

REPORT ON NEARTHROSIS OF THE SHAFT OF THE HUMERUS FOR AMPUTATIONS ROUND THE ELBOW-JOINT

BY

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The loss of an arm, especially in the case of a manual worker, is a much more serious matter than the loss of a leg, and everything should be done to enable the sufferer to make use of whatever remains of it. Two alternatives offer themselves for this purpose: (1) the provision of an artificial limb, or (2) cineplastic operations (in suitable cases).

For many good reasons cineplastic surgery has not been popular in this country, and the almost universal trend has been to provide an artificial arm with fitments in the form of appropriate appliances for toilet, feeding, and work. In the majority of cases this has proved successful. There is, however, a marked difference in the success attained, depending on whether the amputation is above or below the elbow, the prosthesis for the latter being infinitely more useful. So much has this fact been impressed on us that every endeavour is made to save at least some inches of the forearm, and the limb-makers have succeeded in fitting useful limbs to short forearm stumps. Hitherto, arms which had of necessity to be amputated primarily just above the elbow-joint, through the joint, or immediately below the joint required reamputation at the site of election, which is 7 or 8 in. below the tip of the acromion, so as to provide enough space below the end of the humerus for the simple mechanism of the artificial elbow-joint.

The loss of often healthy skin, muscles, and bone in these reamputations caused me to wonder if more use could not be made of them, and the idea was conceived to construct a simple hinge-joint in the shaft of the humerus and so conserve the power of the muscles surrounding it and give a short secondary stump which would, to some extent, act as a forearm.

So far as one could see, nothing could be lost except some time. If the arthroplasty proved a failure, then the joint having been made at the normal site of election, reamputation could still be carried out without further loss of tissue than would have been the case had the normal reamputation been undertaken in the first instance.

Purpose of the Operation.—This is: (1) to conserve the muscular power of the flexors and extensors of the forearm and harness their power usefully; and (2) to make a joint in the shaft of the humerus so that there is about 4 in. of bone distal to the joint. Up to the present 24 operations of this type have been performed on 16 patients.

Problems Concerned in Making the Nearthrosis

1. Prevention of Callus Formation and Subsequent Ankylosis of the Joint.—It is interesting to note that fractures of the middle third of the humerus have a tendency to non-union. The treatment of the bone-ends and medullary cavity with bone-wax, we had hoped, would further discourage bony union, but in the first eight cases bony union was taking place and exuberant callus being formed. Over one hundred years ago Charles Bell wrote: "Scrape a bone and its vessels bleed; cut a bone and its granulations sprout up; break a bone and it will heal; cut a piece away and more bone will readily be produced; burn it and it dies."

From the eighth operation onwards we adopted the following methods to prevent callus formation and bony union: (1) We removed 1½ to 2 in. of the shaft of the humerus, *extra-periosteally*, at the proposed site of the new joint. (2) The bone-ends were fulgurized by electrocautery. (3) 10 to 15 g. of sulphanilamide powder was packed into the space between the bone-ends. Sulphanilamide in high concentration is said to inhibit phosphatase activity, which is intimately concerned with calcification. (4) The arm was immobilized in a straight plaster case for two to three weeks and muscle activity was discouraged at first.

2. Provision of a Useful Range of Movement.—Lateral instability is largely controlled by the hinge prosthesis, and is not so important as might at first appear. As regards the range

of movement necessary to be of real value, we are advised by experts on artificial arms that in the case of a single arm amputation a range of 90°—that is, from the straight 180° to 90°—would be very valuable, but half this range would still be useful. Our last 10 cases have an active range of 90° and a passive range of a little more. In double arm amputations the important arc of movement is from 90° to 30°, so that the hand can be brought to the mouth. It seems unlikely that this could be achieved with the nearthrosis described without additions to the prosthesis. In general, the simpler the type of joint made the greater the range of movement. If only freedom of movement at the nearthrosis can be maintained, one can expect an increase in the active range owing to shortening and accommodation of the flexors, with improved muscle power and co-ordination.

3. Provision of a Fulcrum.—This is a problem, and crepitation and telescoping of bone-ends reduce the efficiency of the muscles acting round the new joint. However, the operation of removing 1½ to 2 in. of bone not only encouraged non-union but also enhanced the range of movement and eliminated crepitation of the bone-ends, which was sometimes irritating to the patient but never painful. Improvements contemplated in this respect include the trial of a simple compact vitallium hinge, the limbs of which consist of two short spokes which could be pegged into the medullary cavity of the bone-ends or metal caps to fit the bone-ends. This again has obvious theoretical advantages but the hinge might soon become so closely invested in fibrous tissue as to "seize up."

Operative Details

Type of Case.—The operation is indicated in: (1) above-elbow amputations, where at least 4 in. of the shaft of the humerus below the insertion of the deltoid muscle still remains; (2) in through-elbow amputations; (3) in very short below-elbow amputations which cannot be fitted with a below-elbow prosthesis; (4) in cases of congenital absence of the forearm.

Pre-operative Treatment.—We think it is important to explain to the patient the nature of the operation and impress on him that his remaining muscles will be able to perform their own function again. He is taught to contract his muscles before the operation and to develop maximum power.

Operative Technique.—For the first 16 operations the incision used for exposure of the shaft of the humerus was a 3½-in. incision over the lateral intermuscular septum. The brachialis anterior and biceps were retracted forwards and the triceps retracted backwards. Sometimes the musculospiral nerve was seen. It, too, was retracted backwards. This incision was altered to a muscle-splitting posterior incision in the last eight operations because it was felt: (a) that, however carefully the operation was performed, a certain amount of weakness of the flexor muscles was inevitable; and (b) that an incision passing through the triceps muscle was of more value because extension was not so important and, in any case, is assisted by gravity. At first the periosteum of the humerus was exposed and incised. The humerus was sawn through and about half an inch of the shaft removed and the ends bevelled at an angle of 45° in front so as to allow maximum flexion (Figs. 1 and 2).

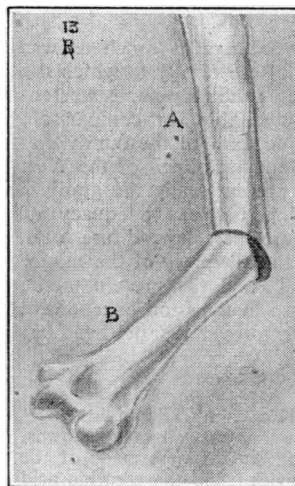


FIG. 1

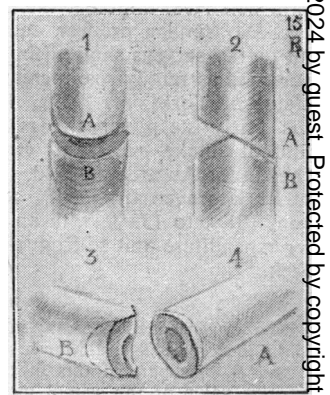


FIG. 2

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The medullary cavity of the bone was curetted, the bone-ends were treated with Horsley's wax, and the medullary cavity was plugged with the wax. This has now been supplanted by liberal excision of the bone—i.e., at least 1½ to 2 in. of it—and fulguration of the bone-ends.

Post-operative Treatment

Originally the new forearm was put up in acute flexion, which was retained for 24 to 48 hours by a posterior plaster support. In the first six cases the patient began to contract his flexor muscles actively within 24 hours of the operation. Faradism was started on the third day. After three to four days the patient realized he had control of the distal end of the stump. A special plaster arm cage was supplied to keep the stump flexed and to improve flexor power. After one week he was allowed to leave the apparatus off for an hour in the morning and an hour in the afternoon, and graduated exercises were given. The new forearm could be flexed to a right-angle without interfering with the nutrition of the distal stump.

The revised post-operative treatment now starts about three weeks after the operation, when a straight plaster case in which the limb has been immobilized is removed. Apart from faradism, graduated exercises, and swimming, it is important to flex the stumps and bandage them with a figure-of-8 crepe bandage, which reduces the oedema, helps to stretch the triceps muscle, and allows the flexors to take up the slack. The patients also sleep quite comfortably with this figure-of-8 bandage, which is put on with maximum tension.

Up to the present it has not been necessary to interfere in any way with the retracted muscle or tendon ends which reinsert themselves in the fibrous mass of the amputation stump.

Case I

Pte. P., aged 34. Shell wounds of left arm and forearm on Oct. 24, 1944, in Holland. Amputation through the elbow-joint was performed the same day, and compound comminuted fracture of the upper third of the humerus treated by wound toilet and immobilization. By Jan., 1945, all wounds were healed and the fractures of the humerus were soundly united in good position. Despite the fracture and scarring, the arm muscles were well developed and powerful, the tendons of triceps, biceps, and brachialis apparently being firmly adherent to the end of the stump.

Operation, Feb. 1, 1945.—The shaft of the humerus was exposed through a 3½-in. vertical incision on the outer side of the lower third of the arm and by blunt dissection through the lateral intermuscular septum. The bone was divided 4 in. from the distal end with an electric saw. The ends of the bone were turned out into the wound and shaped to fit loosely one in the other. A hole was drilled through them and a steel wire passed through the hole to act as a pivot. All bone dust and chips were carefully removed from the wound, but no bone wax was employed in this case. A posterior plaster slab was applied, keeping the stump flexed to a right-angle.

After-treatment.—After 48 hours the slab was removed and active movements encouraged. The slab was replaced at night and when resting. About a week after operation a light hinged elbow cage was applied to the arm and movement was encouraged.

Progress since Operation.—The operation wound healed cleanly. After two weeks there was marked improvement in voluntary contraction, and the stump could be flexed actively through 45° from the straight. Considerable crepitus occurred on active movement, but surprisingly this caused no pain. One month after operation the range of movement remained the same, but there was marked improvement in power and control of the nearthrosis. Six weeks after operation, although accurate measurement was difficult, we had the impression that the range of movement was decreasing.

Second Operation.—Ten days later there was no doubt that the range of movement was diminishing, only a few degrees of active movement being then possible. Radiography revealed a well-marked sheath of callus around the bone-ends. It was plain that bony union was imminent. Operation was decided upon, and on March 26 the original incision was reopened. A spindle-shaped mass of callus was found surrounding the bone-ends and the wire which had been left in at the previous operation. The ossifying mass was chiselled and scraped away; the steel wire was then removed and the bone-ends trimmed. In an attempt to prevent further new bone formation the bone-ends were then treated as follows: The medullary cavity was curetted; the bone-ends were cauterized all over their exposed surfaces with a hot soldering-iron and an electrocautery. After this, bone wax was smeared over them and the medullary cavity plugged. The whole periosteal cavity was then thoroughly swabbed out with alcohol in the hope of still further inhibiting the osteoblastic cells in the periosteum. The wound was closed and a

plaster slab applied, holding the stump flexed. This patient is now wearing a prosthesis flexing his new forearm to a right-angle, and has great muscular power. He does carpentry.

Case II

L/Cpl. B., aged 22, wounded in Holland on Nov. 20, 1944. On admission he presented a healed amputation stump of the left arm. Radiographs showed that the humerus had been sawn off immediately above the condyles. The muscles had evidently been sutured together over the bone-end, as a terminal pad of soft tissue could be moved voluntarily.

Operation, Feb. 22, 1945.—Humerus exposed (as described). The bone was divided with an electric saw and osteotome 4½ in. from the distal end. The bone-ends were in turn projected out of the wound and about 1/4 in. of bone trimmed off each. The upper end was then bevelled to a convex shape and the lower end excavated into a cup shape to receive it. Both bone-ends were smeared with Horsley's wax, and the medullary cavity was plugged with the same substance. No anchorage of any sort was attempted. A posterior plaster slab kept the lower fragment flexed at a right-angle.

After-treatment.—The slab was removed after 48 hours, and active exercise and faradism to the arm muscles were given. After four days an elbow cage was applied.

Progress.—Three weeks after operation the wound was soundly healed and muscle power and control were improving. The range of active movement was about 30° (i.e., from 180° to 150°). Considerable crepitus with overlapping of the bone-ends, was felt when flexion was carried out against resistance, but there was no pain.

Increasing limitation of movement necessitated a second operation on June 27, under the revised technique. The patient is at present wearing a prosthesis and is able to flex well to a right-angle. He is a farm labourer, and is pleased with the result.

Case III

Rfm. B., aged 24, had a traumatic amputation of the left forearm on Jan. 18, 1945, by shell-burst in Germany. Reamputation, with primary suture, was performed above the elbow-joint the next day at a field surgical unit. The amputation wound healed by first intention, and on admission he presented an arm stump of 11½ in. (from acromion to bone-end), with a soundly healed scar. The arm muscles were very little wasted, retaining good power of voluntary contraction, the cut end of biceps and triceps tendons being firmly adherent to the scar on the end of the stump.

Operation, March 2, 1945.—The shaft of the humerus was exposed as previously described. The humerus was divided transversely 3½ in. from the lower end with a Gigli saw (this has proved to be technically much the easiest and neatest method of osteotomy). The bone-ends were dislocated out into the wounds and a "step" was cut in the upper one, the lower one being bevelled anteriorly. The cut ends of the bone were treated with Horsley's wax and the medullary cavity was plugged with that substance. The bone-ends were then drilled from before backwards, and two stout silk sutures were passed through and tied so as to keep the bones in position, yet loosely enough to allow flexion and extension. A plaster slab was applied to keep the lower fragment flexed at a right-angle. After-treatment was carried out as in Case II.

Progress.—Two weeks after operation the wound was soundly healed and there was an active range of 40° flexion from the straight; in this case there appeared to be less instability of the joint. Passive flexion to a right-angle was possible, but this could not be achieved by the patient's own efforts.

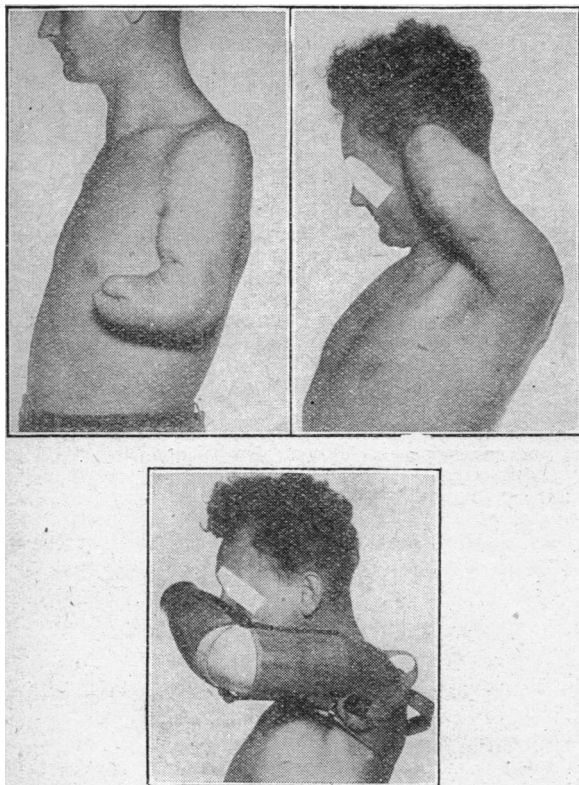
Increasing limitation of movement necessitated a second operation on June 28, under the revised technique. The patient is at present wearing a prosthesis and is able to flex well to a right-angle.

Case IV

Spr. L., aged 25, wounded by mortar in Holland, Nov. 3, 1944. Amputation through the upper third of the left forearm was performed on Nov. 5, the flaps being left open owing to gross sepsis. The remains of the head and shaft of the radius were removed after two weeks; the stump of the ulna separated as a sequestrum a few weeks later, leaving the olecranon and coronoid notch intact. By the end of Feb., 1945, the stump was almost healed. A few degrees of movement were present in the olecranon stump, but a forearm prosthesis was out of the question.

Operation, March 14, 1945.—Incision and exposure as before. The shaft of the humerus was divided 4½ in. from the distal end with the Gigli saw. In this case the bone-ends were bevelled at a more acute angle, the object being to facilitate flexion even at the expense of loss of full extension. Holes were drilled laterally through each bone and a double stout silk ligature was passed through them, which, when tied, formed artificial lateral ligaments and served to anchor the bone-ends together. The bone-ends were treated with wax as previously described and the wound was closed.

Increasing limitation of movement necessitated a second operation on May 24, under the revised technique. The patient is at present wearing a prosthesis and is able to flex well to a right-angle (Figs. 3-5). He is back at work driving a tractor.



Figs. 3 to 5.—Photographs showing amount of flexion obtained with the stump, the temporary prosthesis worn, and the useful movements accomplished.

Case V

Lieut. L. G., aged 22, wounded in Italy May 29, 1944. Arm amputated through elbow the same day. This was a through-elbow amputation soundly healed, with a terminal scar.

Operation, April 5, 1945.—Through a 3½-in. incision over the lateral intermuscular septum the humerus was exposed. On this occasion the periosteum was not raised, but an aneurysm needle was passed round the bone *outside the periosteum*, and with a Gigli saw the bone was divided. Half an inch of bone was cut off each end. The distal end was slightly bevelled in front and the medullary cavity curetted. The ends were then treated with the electrocautery. The medullary cavity was plugged with wax and the bone-ends replaced. The arm was then put up in full flexion with a plaster slab.

Increasing limitation of movement necessitated a second operation on June 12 under the revised technique. The patient is at present wearing a prosthesis and is able to flex well to a right-angle. He is back at work farming.

Conclusion

Up to date I have performed 24 operations, the first 16 through the lateral approach described. The last 8 have been performed through a posterior muscle-splitting incision. The bone-ends have been fulgurized with diathermy after removal of at least 1½ to 2 in. of humerus. The cavities resulting between bone-ends have been packed with sulphanilamide powder. The first eight cases have been operated on twice, either for removal of exuberant callus or for removal of the wire or the twisted silk, which had become involved with the callus and caused the new joint to "seize up."

In 10 of these cases the new forearm can be actively and painlessly flexed to a right-angle. The remaining 6 have varying degrees of active flexion, which is still improving. Passive flexion in all the cases can be increased beyond the range of active flexion. All these patients have good position sense and can manipulate their new forearms so that they can either scratch the back of the head or bring the stump to the mouth. The nutrition of the distal stump has not been interfered with. The point which has been established is that

the arm muscles are capable of acting on a new joint in the humerus to effect and control a useful range of movement. The new forearm can be fitted with a very useful below-elbow prosthesis.

At present not all the problems referred to in this paper can be answered, and their satisfactory solution must await further study. In the meantime, the above series of cases may serve to direct attention to this work, and we hope will bring forward suggestions for solving those problems. Some possible uses of this operation include: (1) to provide a controlled "forearm" stump for amputations as described; (2) to enable a forearm prosthesis to be fitted to very short below-elbow amputations, the elbow being arthrodeseis; (3) to use the short end of the new forearm as a cineplastic stump.

Summary

A new operation is described for making a joint in the shaft of the humerus for cases of amputation near the elbow-joint. The muscles are able to act over this joint with useful power and without pain. Work is in progress to try to improve the actual joint and to overcome the technical difficulties.

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AGRANULOCYTOSIS AFTER SULPHONAMIDE SENSITIZATION: PENICILLIN THERAPY: DEATH FROM *PS. PYOCYANEA* SEPTICÆMIA

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This case is reported because of the unusual circumstances of onset, and in view of the recent interest centred round *Ps. pyocyanea* infection and penicillin therapy.

Case Report

An otherwise healthy soldier, aged 19, was admitted to hospital on Nov. 14, 1944, with extensive scarring of the left forearm which had resulted from a gunshot wound on Sept. 19. Between Sept. 19 and 22 he had received sulphanilamide 10 g. and sulphadiazine 35 g., with no signs of intolerance. On admission the wound was completely healed except for a small dry scab. On Nov. 24 the patient became ill, and complained of a sore throat. On examination a grossly enlarged and inflamed right tonsil was found; temperature 101.6°. Sulphathiazole, 1 g. 4-hourly, was started.

Nov. 26.—Temperature 102°. A throat swab was reported to grow pneumococci. The throat was much improved, but the wound now showed early inflammation.

Nov. 28.—Temperature 101.6°. Inflammation of tonsil subsided and patient stated he felt much better. The wound showed a surrounding area of induration with inflammation, and superficial vesiculation in the centre. Sulphathiazole discontinued (total 15 g. in 4 days).

For the next two days the patient stated he felt quite well, but he continued to run a temperature of 101-102°.

Nov. 30.—Temperature 103°. Wound sloughing; axillary adenitis. Sulphapyridine 1 g. 4-hourly started.

Dec. 2.—Temperature 102°. Wound showed a large central slough; a swab from the wound was reported to grow (1) penicillin-sensitive *Staph. aureus*, (2) penicillin-insensitive *Ps. pyocyanea*. Penicillin, 15,000 units intramuscularly 3-hourly, was started.

Dec. 3.—Patient was flushed and ill. Temperature 103.4°; pulse 120. A waxy pallor of the skin was noted. The throat was normal, but breaking down of the wound was extending in spite of treatment. Blood count: R.B.C., 3,500,000 per c.mm.; Hb, 65%; W.B.C., 2,000 (80% lymphocytes). Sulphapyridine was discontinued (14 g. total in 2 days). Pentnucleotide, 10 c.cm. intramuscularly 6-hourly, was started.

Dec. 4.—Temperature 104°; pulse 120. W.B.C., 1,000 per c.mm. (lymphocytes 900, polymorphs 90, myelocytes 5, eosinophils 5). Two