arbitrator to go on to consider whether in the particular case before him the appellant's refusal was unreasonable. He held that it was not, and I can find nothing inconsistent in the two findings. Nor can I find in the later of the two findings any indication that the recorder regarded himself as bound by law to hold that a workman necessarily acted reasonably in refusing an operation merely because his own surgeon advised him to do so. The recorder was careful to confine his finding to the advice of the "competent surgeon" "in the present case." I cannot think that he would have described the surgeon as competent if he had considered neither the grounds nor the sufficiency of his opinion, nor would he have added the words "in the present case" if he had been merely intending to state a proposition of law. The surgeon had stated in his evidence that, although the operation, if successful, would prevent lateral movement of the joint, it would, if unsuccessful, result in there being no movement in the joint at all. I can find no indication in the award that this evidence was not accepted by the recorder, and, if he did accept it, it is only reasonable to suppose that he took it into consideration in forming an opinion as to the reasonableness or otherwise of the appellant's refusal. With all deference to the Court of Appeal I am unable to agree with them that the recorder misdirected himself in any way. If he did not, his finding that the appellant was not unreasonable in his refusal must be taken to be conclusive. For these reasons I would allow the appeal, and I concur in the motion now before the House.

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LORD PORTER. My Lords, I agree and have little to add. The only question in the present case, as I understand the matter, is to determine whether the learned arbitrator was justified in law on the facts found or admitted in holding that the respondents had not proved the appellant to have acted unreasonably in refusing to undergo the operation which was suggested. His main findings were (1.) that on a balance of evidence the operation is one which a man might reasonably undergo, but (2.) "I cannot hold the claimant unreasonable" "in following the advice of a competent surgeon *in the present case.*" The italics are mine. If this were all, the respondents' case would be unarguable, but it is said that the second finding, when read in the light of his other conclusions, means: "I cannot hold any claimant including this one unreasonable

"in any case where he follows the advice of a competent H. L. (N. I.)
 "surgeon. If it were not that I take this view, I should
 "hold him unreasonable." The other findings which are
 relied on to support this contention are : (i.) "The man seemed
 "more anxious to establish his right under workmen's com-
 "pensation than to get well" ; (ii.) The operation "affords a
 "reasonable chance of relief from pain and ability to do some
 "work, and the alternative is a lifetime of pain and idleness.
 "There is no other remedy."

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 Lord Porter.

As to the first of these additional findings, it is said that the true test is laid down in the Court of Session in the judgment of Lord Macdonald in *Donnelly v. Baird & Co., Ltd.* (1), and that where a tribunal has to decide as to the reasonableness or unreasonableness of a workman's attitude in refusing to undergo an operation, the questions to be determined are : Was there any serious risk ? and, Would a workman of manly character undergo the operation ? In making up his mind, it was said, the workman was not entitled to consider that, by refusing, he would retain his compensation when, by consenting, he might lose the whole or part of it. This statement of the law does not, to my mind, mean that wherever a workman is influenced by the fact that he is receiving compensation he is acting unreasonably in refusing to undergo an operation. Probably, no workman can fail to be moved to some extent by such a consideration. Between starvation and an operation involving a serious risk he might well choose the latter, but yet refuse to undergo it where he was in receipt of compensation, and yet not be held unreasonable in doing so. But the overriding consideration must not be the retention of compensation where other circumstances make the refusal to undergo the operation unreasonable. It is true that in the present case the operation is not a serious one, but, nevertheless, it seems to me impossible to overrule the finding of an arbitrator who comes to the conclusion that the workman has not been unreasonable in the circumstances in following the advice of a competent surgeon—the circumstances, apparently, being that the surgeon took the view that, if the operation were unsuccessful, the workman would be worse than before, and that both the man himself and his trade union representative thought that, even if it were successful, he would be unable to follow his former employment. The witnesses might be wrong in their beliefs yet not

H. L. (N. I.) unreasonable in holding them and the appellant not unreasonable in acting on them. It is admitted that the onus of proving that the workman has been unreasonable is on the employer, and to succeed he must, I think, procure a finding of the arbitrator to that effect. It is not enough that there was evidence both ways or even that there was evidence from which a finding might be drawn that the man was unreasonable. In default of such a finding the matter should be referred back to the arbitrator. It could only be decided by a Court of Appeal in favour of the employer if it inevitably followed from the facts found that the workman must in law have been held to be unreasonable. So far from this being the case in the present instance, there is a finding of fact in favour of the appellant, and, in my view, no lack of evidence to support it. There are no findings or admitted facts from which it was incumbent on the arbitrator to find the appellant unreasonable.

In the course of the argument we have been referred to a number of cases where the workman has or has not been held to be unreasonable as the case might be. I do not find myself much assisted by them. They seem to turn largely on the facts of the individual case and on the findings of the several arbitrators.

My Lords, in arriving at this conclusion, I am not conscious of differing from the views of the members of the Court of Appeal in Northern Ireland in any general matter of the law applicable to workmen's compensation. I differ only on their construction of the finding of the learned arbitrator. They took him to mean that where the workman followed the advice of his doctor he could never be held to be unreasonable and that in this particular case he would have found the appellant unreasonable had it not been for this view. As I have pointed out, I do not so understand him. I think he took into consideration, as indeed he states, all the circumstances of the case, and having regard to those circumstances I think he had legal grounds for his conclusion. I would allow the appeal.

Solicitors for appellant : *L. Bingham & Co., for H. J. Catchpole, Belfast.*

Solicitors for respondents : *C. Grobel, Son & Co., for J. Donnelly & Co., Belfast.*

Savage v Wallis T

No Substantial Judicial Treatment

Court

Court of Appeal

Judgment Date

3 February 1966

Where Reported

[1966] 1 Lloyd's Rep. 357

[1966] 2 WLUK 16

116 N.L.J. 837

[1966] C.L.Y. 3243

Subject

Personal injury

Keywords

Causation; Epilepsy; Medical treatment; Personal injury

Case Digest

Abstract

The plaintiff sustained skull injuries in June 1960. From September 1963 he began to suffer from epileptiform attacks with mental deterioration but refused to undergo a slight operation to stop the headaches of which he complained.

Held, that the epilepsy could not be attributed to the accident of 1960, and that the plaintiff was not unreasonable in refusing the operation but that this did not affect the damages.

back to the Tribunal for it to determine this question. But the Tribunal must remember that the mere fact that the original dismissal was for an indefinite and unlimited period is by no means conclusive—far from it. It must look back at all the facts and circumstances from the time of the first dismissal until the time of the dismissal upon which the claim for a redundancy payment is made and reach a commonsense conclusion upon the whole matter.

My Lords, for this reason I would allow the appeal and remit the matter for further determination by the Tribunal.

LORD WILBERFORCE.—My Lords, I concur with my noble and learned friend, Lord Upjohn, and would allow the appeal.

APPEAL allowed, and the case remitted to the Industrial Tribunal with a direction to proceed in accordance with the majority opinions expressed in the House.

W. H. Thompson, for Courtney & Co., S.S.C., and L. & L. Lawrence, Glasgow
—*Allen & Overy, for Campbell Smith & Co., W.S.*

M'KEW v. HOLLAND & HANNEN & CUBITTS
(SCOTLAND) LTD.

No. 2.
Nov. 26, 1969.

Lords Reid, Hodson, Guest,
Viscount Dilhorne, Lord Upjohn.

ABRAHAM M'KEW, Pursuer (Appellant).—
Gimson, Q.C.—Pinkerton.

HOLLAND & HANNEN & CUBITTS (SCOTLAND) LIMITED,
Defenders (Respondents).—*Hon. H. S. Keith, Q.C.—Edward.*

Reparation—Negligence—Remoteness of damage—Pursuer's leg weakened by accident due to defenders' fault—Second accident arising from weakness of leg while pursuer attempting to descend staircase—Liability of defenders for injury caused by second accident—Reasonableness of pursuer's conduct—Novus actus interveniens—Foreseeability.

A workman sustained an injury in an accident admittedly due to his employers' fault. As a result his left leg was weakened, and on several occasions it became numb and he lost control of it for a short time. Three weeks after the accident he went to inspect a house of which he had been offered the tenancy. On leaving it, accompanied by his wife and brother-in-law, he was making to descend a steep staircase of ten steps without a handrail, when his left leg went numb, and, fearing that he might fall, he jumped to the bottom of the staircase, sustaining further injury.

In an action by him against his employers for damages in respect of both accidents,—

Held (aff. judgment of the Second Division) that the pursuer ought to have realised that he could descend the staircase safely only if he either went extremely slowly and carefully, so that he could sit down in an emergency, or waited for the assistance of his wife and brother-in-law; that he acted unreasonably in choosing to descend as he did; that his unreasonable conduct was *novus actus interveniens*, breaking the chain of causation, and that it and its consequences were not the natural and

probable result of the defenders' admitted fault; and consequently that the defenders were not liable for the injury sustained in the second accident.

Lord Guest was further of *opinion* that the pursuer's decision to jump was unreasonable conduct. Lord Reid, with whom Lord Hodson and Viscount Dilhorne *concurred*, was of *opinion* that the decision to jump, having been taken in an emergency, was no more than an error of judgment.

Per Lord Reid: "I do not think that foreseeability comes into this . . . it is often easy to foresee unreasonable conduct or some other *novus actus interveniens* as being quite likely. But that does not mean that the defender must pay for damage caused by the *novus actus*."

(In the Court of Session 30th September 1968—1969 S.C. 14.)

Abraham M'Kew brought an action against his employers, Holland & Hannen & Cubitts (Scotland) Limited, in which he claimed damages in respect of personal injuries sustained by him in two accidents, the first of which occurred on 14th February 1963 and the second on 7th March 1963.

The following narrative of the facts, as ascertained at a proof before answer, is taken from the opinion of the Lord Justice-Clerk:—"The pursuer sustained certain injuries as a result of an accident which occurred on 14th February 1963, while he was in the defenders' employment. These injuries were mainly to his back, left hip and left leg and were relatively minor. The defenders now concede that this accident was caused by their negligence, and it is common ground that the appropriate award in respect of the injuries then sustained is £200. On 7th March 1963, however, the pursuer met with a further accident, as a result of which he sustained severe injuries to his right ankle. Parties were agreed that, if the defenders be liable to make reparation for those injuries, the appropriate award in respect thereof is £4915. The question in issue is whether the defenders are so liable. According to the pursuer, the second accident was directly attributable to the injury sustained on 14th February 1963. According to the defenders, the second accident was in no way connected with any earlier injury, and they contend that the injuries to the right ankle are too remote to be accepted as consequences of the earlier accident. This contention was upheld by the Lord Ordinary.

"The second accident occurred when the pursuer was about to descend a flight of stairs leading from a house which he had been visiting. His case on record is that, as he was about to do so, 'his left leg suddenly gave way under him (due to the said [*i.e.* earlier] injury which he had sustained) and he fell down the stairs.' His evidence, however, is not that he *fell*, but that his left leg 'just went' and he *jumped* ten steps down to the next landing. The pursuer's own evidence as to what precisely happened at the vital moment is by no means clear. Furthermore, the Lord Ordinary did not accept Mrs M'Kew's evidence as to how the accident happened as being entirely honest and reliable, and he did not get the impression that Jamesina M'Kew's evidence was genuine recollection, apart from her remembering that the pursuer had fallen down the stairs and hurt his legs. After a careful review of the evidence the Lord Ordinary held it to be proved that 'the pursuer deliberately jumped down the stairs by obtaining leverage from his right foot consequent upon feeling a sudden weakness in his left leg (giving the impression of giving way) while at the top of the flight of stairs': and that it was as a result of this voluntary action—the deliberate jump—that he sustained the second accident and the severe injuries to his right leg. These findings were not seriously challenged and, in my opinion, they are justified by the evidence. I agree, however, with the pursuer's counsel that the pursuer's action was voluntary and deliberate, not in the sense of being the result of a planned and premeditated choice, but in the sense that it was intentional and not accidental. It is also clear that, but for the weakness of

the left leg, the jump and the injuries to the right leg would not have occurred and that the first accident was the cause of that weakness."

The pursuer pleaded, *inter alia* :—" (1) The pursuer, having suffered loss, injury and damage through the fault and negligence of the defenders *et separatim* their breach of statutory duty as condescended on, is entitled to reparation therefor."

The defenders pleaded, *inter alia* :—" (1) The pursuer's averments being irrelevant, *et separatim* being lacking in specification, the action should be dismissed."

On 13th July 1967, after a proof before answer, the Lord Ordinary (Robertson) sustained the pursuer's first plea in law and awarded him £200 in respect of the first accident; and sustained the defenders' first plea in law *quoad* the second accident and dismissed the action *quoad* that accident and its effects.

The pursuer reclaimed, but on 30th September 1968 the Second Division (without Lord Milligan) refused the reclaiming motion.

The pursuer appealed to the House of Lords, before which the case was heard on 9th and 13th October 1969.

Argued for the pursuer (appellant);—The weakness of the appellant's leg manifested itself in the course of reasonable conduct by him in seeking to descend the stairs unaided and in reacting as he did when he fell. He acted reasonably in an unforeseeable emergency. His actions in the agony of the moment did not necessarily make him negligent. There was no cross-examination of him or of his doctor to suggest that he should not have taken the course he did or that it was unreasonable of him to be going about. The whole evidence tended to the view that he was allowed by his doctor to come and go as he wished. In the absence of cross-examination it was not open to the respondents to say that this was unreasonable conduct by him amounting to a *novus actus interveniens*. If the alternative to what he did was breaking his neck or fracturing his skull, his choice was the better one. Cross-examination on this point would have given him the opportunity to expand his account of his experience. The time when his movements fell to be considered was the moment of risk. It was the respondents who had caused him to be unstable by reason of the first accident. The result of the second accident was the direct result of the first injury. This case was not analogous to the "thin skull" cases. The respondents had a continuing responsibility for the condition of this man's leg and for the consequences which flowed from that condition. The second accident did not break the chain of causation.¹ In *M'Leod v. Humphrey & Glasgow Ltd.*² Lord Migdale asked himself whether it was foreseeable that the event at the end of the chain of events would have followed from the initial negligence. It was enough to make the respondents liable if it was foreseeable that the appellant would be liable to stumble, and a wide range of physical injuries might follow if a stumble occurred.³ The test which the Lord Ordinary should have applied here was: Was the situation at the head of the staircase, caused by the instability created by the respondents' original negligence, foreseeable? They were liable for what followed from that. The correct test was not whether the respondents could have foreseen the pursuer's jump. The damage was the natural and reasonable result of their negligence.⁴ That applied to the physical condition of the appellant and to his reaction to an emergency. Here the correct question to ask was whether it was reasonably

¹ The Oropesa, [1943] P. 32, Lord Wright at pp. 35-6, 39.

² Outer House (Lord Migdale), 28th May 1954, unreported.

³ Hughes v. Lord Advocate, 1963 S.C. (H.L.) 31, Lord Morris of Borth-y-Gest at pp. 43-4, Lord Pearce at p. 48.

⁴ S.S. Baron Vernon v. S.S. Metagama, 1928 S.C. (H.L.) 21, Viscount Haldane at pp. 25, 26, Viscount Dunedin at p. 27; Steel v. Glasgow Iron and Steel Co., 1944 S.C. 237.

foreseeable that the injury would cause the danger of a fall in the circumstances of the present case. The emergency was the direct consequence of the initial injury, which was linked by a direct chain to the ultimate injury. When an injured person was doing something not in itself unreasonable, which would be safe but for the injury caused by the defenders' negligence, the defenders were not wholly free from liability for a second accident, even in the case of a completely unwarrantable act by the injured person. If the appellant had disclosed by his evidence that his acts were unreasonable, he must fail, but otherwise the onus remained on the respondents in a case such as this. In the moment of emergency the appellant was *bona fide* doing something which in the situation appeared to him to be reasonable and which a reasonable man might have done.

Argued for the defenders (respondents) ;—It was accepted that the respondents were liable for the accident sustained at work. The other and different injuries sustained later were not connected with the first injuries. The basic principle was that of foreseeability. The respondents were liable only for the foreseeable consequences of their negligence. Here the second injuries would not have occurred but for the intervening act of the appellant. If in the course of ordinary normal conduct his leg had given way and he had sustained other injuries, the respondents would have been liable for that. In fact the injuries were immediately caused by his jumping down the staircase. Should what happened have been in the contemplation of the respondents, as reasonable persons, as a consequence of the previous accident and injury to his leg? Clearly not. It was not a reasonable and probable consequence of their failure to take care.¹ This was not the kind of case where the consequence resulted directly from the defender's negligence. A pursuer must show the necessary links in the chain of causation. The situation was different when the original injury was not the direct cause of the damage.² There was a distinction between damage which resulted directly from the original fault and a case where something else came between. In the latter case the injured party must rely on the intermediate link and the onus was on him to prove causation. The onus of proof was dealt with in *Steel's* case.³ It was accepted that in most cases the onus was of no consequence, but in the present case it was not for the respondents to prove that the chain of causation was broken but for the appellant to establish the link. If it was left uncertain whether the appellant's conduct in jumping was reasonable, he must fail. An intervention, whether by the pursuer or by a third party, could be a link only if it represented normal human conduct which should have been in the contemplation of the defenders.⁴ The facts of the present case must be considered in the light of these principles, and so it was necessary to consider whether the appellant's conduct leading up to his second accident was reasonable. Was his act normal human conduct such as a reasonable man in his position would perform? The question was not whether it seemed reasonable to him but whether it was reasonable in a normal man. The test was objective and not subjective. It was for him to prove the causal link. The Lord Ordinary had not found that the pursuer's leg gave way, only that it gave the impression of giving way. The appellant must have been able to put his good leg down : otherwise he could not have made this spectacular leap. It was not normal conduct for a man with a weak leg to get into a situation where he was in danger of falling and hurtling downstairs. A normal reasonable man would have gone down with

¹ *Steel v. Glasgow Iron and Steel Co.*, 1944 S.C. 237, Lord Justice-Clerk Cooper at pp. 247-8 ; *Malcolm v. Dickson*, 1954 S.C. 542, Lord Justice-Clerk Thomson at pp. 547-8.

² *S.S. Singleton Abbey v. S.S. Paludina*, [1927] A.C. 16, Lord Sumner at p. 30, Lord Blanesburgh at p. 36.

³ 1944 S.C. 237, Lord Justice-Clerk Cooper at pp. 249-50.

⁴ *Ibid.*, Lord Justice-Clerk Cooper at p. 248.

extreme caution. It was unnecessary to consider the question of contributory negligence, which could relate only to the original accident. If the appellant did something after the first accident which was not within the range of normal human conduct, that was negligence on his part, and broke the chain of causation. That would be the end of his case so far as the second accident was concerned. *M'Leod v. Humphrey & Glasgow Ltd.*¹ was of no general significance. It was simply a decision on its own particular facts.

At delivering judgment on 26th November 1969,—

LORD REID.—My Lords, the appellant sustained in the course of his employment trivial injuries which were admittedly caused by the fault of the respondents. His back and hips were badly strained, he could not bend, and on several occasions his left leg suddenly “went away from” him. I take this to mean that for a short time he lost control of his leg and it became numb. He would have recovered fully from his injuries in a week or two but for a second accident in which he suffered a severe fracture of his ankle. The question in this case is whether the respondents are liable for the damage caused by this second accident. If they are so liable, then damages have been agreed at £4915. If they are not so liable, then damages are agreed at £200, the sum awarded in the Court of Session.

Some days after the first accident the appellant was offered the tenancy of a flat in Succoth Street, Glasgow. He went to inspect it, accompanied by his wife and child and a brother-in-law. The flat is approached by a steep stair between two walls and there was no handrail. When they left the flat, the appellant sought to descend the stair with his child, in advance of his wife and brother-in-law. The only reliable evidence of what then happened is that of the appellant and it is far from clear. I think it best to quote this evidence.

The appellant first said : “ Well, we came out of the house and I was at the top of the stairs with my daughter, and I had her by the hand, and I think it was my brother-in-law closed the door, and he was holding it while my wife was locking it, and I lifted my right foot to go down the stairs, and as I lifted my right foot, this left leg just seemed to vanish under me, and I threw my daughter back in case I would take her down with me. I found myself going and I couldn't stop, and the only thing I could do was, instead of toppling down head first, I threw myself and I landed on my right—even when I landed on my feet, my left went from me, but it was mostly my right I landed on.” Then later he said : “ I put my right leg down to go, and as I put it down, my left leg just went, and I threw my daughter back and instead of falling I made to jump.” (Q.) “ And did you land on your feet? ” (A.) “ Yes. I ended up sitting down but I was on my feet as I hit the ground.” (Q.) “ Did you jump about 12 feet from the top of the stair down to the next landing? ” (A.) “ Well, I jumped ten steps . . . ” And finally he said : “ I was actually falling, I was completely falling and I had to try and stop myself. My right leg was down then, and I threw myself so that I could land in a standing position instead of falling over and falling down and breaking my neck.” (Q.) “ Did you project yourself into the air with your right foot? ” (A.) “ From the wall and part of my right foot, I kind of pushed myself from the wall on

¹ Outer House (Lord Migdale), 28th May 1954, unreported.

the left." (Q.) "Did you not think of falling backwards, just sitting down?" (A.) "That was impossible, because I was in flight. As a matter of fact, I couldn't come back, not unless I reversed my body, and I wasn't doing that."

The appellant's case is that this second accident was caused by the weakness of his left leg, which in turn had been caused by the first accident. The main argument for the respondents is that the second accident was not the direct or natural and probable or foreseeable result of their fault in causing the first accident.

In my view the law is clear. If a man is injured in such a way that his leg may give way at any moment, he must act reasonably and carefully. It is quite possible that in spite of all reasonable care his leg may give way in circumstances such that as a result he sustains further injury. Then that second injury was caused by his disability, which in turn was caused by the defender's fault. But if the injured man acts unreasonably, he cannot hold the defender liable for injury caused by his own unreasonable conduct. His unreasonable conduct is *novus actus interveniens*. The chain of causation has been broken and what follows must be regarded as caused by his own conduct and not by the defender's fault or the disability caused by it. Or one may say that unreasonable conduct of the pursuer and what follows from it is not the natural and probable result of the original fault of the defender or of the ensuing disability. I do not think that foreseeability comes into this. A defender is not liable for a consequence of a kind which is not foreseeable. But it does not follow that he is liable for every consequence which a reasonable man could foresee. What can be foreseen depends almost entirely on the facts of the case, and it is often easy to foresee unreasonable conduct or some other *novus actus interveniens* as being quite likely. But that does not mean that the defender must pay for damage caused by the *novus actus*. It only leads to trouble if one tries to graft on to the concept of foreseeability some rule of law to the effect that a wrongdoer is not bound to foresee something which in fact he could readily foresee as quite likely to happen. For it is not at all unlikely or unforeseeable that an active man who has suffered such a disability will take some quite unreasonable risk. But if he does, he cannot hold the defender liable for the consequences.

So in my view the question here is whether the second accident was caused by the appellant doing something unreasonable. It was argued that the wrongdoer must take his victim as he finds him and that that applies not only to a thin skull but also to his intelligence. But I shall not deal with that argument because there is nothing in the evidence here to suggest that the appellant is abnormally stupid. This case can be dealt with equally well by asking whether the appellant did something which a moment's reflection would have shown him was an unreasonable thing to do.

He knew that his left leg was liable to give way suddenly and without warning. He knew that this stair was steep and that there was no handrail. He must have realised, if he had given the matter a moment's thought, that he could only safely descend the stair if he either went extremely slowly and carefully, so that he could sit down if his leg gave way, or waited for the assistance of his wife and brother-in-law. But he chose to descend in such a way that, when his leg gave way, he could not stop himself. I agree with

what the Lord Justice-Clerk says at the end of his opinion and I think that this is sufficient to require this appeal to be dismissed.

But I think it right to say a word about the argument that the fact that the appellant made to jump when he felt himself falling is conclusive against him. When his leg gave way, the appellant was in a very difficult situation. He had to decide what to do in a fraction of a second. He may have come to a wrong decision : he probably did. But, if the chain of causation had not been broken before this by his putting himself in a position where he might be confronted with such an emergency, I do not think that he would put himself out of court by acting wrongly in the emergency unless his action was so utterly unreasonable that even on the spur of the moment no ordinary man would have been so foolish as to do what he did. In an emergency it is natural to try to do something to save oneself and I do not think that his trying to jump in this emergency was so wrong that it could be said to be more than an error of judgment. But for the reasons already given I would dismiss this appeal.

LORD HODSON.—My Lords, I have had the advantage of reading the opinion of my noble and learned friend, Lord Reid, with which I agree.

I would dismiss the appeal.

LORD GUEST.—My Lords, the appellant was injured in an industrial accident on 14th February 1963, in circumstances under which the respondents are admittedly responsible. For the injuries sustained by him in that accident the Lord Ordinary has awarded the appellant £200 damages. No question arises as to the respondents' liability for this accident nor as to the amount of damages. The injury was not a serious one, but it left the appellant with a slight weakness of his left leg, which was still present on 7th March 1963, when he met with a second accident on the common stair of a house at Succoth Street, Glasgow. He sustained serious injuries on this occasion when he fractured his right ankle and left os calcis. This has left him with a serious permanent disability. The Lord Ordinary found, and his decision was concurred in by the Second Division of the Court of Session, that the appellant cannot recover damages for this second accident, as it is too remote. If, however, he had considered the respondents liable for the consequences of the second accident, he would have awarded the appellant an additional £4915 damages.

The Lord Ordinary has found the appellant's explanation of his second accident confusing, and I am not surprised, when his evidence is considered. He, his wife, his young daughter and his brother-in-law were inspecting a house in Succoth Street, Glasgow, with a view to his occupancy. He took with him a measuring tape for taking measurements for carpets and wax cloth. After leaving the house his account proceeds as follows : " Well, we came out of the house and I was at the top of the stairs with my daughter, and I had her by the hand, and I think it was my brother-in-law closed the door, and he was holding it while my wife was locking it, and I lifted my right foot to go down the stairs, and as I lifted my right foot, this left leg just seemed to vanish under me, and I threw my daughter back in case I would take her down with me. I found myself going and I couldn't stop, and the only thing

I could do was, instead of toppling down head first, I threw myself and I landed on my right—even when I landed on my feet, my left went from me, but it was mostly my right I landed on.” In cross-examination he explains that he threw himself so that he would land in a standing position instead of falling over and breaking his neck. He further explains that he projected himself from the wall with his right foot and he assents to the suggestion that he jumped the twelve steps clear, hitting the bottom step.

The Lord Ordinary has found that when the appellant was at the top of the stairs he made a deliberate and voluntary—“and apparently unnecessary”—leap down ten steep steps of the tenement stairway. Upon this view he has held that the second accident was not a direct and probable result of the appellant’s first accident.

The Lord Justice-Clerk takes a slightly different approach. He expresses the view that in the situation in which the appellant was placed at the top of the stairs, when his left leg gave way, with an apparent choice between two evils, the appellant may not have been unreasonable in jumping as he did. But the Lord Justice-Clerk considers that, as the appellant’s left leg had “gone away” from him on several occasions before the second accident—“Yet, with this knowledge and experience, he set out to descend a flight of stairs without a stick or other support and without the assistance, which was available, of his wife or brother-in-law. I cannot regard that as a reasonable act and it was, in my opinion, an intervening act which broke the chain of causation.”

Lord Walker’s view is again different. He disagreed with the Lord Ordinary as to the jump and finds that the real cause of the second accident was the appellant’s own reckless conduct in hurrying down the stair in the circumstances. I am doubtful whether the evidence supports a finding of undue haste.

I am not sure what is Lord Wheatley’s approach, but in the concluding passage of his judgment he appears to be agreeing with the Lord Ordinary that the jump was something which no reasonable person would have done.

I would have difficulty in faulting the Lord Ordinary’s view. If the appellant was believed—and the Lord Ordinary bases his judgment upon his evidence—he performed a not inconsiderable acrobatic feat in jumping down ten steps clear. “The grand rule,” said Lord Kinloch in *Allan v. Barclay*¹ (at p. 874) “on the subject of damages is, that none can be claimed except such as naturally and directly arise out of the wrong done; and such, therefore, as may reasonably be supposed to have been in the view of the wrongdoer.” This has been elaborated, discussed and explained in future cases but never improved upon. If, on the other hand, the action which resulted in the injury was something unaccountable, “a new cause which disturbs the sequence of events, something which can be described as either unreasonable or extraneous or extrinsic,” the chain of causation is broken. (See *The Oropesa*,² Lord Wright at p. 39.) In *S.S. Baron Vernon v. S.S. Metagama*³ Viscount Haldane states (at p. 25) that damages are recoverable if they are the natural and reasonable result of the negligence and it will assume this character if it can be shown to be such a consequence as in the

¹ (1864) 2 Macph. 873.

² [1943] P. 32.

³ 1928 S.C. (H.L.) 21.

ordinary course of things would flow from the negligence. "Reasonable human conduct is part of the ordinary course of things."

If the appellant jumped, as found by the Lord Ordinary, I cannot regard this as reasonable human conduct. But whether this is to judge the appellant's conduct in too fine scales, I would regard the Lord Justice-Clerk's ground of judgment as equally satisfactory. The appellant was still convalescent from his first accident when the second accident occurred. He was limping. He had the experience of his leg giving way. Yet he chose without assistance, without hanging on to the wall, to commence to descend those steep stairs holding his young daughter by the hand. Like the Lord Justice-Clerk, I could not characterise such conduct as other than unreasonable in the circumstances. If this be so, then the chain of causation between the first and second accident is broken and the appellant must fail.

I would dismiss the appeal.

VISCOUNT DILHORNE.—My Lords, I have had the advantage of reading the opinion of my noble and learned friend, Lord Reid. I agree with it and would also dismiss the appeal.

LORD UPJOHN.—My Lords, I concur.

APPEAL dismissed.

D. J. Freeman & Co., for Pairman Miller & Murray, W.S., and Hamilton, Givens & Co., Glasgow—Barlow, Lyde & Gilbert, for Simpson & Marwick, W.S.

AITKEN'S TRUSTEES v. AITKEN

No. 3.

Nov. 26, 1969.

Lords Reid, Hodson, Guest,
Viscount Dilhorne, Lord Upjohn.

ROBERT LIVINGSTONE AITKEN AND ANOTHER (John Aitken's Trustees), First Parties.

ROBERT LIVINGSTONE AITKEN, Second Party (Appellant).—*Mackenzie Stuart, Q.C.—A. L. Stewart.*

JOHN MONTGOMERIE AITKEN, Third Party (Respondent).—*Grieve, Q.C.—Shiach.*

Succession—Will—Construction—Beneficiary—Bequest of residue to children jointly with issue of predeceasing children—Issue to take share "which . . . their parent would have taken if such parent had survived"—Whether issue of child predeceasing date of settlement entitled to share.

By his trust disposition and settlement a testator, after providing for certain legacies, directed his trustees to divide the residue of his estate "equally between my children . . . Robert . . . and Morag . . . jointly with the issue who may survive me of such of my children as may have predeceased, the issue of such children taking . . . the share . . . which his, her or their parent would have taken if such parent had survived." The testator had had four sons and a daughter. Three of the sons predeceased the date of the settlement, two without issue, the third leaving one child, John. The remaining son, Robert, and the daughter, Morag, survived the testator. In a question as to the true construction

**WEBB v. BARCLAYS BANK PLC AND
PORTSMOUTH HOSPITALS NHS TRUST**COURT OF APPEAL (Henry, Judge and Hale L.JJ): July 16, 2001¹

[2001] EWCA Civ 1141; [2002] P.I.Q.R. P8

H1 *Personal injuries—existing disability—intervening negligence of doctor—causation—contribution*

H2 The claimant had been a polio victim for most of her life, and had a close professional relationship with J her consultant, who was at all material times employed by the second defendant (“D2”). In 1994, while in the employ of the first defendant (“D1”) she stumbled and fell over a protruding stone in their forecourt, hyper-extending her polio-affected left knee, and leaving the knee grossly unstable. She consulted J who ultimately, in the light of the very severe pain she was suffering and her opposition to a calliper, decided, having discussed the case with a colleague, to suggest an above-knee amputation of the left leg. This was done in February 1995. In May 1996 the claimant commenced proceedings against D1 for damages for personal injury. In July 1999 D1 admitted liability for the fall, asserted that the claimant had been negligently advised and that, if properly advised, alternative treatment, avoiding amputation and the subsequent problems experienced by her, would have been provided. The claimant subsequently amended her particulars of claim to join D2 in the proceedings, and D1 served an amended defence and served a Contribution Notice on D2. Four days before the hearing date for trial, D1 settled the claimant’s action, the intention being to settle the entirety of her claims, against both themselves as her employees and D2, while preserving their claim for contribution against D2 as concurrent tortfeasors. The paperwork was done out of sequence, with the result that the claim against D2 (which was to be assigned to D1) was extinguished by the acceptance of the settlement before the assignment took place. At the trial of the contribution proceedings, the judge ruled that this was saved by the Civil Liability Contribution Act 1978. No evidence was given at that trial by the claimant or her husband, which the judge regarded as handicapping his ability to form a proper judgment, for example as to her reaction when amputation was first suggested. The judge treated the case as one where the claimant was entitled to put her case as loss of a chance. He concluded that the chance of her rejecting the suggestion of amputation after a hypothetical properly detailed advice of the pros and cons was 40 per cent. D2 appealed on the basis that the issue as to whether the claimant would have come to amputation in any event should have been decided on a balance of probabilities, not loss of a chance of amputation. This point was ultimately agreed between the parties, and D2’s appeal was allowed without hearing argument. The appeal proceeded on the basis of D1’s respondent’s notice, in which it was contended that the judge was in error in concluding that the evidence necessary for the claimant to establish causation was not available, that the claimant ought not to have been advised that amputation was the best option, and, on a balance of probabilities would have accepted the advice that ought have been given, and D2’s breach of duty caused her to elect to undergo the amputation.

H3 **Held**, allowing D1’s cross appeal, that, on examination in particular of the expert evidence, J was in breach of duty to the claimant. None of the six independent consultants whose evidence was before the court would have advised her to undergo the amputation which took place. She was not given the information, and hence the

¹ Paragraph numbers in this judgment are as assigned by the court.

knowledge necessary to make a reasoned choice, nor advised to accept the distasteful but less drastic solution of bracing or orthosis. If she had been properly advised by J she would not have consented to the amputation. On the point of contribution, the question was whether, when an employee is injured in the service and by the negligence of her employer, his liability to her is terminated by the intervening negligence of a doctor brought in to treat the original injury, but who in fact made it worse. The chain of causation in such a case would only be broken where the medical treatment was of such a degree of negligence as to be an entirely inappropriate response to the injury. Such was not the case here. Hence the negligence in advising amputation did not eclipse the original wrong-doing. In all the circumstances, D1's responsibility was assessed at 25 per cent, and D2's at 75 per cent.

Legislation judicially considered:

- H4 (1) Civil Liability (Contribution) Act 1978.

Cases judicially considered:

- H5 (1) *Chappel v. Hart* [1999] L.L.R. 222.
 (2) *Mahoney v. Kruschick (Demolitions) Pty Ltd* (1985) 156 C.L.R. 522.
 (3) *Rahman v. Arearose Ltd* [2001] C.A. 351.
 (4) *Sidaway v. Board of Governors of Bethlem Royal Hospital* [1985] A.C. 871.

Cases referred to in judgments:

- H6 (1) *Allied Maples v. Simmons & Simmons* [1995] 1 W.L.R. 1602.
 (2) *Hotson v. East Berkshire H.A.* [1987] 1 A.C. 750.
 (3) *Tahir v. Haringey Health Authority* [1998] Lloyds Med. Rep. 104.
- H7 **Cross-appeal** by the first defendant, Barclays Bank plc, against the decision of Rougier J. ordering the second defendant, Portsmouth Hospitals NHS Trust to pay it £47,989, 40 per cent of the costs of the claimant, Mrs Elizabeth Anne Webb from September 20, 1999 to April 6, 2000 and the cost of the issues raised in amended particulars of claim (to be assessed).
- H8 *Paul Rees Q.C.* instructed by Kennedys, Newmarket, for the appellant/second defendant.
A. Whitfield Q.C. and *Julian Matthews*, instructed by Vizards Staples and Bannister, for the respondent/first defendant.

- 1 **HENRY L.J.:** This is the judgment of the Court. Mrs Webb, the claimant in this action was born in 1949 and contracted polio in the second year of her life. She coped with courage and determination. She took an intelligent and informed interest in her condition and its treatment, and developed a close professional relationship with her consultant, Mr Jeffrey, who is and was at all material times employed by the second defendants, the Portsmouth Hospital NHS Trust, which we will call the Trust.
- 2 In 1994, while in the employ of Barclays Bank she stumbled and fell in their forecourt, tripping over a protruding stone. In this fall she hyper-extended her polio-affected left knee. What appeared to be a minor fall with her returning to work the next day triggered a disproportionate reaction. She was left with a grossly unstable knee.
- 3 She consulted Mr Jeffrey. A month after the accident he wrote that she was left with a wobbly joint with poor muscle control. It needed treatment with physiotherapy, bracing (which she was resistant to because of

childhood experiences with callipers) eventually looking to arthrodesis, or fusion of the joint.

- 4 Mr Jeffrey decided to wait and see how matters developed. Her “knee” (created by McEwan’s osteotomy by Mr Jeffrey in 1984) was grossly unstable. Progress was poor. There was correspondence between the claimant and Mr Jeffrey between June and July. He expressed the view:

“... that with the degree of instability you have got, I do not think that anything other than a long term calliper would be any help.”

She reacted indignantly, saying she did not want to go back to a calliper.

- 5 At about the same time, she began to experience very severe pain in the knee. She tried a calliper. The trial was not a success. It looked ugly, the knee hinges broke, and it did nothing to alleviate her “terrible pain”.

- 6 She saw Mr Jeffrey on November 22. His only not of the consultation was “return in trouble”. Mr Jeffrey then suggested (for the first time) an above-knee amputation of the left leg. The claimant did not give evidence before the judge, but he thought it “highly probable” that she was aghast at the suggestion, but prepared to accept, because of her state of mind at the time, the view that there was really nothing else to be done.

- 7 Mr Jeffrey discussed the case with a colleague, Mr McLaren, who saw the claimant and her husband, and said he endorsed Mr Jeffrey’s view, noting: “I agree that amputation is the best option”. There is no evidence that that colleague (Mr McLaren) performed any independent examination. The claimant’s husband (who also did not give evidence) states in his witness statement:

“It was not an easy decision to take, and after a lost of discussion, we felt that the best option was to follow the advice given above to us by Mr Jeffrey and Mr McLaren and for Elizabeth to have her leg amputated.”

This was done February 22, 1995.

- 8 On May 16, 1996 Mrs Webb commenced proceedings for damages for personal injury against her employer, the Bank, for their failure to properly maintain the forecourt where she had tripped and fallen.

- 9 In the original Particulars of Claim there is no question raised as to either the necessity for or the desirability of the amputation. But in her witness statements, Mrs Webb is very disappointed in her condition. She complains of phantom pains, pains in her lower back, great depression, loss of mobility and how it affected every aspect of her life, forcing her to depend on others.

- 10 She did not realise that there was a question as to whether she should have had the amputation until her third witness statement of August 31, 1999, where she says:

“I had no reason to know there any suggestion that I should not have had the operation until I read Professor Heatley’s report of March 30, 1999.”

- 11 In that report Professor Heatley expresses surprise that the Portsmouth surgeons opted for amputation, doubts whether the advantages and

disadvantages of an above-knee amputation and the risks of becoming wheel chair dependent can have been spelled out to her, and concludes:

“I feel rather sad, indeed despondent, that she had ended up with an amputation, as I personally would have certainly tried a different surgical option.”

Mrs Webb concludes the statement by saying:

“The knowledge that the trial in November may now have to be put off, and that I may now have to sue Mr Jeffrey, in whom I have great trust and who has done a lot for me, and will have to undergo further medical examinations has caused me significant distress and continues to do so.”

- 12 In July 1999 the Bank filed a draft Amended Defence. That document admitted liability for the claimant's fall, asserted that she had been negligently advised, and that had she been properly advised, she would have been unlikely to have consented to the operation, but would have elected to deal with the instability by alternate means, retaining mobility, and avoiding amputation. It is asserted that the claimant's amputation and subsequent problems were due to the intervening negligence of the Trust. Soon after this, the claimant amended her Particulars of Claim to join the Trust in the proceedings, the Bank served its Amended Defence, and on March 28, 2000 served on the Trust a Contribution Notice under Part 20.6 in respect of “any damages” it might have to pay to Mrs Webb.
- 13 On April 6, 2000, four days before the hearing date for trial, the Bank settled the claimant's action for £164,874.35. That sum was in full and final settlement of all the claims for the injuries and damages sustained by her as a result of the fall, that is to say to include both the injuries and damage resulting from the fall, and those resulting from the amputation. It was the clear intention of the Bank to settle the entirety of Mrs Webb's claims, against both themselves as her employers and the Trust, while preserving their claim for contribution against the Trust as concurrent tortfeasors. Unfortunately, the paperwork was done out of sequence with the result that Mrs Webb's claim against the Trust (which was to be assigned to the Bank) was extinguished by the acceptance of the settlement before that assignment took place. But the judge was to rule that the Civil Liability (Contribution) Act, 1978 saved them (this is a point to which we must return).
- 14 The trial of the contribution proceedings between the Bank and the Trust commenced on April 10. By then of course Mrs Webb's entitlement to the agreed damages was secure. In the normal course, she might have been expected to give evidence. But in the event neither she nor her husband did so. No explanation was offered by the Bank, other than that their evidence was not necessary. The judge said that he had been handicapped in his ability to form a proper judgment in that neither Mrs Webb nor her husband had given evidence before him. For instance, he felt he could not resolve the issue of her reaction to Mr Jeffrey first raising the question of amputation. But he concluded that it was “highly probable” that she was considerably aghast at the thought of losing part of her leg, but that in her state of mind at the time, she came to accept the view of Mr Jeffrey that there was really

nothing else to be done. The judge had the benefit of six witness statements taken from the claimant, but indicated (without further detail) that many questions remained unanswered, and these statements were not entirely consistent in relation to her feelings about callipers and braces (as he clarified in his judgment). He recognised that she was a woman of considerable courage and determination (as her many activities made plain) who was intelligent and well-informed as to her medical condition and its treatment. We have no idea why the Webbs did not give evidence. In our judgment, there is nothing to suggest that she would prove to have been an untruthful witness. What she said in her witness statement about not wanting to sue Mr Jeffrey appears to be a *cri de cœur*. One can understand her tiring of doctors and medical examinations. We accept what she there said as what she felt. We see in it nothing to suggest any hostility to Mr Jeffrey or to her employers. At the end of the day, all we can say is that we do not have the benefit of her oral testimony

- 15 A further difficulty arises in the judge's approach. At the conclusion of the evidence he indicated to counsel that he believed this was a case where the claimant was entitled to put her case as the loss of chance. Both counsel sought to dissuade him from this course, but unsuccessfully. The judge therefore set himself the question:

"... had she been given proper advice or exhortation, based on the result of investigations which should have been conducted, what would her reaction have been?" (*i.e.* would she have given consent to the operation?)

- 16 The judge then went on to quote by way of contrast the normal causation test:

"... had it been possible to say, with any certainty, what advice, based on the result of his various enquiries, Mr Jeffrey would have been in a position to give to Mrs Webb, then I accept that the right approach would be to ask whether on the balance of probabilities, the claimant succeeded in proving, either by direct evidence or by necessary inference that she would have accepted that advice, and thereby avoid amputation and its consequences."

- 17 He then went on to place the blame for the evidential gaps in the Trust's case principally on Mr Jeffrey, but partly on Mrs Webb for not giving evidence:

"But the difficulty here is that we do not know what advice Mr Jeffrey would have been in a position to give. We do not know whether a proper examination, both clinical and radiological, would have revealed some bony pathology which was relatively simply curable. The reason we do not know is because Mr Jeffrey never undertook those examinations, and it is no longer possible to examine the knee. By the same token, we do not know what advice Mr Jeffrey would have been able to offer to Mrs Webb as to the range and models of braces available and the chances of ultimately being able to get one which she could tolerate, for the simple reason that such enquiries were never made.

We have, therefore, a situation where the very omissions which have

been proved against the defendant are those which preclude the claimant from advancing the evidence necessary to establish causation. I cannot believe that the law could possibly countenance such a manifestly unjust situation by insisting on a balance of probabilities approach in circumstances such as these. How, I might ask, could I be expected to determine the reaction of a woman whom I have never seen, to a dissertation that never took place, the contents of which could be no more than guessed at?"

- 18 He then, because of the omissions he had complained of, reiterated his "loss of a chance" approach, and said that:

"... had I taken the view urged on me by counsel [*i.e.* deciding the case on the ordinary principles of causation—that is to say deciding on the balance of probabilities] although I am making no definite finding on the point, I feel bound to say that I am extremely doubtful that I should have felt entitled to infer that Mrs Webb would have accepted the suggested advice [*i.e.* to have rejected amputation in the full knowledge of relevant facts] or, that having accepted it initially, she would have persevered with the trials of orthosis which, in all probability, would have been protracted."

- 19 Finally, he assessed his view of the chance of her rejecting the suggestion of amputation after a hypothetical properly detailed advice of the pros and cons, and concluded:

"Mrs Webb's views on braces I have already dealt with. So, upon this distinctly jejune material, I have asked myself what in percentage terms is the value of the chance of which Mrs Webb was deprived? Some answer has to be given. While I am uneasily conscious that I may be moving from the realm of hypothesis to that of wild speculation, my answer is 40 per cent."

- 20 Having reached those conclusions, the judge first apportioned the global settlement figure for both the fall and the amputation with interest (by then £165,953.73) into the amount attributable to each cause of action, adjudicating on a schedule produced by counsel for the Bank, which was not explored in the submissions before us. The judge accordingly ordered the Trust to pay the Bank the sum of £112,808.17. He then took 40 per cent of that figure to represent what Mrs Webb had been deprived of by the notional loss of her chance:

"... of forming a reasoned opinion on the basis of full knowledge of the relevant facts, and in the light of that opinion to have rejected amputation."

- 21 The judgment accordingly orders the Trust to pay the Bank:

- (a) £47,898 (being 40 per cent of £119,745—a figure whose provenance I do not know);
- (b) 40 per cent of the claimant's costs from September 20, 1999 to April 6, 2000; and

- (c) the costs of the issues raised in the Amended Particulars of Claim to be assessed.

22 The Trust then appealed against that order, on the grounds set out in the Notice of Appeal:

“1. The judge was wrong in law to conclude that the correct approach as to whether the claimant would have come to amputation in any event was on of loss of a chance of avoiding amputation; he should have decided that issue on a balance of probabilities. Adopting the correct approach, and given his conclusion that the claimant (and hence the first defendant) could not show that she would have avoided amputation on a balance of probabilities, he would have dismissed the contribution claim.

2. In particular, the judge was wrong to distinguish the decisions in *Hotson v. East Berkshire H.A.* [1987] 1 A.C. 750 and *Allied Maples v. Simmons & Simmons* [1995] 1 W.L.R. 1602.

3. The judge was wrong in law to conclude that because the omissions proved against the second defendant had prevented the claimant from establishing causation, the balance of probabilities approach should not apply. That is in effect to award the claimant the loss of a cause of action, which is not within the scope of the duty owed by the second defendant to the claimant, namely to avoid causing the claimant unnecessary physical harm.”

23 Initially the Bank was disposed to resist this appeal, at least as a fall-back position—see their Respondent’s Notice of May 26, 2000. But Mr Whitfield Q.C. by his skeleton argument of January 2001 accepted that the legal basis of the Trust’s appeal was correct. Mr Whitfield agreed with Mr Paul Rees Q.C. for the Trust that the learned judge should not have awarded damages for the loss of a chance: first the claim brought by the claimant and settled by the Bank was a claim for personal injuries and not a claim for loss of a chance; second, that in such a case “... a plaintiff cannot recover damages for the loss of a chance of a compete or better recovery” (see Otton L.J. in *Tahir v. Haringey Health Authority* [1998] Lloyds Med. Rep. 104 at 108); and third, the judge’s findings that the value of that lost chance was 40 per cent was inconsistent with the view, implicit in his judgment, that if Mr Jeffrey had done his investigation properly, the claimant would as a matter of probability have decided not to take the extreme step of above-the-knee amputation. Accordingly, there was no contest on this point before us. Mr Paul Rees Q.C. asked for judgment on the Trust’s appeal. Mr Whitfield did not oppose that course. We accordingly acceded to the request, and allowed the Trust’s appeal without hearing argument. The appeal then proceeded on the basis of the Bank’s Respondent’s Notice.

24 The Bank’s case as set out in the Respondent’s Notice was:

“1.1 The learned judge was in error in concluding that the evidence necessary for the claimant to establish causation was not available.

1.2 The learned judge ought to have found that:

1.2.1 the claimant ought not to have been advised that the amputation was ‘the best option’ and ‘the right way forward’ but ought to have been cautioned against it (if it was justifiable to

mention it at all) and urged to have further investigations and to consider other options first, and in particular to persist in trying to find a suitable orthosis.

1.2.2 that, on the balance of probabilities the claimant would have accepted the advice that ought to have been given and would not, of her own volition, have been likely to insist on amputation;

1.2.3 the breach of duty at 1.2.1 thus caused the claimant to elect to undergo an above-knee amputation, which was then performed.

1.3 The learned judge therefore erred in reducing the damages attributable to the negligence of the appellant by 60 per cent. The learned judge ought to have awarded the first defendant the full measure of the damages and interest assessed by him as having been occasioned by the amputation.”

25 The first essential step on this path is that to succeed in the contribution proceedings the Bank must show that the claimant would have succeeded against the Trust. For this we go back to the history of events and the judge’s findings in relation to the meeting of November 22, 1994. By then, the judge found, Mrs Webb was complaining of extreme pain, which stopped her sleeping. She remained firmly opposed to either a shoe raise or a calliper which Mr Jeffrey then preferred. Mr Jeffrey concluded that he had reached “... the end of the line ...” with her. So he realised amputation as being the only other solution. He did not even discuss a trial of orthosis (brace or calliper), because of her previously stated dislike. And so he made no attempt to coax or persuade her to give the calliper solution another try. He did not further investigate the cause of her pain, assuming it would be undeveloped arthritis which would not show on further X-rays. He did not investigate any other cause of Mrs Webb’s pain because he believed it to be an unstable arthritic knee, which was enough to account for the pain. He was aware that amputation did not have a good reputation with polio victims, but considered that to be a reflection on the days of crude prostheses, now past. So he did not consult with those who had a special interest in polio victims, though he had done on previous occasions.

26 The judge found that Mr Jeffrey’s views were not endorsed by the experts called before him. He heard from four experts over three days, and also read an illuminating account of a telephone conference between six experts, two of whom did not give evidence at trial. The experts who gave evidence were Professor Heatley, Dr Luff, Professor Solomon, and Mr Spivey, while Dr Kirker and Mr Hay were instructed in the case, but not called as witnesses.

27 We turn to that telephone conference. The consensus there expressed was:

Q4: Some type of intervention would be necessary for the knee in six years.

Q5: That would be some sort of bracing, assuming that the knee was “at that stage” braceable.

Q7: The accident did bring about a change in her condition, albeit a small one. With old polio patients even a comparatively minor change can tip the balance to an accelerated decline in functional activity.

Q8: All agreed that the preferred treatment would have been physiotherapy, hydrotherapy and bracing. Mr Luff would have undertaken further investigations to determine the cause of the pain.

Q10: Went to the heart of the matter: "Would you personally have advised an amputation?" All were agreed that the answer was "No".

Q11: "Would you have accepted amputation as a possible option if bracing failed or was otherwise totally rejected?" The note reads:

"General disagreement

L and RH rejected this option outright, except in the case of some major complication such as infection. K would have been prepared to consider it if pain was a major factor.

FH would have considered it only as a last resort and after exploring all other modes of treatment as set out in his answer to Question 8. He would also have considered a patellar bone-block operation, as described in his report.

JS and LS, while accepting that amputation has a poor reputation in post-polio patients, would not have rejected it completely as an option, considering that in this particular case (unlike the 'usual' polio case) the patient had a considerable degree of pain, hyperaesthesia, joint deformity and rotational instability of the knee."

Q12: All would have warned of the possibility of an adverse outcome.

Q13: Asked whether there was anything in this particular case which would have counted for or against amputation, and K, JS and LS relied on the factors they had alluded to in their answers to Question 11 as being unusual circumstances for a post-polio patient, and would have a significant influence on decision making (but none of them would have amputated) then, but only as a last resort.

Q14: Asked whether the claimant's functional capacity five years on from the amputation "... was better, worse, or the same as it would have been with their preferred treatment". Of those that had examined her, their conclusions were: one, very much worse; one, significantly worse; and two, "... managing about as well now as she would have done after five years in a brace".

28 Then, in answer to Question 15:

"... do you think the decision in this case represented a standard of care below that to which Mrs Webb was entitled to expect?"

L, RH and FH answered yes, and K, JS and LS answered no. And finally:

"It was generally agreed that the standard of note-keeping in the medical records was not of a high standard, making it difficult for those who had not seen Mrs Webb to form firm conclusions about the details of her medical condition."

29 In amplification of that evidence, those witnesses gave evidence as follows:

(a) Professor Heatley first stressed the very limited investigation the Mr Jeffrey had made. He criticised the limited X-rays, and the absence of X-rays taken from all angles, examined under an image intensifier. He regarded physiotherapy, hydrotherapy and bracing as an ideal solution, while accepting that it could be difficult psychologically to get it to work, to persuade those who in their polio-afflicted youth had had troublesome experiences with heavy callipers to give braces another chance. But he himself had never had to amputate on an old polio victim, having found that other patients with experience of the suggested form of brace were persuasive. He felt “rather sad” that she had ended up with an amputation. He was not impressed by the fact that Mr Jeffrey obtained a second opinion accepting amputation from Mr McLaren; the second opinion was given too quickly with inadequate information. He was against amputation, but would not have said it represented a standard of care below what could be expected.

(b) Dr Luff regarded amputation was being last in the list of options. Any intervention may have an enormous impact on the patient, and requires a very careful analysis. It was essential that all reasonable avenues of treatment were considered before a decision to amputate. That had not happened here. Radiographs should have been considered and obtained. Amputation had not got a good record with polio patients. He would have been pessimistic as to its chance. He too was not impressed by Dr McLaren’s second opinion because no reasons were given.

(c) Mr Spivey had never amputated a leg in circumstances such as existed here. He thought that the explanation here must be that both Mrs Webb and Dr Jeffrey were proceeding on the basis that her existing situation was unacceptable and that desperate measures were necessary—otherwise he could not understand the decision. But amputation should only be offered as a last resort.

(d) In his original witness statement Mr Spivey said that the quality of the medical records produced made it difficult to be certain what the medical condition of the knee was, and what degenerative changes there were. In his evidence he expanded that he had seen no record of a proper clinical examination. He would have explained how a calliper could be expected to ease the patient’s pain, and he would have spent a lot of time dealing with her objections. He would have persisted with non-sergical means of management for as long as he could. He said that he found that eventually he and his patients agreed. He agreed that some sort of bracing would have been needed, but this turned first on acceptance and compliance by Mrs Webb, and second on whether the knee at the time was “braceable”. While he would not have amputated, he did not believe that the decision to amputate represented a standard of care below that which Mrs Webb was entitled to expect.

(e) Professor Solomon would have made Mrs Webb aware of all the problems associated with surgical management, and would have

advised against amputation at this stage. He would have wanted a good X-ray. However, because there was no evidence that she had reasonably good muscle control around her hip, he would not have branded the advice as falling below the standard of care. But, as he made clear in his evidence, he would have been extremely reluctant to amputate, and would have done so only as a last resort. He had, more often than not, been able to persuade patients to carry on with a brace.

30 The judge, having heard the evidence summarised the consensus:

“All agree that they would not have advised amputation. It has a notoriously bad outcome for old polio patients and it was the consensus of opinion that it would only be used as a very last resort and as a result of some secondary and potential life threatening complication. They were also in agreement that, subject to being able to coax Mrs Webb to acquiesce, bracing or orthosis of some sort was by far the preferred option, with occasional assistance from crutches.

Another criticism which all the expert witnesses made, to a greater or lesser degree, concerned the apparent omission, in November 1994, to investigate Mrs Webb’s knee in far greater depth and detail, in order to discover just what the underlying pathology was which was causing such severe pain. Various possible methods were suggested.

...

But I do accept the view of those who tell me that, before deciding on anything so drastic, disfiguring and irreversible as amputation, a full clinical examination, plus a set of good quality X-rays, taken from various angles, were highly desirable.

It is in this respect that I consider the two surgeons who advised Mrs Webb can be validly criticised. In my view Mr Jeffrey was too quick to believe that he had reached the end of the line. By not conducting these investigations, he deprived both himself and Mrs Webb of the full ambit of the knowledge necessary to make a reasoned choice. He was also somewhat too quick to think that there was no point in trying to coax Mrs Webb to try again with the orthosis. He was aware that there were various types and designs that could be made, but there is no evidence that he made any enquiry of the unit that supplied them as to the chance of getting or producing a brace that would have succeeded in significantly reducing Mrs Webb’s pain and instability, besides being cosmetically acceptable.

Therefore I agree with those who say he should have done more to indicate how much more preferable it would be to try a brace which would be both effective and acceptable to the wearer.

The breach of duty lies not in the amputation by itself, for any such allegation would be met with the counter that Mrs Webb had specifically consented to it, but rather in the failure to take the steps that were necessary to provide himself and Mrs Webb with the complete information necessary for a choice to be made. Of course it may be that, even with the utmost persuasion, Mrs Webb’s loathing of braces could not have been overcome, and she would still have opted for amputation. But she should have been given the fullest information

and encouragement in order to wean her towards what all have agreed was the best option.”

- 31 The judge then went on to ask the proper question that would have to be answered in “... an ordinary balance of probabilities case”:

“In other words had she been given proper advice and exhortation, based on the results of investigations which should have been conducted, what would her reaction have been?”

- 32 The judge then found that that question could not be answered on the balance of probabilities because not enough was known about the knee, nor the availability of braces. But the reason for the claimant’s ignorance was that Mr Jeffrey had negligently failed to make proper enquiries:

“We have, therefore, a situation where the very omissions which have been proved against the defendant are those which preclude the claimant from advancing the evidence necessary to establish causation.”

- 33 We do not agree with the suggestion that the question posed in paragraph 30 above could not be answered on the balance of probabilities. And, as Mrs Webb did not give evidence before the trial judge, we believe that we are as well placed as him to draw inferences from the primary facts as to what she would have done. The fall itself was a relatively minor incident, but it aggravated the claimant’s problems. Initially Dr Jeffrey advised Mrs Webb that the options were physiotherapy, bracing or ultimately arthrodesis, but he advised Mrs Webb to carry on as she was. Later he was to advise the trial of the calliper, but he had nothing to do with the trial itself. His decisive involvement came in and after the November 22 visit, when he first raised the question of amputation, and wrote to Mr McLaren seeking a second opinion, while expressing his own: “... this leg would be better amputated.” Mr McLaren, who spent 10 minutes with the Webbs, but conducted no separate examination, agreed with this view.

- 34 The decision to amputate was taken on January 30, 1995, where Mr Jeffrey’s note reads:

“Been through [above-knee] amputation of this left leg with her and her husband today. Everybody’s agreed that this is the best way forward.”

But, as the judge was to find, it was too early to proceed to amputation. As the telephone conference showed, none of the doctors taking part would have recommended amputation then, though three of the six would recommend it as a last resort. But matters had not reached that irreversible stage. On the judge’s finding, any such advice or recommendation would be premature because first, Mr Jeffrey’s had not fully investigated the causes of the pain in the left knee, nor had he investigated, or caused to be investigated what modern bracing had to offer Mrs Webb.

- 35 Rougier J.’s findings were:

(a) All experts were agreed that they would not then have advised amputation, with the three who would contemplate it only doing so as a matter of "... very last resort ...", and as a result of some secondary and potentially life-threatening complication;

(b) before one reaches "... the end of the line ...", *i.e.* amputation, it was necessary first, to investigate Mrs Webb's knee in far greater depth and detail to discover what the underlying pathology was *before* deciding on anything "... so drastic, disfiguring and irreversible as amputation ...", including a full clinical examination, and good quality X-rays, and second, conducting investigations to try and find a brace "... which would be both effective and acceptable ..." to the wearer;

(c) that Mr Jeffrey should have given Mrs Webb the fullest information and encouragement to "... wean her towards what all have agreed to be the best option" (*i.e.* bracing).

36 It seems to us that Mr Jeffrey was in breach of each of those duties owed to Mrs Webb. It is elementary, and no expert evidence is needed to confirm, that an above-knee amputation is not to be entertained lightly. None of the six independent consultants, whose evidence was before the court, would have advised Mrs Webb to undergo the amputation which took place in February 1995. Amputations have a bad reputation with polio victims, and are infrequently the preferred route to treat pain—see Professor Heatley: "... amputation is a bad operation for pain, unless the pain is very specifically defined". Even though that evidence does not, of itself, establish negligence against the consultant who advised and performed the operation, Mr Jeffrey, it provides compelling confirmation this amputation should have been regarded as the "... very last resort", a view lent particular emphasis by Mrs Webb's medical history.

37 The first and immediate negligence established against Mr Jeffrey was that he failed to inform himself, and therefore to provide Mrs Webb with the knowledge "... necessary to make a reasoned choice" whether to consent to the operation. Furthermore, the judge went on to find that in consequence Mr Jeffrey did not even begin to advise Mrs Webb to accept the distasteful but less drastic solution of bracing or orthosis. He offered neither information nor encouragement. She was entitled to a full measure of each.

38 Because of that, in our judgment the judge was wrong to conclude that Mr Jeffrey should be exonerated from a finding of negligence arising from the performance of the amputation itself on the basis that Mrs Webb had "... specifically consented to it". We doubt whether the judge's conclusion on the basis of "consent" can be sustained. If, through ignorance brought about by the negligent failure of Mr Jeffrey to inform himself, and therefore to advise the claimant on the relevant consideration and possible alternatives. Mrs Webb consented to a procedure with such drastic and irreversible consequences, in our judgment her consent, even if specific, did not absolve Mr Jeffrey from liability for the consequences of his negligent advice. The problem here was not the absence of general warnings about known or possible risks (*Sidaway v. Board of Governors of Bethlem Royal Hospital* [1985] A.C. 871) but rather that Mr Jeffrey's failure sufficiently to inform himself of all the relevant alternatives left her bereft of the medical

advice to which she was entitled. In simple terms she should have been told: “Mrs Webb, amputation is the very last resort and until we can properly advise you as to the pathology of your left knee and have fully investigated with you modern bracing, you should not consent to amputation.”—and he should have given reasons why.

- 39 What would have happened? It is common ground that Mrs Webb had been a patient of Mr Jeffrey for many years. She had every reason to have, and did have, great respect for and confidence in him and his professional judgment and expertise. It therefore comes as no surprise that, although she described herself in a witness statement as being “devastated” by the idea of an amputation, she eventually accepted his unequivocal advice that this was the appropriate procedure for her. As Rougier J. found, it was

“... highly probable that Mrs Webb was considerably aghast at the thought of losing part of her leg but that, in her state of mind at the time, was prepared to accept the view of Mr Jeffrey that there was really nothing else to be done.”

- 40 In his judgment the judge gave two tentative, further indications of relevance to this topic. First:

“... it may be that even with the utmost persuasion Mrs Webb’s loathing of braces could not have been overcome, and she would have still opted for amputation. But she should have [been] given the fullest information and encouragement in order to wean her towards what all have agreed was the best option.”

Later, he said that although he was not making a definite finding:

“I am extremely doubtful that I should have felt entitled to infer that Mrs Webb would have accepted the suggested advice or, that having accepted it initially, she would have persevered with the trials of orthosis which, in all probability, would have been protracted.”

- 41 Much has been made by Mr Paul Rees Q.C. of the fact that the bank did not call Mrs Webb to give evidence of her likely reaction if Mr Jeffrey had advised not amputation, but orthosis. Neither side called her. The bank did not call her to say that she would have accepted that advice: the Hospital Trust did call her to say that she would have rejected it. In the present context, of course, the burden of establishing causation rested on the bank, not the hospital, but the reality is that any assertion by Mrs Webb of her state of mind in February 1995 would have been open to the criticism that she could not now positively know what she would have done then, particularly as no attempt had in fact been made to “wean” her away from amputation. By the time of trial, her own assessment of the notional answer she would have given to a theoretical question would have been affected by the extent to which she had been able to come to terms with the amputation, and whether she believed that the operation had been successful or not. We can understand her disliking suing Mr Jeffrey. We can understand her wanting to be shot of the case and not to have to give evidence. But in our judgment it would be unsafe to draw any further inference from her absence from the witness box.

- 42 It was submitted that it was a principle of law that:

“... where there is a duty to inform it is, of course, necessary for a plaintiff to give evidence as to what would or would not have happened if the information in question had been provided” (*per* Gaudron J. in *Chappel v. Hart* [1999] L.L.R. 222 at 227).

We respectfully disagree with the suggestion that where a patient has sustained injury in the circumstances envisaged by Gaudron J. any claim must fail unless the patient gives evidence personally about what would or would not have happened if he had been properly informed of the facts before making his decision. What if the patient had suddenly died between a medical procedure carried out when he was not given proper information, and the trial, and without a statement having been taken from him on this direct question? Carried to its logical conclusion, the principle for which Mr Rees was contending would mean that, as a matter of law, such a claim would be bound to fail. That cannot be right. The likely consequences, if any, of medical negligence, in whatever form it may be established, depends entirely on the evidence before the judge, and the conclusions which, as a matter of fact, he is prepared to draw.

- 43 In this case we are in as good a position as the trial judge to draw inferences from the evidence available to him. Given the awesome finality of an above knee amputation, and the long history of confidence built up by the relationship between Mr Jeffrey and Mrs Webb, it seems to us improbable that if he had advised her, as he should, that the time for an amputation was premature and an operation was not inevitable, or even recommended, and orthosis was a viable option, Mrs Webb would nonetheless have tried to persuade him to proceed to amputation, or indeed have insisted on it. Events show her to be a sensible lady, and when pros and cons are fairly spelled out, we do not believe that she would have opted for amputation in this case. Expert evidence supported the view that given persuasion, patients accept the evidence given to them by their doctors, particularly when the doctor enjoys the patient's trust. In her witness statement, Mrs Webb said:

“I therefore agreed to the amputation as Mr Jeffrey thought it was the best solution.”

It seems to us probable that if Mr Jeffrey had decided and advised against amputation pending the further enquiries, it would not have taken place. And the judge in his judgment rightly proceeded on the footing that he did not “... believe that the search for a successful brace would be a short one”. He did not find that she would have waited, and such a finding would be out of character with the view we have formed of her.

- 44 So we are satisfied that Mrs Webb would not have consented to the amputation had she been properly advised by Mr Jeffrey. She would not have lost a leg if properly advised. Therefore Mrs Webb would have succeeded in her claim against the Trust. Because of Mr Jeffrey's negligent breach of duty in failing properly to inform Mrs Webb's consent to the operation she establishes a good cause of action against the Trust, the

second defendants. There are no difficulties about causation in our judgment.

- 45 We turn next to the question of damages and contribution between tortfeasors. Because of the events set out in paragraph 13 the Bank, who seek contribution, must rely on the Civil Liability (Contribution) Act, 1978 (“the 1978 Act”). The Act provides:

“1 Entitlement to contribution

(1) Subject to the following provisions of this section, any person liable in any respect of any damage suffered by another person may recover contribution from any other person liable in respect of the same damage (whether jointly with him or otherwise).

...

(4) A person who has made or agreed to make any payment in bona fide settlement or compromise of any claim made against him in respect of any damage (including a payment into court which has been accepted) shall be entitled to recover contribution in accordance with this section without regard to whether or not he himself is or ever was liable in respect of the damage, provide, however, that he would have been liable assuming that the factual basis of the claim against him could be established.

...

2 Assessment of contribution

(1) Subject to subsection (3) below, in any proceedings for contribution under section 1 above the amount of the contribution recoverable from any person shall be such as may be found by the court to be just and equitable having regard to the extent of that person’s responsibility for the damage in question.”

As a matter of statutory construction, we proceed on the basis that “the damage” in section 1(4) must be read as being “the same damage” as is mentioned in section 1(1).

- 46 The settlement was for the global sum of £165,453.75. That figure represented the total of the two linked claims for damages. First (Basis A), there was the tripping accident, brought against the claimant’s employers, the Bank, for their negligent failure to maintain their forecourt. The Bank and nobody else was liable for that claim. Second (Basis B), there was the claim for the doctor’s negligent advice as a result of which the leg was amputated. That claim was for damages attributable to the amputation, based on Mrs Webb’s actual condition following the amputation.

- 47 Mr Matthews, for the Bank, prepared a detailed schedule, attributing the global settlement figure on both bases, the object of the exercise being to attribute each head of damage appropriately in order to arrive at the figure under Basis A (“the effects of D1’s negligence, excluding the alleged intervening cause”). This attribution was arrived at by the exercise of Basis B minus Basis A (which calculation attributed £53,945.50 to the Bank’s sole liability for the claim against them, leaving £112,008.17 as the total damages attributed to the amputation). Mr Rees Q.C. accepts these figures, but takes the point that:

“Had Mrs Webb had to sue the Bank to judgment and the Bank had

established an intervening act of negligence on the part of the Hospital, it would have sought to limit Mrs Webb's claim against it to £53,945.56" (the Trust's second skeleton paragraph 6.2).

- 48 While we know nothing of the settlement negotiations, if the Bank did so seek, they plainly did not succeed. But it is right that the Bank, in September 1999, in their Amended Defence, pleaded that:

"For the reasons stated above, the claimants amputation and the subsequent problems related thereto were thus not caused or contributed to by defendants but were solely due to the intervening negligence on the part of the claimant's treatment hospital and doctors."

The plain object of this amendment was achieved when the claimant amended her pleadings to make against the Trust the same criticisms as the Bank had made, as they were to do.

- 49 So far as we are aware, that amendment only featured in the trial below in one respect. Before the trial proper started, there were submissions made to the judge by junior counsel on both sides as to whether:

"... the fact that the first defendant has by its pleading argued that it is not liable for post-amputation disability [prevents] it from seeking a contribution."

- 50 The judge held that it did not have that effect:

"[section 1 (4)] clearly contemplates a settlement of a claimant's claim before all questions of liability, as between defendants, have been decided. ... In my judgment, at this stage of the proceedings, what we are looking at is the damages claimed by the claimant. Either they will all be ultimately found the responsibility of the first defendant, or they will in part be found to be the first defendant's responsibility and in the other part that of the second. But at this stage, we are looking at the claimant's claim and the contribution sought in respect of that claim."

- 51 We do not have a Notice of Appeal in the bundles, unless what is referred to in Appeal Bundle 82 as "Please see attached" refers to the skeleton argument exhibited between pages 89 and 99. From that document it would seem that there was no appeal against this ruling. There after it would seem that the amendment played no part in the trial. We say that because it does not seem from the papers that the judge was ever asked to rule on it, even though in his judgment he made it plain that he was dealing with a situation where:

"... many of the disabilities and aspects of financial loss have two concurrent causes, which would produce overlaps. The proper approach, therefore, is to look at the total settlement sum, assess to what extent the breach of duty of the second defendants contributed to that sum ..."

We conclude that there is no ruling on the pleading point because there was no point raised as to it in the trial proper.

52 However, we will consider it as a matter of substance. The question here is whether, when an employee is injured in the service, and by the negligence, of her employer, his liability to her is terminated by the intervening negligence of a doctor brought in to treat the original injury, but who in fact made it worse.

53 Unsurprisingly, there is no general rule on this question. As Laws L.J. said in *Rahman v. Arearose Limited* [2001] C.A. 351 at 366G:

“... it does not seem to me to be established as a rule of law that later negligence always extinguishes the causative potency of an earlier tort. Nor should it be. The law is that every tortfeasor should compensate the injured claimant in respect of that loss and damage for which he should justly be held responsible.”

54 The same question was considered in the High Court of Australia in *Mahoney v. Kruschick (Demolitions Pty Ltd)* (1985) 156 C.L.R. 522 where the Court (presided over by Gibbs C.J.). We get from the headnote:

“*Held*, that if the employer were held liable in damages to the workman, it might be able to prove that if the doctor had been sued by the workman, the doctor would have been liable for some of the damages recovered by the workman, and, in that event, the employer would be entitled to an order for contribution under section 5(1)(c) of the Act.

Whether a tortfeasor can avoid liability for a subsequent injury tortuously inflicted by a second tortfeasor depends on whether or the subsequent tort and its consequences are themselves foreseeable consequences of the first tortfeasor’s negligence.

Per curiam. What an injury is exacerbated by medical treatment, the exacerbation may easily be regarded as a foreseeable consequence for which the first tortfeasor is liable. If the plaintiff acts reasonably in seeking or accepting the treatment, negligence in the administration of the treatment need not be regarded as a novus actus interveniens which relieves the first tortfeasor of liability for the plaintiff’s subsequent condition. The original injury can be regarded as carrying some risk that medical treatment might be negligently given.”

55 Finally, we agree with the editors of *Clerk & Lindsell on Torts*, when they say:

“Moreover, it is submitted that only medical treatment so grossly negligent as to be a completely inappropriate response to the injury inflicted by the defendant should operate to break the chain of causation” (18th ed., 2–55).

56 We are of clear opinion that where the chain of causation was not broken. We have in mind that:

(a) the original wrong-doing remained a causative force, as it had increased the vulnerability of the claimant and reduced the mobility of the claimant over and above the effect of the amputation;

(b) the medical intervention was plainly foreseeable, and it was also foreseeable that the claimant's pre-existing vulnerability would impose its own risks;

(c) given the doctor's conduct was negligent, but was not grossly negligent, and given the findings expressed at (a) and (b) it would not be just and equitable, nor in keeping with the expansive philosophy of the 1978 Act for the wrongdoer to be given, in these circumstances, a shield against (i) being liable to the claimant for any part of the amputation damages; and (ii) being liable to make such contribution to the Trust's amputation damages as was just and equitable.

57 In short, the negligence in advising amputation did not eclipse the original wrong-doing. The Bank remained responsible for their share of the amputation damages. The negligence of Mr Jeffrey was not an intervening act breaking the chain of causation.

58 Lastly, the question of apportionment or contribution between the two defendants in relation to what we have held to be the same damage. We have not heard argument on questions of factual detail in relation to this matter, but are merely asked to arrive at a figure:

“... such as may be found to the court to be just and equitable having regard to the extent of that person's responsibility for the damage in question” (section 2(2) of the 1978 Act).

59 The Bank, by their negligent maintenance of the forecourt, was responsible for getting the vulnerable Mrs Webb before the doctors employed by the Trust. But it was the latter's negligence that was much more responsible for the amputation and all that went with it. In all the circumstances, we assess the Bank's responsibility at 25 per cent and the Trust's at 75 per cent.

60 We will hear counsel as to the orders to be made.



Neutral Citation Number: [2023] EWHC 872 (KB)

Appeal No.: KA-2022-CDF-000004

Claim No.: KB-2021-CDF-000027

IN THE HIGH COURT OF JUSTICE

KING'S BENCH DIVISION

CARDIFF DISTRICT REGISTRY

On Appeal from an Order of DJ Vernon dated 20 October 2022

Cardiff Civil and Family Justice Centre

(but handed down at the Royal Courts of Justice, Rolls Building, London)

Date: 18/04/2023

Before :

MR JUSTICE ANDREW BAKER

Between :

ALUN JENKINSON

Claimant
(Respondent)

- and -

HERTFORDSHIRE COUNTY COUNCIL

Defendant
(Appellant)

Nigel Spencer Ley (instructed by **Parry Davies Clwyd-Jones & Lloyd LLP**)
for the **Claimant**

Geoffrey Brown (instructed by **Plexus Law**) for the **Defendant**

Hearing date: 31 March 2023

Approved Judgment

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MR JUSTICE ANDREW BAKER

Mr Justice Andrew Baker:

Introduction

1. The claimant suffered a bad fracture to his right ankle on 21 December 2017 when his foot went into an uncovered manhole or drain gully on Panshanger Lane in Hertford. The defendant admits liability for negligence or breach of statutory duty under s.41 of the Highways Act 1980.
2. The claimant issued his Claim Form on 9 September 2021. The defendant filed its Defence on 30 November 2021, admitting negligence but making no admission as to the extent of injury and putting the claimant to proof on *quantum*. It indicated an intention to instruct its own orthopaedic expert.
3. The case was listed for a CCMC on 7 April 2022. On 20 March 2022, the orthopaedic expert instructed by the defendant, Mr Machin, reported. His report was disclosed to the claimant on 31 March 2022. It opined that though surgical treatment of the damage to the claimant's right ankle, in December 2017, had been the appropriate intervention, following an accurate diagnosis and a correct assessment of the injury, the surgery was performed negligently.
4. Mr Machin concluded that *"had the initial surgery been carried out to the correct standard, then Mr. Jenkinson, in all probability, would have been able to return to work within 3 to 6 months post injury. He would have returned to the same job with minimal restriction and whilst he would have experienced some minor stiffness and ache this would not have prevented him carrying out his normal activities."*
5. Whether or not the initial surgery was negligently performed, it is common ground that it did not have a good outcome. Over the course of the following three years or so, the claimant underwent six further surgeries, and has a much poorer prognosis than Mr Machin said he ought to have achieved. Mr Ley told me indeed that at one stage amputation was given serious consideration.
6. On 15 March 2022, the claimant wrote to the court proposing an 8-week adjournment of the CCMC to allow the parties to review the case in the light of (a) the claimant's return to work and (b) Mr Machin's anticipated report. The court refused the adjournment.
7. At the CCMC, the defendant renewed what had been the claimant's suggestion that there should be an adjournment to take stock, and indicated an intention to apply to amend the Defence and join the NHS Trust with responsibility for any negligence in the claimant's December 2017 surgery. The claimant resisted the suggestion and the CCMC went ahead, on the basis that any proposal to amend or join the NHS Trust would require a formal application.
8. Directions and a trial date were set without reference to the issues that would arise if the Defence were amended or if the NHS Trust were joined as co-defendant to the Claim and/or defendant to a Part 20 Claim. The trial was listed for 3 days commencing on 21 August 2023. Mr Ley accepted before me that if the Defence served in November 2021 had been the Amended Defence for which the defendant seeks permission, or permission for that Amended Defence had been granted at the

CCMC, in all probability a later trial date would have been required because the claimant would want to join the NHS Trust as a co-defendant.

9. The defendant issued its application to amend the Defence on 25 May 2022. It was heard by District Judge Vernon on 26 September 2022. He handed down a reserved judgment on 20 October 2022. For the reasons he gave in that judgment, and by Order of that date, DJ Vernon refused the application.
10. The defendant now appeals against that refusal, with permission granted by Jefford J, DBE.

The Decision

11. The proposed amendment to the Defence would add a new paragraph 3A, in the following terms:

“3A. Furthermore, the Defendant denies that it can properly [be] held responsible for injury loss and damage arising from negligent treatment of the Claimant’s original injury, by way of the surgical operation undertaken to reduce and fix the fracture dislocation of his ankle on 22 December 2017 ... at the East and North Hertfordshire NHS Trust Lister Hospital. Such treatment was negligent in that:

- (i) The Claimant’s ankle was not stabilised in the correct position;*
- (ii) The surgical fixation was inadequate in regard to reduction of the fracture fragments, lack of removal of the interposed die punch fragment in the tibia and metal work used to hold the fracture;*
- (iii) Non-removal of the die punch fragment precluded reduction of the posterior malleolar fragment and potentially the medial malleolar fragment;*
- (iv) The metal work used in the fixation was inadequate;*
- (v) The three-hole plate in the fibula fracture did not have adequate hold;*
- (vi) There was no lagging of the fibula fracture;*
- (vii) Use of a straight four hole locking plate with lateral placement for fixation of the posterior malleolus did not afford the posterior malleolar fragment a significant buttress effect across its entirety, such that the reduction was not as good as it should have been and was likely [sic., unlikely] to be maintained;*
- (viii) Use of a single posterior to anterior screw in the posterior malleolar fragment will have been insufficient to hold that fracture reduced and was a sub-optimal choice of hardware, even in combination with the plate;*
- (ix) The plate for the medial malleolar fixation was tenuous on account of its having been positioned too superiorly and the limited number of screws used and*
- (x) The fixation was inadequate, such that it failed within a few days.*

It was as a result of such negligence that the Claimant had to undergo a further 6 operations and has significant problems with working and hobbies, significant pain and dysfunction. But for the negligent treatment, such would not have befallen him. Accordingly, responsibility for the above rests not with the Defendant but with the NHS Trust. Further or alternatively, any chain of causation between the accident and the above has been broken by negligent treatment, which constitutes a novus actus interveniens.”

12. DJ Vernon directed himself (judgment at [33]) that on the authorities:

“a) Assessing loss in cases of tort involves consideration of both factual causation and legal causation. An assessment of legal causation requires the court to consider the extent of the loss for which the defendant ought to be responsible;

b) Every tortfeasor should compensate the injured claimant in respect of that loss and damage for which he should justly be held responsible;

c) There is no rule of law that later negligence always extinguishes the causative potency of an earlier tort; and

d) In cases where alleged negligent medical treatment is given to address injuries sustained as a result of an earlier tort, only medical treatment so grossly negligent as to be a completely inappropriate response to the injury inflicted by the defendant should operate to break the chain of causation.”

13. DJ Vernon derived that final proposition from *Webb v Barclays Bank and Portsmouth Hospitals NHS Trust* [2001] EWCA Civ 1141. He considered that *Webb* establishes as a rule of law that medical treatment of an injury caused by a defendant’s tort *cannot* break the chain of causation unless it is such grossly negligent treatment as to be a completely inappropriate response to the injury (“the Specific Rule”).

14. On that basis, DJ Vernon reasoned correctly, permission to amend ought not to be granted unless there was a real prospect, under the proposed amendment, of a finding at trial that the December 2017 surgery had been “*so grossly negligent as to be a completely inappropriate response*” to the initial injury caused by the defendant. He concluded that there was no real prospect of the defendant establishing such negligence.

15. On the basis, therefore, that the defendant had not shown a real prospect of establishing a necessary ingredient of the proposed defence, permission to amend was refused.

16. I agree with Mr Brown’s submission that as a result, DJ Vernon did not exercise a discretion over whether to grant permission. The question did not arise and the refusal of permission was not on discretionary grounds. If, which is the defendant’s case on appeal, *either* the Specific Rule does not exist *or* DJ Vernon was wrong to find that there was no real prospect of the defendant satisfying the Specific Rule at trial, then I shall be entitled to exercise my discretion afresh.

17. That said, DJ Vernon made some observations concerning the exercise of discretion that, if sound, I would consider it appropriate to take into account. Having expressed

his decision to refuse permission on the ground that the proposed amendment had no real prospect of success, he said this:

“45. In addition, I should also say that there are a number of reasons why permission to amend should not be granted in this case which would have been relevant to the exercise of the Court’s discretion.

46. First, I agree with and accept the significance of the issues identified by Mr Ley in paragraphs 10 a. to c. of his written submissions. They are all matters which show that prejudice would be suffered by the Claimant in the event that permission for the amendment was granted. By contrast, I consider that there is little (if any) prejudice to the Defendant in my refusing permission. In light of my conclusion above on the prospects of success of the issue raised by the proposed amendment, there is no prejudice caused to the Defendant by way of possibly being found liable for losses which should not be attributed to the Defendant. That is a point reinforced by the fact that it is still open to the Defendant to issue proceedings for an indemnity or a contribution from the alleged negligent treatment provider.

47. Second, to grant permission for the amendment is very likely to cause real disruption to the litigation generally and is likely to lead to the loss of the trial which has already been listed. It is also a course of action which would necessitate extensive further case management and further costs management, including budgeting for an additional party.”

18. I regret to say that I consider every element of that analysis to be flawed. The starting point for any exercise of discretion would be that contrary to the District Judge’s conclusion, the proposed amendment had a real prospect of success. Only then would the question arise whether as a matter of discretion the court should grant permission. The defendant had acted promptly and the prospect of amending had arisen early in the proceedings, only a few months after Defence and before the CCMC listing. There was a trial listing, but only because the court had refused *the claimant’s* request to allow the parties time to reflect on the implications of the possible negligence of the NHS Trust before holding the CCMC.

19. The points taken by Mr Ley in paragraphs 10 a. to c. of his written submission before the District Judge, with respect, were all plainly bad points:

(i) “a. If the Defendant pleads a defence of novus actus whatever the merits of that defence, Mr. Jenkinson will need to be advised that the only completely safe course is to apply to join the Hospital as a second Defendant, so that if the defence succeeds, he is able to recover compensation from the Hospital;”

That is not prejudice, it is merely the consequence of a properly arguable possibility (if it exists) that the Hospital was responsible, *and the defendant was not*, for a major part of the loss and damage that the claimant wants to claim. In any event, it would have been the situation faced by the claimant if the proposed amendment had appeared in the original Defence at the end of November 2021

(ii) “b. a direct claim against the Hospital is now statute-barred (the operation took place on 22/12/17 and the 3-year limitation period expired in

December 2020); Mr. Jenkinson would doubtless face a limitation defence and be forced to rely on s.33 of the Limitation Act, and to have a split trial on this issue against the Hospital;”

There was no explanation, or evidence, before the District Judge as to why 22 December 2017 (the date of the initial surgery) might be the ‘date of knowledge’ under s.14 of the Limitation Act 1980 for any claim by the claimant against the NHS Trust. There was and is no basis for any suggestion, nor was the suggestion made, that *if* such a claim was time barred, it was not already time barred when the claimant commenced proceedings. In any event, a time bar difficulty, if there is one, over suing the NHS Trust, was not arguably created by the failure of the proposed causation defence and associated allegation of negligence against the NHS Trust to appear in the original Defence at the end of November 2021. Mr Ley rightly conceded as much in the oral argument before me, accepting, on reflection, that he could not rely on any time bar issue as relevant prejudice.

- (iii) “c. *if successful in being able to proceed against the Hospital, it would be necessary for Mr. Jenkinson to embark (unwillingly) on a clinical negligence claim against the Hospital, obtaining orthopaedic evidence either to confirm the allegations of negligence made by Mr. Machin or to rebut them; the costs of such further medical evidence would (at least initially) be borne by Mr. Jenkinson.*”

Like the first point, this is not prejudice at all, let alone prejudice caused by the causation plea not appearing in the original Defence, it is merely the consequence of a properly arguable defence that the NHS Trust *and not the defendant* has liability for much of the loss and damage the claimant seeks to claim.

20. The District Judge’s conclusion, therefore, that the points taken by Mr Ley showed relevant prejudice, is flawed. His conclusion that the defendant would not be prejudiced by a refusal of permission to amend was irrelevant to any exercise of discretion, because it was premised on the prior conclusion that the proposed amendment had no real prospect of success. The question of discretion only arises if that prior conclusion is wrong.
21. Finally, as to discretion, the District Judge’s reliance on the need for different case management decisions, and a new, later, trial listing, was to my mind misplaced in the circumstances of this case. The CCMC proceeded, and directions including a trial listing were set, in full knowledge that those directions, and trial listing, were suitable only if the expected amendment application either did not materialise or failed. To rely upon their existence as a reason to refuse permission to amend, if it were otherwise appropriate to grant permission, was unfair.
22. This was an amendment application brought in timely fashion, the defendant having acted promptly, prior to the CCMC, in making clear that it would wish to amend, once Mr Machin’s report was to hand. There was no suggestion that the defendant could reasonably have obtained Mr Machin’s report (or a similar report) any earlier; and it would not have been responsible to plead the causation defence proposed by the amendment without such a report. The trial listing and pre-trial directions set at the

CCMC were only apt if there was no such defence, and cannot fairly have been intended to pre-judge whether the expected amendment application should succeed.

23. In short, if the causation defence has a real prospect of success, then this was and is straightforwardly a case for granting permission to amend, to ensure that the real issues are contested and that the defendant is not at risk of being held liable for loss and damage that was not its responsibility merely because it only became able to put that defence forward a few months after it had been required to file its Defence.
24. The refusal of permission to amend here stands or falls, therefore, upon DJ Vernon's conclusion that the causation defence that the amendment would plead has no real prospect of success.

The Specific Rule

25. In *Webb*, the claimant, an employee of Barclays Bank, stumbled and fell over a protruding stone in their forecourt. In the fall, she hyper-extended her left knee, which was affected by the consequences of polio she had contracted as an infant. The knee was left in a grossly unstable condition. She accepted the recommendation of her long-term consultant, an employee of the Portsmouth Hospital NHS Trust, to have an above-knee amputation. That recommendation was negligently given. Amputation should only have been considered, if at all, as a last resort, and even then only with proper disclosure of the prospects and risks. The trial judge, Rougier J, had found *inter alia* that amputation "*has a notoriously bad outcome for old polio patients and it was the consensus of opinion that it should only be used as a very last resort and as a result of some secondary and potential life threatening complication*" (quoted by the Court of Appeal at [30]).
26. In the Court of Appeal, Henry LJ presided and gave a judgment with which Judge and Hale LJ agreed. As Henry LJ put it, at [38]: "*In simple terms, [the claimant] should have been told: "Mrs Webb, amputation is the very last resort and until we can properly advise you as to the pathology of your left knee and have fully investigated with you modern bracing, you should not consent to amputation."*—and [her consultant] should have given reasons why."
27. Barclays had pleaded that the amputation and subsequent problems related to it were not caused or contributed to by their negligence but were solely due to the intervening negligence of the claimant's treatment hospital and doctors.
28. In the event, however, Barclays settled with the claimant on terms that covered her claim against them *and* her claim against the NHS Trust. The only matter arising for determination by the Court of Appeal was Barclays' contribution claim against the NHS Trust under the Civil Liability (Contribution) Act 1978. For that purpose, Rougier J had held in a pre-trial ruling that the fact Barclays had pleaded that causation defence did not defeat the contribution claim, relying on s.1(4) of the 1978 Act: "*A person who has made or agreed to make any payment in bona fide settlement or compromise of any claim made against him in respect of any damage (including a payment into court which has been accepted) shall be entitled to recover contribution in accordance with this section without regard to whether or not he himself is or ever was liable in respect of the damage, provided, however, that he would have been liable assuming that the factual basis of the claim against him could be established.*"

29. In his trial judgment, Rougier J had proceeded on the basis that “*many of the disabilities and aspects of financial loss have two concurrent causes, which would produce overlaps. The proper approach, therefore, is to look at the total settlement sum [and] assess to what extent the breach of duty of the [NHS Trust] contributed to that sum ...*” (quoted by the Court of Appeal at [51]). The Court of Appeal dealt with the appeal, in effect, on an assumption in the NHS Trust’s favour that it would be a defence to the contribution claim against it to show that Barclays’ pleaded causation defence was well founded. That meant:

“52. ... The question here is whether, when an employee is injured in the service, and by the negligence, of her employer, his liability to her is terminated by the intervening negligence of a doctor brought in to treat the original injury, but who in fact made it worse.

53. Unsurprisingly, there is no general rule on the question. As Laws L.J. said in Rahman v Arearose Limited [2001] [QB] 351 at 366G:

“... it does not seem to me to be established as a rule of law that later negligence always extinguishes the causative potency of an earlier tort. Nor should it be. The law is that every tortfeasor should compensate the injured claimant in respect of that loss and damage for which he should justly be held responsible.”

54. The same question was considered in the High Court of Australia in Mahoney v Kruschick (Demolitions) Pty Ltd (1985) 156 C.L.R. 522 ...

55. Finally, we agree with the editors of Clerk & Lindsell on Torts, when they say:

“Moreover, it is submitted that only medical treatment so grossly negligent as to be a completely inappropriate response to the injury inflicted by the defendant should operate to break the chain of causation” (18th ed., 2-55).”

56. We are of clear opinion that [here] the chain of causation was not broken. We have in mind that:

(a) the original wrong-doing remained a causative force, as it had increased the vulnerability of the claimant and reduced the mobility of the claimant over and above the effect of the amputation;

(b) the medical intervention was plainly foreseeable, and it was also foreseeable that the claimant’s pre-existing vulnerability would impose its own risks;

(c) given the doctor’s conduct was negligent, but was not grossly negligent, and given the findings expressed at (a) and (b) it would not be just and equitable, nor in keeping with the philosophy of the 1978 Act for the wrongdoer to be given, in these circumstances, a shield against (i) being liable to the claimant for any part of the amputation damages; and (ii) being liable to make such contribution to the Trust’s amputation damages as was just and equitable.

57. In short, the negligence in advising amputation did not eclipse the original wrong-doing. The Bank remained responsible for their share of the amputation

damages. The negligence of [the consultant] was not an intervening act breaking the chain of causation.”

30. Henry LJ had also presided in the Court of Appeal in *Rahman v Arearose Ltd* [2001] QB 351, decided a month before *Webb*. In that case, Laws LJ gave a judgment, with which Henry and Schiemann LJ agreed. Rougier J had again been the trial judge.
31. The claimant was a branch manager at the King’s Cross branch of Burger King. He was subjected to a vicious assault by two black youths that caused *inter alia* a fracture of the orbital wall of his right eye, for which he was treated at UCLH. Surgery was carried out by way of bone graft to prevent the eye from sinking in its socket. The surgery was performed negligently, such that the bone graft impinged on the optic nerve resulting in permanent blindness in that eye. The claimant’s employer was held liable for negligence in and about providing a safe place of work; the University College London Hospital NHS Trust was liable for the negligence in the surgery.
32. In addition to the physical injuries and impairments he suffered, the claimant was left with complex psychological injuries: PTSD largely in reaction to his right-eye blindness; a specific phobia of black people of Afro-Caribbean ethnicity caused by the assault and traumatic elements of criminal proceedings relating to it; and a severe depressive disorder of psychotic intensity with an enduring personality change due to the synergistic effect of the depression and the PTSD that would probably not have developed had the claimant not lost the sight of his right eye.
33. The NHS Trust conceded that the negligent execution of the surgery, causing blindness, was something for which it had sole responsibility, and the employer had none. That was of course the employer’s case; and it was also the claimant’s case: see the claimant’s argument in the Court of Appeal at [2001] QB 354E-F. In light of the findings summarised in the previous paragraph concerning the claimant’s psychological injuries, as Laws LJ put it at [23] ([2001] QB 354D): “*Upon the correct view of the sense to be accorded to “concurrent” tortfeasors, the case before us is ... not one of concurrent torts. The reason is that on the evidence the respective torts committed by the defendants were the causes of distinct aspects of the claimant’s overall psychiatric condition, and it is positively established that neither caused the whole of it.*”
34. The question arose whether the employer should be held responsible for loss or damage beyond that which the claimant would have suffered if the eye injury caused by the NHS Trust’s negligence had not occurred (*per* Laws LJ at [26] ([2001] QB 365F)). It being conceded that the NHS Trust had sole responsibility for the loss of the eye, so it was not a case of concurrent torts, the employer argued that the only question for the court was what would the position have been absent the second tort (*ibid*).
35. Laws LJ concluded that, from the point of view of causation, there is no rule of English law that later negligence always extinguishes the causative potency of an earlier tort (*ibid* at [29]). The real question in such cases, he considered (*ibid*, at [33]), is “*what is the damage for which the defendant under consideration should be held responsible. The nature of his duty (here, the common law duty of care) is relevant; causation, certainly will be relevant—but it will fall to be viewed, and in truth can only be understood, in light of the answer to the question: from what kind of harm was it*

the defendant's duty to guard the claimant? ... Novus actus interveniens, the eggshell skull rule, and (in the case of multiple torts) the concept of concurrent tortfeasors are all no more and no less than tools or mechanisms which the law has developed to articulate in practice the extent of any liable defendant's responsibility for the loss and damage which the claimant has suffered" (original emphasis).

36. Applied to the facts of that case (*ibid* at [34]), Laws LJ rejected the submission that the NHS Trust's "*inevitable acceptance of responsibility for loss of the claimant's eye possesses an absolving effect upon [the employer's] responsibility for the psychological sequelae once the eye injury had been inflicted. ... Once one leaves behind, as for reasons I have given one should, the dogmas of novus actus and eggshell skulls, there is nothing in the way of a sensible finding that while the [NHS Trust] obviously (and exclusively) caused the right-eye blindness, thereafter each tort had its part to play in the claimant's suffering.*"
37. If the Specific Rule existed, it is surprising that Laws LJ should consider the NHS Trust's concession of sole responsibility for the right-eye blindness and its consequences to have been inevitable and obviously correct. There was no finding of gross negligence, even if that meant only a high degree of negligent fault; there was not even a suggestion of gross negligence in the sense referred to in *Webb* of medical treatment amounting to "*a completely inappropriate response to the injury inflicted by the defendant*".
38. *Rahman* in the Court of Appeal is not, however, a decision against the Specific Rule, since the point was not taken, by either the NHS Trust or by the claimant, that the employer was liable to the claimant for the right-eye blindness (and its psychological consequences) because the eye surgery in response to the injury resulting from the employer's negligence as to the claimant's safety at work was an appropriate medical response, negligently executed, that did not break the chain of causation.
39. The suggestion in *Clerk & Lindsell*, endorsed by *Webb* at [55], appears in the current (23rd) Edition, at 2-124, as part of the discussion of the House of Lords decision in *Hogan v Bentinck West Hartley Collieries (Owners) Ltd* [1949] 1 All E.R. 588. In that case, a miner with an additional top joint to the thumb injured that thumb at work. After initial treatment failed to relieve his pain, part of his thumb, including the additional top section, was amputated. The evidence was that amputation was not an appropriate treatment for the workplace injury. The House of Lords held (by a bare majority) that the inappropriate treatment operated as a *novus actus*. The Editors of *Clerk & Lindsell* prefer Lord Reid's dissenting view that only a "*grave lack of care and skill*" should suffice to break the chain of causation, expressing their position thus: "*It is submitted that Lord Reid was correct, and that only medical treatment so grossly negligent as to be a completely inappropriate response to the injury inflicted by the defendant should operate to break the chain of causation.*"
40. At 2-114, summarising the law more generally on the intervening conduct of a third party, *Clerk & Lindsell* has it that: "*No precise or consistent test can be offered to define when the intervening conduct of a third party will constitute a novus actus interveniens sufficient to relieve the defendant of liability for his original wrongdoing. The question of the effect of a novus actus "can only be answered on a consideration of all the circumstances and, in particular, the quality of that later act or event" [per Lord Simonds, one of the majority, in Hogan, at 593]. Four issues need to be*

addressed. Was the intervening conduct of the third party such as to render the original wrongdoing merely a part of the history of events? Was the third party's conduct either deliberate or wholly unreasonable? Was the intervention foreseeable? Is the conduct of the third party wholly independent of the defendant, i.e. does the defendant owe the claimant any responsibility for the conduct of the intervening third party? In practice, in most cases of novus actus more than one of the above issues will have to be considered together." By a footnote to the end of that paragraph, the Editors note that it was considered at length by Aikens LJ in *Chubb Fire Ltd v Vicar of Spalding* [2010] EWCA Civ 981, who concluded that "*the ultimate question is: what is the extent of the loss for which a defendant ought fairly or reasonably or justly to be held liable*".

41. Notwithstanding the apparently unqualified endorsement of the Specific Rule in *Webb* at [55], it was not applied by the Court of Appeal to decide that case. Rather, Henry LJ at [56] considered a range of factors, only one of which was that there had been negligence but not gross negligence. Furthermore, I agree with Mr Brown that the concessions by both the claimant and the NHS Trust in *Rahman* were incorrect, not inevitable and obviously correct as the Court of Appeal considered, if the Specific Rule existed as a rule of law. Still further, I consider there is no logical justification or policy reason for creating a specific rule of law in the context of negligent medical intervention, and that a rule of law in terms of the Specific Rule is a recipe for litigation within litigation over when treatment otherwise proper in kind is so poorly executed as to become an inappropriate medical response.
42. On that last point, take this case, for example. One of the serious concerns raised by Mr Machin's report is that the surgical method was wrong (failure to remove the interposed fragment), and the surgical hardware selected was wrong (inappropriate surgical fixtures and fittings for the intended fixation). If a test of 'inappropriate surgical response' has to be satisfied, intended to stand in contradistinction to 'negligent execution of appropriate surgery', I do not find it difficult to see how, after a trial, Mr Machin's criticisms realistically might be thought to satisfy it. The real point, though, is that it is an unnecessary and unjustified distraction to be considering on which side of some such boundary the surgical negligence, if established, fell. The degree to which the claimant's treatment diverged, if it did, from good treatment competently delivered, will of course be relevant. At this stage, that is to say considering Mr Machin's report prior to seeing how it stands up to being tested at trial and what emerges from that scrutiny, it is realistic to envisage the possibility of a trial judge concluding that the divergence was very significant, and basic, if all of Mr Machin's criticisms stand up.
43. In my judgment, the Specific Rule does not exist as a principle of law defining a necessary ingredient of a *novus actus* defence in the context of medical interventions. It follows that by paragraph 33(d) of his judgment in this case, DJ Vernon misdirected himself.
44. Without the constraint of the Specific Rule as a principle of law, in my judgment there is a real prospect on the basis of Mr Machin's opinion, if accepted at trial, of a finding that the claimant's initial injury, admittedly the result of the defendant's negligence, was so badly mistreated that the defendant ought not, in fairness, to be considered responsible for the consequences of that mistreatment. How precisely, if that finding were made, the defendant's liability would be reduced from full liability for all loss

and damage the claimant will allege, is not something that arises for consideration at this stage. There was no suggestion that it could be said now to be plainly so minor in likely impact as to be fair to prevent the defendant from taking the point so as to avoid the added complexity and expense of involving the NHS Trust in the claimant's claim.

45. I have effectively already indicated why, if the Specific Rule exists as a rule of law, I also find myself in disagreement with DJ Vernon over whether the defendant in this case has raised a real prospect of success at trial by reference to it. The gist of DJ Vernon's reasoning (judgment at [41]) was to say that:

"The fact that treatment was performed inadequately (including negligently) is not sufficient ... and where the choice of treatment and the approach to treatment are not criticised and the focus of criticism is the quality of the surgery performed, its outcome and consequences, I am not persuaded that there is a real prospect of the Defendant showing that the treatment was grossly negligent."

46. That seems to me, with respect, wrongly to hold that the "*quality of ... surgery performed*" could never turn what might otherwise have been appropriate treatment into a completely inappropriate response. DJ Vernon also appears to me to have read far too much into Mr Machin's comment that "*The choice to proceed to surgery was correct as was the surgical approach.*" I consider that, on Mr Machin's report, it is realistically possible that his view, when explored as it can only be at a trial, may be held to amount to this, namely that whereas there was here a correct choice to recommend surgery and a correct view that the surgery should be an open reduction and internal fixation, what was actually done amounted, in substance, to no such thing, but rather was a botched job that did not amount to reduction and fixation worthy of those names, or as Mr Brown put it, less colloquially, that there was "*a comprehensive failure to carry out a correct surgical procedure*". A fracture repair that fails within a few days, it might realistically be concluded after a trial, was not a fracture repair at all.
47. Before concluding, I should make explicit that nothing I have said in this judgment should be taken as prediction or provisional view as to how the causation defence the defendant wishes to plead will in fact, or should, turn out at trial. At this stage, the only question is whether there is a real prospect, not only a fanciful possibility or barely arguable possibility, that it may turn out to be well founded. In my judgment, it does satisfy that test, and DJ Vernon erred in concluding otherwise.

Conclusion

48. This was a straightforward case in which permission to amend should have been granted but for the view that was taken that the proposed causation defence has no real prospect of success.
49. In my judgment, that view was wrongly taken, in that (a) the premise was that the Specific Rule exists, i.e. a rule of law requiring proof of "*medical treatment so grossly negligent as to be a completely inappropriate response to the injury inflicted by the defendant*", when there is no such rule of law, and (b) the conclusion was reached erroneously that there was no real prospect of satisfying that rule, because it was wrongly considered that poor quality surgery cannot turn appropriate treatment into

inappropriate medical response, and the potential import of Mr Machin's evidence was not correctly identified.

50. This appeal will therefore be allowed. I understand it to be agreed that in those circumstances, the appropriate course will be for me to deal with the costs of the appeal, and it may be any consequential adjustment to what was ordered below in relation to the costs of the application to amend that will now be allowed, but to leave other case management consequences of allowing the application to amend to a further hearing in the District Registry that I should direct.

A critique of medical negligence as an intervening act

Rachael Mulheron ^{*}

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Journal Article

Journal of Personal Injury Litigation

J.P.I. Law 2025, 1, 12-24

Subject

Personal injury

Other related subjects

Negligence; Torts

Keywords

Causation; Clinical negligence; Intervening events; Joint tortfeasors; Successive causes

Cases cited

[Webb v Barclays Bank Plc](#) [2001] EWCA Civ 1141; [2002] P.I.Q.R. P8; [2001] 7 WLUK 360 (CA (Civ Div))

[Rahman v Arearose Ltd](#) [2001] Q.B. 351; [2000] 6 WLUK 387 (CA (Civ Div))

[Wright \(A Child\) v Cambridge Medical Group \(A Partnership\)](#) [2011] EWCA Civ 669; [2013] Q.B. 312; [2011] 6 WLUK 92 (CA (Civ Div))

[Jenkinson v Hertfordshire CC](#) [2023] EWHC 872 (KB); [2024] 2 All E.R. 514; [2023] 4 WLUK 108 (KBD)

[Norney v Watt](#) [2024] NIKB 78; [2024] 10 WLUK 41 (KBD)

***J.P.I.L. 12 A. Introduction**

Whenever a victim is tortiously injured in, say, a car accident, work accident, medical mishap or recreational accident—the sorts of accidents which give rise to the majority of law reports which entail physical injury to a claimant—then it is entirely foreseeable that medical treatment of the victim may follow. It is equally as foreseeable that the medical treatment by a doctor or other healthcare practitioner may be negligently administered. The legal conundrum confronted in this article is to consider in what legal circumstances that medical negligence by defendant D2 should constitute an intervening act, in the sense that it severs the chain of causation between the original tortfeasor's (D1's) tort and the victim's (C's) ultimate damage. Three Court of Appeal decisions, those of *Webb v Barclays Bank Plc*,¹ *Rahman v Arearose Ltd*,² and *Wright v Cambridge Medical Group*,³ have come to govern primarily this area of English medico-legal jurisprudence.

However, medical negligence as an intervening act has become an issue of controversy and topicality, courtesy of the recent decisions of the English High Court in *Jenkinson v Hertfordshire CC*⁴ and of the Northern Ireland High Court in *Norney v Watt*.⁵ In the former, Baker J declared⁶ that the trial judge's reliance upon a principle espoused in *Webb* (and based upon textbook analysis⁷), that "only medical treatment so grossly negligent as to be a completely inappropriate response to the injury inflicted by the defendant should operate to break the chain of causation",⁸ was incorrect. There was no such rule. The aforementioned quote "does not exist as a principle of law defining a necessary ingredient of a *novus actus* defence in the context of medical interventions", said Baker J.⁹ Most curiously, *Wright* was not cited in the judgment. The other decision, that of *Norney v Watt*, considered the question as to whether medical negligence could constitute an intervening act where the first tort was also medical (rather than work-related) negligence. Obversely, it did not cite *Webb* but relied upon *Wright*. It is all becoming rather confusing, and arguably, longstanding appellate authority is not receiving the weight that *should* be accorded to it.

Jenkinson itself concerned a mishap in which Alun Jenkinson stepped into an uncovered manhole or drain gully and fractured his ankle, for which the Council admitted liability in negligence or for breach of statutory duty.¹⁰ Mr Jenkinson then alleged that the surgical treatment to repair his right ankle was negligently performed. Baker J permitted the Council to raise the allegation that the medical negligence constituted an intervening act, even where no proof of gross negligence had been pleaded, on the basis that its causation issue had real prospects of success. In *Norney v Watt*, the defendant neurologist was **J.P.I.L. 13* alleged to have committed a negligent misdiagnosis of the claimant's headaches whilst she was a private patient, and then carried out an epidural blood patch treatment plan negligently several months later whilst she was an NHS patient. Colton J held that the latter was not an intervening act of which the neurologist's private employer could take advantage, and the just and fair apportionment between the private and NHS defendants was a 50/50 split.¹¹

In this article, it will be argued that, whilst *Norney's* result was predictable, *Jenkinson* represents a wrong turn in the law, and that the appellate authorities of *Webb*, *Rahman* and *Wright* collectively stand for the principle that whether or not medical treatment constitutes an intervening act depends upon three matters, viz:

- (1) that the medical negligence committed by D2 must both (a) be so gross and egregious as to be exceptional; and (b) eclipse entirely the tort first in time, so as to deprive D1's wrongdoing of its causative potency; and
- (2) it would not be fair or just to hold D1 responsible for C's damage which occurs after the occurrence of the medical negligence committed by D2.

This thesis is developed by means of four principal points.

First, treating medical negligence as an intervening act is an exceptional instance because many of the classic tests by which to define intervening acts do not fit that context comfortably at all. That is because the fact of medical negligence during treatment, and following an earlier tort-related event involving that claimant, is always foreseeable,¹² so it is not the act that matters, it is the *quality* of the negligence which has to be treated to be the precursor of an intervening act. Secondly, and despite the views expressed in *Jenkinson* that *Webb's* insistence upon proof of gross medical negligence is not a "necessary ingredient of a *novus actus* defence in the context of medical interventions",¹³ the argument will be put that such proof is *precisely* what *Webb* required. Mere errors of medical judgment should not suffice (and should be rejected entirely); and "ordinary" negligence of the type seemingly advocated by *Jenkinson* (and which has obtained previous judicial support in England from time to time) is not exceptional enough. Thirdly, and as an additional criterion to gross negligence, the medical negligence of D2's which

constitutes the second-in-time tort must obliterate or eclipse the tort earlier-in-time committed by D1, or else the earlier tort retains causative potency. Where medical negligence is the intervening act, that has been difficult to prove. Fourthly and finally, there is inevitably a large dollop of policy or value judgment at play where intervening acts are concerned. Part of the judicial assessment is whether D1 *should* be liable for causing C's injury or whether D2 should be left to bear the burden alone, although it is not clear as to precisely what policy reasons apply. But split apportionment (of the type that occurred in *Webb* itself¹⁴) will almost always be a better policy outcome when allocating liability amongst successive tortfeasors than an all-or-nothing outcome.

Each point will be expanded in turn.

B. The many judicial tests of intervening acts revisited

It is not particularly promising that, in a case of medical negligence as an alleged intervening act, Keith J wrote that, when it comes to defining that act, "[t]he guiding principle is that there is no guiding principle".¹⁵ Since then, another court has correctly noted that "[w]hat may amount to an intervening act has been the subject of much judicial discussion and there is very real difficulty in finding a common *J.P.I.L. 14 thread to knit together disparate judicial utterances".¹⁶ Bearing in mind that an intervening act can be any one of several possibilities—the claimant's own conduct, D2's later act (with which we are concerned), the act of an entirely unknown third party, or a natural event¹⁷—the lack of an overarching definition may be understandable. It must cater for many different scenarios, some of which do not involve a subsequent negligent act at all.

Some of the judicial descriptors of intervening acts stress the importance of evaluating the extent to which the intervening conduct was unforeseeable: "in general, the more foreseeable it is, the less likely it is to be a *novus actus interveniens*",¹⁸ and vice versa. Some cases fit this mould perfectly. For example, in *Knightley v Johns*, where the defendant police inspector, D2, forgot to close a tunnel in the chaos that followed a vehicular accident caused by Mr Johns, D1, and then instructed PC Knightley, C, to ride against the traffic down the tunnel to close it which resulted in yet a further accident, the Court of Appeal concluded that the inspector's negligent instructions were "so unforeseeable as not to be something likely to flow from the original negligence [of D1]".¹⁹ D2's negligence broke the chain of causation between D1's negligent driving and C's eventual collision with the unwitting Mr Cotton. None of these events would have happened, had D1 not negligently overturned his car, but "the breakdown of the system ... provid[ed] evidence of improbable and unforeseeable ineptitude, and the breaches of the standing orders".²⁰ The disastrous intervention in *Chubb Fire Ltd v Vicar of Spalding*,²¹ where vandals broke into the medieval parish church of St Mary and St Nicholas at Spalding and used two dry powder fire extinguishers from the kitchenette to cause extensive damage to the church and organ, falls into the same category of case: the precise combination of events that led to such damage to the church was not reasonably foreseeable when the wrong sort of fire extinguisher was provided to the church seven years earlier.²² Intervening acts occurred in both cases.

However, those sorts of cases are a world away from most medical negligence scenarios, precisely because the medical intervention by D2 following D1's tortious act is usually very foreseeable, even likely, and often, even certain. In rare cases, it is true that whether D2's intervention is reasonably foreseeable can be at issue, as it was, for example, in *Horton v Evans*.²³ A pharmacist's mistake²⁴ in prescribing an overdose of dexamethasone which led to the patient's developing Cushing's syndrome was then repeated by a GP, D2, whom the patient consulted to seek a repeat prescription during her stay with her mother in New York State. The Court was satisfied that the pharmacist, D1, should have reasonably foreseen the intervention of a GP other than the patient's usual doctor, and the reliance which might be placed by that GP on the pharmacist's label on the bottle. However, those cases are the more unusual type. Generally speaking, *the act* of the medical intervention is not the issue; it is *the standard or quality* of the medical treatment undertaken by D2 which is at the nub of the conundrum.

Hence, once the requirement of "unforeseeability" is stripped away from the judicial descriptors of an intervening act—which it is contended that it must be for medical negligence—that leaves descriptors which are truly aimed at the quality or the mindset of D2's conduct. And all of these point to something that is really exceptional about the intervening act, viz, "a new cause which ... can be described as either *J.P.I.L. 15 unreasonable or extraneous or extrinsic" (per *Oropesa, The* ²⁵); an act that was "reckless ... shutting his eyes to the obvious risks that existed [for C]" (per *Wright v Lodge* ²⁶); and that the "degree of unreasonableness of the conduct" really matters, so that, generally speaking, "the more unreasonable the conduct, the more likely it is to be a *novus actus interveniens* ... stress[ing] the need for a high degree of unreasonableness".²⁷

This invites an examination of key decisions in English medico-legal jurisprudence which have addressed how that "unreasonableness", or quality of negligence, has been adjudged when considering whether medical treatment by D2 was an intervening event so as to relieve D1 from liability, and of how *Jenkinson* is taking the law on an unfortunate route that revisits the past.

C. The quality of the intervening medical negligence

Whether D2's conduct was so unreasonable so as to be an intervening act "can only be answered on a consideration of all the circumstances and, in particular, the quality of that later act or event", according to the House of Lords in *Hogan v Bentinck West Hartley Collieries*.²⁸ As other commentators have noted,²⁹ Baker J did not explicitly state what standard or quality of medical negligence would suffice to constitute an intervening act in *Jenkinson*, except to say that the claimant must have been "badly mistreated",³⁰ but the position will be taken in this article that it was impliedly a standard of "ordinary" negligence which Baker J contemplated to be sufficient, certainly something less than "gross" negligence.

In terms of medical negligence, "quality" is directed to the question as to whether the intervening act (1) can be a mere error of judgment which is a non-negligent mistake that falls above the requisite standard of care which D2 must discharge; (2) can be "ordinary" negligence, i.e. a mistake that falls below the standard of reasonable care, as adjudged by the court (if a mistake of fact) or in accordance with the *Bolam/Bolitho* enquiry (if a point upon which expert evidence is required); or (3) must be of the ilk of "gross negligence", whatever that may mean in this context. English law's answer to this has varied considerably over the decades.³¹ Dealing with each in turn:

(1) Mere medical mistakes

Non-negligent errors of judgment on D2's part have typically not severed the chain of causation in English law. However, the point is not entirely free from doubt because it was specifically argued in *Robinson v Post Office*,³² and without definitive conclusion.

Keith Robinson, a Post Office technician, scraped his shin when slipping off a ladder at work (for which his employer, D1, conceded negligence), and eight hours later, his doctor, D2, gave him an injection of anti-tetanus serum, but did not follow the accepted procedure for giving a test dose. Nine days later, Mr Robinson developed encephalitis which resulted in brain damage and permanent partial disability. He brought an action for damages against both defendants claiming that his injuries and illness were caused by their negligence. D1 denied liability for any damages attributable to the encephalitis and the permanent disability, claiming that those were caused solely by negligent medical treatment by D2. Ultimately, the trial judge found (and the Court of Appeal upheld these findings) that D2 was not negligent in deciding **J.P.I.L. 16* to administer the serum.³³ Hence, D1 specifically argued on appeal that the non-negligent administration of the serum could nevertheless constitute an intervening act upon which D1 could rely, and that any conduct of a doctor's falling short of negligence *could* amount to an intervening act. Some support for that position could be drawn from the judgment of du Parc LJ in *Rothwell v Caverswall Stone Co Ltd*, that "negligent or inefficient treatment by a doctor" was capable of amounting to an intervening act.³⁴ This phrase was later endorsed by Lord Simonds, one of the majority in *Hogan*;³⁵ and cited with approval by the Privy Council.³⁶ On the other hand, in *Hogan*, Lord Reid explicitly rejected any notion that an error falling short of negligence could constitute an intervening act.³⁷ Ultimately, in *Robinson*, Orr LJ concluded that he *doubted* whether it was the law that "inefficient", as opposed to negligent, acts could sever the chain of causation, but even if they could (and without deciding that point), the decision by the doctor to administer the serum to Mr Robinson was not "inefficient".³⁸ Hence, the disputed viewpoints that had emanated years earlier between Lords Simonds and Reid was not resolved.

Perhaps it was with this in mind, when Laws LJ stated in *Rahman v Arearose* (having cited *Robinson*) that "[t]he English authorities are with deference somewhat equivocal upon the question [of what constitutes an intervening act in medical scenarios]".³⁹ However, the principle that a non-negligent act or omission on a medical defendant's (D2's) part *cannot* suffice as an intervening act seems to have been accepted without judicial question since. For example, in *Horton v Evans*,⁴⁰ any criticisms of the New York State-based GP who followed the Lloyds' pharmacist's label on the patient's bottle in issuing a repeat were not adjudged to be negligent (according to the court, reliance on *Bolam* evidence "is all one way", that a reasonable

GP would have acted no differently in relying upon the pharmacist's label⁴¹); and in *Forbes v Merseyside Fire & Civil Defence Authority*,⁴² where Anthony Forbes was injured at work when undertaking fitness tests as part of his training as a fire officer, the occupational health doctor, D2's, decision to prematurely retire Mr Forbes may have been "wrong", but it was taken bona fide and without negligence.⁴³ In both cases, the courts held that there was no room for an intervening act to apply, and D1 remained liable. Unfortunately, *Robinson* was not referred to in either case.

Indeed, the author's searches have been unable to turn up any case in which the open question from *Robinson*, as to whether "inefficient" (as an alternative to "negligent") is sufficient to constitute an intervening act, has been explored. In modern English case law, the general consensus seems to be that anything non-negligent on a medical defendant's part will not suffice, and other scholarly opinion has come to the same conclusion.⁴⁴ Still, the faint possibility left open by *Robinson* could be helpfully put to bed judicially.

(2) "Ordinary" negligence

This where the decision in *Jenkinson v Hertfordshire CC*⁴⁵ really bites, for Baker J opined that there is no principle in English law that requires proof of gross negligence when seeking to prove that a medical *J.P.I.L. 17 defendant's, D2's, negligence constituted an intervening act. The trial judge had cited *Webb v Barclays Bank* as authority for the proposition that medical treatment of an injury caused by D1's tort can only break the chain of causation if it is such grossly negligent treatment as to be a completely inappropriate response to the injury. As a matter of law, Baker J considered that such a proposition could not be drawn from *Webb*, and that "gross negligence" is not a precondition to an intervening act arising.⁴⁶ In other words, "ordinary" negligence could seemingly suffice. The decision is unsettling, from both a doctrinal and a practical point of view.

(a) Doctrinal analysis

Although not cited in *Jenkinson* on this point, some early English case law supported the notion that ordinarily negligent medical treatment (and nothing higher than that) by D2 could suffice to break the causal chain between D1's tort and the victim's eventual disability. In the (previously mentioned) case of *Rothwell v Caverswall Stone Co Ltd*,⁴⁷ it will be recalled that du Parc LJ referred to "negligent or inefficient treatment by a doctor" as being sufficient as an intervening act, and that was applied in that decision. Edgar Rothwell suffered an accident at work due to his employer's, D1's, negligence, and D1 pointed to subsequent medical treatment in which Mr Rothwell's injury (a dislocated shoulder) was inaccurately diagnosed by the hospital doctor, D2, and he was left with a stiff arm and serious disability. du Parc LJ referred to D2's treatment as "bad treatment", and it was an intervening act. There was no reference to gross negligence as being either necessary or proven. Later, in *Hogan v Bentinck West Hartley Collieries (Owners) Ltd*,⁴⁸ an operation upon an injury which a miner suffered to his thumb at work was variously described as "ill-advised" (per Lord Simonds⁴⁹ and Lord Morton⁵⁰) and "unskilful or negligent, [showing] lack of skill or failure in reasonable care" (Lord Normand).⁵¹ These judges, comprising the majority, also permitted that medical conduct to be an intervening act. It is unfortunate that the *Jenkinson* judgment did not engage with these judgments so as to clarify whether English law was set to return to its past.

However, the Court in *Jenkinson* did cite⁵² *Rahman v Arearose*, in which Laws LJ remarked that a chain of causation "can be broken by a later negligent act", and that "it does not seem to me to be established as a rule of law that later negligence always extinguishes the causative potency of an earlier tort. Nor should it be".⁵³ These passages again may appear to support the notion that ordinary negligence should be sufficient to constitute an intervening act.

However, the limitations of these cases should be noted. Both *Rothwell* and *Hogan* were decided on a very specific point, i.e. whether, in order to recover workers' compensation payments under the relevant statute, the employees could prove that their "incapacity ... for work results from the injury".⁵⁴ As Hodgson notes, these cases are "merely persuasive" in respect of the treatment of intervening acts in the context of negligence.⁵⁵ In fact, Lord Reid's judgment in *Hogan* summarises the precise problem at issue in that case, that "[i]f liability to pay compensation is to cease, not only must a new cause of incapacity come in, but the old must go out: there must no longer be any causal connection between the injury by accident and the present incapacity".⁵⁶ Hence, arguably the focus of an intervening act under the relevant workers' *J.P.I.L. 18 compensation statute was whether D2's tort eclipsed the employer's wrongdoing, rather than upon the quality of D2's negligence. Furthermore, no intervening act was proven in *Rahman v Arearose* —again, for reasons to do with the lack of eclipse there, and unconnected to

the quality of D2's negligence.⁵⁷ None of these cases are strictly ratio endorsements of the position which is now the apparent result of *Jenkinson*, i.e. that ordinary negligence should suffice as an intervening act in the medical negligence context.

Furthermore, in *Jenkinson*, Baker J sought to explain the reasoning in *Webb v Barclays Bank*⁵⁸ in a matter that is somewhat less-than-convincing: "[n]otwithstanding the apparently unqualified endorsement of the [requirement of gross negligence] in *Webb*, it was not applied by the Court of Appeal to decide that case. Rather, Henry LJ considered a range of factors, only one of which was that there had been negligence but not gross negligence."⁵⁹ This passage is puzzling for two reasons. First, it is certainly true that Henry LJ referred to three factors, that "(a) the original wrong-doing remained a causative force", that "(b) the medical intervention was plainly foreseeable", and that "(c) given the doctor's conduct was negligent, but not grossly negligent, it would not be just and equitable ... for the wrongdoer [employer D1] to be given ... a shield against being liable to the claimant for any part of the amputation damages".⁶⁰ Each of these played a part in the finding that there was no break in the chain of causation brought about by the negligent amputation; indeed, it follows from Henry LJ's words that gross negligence was a necessary (not a sole, but a *necessary*) pre-condition to the finding of an intervening act. Secondly, this interpretation is also one that is supported by other courts, such as the Alberta Queen's Bench, where *Webb* was discussed in these terms: "Lord Justice Henry agreed that medical treatment operated to break the chain of causation only if it was so grossly negligent as to be a completely inappropriate response to the injury inflicted by the defendant".⁶¹

(b) Practical considerations

Jenkinson puts down a strong marker that nothing more than ordinary negligence is required, when seeking to prove that D2's medical negligence can constitute an intervening act—and this will have *practical* consequences for litigation up and down the country, where some medical treatment of C's injury was required after D1's tortious conduct towards C, and which was alleged to have been negligently undertaken.

Commentary since the decision in *Jenkinson* has noted its potentially wide-ranging impact. A sample will illustrate. Upadhyay remarks that "[a]t first glance, Baker J appears to have comprehensively dismantled a long-standing principle of law. However, it may be too early yet to see the full consequences: is this High Court decision going to be treated as an anomaly? ... Baker J has opened the way for defendants to successfully raise additional causation arguments in cases where a claimant appears to have gone on to have negligent medical treatment following an initial injury caused or contributed to by the defendant".⁶² Marnham notes that "Baker J's decision has far-reaching implications ... one may see a flurry of applications, for example with the Defendant applying to amend their defences in cases where the issue of Novus Actus Interveniens had not previously been taken".⁶³ McCracken makes the point that *Jenkinson* "has thrown the cat amongst the pigeons on the question of when medical treatment following a tort can break the chain of causation", and that, previously, "by setting the bar for proving subsequent negligent treatment so high [at gross negligence], speculative attempts by [D1] to raise a causation defence of this **J.P.I.L. 19* type were discouraged".⁶⁴ Davis observes that "both claimant and defendant personal injury practitioners are likely to want to give careful consideration to joining NHS Trusts to proceedings, meaning such Trusts may also expect to see an increase in clinical negligence claims".⁶⁵

Each of these comments point to the practical consequences of further litigation becoming likely (whether by claim or by contribution proceedings) against NHS Trusts, as well as against private entities, consultant doctors and other medical professionals. Whereas previously the prospect of proving "gross negligence" may have seemed very unlikely against these defendants, the rewards for joining that medical defendant in the lawsuit may be reaped by D1, if ordinary negligence can suffice to break the chain of causation to D1's benefit. It opens up causation arguments in a way that hitherto was not possible in the light of *Webb* and *Wright*, which are considered next.

(3) "Gross" negligence

First and foremost, what does this phrase even mean? It is a fairly foreign concept to the English common law of negligence. Indeed, in *West Wallasey Car Hire Ltd v Berkson & Berkson*, Judge Brown stated that "gross negligence" has not been the test of breach in the tort of negligence "since at least 1910".⁶⁶ In *Jenkinson* itself, Baker J suggested two descriptors: "a high degree of negligent fault", or the sense in which it was used in *Webb*, "a completely inappropriate response to the injury inflicted by the defendant".⁶⁷

To flesh out other possibilities: there are a few exceptions in English common law where the concept has arisen from time to time. In the context of punitive or exemplary damages, and according to the Privy Council majority in *A v Bottrill*, gross negligence means a flagrant departure from the reasonable standard of care—showing an appalling level of skill, and a standard of conduct distantly removed from the prudent behaviour of the reasonable defendant.⁶⁸ It was said that gross negligence requires, inescapably, a judgment about "degrees of negligence", for which there would be "an element of forensic uncertainty in borderline cases".⁶⁹ In the case of the "good Samaritan" who attempts a rescue or who tries to assist a victim, the same test of conduct "manifestly short of the standard to be expected" was argued for and rejected in *Cattley v St John Ambulance Brigade*,⁷⁰ as being a concept unknown to English Good Samaritan law, as well as "confusing and ... unnecessary". In the case of amateur referees, the Court of Appeal rejected the submission in *Smoldon v Whitworth*⁷¹ that a referee should only be liable for breach if he had shown gross negligence, which was argued there to be "a deliberate or reckless disregard for the safety of player". In *Camerata Property Inc v Credit Suisse Securities (Europe) Ltd*,⁷² the Court noted that where "gross negligence" is used in Contract to limit a defendant's liability for negligence, the term must mean something different from "mere" negligence, and that it was capable of meaning that the defendant acted with "serious disregard of or indifference to an obvious risk". Hence, the meaning of the phrase, "gross negligence", has never been consistently applied in English negligence law.

In any event, the citation of "gross negligence" by Henry LJ in *Webb* was not the first occasion in English case law in which this concept had been linked to proving an intervening act in the medical negligence context. In *Hogan*, Lord MacDermott (dissenting) appeared to consider gross negligence as **J.P.I.L. 20* being a requirement to establish an intervening act under the workers' compensation law being considered therein, when giving the example of "acts of surgical negligence of such an exceptional kind that what has been done cannot fairly be related to an endeavour to cure or reduce the infirmity—as, e.g. where a workman loses a sound limb because the surgeon takes him for somebody else".⁷³ Some suggestion of the need for gross negligence may possibly also be found in Lord Reid's judgment (also dissenting) that there is no "warrant for applying the doctrine of *novus actus interveniens* unless there has been grave lack of skill or care on the part of the doctor".⁷⁴

Still, *Webb* appeared to put the matter beyond doubt (or so it was thought prior to *Jenkinson*). Henry LJ cited from the then current edition of *Clerk & Lindsell on Torts*,⁷⁵ where the editors had preferred the abovementioned dissenting views from *Hogan* to suggest that an intervening act would need "medical treatment so grossly negligent as to be a completely inappropriate response to the injury inflicted by the defendant". That test could not be proven by Elizabeth Webb in respect of the amputation carried out by D2.

However, the case which *really* embedded the test of gross negligence within medical negligence as intervening acts was that of *Wright v Cambridge Medical Group*,⁷⁶ and which was not referred to in *Jenkinson* at all. Elias LJ was the only member of the Court of Appeal to cite *Webb*, but in doing so, there is no doubt that *Webb* was both endorsed and applied. His Lordship did not consider that the negligence perpetrated by the hospital D2, "although serious, deserved to be characterised as gross or egregious so as to break the chain of causation and make it unjust for that reason to impose liability on the doctor [D1], such as was envisaged in *Webb*".⁷⁷ Lord Neuberger MR also cited the need for some "egregious ineptitude" on D2's part in order for an intervening act to apply, and agreed that this did not apply in *Wright*. The hospital's negligence was not of "such significance that it justifies a finding that ... it broke the chain of causation between the [GPs'] negligence and the claimant's injury. It was not such an egregious event, in terms of the degree or unusualness of the negligence, or the period of time for which it lasted, to defeat or destroy the causative link between the [GPs'] negligence and the claimant's injury".⁷⁸ Hence, in both judgments, there was a clear approval and application of the gross negligence test when considering medical negligence as an intervening act. Academic scholarly commentary has frequently noted that these judgments, in combination, have this effect.⁷⁹

In failing to engage with *Wright* and these statements, the cogency of the reasoning in *Jenkinson* is arguably lessened. Both *Webb* and *Wright* have clearly set the bar of negligence higher than "ordinary", and this is entirely consistent with the ethos that an intervening act in *any* context is an *exceptional* finding.

D. The "eclipse" effect of the intervening act

As an entirely independent criterion necessary to prove an intervening act, case law regularly demonstrates that the "causative potency" of D1's tort must be obliterated or eclipsed if D2's tort is to be an intervening act. It is described in Clerk and Lindsell's current (and former) text exposition as to whether the intervening conduct was "such as to render the original wrongdoing

merely a part of the history of events".⁸⁰ In *Chubb v Vicar of Spalding*,⁸¹ for example, the vandalism by D2 occurred seven years after the installation of the **J.P.I.L. 21* dry fire extinguishers by Chubb; these were deliberate and criminal acts of three vandals for which Chubb had no responsibility; and the church was left unattended and unlocked—all of this contributed to the view that the intervening conduct of the vandals was such as to render the original breach of duty by Chubb merely a part of the history of events, so that Chubb was not responsible for the damage caused by the vandals.⁸² It is a frequently applied test,⁸³ and as Lord Neuberger MR remarked in *Wright*, "depends very much on the facts of the particular case".⁸⁴

It has been noticeable in key medical negligence cases that it can be very difficult for D1 to successfully argue that the causative potency of its tort was eclipsed by the medical negligence which followed on D2's part. However difficult the test of "gross negligence" might be to prove under the previous criterion of an intervening act, the eclipse test is no easier for D1 to meet. For example, in *Webb*,⁸⁵ D1's tort in causing Mrs Webb to trip over the flagstone "remained a causative force, as it had increased the vulnerability of the claimant and reduced the mobility of the claimant over and above the effect of the amputation"; in *Wright*,⁸⁶ a GP's (D1's) delay in referring patient Clarice for hospital admission retained its causative potency, because the less time that Clarice was in hospital before the infection became embedded, the more chance there was that the hospital, D2 (also guilty of negligent delay in diagnosing the infection) would not be able to treat the infection appropriately; and in *Horton v Evans*,⁸⁷ the pharmacist's labelling of the patient's medication was precisely what the US-based GP was entitled to rely upon when treating the patient, and that could not be "relegated to no more than a mere occurrence in the history of events" either.

This is also why (it is suggested) not too much emphasis can be placed upon the case of *Rahman v Arearose*⁸⁸ when considering what quality of negligence is required for an intervening act in medical negligence. *Rahman* did not turn on the point of quality, but on the point of eclipse. Mr Rahman, C, was the branch manager at the Burger King at King's Cross, and was seriously assaulted one night by two gang members, with his employer, D1, conceding breach for failing to provide a safe system of work. Mr Rahman suffered a fractured orbital wall of his right eye which was treated at D2's hospital—negligently, as it turned out, for a bone graft was attempted, but Mr Rahman was blinded because his optic nerve was severed during the operation. D2 conceded that the negligent surgery and right-eye blindness was something for which it had sole responsibility, and the employer, D1, had no liability for that injury and its consequences. In *Jenkinson*, Baker J queried why that concession would have been accepted by the Court of Appeal in *Rahman*, when there was no suggestion of any gross negligence on the surgeon's part, if gross negligence was indeed part and parcel of an intervening act.⁸⁹ This, suggested Baker J, provided further doctrinal support for the fact that the "gross negligence" requirement was *not* part of the law governing intervening acts.

However, as Baker J notes, *Rahman* cannot be said to be an authority which is against the requirement of gross negligence, because the point was not addressed by either claimant Mr Rahman or by the defendant employer and defendant NHS Trust.⁹⁰ This is undoubtedly true, because *Rahman* revolved around whether or not the surgery on Mr Rahman's eye eclipsed the wrongdoing of his employer, and it was held that it did not. Laws LJ rejected the submission that the NHS Trust's, D2's, "inevitable acceptance of responsibility for loss of the claimant's eye possesses an absolving effect upon [the employer's, D1's] responsibility for the psychological sequelae once the eye injury had been inflicted".⁹¹ D1's negligence never lost its causative **J.P.I.L. 22* potency, because the experts in *Rahman* agreed that certain damages post-surgery flowed solely or "largely" from the earlier assault which D1's negligence had enabled—viz, a specific phobia of black or Caribbean people with paranoid elaboration; and PTSD. Other disorders from which Mr Rahman suffered—a severe depressive condition of psychotic intensity, and an enduring personality change—were attributed to the loss of his vision in one eye caused by D2's subsequent negligence. Hence, given this expert opinion—which Laws LJ regarded as being "of the first importance"⁹²—there was absolutely no avenue for employer D1 to argue that D2's negligent surgery was an intervening act, because D2's surgery did not obliterate or eclipse the first tort. The continuing causative potency mattered hugely in that case ("each tort had its part to play in the claimant's suffering", and it was "beyond doubt that neither tort caused the whole of the claimant's psychological deficit"⁹³). It is unsurprising that, given all this, the quality of D2's medical negligence did not merit judicial comment.

It follows that the "quality" and the "eclipse" are separate pre-requisites for an intervening act to apply, and the Court of Appeal did not have to (and did not) address the former of those in *Rahman*. As such, it cannot be taken to be a case that undermines the efficacy of *Webb* and of *Wright*. The very recent decision of *Norney v Watt*⁹⁴ exhibits the same pattern. The causative effect of D1's tort was also not eclipsed, and *Wright* and *Rahman* were cited in support—but again, the quality of D2's medical negligence was not judicially considered, and it did not have to be.

E. Should the intervening act count as a matter of policy?

The third and final pre-requisite for an intervening act is whether D1 *should* be liable for C's damage, or whether the entirety of the liability should be placed upon D2. In *Chubb v Vicar of Spalding*, Aikens LJ said that "the ultimate question is: what is the extent of the loss for which a defendant ought fairly, or reasonably or justly to be held liable".⁹⁵ It entails value judgments. This renders it a policy question which is divorced from a purely factual assessment. In the medical context with which we are concerned, and when assessing for what a defendant doctor, D2, should be liable damages-wise, the Court of Appeal acknowledged in *Wright v Cambridge Medical Group* that "considerations of policy loom large in the analysis ... although they are generally concealed beneath the legal concepts used to justify the result".⁹⁶

Indeed, teasing out these policy reasons is not easy, but hints do appear in the judgments. First, *comparative blameworthiness* may matter. In *Rahman*, Laws LJ noted, when reviewing the apportionment of damages liability as between D1 and D2, that "blame may be material to the application or disapplication in any particular case of our ideas of *novus actus*".⁹⁷ Both D1 and D2 are negligent, of course, but is D2 so much more morally culpable than the other so as to deserve the punishment which an intervening act entails for D2? In some cases which have been reviewed in this article, that sort of assessment may have been evident. For example, in *Wright*, Lord Neuberger compared the periods of negligent delay as between D1 and D2: "it took the [GP surgery] a little over two days more than it should have done to refer the claimant to the hospital", i.e. almost as long as the hospital's whose delay in diagnosing Clarice's condition was "less than three days more than it should have taken".⁹⁸ The equivalence of these delays may have counted against an intervening act on the part of the hospital there. Comparative blameworthiness also seemed to matter in *Horton v Evans*. D2 relied on the label on the bottle presented to him by the patient, and the author of that label, the pharmacist D1, was the more culpable than D2 was: the pharmacist "must bear a real responsibility for why [the US GP] thought that the patient had been prescribed 4 mg tablets *J.P.I.L. 23 a day".⁹⁹ If D1's blameworthiness is more than, or fairly equal to, D2's wrongdoing, then why should D2 bear the financial consequences of an intervening act?

Perhaps the time over which the events occurred between D1's and D2's torts should matter too, for when the law terms it to be a "chain of causation", one envisages some degree of close temporal connectivity. In *Barings Plc v Coopers & Lybrand*, Evans-Lombe J suggested that, where a lapse of time reduces that connectivity, then D2 may truly be considered to be a "new cause". In his Lordship's words, a court should have regard to "a new cause coming in and disturbing the sequence of events, ... which may result from an accumulation of events which in sum have the effect of removing the negligence sued on as a cause, which accumulation of events may take place over time".¹⁰⁰ *Chubb* was a perfect illustration of that statement—a 7-year lapse.

Furthermore, the financial consequences of an intervening medical act may matter too. Where medical negligence is upheld as an intervening act, then the entirety (or at least a large part) of the damages suffered by C will fall upon the medical insurer, to the exclusion of, say, the insurer of the motor vehicle driver, the employer, or the occupier whose insured (D1) caused C injury in the first place. One of the recognised roles of Tort law is to allocate responsibility and to apportion risk among tortfeasors (or their insurers). In that regard, this branch of the common law pays particular regard to two factors, viz, which of D1 or D2 is better equipped to insure against the risks associated with their acts or omissions, and which of D1 or D2 is better positioned to minimise or to prevent C's injury?¹⁰¹ If the answers to these are "neither" (and in competing causation battles between D1 and D2, both are likely to be insured, and both are likely to be well-advised as to "breach-minimising" measures), then an all-or-nothing outcome is more difficult to rationalise. Should D1's insurer escape liability? The answer must surely be, only in the most exceptional circumstances.

F. Conclusion

The legal conundrum which has been examined in this article has focussed upon the doctrinal and value-judgment questions which intervening acts inevitably give rise to. But there is an important financial implication too, if medical defendant D2 is to be drawn into causally-related litigation to fend off contribution claims from D1 that D2's medical negligence constituted an intervening act so that the consequences of D1's negligence should be substantially limited. In the types of cases which have been considered in this article, and if an intervening act is upheld, C will likely have *some* claim against D1 for the injuries caused between the date of D1's and D2's torts (it is unlikely to be a *Chubb*-type scenario where C suffered no harm prior to D2's tort); but the intervening act will certainly ring-fence or limit the extent of D1's liability for damages post D2's tort. Medical insurers should take real heed of the increased payouts that *Jenkinson* might mean for them. For victims too, it is vitally important that, if an increased burden of payouts is to be borne by medical insurers, then D2's professional indemnity insurance

must provide sufficient cover, and that nothing should subvert that cover (such as some non-disclosure of a material fact by D2 when taking out the policy).

It has been argued in this article that intervening acts should be exceptional, and that this has largely been preserved by case law via three pre-requisites: the medical negligence committed by D2 must so gross or egregious as to be unforeseeable; D2's medical negligence must eclipse entirely the tort first in time, so as to deprive D1's wrongdoing of its causative potency; and it would not be fair or just to hold D1 responsible for C's damage which occurs after the occurrence of the medical negligence committed **J.P.I.L. 24* by D2. The decision in *Jenkinson* has done real "harm" to the first of those requirements, whilst the even more recent decision of *Norney v Watt* has upheld the importance of the second.

At a time when the annual payout for medical negligence claims is measured in billions of pounds (e.g. almost £2 billion was paid out by the NHS to injured patients in 2022/23¹⁰²), and when the total cost of outstanding NHS compensation claims in England is estimated to be over £58 billion,¹⁰³ any judgments which potentially increase the burden on NHS Resolution are very significant. It is suggested that *Webb*, *Rahman* and *Wright* struck the right balance for intervening acts, doctrinally and practically, and that any departure from those authorities will create significant risk to medical insurers going forward.

Rachael Mulheron

Footnotes

- 1 *Webb v Barclays Bank Plc* [2001] EWCA Civ 1141; [2002] P.I.Q.R. P61.
- 2 *Rahman v Arearose Ltd* [2000] EWCA Civ 190; [2001] Q.B. 351.
- 3 *Wright (A Child) v Cambridge Medical Group (A Partnership)* [2011] EWCA Civ 669; [2013] Q.B. 312.
- 4 *Jenkinson v Hertfordshire CC* [2023] EWHC 872 (KB) (Baker J); [2023] Med. L.R. 353.
- 5 *Norney v Watt* [2024] NIKB 78 (Colton J).
- 6 *Jenkinson v Hertfordshire CC* [2023] EWHC 872 (KB) at [43], [49].
- 7 A.M. Dugdale, *Clerk and Lindsell on Tort*, 18th edn (London: Sweet and Maxwell, 2000), para.2-55.
- 8 Baker J called this "the Specific Rule" in the judgment, but that language will be eschewed in this article, in favour of the descriptor of "gross negligence".
- 9 *Jenkinson v Hertfordshire CC* [2023] EWHC 872 (KB) at [43].
- 10 Pursuant to their obligations under the Highways Act 1980 s.41, noted in *Jenkinson v Hertfordshire CC* [2023] EWHC 872 (KB) at [1].
- 11 *Norney v Watt* [2024] NIKB 7 at [124].
- 12 As acknowledged by the High Court of Australia in *Mahony v J Kruschich (Demolitions) Pty Ltd* (1985) 156 C.L.R. 522, and cited with approval in: *Rahman v Arearose Ltd* [2000] EWCA Civ 190 at [28].
- 13 *Jenkinson v Hertfordshire CC* [2023] EWHC 872 (KB).
- 14 A 75/25 split as between the NHS Trust and the Bank: *Webb v Barclays Bank Plc* [2001] EWCA Civ 1141 at [59].
- 15 *Horton v Evans* [2006] EWHC 2808 (QB) at [53]; [2007] LS Law Medical 212.
- 16 *Maitland Hudson v Solicitors Regulation Authority* [2017] EWHC 1249 (Ch) at [57] (Chief Master Marsh).
- 17 Each of these is discussed by the author, by reference to case law, in: R. Mulheron, *Principles of Tort Law*, 2nd edn (Cambridge: CUP, 2020), 458–68. A small amount of the discussion in this article is drawn from that section.
- 18 *Clay v TUI UK Ltd* [2018] EWCA Civ 1177 at [28].
- 19 *Knightley v Johns* [1982] 1 W.L.R. 349 CA at 366; [1982] R.T.R. 182, citing the trial judge with approval.
- 20 *Knightley v Johns* [1982] 1 W.L.R. 349 at 357 (emphasis added).
- 21 *Chubb Fire Ltd v Vicar of Spalding* [2010] EWCA Civ 981; [2010] 2 C.L.C. 277.
- 22 *Chubb Fire Ltd v Vicar of Spalding* [2010] EWCA Civ 981 at [73] ("[t]hat combination was, at its highest, a mere possibility").

23 *Horton v Evans* [2006] EWHC 2808 (QB).
 24 As described in *Horton v Evans* [2006] EWHC 2808 (QB) at [46] ("I have no doubt that what [the
 pharmacist] should have done was to follow the instruction in the branch procedures manual and question
 the correctness of the prescription with [the initial GP] or [the patient]. Had he done that, [the initial GP's]
 mistake would have been discovered. In failing to do that, [the pharmacist] fell below the standards which
 could reasonably have been expected of a reasonably careful and competent pharmacist").
 25 *Oropesa, The* [1943] P.32 [1943] 1 All E.R. 211 CA at 215.
 26 *Wright v Lodge* [1993] R.T.R. 123; [1993] P.I.Q.R. P31 CA at P37.
 27 *Clay v TUI UK Ltd* [2018] EWCA Civ 1177 at [28(2)].
 28 *Hogan v Bentinck West Hartley Collieries* [1949] 1 All E.R. 588 HL at 593; [1949] W.N. 109.
 29 E. Davis, "When will negligent surgical treatment breach the chain of causation?" (*The Dekagram*, 24
 April 2023), <https://www.dekachambers.com/2023/04/24/the-dekagram-24th-april-2023/>.
 30 *Jenkinson v Hertfordshire CC* [2023] EWHC 872 (KB) at [44].
 31 For an excellent analysis, see D. Hodgson, "Intervening Causation Law in a Medical Context" (2013) 15
 University of Notre Dame Australia L. Rev. 22, 39–45, who also discusses several of the cases considered
 herein.
 32 *Robinson v Post Office* [1974] 1 W.L.R. 1176 CA; 16 K.I.R. 12.
 33 *Robinson v Post Office* [1974] 1 W.L.R. 1176 at 1189.
 34 *Rothwell v Caverswall Stone Co Ltd* [1944] 2 All E.R. 350 HL at 365 (emphasis added), cited in *Robinson*
v Post Office [1974] 1 W.L.R. 1176 at 1189.
 35 *Hogan v Bentinck West Hartley Collieries* [1949] 1 All E.R. 588 HL at 592.
 36 *Algol v Antonio Galleguillos Acori* [1997] 4 L.R.C. 575 PC at 579.
 37 *Hogan v Bentinck West Hartley Collieries* [1949] 1 All E.R. 588 HL at 607 ("[i]t could not ... be
 maintained that the chain of causation is broken by a mistake which is not in any degree blameworthy ... I
 do not think that such a degree of inefficiency has ever been held to be *novus actus interveniens*").
 38 *Robinson v Post Office* [1974] 1 W.L.R. 1176 CA at 1189.
 39 *Rahman v Arearose Ltd* [2000] EWCA Civ 190 at [28].
 40 *Horton v Evans* [2006] EWHC 2808 (QB).
 41 *Horton v Evans* [2006] EWHC 2808 (QB) at [56].
 42 *Forbes v Merseyside Fire & Civil Defence Authority* [2002] EWCA Civ 1067.
 43 *Forbes v Merseyside Fire & Civil Defence Authority* [2002] EWCA Civ 1067 at [8].
 44 Hodgson, "Intervening Causation Law in a Medical Context" (2013) 15 University of Notre Dame
 Australia L. Rev. 22, 40–42.
 45 *Jenkinson v Hertfordshire CC* [2023] EWHC 872 (KB).
 46 *Jenkinson v Hertfordshire CC* [2023] EWHC 872 (KB) at [43]–[49].
 47 *Rothwell v Caverswall Stone Co Ltd* [1944] 2 All E.R. 350 HL at 365 (emphasis added), cited *Robinson v*
Post Office [1974] 1 W.L.R. 1176 at 1189.
 48 *Hogan v Bentinck West Hartley Collieries* [1949] 1 All E.R. 588 HL at 593.
 49 *Hogan v Bentinck West Hartley Collieries* [1949] 1 All E.R. 588 HL at 591.
 50 *Hogan v Bentinck West Hartley Collieries* [1949] 1 All E.R. 588 HL at 599 (this word had been used by the
 trial judge to describe the surgeon's treatment of the miner's thumb injury).
 51 *Hogan v Bentinck West Hartley Collieries* [1949] 1 All E.R. 588 HL at 597.
 52 *Jenkinson v Hertfordshire CC* [2023] EWHC 872 (KB) at [29].
 53 *Rahman v Arearose Ltd* [2000] EWCA Civ 190; [2001] Q.B. 351 at 366 (emphasis added).
 54 per the *Workmen's Compensation Act 1925* s.9.
 55 Hodgson, "Intervening Causation Law in a Medical Context" (2013) 15 University of Notre Dame
 Australia L. Rev. 22, 41.
 56 *Hogan v Bentinck West Hartley Collieries* [1949] 1 All E.R. 588 HL at 605.
 57 Discussed further at pp.20–22 below.
 58 *Webb v Barclays Bank Plc* [2001] EWCA Civ 1141.
 59 *Jenkinson v Hertfordshire CC* [2023] EWHC 872 (KB) at [41].
 60 *Webb v Barclays Bank Plc* [2001] EWCA Civ 1141 at [56].
 61 *Phillip v Bablitz* [2010] ABQB 566 at [337].
 62 K. Upadhyay, *Breaking the chain of causation: Jenkinson v Hertfordshire County Council* (*Guildhall*
Chambers Newsletter, 25 August 2023), <https://www.guildhallchambers.co.uk/2023/08/25/breaking-the-chain-of-causation-jenkinson-v-hertfordshire-county-council/>.

- 63 *M. Marnham, Novus actus interveniens: A critical analysis of Jenkinson v Hertfordshire CC* (3PB Barristers Newsletter, 2 May 2023), <https://www.3pb.co.uk/content/uploads/Novus-Actus-Interveniens-A-Critical-Analysis-of-Jenkinson-v-Hertfordshire-CC-2023-EWHC-872-KB-by-3PB-Barristers.pdf>.
- 64 J. McCracken, *Grossed out? Subsequent medical negligence need not be gross negligence to break the chain of causation* (Ropewalk Chambers Newsletter, 25 April 2023), <https://ropewalk.co.uk/blog/grossed-out-subsequent-medical-negligence-need-not-be-gross-negligence-to-break-the-chain-of-causation/>.
- 65 Davis, *When will negligent surgical treatment breach the chain of causation?* (The Dekagram, 24 April 2023).
- 66 *West Wallasey Car Hire Ltd v Berkson & Berkson (A Firm)* [2009] EWHC B39 (Merc); [2010] P.N.L.R. 14 at [32], citing: *Ridehalgh v Horsefield* [1944] Ch. 205 CA at 237; [1994] 3 W.L.R. 462.
- 67 *Jenkinson v Hertfordshire CC* [2023] EWHC 872 (KB) at [37].
- 68 *A v Bottrill* [2002] UKPC 44; [2003] 1 A.C. 449 PC, from NZCA at [24], [27], [33], [35].
- 69 *A v Bottrill* [2002] UKPC 44; [2003] 1 A.C. 449 at [45], citing: *Ellison v L* [1998] 1 NZLR 416 HC 419.
- 70 *Cattley v St John Ambulance Brigade* unreported, 25 November 1988.
- 71 *Smoldon v Whitworth* [1996] EWCA Civ 1225; [1997] P.I.Q.R. 133 at 138–139.
- 72 *Camerata Property Inc v Credit Suisse Securities (Europe) Ltd* [2011] EWHC 479 (Comm) at [161]; [2011] 2 B.C.L.C. 54, citing: *Red Sea Tankers Ltd v Papachristidis (The Ardent)* [1997] 2 Lloyd's Rep. 547 HL at 586.
- 73 *Hogan v Bentinck West Hartley Collieries* [1949] 1 All E.R. 588 HL at 601.
- 74 *Hogan v Bentinck West Hartley Collieries* [1949] 1 All E.R. 588 HL at 607.
- 75 Dugdale, *Clerk and Lindsell on Tort*, 18th edn (2000), para.2-55.
- 76 *Wright v Cambridge Medical Group* [2011] EWCA Civ 669; [2013] Q.B. 312.
- 77 *Wright v Cambridge Medical Group* [2011] EWCA Civ 669; [2013] Q.B. 312 at [111] (albeit dissenting in the ultimate outcome).
- 78 *Wright v Cambridge Medical Group* [2011] EWCA Civ 669; [2013] Q.B. 312 at [37].
- 79 e.g. K. Amirthalingam, "Causation and the medical duty to refer" (2012) 128 Law Quarterly Review 208, 210; J. McQuater, "Wright v Cambridge Medical Group: Case comment" [2011] J.P.I.L. C172, C176–C177.
- 80 M.A. Jones, A.M. Dugdale and M. Simpson, *Clerk and Lindsell, 1st supplement to the 23rd edn* (London: Sweet and Maxwell, 2024), para.2-82. The "eclipse" test was cited in *Webb v Barclays Bank Plc* [2001] EWCA Civ 1141 at [57].
- 81 *Chubb Fire Ltd v Vicar of Spalding* [2010] EWCA Civ 981.
- 82 *Chubb Fire Ltd v Vicar of Spalding* [2010] EWCA Civ 981 at [73].
- 83 The eclipse effect also occurred in, e.g. *Clay v TUI UK Ltd* [2018] EWCA Civ 1177 at [36].
- 84 *Wright v Cambridge Medical Group* [2011] EWCA Civ 669 at [32].
- 85 *Webb v Barclays Bank Plc* [2001] EWCA Civ 1141 at [56].
- 86 *Wright v Cambridge Medical Group* [2011] EWCA Civ 669 at [109].
- 87 *Horton v Evans* [2006] EWHC 2808 (QB) at [53].
- 88 *Rahman v Arearose Ltd* [2000] EWCA Civ 190; [2001] Q.B. 351.
- 89 *Jenkinson v Hertfordshire CC* [2023] EWHC 872 (KB) at [37].
- 90 *Jenkinson v Hertfordshire CC* [2023] EWHC 872 (KB) at [38].
- 91 *Rahman v Arearose Ltd* [2000] EWCA Civ 190 at [34].
- 92 *Rahman v Arearose Ltd* [2000] EWCA Civ 190 at [7].
- 93 *Rahman v Arearose Ltd* [2000] EWCA Civ 190 at [34].
- 94 *Norney v Watt* [2024] NIKB 78.
- 95 *Chubb Fire Ltd v Vicar of Spalding* [2010] EWCA Civ 981 at [64].
- 96 *Wright v Cambridge Medical Group* [2011] EWCA Civ 669 at [110].
- 97 *Rahman v Arearose Ltd* [2000] EWCA Civ 19 at [35].
- 98 *Wright v Cambridge Medical Group* [2011] EWCA Civ 669 at [37].
- 99 *Horton v Evans* [2006] EWHC 2808 (QB) at [53].
- 100 *Barings Plc (In Liquidation) v Coopers & Lybrand (No.7)* [2003] EWHC 1319 (Ch) at [838]; [2003] Lloyd's Rep. I.R. 566.
- 101 See Mulheron, *Principles of Tort Law*, 2nd edn (2020), p.12, citing *Deep Vein Thrombosis and Air Travel Group Litigation, Re* [2002] EWHC 2825 (QB) at [47], [106]–[108]; [2003] 71 B.M.L.R. 82.
- 102 L. O'Dwyer, "The state of NHS Resolution's payouts for clinical negligence claims" [2024] J.P.I.L. 207, 207.

103

As noted by M. Devlin, "Clinical negligence claims: The compelling case for systemic reform" [2024] J.P.I.L. 215, 215.

Rehabilitation guidelines following Ray, Trans Radius, Trans Humerus, Shoulder Disarticulation and Transpectoral Amputations of the upper limb

These guidelines outline the goals that patients should be aiming to achieve during their rehabilitation. These are *guidelines* and every patient should be assessed and treated as an individual, therefore, there may be variation in timing and outcome.

Patients who have been diagnosed with a tumour are, if appropriate, referred for pre/post op chemotherapy or radiotherapy. (Not all tumours are malignant and not all tumours are chemotherapy/radiotherapy sensitive). These treatments will impact on their rehabilitation. Please see appendix for further information.

Therapy Rehabilitation

Definition

- **Ray:** amputation of digit/digits and metacarpal bone/bones
- **Wrist disarticulation:** disarticulation of the ulnar and radius from the carpal bones
- **Transradial:** amputation from approximately two thirds of radius and ulna
- **Elbow disarticulation:** disarticulation of the humerus from the radius and ulna
- **Transhumeral:** amputation from approximately lower half of humerus
- **Shoulder disarticulation:** disarticulation from gleno-humeral joint sometimes humeral head and deltoid remains, scapula intact
- **Transpectoral:** amputation of humerus, scapula and majority of clavicle, head of clavicle remains

Indications for surgery

- Malignant or invasive tumour of the upper limb
- Congenital limb absence
- Congenital deformity requiring an amputation
- Infection to the limb
- Complex trauma to the upper limb
- Vascular insufficiency e.g. PVD, DM

Possible complications

Early Stages

- Post operative pain
- Bleeding
- Phantom limb sensation and pain
- Potential soft tissue loss due to size/site of tumour
- Stiffness in remaining joints

Intermediate stage

- Delayed wound healing
- Infection
- Haematoma
- Blood clot

Later stages

- Recurrence of tumour
- Revision surgery
- Persistent phantom limb sensation
- Flexion contractures at remaining joints

Expected surgical outcomes

- Relief of pain
- Prevention of infection spreading further
- Improved quality of life
- Excision of the tumour, thus preventing or slowing the spread of the disease
- Cure from disease

Therapy goals

- To ensure there is a multi-disciplinary team approach to patient care and discharge planning
- To inform patients of the post-operative rehabilitation process suitable to their individual circumstances
- To facilitate safe return to the patient's own home environment or appropriate discharge location by optimising his/her functional level of independence e.g. with personal care, transfers, domestic ADL's, driving, work and leisure.
- To encourage self management and independence with treatment programmes, for example exercise programmes, care of the remaining limb, wound and scar management.
- To inform the patient about the prosthetic rehabilitation process as appropriate to their needs
- To ensure on discharge that onward referrals are made as appropriate to the individual and their goals in relation to care and rehabilitation services

- To encourage the patient to reach their maximum potential within their physical and psychological capabilities with or without a prosthesis

Patient education

- “A Patient’s guide for completing Activities of Daily Living with One Hand”
- Education and advice on returning to functional activities appropriate to level of amputation and the individual
- Advice regarding pacing in activities
- Advice on care of the remaining limb e.g. joint protection
- Advice on care of the residual limb
- Advice on scar management

Therapy rehabilitation

Pre-admission

- Where possible the patient should have a pre-amputation discussion with an occupational therapist and any other relevant members of the amputee rehabilitation team
- Therapist introduces self to the patient and explains the role with this patient group and obtains consent
- Gather relevant information using the initial assessment forms as is appropriate at the time of the interview
- Provide advice, information and reassurance about the initial post-operative process, rehabilitation and functional outcomes expected
- Explain the possibility of phantom limb pain / sensation
- If indicated provide pre-operative exercise regime to maximise post-operative outcome
- Refer to social services OT for pre-admission assessment if appropriate
- Discuss centre for prosthetic limb fitting and time frame for starting prosthetic rehabilitation if appropriate for patients’ individual circumstances. (Patients have the option to attend Stanmore Prosthetic Rehabilitation Unit however, it may be more appropriate to attend locally -this is dependant on level of amputation and rehabilitation needs)
- If patient has not seen the therapy team pre-admission then complete the above prior to surgery as an inpatient

Day 1-3 post surgery

- Review theatre notes for surgical procedure undertaken and post-operative instructions
- Review post-op analgesia management and liaise with MDT as appropriate
- Liaison with ward staff with respect to their progress
- Provide advice regarding management of swelling and maintaining range of movement in remaining joints
- Provide advice regarding scar management procedures with patient

- Teach and encourage bed mobility
- Assess transfers and ability to mobilise
- If a walking aid is used or required, consider adaptation where possible to allow safe use
- Assessment and intervention in following occupational performance areas: self-care; domestic tasks; functional transfers
- Discuss potential future prosthetic options if appropriate
- If indicated, fabricate temporary shoulder cap for trans-pectoral amputation
- Provision of equipment i.e. loan or sale from RNOH stock or follow- up to confirm social services equipment is in situ
- If indicated, refer to outside agencies for follow up and continuing rehabilitation in the home
- If indicated, refer patient to local hospital or specialist unit for further treatment and liaise with the therapy staff prior to transfer

Discharge Home when

- Wound healing satisfactorily
- Safe transfers and mobility achieved
- Safe mobilising with walking aids if appropriate
- Independent with personal and domestic activities of daily living and / or appropriate support and follow up organised
- Education has been given to patient about care of residual limb, wound and scar
- Pain well controlled

Organise

- Distribution of therapy discharge summary to the patient and appropriate agencies
- Appropriate onward referral may include:
 - Community Occupational Therapy
 - Physiotherapy services
 - Hand therapy services
 - Prosthetic limb fitting services
 - If the patient is having chemo or radiotherapy transfer information to be sent to the therapy team at that centre

Estimated length of Stay – 1 -3 days for amputations below the level of the humerus. 3-5 days for amputations above the level of the humerus

Appendix

Some chemotherapy and radiotherapy side effects - implications for treatment

- Bone marrow toxicity, ↓white cell count, ↓platelets, ↓Hb and ↓rate of healing. White cell count will be at its lowest approximately 10 days post chemotherapy and signs of wound infection should be watched for.
- Tissue viability / skin integrity – Therapists among other treatment, would aim to maintain independence, improve quality of life and prevent pressure ulcers.
- Nausea, vomiting, diarrhoea, ↓appetite, lethargy and ↓exercise tolerance. Physiotherapy will be particularly important during and immediately after chemo and radiotherapy, as patients often lose ROM and strength after a cycle. Community physiotherapy may need to be arranged after discharge if the patient is too unwell to attend for outpatient treatment. The occupational therapist may need to advise on the practical implications of the symptoms such as meal and drink preparation, laundry and hygiene. Relaxation techniques may also be used to reduce nausea and vomiting in addition to reducing anxiety levels associated with food and meal times.
- Fatigue – needs to be addressed / acknowledged as it can affect a person's physical and cognitive ability to carry out normal activities. The therapists will need to take this into consideration and tailor the rehabilitation accordingly.
- Anaemia which can lead to tiredness, lethargy and breathlessness)
- Anxiety and depression – these can diminish people's concentration, ability to assimilate information and motivation to carry out activities. The therapists, among other treatment, will identify goals which increase a person's sense of control.

Radiotherapy only

- Fibrosis of soft tissues – can continue for up to two years and may lead to contractures. Passive exercise is very important during and immediately post radiotherapy to prevent loss of ROM
- Demineralisation of bone – increases risk of fracture
- Redness, soreness and sensitivity of the skin to heat – care of the skin is important. Heat modalities are contraindicated post DXT. Application of lotions and manual treatments are contraindicated during DXT, but can be used with caution post DXT. Electrical modalities e.g. TNS and FES can be used with caution



British Society of Physical
& Rehabilitation Medicine

BSPRM position statement on Interventional Procedure Guidance by National Institute for Health and Care Excellence (NICE): Targeted Muscle Reinnervation (TMR) for managing limb amputation pain

NICE Guidance (<http://www.nice.org.uk/guidance/ipg804>) Published: 12 June 2025

NICE has published its guidance on the role of Targeted Muscle Reinnervation (TMR) for managing limb amputation pain. As UK's national society for rehabilitation medicine physicians, BSPRM was actively engaged in the guideline development and fully supports the recommendations put forward by the committee.

Chronic pain after amputation is common and can be difficult to manage with medications. The pain can be debilitating, with a negative impact on quality of life. It can also stop people from moving comfortably using their prosthetic limbs. Conventional surgical treatments for painful neuromas include excising and burying the nerve endings in muscle or other deep tissue. But the neuroma can reform, and the pain often comes back.

TMR is a procedure that redirects nerves severed by amputation to new muscle targets. The procedure can be done at the same time as the amputation (Primary TMR), to prevent pain developing (prophylactic procedure, anticipating neuroma pain post-amputation), or as a secondary TMR procedure to treat neuroma pain that has developed after amputation and not responded to conventional treatments. TMR also allows to have improved prosthetic control by creating additional myoelectric points.

Regenerative peripheral nerve interface (RPNI) is another technique that involves innervation of denervated muscle. The severed nerve is split lengthwise into its main fascicles, which are then implanted into free muscle grafts. RPNI might be done instead of TMR, if no suitable muscle target is available. It is sometimes done at the same time as TMR, if multiple nerves are involved.

The key recommendations in the NICE guidance are:

- Secondary TMR procedure can be done to treat problematic pain after limb amputation. Clinicians wanting to do TMR to treat problematic pain that has developed after limb amputation should: inform the clinical governance leads in their healthcare organisation; ensure that people (and their families and carers as appropriate) understand the procedure's safety and efficacy, and any uncertainties about these. Healthcare organisations should: ensure systems are in place that support clinicians to collect and report data on outcomes and safety for everyone having this procedure; regularly review data on outcomes and safety for this procedure. Patient selection should be done by a multidisciplinary team, which could include a rehabilitation medicine consultant.
- TMR can be used in the NHS, while more evidence is generated, as a secondary procedure to treat problematic pain that has developed after limb amputation. It can only be used with special arrangements for clinical governance, consent, and audit or research.
- More evidence is needed on primary TMR to prevent post-amputation limb pain before it can be used in the NHS. This procedure should only be done as part of a formal research study and a research ethics committee must approve its use.
- Evidence on this procedure shows there are no major safety concerns. However, there is a lack of high-quality evidence.

NICE's recent guidance marks a major step forward in recognising TMR's therapeutic potential for treating persistent post-amputation pain. BSPRM fully supports and values the practice of these novel procedures to improve limb pain developed after amputation, resistant to conventional treatment. However, BSPRM fully supports NICE's decision to recommend its use only as secondary procedure, not at the time of amputation (primary). BSPRM believes that the right patient selection and the right decision by the MDT, led by a consultant in rehabilitation medicine with expertise in amputee medicine, holds the key to a successful outcome. In clinical practice, although a large proportion of limb amputees develop phantom or residual limb phenomenon, a large proportion of them also grow out of it eventually. BSPRM believes performing the lengthy and complex procedure of TMR at the time of primary amputation surgery is superfluous and not needed in all cases. BSPRM fully supports the TMR procedure and recommends suitable and adequate training for the surgeons to perform this procedure successfully in the NHS.

**Dr Bhaskar Basu, Special Interest Group in Amputee Medicine (SIGAM) Chair, on behalf of SIGAM and Research and Clinical Standards (RCS) Committee
British Society of Physical and Rehabilitation Medicine**



Perspective

An Algorithm for Elective Amputation Combined with Targeted Muscle Reinnervation in Complex Regional Pain Syndrome—A Perspective

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Abstract: Complex regional pain syndrome (CRPS) can result in a devastating condition. For a small number of patients, there is a non-response to any existing multimodal therapies and they ultimately request amputation. Such a drastic and final decision is not easy to take for both the patient and the surgeon and requires careful and interdisciplinary assessments and considerations. Furthermore, new surgical procedures, such as targeted muscle reinnervation (TMR) and hybrid prosthetic fitting, and multidisciplinary board advice should be included when considering amputation. In order to help other therapeutic teams in decision making for such rare but more than demanding cases, we aimed to propose an advanced algorithm for amputation indications in CRPS patients combining all these new factors. This algorithm consists of extensive pre-operative psychiatric assessment, diagnostic hybrid prosthetic fitting including fMRI analyses, multidisciplinary board advice as well as targeted muscle reinnervation and amputation procedures with final prosthetic fitting and rehabilitation. By involving multiple disciplines, this algorithm should provide optimized and individualized patient treatment on the one hand and a reliable base for decision making for therapists on the other.

Keywords: CRPS; targeted muscle reinnervation; TMR; amputation; sudeck disease; nerve transfer; prosthesis; fMRI



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1. Introduction

The final therapy-resistant stages of chronic complex regional pain syndrome (CRPS) are a devastating condition. Patients suffer from severe pain, trophic changes and loss of function, influencing all aspects of daily life as well as their psychological wellbeing [1]. Patients at this stage usually undergo a long lasting, partly frustrating multidisciplinary treatment approach involving not only physiotherapy and occupational therapy but also excessive pharmacological and psychological diagnostic and treatment. Even with advanced inpatient treatment, a small number of these patients do not recover from CRPS and become therapy resistant [2]. Some of these patients then request amputation of the affected extremity. As amputation is a severe surgical intervention with lifelong irreversible functional and psychological consequences and its effect on the course of CRPS is still under discussion, the indication of surgery must be considered carefully. Therefore, a multidisciplinary approach is indispensable, as patients are in an extreme and often desperate condition and may not be fully aware of potential consequences [3]. Further,

recurrence of CRPS or the appearance of other chronic pain conditions after amputation (such as phantom limb pain, stump pain) may occur after amputation, which is a daunting condition for patients and surgeons. New surgical techniques such as targeted muscle reinnervation (TMR) are known to reduce phantom limb pain and neuroma formation after amputation [4]. Although gaining popularity, TMR is not commonly used in (elective) extremity amputation.

We therefore aimed to propose an advanced algorithm, including these new surgical techniques and our experience with careful interdisciplinary preoperative board assessments to facilitate therapeutic decision making for elective amputation in cases of final-stage CRPS.

2. Background

2.1. CRPS and Amputation

Amputation is the most radical procedure which can be considered as a salvage strategy in therapy resistant CRPS. It may be suitable for patients who do not recover from CRPS after long term physiotherapy, occupational therapy, neuromodulation and extensive pharmacological pain treatment [2]. In fact, a recent study from Ayyaswamy et al. [5] showed that about 66% of the patients suffering from CRPS benefited from amputation with a general increase in quality of life. De Boer et al. [6] also found a significant improvement in the quality of life rating after amputation. Dielissen et al. [7] demonstrated an increase of 60% in function, although the extremity was amputated. Even though they could only demonstrate pain relief of 40%, the majority of the patients (85%) were satisfied with the outcome after surgery, thus showing that pain relief is not necessarily the main outcome after amputation. Patients also may see benefit in reduced anxiety and avoidance behavior due to the loss of the hyperpathic extremity [3,8].

Some authors hereby suggest that the main importance of amputation in CRPS is defining the level of amputation [7]. The level of amputation should be proximal to the level of allodynia to decrease the chance of recurrence. This is in contrast to the reports of Bodde et al., who proposed the level of amputation be secondary for the outcome and potential recurrence [8].

Ayyaswamy et al. [5] indicated that only 37% of the patients were using a prosthetic device after amputation due to recurrence of pain. Unfortunately, they were not able to differentiate between post-surgical pain, neuroma formation, recurrence of CRPS or phantom limb pain in terms of which aspect restrained people from using a prosthetic device.

2.2. Targeted Muscle Reinnervation

An innovative method to reduce phantom limb pain and neuroma formation is targeted muscle reinnervation (TMR). In this method, the transected nerves are transferred to residual muscles in the stump via selective nerve transfers. This has not only been proven to reduce occurrence of painful neuromas and phantom limb pain but furthermore to improve prosthetic function of bionic prostheses [9]. By reinnervating these muscles, more potential control signals can be created, resulting in superior prosthetic function and, therefore, higher patient satisfaction [10]. TMR can be performed on all levels of amputation in the upper and lower extremities. As amputations are performed mostly electively in such situations, and the affected extremities had only minor previous trauma, natural anatomy is preserved facilitating standard nerve transfer matrices for TMR.

From a neurophysiological perspective, TMR leads to structural changes on all levels of the motor unit. By surgically transferring nerves to new target muscles, a hyperinnervation of the muscle or the distal target is created [11]. This is especially relevant for advanced prosthetic control, as the amputated limb should be replaced and the patient should be given the chance to have a functional improvement after amputation [12]. Structural changes in the central nervous system could also be observed [13]. Functional magnetic resonance imaging (fMRI) revealed an adapted cortical representation of the residual limbs after nerve transfers [14], which might also have a beneficial aspect in patients with CRPS.

The main fear in amputation planning is the conversion of CRPS into amputation-related pain syndromes. Some studies suggest that phantom limb pain occurs in up to 50% to 80% of patients after amputation [13,15–17]. Midbari et al. described a rate of 89% of phantom limb pain in their cohort of patients who underwent amputation after CRPS, which has to be examined in the context that the non-amputation controls reported higher pain scores and more impairment due to the pain and a lower quality of life compared to the patients which underwent amputation [18]. This aspect points out the high importance of phantom limb pain prophylaxis when performing amputation. Dumanian et al. demonstrated a significant improvement in phantom limb pain after TMR [19]. Especially in patients suffering from CRPS, care must be taken not to confuse phantom limb pain with recurrence of CRPS or postoperative pain of the stump. Therefore, we refer to the BUDAPEST criteria for detailed evaluation, but we are aware of potential overlaps and unclear cases [20].

2.3. Multidisciplinary Board

Multidisciplinary boards are nowadays common practice for complex situations such as those in oncology. Although gaining popularity, these boards are so far not common practice in other complex areas such as extremity surgery. In our unit, we established such a board for complex extremity reconstruction many years ago [21]. Furthermore, we run a specialized interdisciplinary CRPS outpatient clinic. By combining these two programs, we were able to set up an interdisciplinary CRPS board for complex cases and treatment questions. By involving all relevant medical disciplines, such as plastic and reconstructive surgery, orthopedic surgery, vascular surgery, rehabilitation medicine, pain therapists, physiotherapy, social services, prosthetists, psychiatry and psychology, the optimum treatment for the patient is discussed and decided together. This provides not only a profound basis for therapy but furthermore is important for medicolegal issues, especially for complex decisions such as elective amputation. Therefore, decision making should be carried out by all team members.

2.4. Functional Magnetic Resonance Imaging (fMRI)

With fMRI, functional activation patterns of the affected extremity can be visualized for evaluation of the cortical representation of the limb.

Previous studies described alterations in fMRI in CRPS patients, such as a diminished representation of the affected extremity in the primary sensory and in the motor cortex. These alterations are not exclusively seen in CRPS but also in psychiatric disorders such as xenomelia and body integrity disorder [22–24]. Therefore, fMRI acts only as supportive data to visualize potential neglect and a long-time disuse of the affected extremity, which is usually accompanied by functional changes in the central nervous system.

3. Advanced Algorithm for Amputation

As amputation is an irreversible lifelong consequence for the patient, precise patient selection is of utmost importance. In the decision making process, the first step should be to ensure non-response to any other therapy modalities for more than 2 years [25]. Therefore, it is most important to establish a complete report of pretreatment strategies and their outcome. Therapy options such as pharmaceutical as well as interdisciplinary pain treatments should have been exhausted. Although most patients have psychological treatment as part of their CRPS treatment, patients longing for amputation should be referred to a psychiatric assessment in advance of surgery planning. Patients should be assessed for psychiatric disorders, their ability to give informed consent as well as their awareness of the potential consequences of the amputation. This is also relevant for medicolegal issues. In case of any doubt, surgery should be postponed and psychological treatment should be assured [3,26]. Since CRPS patients have a higher risk for depressive, anxiety and post-traumatic stress disorder (PTSD) symptoms [1], existing psychiatric disorders may not automatically lead to a refusal of the amputation request but must be

considered carefully in the decision making process. However, in conditions which impede informed decision making (such as acute psychosis or dementia) or significantly reduce the probability of successful aftercare, such as severe substance abuse, amputation should be denied. If any psychiatric disorder exists, it must be carefully weighed as to what impact the amputation will have on the psychiatric disorder and vice versa. In the course of this, coping strategies, psychosocial support at home and motivation for the amputation request should be assessed. The expected outcome should be discussed with the patient regarding his or her desired results, and any discrepancies must be addressed.

In special cases of uncertainty, we refer our patients to the department of neuroradiology to assess the cortical representation of the affected limb in fMRI as an additional diagnostic tool. In these cases, the affected extremity is mostly neglected by the patient. With a follow up fMRI after the hybrid fitting of a prosthetic device, reactivation patterns in the area of the affected limb might be observed, indicating a further benefit from amputation for the patient.

Furthermore, to increase full awareness of potential consequences of amputation and prosthetic rehabilitation, our patients are referred to the prosthetist to create a hybrid fitting of the prosthesis. Thus, socket and prosthetic devices are created to be connected to the residual limb to give the patient an idea of future prosthetic replacement after amputation. As such, the patient is able to visualize the consequences of amputation and the potential functional outcome [26]. Hybrid fitting is indicated in any case, independent of additional fMRI.

When all assessments are completed and the results obtained, a multidisciplinary advisory board discussion regarding the amputation is then carried out (Figure 1).

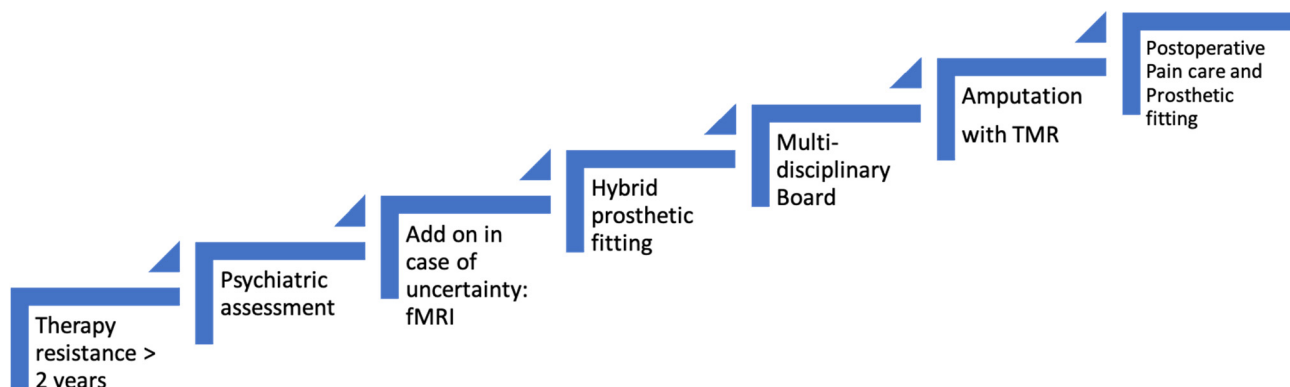


Figure 1. Algorithm for indicating amputation in CRPS patients.

Once these steps are taken, surgery can be planned. From our perspective, we prefer amputation at a level proximal to the level of allodynia. The incision should be planned to be extended and combined with TMR. An individual nerve transfer matrix is planned, depending on upper or lower extremity and level of amputation. We use the common nerve transfers shown in Table 1 [4,27]. Perioperative catheter placement is performed for regional anesthesia. Postoperatively, a consultant specializing in pain treatment is referred to the patient to ensure minimum post-operative pain and to minimize potential recurrence of CRPS. Additional psychological and supportive therapy, such as reduction of swelling, mirror therapy, stump desensitization etc. are also carried out.

Table 1. TMR nerve transfer matrix according to different levels of amputation used in our facility. Note that individual planning is required according to definite level of amputation. The transfers were adapted from our experience from [4,27–30].

Level of Amputation.	Nerve	Targeted Muscle Motor Branch
Glenohumeral Amputation	Musculocutaneous	Clavicular part—pectoralis major
	Ulnar	Pectoralis minor
	Median	Sternocostal part—pectoralis major
	Radial	Abdominal part—pectoralis major Latissimus dorsi
	Deep radial branch	Infraspinatus
Above Elbow Amputation	Musculocutaneous	long head biceps brachii
	Ulnar	Short head biceps brachii
	Median	Brachialis
	Radial	Long head/medial head triceps brachii
	Deep branch of the radial nerve	Lateral head triceps brachii
	Deep branch of the radial nerve	Brachioradialis
Below Elbow Amputation	Median	Flexor digitorum superficialis
	Ulnar	Flexor carpi ulnaris
	Superficial branch of the radial nerve	Anterior interosseus nerve
Above Knee Amputation	Tibial	Semitendinosus
	Peroneal	Biceps femoris
	Posterior cutaneous nerve	Biceps femoris
	Saphenous	Vastus medialis
Below Knee Amputation	Posterior tibial nerve	Medial or lateral gastrocnemius
	Deep peroneal nerve	Tibialis anterior, peroneal mm.
	Superficial peroneal nerve	Peroneal mm.
	Saphenous nerve	Medial gastrocnemius
	Sural nerve	Tibialis posterior

After 6 weeks of wound healing and reduction of stump swelling, we then refer the patient to the prosthetist for prosthetic replacement. Hereafter, extensive prosthetic training in inpatient rehabilitation can be initiated to improve functional outcome and patient satisfaction with the new prosthesis. Furthermore, regular outpatient controls are necessary to ensure the best potential outcome and to be able to intervene directly if any signs of recurrence are present.

4. Algorithm Demonstration

For a better understanding of the proposed algorithm, we present its application on a 16-year-old, young female patient. Four years prior to amputation, she had a distortion trauma of the left knee and underwent arthroscopy. Just a few days after arthroscopy, she developed a fixed flexion contraction of the knee, which could not be improved with all possible therapies with and without anesthesia. Severe allodynia, increased hyperalgesia to cold, reduced body temperature of the affected extremity and increased hair growth as well as a neglect for the extremity followed as well as pressure sores and foot deformity due to constant sitting on the left foot. The progression of the foot deformity pointed towards a pronounced neglect of the affected extremity. Furthermore, the patient was diagnosed with anorexia nervosa, which developed during one of the inpatient pain treatments. After

4 years of extensive multimodal inpatient and outpatient treatment, which ended up as non-response to any therapy, the patient requested an amputation, supported by her parents. Their idea was to overcome the pain and the grotesque deformity of the leg, which was more than burdensome for her, resulting in her avoidance of any social contacts and school. After several outpatient consults in our clinic discussing amputation, we referred the patient to the psychiatrist, according to our algorithm. Psychiatry confirmed the patient's and parents' wish for amputation and her and her parents' insight into the consequences. As the patient was of a very young age with a clinical neglect of her leg and had a history of the psychiatric disorder anorexia, we then referred her to the department of neuroradiology for fMRI analysis to obtain a further idea of the potential neglect of the extremity (Figure 2).

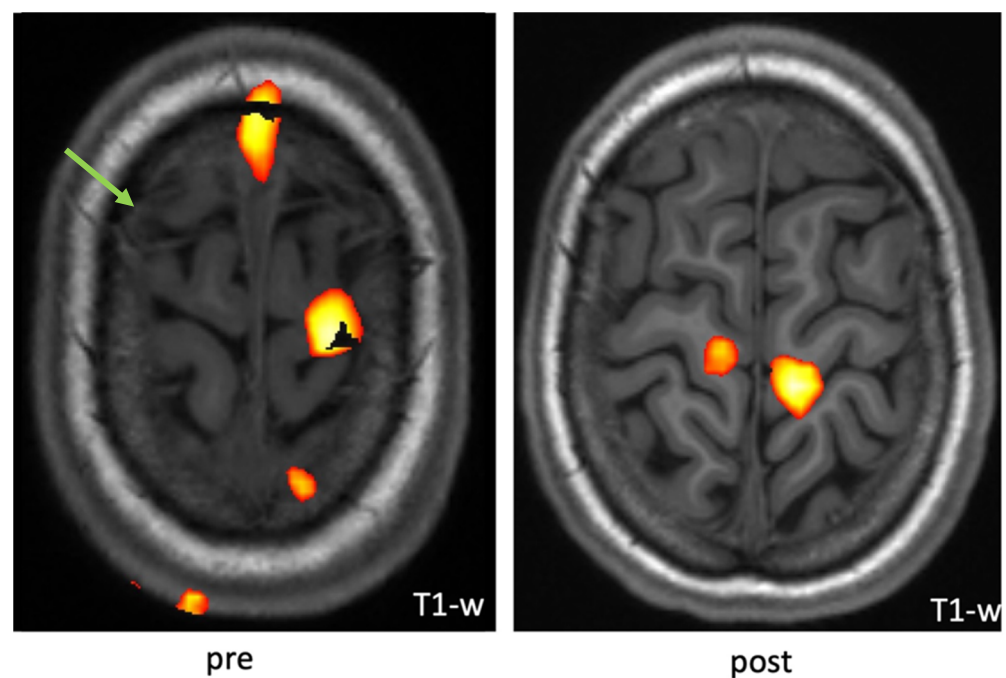


Figure 2. Example fMRI activation pattern upon a voluntary knee-bending task with the patient's right leg showing new co-activation of the right primary motor area. The green arrow indicates area of underrepresented activation while knee bending, whereas after hybrid fitting and training, new activation patterns could be observed.

We included this in our algorithm, as stated above, to further support indication for surgery with additional insights from cortical representation and activation patterns of the affected extremity. The fMRI indicated lower activation patterns of the affected extremity compared to the contralateral control. Afterwards, hybrid fitting of a prosthesis was initiated (Figure 3).

The patient used the prosthetic device for about 3 h a day over a 6-month period. We performed a second fMRI to evaluate cortical representation after prosthetic use, which showed a trend of increased cortical activation, further supporting the idea of a potential benefit of amputation and prosthetic replacement. A multidisciplinary board finally consented to amputation above the allodynia area of the knee. Operation was performed in combination with TMR of the sciatic nerve via transferring the tibial nerve to a motor branch of the semitendinosus muscle and the peroneal branch to a motor branch of the biceps femoris (Figure 4).

After wound stabilization, pain medication could be reduced significantly. The patient was fitted with a prosthetic device, which she is currently still using.



Figure 3. Algorithm demonstration on a 16-year-old female patient with CRPS of the left knee. She developed flexion contracture. After hybrid fitting of the prosthesis, she was able to experience walking with her prospective future prosthetic device.

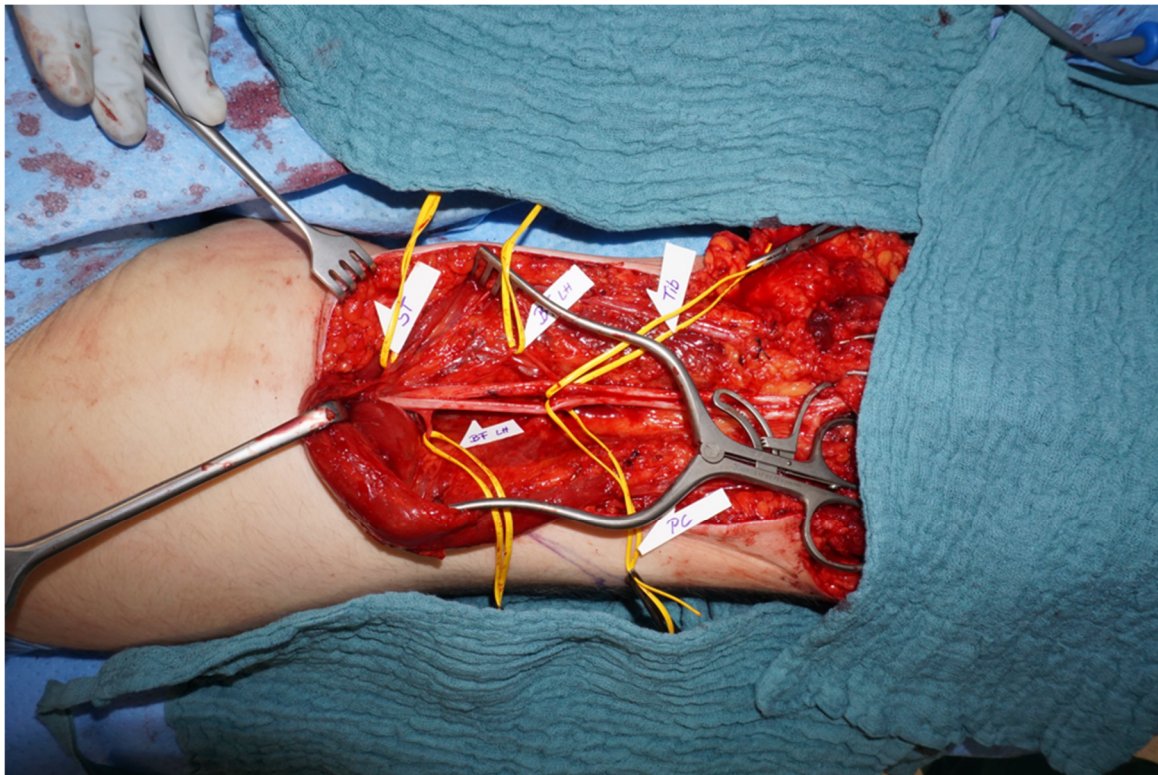


Figure 4. Amputation at above-knee level was performed in combination with TMR. Individual nerve transfers are displayed in main text and Table 1.

5. Challenges and Conclusions

We present an advanced algorithm which we use in our patients suffering from non-responding CRPS for elective amputation planning. As amputation is the last therapeutical option, a history of resistance to any other therapy options which are recommended for treatment of CRPS for at least two years and having a high level of suffering are requirements [25]. The expected outcome must be discussed with the patient with regard to his or her desired results and any discrepancies must be addressed.

Psychiatric evaluation ensures that the patients have full insight into the consequences of an amputation. This expert opinion is also important for medicolegal issues. FMRI can support an amputation decision by indicating reversible changes of limb neglect and limb disuse in the cortical representation. This tool thereby represents a non-compulsory examination, which might not be necessary in every patient.

By fitting a hybrid prosthesis, patients cannot only see their future prosthetic device but furthermore test its function in daily life activities prior to surgery [26]. We strongly advocate hybrid fitting prior to surgery but are aware that, in certain cases, fitting a hybrid prosthesis prior to surgery might not be achievable due to intolerance of the patient.

Combining the amputation with TMR can not only decrease phantom limb pain and neuroma pain but also increase prosthetic function of a myoelectric prosthesis [9,19].

With a final prosthetic fitting and rehabilitation best potential outcome can be assured.

Further studies are necessary to prove the potential benefit of TMR in CRPS patients, although studies have described a high potential for decreasing phantom limb pain in patients suffering from traumatic amputations. Although current CRPS guidelines reflect that surgery in CRPS patients is theoretically possible (especially in type II), they do not state the value of amputation [29].

We think that this algorithm is helpful to decide for the complex indication of amputation in patients suffering from CRPS. The inclusion of new surgical techniques may

help to improve the functional outcome and reduce recurrence and phantom limb pain after amputation.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

CRPS	complex regional pain syndrome
fMRI	functional magnetic resonance imaging
PTSD	post-traumatic stress disorder
TMR	targeted muscle reinnervation

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Long-term outcomes of amputation in patients with complex regional pain syndrome (CRPS): a mixed-methods study

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ABSTRACT

Introduction Amputation in patients with complex regional pain syndrome (CRPS) remains controversial, with variable outcomes in quality of life (QoL), disability, pain reduction, and complications. This study aims to evaluate long-term outcomes in CRPS patients who underwent amputation.

Methods We conducted a single-center retrospective observational study combined with a cross-sectional survey of all CRPS patients who underwent limb amputation between 2003 and 2023 at the Erasmus MC University Medical Center. Pre-amputation and short-term post-amputation outcomes were extracted from medical records, with short-term pain scores reflecting measurements within the first year after amputation. Long-term outcomes, including QoL, disability, pain, and satisfaction, were assessed through patient-reported questionnaires. Subgroup analyses were performed based on the presence of a neurostimulator implant.

Results A total of 39 patients with a median CRPS Severity Score of 12 (IQR 11–13) were included. 34 patients (87%) completed the survey a median of 6.4 years (IQR 3.0–11.7) after amputation. The 36-Item Short Form Health Survey yielded mean physical and mental health summary scores of 45.4 (± 26.1) and 67.7 (± 22.3), respectively. The mean Pain Disability Index score was 29.3 (± 15.1). Pain decreased by a mean of 3.54 points (95% CI: 2.46 to 4.62) at short-term follow-up (median 5 months, IQR 2–6) and 2.71 points (95% CI: 1.76 to 3.65) at long-term follow-up. Residual limb pain occurred in 77%, phantom limb pain in 85%, and CRPS recurrence in the stump in 10%. Overall, 94% of respondents were satisfied and would choose amputation again. Neurostimulator status did not influence measured outcomes.

Conclusions In this cohort of severe, therapy-resistant CRPS, amputation was associated with meaningful improvements in QoL, disability, and pain in carefully selected cases, although complications remained common. Amputation should, therefore, be reserved as a last-resort intervention, offered only in specialized multidisciplinary centers.

INTRODUCTION

Amputation in patients with severe, therapy-resistant complex regional pain syndrome (CRPS) rests on a fine line between hope and clinical hesitation. Despite advances in pain management, therapy-resistant CRPS remains a devastating

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Amputation is rarely performed in patients with severe, therapy-resistant complex regional pain syndrome (CRPS). The limited literature describes variable outcomes in quality of life (QoL) and pain relief, along with reports of significant complications.

WHAT THIS STUDY ADDS

⇒ In our long-term single-center cohort, amputation was associated with clinically meaningful improvements in QoL, disability, and pain, though residual-limb and phantom-limb pain remained frequent. Neurostimulation was not associated with improved outcomes in this cohort.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The findings support considering amputation as a credible but extreme last-resort option in carefully selected patients with severe, therapy-resistant CRPS. They also underline that it should be offered only in specialized multidisciplinary centers with comprehensive expertise.

condition, raising difficult questions about last-resort interventions such as amputation, given the irreversibility of removing a “viable” limb. A recent meta-analysis of 2.5 million at-risk patients estimated 12-month and 24-month CRPS prevalence rates of 3.0% and 6.5%, respectively, underscoring the global burden of the disorder.¹ On an individual level, patients with CRPS generally experience poor quality of life (QoL).² In some cases, they may even develop a sense of disconnection from the affected limb,³ ultimately expressing a desire for amputation.⁴ Although the exact pathophysiology of CRPS remains unresolved, evidence suggests that an aberrant inflammatory and immune response following trauma plays a vital role in its development. In turn, other mechanisms, such as vasomotor dysfunction and alterations in the peripheral and central nervous system, further contribute to its persistence and severity.^{5–8} These complex, multifactorial mechanisms reflect the profound clinical challenge of treating CRPS and illustrate that there is no one-size-fits-all approach.⁹



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As a result, current (Dutch) guidelines treat amputation as one of the most controversial and carefully restricted last-resort interventions in patients with CRPS.^{9–11} Specifically, amputation should only be considered in cases of severe (recurring) wounds or infections, or when it may reduce disability or improve QoL in patients.¹¹ If the question for amputation arises, given its controversy and the concern that the pain often extends beyond the initially affected area (as in central sensitization), it may only be an option to be considered if all feasible treatments have failed.^{9,12} In addition, the decision requires a careful evaluation by a multidisciplinary team⁴ and individualized decision-making in specialized centers.⁹ Such caution illustrates the need for evidence-based guidance in determining when, if ever, amputation may be appropriate in patients with CRPS.

Existing studies on amputation for CRPS are limited, methodologically heterogeneous, and offer little insight into prognostic factors. Reported outcomes vary widely, with some patients gaining meaningful improvements in QoL, disability, and pain, whereas others experience little to no benefit. These potential improvements often come at the cost of residual limb pain (RLP), phantom limb pain (PLP), or even CRPS recurrence—sometimes in a more severe form.^{13–16} This heterogeneity in outcomes limits evidence-based counseling and shared decision-making. Accordingly, our study aimed to quantify postamputation QoL, evaluate functional disability and pain trajectories, capture patient-reported satisfaction with the amputation decision, and document the occurrence of complications among CRPS patients at our expertise center. Given the potential for neurostimulation to modulate ascending nociceptive input and central sensitization,¹⁷ we conducted subgroup analyses comparing individuals who received a neurostimulator with those who did not, to explore possible associations with postamputation outcomes and complication rates. Clarifying its prognostic role could help inform both timing and patient selection in cases where amputation is considered, supporting evidence-based, individualized decision-making.

METHODS

Study design and patient selection

We conducted a single-center retrospective observational study combined with a cross-sectional survey complying with the Declaration of Helsinki and the principles of Good Clinical Practice. The applicable Strengthening the Reporting of Observational Studies in Epidemiology guidelines were applied to this study.¹⁸

Electronic patient records from the Erasmus MC were systematically searched to identify patients with CRPS who underwent limb amputation at our center. We used the International Classification of Diseases-10 codes G90.5, G90.6, and G90.7 for CRPS. This list was cross-referenced with amputation procedures, and relevant cases were extracted. Patients were screened for eligibility based on the following criteria: (1) diagnosis according to the Valencia consensus-based adaptation of the International Association for the Study of Pain,¹⁹ prospectively determined based on the signs and symptoms present at that time, (2) limb amputation performed at our center between 2003 and 2023, and (3) age >18 years at time of amputation. Patients were excluded if they had undergone amputation at another center, unless they later underwent amputation of another limb at our center. In this case, they were included based on data from the latter procedure. For patients who underwent multiple amputations at our center, only the data from the first amputation was used.

Outcomes

The primary outcome was long-term QoL after amputation in CRPS patients, assessed using the 36-Item Short Form Health Survey (SF-36). Secondary outcomes included functional disability (assessed with the Pain Disability Index (PDI)), pain trajectories (preamputation and postamputation, including short-term and long-term pain scores), satisfaction with the amputation, and occurrence of postoperative complications (eg, CRPS recurrence, RLP, and PLP). Exploratory subgroup analyses were also performed based on the presence of a neurostimulator and opioid use at the time of amputation.

Amputation procedure

At our center, patients for whom amputation is necessary or who express a desire for amputation undergo a comprehensive evaluation by a multidisciplinary team, including a CRPS pain specialist, trauma surgeon, physical rehabilitation specialist, and psychologist. Before amputation is even considered, patients are required to exhaust all feasible conservative and interventional therapies, except in cases requiring urgent care (eg, severe wounds or infections). The amputation is only performed when the multidisciplinary team reaches unanimous agreement, ensuring that all possible alternatives have been thoroughly explored. If any team member suspects a clinically relevant psychiatric disorder or psychological factor, the amputation will not proceed, and the patient will first be referred for a psychiatric/psychological consultation. Approaching patients through such a team provides a structured assessment that underscores limitations in daily activities, sets realistic expectations regarding postoperative pain relief and prosthetic feasibility, and facilitates a balanced discussion of the potential benefits and drawbacks of amputation.

Data collection and materials

Data were collected through a combination of medical chart review and patient-reported questionnaires. From the medical records, we extracted patient demographics (age, sex, body mass index), CRPS characteristics (date of diagnosis, cause, type, and affected limb(s)), and signs and symptoms at the initial visit, which were used to calculate the CRPS Severity Score (CSS).²⁰ Preamputation pain intensity was collected from the most recent available outpatient visit prior to amputation using an 11-point Numeric Rating Scale (NRS), typically recorded as the patient's reported average pain over the past week. Additional chart-based variables included the presence and type of neurostimulation: dorsal root ganglion stimulation (DRG-S) or spinal cord stimulation (SCS); pre-existing psychiatric comorbidity; amputation characteristics (reason for amputation, degree of amputation, and previous amputations); postoperative complications (surgical complications, RLP, PLP, CRPS recurrence, and reinterventions); and prosthetic information. Short-term postamputation pain scores, where available, were extracted from follow-up notes within the first year (after resolution of acute postoperative pain), typically reflecting average pain over the past week as reported by the patient. Data on postoperative complications were collected throughout the entire follow-up period.

Long-term outcomes were assessed using a patient-reported questionnaire administered at the time of study participation. This survey included the SF-36, the PDI, the NRS, the global perceived effect (GPE), and a set of custom questions. The SF-36 is a validated QoL instrument covering eight physical and mental health domains, with higher scores (ranging from 0 to 100) indicating better QoL.²¹ The Physical Health Summary

(PHS) score is derived from the domains of physical functioning, role limitations due to physical health, pain, and general health. The Mental Health Summary (MHS) score is calculated from the domains of energy/fatigue, social functioning, role limitations due to emotional problems, and emotional well-being. The PDI measures the impact of pain on daily activities across seven domains, with higher scores (0–70) indicating greater disability.²² The NRS in the questionnaire assessed both current pain and average pain over the past week. The GPE records perceived recovery and satisfaction with the amputation on a 7-point Likert scale.²³ Finally, three custom questions were asked, originally written and administered in Dutch and translated into English: ‘If you were in a similar situation as before the amputation, would you choose to undergo the procedure again?’, ‘Will you recommend amputation to other CRPS patients whose symptoms have not responded to other therapies?’, ‘Do you currently perform paid labor or voluntary work?’.

Data collection was conducted between June 2024 and March 2025 and stored in a pseudonymized format using Castor EDC V.2024.3.6.0.

Statistical analysis

Data analysis was performed using R (V.4.4.1). The normality of the data was assessed by inspecting histograms, residual plots, and the Shapiro-Wilk test. Numerical data were presented as mean±SD for normally distributed data, or as median with IQR for non-normally distributed data. Categorical variables were reported as counts with percentages.

For the analysis of pain differences over time (preamputation, short-term postamputation, and time of study participation), the Wilcoxon signed-rank test was used. To assess the robustness of the findings of the primary outcomes (SF-36 summary scores, short-term and long-term changes in pain, and complications (RLP, PLP, CRPS recurrence in the stump)), sensitivity analyses were performed by stratifying outcomes based on the reason for amputation (categorized as urgent care vs elective amputation, eg, due to pain or a non-functional limb), the period of amputation (dichotomized as before or after 2014, the midpoint of the inclusion period), and the duration of follow-up (more or less than 5 years after amputation). For the subgroup and sensitivity analyses, the Mann-Whitney U test or Fisher’s exact test was applied, as appropriate. P values <0.05 (two-tailed) were considered statistically significant.

RESULTS

Baseline characteristics

Out of 106 screened patients, 39 were included in the study. The remaining 67 were excluded primarily due to the absence of a confirmed CRPS diagnosis or because no amputation had been performed (see figure 1). As shown in table 1, the cohort consisted predominantly of females (33 patients, 85%), with a median age at diagnosis of 35 years (IQR 24–42). The median CSS was 12 (IQR 11–13), and 23 patients (59%) used opioids at the time of amputation. Amputations were performed a median of 5.3 years (IQR 3.1–10.5) after diagnosis.

Outcomes after amputation

Table 2 summarizes the clinical outcomes after amputation. Five patients were unable or declined to participate in the prospective part of the study, resulting in 34 patients contributing to long-term outcomes (see figure 1). The median time from amputation to study participation was 6.4 years (IQR 3.0–11.7). QoL assessed using the SF-36 yielded a mean PHS score of 45.4

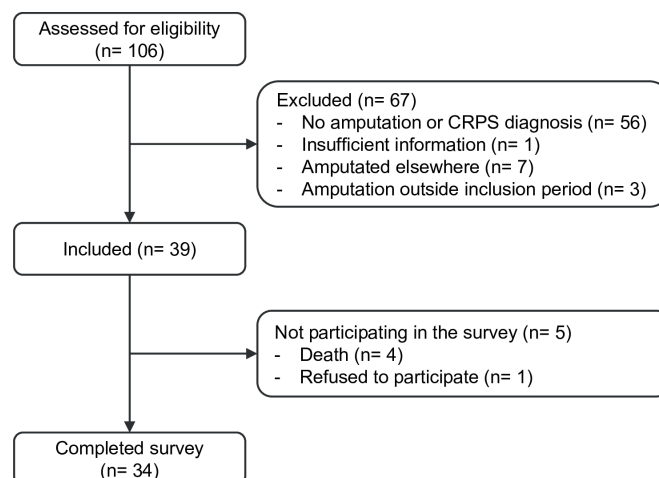


Figure 1 Flow chart of patient inclusion and exclusion. CRPS, complex regional pain syndrome.

(±26.1) and a mean MHS score of 67.7 (±22.3). In line with these findings, the mean PDI score was 29.3 (±15.1). Additionally, a significant reduction in pain was observed from preamputation to postamputation, with a mean decrease of 3.54 points (95% CI: 2.46 to 4.62) at short-term follow-up (median 5 months (IQR 2–6) postamputation), and 2.71 points (95% CI: 1.76 to 3.65) at long-term follow-up, assessed at the time of study participation (see also figure 2).

The occurrences of postamputation complications are shown in table 3. RLP was reported by 30 (77%) patients, and PLP developed in 33 patients (85%). CRPS recurrence in the stump was confirmed in 4 patients (10%), while 7 (28%) recurrences occurred in another limb. Surgical reintervention was required in 14 cases (36%) due to CRPS recurrence, RLP, PLP, or infection.

Despite these complications, satisfaction was relatively high as 30 patients (94%) reported improvement and satisfaction with the amputation according to the GPE. Additionally, 31 patients (91%) indicated they would choose amputation again, and 28 (82%) would recommend it to others in similar circumstances. A prosthesis had been fitted in 23 patients (59%), and 13 patients (38%) were currently able to perform (voluntary) work.

Subgroup and sensitivity analyses

Patients with a neurostimulator implant (DRG-S or SCS) at the time of amputation did not demonstrate significantly different pain outcomes compared with those without. At short-term follow-up, the mean difference (MD) between the neurostimulator and no-stimulator groups was 0.12 points (95% CI: −1.89 to 2.13), and at long-term follow-up 0.39 points (95% CI: −1.49 to 2.27). Similarly, there were no significant differences in PHS, MHS, changes in pain scores, CRPS recurrence in the stump, RLP, or PLP. Opioid use at the time of amputation likewise showed no significant association with short-term pain outcomes (MD 1.64 (95% CI: −0.31 to 3.6)), and there were no statistical differences in RLP or PLP. Full results of the subgroup analyses are provided in online supplemental Table 1. Moreover, sensitivity analysis stratifying by reason for amputation (urgent vs elective), by period of amputation (before or after 2014), and follow-up duration (more or less than 5 years) yielded no significant differences in any of the primary outcomes (data not shown), indicating consistent results across these subgroups.

Table 1 Baseline characteristics

	n=39
Median age at diagnosis (IQR) in years	35 (24–42)
Median age at amputation (IQR) in years	44 (36–49)
Sex, female, n (%)	33 (85)
Mean BMI (SD) in kg/m ²	26.7 (5.2)
Deceased, n (%)	4 (10)
Cause of CRPS, n (%)	
Surgery	6 (15)
Trauma	28 (72)
Unknown/spontaneous	5 (13)
CRPS type 1, n (%)	35 (90)
Median CRPS severity score* (IQR)	12 (11–13)
CRPS in multiple extremities, n (%)	14 (36)
Median CRPS duration at time of amputation (IQR) in years	5.3 (3.1–10.5)
Average NRS pre-amputation, median (IQR)	8 (7–9)
Psychiatric comorbidity†, n (%)	10 (26)
Primary reason for amputation, n (%)	
Infection/wounds	14 (36)
Non-functional extremity/contractures	19 (49)
Unbearable pain	6 (15)
Level of amputation, n (%)	
Upper extremity	10 (26)
Shoulder disarticulation	1 (3)
Trans-humeral	4 (10)
Trans-radial	4 (10)
Partial hand	1 (3)
Lower extremity	29 (74)
Trans-femoral	18 (46)
Knee disarticulation	3 (8)
Trans-tibial	8 (20)
Opioid use at time of amputation, n (%)	23 (59)
Neurostimulator at time of amputation, n (%)	17 (44)
Spinal cord stimulation	11 (65)
Dorsal root ganglion stimulation	6 (35)
Amputation of multiple extremities‡, n (%)	9 (23)

*CRPS severity score ranging from 2 to 16, with higher scores indicating greater severity.

†Defined as a pre-existing clinical diagnosis of depression, anxiety disorder, post-traumatic stress disorder, personality disorder, or autism spectrum disorder, documented in the medical records.

‡Amputation of multiple extremities either before or after the current amputation. BMI, body mass index; CRPS, complex regional pain syndrome; NRS, Numeric Rating Scale.

DISCUSSION

In this combined retrospective cohort and cross-sectional study, we evaluated long-term outcomes in patients with CRPS who underwent amputation for various indications. Our primary findings indicate that QoL and disability were rated favorably, and that pain decreased significantly in the long term after amputation. Most patients expressed satisfaction with the procedure and indicated they would choose the amputation again. However, these positive outcomes were tempered by frequent complications, including RLP, PLP, and CRPS recurrence—underscoring the delicate balance between risk and benefit that defines this last-resort intervention.

Baseline demographics

Our cohort differed notably from the general CRPS population, as patients were younger at diagnosis (35 vs 47–70 years),

Table 2 Outcomes after amputation

Short-term results (chart review)	
Sample size, n	39
Average NRS postamputation*, median (IQR)	4 (2–7) (n=37/39)
Received a prosthesis, n (%)	23 (59)
Bone-anchored	3 (13)
Prosthesis in use, n (%)	10 (43) (n=14/23)
Long-term results (patient-reported)	
Sample size, n	34
Years between amputation and study participation, median (IQR)	6.4 (3.0–11.7)
NRS (current)†, median (IQR)	5 (3–8)
Average NRS (past week)†, median (IQR)	6 (3–7)
Would choose for amputation again, n (%)	31 (91)
Would recommend amputation to others, n (%)	28 (82)
Performs paid or volunteer work, n (%)	13 (38)
SF-36, mean (SD)	
Physical Health Summary score	45.4 (26.1)
Physical functioning	41.2 (33.0)
Role limitations due to physical health	39.0 (44.0)
Pain	41.5 (27.6)
General health	60.0 (20.4)
Mental Health Summary score	67.7 (22.3)
Energy/fatigue	56.8 (19.3)
Social functioning	64.3 (25.8)
Role limitations due to emotional problems	71.6 (42.7)
Emotional well-being	78.2 (20.3)
Pain Disability Index, mean (SD)	29.3 (15.1)
Global Perceived Effect, n (%)	
Recovery after amputation	
Very much improved	14 (41)
Much improved	9 (26.5)
A little improved	9 (26.5)
No change	2 (6)
A little deterioration	0
Much deterioration	0
Deterioration	0
Satisfaction with amputation	
Completely satisfied	14 (41)
Very satisfied	15 (44)
Somewhat satisfied	3 (9)
Mixed	1 (3)
Somewhat dissatisfied	0
Very dissatisfied	0
Completely dissatisfied	1 (3)

*Short-term average NRS pain scores were collected a median of 5 months (IQR 2–6) postamputation.

†Long-term NRS scores reflect the current pain and average pain over the past 7 days, assessed at the time of survey participation (median 6.4 years (IQR 3.0–11.7) postamputation).

NRS, Numeric Rating Scale; SF-36, 36-Item Short Form Health Survey.

more frequently had multiple limbs involved (36% vs 20%), and exhibited higher average pain (NRS 8 vs 6) and CSS (12 vs 10).^{2 20 24 25} Patients were predominantly female, consistent with the general CRPS population.^{2 20 24 25} Despite these differences, demographic characteristics, pain levels, and time to amputation mirrored findings from previous amputee cohorts.^{14–16} This suggests that while our sample is generalizable to this select

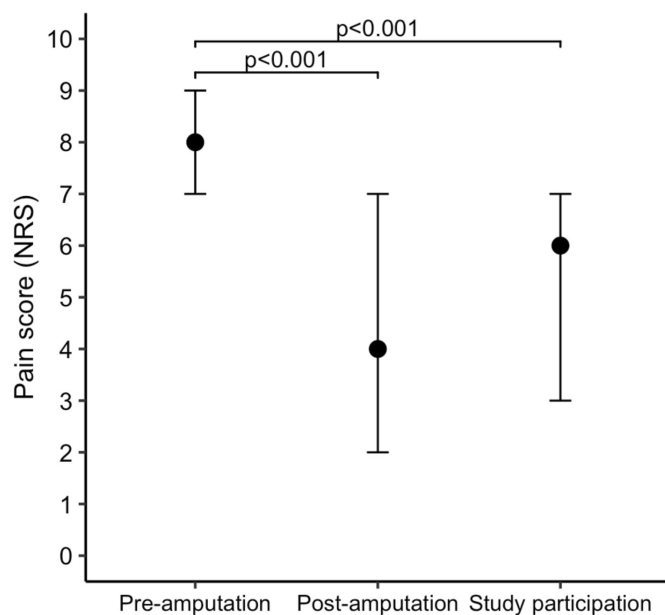


Figure 2 Median pain scores over time with IQR. Pain decreased with a mean difference of 3.54 points (95% CI: 2.46 to 4.62) at short-term follow-up (median 5 months (IQR 2–6) postamputation), and 2.71 points (95% CI: 1.76 to 3.65) at long-term follow-up (median 6.4 years (IQR 3.0–11.7) postamputation). Significant differences between timepoints were assessed using the Wilcoxon signed-rank test. NRS, Numeric Rating Scale.

subgroup, it also represents a particularly severe and complex subset within the broader CRPS population, highlighting the relevance of our findings for similarly advanced, treatment-resistant cases.

Postamputation outcomes

Previous studies have shown that amputation can lead to improvements in QoL in the majority of patients.^{13–16} SF-36 scores from the study by Midbari *et al* reflected modest QoL but were significantly better than those of patients who did not undergo amputation.¹⁶ In line with these findings, our cohort demonstrated relatively high SF-36 summary scores for both physical and mental health (47 and 68, respectively). Across the eight individual domains, scores were largely comparable to those of the amputation group reported by Midbari *et al*. They also tended to exceed average scores reported in broader CRPS cohorts, particularly for role limitations due to physical health, pain, energy, social functioning, and emotional roles.^{2–20} These

findings suggest that amputation may offer meaningful improvements in QoL, restoring it to levels seen in the general CRPS population, despite long-standing and severe disease.

Disability, pain, and satisfaction have also been explored in earlier work. PDI scores for the general CRPS population and CRPS amputees range from 34 to 41.^{3 16 26} Our cohort reported a slightly lower mean PDI score of 29, suggesting limited disruption in daily activities and overall disability. This perceived disability is closely tied to pain, which has been more variable in previous research. While Geertzen *et al*¹⁴ and Midbari *et al*,¹⁶ observed important improvements in pain in the majority of patients, the latter still reported a median Visual Analogue Scale pain score of 80. In our cohort, pain decreased significantly by 2.71 points (95% CI: 1.76 to 3.65) to a median NRS of 6 after 6.4 years postamputation. Patient satisfaction has remained consistently high in the literature, with reported rates ranging from 66% to 98%.^{14 16} Our findings align with this trend, with 94% of patients in our cohort expressing satisfaction postamputation. However, this should be interpreted with caution, given the persistence of RLP, PLP, and CRPS recurrence in many patients. The perceived benefit may stem less from complete pain relief and more from functional improvements (eg, hygiene, mobility) and overall well-being. Several factors may explain this apparent paradox. Psychological elements such as a regained sense of agency, cognitive dissonance, or social validation may influence satisfaction. A shift in the quality of pain, from CRPS-related pain to RLP or PLP, may also be experienced as a lesser burden. Furthermore, the higher mental health scores on the SF-36 compared with the physical health scores suggest that satisfaction may reflect psychological adaptation despite physical suffering.

Complications

The potential improvements in QoL, disability, and pain must be balanced against a substantial risk of complications following amputation. Lifetime prevalences of RLP and PLP in amputees from all causes are reported to range between 0%–85% and 75%–87%, respectively.^{27 28} In our cohort, the figures were at the upper end (RLP 77%, PLP 85%), a result that may reflect several known risk factors, such as younger age, (chronic) preoperative pain, and psychological comorbidities.¹⁷ Opioid use at the time of amputation may also contribute to central sensitization,²⁹ potentially increasing the risk of RLP or PLP, although no association was found in our cohort. The high prevalence of RLP in our cohort could explain why only 59% of our patients were fitted with a prosthesis, compared with 73% in studies that reported lower prevalences of postamputation pain.^{14 15} Among those who did receive a prosthesis, overall usage remained low (43%), consistent with 37%–53% in previous studies.^{13–16} One-third of patients required additional surgery for postamputation pain, underscoring how difficult this pain is to control. Evidence for specific interventions remains limited, so recent guidelines advocate a multimodal approach.¹⁷

Pooled analyses estimate CRPS recurrence after amputation at up to 48%.^{13 15} In our cohort, recurrence occurred in 10% in the stump and in 18% in another limb, while Geertzen *et al* even reported lower rates (2% and 6%, respectively).¹⁴ These discrepancies largely reflect methodological heterogeneity across studies. Many series rely on patient self-report or outdated diagnostic criteria, increasing the risk of overestimating recurrence. In contrast, both Geertzen *et al* and our study applied current diagnostic criteria and did not rely on self-reported diagnoses. Moreover, recurrence in another limb may represent a new onset

Table 3 Complications following amputation

Characteristics	n (%)
Surgical complications*	6 (15)
Residual limb pain (RLP)	30 (77)
Phantom limb pain (PLP)	33 (85)
CRPS recurrence	11 (28)
in stump	4 (10)
elsewhere	7 (18)
One or more surgical reinterventions in stump†	14 (36)

*Surgical complications due to bleeding, decubitus, infection, central line infection.
†Surgical reintervention due to CRPS recurrence, RLP, PLP, infection, or a combination of these.
CRPS, complex regional pain syndrome.

or spread of CRPS rather than true recurrence. Spread has previously also been associated with younger age and more severe disease.³⁰

Neurostimulation

We hypothesized that neurostimulation might function as a prognostic factor for postamputation outcomes and complications. However, no significant differences were observed between patients with and without a neurostimulator. Importantly, this study did not assess whether neurostimulation influences the severity of these complications, leaving its potential role uncertain.

Limitations

The single-center, retrospective design, small sample size, and absence of a control group might have limited the methodological strength of this study. First, the retrospective nature and 20-year inclusion window inevitably produced missing or inconsistently reported data. These omissions were almost entirely related to prosthesis use (see table 2) and, therefore, had minimal influence on the primary outcomes. The long window may also have introduced heterogeneity as treatment protocols evolved over the past decades. This historical shift likely explains why only 44% of patients had a neurostimulator at the time of amputation. The small sample size could further explain why no significant difference in outcomes was found for this subgroup. Furthermore, extended follow-up can introduce survival bias, potentially skewing outcomes upward. In our cohort, 87% of patients were still alive at the time of analysis, suggesting that any such bias, if present, is probably modest.

Next, the absence of a formal comparison group also leaves certain systematic differences unmeasured. As this is a particularly unique subpopulation of CRPS, identifying a representative control cohort is difficult. Domerchie *et al* interviewed CRPS patients who were denied amputation and showed improvement via alternative interventions.¹² However, both their study and ours underscore that all other feasible interventions should be exhausted before considering amputation, making those patients not always an ideal comparison group.

Following this, confounding by indication may exist, as patients could systematically differ based on the primary reason for amputation. Nevertheless, we performed subgroup analysis by both reason and year of amputation, which revealed no differences in outcomes or complications. While these findings suggest that neither the indication for amputation nor amputation period influenced outcomes in our cohort, we acknowledge the possibility of unmeasured confounders (such as minor psychological factors) and the limitations posed by a relatively small sample size.

Lastly, as our study did not prospectively collect data, QoL questionnaires were administered only once, limiting direct preamputation and postamputation comparisons. Nonetheless, our cohort exhibited markedly higher QoL scores in nearly all domains compared with the general CRPS population, implying that significant improvements would have occurred.

CONCLUSIONS

Our results underscore the delicate balance between hope for patients with severe, therapy-resistant CRPS and the long-standing controversy surrounding the amputation of a “viable” limb. While complications such as residual-limb and phantom-limb pain remain common, amputation in this cohort was associated with meaningful improvements in QoL, reduced

disability, and long-term pain relief. Nearly all patients reported satisfaction and indicated they would choose the procedure again. Although our findings do not resolve the controversy, they offer important insights to support evidence-based counseling and shared decision-making. Accordingly, we recommend approaching amputation with measured restraint as a true last-resort intervention, performed only in specialized centers with multidisciplinary expertise.

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How to Reduce the Re-traumatisation of Claimants in Medico-Legal Litigation Claims

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Aim and Objective

Recommendations are made to minimise the risk of re-traumatisation and the potential for causing additional iatrogenic harm during the medicolegal process in personal injury and clinical negligence claims due to claimants being asked unnecessary questions by experts regarding the index event(s).

The Claimant's Perspective

Life-changing acquired injuries (also known as catastrophic injuries) are defined by their severity, causing permanent disability and long-term health problems and changing the course of the individual's life, as well as the lives of those in their immediate circle^{1,2}. Such injuries can encompass a combination of challenges, including chronic pain, limb loss, loss of function, disfigurement and a range of mental health conditions including anxiety disorders, depression or trauma and stress-related disorders³⁻¹⁰. These life-changing injuries may be sustained through various means such as sport-related incidents, motoring accidents, work-related injuries or because of clinical negligence^{11, 12, 13}. Life-changing injuries have the potential to impact almost every aspect of an individual's life, physically, mentally and emotionally^{14, 15}. Their previous work, education, interests and hobbies may become impractical, reshaping both their daily lives and overall well-being^{16, 17}. This transformation disrupts and challenges their sense of self, identity, self-esteem, body image and quality of life^{18, 19} as well as the life they thought they were going to lead. The suddenness and circumstances of significant unwanted and unexpected changes in people's physical, emotional and psychological health often make acceptance of their new life and situation very challenging^{20, 21, 22}.

The Physiological Response to Trauma

When faced with traumatic circumstances, the body may initiate a fight, flight or freeze response. However, individual responses vary, and people may become confused, panicked, anxious and frozen with fear, or they may become angry, energised and active. The release of high levels of cortisol hormone in response to trauma can trigger various endocrine, metabolic and immunological changes²³. Quick and intuitive reactions mediated primarily by the limbic system – the seat of the fight-flight response – tend to be engaged in preference to the slower, reasoned thinking that occurs in the frontal lobe²⁴. Emotions may be under-controlled, leading to fear and pain, or over-controlled, leading to emotional numbing²⁵. There are also changes to memory processing. In normal stressful circumstances, both the amygdala, the part of the limbic system responsible for processing emotion, and the hippocampus, the part of the brain that encodes in the context in which events are happening, are involved in memory formation. In the most frightening or horrifying moments of traumatic events, the hippocampus is downregulated, and memories are encoded that largely consist of sensory images and emotions, devoid of context²⁶. It may be difficult to control this type of memory, and the victim may suffer from frequent intrusive thoughts, flashbacks and/or nightmares. People with post-traumatic stress disorder (PTSD) have repeated and unwanted recollections of the traumatic event, which can make them feel as if the event(s) is happening again and produces a strong sense of current, ongoing threat²⁷. The reported incidence rate of PTSD varies widely. WHO suggests that whilst around 70% of people globally will experience a potentially traumatic event during their lifetime, the majority of trauma-exposed individuals will not develop PTSD²⁸. However, there are a multitude of incident, individual and relational factors which influence whether someone develops PTSD, with a recent Cambridge University Press umbrella review concluding that between 2.5% and 74% of trauma-exposed individuals go on to develop PTSD²⁹. Traumatic injury sufferers can be susceptible to misinterpreting safe situations as dangerous when the amygdala overrides rational thought, causing a defensive, visceral reaction. Unless successfully treated, people with PTSD are prone to suffering repeated episodes of anxiety and panic due to reminders of the trauma. Such 'triggers' may include sights, sounds, smells, locations, thoughts, emotions and memories relating to the index event and/or subsequent events, such as the distress of waking up in a hospital and being connected to lots of tubes and machines.

Psychological and Emotional Impact

Research has evidenced the potential for profound and long-lasting destructive psychological and emotional impact that medicolegal claims can have on the claimant³⁰. The impacts can encroach on the claimant's adjustment and recovery³¹ and, as described by one researcher, prevent the claimant from 'moving on'³². Recounting or reliving traumatic experiences for litigation purposes carries the risk of causing iatrogenic harm by re-traumatising the claimant, resulting in additional distress. However, as part of a medicolegal claim for personal injury or clinical negligence, the provision of expert evidence is almost invariably crucial for

establishing breach of duty, causation and/or quantum. Instructing parties may request the expert's insights on the injuries sustained, the treatment received and the present condition of the claimant, as well as their likely prognosis. Whilst the literature suggests that litigation is almost always stressful for the parties involved³³, appropriate care should be taken to minimise the risk of further harm being caused as far as reasonably possible.

Personal Perspective

By way of example, a young male claimant who had suffered severe burns from molten zinc, attended a pain assessment conducted by an expert for the defence. During the appointment, the claimant was asked to recount the events of the accident and immediate hospitalisation. During this distressing recollection of his intensive care stay, the claimant experienced an extremely visceral and traumatic flashback of an event where he believed molten zinc was cascading from the ceiling onto him whilst in his hospital bed, burning him alive. This triggered considerable distress and a temporary exacerbation of PTSD symptoms which set him back in his psychological and physical recovery, reduced his willingness to engage in further medicolegal assessments and significantly compromised his overall well-being.

The Expert's Perspective

Empirical surveys of experts reveal that demanding clinical caseloads mean that the additional responsibilities of being an expert witness are regularly squeezed into already busy schedules. As a result, it is common for experts to arrive at medicolegal appointments with limited preparation or detailed knowledge of the case, including key aspects such as the incident, injuries, or treatment history. This frequently leaves experts to rely on the claimant to provide critical information to fill in these gaps.

The Impact of Asking: How Did You Sustain Your Injuries?

Reliving and recounting these events can transport the individual right back to the specific time and place, creating a highly distressing visceral, sensory and emotional response. Answering questions about the index events and their consequences can stimulate a traumatic stress reaction, which may result in the circumstances of the medicolegal assessment being interpreted as threatening and distressing. Furthermore, experts with little, if any, psychological training who unnecessarily ask traumatised claimants to recount exceptionally difficult and challenging times in their lives, run the risk of causing avoidable additional harm and suffering. When psychiatric and psychology experts are instructed, care should be taken to ensure that any such expert has the necessary qualifications, experience and specialism to advise in traumatic injury cases.

To present a complete picture of the impact of the claimant's injuries to the court, the expert requires the individual to be open and honest. However, being asked to revisit traumatic events may result in an emotional response which overrides a claimant's rational and reasoned thought processes. This can result in a loss of confidence and an inability to engage in meaningful dialogue. Consequently, the expert report may end up lacking in detail in respect of the claimant's current function and abilities. In the worst-case scenario, the expert may have unintentionally lost the claimant's trust and willingness to cooperate with the assessment. The common theme amongst claimants and their families is that the repeated recounting of the worst moments of their lives is the most challenging part of the litigation process.

Reform Proposal:

We put forward the following recommendations for industry-wide consideration:

1. Instructing solicitors should provide, in their letter of instruction to experts, sufficient background information regarding the circumstances surrounding the claimant's traumatic injuries and make available all up-to-date medical and treating records alongside witness statements, to minimise the need for expert witnesses to ask any direct questions about the index event(s) during their examination of the claimant. Instructing solicitors should explicitly direct experts to refrain from asking unnecessary questions about the index event(s) during their examination.
2. Experts before any examination of the claimant, should carefully review the instructions and medical records for the purposes of acquiring details of the background to the index event(s) so that unnecessary questions may be avoided.
3. Experts should not ask claimants about the index event(s) preceding, during or immediately after the injuries were sustained unless there is a clear need to do so. For example, neuro experts may need to ask questions to explore the extent of any post-traumatic amnesia and possible traumatic brain injury. Only experts who have the appropriate skills, training and experience to take a history from traumatised individuals (usually but not exclusively psychiatrists and psychologists) should ask claimants detailed questions regarding the index event(s) resulting in their injuries.
4. If there are issues concerning veracity, diagnosis or causation of psychological/psychiatric injuries and it is important to ask questions regarding the circumstances giving rise to the injuries, care should be taken to minimise the risk of re-traumatisation or the potential for causing additional iatrogenic harm.
5. In general expert medicolegal assessments should cover a claimant's history as it relates to the matters they have been instructed to deal with. In most cases, the focus of the assessment should be on the current history and presentation. Avoiding re-traumatisation of the claimant and reframing the medicolegal assessment so that claimants do not need to recount the worst events of their lives will reduce the risk of causing avoidable additional distress.

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Review

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Emerging role of artificial intelligence in the care and management of lower extremity amputations and peripheral nerve injuries

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Abstract

Lower limb amputation (LLA) secondary to trauma, oncologic, diabetic, and vascular disease represents a significant patient challenge in terms of restoring function to pre-injury levels. This can be secondary to wear and use of a prosthetic limb, as well as limitations in range of motion or chronic pain. This study aimed to review and discuss the available, and potentially soon-to-be-available, roles of artificial intelligence (AI) in extremity amputation care. Specifically, we discuss the current state of AI technology in LLA prevention, management, peripheral nerve injury treatment, and lower limb prosthesis design, as well as highlighting current advancements and the direction of these linked fields.

Keywords: Artificial intelligence, machine learning, deep learning, lower limb, amputation, prosthesis, peripheral nerve injury

INTRODUCTION

Artificial intelligence (AI) and machine learning (ML) offer the potential to improve treatments and outcomes among lower limb amputation (LLA) patients, with more than 150,000 patients in the United States each year^[1]. Of these, over half are secondary to peripheral artery disease (PAD) and diabetes



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mellitus^[2,3]. Chronic limb-threatening ischemia (CLTI), the most severe form of PAD, carries an estimated 1-year major limb amputation rate of 22%^[4], and patients with concomitant PAD and diabetes have a four times higher risk of amputation compared to the national average^[3,5]. In addition, various forms of oncologic management, severe trauma, and battlefield injuries are affected by LLA. The 5-year mortality rate for patients with index LLA is reported to be as high as 77%^[6], especially with comorbid diseases such as diabetes mellitus. When compared to amputation above the ankle, limb free-flap reconstruction has been shown to significantly increase the 5-year survival rate (86.8% vs. 41.4%, $P < 0.001$)^[7].

The conventional socket attachment of a prosthetic limb presents inherent functional limitations, and many of these limitations may remain chronic or present despite numerous treatments. Mechanical imbalance can contribute to difficulty with gait or even increased wear and osteoarthritis on the spine and contralateral lower extremity^[8]. Even with an optimal soft-tissue envelope, changes in strength, tactile feedback, and range of motion can be limited. Relative motion between the residual limb and socket may also cause chronic pain, ulceration, and breakdown^[9].

Another limiting factor following LLA contributing to decreased prosthetic use, increased rate of surgical revision or proximal amputation can be the various forms of neurogenic pain following amputation. Chronic post-amputation pain, including residual limb pain and/or phantom limb pain (PLP), limits function by interfering with the use of lower limb prosthesis^[10-12]. Surgical methods such as targeted muscle reinnervation and regenerative peripheral nerve interfaces have led to improvements in both amputation-related pain symptoms and myoelectric prosthetic control^[13-17]. Current autonomous lower limb prostheses can assist in cyclic gait; however, they lack versatility and anticipatory adjustment based on user input^[18,19]. In the last decade, research on myoelectric lower limb prostheses has started to emerge^[20,21], yet the literature lacks consensus on the methodology for electromyographic control of lower limb prostheses^[18].

Novel strategies and technologies such as AI and ML are emerging to overcome the distinct challenges faced by patients with LLA. Herein, we present a scoping review describing how AI and ML can optimize diagnosis, treatment, and postoperative outcomes among patients with LLA. Further, we aimed to describe how AI and ML applications can improve peripheral nerve injury outcomes in this population.

EVALUATING THE ROLE OF AI

AI refers to the ability of computer systems to resemble human cognition in learning, synthesis, and perception of information. ML is a subset of AI in which algorithms can learn from data. ML is driven by mathematical models that are trained to yield optimized predictions based on a training dataset. There are two primary methods by which these models are trained. In supervised training, the algorithm learns from pre-labeled data known as the “ground truth”. In unsupervised training, the input data are not labeled, and the algorithm autonomously derives meaningful organization from the dataset. A subfield of ML known as “deep learning” (DL) employs multiple layers of artificial neural networks. This method allows for an increased level of abstraction and performance via convolutional neural networks (CNN) [Figure 1].

While basic science and translational research is well established in lower extremity amputation care, there are limited studies elucidating the direct application of AI in the field of LLA. Until recently, most AI extremity research had focused on hand and upper extremity amputations^[22], though an understanding of prior applications can guide efforts to improve LLA outcomes. AI-assisted analysis of medical images is well established in the literature, including the interpretation of radiographs, electrocardiograms, magnetic resonance imaging (MRI) slices, and histopathological images^[23-26].

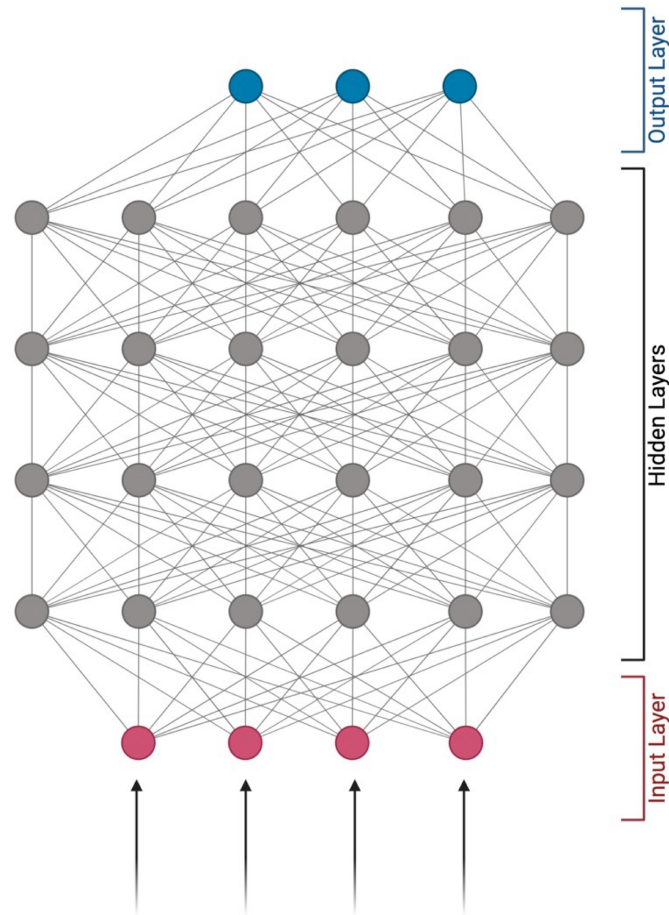


Figure 1. Simplified illustration of an artificial neural network divided into an input layer, a series of interconnected hidden layers that organize and process data, and an output layer. Created in BioRender. Jabbari, K. (2025) <https://BioRender.com/9vvp8o3>.

AI in the prevention of LLAs

Although peripheral arterial disease is associated with LLA, rates of PAD diagnosis remain persistently low due to variable, atypical presentation^[27]. As such, early diagnosis and staging may help attenuate poor management and amputation rates. Dai *et al.* recently developed a CNN for the analysis of lower extremity computed tomography angiograms and the classification of PAD^[25]. Their CNN utilized 17,050 axial images to develop distinct classification systems for both above-knee and below-knee artery stenoses. Compared to the reference standard of digital subtraction angiography, the CNN model demonstrated an accuracy of greater than 90% across most stenosis classes.

Similar innovations have been made in MRI processing and analysis. Zhang *et al.* developed a model with accelerated interpretation of dynamic contrast-enhanced MRIs and mapping of calf muscle perfusion^[26]. They created a feedforward neural network using pre- and post-exercise MRI scans from subjects with and without PAD. Compared to the reference standard of tracer kinetic analysis, the model produced comparable exercise-stimulated perfusion estimates and notably faster calf muscle perfusion maps. Similarly, another group assessed atherosclerosis of popliteal arteries with a CNN model, which reduced vessel wall segmentation times from an order of hours to only minutes^[28,29].

Affordable and convenient PAD screening may offer significant benefits in various clinical settings. Kim *et al.* performed one of the first proof-of-concept studies using deep CNN to detect and assess the severity of PAD based on brachial and arterial pulse waveforms^[30]. Their work showed that DL may diagnose PAD more accurately compared to current ankle-brachial index techniques. Allen *et al.* further demonstrated the value of DL-based approaches in PAD screening^[31]. Their team used DL-based photoplethysmography (DLPPG) classification to achieve high diagnostic performance with toe PPG signals. Within this portable and inexpensive model, data are transmitted to servers where DL algorithms facilitate accelerated and accurate diagnoses of PAD.

Additionally, timely detection of diabetic foot ulcers is critical in preventing LLA. Several reviews have reported on the application of AI in the diagnosis and treatment of diabetic foot^[32,33]. A recent proof-of-concept study by Cassidy *et al.* demonstrated accurate diabetic foot ulcer detection with an AI system on smartphones^[34]. A total of 203 photographs were taken by smartphone, analyzed by the AI system, and compared against expert clinical judgment. The predictions and decisions made by the AI system displayed high sensitivity (0.92) and specificity (0.86).

AI in patient management and clinical decision making

The application of AI in clinical decision making may revolutionize surgical practice through novel patient-centered approaches. Chung *et al.* used ML to generate an accurate risk prediction model for CLTI^[35]. Their multicenter, nested study included clinical trial data from 1,238 patients undergoing infrainguinal vein bypass for the treatment of ischemic rest pain or ischemic tissue loss. Supervised topic model cluster analysis was able to differentiate three distinct clusters of patients within the nested cohort, each designated as a specific stage within CLTI. Cluster analysis revealed 1-year CLTI-free survival rates of 82.3% for stage 1, 61.1% for stage 2, and 53.4% for stage 3. Stratification by stage revealed major limb amputation rates of 4.2% for stage 1, 10.8% for stage 2, and 18.4% for stage 3. Among those without a major amputation, the rate of CLTI recurrence was directly related to increasing stage number. Similarly, Oei *et al.* developed ML algorithms to predict the risk of LLA in 2,559 patients with diabetic foot ulcers^[36]. Their model performed well in the prediction of major [area under the receiver operating characteristic curve (AUROC): 0.820], minor (AUROC: 0.637), and any (AUROC: 0.756) LLA events. They further determined total white cell count, comorbidity score, and red blood cell count as key factors associated with the risk of major amputation. The above studies depict emerging methods for risk stratification and outcome prediction, highlighting the power of AI applications in surgical decision making.

The management of the mangled extremity represents yet another complex decision-making scenario. The decision for amputation or limb salvage will likely be innovated by AI models and replace traditional scoring systems^[37]. Perkins *et al.* developed a Bayesian network (BN) prediction model using a supervised ML approach to estimate the outcome of limb revascularization, a metric often critical to attempting limb salvage versus amputation^[38]. The prediction model sourced information from domain knowledge, published data, and US Department of Defense Data. Their model accurately predicted failed revascularization (AUROC: 0.95), with maintained performance on external validation (AUROC: 0.97). The BN prognostic model outperformed the traditional mangled extremity severity score in predicting the need for amputation [AUROC: 0.95 (0.92-0.98) vs. 0.74 (0.67-0.80); $P < 0.0001$].

Following the decision to perform a procedure, surgeons are often faced with postoperative patient complications. In general, the perioperative period serves as the source of initial exposure for many patients with chronic opioid use^[39,40]. Using a ML approach, Gabriel *et al.* developed predictive models for persistent opioid use following lower extremity joint arthroplasty^[41]. They demonstrated that ensemble learning can

improve predictive models, as evidenced by the balanced bagging classifier with a F1 score of 0.80 and an AUC of 0.94. This model identified several important features, such as postoperative day 1 opioid use, body mass index, age, preoperative opioid use, prescribed opioids at discharge, and hospital length of stay. The identification of high-risk patients may guide clinical decisions and interventions.

Another postoperative challenge specific to amputation patients is the development of pain or sensation that originates from the absent, amputated limb, known as PLP. Ortiz-Catalan *et al.* showed that motor execution of the phantom limb via ML, augmented and virtual reality, and gaming may hold potential as a treatment for PLP^[42]. Their cohort included fourteen patients with upper limb amputation and chronic intractable PLP. After the 12-session study period, a comparison of pre- and post-treatment PLP demonstrated significant decreases by 47% ($P = 0.001$) for weighted pain distribution, 32% ($P = 0.007$) for the numeric rating scale, and 51% ($P = 0.0001$) for the pain rating index. These findings further exemplify the potential role of AI applications in the evolution of treatment options for LLA patients.

AI in lower extremity nerve injuries

There is a need for innovative peripheral nerve injury strategies among LLA patients, as neurogenic pain secondary to hyperactive terminal neuroma formation is largely responsible for postoperative morbidity. In this effort, AI technologies can be used to understand the pathology of PNI and to better explore therapeutic approaches.

Such an approach has led to the development of new research methods and strategies for nerve regeneration. Romeo-Guitart *et al.* showed the power of therapeutic performance mapping system (TPMS) technology for the design of drug therapies promoting nerve regeneration and functional recovery after PNI^[43]. TPMS develops mathematical models that simulate human physiology *in silico*, a process that is based on AI and pattern recognition models that source all available biological, medical, and pharmacological knowledge. A total of 5,400 drugs were screened, generating approximately 15 million binary drug combinations. After further screening, the team selected the top 3 binary combinations with more than 75% of potential regenerative capabilities. The neuroprotective effects of these drug combinations were then validated in *in vitro* and *in vivo* models. This strategy elucidated the therapeutic actions of combinatorial drug therapy with acamprosate plus ribavirin. Most importantly, the authors demonstrated the discovery of repurposed drug therapies with a network-centric approach, which uses ML tools to validate both efficacy and mechanism of action with preclinical *in vivo* models.

Additionally, large image datasets can be utilized by AI systems for rapid biomedical research. Daeschler *et al.* validated a DL model of automated segmentation and histomorphometry of myelinated peripheral nerves via light microscopic images^[44]. A CNN was trained for automated axon and myelin segmentation using a dataset of light-microscopic cross-sectional images of rat nerves at various stages of axonal regeneration. Their CNN model demonstrated high pixel-wise accuracy for nerve fiber segmentation with ground truth overlap (mean $\pm$ standard deviation) of 0.93 ± 0.03 and 0.99 ± 0.01 for axons and myelin sheaths, respectively. Nerve fibers were identified with high sensitivity (0.99) and precision (0.97), with automated histomorphometry reducing analysis time to less than 2.5% of that for manual morphometry. Neural network-powered biomedical image analysis can significantly increase the rate of experimental nerve research via performance, time, and resource efficiency.

Beyond its role in drug therapy and image processing, AI has potential applications in the direct repair of PNI using 3D printing and biomaterials. Nerve guidance conduits (NGCs) have been widely explored for the treatment of PNI. Current research on functional NGCs attempts to create microenvironments that

promote greater axonal elongation and myelination^[45,46]. In this effort, ML modeling can significantly accelerate biomaterial experimentation by identifying optimal biochemical and biophysical properties from large datasets^[47]. For instance, Li *et al.* developed a library of 2,000 peptide-based self-assembling hydrogels to identify optimal motifs for hydrogel self-assembly^[48]. In another ML model of biomaterial synthesis, Kosuri *et al.* discovered chondroitinase ABC complexes that best retained enzymatic activity for neural regeneration applications^[49]. Such AI-driven advances in NGC and biomaterial design may be applied to emerging strategies in lower extremity nerve repair and the parallel application of AI technology to nerve regenerative strategies has potential for revolutionary biotechnologies.

AI in lower extremity prosthetic use and design

The ability to stimulate and record signals from the peripheral nervous system (PNS) is an important component of new bioelectronic systems. In neurologically intact individuals, sensory signals from the lower limbs, such as tactile sensation in the foot and proprioception, influence motor output^[50]. Traditional prostheses do not restore sensory feedback in amputees, which contributes to asymmetric gait, poor balance, risk of falls, and perception of the prosthesis as an external object (low embodiment)^[50-53]. Several strategies have been employed to restore somatosensory feedback to lower extremity amputees^[54-57]. Notably, advances in PNS interfacing represent a promising alternative to current neuromodulation modalities^[58].

Direct interface with remaining nerves in the residual limb may restore the sensations necessary for human locomotion among patients with LLA^[59,60]. Charkhkar *et al.* mapped elicitation sensations in transtibial amputees with implanted nerve cuff electrodes^[61]. Neural stimulation was perceived by patients as originating from the missing limb, with discrete localization to missing toes, foot, and ankle, as well as the residual limb. These findings reflect the paradigm shift in prostheses development, where high-density cuff technology can be applied to neuroprosthesis with natural sensory feedback [Figure 2]. To this end, AI-driven methodology can be applied to the evolution of prosthesis development. Koh *et al.* used CNN to correlate signals from naturally evoked compound action potentials (CAPs) and neural pathways of interest^[62]. Using a rat model, nerve cuff electrodes were implanted on the sciatic nerve and afferent activity was selectively evoked in different fascicles via mechanical stimuli. Based on the predicted firing patterns from the CNN, a recurrent neural network was used to predict joint angles. They showed high accuracy in CAP-based classification, which can track physiological measurements such as joint ankles. These results demonstrate the role of AI in the development of more effective neuroprosthetic systems.

Although promising, the above reports lacked prosthesis connection or functional assessment. This was addressed by Petrini *et al.*, who utilized intraneural electrodes to develop a leg neuroprosthesis with real-time tactile and proprioception feedback through nerve stimulation^[63]. Functional assessment showed improved mobility, fall prevention, and increased embodiment of the prosthesis. It has become evident that induced sensory feedback integration is an important component of care for LLA patients. As such, there is a need to optimize neural interface design. Zelechowski *et al.* developed a computational model of sciatic nerve behavior in response to electrical stimulation^[64]. Their model reported optimal interfaces for use in humans and their surgical placement. The authors noted, however, that limitations in imaging technique and computational power precluded their ability to develop patient-specific devices. Instead, their study suggests indications for the use and design of these devices. This barrier represents yet another potential application of AI in the natural evolution of lower limb prostheses.

Osseointegration of prosthetic implants has recently emerged as a viable alternative to traditional socket prostheses, which are not always suitable for LLA patients^[65]. Yet, to our knowledge, the application of AI technology to osseointegration strategies is not well studied outside the field of implant dentistry^[66,67]. Lu

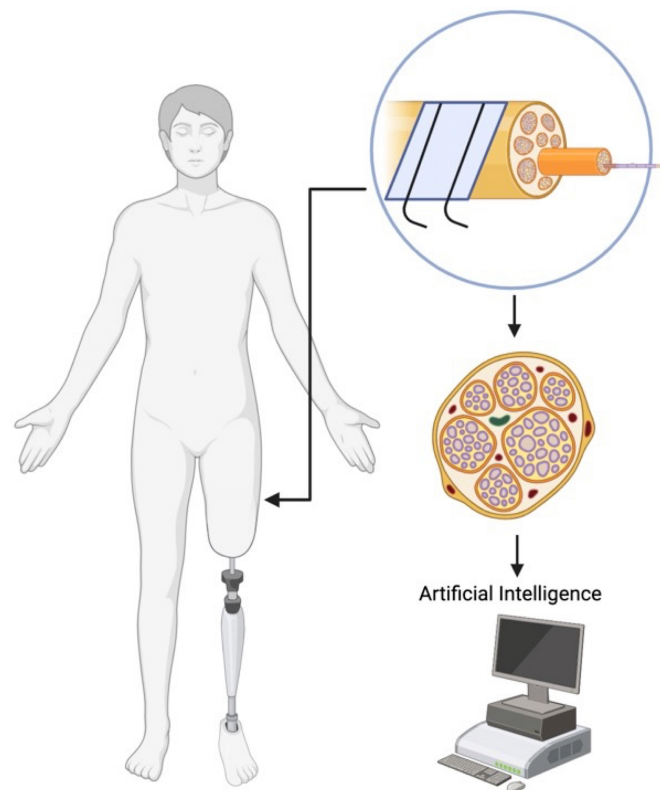


Figure 2. Schematic of implanted nerve cuff electrode technology and potential application of AI to develop patient-specific devices via advanced imaging and computational power. Created in [BioRender](https://BioRender.com/tOgdy9v). Jabbari, K. (2025) <https://BioRender.com/tOgdy9v>.

et al. utilized artificial neural networks to enhance the antimicrobial and osteointegration-promoting properties of micro/nanostructures in the setting of dental implantation^[66]. A similar application of AI-driven strategies for LLA prosthetic osteointegration would likely prove to be invaluable. Osseointegration aids in the relief of socket-related pain and further facilitates sensory feedback via the phenomenon of osseoperception^[65].

CONCLUSIONS

AI-based strategies complement clinical judgment and support innovations in lower extremity amputation care. In this scoping review, we described the current and emerging roles of AI in LLA prevention, management, peripheral nerve injury treatment, postoperative outcomes, and lower limb prosthesis design. AI as a methodology holds promise in revolutionizing the practice of LLA by way of computational analysis of large datasets. This feature of AI represents both an inherent strength and challenge in the field. Recent research has underscored that AI algorithms could be susceptible to security breaches^[68]. Thus, the integration of AI into LLA care also necessitates comprehensive guidelines for secure use and safety. Nonetheless, our review suggests that the integration of AI in LLA is not only rapidly growing but is seemingly inevitable.

DECLARATIONS

Authors' contributions

Made substantial contributions to the conception and design of the study and performed data analysis and interpretation: Jabbari K, Orfahli LM, Iorio ML

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Conflicts of interest

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Stable cortical body maps before and after arm amputation

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The adult brain's capacity for cortical reorganization remains debated. Using longitudinal neuroimaging in three adults, followed before and up to 5 years after arm amputation, we compared cortical activity elicited by movement of the hand (before amputation) versus phantom hand (after amputation) and lips (before and after amputation). We observed stable cortical representations of both hand and lips in primary sensorimotor regions. By directly quantifying activity changes across amputation, we demonstrate that amputation does not trigger large-scale cortical reorganization.

What happens to the brain's map of the body when a part of the body is removed? Over the last five decades, this question has captivated neuroscientists and clinicians, driving research into the brain's capacity to reorganize itself. Primary somatosensory cortex (S1), known for its highly detailed body map, has historically been the definitive region for studying cortical reorganization^{1,2}. For example, foundational research in monkeys reported that, after an amputation or deafferentation, the affected region within the S1 body map suddenly responds to inputs from cortically neighboring body parts (for example, the face)^{3,4}. Additional neuroimaging studies in human amputees supported the theory that amputation of an arm triggers large-scale cortical reorganization of the S1 body map^{5–7}, with a dramatic redistribution of cortical resources, hijacking the deprived territory¹.

Recent studies have challenged this view by harnessing human amputees' reports of experiencing vivid sensations of the missing (phantom) limb. First, human neuroimaging studies demonstrated that voluntary movements of phantom fingers engage neural patterns resembling those of able-bodied individuals^{8–10}. Second, phantom sensations are evoked by cortical¹¹ or peripheral^{12,13} nerve stimulation, suggesting an intact neural representation of the amputated limb, despite its physical absence. Third, neuroimaging studies using both

tactile stimulation and movement paradigms reported no changes in face or lip activity within the deprived cortex of adult amputee participants compared to able-bodied controls^{14,15} (although remapping has been observed in children)¹⁶.

This debate—whether or not amputation triggers large-scale reorganization—remains unresolved^{17,18}, with some suggesting that the two views are not conceptually exclusive, that is, preservation and reorganization can coexist^{5,19,20}. However, a fundamental issue with the evidence on both sides of this debate is a methodological reliance on cross-sectional designs (that is, comparisons between participants). While offering valuable proofs of concept, these studies cannot determine whether the maps of the phantom hand or face are truly preserved or changed relative to their pre-amputation state. To directly track the evolution of cortical representations before and after amputation, we implemented a longitudinal functional magnetic resonance imaging (MRI) approach to track the cortical representations of the hand and face (lips) in three adult participants up to 5 years after arm amputation (Supplementary Video 1), compared with able-bodied control participants (Ctrl) (Fig. 1a). Avoiding the confounding effects of cross-sectional designs²¹, we directly quantified the impact of arm amputation on S1 (re)organization.

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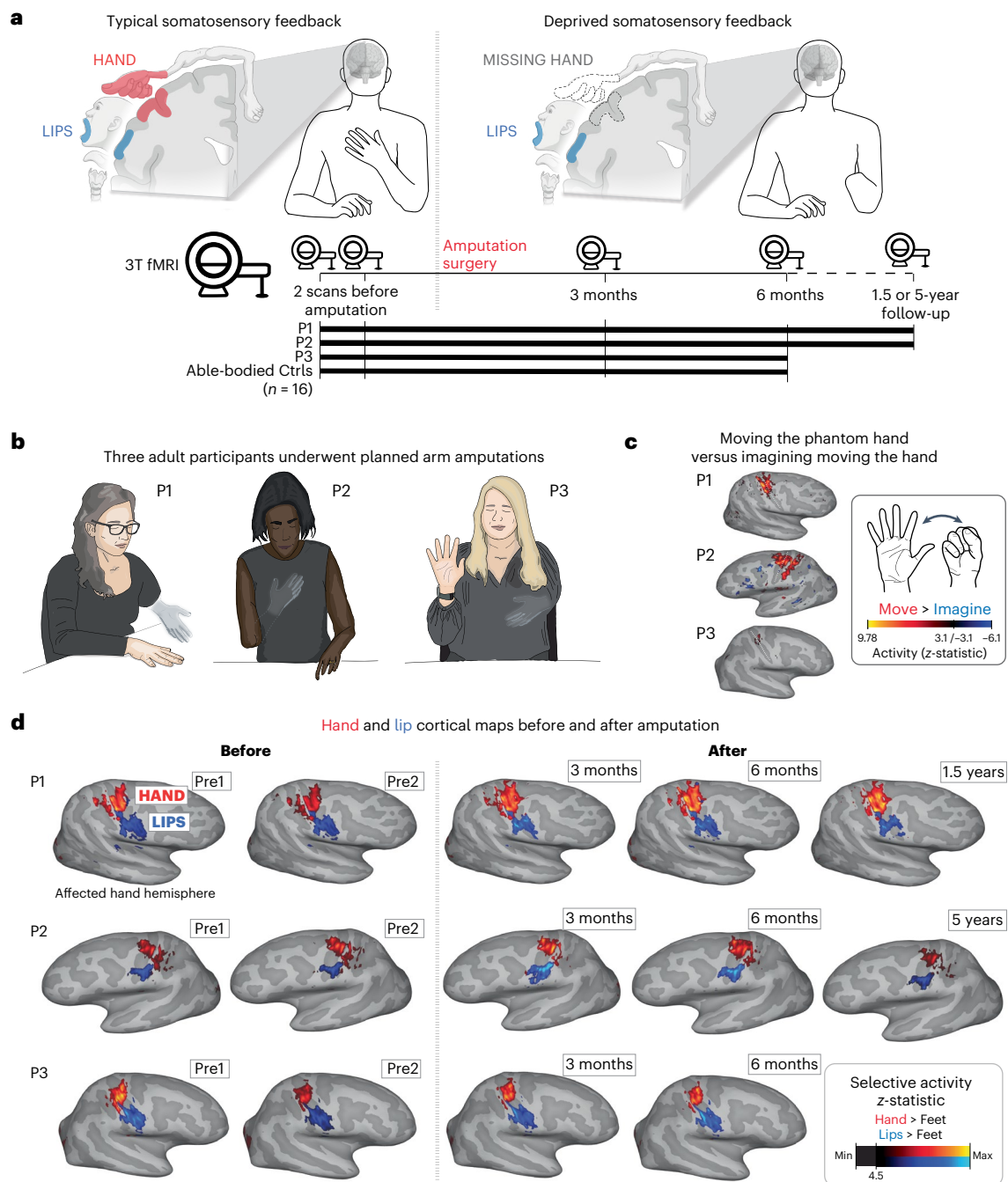


Fig. 1 | Longitudinal investigation of participants with planned arm amputations. **a**, Experimental timeline. Scans before and after amputation were conducted across 4–5 time points: twice before, and at 3 months, 6 months and 1.5 (P1)/5 years (P2) after amputation. **b**, Illustration depicting the three participants 6 months after amputation, including their subjective description of their phantom limb position. **c**, Phantom movements are not imaginary. Univariate activity (z-scored) contrast map displaying a participant's attempts to

open and close the phantom hand versus imagining movement, 6 months after amputation. **d**, Participant's hand (red) and lip (blue) cortical activation maps (contrasted against feet movements) in the affected hand hemisphere across 4–5 sessions. All maps were minimally thresholded at 33% the maximum z-statistic and used a common color scale (the participant's maximum z-statistic > 4.5). Participants agreed to have their image reproduced. Brain illustrations in **a** were created in [BioRender](#).

We studied three adult participants (case studies P1, P2 and P3) undergoing arm amputation (demographics in Extended Data Table 1) across 4–5 time points, and 16 able-bodied Ctrls at four time points over 6 months (Fig. 1a). Before amputation, all participants could move all fingers to varying ranges (Extended Data Fig. 1 and Supplementary Video 2). After amputation, all participants reported vivid phantom limb sensations (Fig. 1b), including volitional phantom finger movement (Extended Data Table 1 and Extended Data Fig. 1). Motor control

over the phantom hand was further confirmed by residual limb muscle contractions during phantom movements (Supplementary Video 2), and selective activation in primary sensorimotor cortex for attempted, but not imagined, phantom movements (Fig. 1c). The critical question is to what degree S1 phantom activity reflects the pre-existing hand.

During scanning, participants performed visually cued movements involving tapping individual fingers, pursing lips and flexing toes. Case study participants demonstrated strikingly consistent hand

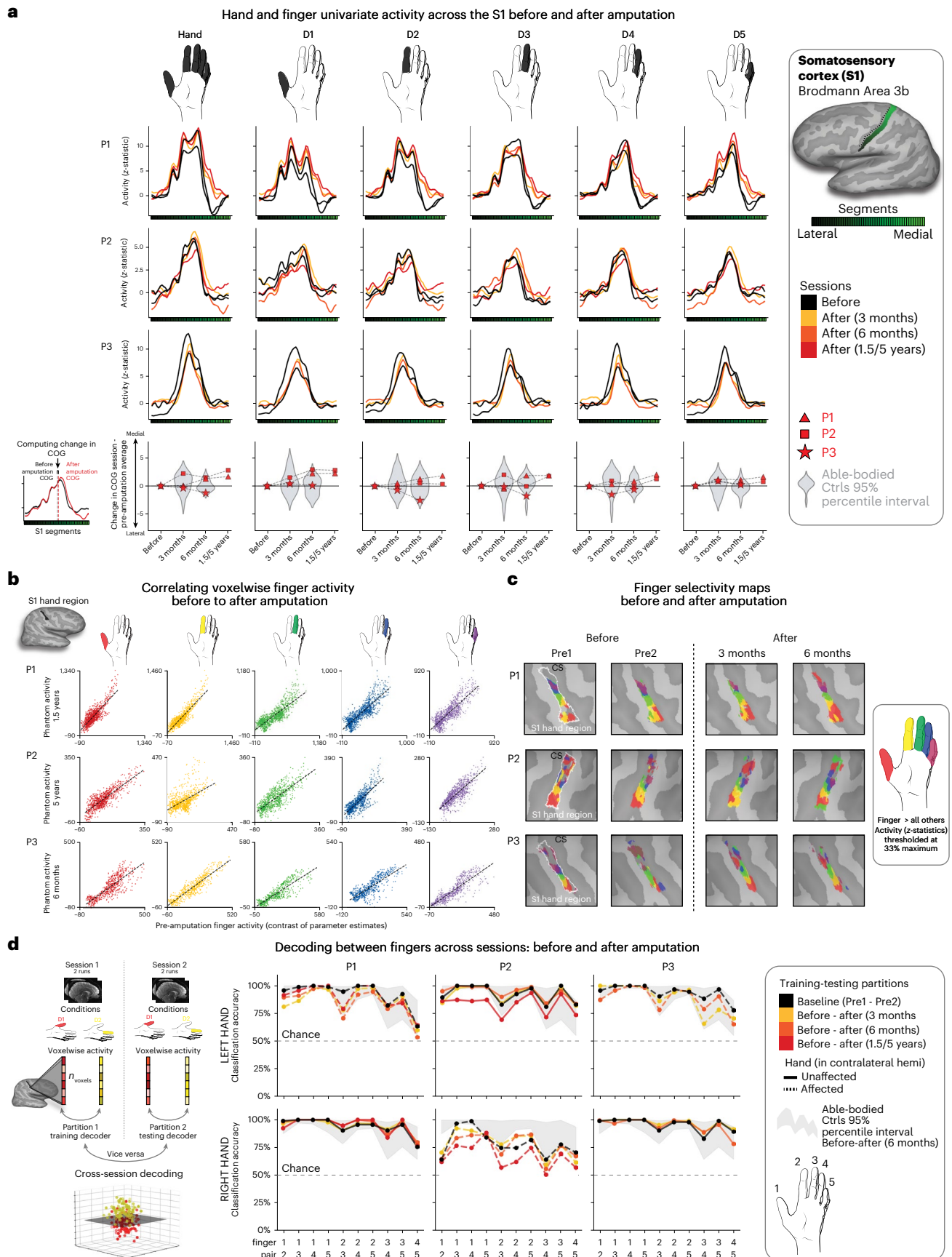


Fig. 2 | Stable hand representation in the affected hemisphere despite amputation. **a**, Longitudinal hand and individual finger activity (versus rest) projected across the S1 (BA3b) region of interest (ROI) segmented into 49 segments of similar height. The affected hand's activity over five sessions (indicated in the legend) for each of the case study participants who underwent an amputation is shown; the bottom row shows the finger COG shifts before and after amputation. The black lines reflect the activity before amputation, the yellow, orange and red lines after amputation. The COG shifts of the case study participants (red) for the hand and individual fingers fell within the distribution of Ctrl (gray; six comparisons per participant; two-tailed Crawford *t*-test: P1 (6 months): $0.14 \leq P_{\text{uncorr}} \leq 0.58$; P2 (6 months): $0.06 \leq P_{\text{uncorr}} \leq 0.81$; P3 (6 months): $0.10 \leq P_{\text{uncorr}} \leq 0.91$). Positive values indicate medial shifts (toward the feet); negative values indicate lateral shifts (toward the lips) in S1. Ctrl 95% percentile interval data are shown as gray violin plots. P1 data are shown as a red triangle. P2 data are shown as a red square. P3 data are shown as a red star. For simplicity, the Ctrl values are all for the left (nondominant) hand. **b**, Before and after amputation single-finger multivoxel correlations: for each finger of the case study participants, voxelwise activity correlations before and at the final scan after amputation are shown. All other correlations are comprehensively

reported in Extended Data Fig. 5. The before to after amputation correlations for all participants were statistically significant (five two-tailed Pearson correlations per participant; P1 (6 months): $0.68 \leq r \leq 0.90$, $P_{\text{uncorr}} < 0.001$; P2 (6 months): $0.80 \leq r \leq 0.85$, $P_{\text{uncorr}} < 0.001$; P3 (6 months): $0.88 \leq r \leq 0.91$, $P_{\text{uncorr}} < 0.001$). **c**, Finger selectivity maps before and after amputation. Each contrast map reflects the selective activity for each finger (versus all others), masked to the hand ROI. Each mask was minimally thresholded at 33% the maximum *z*-statistic and binarized. Color codes are indicated on the right. To visualize the multi-finger activity at a single voxel, a 70% opacity filter was applied to all finger maps. **d**, Left, Graphic illustration of multivoxel analyses using a linear SVM decoder. Right, Longitudinal classifier performance. The line colors denote training-testing cross-validation session pairs, respectively, as indicated in the legend. The gray-shaded area reflects the data of able-bodied Ctrl before and after (6 months) (95% percentile interval). Training the classifier on the pre-amputation data and testing it on the post-amputation data (and vice versa) revealed significantly above chance classification accuracies for all case study participants at all post-amputation sessions (two-tailed, one-sample *t*-test: P1: before 1.5 years: 89%; $P < 0.001$; P2: before 5 years: 67%; $P < 0.001$; P3: before 6 months: 88%; $P < 0.001$). All other annotations are depicted in Fig. 1.

and lip cortical maps before and after amputation (Fig. 1d). Projecting hand and individual finger activity profiles across S1 revealed stable activity before and after amputation, with phantom activity resembling the amplitude and spatial activity spread before amputation (Fig. 2a). A center of gravity (COG) analysis of these profiles revealed spatially consistent hand and individual finger activity in our case studies, with similar pre- and post-amputation session differences over 6 months as Ctrl (six Crawford *t*-tests per participant; P1: $0.14 \leq P_{\text{uncorr}} \leq 0.58$; P2: $0.06 \leq P_{\text{uncorr}} \leq 0.81$; P3: $0.10 \leq P_{\text{uncorr}} \leq 0.91$). Notably, this stability could not be attributed to a pre-existing baseline difference as hand activity before amputation was normal relative to Ctrl (Extended Data Fig. 2a). Similar pre- and post-amputation stability was observed in the motor cortex (M1) (Extended Data Fig. 3a) and for the intact (unaffected) hand (Extended Data Fig. 4a).

Next, we investigated the stability of S1 finger representation in greater detail using a multivoxel pattern analysis (Fig. 2b and Methods). Multivoxel activity patterns for the pre-amputated versus phantom fingers were significantly correlated at 6 months (five Pearson correlations per participant; P1: $0.68 \leq r \leq 0.90$, $P_{\text{uncorr}} < 0.001$; P2: $0.80 \leq r \leq 0.85$, $P_{\text{uncorr}} < 0.001$; P3: $0.88 \leq r \leq 0.91$, $P_{\text{uncorr}} < 0.001$). Correlation coefficients at 6 months fell within the typical distribution seen in Ctrl (see Extended Data Fig. 5 and Supplementary Table 1 for the Ctrl values). Similar stability was observed in M1 (Extended Data Fig. 3b) and for the intact hand (Extended Data Fig. 4c). Combined, this confirmed that activity was largely stable before and after amputation at the single-voxel level.

We next considered finger selectivity, that is, the activity profiles for each finger versus the other fingers. Qualitative finger-mapping revealed preserved somatotopy before and after amputation (Fig. 2c). We applied a multivoxel pattern analysis using a linear

support vector machine (SVM) classifier (Fig. 2d) to explore whether a pre-amputation-trained classifier could decode phantom finger movements (and vice versa). This analysis revealed significantly above chance classification for all case study participants across all post-amputation sessions (Fig. 2d; 2–3 one-sample *t*-tests per participant: P1 (before/1.5 years): 90%; $t_{(9)} = 10.5$, $P_{\text{uncorr}} < 0.001$; P2 (before/5 years): 67%; $t_{(9)} = 4.85$, $P_{\text{uncorr}} < 0.001$; P3 (before/6 months): 89%; $t_{(9)} = 11.0$, $P_{\text{uncorr}} < 0.001$), with similar evidence in M1 (Extended Data Fig. 3c).

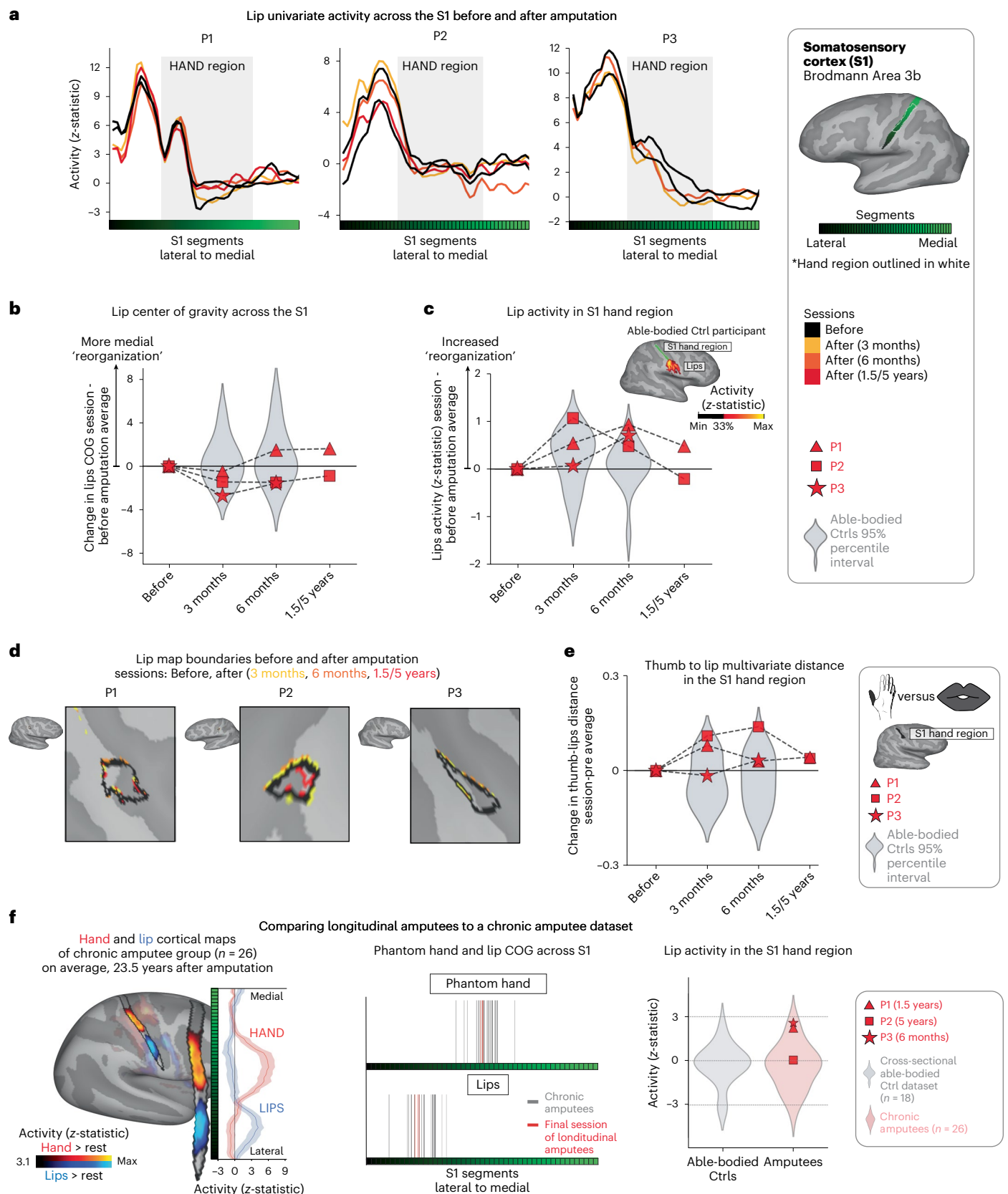
We next investigated whether amputation reduces finger-selective information, as suggested by previous cross-sectional studies²². Assessing for abnormalities in the pre-amputation data, we noted that one of the case study participants, P2, exhibited lower classification for the pre-amputation hand relative to Ctrl (Extended Data Fig. 1), probably because of P2's impaired motor control before amputation (Supplementary Video 2). Our key question remains whether this information degrades further after amputation. When comparing selectivity differences over 6 months relative to Ctrl, none of the case study participants showed significant reductions in average finger selectivity (Crawford *t*-test: P1: $t_{(15)} = -0.34$, $P = 0.73$; P2: $t_{(15)} = -0.24$, $P = 0.80$; P3: $t_{(15)} = -1.0$, $P = 0.33$; Extended Data Fig. 6c). While finger selectivity was reduced at P2's and P3's final scan relative to their baseline (Fig. 2d; three Wilcoxon rank-sum tests per participant: P1 (1.5 years): $W = 3.0$, $P_{\text{uncorr}} = 0.11$; P2 (5 years): $W = 2.0$, $P_{\text{uncorr}} = 0.005$; P3 (6 months): $W = 1.0$, $P_{\text{uncorr}} = 0.01$), these reductions could be attributed to the much greater longitudinal variability between training and testing classifier samples²³. To further explore this, we directly compared the finger selectivity of the affected hand versus the unaffected hand. For two of three of our participants, at the 6-month time point, we observed decreased finger-selective information in the affected hand relative to the unaffected hand, compared

Fig. 3 | No evidence for lip reorganization after amputation. **a**, The lip activity (versus rest) of each case study participant for their sessions projected across the S1 ROI. The black lines reflect pre-amputation activity, with the yellow (3 months), orange (6 months) and red (1.5/5 years) lines reflecting activity after amputation. The gray region depicts the approximated coverage of the hand portion in the S1. **b**, All case study participants showed typical longitudinal variability at their 6-month scan, relative to Ctrl, for the lip COG. Positive values reflect medial shifts (toward the hand). **c**, All case study participants showed typical lip activity in the S1 hand region at the final scan. The right corner depicts representative Ctrl participant activity for the lips (versus the feet) minimally thresholded at 33% the maximum *z*-statistic. **d**, All case study participants exhibited no expansion of the lip map boundaries toward the hand region. Maps were masked to the S1 ROI and were minimally thresholded ($z > 4.5$). **e**, All case study participants showed stable thumb-to-lip multivariate Mahalanobis distances cross-validated

at their final scan, relative to Ctrl. **f**, Comparing the case study participants to a chronic amputee dataset ($n = 26$). Left, Chronic amputee's group-level cortical activation maps of the phantom hand and lips (versus rest) projected onto a single hemisphere (minimally thresholded at $z > 3.1$). Opacity was applied to activity outside the S1 ROI. Group univariate activity was plotted as a line (group mean $\pm$ s.e.) for the phantom hand (red) and lips (blue) across the S1 ROI. Middle, All case study participants, relative to chronic amputees, showed a typical COG for both the phantom hand (top) and lips (bottom). Right, All case study participants exhibited typical lip activity in the S1 hand region during their final session, which is consistent with chronic amputees. The magnitude of lip activity (95% percentile interval) in the S1 hand region for a secondary able-bodied Ctrl group ($n = 18$) is shown in gray. Chronic amputees are shown in light red and the last session data for the case study participants are shown in dark red. All other annotations are the same as described in Fig. 2.

with Ctrls (dominant hand versus non-dominant hand; two Crawford *t*-tests per participant; before 6 months: P1: $P_{\text{uncorr}} = 0.03$; P2: $P_{\text{uncorr}} = 0.03$; P3: $P_{\text{uncorr}} = 0.10$; Supplementary Fig. 1). Collectively across analyses, the decoding results suggested slight (uncorrected) reductions in finger selectivity or increased finger selectivity for the intact hand.

We also performed a complementary representational similarity analysis (RSA) using Mahalanobis distances (a continuous measure of finger selectivity), cross-validated across sessions. Like the decoding, RSA confirmed that finger-selective information was significantly consistent across amputation for all case study participants at all



post-amputation time points (2–3 one-sample t -tests per participant: $P_{\text{uncorr}} < 0.0001$; Extended Data Fig. 6a,b), with similar evidence in M1 (Supplementary Fig. 3c). We noted a few temporary, idiosyncratic (uncorrected) instances of reduced finger selectivity relative to Ctrl (Extended Data Fig. 6c). Using the RSA distances, we also tested the typicality of the inter-finger representational structure, an additional feature of hand representation. Correlating each participant's inter-finger pattern to a canonical pattern revealed no deterioration in typicality scores 6 months after amputation compared to Ctrl, with P3 even showing higher typicality than the Ctrl group (Crawford t -test: P1: $t_{(15)} = -0.9$, $P = 0.38$; P2: $t_{(15)} = -0.9$, $P = 0.38$; P3: $t_{(15)} = -3.5$, $P = 0.003$; Extended Data Fig. 6d). Therefore, despite idiosyncratic reductions in finger selectivity, the representational structure was preserved after amputation.

Finally, we examined changes in lip representation, previously implicated with reorganization after arm amputation^{4,7}. Projecting hand and lip univariate activity onto the S1 segments revealed no evidence of lip activity shifting into the hand region after amputation (Fig. 3a). All case study participants showed typical longitudinal variability at their 6-month scan, relative to Ctrl, for lip COG (Fig. 3b; Crawford t -test: P1: $t_{(15)} = 0.25$, $P = 0.80$; P2: $t_{(15)} = -0.89$, $P = 0.38$; P3: $t_{(15)} = -0.9$, $P = 0.37$). Furthermore, lip activity in the S1 hand region at the final scan was typical (Fig. 3c; P1 (1.5 years): $t_{(15)} = 0.8$, $P = 0.20$; P2 (5 years): $t_{(15)} = -0.5$, $P = 0.71$; P3 (6 months): $t_{(15)} = 1.2$, $P = 0.10$). Also, when visualizing the lip map boundaries within S1 for all sessions, using a common minimum threshold, there was no evidence for an extension of the lip map (Fig. 3d). Examining the multivariate lip representational content, P2 showed an increased lip-to-thumb multivariate distance at their 6-month scan, relative to Ctrl (Fig. 3e; Crawford t -test: P1: $t_{(15)} = 0.69$, $P = 0.25$; P2: $t_{(15)} = 3.1$, $P = 0.003$; P3: $t_{(15)} = 0.74$, $P = 0.23$; intact hand and feet data are included in Extended Data Fig. 7). However, it returned to the typical range of Ctrl when assessed at their 5-year time point. Similar stability was found in M1 (Extended Data Fig. 3) and the unaffected hemisphere (Extended Data Fig. 4). These results demonstrate that amputation does not affect lip topography or representational content in S1.

To complement our longitudinal findings, we compared our case studies to a cohort of 26 chronic upper-limb amputee participants, on average 23.5 years after amputation (Fig. 3f; individual hand and lip cortical maps shown in Extended Data Fig. 8). The topographical features of our case studies were comparable to chronic amputees for both the phantom hand [Crawford t -test: P1 (1.5 years): $t_{(15)} = 0.28$, $P = 0.77$; P2 (5 years): $t_{(15)} = 0.29$, $P = 0.77$; P3 (6 months): $t_{(15)} = 0.28$, $P = 0.22$; $P = 0.82$] and lips [P1 (1.5 years): $t_{(15)} = 0.53$, $P = 0.59$; P2 (5 years): $t_{(15)} = 0.01$, $P = 0.98$; P3 (6 months): $t_{(15)} = 0.37$, $P = 0.71$]. Average lip activity within the S1 hand region was slightly (although not significantly) higher for a few of our case studies relative to chronic amputees [Crawford t -test: P1 (1.5 years): $t_{(15)} = 1.6$, $P = 0.10$; P2 (5 years): $t_{(15)} = 0.24$, $P = 0.81$; P3 (6 months): $t_{(15)} = 1.8$, $P = 0.065$], reflecting that lip activity does not steadily increase in the years after amputation. Collectively, these results provide long-term evidence for the stability of hand and lip representations despite amputation.

Beyond the stability of lip representation across amputation, our findings reveal highly consistent hand activity despite amputation. This unchanged hand representation challenges the foundational assumption that S1 activity is primarily tied to its peripheral inputs, suggesting S1 is not a passive relay of its peripheral input, but an active supporter of a resilient 'model' of the body, even after amputation. Therefore, we conclude that, in the adult brain, S1 representation can be maintained by top-down (for example, efferent) inputs. This interpretation sheds new light on previous studies showing similar S1 topographical patterns activated by touch²⁴, and executed²⁵ and planned movement²⁶.

Because of the limitations of nonhuman models that cannot communicate phantom sensations, it is not surprising that the persistent representation of a body part, despite amputation, has been neglected

in previous studies. Without access to this subjective dimension, researchers may have missed the profound resilience of cortical representations. Instead, previous studies determined S1 topography by applying a 'winner-takes-all' strategy, probing responses to remaining (intact) body parts and noting the most responsive body parts in the input-deprived cortex. Ignoring phantom representations in these analyses leads to severe biases in the interpretation of the area's inputs (as demonstrated in Extended Data Fig. 9). Combined with cross-sectional designs, this has incorrectly led to the impression of large-scale reorganization of the lip representation after amputation. Our longitudinal approach reveals no signs of topographic reorganization in S1, not even subtle upregulation from homeostasis, further reinforcing the notion that S1 is not governed by deprivation-driven plasticity.

For brain–computer interfaces, our findings demonstrate a highly detailed and stable representation of the amputated limb for long-term applications²⁷. For phantom limb pain treatments, our study indicates that targeted muscle reinnervation and regenerative peripheral nerve interfaces do not 'reverse' reorganization or alter the cortical hand representation^{22,28}. Finally, our findings affirm the unaltered nature of adult sensory body maps after amputation, suggesting that Hebbian and homeostatic deprivation-driven plasticity is even more marginal than considered by even the field's strongest opponents of large-scale reorganization^{17,29}.

Online content

Any methods, additional references, Nature Portfolio reporting summaries, source data, extended data, supplementary information, acknowledgements, peer review information; details of author contributions and competing interests; and statements of data and code availability are available at <https://doi.org/10.1038/s41593-025-02037-7>.

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Methods

Our key methodology involved longitudinal comparisons across amputation. This approach was designed to overcome known limitations in cross-sectional designs, where inter-participant variability could spuriously influence group comparisons, particularly when considering small group sample sizes or small effects. An important additional consideration regarding reorganization research in amputees is the difficulty to interpret whether sensorimotor activity for the missing (phantom) hand reflects preserved representation (that is, whether it reflects the same representational attributes as the physical hand before amputation), or an altered hand representation, which exhibits canonical hand representation features, albeit distinct from the pre-amputation hand. The main limitation of longitudinal designs is the contribution of any time-related effects, for example, because of changes in magnetic resonance scanning hardware³⁰ or participants' experience (for example, familiarity with the study environment³¹), which are not directly related to the amputation. To account for nonrelated variables, we also scanned our case studies and Ctrl participants over a similar time frame. For two of our case studies, we had an opportunity to follow up on our procedures after an extended period (1.5/5 years after amputation). As this was not planned in the original design, we were unable to obtain related time points in our Ctrl. Therefore, all comparisons to the Ctrl cohort are focused on the 6-month post-amputation time point.

Participants

Longitudinal case study participants who underwent an amputation. Over a 7-year period and across multiple NHS sites in the UK, we recruited 18 potential participants preparing to undergo hand amputations. Because of many factors (for example, MRI safety contraindications, no hand motor control, age outside the ethics range, high level of disability), we could only perform pre-amputation testing on six volunteers. Because of additional factors (complications during surgery, general health, retractions), we successfully completed our full testing procedure on three participants (for participant demographics, see Extended Data Table 1).

Pre-amputation scans for P1 and P2 were collected 24 h apart and within 2 weeks of their amputations. P3 had a 2.5-year gap between the pre-amputation scans due to coronavirus disease-related delays in testing and in scheduling uncertainty related to their amputation surgery. Their amputation surgery took place 3 months after their second pre-amputation scan.

Case study participant amputation surgeries. There are noteworthy differences in the amputation surgeries of the three case study participants. P1 underwent an amputation to combat a rapidly developing arteriovenous malformation in the upper arm. Before amputation, they had a relatively high level of motor control in the pre-amputation hand. Additionally, P1's amputation included more advanced surgical techniques, involving a combination of targeted muscle reinnervation³² and regenerative peripheral nerve interfaces³³. In these approaches, rather than simply cutting the residual nerve, the remaining nerves were sutured to a new muscle (targeted muscle reinnervation) or implanted with a nerve graft (regenerative peripheral nerve interface) (in P1's case, the technique varied depending on the muscle; Supplementary Fig. 2). P2 underwent a traditional amputation procedure to remove a sarcoma tumor that had been slowly progressing since 1995. Multiple surgeries of the arm, before the amputation, left them with restricted motor control of the fingers, although still able to move them (Supplementary Video 2). Similarly, P3 was diagnosed with Severell–Martorell syndrome, which had led to their left arm having multiple chronic bone fractures. They underwent a traditional amputation procedure, where the major nerves were left to naturally retract. It is important to note that the diversity of conditions, procedures and postoperative states across

our case studies strengthen the universality of our results, which were consistent across case studies.

Longitudinal able-bodied Ctrl group. In addition to the case study participants who underwent an amputation, we tested a Ctrl group that included 16 older able-bodied participants (nine females; mean age $\pm$ s.d. = 53.1 ± 6.37 ; all right-handed). The Ctrl group also completed four functional MRI (fMRI) sessions at the same timescale as the participants who underwent an amputation and were age-matched to P2 and P3. Four additional Ctrl. were recruited for this group; however, we did not complete their testing because of dropout and incidental findings captured during the MRI sessions.

Ethical approval for all longitudinal study participants was granted by the NHS National Research Ethics Committee (no. 18/LO/0474) and in accordance with the Declaration of Helsinki (v.2013). Written informed consent was obtained from all participants before the study for their participation, and for data storage and dissemination.

Cross-sectional datasets. From three previous studies (one unpublished study and refs. 14,34), we pooled two cross-sectional fMRI datasets: (1) a group of chronic amputees ($n = 26$) and (2) a secondary group of able-bodied Ctrl. ($n = 18$). The chronic amputee group included 26 upper-limb amputee participants (four females; mean age $\pm$ s.d. = 51.1 ± 10.6 ; 13 missing the left upper-limb; level of amputation: 17 transradial, eight transhumeral and one at the wrist; mean years since amputation $\pm$ s.d. = 23.5 ± 13.5). The secondary able-bodied Ctrl group included 18 able-bodied participants (seven females; mean age $\pm$ s.d. = 43.1 ± 14.62 ; 11 right-handed). For more information on these datasets, see the Supplementary Methods (<https://osf.io/s9hc2/>).

Longitudinal younger adult able-bodied Ctrl dataset. P1 is younger than the longitudinal Ctrl group. As such, we reanalyzed a previously collected dataset including 22 able-bodied Ctrl. of a similar age to P1 (mean $\pm$ s.d. = 23.2 ± 3.8); each were scanned twice, 1 week apart on the same fMRI task and scanner³⁵.

Questionnaires

Because of a restricted time window for performing the tests before amputation, and the participants' high level of physical discomfort and emotional distress, we were highly limited in the number of assessments we could perform. As such, we primarily focused on the functional neuroimaging tasks. However, in addition, we collected data on multiple questionnaires and had participants perform a functional ecological task.

Kinesthetic vividness. Kinesthetic vividness was quantified for each finger before and after the amputation (When moving this finger, how vivid does the movement feel? Please rate between 0 (I feel no finger movement) to 100 (I feel the finger movement as vividly as I can feel my other hand finger moving)).

Finger motor control. Perceived finger movement difficulty was quantified for each finger before and after amputation (When moving this finger, how difficult is it to perform the movement? Please rate between 100 (I found it as easy as moving the homologous finger in the unimpaired hand) to 0 (the most difficult thing imaginable)).

Pain ratings. Before and after amputation, case study participants were asked to rate the frequency of their pre-amputation limb pain or post-amputation phantom limb pain, respectively, as experienced in the last year, as well as the intensity of the worst pain experienced during the last week (or in a typical week involving pain; Extended Data Table 1). Chronic pain was calculated by dividing the worst pain intensity (scale 0–100; ranging from no pain to worst pain imaginable) by pain frequency (1, all the time; 2, daily; 3, weekly; 4, several times

per month; and 5, once or less per month). This approach reflects the chronic aspect of pain because it combines both frequency and intensity^{36,37}. A similar measure was obtained for painless phantom sensation vividness and stump pain. Participants also filled out the painDETECT questionnaire³⁸. Additionally, before and after amputation, participants reported intensity values for different words describing different aspects of pain, quantified using an adapted version of the McGill Pain Questionnaire³⁹. For each word, participants were asked to describe the intensity between 0 (nonexisting) to 100 (excruciating pain) as it related to each word. We used a larger response scale than standard to allow participants to articulate even small differences in their pain experience (Extended Data Fig. 1).

Functional index. Before and after amputation, case study participants were asked to rate their difficulty at performing a variety of functional activities because of their upper-limb problem, quantified using the Upper Extremity Functional Index⁴⁰.

Ecological task

To characterize habitual compensatory behavior, participants completed a task involving wrapping a present (based on ref. 41). Task performance was video-recorded but is not reported in this paper.

Finger movement task

To qualitatively capture how participants moved when cued to perform individual finger movements, at each session, we asked participants to perform a finger movement task where we cued them to move a single finger. Case study participants were cued to perform unilateral movements of the phantom fingers and intact fingers, and then mirrored the movements of the intact and phantom fingers simultaneously. Task performance was video-recorded and is shown in Supplementary Video 2.

Intact finger kinematic task

To test whether the intact fingers were being moved simultaneously during phantom finger movements, we invited two of the three case study participants back for a separate session to assess the kinematics of the intact fingers. The task setup and data are shown in Supplementary Fig. 4.

Scanning procedures

Each MRI session for the longitudinal cohort consisted of a structural scan, four fMRI finger-mapping scans and two body localizer scans, which we report in this article. The additional cross-sectional datasets are detailed in the Supplementary Methods.

fMRI task design

Finger-mapping scans. The fMRI design was the same as a previous study from our laboratory³⁵, although specific adaptations were made to account for the phantom experience of the case study participants who underwent an amputation (described below). Considering that S1 topography is similarly activated by both passive touch and active movement²⁴, participants were instructed to perform visually cued movements of individual fingers, bilateral toe curling, lips pursing or resting (13 conditions in total). This was performed using PsychoPy (v.2021.1.1). The different movement conditions and rest (fixation) cue were presented in 9-s blocks, each repeated four times in each scan. Additionally, each task started with 7 s of rest (fixation) and ended with 9 s of rest.

To simulate a phantom-like tactile experience for the participants before amputation, the affected hand was physically slightly elevated during scanning such that affected finger-tapping-like movements were performed in the air. Alternatively, for the unaffected hand (before and after amputation), the individual finger movements were performed as button presses on an MRI-compatible button box (four buttons per box) secured on the participant's thigh. The movement of

the thumb was performed by tapping it against the wall of the button box. For the Ctrl participants, half of the participants had the right hand elevated, performing the finger movements in the air, and the other half had the left hand elevated.

Instructions were delivered via a visual display projected into the scanner bore. Ten vertical bars, representing the fingers, flashed individually in green at a frequency of 1 Hz, instructing movements of a specific finger at that rate. Foot and lip movements were cued by flashing the words 'Feet' or 'Lips' at the same rate. Each condition was repeated four times in each run in a semi-counterbalanced order. Participants performed four scan runs of this task. One Ctrl participant was only able to complete three runs of the task for one of the sessions.

Imagery control scans. In each of the two body localizer scans, participants were visually cued to move each hand, imagine moving the affected (case study participants) or nondominant hand (Ctrls), in addition to actual lip, toe (on the affected side only) and arm (on the affected side only) movements. The different movement conditions and a rest (fixation) cue were presented in 10-s blocks and repeated four times in each scan.

MRI data acquisition

MRI images were obtained using a 3T Prisma scanner (Siemens) with a 32-channel head coil. Anatomical data were acquired using a T1-weighted magnetization prepared rapid acquisition gradient echo sequence with the following parameters: repetition time (TR) = 2.53 s, echo time (TE) = 3.34 ms, field of view (FOV) = 256 mm, flip angle = 7 degrees and voxel size = 1-mm isotropic resolution. Functional data based on the blood-oxygenation-level-dependent signal were acquired using a multiband gradient echo-planar T2*-weighted pulse sequence⁴² with the following parameters: TR = 1.5 s, TE = 35 ms, flip angle = 70 degrees, multiband acceleration factor = 4, FOV = 212 mm, matrix size of 106 × 106 and voxel size = 2-mm isotropic resolution. Seventy-two slices, with a slice thickness of 2 mm and no slice gap, were oriented parallel to the anterior commissure–posterior commissure, covering the whole cortex, with partial coverage of the cerebellum. Each of the four functional runs comprising the main task consisted of 335 volumes (8 min 22 s). Additionally, there were 204 volumes for the two imagery control scans (5 min 10 s). For all functional scans, the first dummy volume of every run was saved and later used as a reference for coregistration.

fMRI analysis

fMRI data processing was carried out using the FMRIB Expert Analysis Tool (FEAT v.6.0), part of FSL (the FMRIB Software Library, www.fmrib.ox.ac.uk/fsl), in combination with custom bash, Python (v.3) and MATLAB scripts (R2019b, v.9.7, MathWorks, including an RSA toolbox)^{43,44}. Cortical surface reconstructions were produced using FreeSurfer v.7.1.1 (refs. 45,46) and the Connectome Workbench (<https://humanconnectome.org/>) software. Decoding analyses were carried out using scikit-learn v.1.2.2.

fMRI preprocessing

The following prestatistical processing was applied: motion correction using MCFLIRT⁴⁷, non-brain removal using BET⁴⁸, spatial smoothing using a Gaussian kernel of full width at half maximum FWHM of 3 mm for the functional task data, grand-mean intensity normalization of the entire four-dimensional dataset by a single multiplicative factor and high-pass temporal filtering (Gaussian-weighted least-squares straight line fitting, with $\sigma = 90$ s). Time series statistical analysis was carried out using FILM with local autocorrelation correction⁴⁹. The time series model included trial onsets convolved with a double gamma hemodynamic response function; six motion parameters were added as confound regressors. Indicator functions were added to model out single volumes identified to have excessive motion (>0.9 mm).

A separate regressor was used for each high-motion volume (deviating more than 0.9 mm from the mean position). For the finger-mapping scans, the average number of outlier volumes for an individual scan, across all participants, was 1.5 volumes.

To ensure that all longitudinal sessions (Pre1, Pre2, 3 months, 6 months, 1.5/5 years) were well aligned for each participant, we calculated a structural mid-space between the structural images from each session, that is, the average space in which the images were minimally reoriented⁵⁰. The functional data for each individual scan run in a session were then registered to this structural mid-space using FLIRT^{47,51}.

Low-level task-based analysis

We applied a general linear model (GLM) using FEAT to each functional run. For the primary task, the movement of each finger or body part (ten fingers, lips and feet, total of 12 conditions) was modeled against rest (fixation). To capture finger selectivity, the activity for each finger was also modeled as a contrast against the average activity of all other fingers of the same hand.

We performed the same GLM analysis on the six conditions of the imagery scans. To capture the selectivity of actual attempted phantom movements versus imagine phantom hand movements, the activity of the attempted hand movement was also modeled as a contrast against the imagined hand movement.

For each participant, parameter estimates of each of the different conditions (versus rest) and GLM residuals of all voxels were extracted from each run's first-level analysis. All analyses were performed with the functional data aligned to the structural mid-space.

ROIs

S1: Brodmann area 3b. We were specifically interested in testing changes in topography within (and around) Brodmann area 3b (BA3b). First, the structural mid-space T1 image were used to reconstruct the pial and white-gray matter surfaces using FreeSurfer's recon-all. Surface coregistration across hemispheres and participants was conducted using spherical alignment. Participant surfaces were nonlinearly fitted to a template surface, first in terms of the sulcal depth map and then in terms of the local curvature, resulting in an overlap of the fundus of the central sulcus across participants⁵².

S1 (BA3b) hand ROI. The BA3b ROI was defined in the fsaverage template space using probabilistic cytoarchitectonic maps⁵² by selecting all surface nodes with at least 25% probability of being part of the gray matter of BA3b⁵³. Furthermore, for the multivoxel pattern analyses, we restricted the BA3b ROI to just the area roughly representing the hand. This was done by isolating all surface nodes 2.5 cm proximal or distal of the anatomical hand knob⁵⁴. An important consideration is that this ROI may not precisely reflect BA3b for each participant and may contain relevant activity from neighboring S1 areas because of the nature of our data (3T fMRI, smoothing full width at half maximum 3 mm) and the probabilistic nature of the atlas. As such, we considered this as a definitive localizer of S1 and an indicative localizer of BA3b. Surface ROIs were then mapped to the participant's volumetric high-resolution anatomy.

Forty-nine segments of the BA3b. To segment the BA3b into 49 segments, we loaded the fsaverage flattened cortical surface with the boundaries of the BA3b ROI, as defined by the Glasser atlas⁵⁵. We rotated the map so that the central sulcus was perpendicular to the axis. We overlayed a box with 49 segments of equal height on this ROI. By masking the box to the ROI, we constructed the 49 segments of the BA3b ROI. Because this masking approach requires drawing boundary lines using the vertices on the cortical flat map, we could optimally only get 49 segments (maximum) without issues with the boundary drawing approach. These ROIs were then mapped onto the participant's volumetric high-resolution anatomy and further to the participant's cortical surfaces.

M1: Brodmann area 4. The approach for defining the motor cortex ROI was the same as described above, with the sole exception of selecting the Brodmann area 4 region.

Projecting functional activity onto the cortical surface

Using the cortical surfaces generated using recon-all, fMRI maps were projected to the surface using the workbench command's volume-to-surface mapping function, which included a ribbon-constrained mapping method. The cross-sectional datasets were the only exception, where we projected all maps onto a standard cortical surface (Supplementary Methods).

Univariate activity

Contrast maps for moving versus imagine moving the phantom.

To visualize the contrast maps for attempted versus imagine phantom hand movements, estimates from the two imagery control scan runs for the participant's post-amputation (6-month) session were averaged in a voxelwise manner using a fixed-effects model with a cluster-forming z -threshold of 3.1 and family-wise error-corrected cluster significance threshold of $P < 0.05$. Maps were then projected onto each participant's cortical surface. These contrast maps are visualized in Fig. 1c with a minimum z -threshold in both directions of 3.1.

Contrast maps for the hand and lips. To visualize the contrast maps for the hand and lip movements, estimates from the four finger-mapping scan runs for each session were averaged in a voxelwise manner using a fixed-effects model with a cluster-forming z -threshold of 3.1 and family-wise error-corrected cluster significance threshold of $P < 0.05$. Maps were then projected onto the participant's cortical surface. These contrast maps (hand in red and lips in blue) are visualized in Fig. 1d with a minimum z -threshold of 33% the maximum participant-specific z -statistic.

For completion, the boundaries of the lip maps, for all participants who underwent an amputation across all sessions, are visualized in Fig. 3d. All maps were minimally thresholded at $z > 4.5$ to provide a complementary thresholding approach relative to Fig. 1d.

Hand topography across the 49 segments of the BA3b. Using the 49 segments of the BA3b (described above), we projected the neural activity for the hand (versus rest) for each hemisphere (contralateral to the hand being moved), session and participant. The average activity across all voxels in each segment was averaged to extract a single value per segment.

COG. To quantify changes in the hand, finger or lip topography, we computed the COG of activity (for a single body part) across the 49 BA3b segments. To do this, we first computed the weighted activity (β_w) across the segments. To do this each segment number was multiplied by the average activity in the segment:

$$\beta_w = (1 \times \beta_1) + (2 \times \beta_2) \dots$$

To compute the COG, we then divided the sum of the weighted activity ($\Sigma \beta_w$) by the sum of the activity ($\Sigma \beta$).

$$\text{COG} = \frac{\Sigma \beta_w}{\Sigma \beta}$$

When comparing changes in the COG for the hand or a finger, the COG for each post-session was subtracted from the average COG of the pre-sessions (for example, 3-month COG–pre. avg COG). A value greater than zero reflects the COG moving more medially in the post-session compared to the pre-session. A value less than zero reflects the post-session COG being more lateral compared to the pre-session COG.

Finger selectivity maps. To visualize the selectivity maps, estimates from the four finger-mapping scan runs for each session were averaged in a voxelwise manner using a fixed-effects model. When visualizing the clusters, we minimally thresholded each z -statistic at 33% the maximum z -statistic. We stacked the images such that the smallest cluster was the highest overlay (for example, the pinkie finger) and the largest cluster was the underlay. Finally, we applied a 70% opacity to the visualizations to capture multi-finger activity at each voxel.

Representative Ctrl participant body part maps. To provide an example visualization of the activity for each of the body parts shown in Fig. 3c, estimates from the four finger-mapping scan runs for each session were averaged in a voxelwise manner using a fixed-effects model, with a cluster-forming z -threshold of 3.1 and family-wise error-corrected cluster significance threshold of $P < 0.05$. We then visualized the z -statistic map for the contrast of lips > feet and all left fingers > feet on an inflated cortical surface and applied a threshold to each body part ($z > 3.1$).

Lip activity in the BA3b hand region. To test whether there was an increase in lip activity in the BA3b hand region, the average activity for all voxels (non-thresholded) in the ROI was computed for each session and each run. Activity was averaged across runs to compute a session estimate. When testing for a difference between the after and before amputation sessions, the activity for the two pre-amputation sessions was averaged for a pre-amputation average estimate. The activity in each post-amputation session (3 months, 6 months, 1.5/5 years) was then subtracted to the activity of the pre-amputation average.

Winner-takes-all analysis

As a qualitative demonstration of our findings been compatible with previous studies investigating cortical reorganization that used a winner-takes-all approach, we applied a winner-takes-all analysis to S1 functional activity of the case study participants who underwent an amputation. Using each participant's final post-amputation session data, we performed two variations of the analysis including the following conditions: (1) lips, hand and feet; or (2) lips and feet (excluding the hand). Each voxel was assigned exclusively to the condition with the highest activity. The resulting images were mapped to the participant's cortical surface and are visualized in Extended Data Fig. 9.

Multivoxel pattern analyses

We performed several multivoxel pattern analyses that can be broadly categorized into three themes: intra-finger; inter-finger; and inter-body part. In these measures, we were interested in capturing differences within a session and differences between sessions. For all these analyses, we only included voxels in the BA3b hand region.

Intra-finger. Pearson correlations. We first wanted to quantify changes in the pattern of activation for single fingers (intra-finger). We performed Pearson correlations on the beta weights for each finger using data from runs from different sessions (Fig. 2b and Extended Data Fig. 5). For between-session correlations, the beta weights (in our instance, contrast of parameter estimates) for each finger in the four scan runs were separated into partitions, each with two runs, and each set from different sessions. The activity in each two-run set was averaged at every voxel. A Pearson correlation was then performed between the averaged activity in each of the splits. We performed all unique two-run combinations between sessions (36 total combinations) and averaged these correlation coefficients to get a single value per finger. Between-session correlations were performed for all six unique session comparisons: Pre1 to Pre2, Pre1 to 3 months, Pre1 to 6 months, Pre2 to 3 months, Pre2 to 6 months and 3 months to 6 months. Additionally, for P1 and P2, correlations were performed for Pre1 to 1.5/5 years and Pre2 to 1.5/5 years. All correlation coefficients were then averaged and

plotted in Extended Data Fig. 5. For a simpler visualization, we plotted just the first combination for each participant's final scan relative to the pre-amputation average in Fig. 2b.

Inter-finger. We next wanted to quantify changes in the pattern of activation between finger pairs (inter-finger) using a decoding approach (Fig. 2d) and cross-validated Mahalanobis distances (Extended Data Fig. 6). Both approaches capture slightly different aspects of the representational structure⁵⁶, which we elaborate on below.

For these two analyses, the beta weights from the first-level GLM for each participant were extracted and spatially pre-whitened using a multivariate noise normalization procedure (as described in ref. 56). This was done for each scan using the residuals from the GLM. We then used these noise-normalized beta weights for the next analyses.

Decoding. First, we performed a decoding analysis. A strength of this approach is that it provides an estimate for chance performance (50%), that is, it is a classification accuracy significantly greater than chance. For the case study participants who underwent an amputation, the decoding approach can tell us whether a decoder trained on pre-amputated finger pairs can correctly decode the same information on a phantom hand.

We used a linear SVM classifier (scikit-learn v.1.2.2; sklearn.svm, LinearSVC) to quantify the between-session decoding for each finger pair. Default parameters were used for the classifier. Classification accuracy above chance (50%) denotes that there is some amount of shared information between the training and testing datasets.

We trained the classifier on the noise-normalized beta weights for each finger pair (ten in total). The training and testing splits were performed using data from different sessions, such that the classifier was trained on each unique two-run combination from one session and tested on all unique two-run combinations in a separate session (36 combinations for each finger pair). We performed the same classification approach in the reverse direction (72 combinations in total) because the forward and reverse directions provide unique values. The accuracies for each finger pair for each two-run combination for each training and testing direction were then averaged. Between-session accuracies are shown in Fig. 1d.

Cross-validated Mahalanobis distances. Because our decoding analysis was performed at ceiling (close to 100%), we also performed a RSA using cross-validated Mahalanobis distances. The strength of this approach is that it computes a distance measure (continuous) rather than a binary decoding measure. As such, it is arguably more sensitive for capturing the inter-finger representational structure. Larger distances reflect more dissimilar (distinct) activity patterns and smaller distances reflect more similar patterns.

We performed this analysis using data from different sessions to compute between-session distances (our desired measure for representational stability over time). A distance cross-validated between sessions captures the stability of the information content.

We calculated the squared cross-validated Mahalanobis distance between activity patterns as:

$$d^2(x_y, x_z) = (x_y - x_z)_A^T \Sigma^{-1} (x_y - x_z)_B$$

where $(x_y - x_z)_A$ corresponds to the difference between the activity patterns of conditions y (for example, thumb) and z (for example, index finger) in partition A, and Σ refers to the voxelwise noise covariance matrix. We performed this procedure over all possible two-run cross-validation folds and then averaged the resulting distances across folds. There were 36 unique cross-validation folds between sessions. Note that the cross-validated distance gives you the same distance value regardless of whether it is assigned partition A or partition B. Between-session distances are shown in Extended Data Fig. 6.

Typicality. To quantify a measure that represents the degree of ‘normality’ of the hand representation, we computed a representational typicality measure¹⁰. For each participant’s nondominant left hand, we extracted the ten crossnobis distances for the Pre-3 month and Pre-6 month comparisons. We then averaged these vectors across all able-bodied participants to get an average typical hand pattern. We then performed a Spearman rho correlation between the cross-validated Mahalanobis finger-pair distances for each participant’s affected or nondominant (left) hand and the average typical hand pattern. When comparing a Ctrl participant to the Ctrl mean, the respective participant was left out from the estimation of the Ctrl mean distances. These values are depicted in Extended Data Fig. 6.

Inter-body part. Finally, we wanted to quantify changes in the pattern of activation between the thumb, lips and feet in the S1 hand region. We computed the cross-validated Mahalanobis distances between these body parts in the same manner as the inter-finger analysis. The thumb to lips distances are plotted Fig. 3. The distances between all conditions are plotted in Extended Data Fig. 7.

Statistical analyses

All statistical analyses were performed either with Python scripts using `scipy.stats` and `statsmodels.stats.multitest` or JASP (v.0.17.2.1). Normality was ascertained using a Shapiro–Wilk test. For most of the analyses, to test whether a case study participant was significantly different from the Ctrl group, we used Crawford & Howell’s method, which provides a point estimate of the abnormality of the distance of each case from a Ctrl sample⁵⁷. For all Crawford tests, we report uncorrected, two-tailed *P* values. When comparing estimates to zero or chance decoding (50%), we used a two-tailed, one-sample *t*-test. When testing for a decrease in measures within-participant, we used a Wilcoxon signed-rank test. When further testing for differences between hands within-participant, we performed a Wilcoxon signed-rank test on the classification accuracy values and a paired samples *t*-test on the Mahalanobis distances. The resulting *P* values were *z*-transformed and are plotted in Supplementary Fig. 1. Additionally for the correlation analyses, Pearson correlations were used for the intra-finger multivoxel pattern analysis and Spearman correlations were used for the typicality analysis.

Across all our previous studies, we operationally defined amputees’ intact hand as their de facto dominant hand, and as such have always compared the nondominant hand of Ctrl to the missing hand of amputees (for example, see refs. 9,14,37,41,58–60). Therefore, across all case study to Ctrl comparison analyses, we statistically compared (and plotted) the left (nondominant) hand side of Ctrl to the case study participants missing hand side.

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

Data for the primary results have been made publicly available (<https://osf.io/s9hc2/>).

Code availability

The code for the primary results has been made publicly available (<https://github.com/hunterschone/longitudinal-amputation>).

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Author contributions

H.R.S. designed the research, collected the data, analyzed all the datasets and wrote the manuscript. T.R.M. and C.I.B. designed the research, supervised the analyses and edited the manuscript. M.K. helped collect the data, preprocessed the cross-sectional datasets and edited the manuscript. M.A.S. helped with collecting the data and edited the manuscript. R.O.M.M. designed the research, collected the data, supervised the analyses and edited the manuscript. C.G., A.W. and N.V.K. were involved in recruitment and editing the manuscript.

Competing interests

The authors declare no competing interests.

Additional information

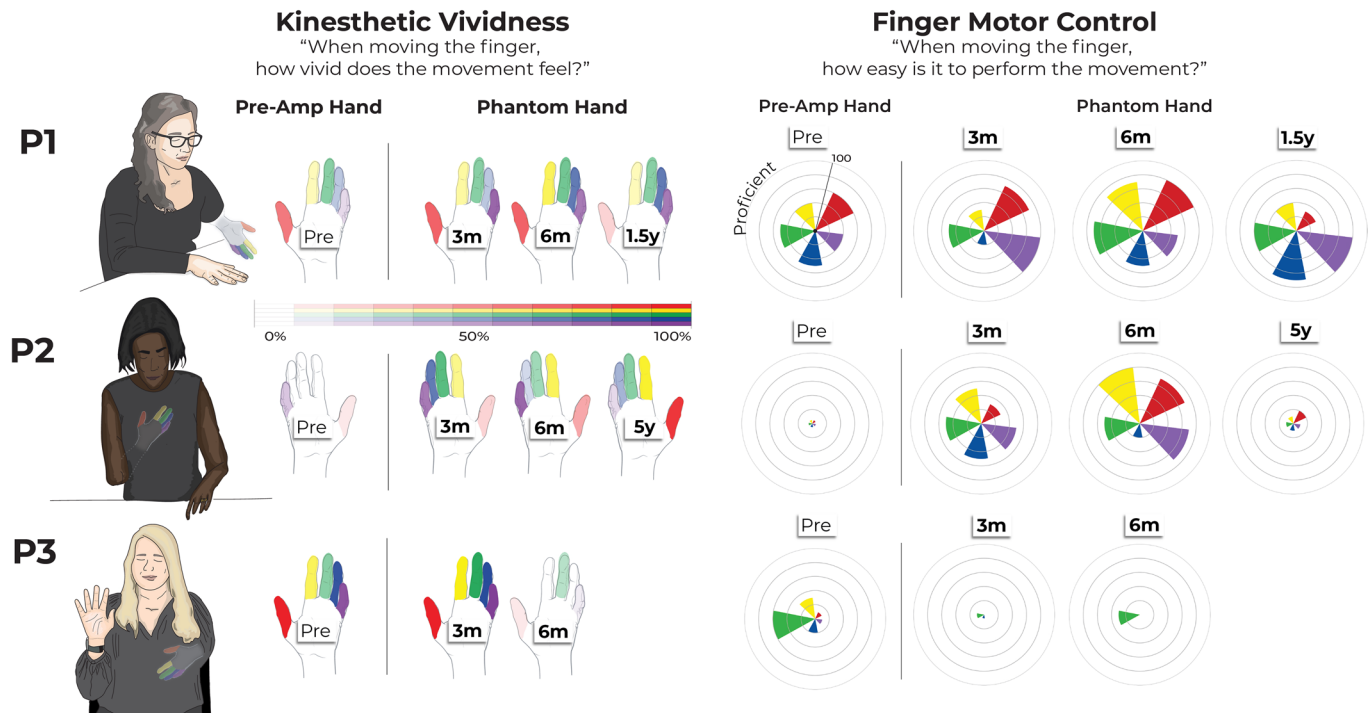
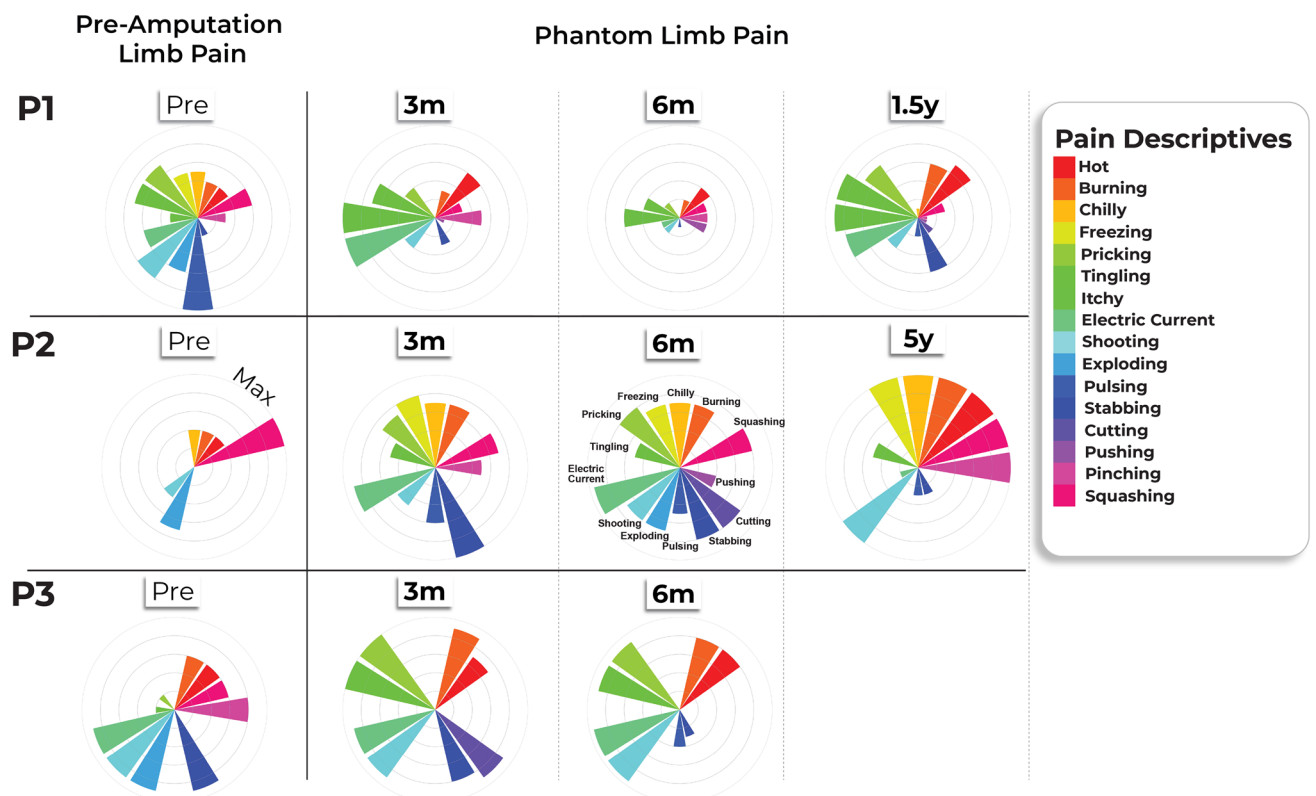
Extended data is available for this paper at <https://doi.org/10.1038/s41593-025-02037-7>.

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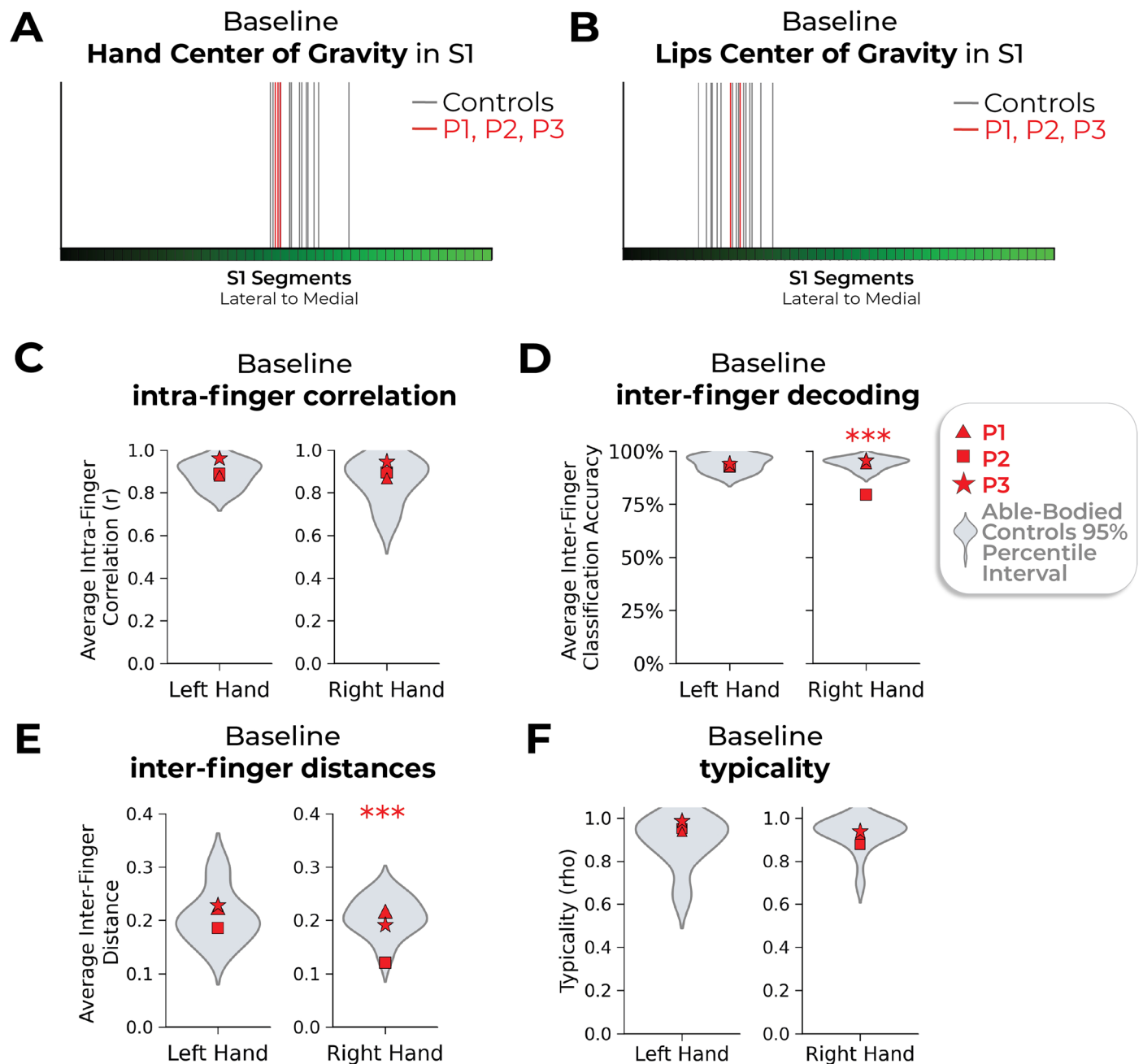
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A**Subjective feeling of fingers before and after amputation****B****Descriptives of limb pain before and after amputation**

Extended Data Fig. 1 | See next page for caption.

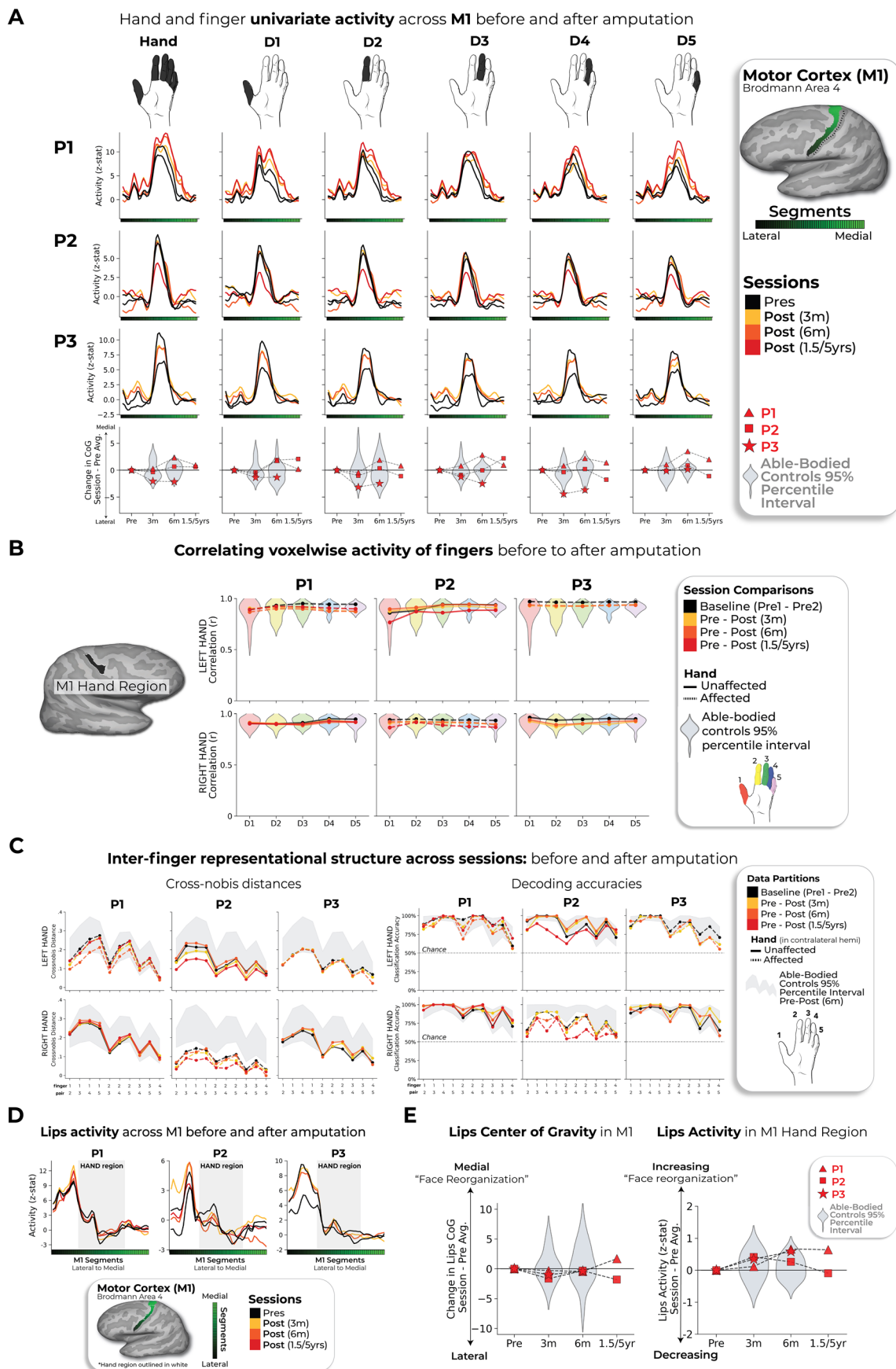
Extended Data Fig. 1 | Longitudinal characterization of finger sensations and limb pain. (a) Affected hand sensations before and after amputation. Finger vividness and motor control for the phantom fingers, relative to the pre-amputated fingers. Kinesthetic vividness rated on a scale from 0 (no sensation) to 100 (as vivid as the unaffected hand) with color intensity indicating level. Movement difficulty rated from 100 (as easy as the unimpaired hand) to 0 (extremely difficult). Finger colors: red=D1, yellow=D2, green=D3, blue=D4,

purple=D5 (palm excluded). **(b)** Before and after amputation, participants reported intensity values for each pain descriptive word, broadly categorized into sensations that are mechanical, temperature-related and other. For each word, participants were asked to describe the intensity between 0 (non-existing) to 100 (excruciating pain) as it relates to that particular word. A value of 100 (Max) is the largest radii on the polar plot. 3 M=3months post-amputation; 6 M=6months post-amputation. 1.5/5 yrs=1.5 or 5 years post-amputation.



Extended Data Fig. 2 | Baseline measures for the case-study participants that underwent an amputation versus able-bodied controls. Across all panels, we only report statistics when significant. Case-study participants showed similar responses to able-bodied controls in the baseline (pre-amputation) S1 center of gravity for the (a) hand and (b) lips. (c) All case-study participants had similar average intra-finger correlations between the two pre-sessions as controls.

For baseline average inter-finger (d) classification accuracy and (e) distances. One case-study participant exhibited lower values for their affected hand only, relative to controls [Crawford t-test: decoding and distances: P2: $p < 0.001$] (f) All case-study participants had similar hand typicality between the two pre-sessions as controls. All other annotations the same as described in Figs. 2 and 3.

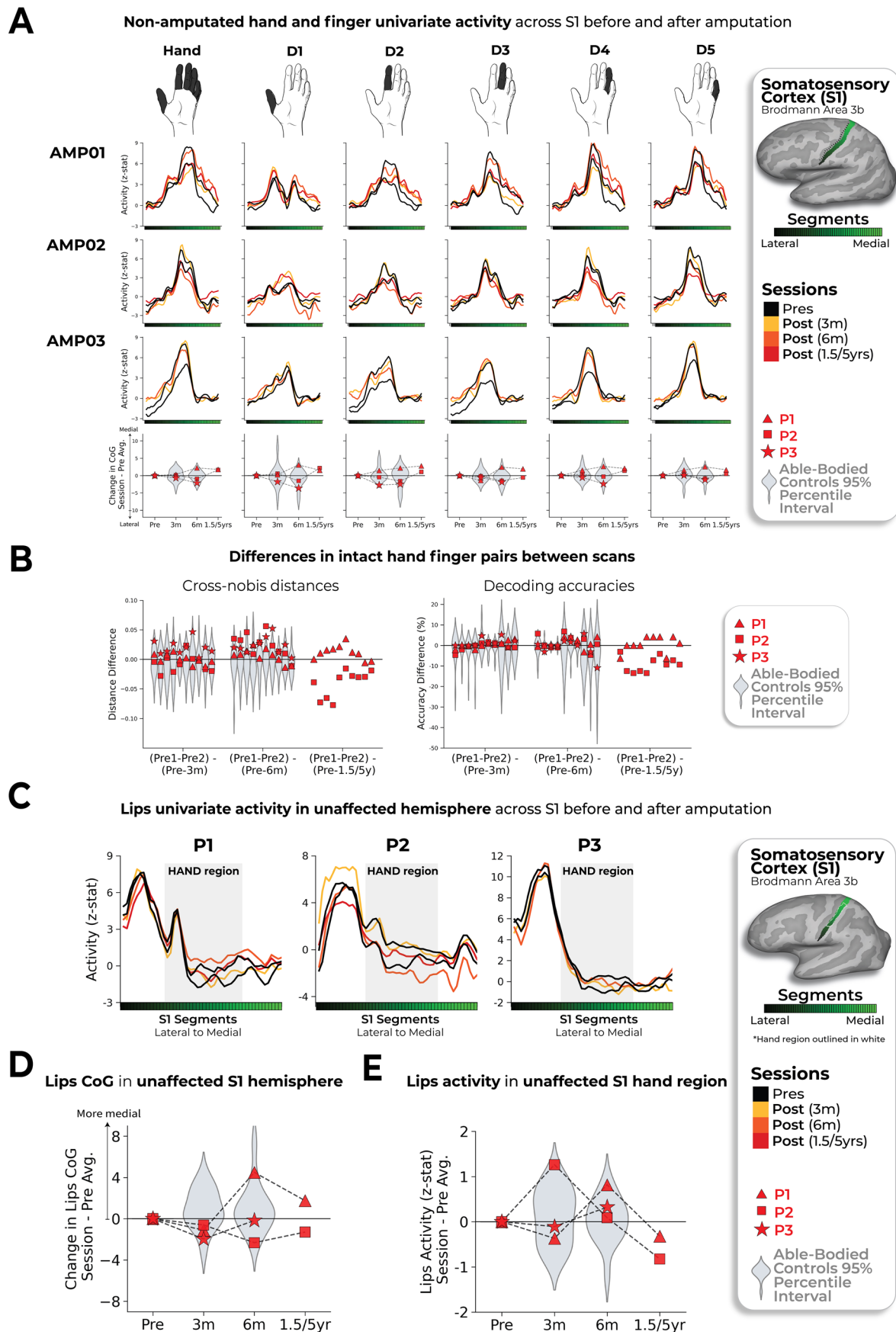


Extended Data Fig. 3 | See next page for caption.

Extended Data Fig. 3 | Replication of all primary results within motor cortex.

(a) Hand and finger univariate activity across M1 before and after amputation. When testing the stability of the whole hand condition across sessions, all case-studies fell within the distribution of controls at all timepoints. (b) When correlating voxel wise finger activity across sessions, all case-studies exhibiting similar correlation coefficients as controls, for all fingers. Please refer to the Extended Data Fig. 5 caption for a more detailed understanding of the correlation analysis. (c) Inter-finger representational structure across sessions, measured using cross-nobis distances (left) and decoding accuracies (right). First, when assessing for atypicality in our case-studies pre-amputation compared to controls, only case-study P2 exhibited reduced average finger selectivity pre-amputation based on the RSA (Crawford t-test: $t(15) = -3.15$, $p = 0.007$) and decoding ($t(15) = -3.9$, $p = 0.001$; similar to what was observed in S1). Next, when

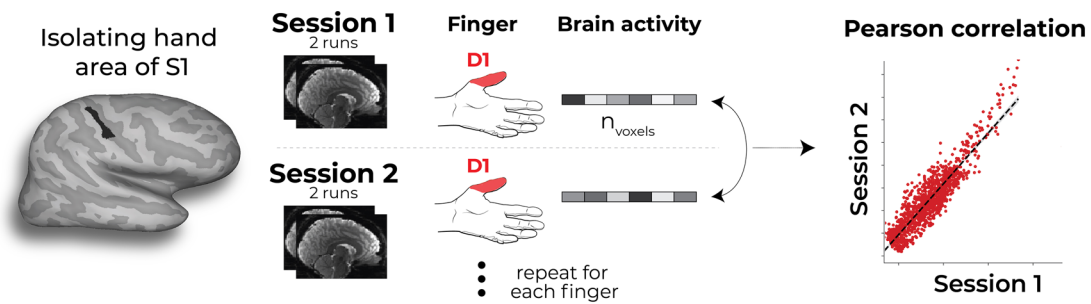
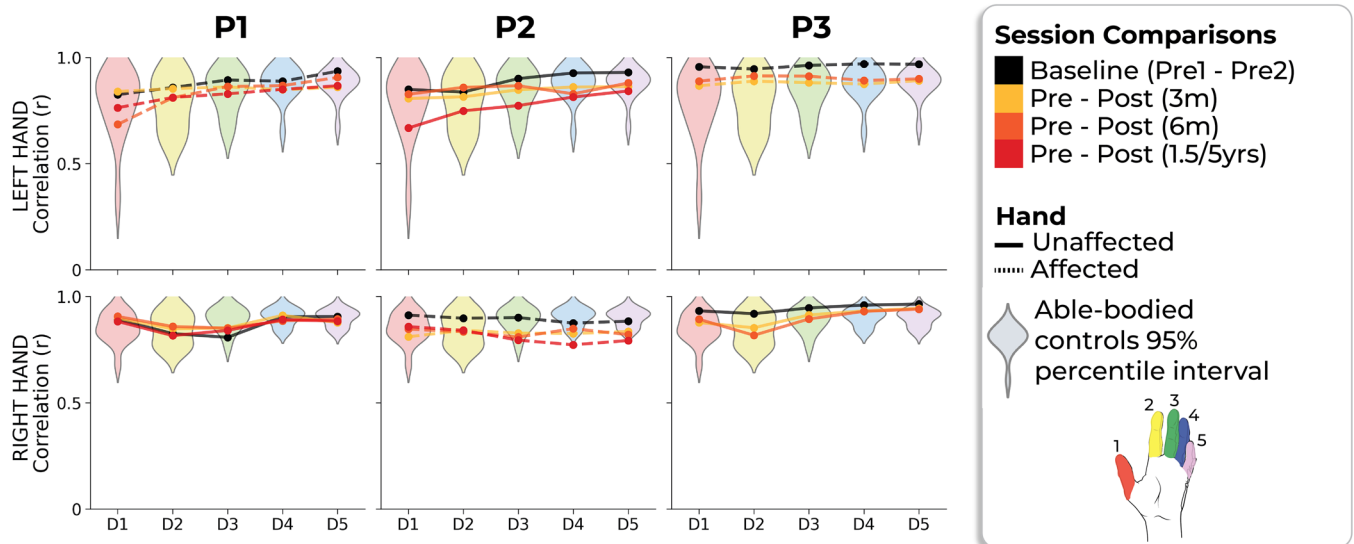
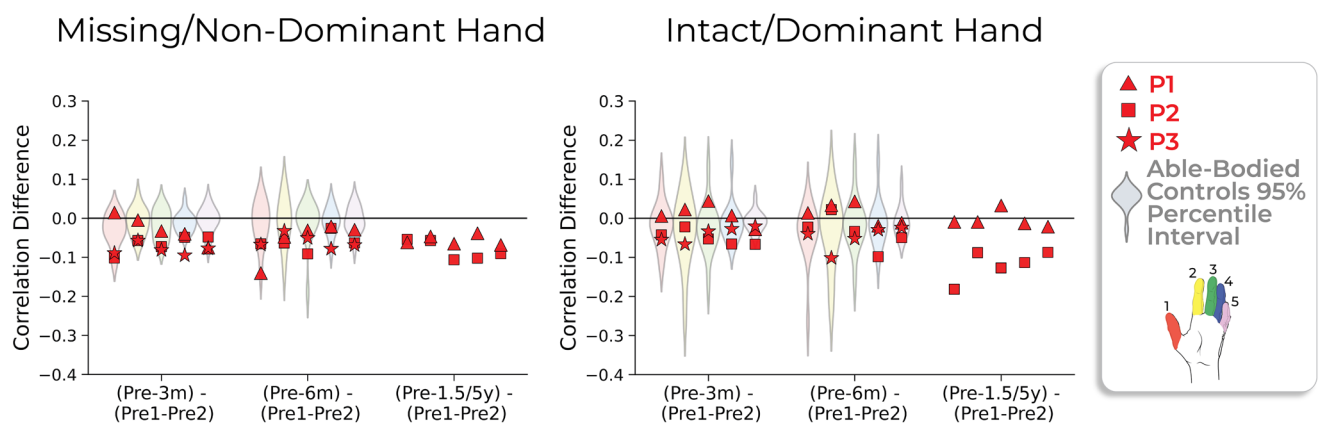
testing for reductions in average finger selectivity at the 6-month timepoint, relative to baseline, only case-study P1 exhibited a significant reduction compared to controls [cross-nobis distances: 3 comparisons; $t(15) = 2.33$; $p_{\text{uncorr}} = 0.02$; decoding: 3 comparisons; $t(15) = 2.32$; $p_{\text{uncorr}} = 0.03$]. However, it returned to the typical range when later assessed at the 1.5 year timepoint (for both measures). We also noted that case-study P3 showed a significant reduction at the 6-month timepoint, relative to controls, in the decoding (3 comparisons; $t(15) = 2.18$, $p_{\text{uncorr}} = 0.046$), but not the cross-nobis. (d) Lips univariate activity plotted across M1 before and after amputation. (e) All case studies showed typical session to session variability as controls in (left side) the lips center of gravity across M1 and (right side) lips activity in the M1 hand region. All annotations are the same as described in the captions of the Figs. 2–3 and Extended Data Fig. 5. Across all panels, we only report statistics when significant.



Extended Data Fig. 4 | See next page for caption.

Extended Data Fig. 4 | Stability of the intact (non-amputated) hand and lip topography in the non-affected hemisphere across amputation. (a) Intact hand and finger univariate activity across S1 before and after amputation. When testing the stability of the whole hand condition across sessions, all case-studies fell within the distribution of controls at all timepoints. (b) Unaffected (intact) hand between-session differences in inter-finger values. Difference values are depicted for the (left) cross-validated distances and (right) decoding accuracies. Classification/distance differences before and after amputation are visualized for each finger pair [Pre1-Pre2] minus [Pre Avg. – Post1 (3 m)] minus, [Pre1-Pre2] minus [Pre Avg. – Post2 (6 m)] and [Pre1-Pre2] minus [Pre Avg. – Post3 (1.55/y)]. Each violin plot reflects an individual finger pair (same order of finger-pairs as detailed in Fig. 2d). For consistency, the control values are all for the left-hand. When computing the session-to-session differences relative to controls, all

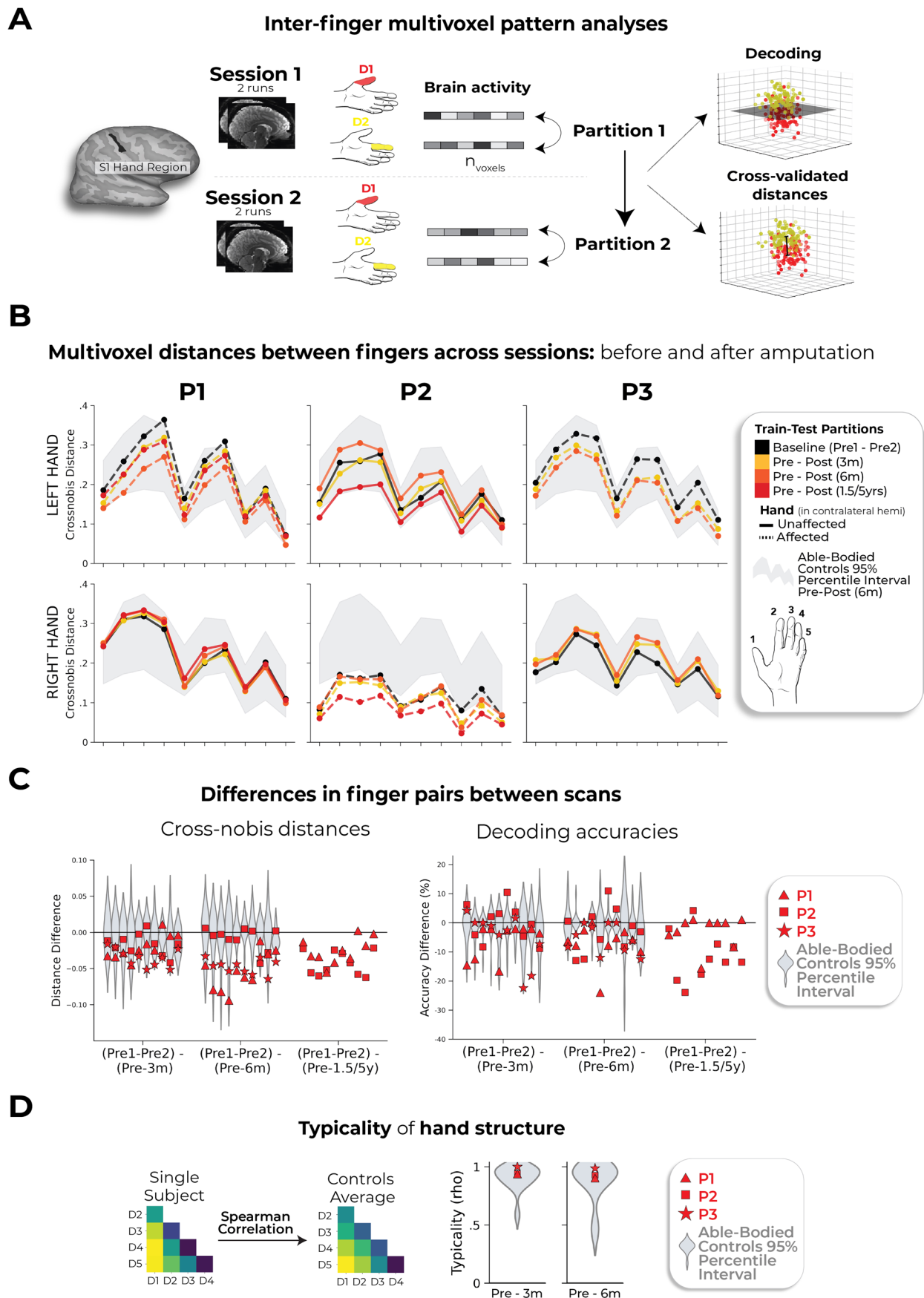
case-study participants showed typical session-to-session variability in finger selectivity at the 6-month timepoint, relative to controls. (c) Longitudinal lips univariate in the unaffected hemisphere (contralateral to intact hand) across S1 before and after amputation. (d) All case study participants showed typical changes in the lips center of gravity (CoG) in the unaffected S1 hemisphere across scans, relative to controls. (e) When testing for changes in lip activity (in the unaffected hand region), one case-study, P1, exhibited a significant atypical increase in lip activity relative to controls at the 6-month timepoint (Crawford t-test: $t(15) = 2.75$, $p_{uncorr} = 0.01$). However, the activity returned into the distribution of controls when tested at the 1.5 year timepoint ($t(15) = 0$, $p_{uncorr} = 0.99$). All other annotations are the same as described in Figs. 2 and 3. We only report statistics when significant.

A**Correlating voxelwise activity of fingers before to after amputation****B****Finger correlation coefficients****C****Changes in correlation coefficients across sessions**

Extended Data Fig. 5 | See next page for caption.

Extended Data Fig. 5 | Correlating pre- to post-amputation multivoxel finger activity patterns. (a) Visualization depicting the inter-session Pearson correlations of individual fingers within the BA3b hand region. (b) Inter-session correlations for the left (top row) and right hands (bottom) in the contralateral hand ROI. Line colors indicate session pairings (indicated in the legend). For case-study participants, dashed line denotes the affected hand; solid line unaffected hand. Violin plots reflect able-bodied control's Pre – Post (6 m) values. (c) Between-session differences in finger correlation coefficients. Difference values are depicted for the (left) missing or non-dominant hand of controls and (right) intact or dominant hand of controls. The difference values are ordered to reflect the increasing gap between sessions: [Pre1-Pre2] minus [Pre Avg. – Post1

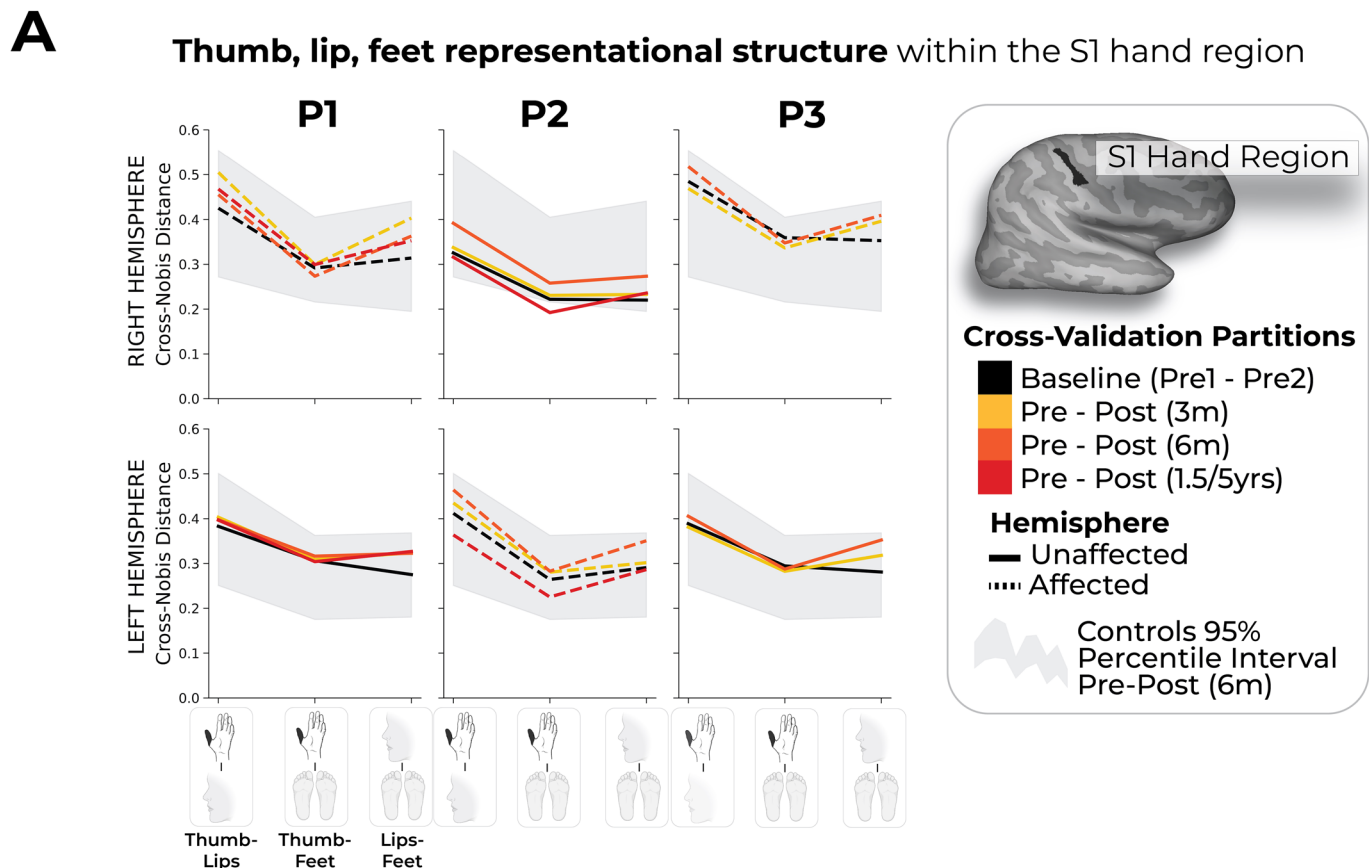
(3 m)] minus, [Pre1-Pre2] minus [Pre Avg. – Post2 (6 m)] and [Pre1-Pre2] minus [Pre Avg. – Post3 (1.55/y)]. Each violin plot reflects an individual finger. When testing whether the case-study participants showed a unique reduction in the average correlation, across fingers, relative to controls, for the missing hand, only P3, at the 3-month timepoint, for the missing hand (not intact), showed a significant pre-post reduction in the average correlation coefficient, relative to controls ($t(15) = -2.59$, $p_{\text{uncorr}} = 0.02$). However, this difference returned to the typical range of controls when later tested at the 6-month timepoint ($t(15) = -1.23$, $p_{\text{uncorr}} = 0.23$). All other annotations are as in Fig. 2. We only report statistics when significant.



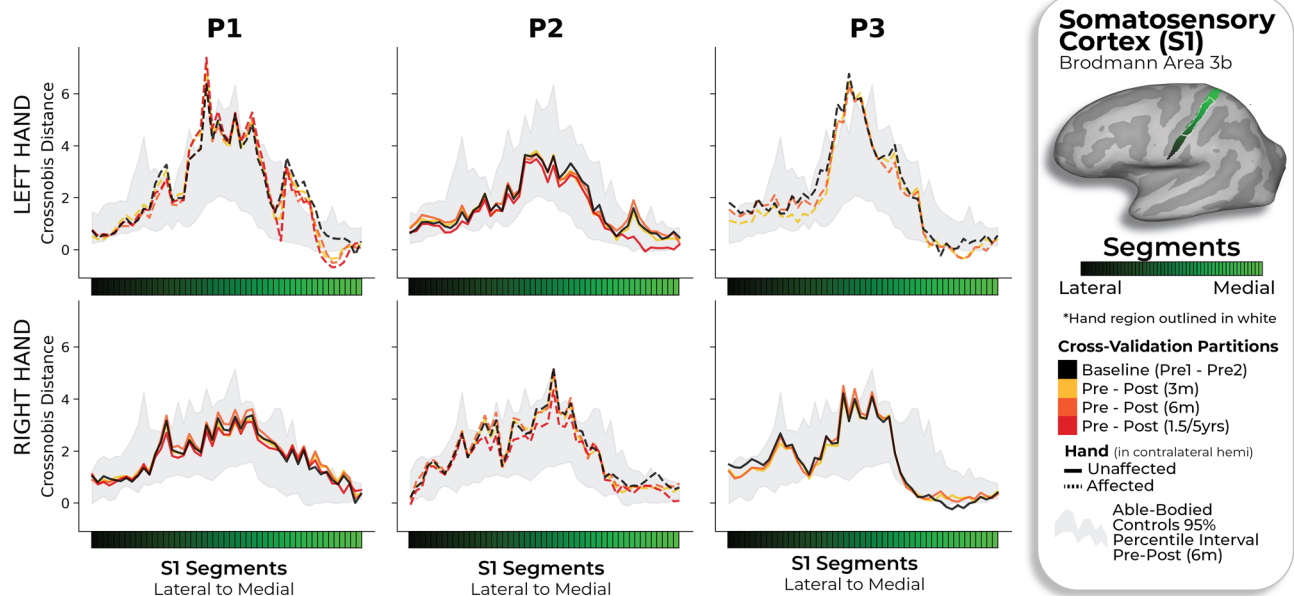
Extended Data Fig. 6 | See next page for caption.

Extended Data Fig. 6 | Representational similarity analysis of inter-finger representational structure. (a) Graphic illustration of multivoxel pattern analyses. (b) Inter-finger multivariate analysis using cross-validated Mahalanobis (cross-nobis) distances. Line colors denote train-test/cross validation session pairs, respectively as indicated in the legend. The gray shaded area reflects able-bodied control's Pre – Post (6 m) data (95% percentile interval). (c) Classification/distance differences before and after amputation are visualized for each finger pair [Pre1-Pre2] minus [Pre Avg. – Post1 (3 m)] minus, [Pre1-Pre2] minus [Pre Avg. – Post2 (6 m)] and [Pre1-Pre2] minus [Pre Avg. – Post3 (1.55/y)]. Each violin plot reflects an individual finger pair (same order of finger-pairs as detailed in b). When comparing differences relative to controls, we observed some temporary, idiosyncratic reductions in average finger selectivity, relative to controls. First for the cross-nobis results, P1 showed a temporary reduction in average finger

selectivity at 6 months (3 comparisons; $t(15) = -2.79$, $p_{\text{uncorr}} = 0.01$), though later offset to the typical range at their follow-up 1.5-year scan. P2 only exhibited reduced selectivity only at the 5-year timepoint, though reduction seen in the intact hand as well (Extended Data Fig. 4). Finally, P3 exhibited reduced selectivity at 6 months relative to controls (2 comparisons; $t(15) = -2.36$, $p_{\text{uncorr}} = 0.03$). For the decoding results, P2 seemed to show significantly reduced selectivity at the 5-year timepoint, though also reduced for the intact hand (Extended Data Fig. 4). (d) The representational typicality of the hand structure was estimated by correlating each session's cross-validated Mahalanobis distances for each participant to a canonical inter-finger structure (controls average). All case-study participant's typicality values fell within the distribution of controls. All other annotations are as in Fig. 2. We only report statistics when significant.



B **Hand-lips multivoxel distance at every S1 segment cross-validated across sessions**



Extended Data Fig. 7 | Thumb, lip and feet distances within the S1 hand region.

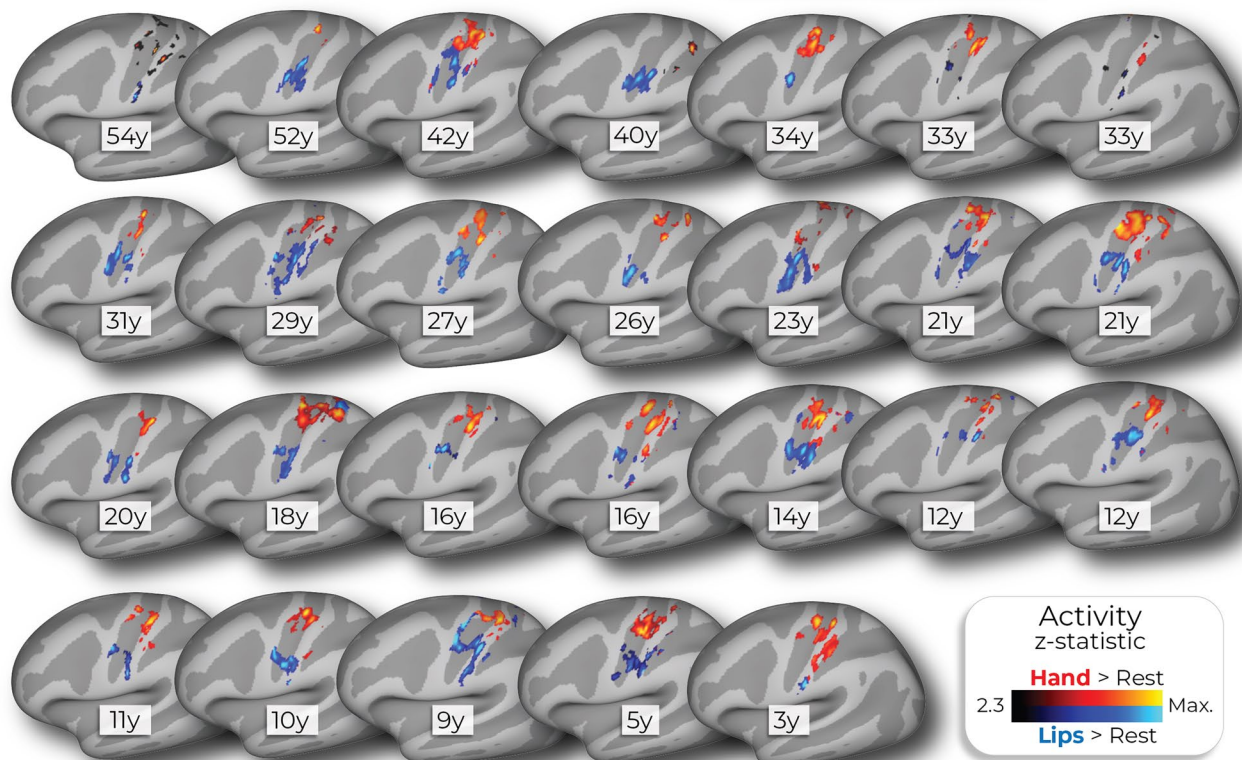
(a) Multivariate distances between the thumb, lip and feet cross-validated across sessions depicted for the right (top row) and left hemisphere (bottom) of the case-study participants that underwent an amputation and controls, contralateral to the thumb side being moved. Distances appear in the following order: (1) thumb-lips, (2) thumb-feet, (3) lips-feet. Line colors indicate session pairings (indicated in the legend). For case-study participants, dashed line denotes the

affected hemisphere; solid line unaffected hemisphere. Grey shaded area reflect able-bodied control's Pre - Post (6 m) values. For the affected hemisphere of the case-study participants, all distances fell within the typical range of the able-bodied controls. (b) We also tested whether changes occurred in the multivariate hand-lip distance when performed within each of the 49 S1 segments/ All case-study participants showed similar distances across sessions, before and after amputation. All other annotations are the same as described in Fig. 2.

Cross-sectional datasets

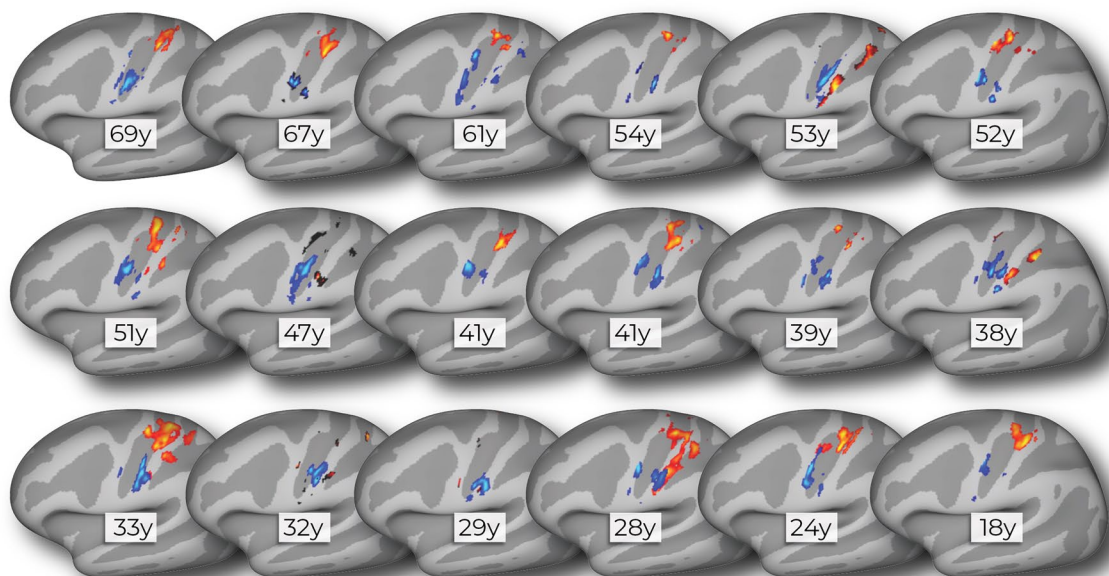
Phantom hand and lip cortical maps of chronic amputees (n=26)

Affected hand hemisphere | Ranked by "Years since amputation"



Non-dominant hand and lip cortical maps of able-bodied controls (n=18)

Hemisphere contralateral to non-dominant hand | Ranked by "Age"



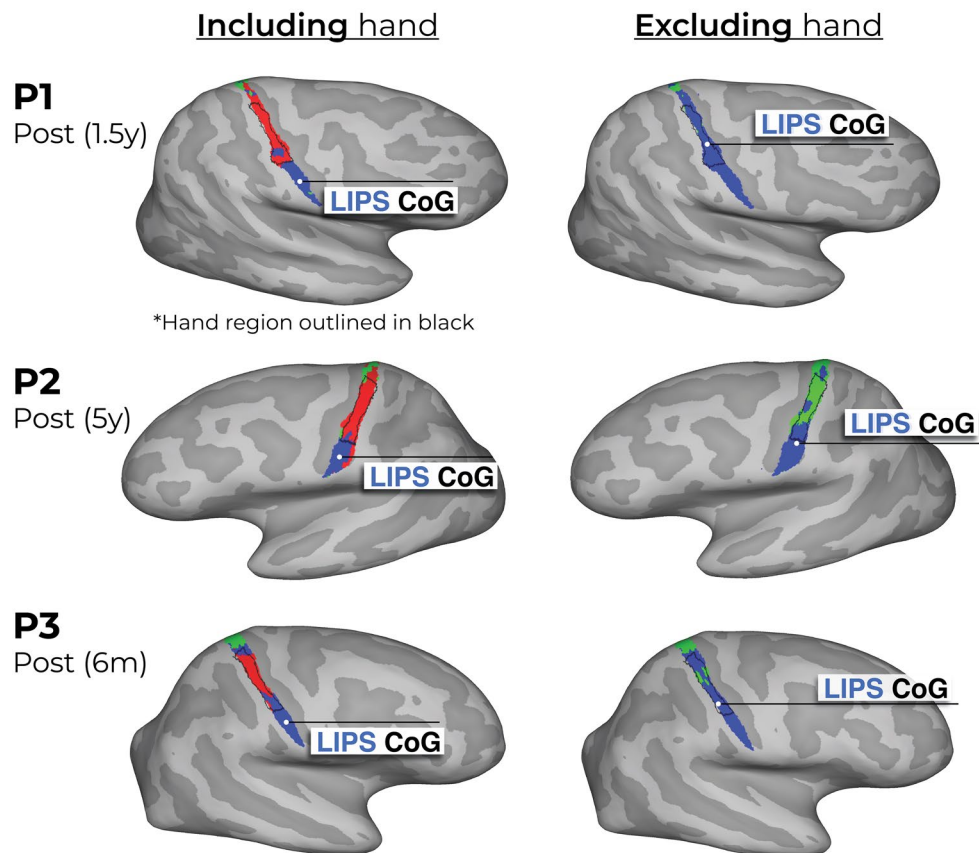
Extended Data Fig. 8 | See next page for caption.

Extended Data Fig. 8 | Hand and lip cortical maps of cross-sectional datasets.

Participant hand and lip cortical maps – registered to a standard cortical surface – are visualized for the chronic amputee participants (top row; $n = 26$) and secondary able-bodied control participants who underwent the same procedures as the chronic amputees ($n = 18$; bottom row). Hand maps for the amputees reflect moving their phantom hand, while for controls reflect moving

their non-dominant hand (in the contralateral hemisphere). All maps are contrasted against rest, minimally thresholded at 50% the maximum z -statistic and masked to Brodmann regions: 1, 2, 3a, 3b, and 4. Amputee maps are ranked by the numbers of years since amputation at the time of the scan and control maps are ranked by the participants age at the time of the scan.

Winner-takes-all analysis of the major body-parts across S1



Extended Data Fig. 9 | Winner-takes-all analysis of the major body parts (hand, lips and feet) across S1. Using the data from the last session of each participant, each voxel was awarded to the body-part with the highest response. Left column – we show the winner-takes-all analysis when performed on 3 body-parts: hand (red), lips (blue) and feet (green) versus (Right column) when excluding the physically absent hand. This comparison reveals supposed large-scale expansions of the lips or feet into the deprived hand region (black outline) post-amputation. We've also depicted the center of gravity (CoG) of the winner-takes-all lip cluster (white circles) to further demonstrate this. When excluding the

hand activity, the CoG of the lips 'shifts' towards the hand area. Thus, ignoring the primary body part – depending on your analysis choices – can substantially bias the results^{61,62}. Combined with the use of cross-sectional designs, this analysis approach has led to the impression of cortical remapping and even large-scale reorganization of the lip representation following amputation. Crucially, the newly assigned winner in the hand area [left panel] has rarely been directly compared against the persistent representation of the missing hand, and indeed, indicative evidence show that this recorded activity in the hand area is weak (we extensively discuss this in our recent review ref. 17).

Extended Data Table 1 | Demographics of the case study participants who underwent an amputation

	P1	P2	P3
Sex	Female	Female	Female
Age (at first scan)	26	57	49
Handedness at birth	Left-handed	Right-handed	Right-handed
Cause of amputation	Arteriovenous vascular malformation (AVM)	Sarcoma tumour	Severell-Martorell syndrome led to multi-fractured arm with bones not healing
Disability duration	AVM progressed over a few years	Tumour slowly developing since 1995	Musculoskeletal issues since childhood
Amputated limb	Left upper limb	Right upper limb	Left upper limb
Level of amputation	Transhumeral	At elbow	Transhumeral
Amputation surgery	Combination of targeted muscle reinnervation and regenerative peripheral nerve interfaces, see Supplementary Figure 2 .	Traditional: sharply transected the nerves and allowed to retract	Traditional: sharply transected the nerves and allowed to retract
Phantom position and mobility	Phantom hand positioned slightly above the elbow; only feels the hand, not the forearm; can move all phantom fingers (Figure 1B).	Phantom hand positioned upright towards chest; only feels the hand, not the forearm; can move all phantom fingers (Figure 1B).	Phantom hand positioned upright towards chest; mostly hand and fingers (little elbow); can move all phantom fingers (Figure 1B).
When did phantom sensations occur	Immediately after amputation	Immediately after amputation	Immediately after amputation
Phantom limb sensation (PLS) intensity (100 max) (3m, 6m, 1.5/5yrs respectively)	40, 60, 40	90, 100, 100	100, 90, NA
PLS frequency (3m, 6m, 1.5/5yrs)	3m: once a week; 6m: several times per month; 1.5yr: once or less per month	3m: all the time; 6m: all the time; 5yrs: all the time	3m: all the time; 6m: daily
Chronic PLS (100 max) (3m, 6m, 1.5/5yrs)	13.3, 15, 8	90, 100, 100	100, 45, NA
Limb pain intensity (Pre, 3m, 6m, 1.5/5yrs)	90, 20, 0, 0	80, 50, 70, 70	50, 80, 70, NA
Limb pain frequency (Pre, 3m, 6m, 1.5/5yrs)	Pre: all the time; 3m: several times per month; 6m: once or less per month; 1.5yr: once or less per month	Pre: all the time; 3m: daily; 6m: daily; 5yrs: all the time	Pre: daily; 3m: daily; 6m: once a week
Chronic limb pain (Pre, 3m, 6m, 1.5/5yrs)	90, 5, 0, 0	80, 25, 35, 70	25, 40, 23.3, NA
Transient (on the day) limb pain (Pre, 3m, 6m, 1.5/5yrs; 100 max) (Pre, 3m, 6m, 1.5/5yrs)	50, 30, 0, 0	80, 45, 50, 70	50, 40, 20, NA
Pain Detect Score (% max possible score) (Pre, 3m, 6m, 1.5/5yrs)	51%, 34%, 14%, 40%	68%, NA, 42%, 45%	65%, 65%, 65%, NA
Pain Detect Pain Course	- Persistent pain with pain attacks (Same pre and 3m) - Persistent pain with slight fluctuations (6m, 1.5yrs)	- Persistent pain with pain attacks (Same pre and 6m) - Persistent pain with slight fluctuations (5yrs)	- Pain attacks with pain between them (pre) - Persistent pain with pain attacks (3m) - Pain attacks without pain between them (6m)
Upper Extremity Functional Index (Pre, 3m, 6m, 1.5/5yrs) 100% = no impairment	47%, 23%, 36%, 57%	30%, NA, 11%, 28%	0%, 39%, 69%, NA
Prosthesis Type	None	None (fitted with a cosmetic prosthetic)	Cosmetic prosthesis
Prosthesis Use	None	None. Briefly used in the first 6 months post-amputation (2 days a week, ~2 hours a day)	6m: 2 days a week, 8 hours a day

PLS = phantom limb sensation; Limb pain reflects pre-amputation limb pain or post-amputation phantom limb pain. Frequency scores: 1 – all the time, 2 – daily, 3 – weekly, 4 – several times per month, and 5 – once or less per month. Chronic pain/sensation values were calculated by dividing intensity by frequency. NA = not available/applicable. Upper extremity functional index measures participant difficulty with performing activities due to their missing limb.

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- | | | |
|--------------------------|-------------------------------------|--|
| ☐ | ☒ | The exact sample size (n) for each experimental group/condition, given as a discrete number and unit of measurement |
| ☐ | ☒ | A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly |
| ☐ | ☒ | The statistical test(s) used AND whether they are one- or two-sided
<i>Only common tests should be described solely by name; describe more complex techniques in the Methods section.</i> |
| ☐ | ☒ | A description of all covariates tested |
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| ☐ | ☒ | For null hypothesis testing, the test statistic (e.g. F , t , r) with confidence intervals, effect sizes, degrees of freedom and P value noted
<i>Give P values as exact values whenever suitable.</i> |
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| ☐ | ☒ | For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes |
| ☐ | ☒ | Estimates of effect sizes (e.g. Cohen's d , Pearson's r), indicating how they were calculated |

Our web collection on [statistics for biologists](#) contains articles on many of the points above.

Software and code

Policy information about [availability of computer code](#)

Data collection Presentation software included PsychoPy (v2021.1.1).

Data analysis Imaging software included FMRIB'S FEAT (v6), part of FSL, and Freesurfer (v7.1.1). All statistical analyses were performed using JASP (v0.17.21). All data was analyzed using custom Python (version 3) scripts. Code used in the study can be accessed at <https://github.com/hunterschone/longitudinal-amputation>.

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Data for the primary results and supplementary methods have been made publicly available (<https://osf.io/s9hc2/>).

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Reporting on sex and gender

The participants who underwent planned hand amputations included 3 volunteers: P1 [female; age = 26; lefthanded; left transhumeral amputation], P2 [female; age = 57; left-handed; right at elbow amputation], P3 [female; age = 49; right-handed; left transhumeral amputation], were recruited through the National Health Service. The longitudinal able-bodied control group included 16 able-bodied volunteers [9 females; mean age $\pm$ std = 53.1 $\pm$ 6.37; all right-handed]. The chronic amputee group included 26 upper-limb amputee volunteers [4 females; mean age $\pm$ std = 51.1 $\pm$ 10.6; 13 missing left upper-limb; level of amputation: 17 transradial, 8 transhumeral and 1 at wrist; mean years since amputation $\pm$ std = 23.5 $\pm$ 13.5], which were recruited through the NHS. The secondary able-bodied control group included 18 able-bodied volunteers [7 females; mean age $\pm$ std = 43.1 $\pm$ 14.62; 11 right-handed]. Information on sex was self-reported by the volunteers. All able-bodied participants were recruited through University College London and the London metro area.

Reporting on race, ethnicity, or other socially relevant groupings

Not applicable

Population characteristics

See above.

Recruitment

All amputee participants were recruited via NHS participant identification centres. There were no self-selection biases that would impact our results. All able-bodied participants were recruited through University College London and the London metro area.

Ethics oversight

The study and its experimental procedures were approved by the NHS National Research Ethics Committee (18/LO/0474).

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

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Study description

Quantitative experimental

Research sample

"The participants who underwent planned hand amputations included 3 volunteers: P1 [female; age = 26; left-handed; left transhumeral amputation], P2 [female; age = 57; left-handed; right at elbow amputation], P3 [female; age = 49; right-handed; left transhumeral amputation], were recruited through the National Health Service. The longitudinal able-bodied control group included 16 able-bodied volunteers [9 females; mean age $\pm$ std = 53.1 $\pm$ 6.37; all right-handed]. The chronic amputee group included 26 upper-limb amputee volunteers [4 females; mean age $\pm$ std = 51.1 $\pm$ 10.6; 13 missing left upper-limb; level of amputation: 17 transradial, 8 transhumeral and 1 at wrist; mean years since amputation $\pm$ std = 23.5 $\pm$ 13.5], which were recruited through the NHS. The secondary able-bodied control group included 18 able-bodied volunteers [7 females; mean age $\pm$ std = 43.1 $\pm$ 14.62; 11 right-handed]. Due to the rarity of identifying and testing participants pre-amputation, the sample size was based on the total number of amputees that could be successfully recruited. The researcher was not blinded to experimental condition and/or the study hypothesis."

Sampling strategy

Due to the rarity of identifying and testing participants pre-amputation, the sample size was based on the total number of amputees that could be successfully recruited.

Data collection

"There 3 data-types reported in the study: (1) fMRI data, (2) kinematic data and (3) questionnaire data. MRI images were obtained using a 3-Tesla Prisma scanner (Siemens, Erlangen, Germany) with a 32-channel head coil. Kinematic data was acquired by video recordings using 4 Logitech brio cameras. Questionnaire data was acquired via paper and pen. For all sessions, a single researcher and the research participant were present."

Timing

All data collection took place between May 4, 2019 to May 17, 2024.

Data exclusions

No data were excluded.

Non-participation

Over a 7-year period and across multiple NHS sites in the UK, we recruited 18 potential patients preparing to undergo hand amputations. Due to a multitude of factors (e.g., MRI safety contraindications, no hand motor control, age outside ethics, high level

of disability), we could only perform pre-amputation testing on 6 patients. Due to additional factors (complications during surgery, general health, retractions) we successfully completed our full testing procedure on 3 patients. For the able-bodied controls, 4 volunteers did not complete their testing, due to drop-out and incidental findings captured in the MRI sessions.

Randomization

No randomization was performed because all participants underwent the same testing procedures.

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☒	☐ Dual use research of concern
☒	☐ Plants

Methods

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☒	☐ Flow cytometry
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