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OSTEOSYNTHESIS WITH A THICK MEDULLARY NAIL IN NON-UNION OF LONG BONES

By

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The results of treatment of pseudarthroses at the Orthopaedic Hospital of the Invalid Foundation during the period 1945–1960 have been reported by *Kivilaakso & Saarialho* (1963). The series consisted of 160 patients and healing was achieved in 87 per cent of cases. At the Sicot congress in 1960, large series were presented by *Boyd, Lipinski & Wiley* (842 cases) and by *Merle d'Aubigné & Cauchoix* (814 cases). The results in these series were excellent, healing being achieved in 94 per cent of the cases.

Although we obtained satisfactory results with our earlier method of treating pseudarthrosis, in which onlay or inlay graft and z-resection were employed in the majority of cases, it seemed justifiable to try a method which permitted earlier mobilization. When the patients were sent to this hospital for treatment, several unsuccessful operations had often been carried out, the injured extremity had not been subjected to weight-bearing and the patients had been incapable of work for several years. Owing to earlier immobilization there was often severe stiffness in the joints on either side of the pseudarthrosis, and marked osteoporosis. It therefore seemed important to try a method in which external fixation could be avoided, if possible, and in which early weightbearing by the limb could be permitted. Reaming of the medullary cavity and fixation with a thick medullary nail according to *Küntscher* seemed to fulfil these requirements. We have therefore been using this method since 1964.

Good results from the treatment of pseudarthrosis with medullary nails without reaming of the medullary cavity usually combined with free bone grafts, have been reported by *Merle d'Aubigné, Matzen, Lot-*

tes, and *Palmer*, among others. A number of other workers besides *Küntscher* have reported good results from the medullary nailing of pseudarthroses with thick nails, including *Merle d'Aubigné*, *Böhler*, *Herzog*, *Müller*, *Salem* and *v. Hellens et al.*

The following principles were adopted in the treatment of patients with pseudarthrosis before osteosynthesis was performed:

If osteitis or fistulae are present, excision and sequestrectomy are carried out. We usually wait half a year after the fistulae have closed before we perform the osteosynthesis.

If, owing to scarred or poorly vascularized skin, there appears to be any risk of infection or skin necrosis in connection with osteosynthesis, excision of cicatricial tissue and free or pedicle grafting are carried out.

Stiff joints are mobilized by means of physiotherapy and, when necessary, by manipulation under anaesthesia. In the knee, we aim at achieving full range of flexion before operation if possible.

Osteoporosis is counteracted by permitting the patient to use the injured limb, if necessary with the aid of a supporting bandage. This requires special supervision by the attending surgeon, since the patient is afraid to place any weight on the pseudarthrosis.

Table 1. Age of the patients at operation.

Age	Under 20	20–29	30–39	40–49	50–59	Over 60
Number	3	4	7	12	5	4

Table 2. Nature of the material.

Location of non-union	Tibia	Femur	Humerus	Radius or Ulna	Total
Number of patients	17	12	4	2	35
Open fracture	8	–	2	1	11
Primary open reduction	6	8	1	–	15
Osteitis	3	1	1	1	6
Previous operations for non-union:					
One operation	4	3	2	–	9
Two operations	1	2	1	1	5
Three or more	1	–	1	–	2
Average time between fracture and nailing in months	27	26	37	24	

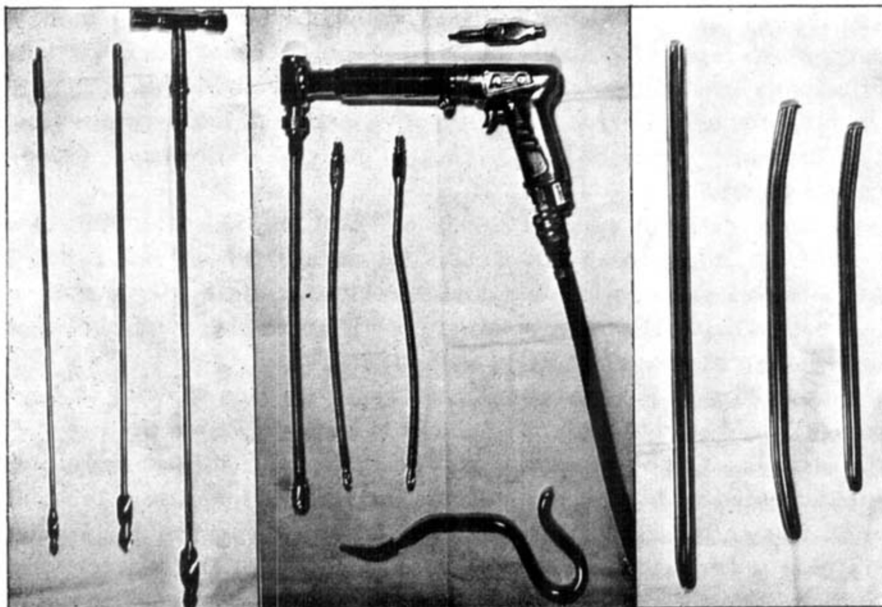


Figure 1. The reamers, the pneumatic drill and medullary nails used for osteosynthesis.

MATERIAL

The series consists of 35 patients treated during the period 1964–1966. The age of the patients is given in Table 1.

The site of the pseudarthrosis and some particulars of the nature of the injuries and earlier treatment are presented in Table 2.

There was a complicated fracture in 11 cases. Primary surgical fixation had been carried out in 15 cases. The fracture had been fixed with an ordinary Küntscher medullary nail in 7 cases, with a Rush pin in 3 cases, with a Lane's plate in 4 cases and by means of a wire loop in 1 case. Operation for pseudarthrosis had previously been carried out on 16 patients, the number of operations involved being 26. Operation for osteitis before osteosynthesis was carried out six times. Skin grafting was performed preoperatively in three cases. The average interval between fracture and osteosynthesis was 28 months.

OPERATIVE TECHNIQUE

The instruments used for the operation can be seen in Figure 1.

For reaming the medullary cavity we have, since 1965, used a pneumatic AOI drill, which has functioned to our satisfaction. The diameter of the burrs increases by 0.5 mm per burr, which has proved adequate.

The type of drill we used earlier had a diameter increase of 1 mm per burr, which proved too much. The drill became hot and stuck. We have principally used Zimmer's medullary nails. The tibial nail is bent at the proximal end (*Herzog*). The operative technique has been described by *Küntscher* (1962) and by *Müller, Allgöwer & Willenegger* (1965), among others.

In three cases of pseudarthrosis of the tibia, closed nailing was carried out, while in all other cases the pseudarthrosis was exposed. An X-ray television, which no doubt greatly facilitates closed nailing, was not available. However, polaroid radiograms, which can be obtained in some minutes, were of great help.

In pseudarthrosis with a defect, in case in which the nail did not seem to prevent rotation entirely, and in cases in which the pseudarthrosis was situated comparatively near the joint, the operation was supplemented with a free transplant. In 11 cases, bone from the tibia or the iliac crest was transplanted and fixed with screws as an onlay graft. In a further six cases cancellous bone from the iliac crest or from the tibia was transplanted to the site of the pseudarthrosis. In order to prevent any reduction of the osteogenic capacity of the graft, the transplants were not allowed to dry even momentarily (*Puranen* 1966).

TIBIA

The operative method and the results are given in Table 3.

Table 3. Tibia.

Method	Number of cases	Union	Flare-up of infection	Failure
Nail+graft from tibia or the iliac crest	4	4	3	–
Nail+cancellous bone	3	2	2	1
Nail alone	7	7	2	–
Closed nailing	3	3	1	–
Total	17	16	8	1

Osteotomy of the fibula was carried out in 7 cases. As will be seen from the table, healing was achieved in 16 cases. Infection and osteitis spoiled the result in one case and the nail had to be removed. The number of infections was large, 8 cases. Seven of these had previously been infected. Despite infection, healing took place in 7 cases. Closed

nailing was carried out in three cases; infection flared up in one of these but the pseudarthrosis fused. One of the advantages of the method is that the pseudarthrosis heals despite infection, provided the nail is not removed too soon. Fairly long courses of treatment with antibiotics were, of cource, necessary in infected cases. In two cases of pseudarthrosis with a defect, and in which transplantation with a tibial graft was carried out, skin necroses occurred. In these cases, free skin grafting was employed, the necrosed area being excised 2 to 3 weeks after the operation. It is our opinion that early skin grafting in these cases played a decisive role in the results.

In pseudarthrosis of the tibia the diameter of the nail was 10 to 16 mm. In two cases the nail pierced the posterior cortex and had to be bent forwards at its distal end in order to enter the distal fragment. This was done at the metal workshop of the hospital, since nails of more than 11 mm thickness cannot be bent without special instruments. Nails were also shortened, when necessary, at the workshop.

Postoperative Treatment

Eight patients were treated without external fixation. Nine patients were supplied with a walking plaster cast for 6 weeks. The plaster cast was, as a rule, applied 2 weeks after operation, when the wound had healed. Since there is a risk of infection and necrosis of the skin, it is important that the incision can be inspected before application of a walking plaster cast. Weight-bearing was, as a rule, permitted 3 to 4 weeks after the operation.

Healing required an average of about 5 months in cases of pseudarthrosis of the tibia. The patients soon regained preoperative mobility in the knee and talocrural joints.

Figure 2 shows the result in a case of pseudarthrosis of the tibia with a defect.

FEMUR

The operative method and the results are given in Table 4.

Consolidation was achieved in all 12 cases. The average time required for healing was 6 months. There was infection in 2 cases. A free bone graft from the iliac crest or the tibia was used in four cases and fixed with screws, while cancellous bone from the iliac crest was used in three cases.

The diameter of the nail was 11 to 16 mm, the usual size being 14

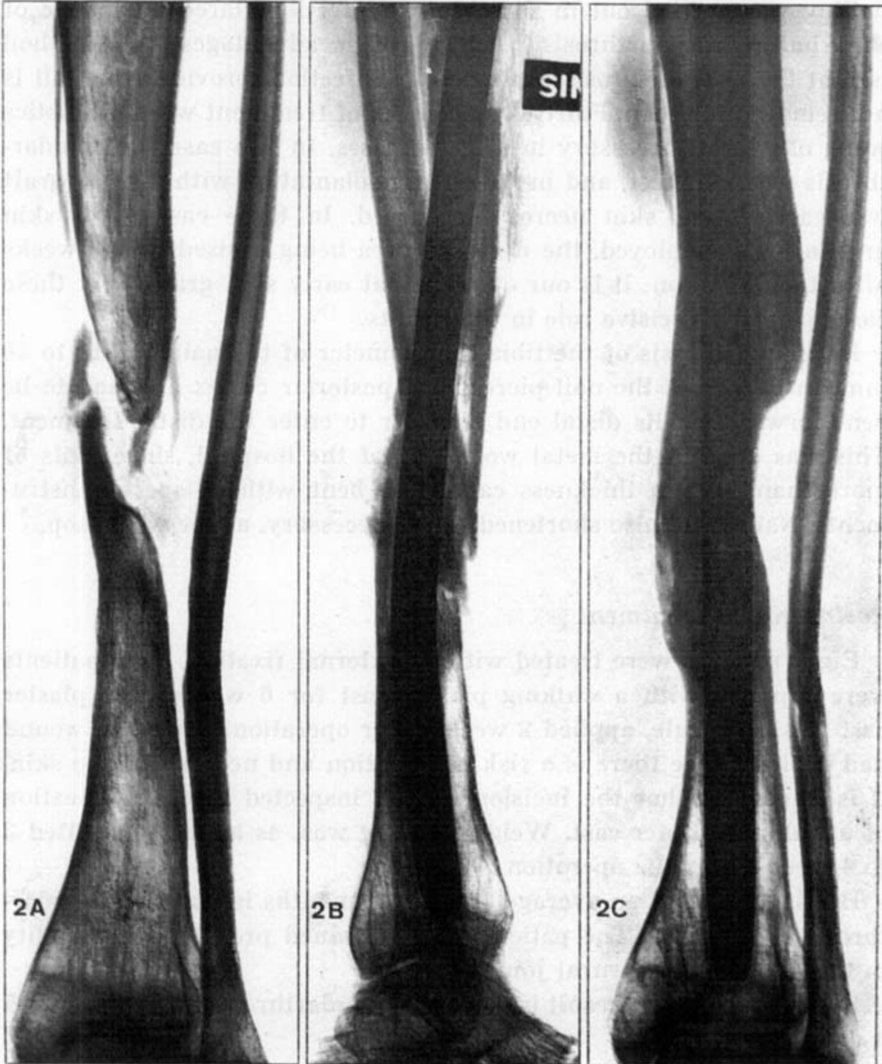


Figure 2 A. Non-union of the tibia with a defect of the diaphysis two and a half years after an open and infected fracture. Male, age 19 years.

B. Side view radiograph five months after medullary nailing and transplantation of a free graft from the other tibia.

C. Solid union eleven months after operation.

mm. The nail penetrated the knee joint in two cases. In one of these the nail was exchanged, a shorter nail being substituted and fixed proximally with a screw. In the second case we did not consider an exchange of the nail necessary. In this case the knee was stiff after a pathological fracture, and there was a pseudarthrosis in the lower end of the femur as a result of myxosarcoma for which had been given X-ray treatment. It had previously been operated on four times.

Table 4. Femur.

Method	Number of cases	Union	Flare-up of infection
Nail+graft from tibia or the iliac crest	4	4	1
Nail+cancellous bone	3	3	–
Nail alone	5	5	1
Total	12	12	2

Eleven patients were mobilized on the first postoperative day with the aid of crutches, and exercise of the knee and hip joints was immediately commenced. One patient was given a hip walking-plaster for six weeks.

In pseudarthrosis of the femur not too close to a joint, this method seems superior to all other ones.

The result in a case of pseudarthrosis of the femur is shown in Figure 3.

Table 5. Humerus.

Method	Number of cases	Union	Flare-up of infection	Failure
Nail+graft from the iliac crest	1	1	–	–
Nail alone	3	–	1	3
Total	4	1	1	3

HUMERUS

The operative method and the results of treatment in four cases of pseudarthrosis of the humerus are given in Table 5.

The diameter of the nail was 11 to 14 mm. Consolidation was only achieved in one case, in which rotation between the fragments was

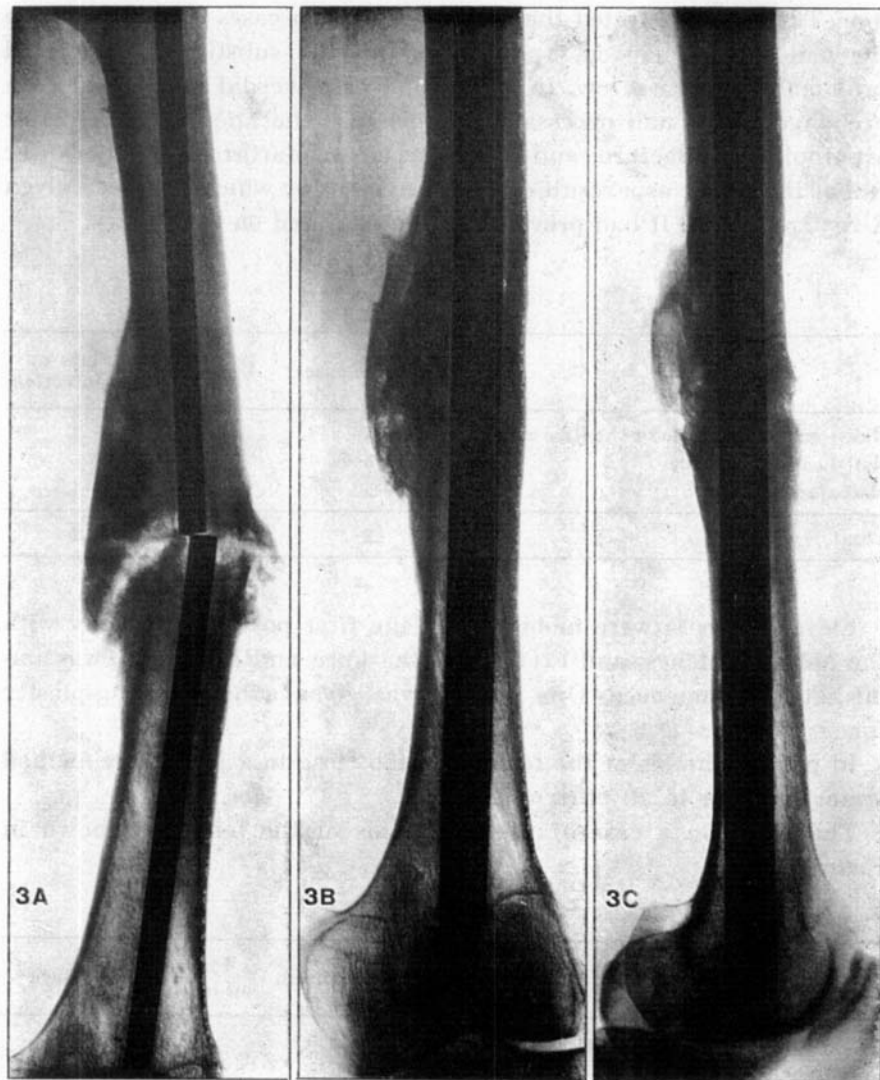


Figure 3 A. Non-union of the femur after nailing with an ordinary Küntscher nail eleven months earlier. Male, age 27 years.

B. Condition eleven months after medullary nailing with a nail of fourteen millimeters thickness.

C. Side-view corresponding to B.

prevented by means of a graft from the iliac crest fixed with screws (Figure 4). In one of the cases an old infection was activated and the nail worked loose. In the two remaining cases, the nail did not prevent rotation between the fragments, resorption occurred and healing did not take place. All the patients had trouble in mobilizing the shoulder joint owing to irritation by the proximal end of the nail. A thoraco-brachial plaster cast was applied in one case.

Thus, in pseudarthrosis of the humerus our experience of the method is not good. If this method is used, a graft fixed with screws must evidently always be applied. *Merle d'Aubigné & Cauchoix* report good results with this method in 99 per cent of 90 cases. If the nail is introduced at the greater tuberosity, there is invariably, in our experience, irritation and reduced mobility in the shoulder joint.

RADIUS AND ULNA

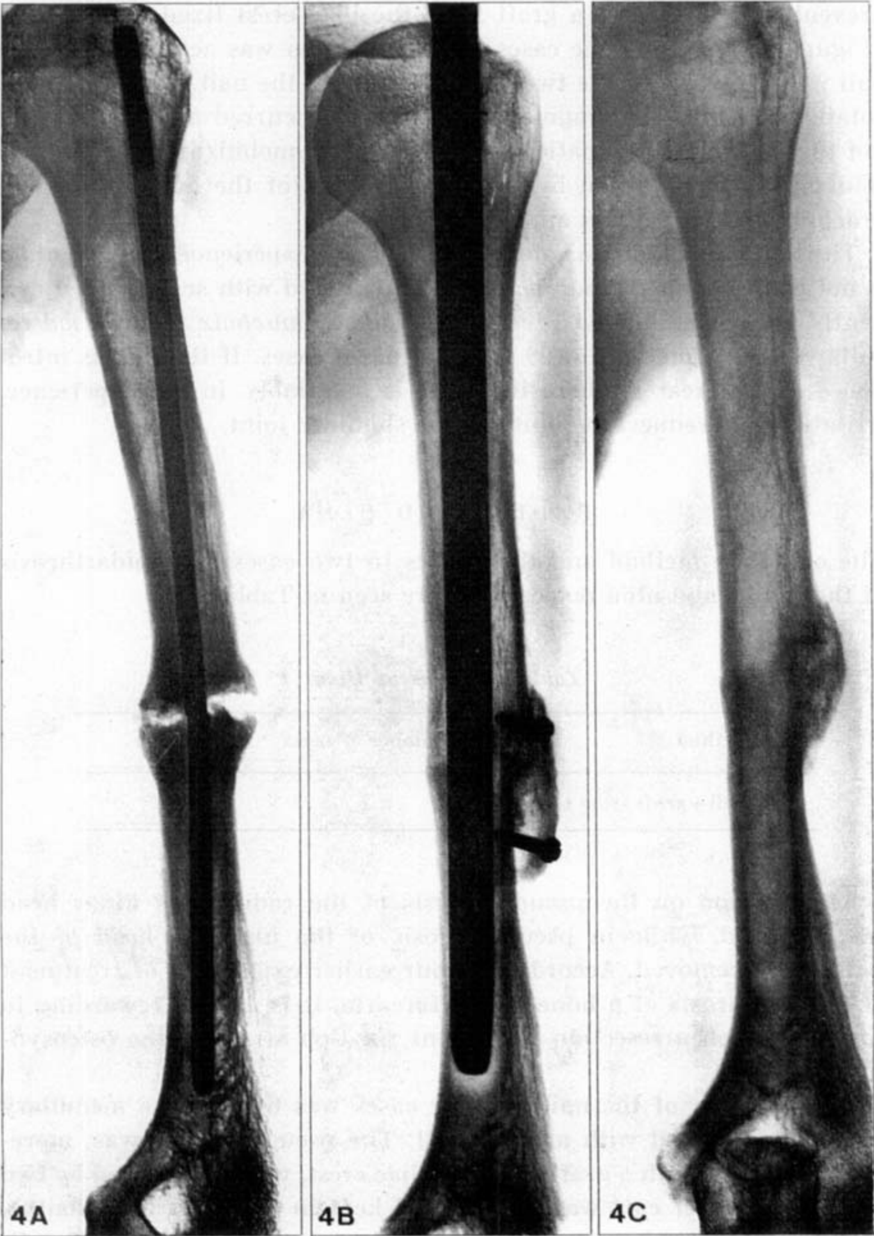
The operative method and the results in two cases of pseudarthrosis of the radius and ulna respectively are seen in Table 6.

Table 6. Radius or Ulna.

Method	Number of cases	Union
Nail+graft from the iliac crest	2	2

At operation on the pseudarthrosis of the radius, the ulnar head was removed, while in pseudarthrosis of the ulna the head of the radius was removed. According to our earlier experience of treatment of pseudarthrosis of a bone of the forearm, it is always rewarding to carry out such a resection to prevent rotation stress of the osteosynthesis.

The diameter of the nail in these cases was 6 mm. The medullary cavity was reamed with a hand drill. The pseudarthrosis was, moreover, stabilized with a graft from the iliac crest, which was fixed by two screws. A plaster cast was applied and kept in place for two months, which was probably unnecessary. Both pseudarthroses were consolidated after 3½ months. Figure 3 shows the case of pseudarthrosis of the radius.


4A
4B
4C

DISCUSSION

The results in all cases can be seen in Table 7.

Healing was achieved in 31 cases, while 4 failed, 2 of them owing to infection, and 2, which were cases of pseudarthrosis of the humerus, because the nail did not prevent rotation between the fragments. The number of cases in which infection flared up, was large, 10 cases. In one case primary infection occurred at the operation carried out for pseudarthrosis.

Table 7. Results of medullary nailing in 35 cases of non-union.

Location	Number of cases	Union	Flare-up of infection	Failure
Tibia	17	16	8	1
Femur	12	12	2	–
Humerus	4	1	1	3
Radius or Ulna	2	2	–	–
Total	35	31	11	4

In *pseudarthrosis of the tibia* the greatest advantage of the method is that owing to the rigid fixation, weight-bearing of the limb can be permitted at an early stage. Mobilization of the knee and talocrural joints may likewise be commenced early. In this way osteoporosis is counteracted and bony union is achieved more rapidly. According to *Anderson*, endosteal bone formation ceases at medullary nailing and union takes place periosteally and from the ends of the bone. The time required for healing after nailing is not always easy to estimate but the method does not seem to require a longer time than other methods. One drawback is the risk of flare-up of infection (*Macausland & Eaton)*, which is particularly high in pseudarthrosis of the tibia. In

Figure 4. A. Non-union of the humerus primarily nailed with a Rush pin four years earlier. Male, age 44 years. Two years after injury the Rush pin was replaced by a thin Küntscher nail which is seen broken in the picture.

B. The humerus nine months after nailing with a nail of eleven millimeters thickness and transplantation of a free graft from the ilium. The nail is loose and has moved cranially.

C. The same humerus one-and-a-half years after the last nailing. The nail has been removed.

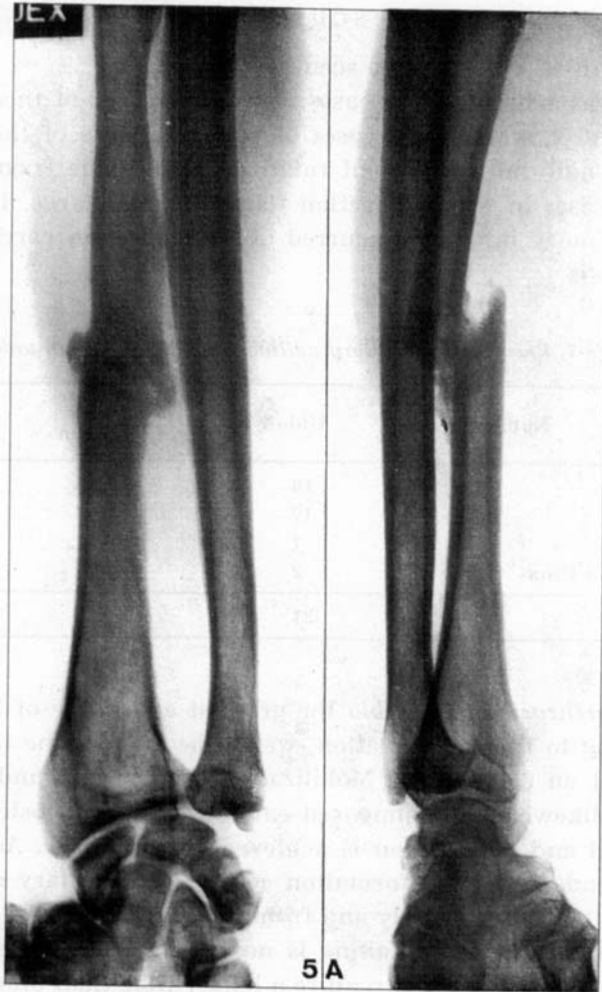
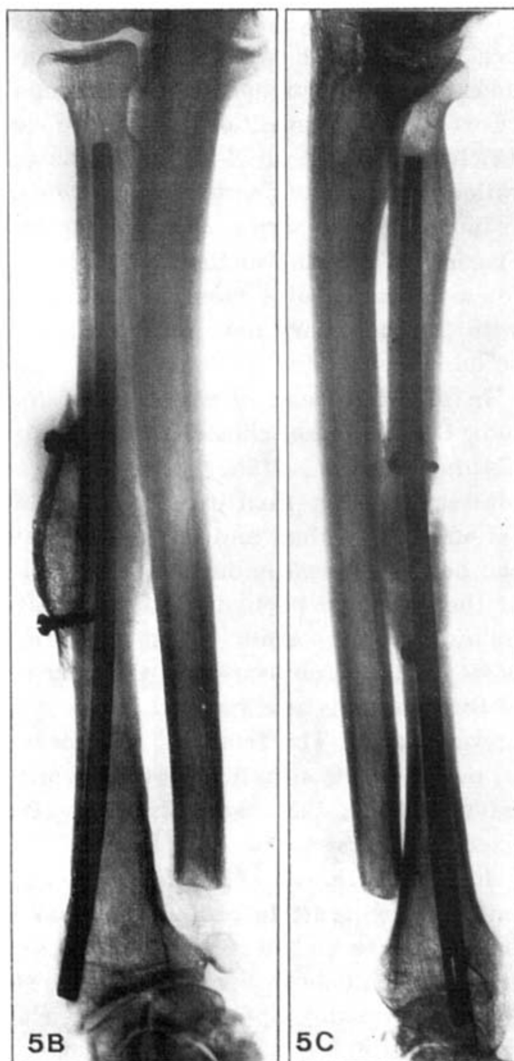


Figure 5. A. Non-union of the radius after fracture one year earlier. Male, age 53 years.

the present series, this was due to earlier infection as a result of open fracture, cicatrices and poorly vascularized soft parts. In most of our cases, however, union took place despite flare-up of infection, which is not, as a rule, the case when other methods are employed. The site of latent infection can be obviated by osteosynthesis with a free graft between the tibia and the fibula by means of lateral incisions (*Merle d'Aubigné,* and others). Of course, this method requires prolonged immobilization in a plaster cast. In pseudarthrosis with a defect, tibio-

Figure 5 B. and C. The same forearm three months after nailing of the radius with a nail of six millimeters thickness and transplantation of a free graft from the ilium. The graft was fixed with screws. The capitulum of the ulna was removed at the same operation.



fibular osteosynthesis can be employed with good results (*Laurent*, and others).

At closed nailing there is less risk of infection, but in most cases malposition must be corrected at open operation, and if the pseudarthrosis is situated in the lower portion of the tibia, a graft must be added in order to prevent rotation. That infection may occur even at closed nailing is demonstrated by one of our cases and has also been mentioned by *Müller et al.* and *Böhler*. By nailing of pseudar-

throsis of the tibia, in most cases by closed nailing, *Herzog* achieved healing in 57 out of 59 cases and Böhler in all of 40 cases. We have no experience of preoperative reduction of the pseudarthrosis by means of extension treatment or transverse osteotomy according to *Küntscher*. At closed nailing, an X-ray television considerably facilitates the operation, as was also pointed out by *Böhler*.

In our earlier series, onlay grafts gave good results (*Kivilaakso & Saarialho*) but this method required immobilization in a plaster cast for a minimum of 4 months. Because of the stable fixation achieved with the medullary nail, we intend to continue using this method in suitable cases.

In *pseudarthrosis of the shaft of the femur* this procedure seems to be the method of choice, a fact also pointed out by *Boyd et al., Merle d'Aubigné et al., Müller et al.,* and others. External fixation with plaster casts can then usually be avoided, which means that mobilization of the patient and the joints on either side of the pseudarthrosis can be commenced immediately after the operation. At pseudarthrosis of the femur in particular, there is often stiffness of the knee joint following some earlier treatment. A method that permits immediate postoperative mobilization of the knee is of great value. The frequency of thrombosis is also reduced. There was no case of thrombosis in the present series. The femur is, moreover, easier to nail than the tibia. If, owing to the situation of the pseudarthrosis, there is a risk of rotation between the fragments, a free transplant should be added and fixed with screws.

In *pseudarthrosis of the humerus* our results were poor, partly because a free graft to prevent rotation was applied in one case only. In one case there had repeatedly been osteitis, and infection spoiled the result. Carcinoma of the liver was later diagnosed in another case and this had probably impaired healing. However, the nail does not seem to provide rigid fixation in the humerus and immobilization in a plaster cast for a short period may be necessary (*Merle d'Aubigné et al.*). Stiffness of the shoulder joint owing to irritation by the head of the nail constitutes a considerable disadvantage, and occurred in all our cases. It is probably that the AOI compression plate can provide rigid fixation in pseudarthrosis of the humerus and may thus constitute a better method (*Müller et al.*). Good results in pseudarthrosis of the humerus have been reported by *Hindmarsh & Unander-Scharin,* who used Egger's plate and cancellous bone. This method required a plaster cast for 4 months. In our earlier series we obtained good results with

z-resection in pseudarthrosis of the humerus. This method likewise required a thoracobrachial plaster cast at least 4 months. Now we use medullary nailing in pseudarthrosis of the humerus in selected cases only.

In *pseudarthrosis of the radius or ulna* nailing is useful as an alternative to other methods. Our two cases do not allow of any further conclusions. *Boyd et al.* recommend medullary nailing particularly in pseudarthrosis of the ulna. It is possible that the AOI compression plate constitutes a better method for the treatment of pseudarthrosis of the radial or ulnar diaphysis, and permits after-treatment without external fixation.

Medullary nailing is not a simple procedure and makes heavy demands on the surgeon's skill. Reaming of the medullary cavity with a pneumatic drill renders the operation easier, however, while at the same time rigid fixation can, as a rule, be achieved. Nails of the correct length and calibre must be available. Upon correct indications and with a good operative technique this method gives good results in pseudarthrosis of the diaphysis of long bones. Risk of infection must be reckoned with and a free bone graft should be added if the healing conditions seem poor, or the fixation uncertain. Since in many cases it is possible to dispense with plaster casts, the after-treatment is considerably facilitated from the point of view both of the patient and of the surgeon.

SUMMARY

The material consists of 35 cases of non-union of the shaft of long bones treated at the Orthopaedic Hospital of the Invalid Foundation with a thick medullary nail. The non-union was located in 17 cases in the tibia, in 12 cases in the femur, in 4 cases in the humerus and in 2 cases in the radius and ulna, respectively. The diameter of the nail was 10–16 mm in the case of non-union of the tibia, in non-union of the femur 11–16 mm, of the humerus 11–14 mm and of the radius and ulna 6 mm. Open reduction was carried out in all cases except in three of non-union of the tibia, where closed nailing was performed. In 17 cases, the osteosynthesis was completed with the application of an autogeneous free graft of bone or cancellous bone. The commonest complication was flare-up of infection, which occurred in 10 cases. In 9 cases, consolidation was achieved despite the infection. The method seems to be very suitable in cases of non-union of the shaft of the

femur and the tibia, permitting mobilization and weight-bearing very soon after operation. The method was less suitable in the case of non-union of the humerus, because the nail loosened and the head of the nail caused irritation and stiffness of the shoulder joint. Sound union was achieved in all cases of non-union of the femur and in 16 of the 17 cases of non-union of the tibia.

RESUME

Les observations portent sur 35 cas de non-soudure du corps d'os longs traités à l'Hôpital Orthopèdique de la Fondation des Invalides au moyen d'un épais clou médullaire. Dans 17 cas, la non-soudure était localisée dans le tibia, dans 12 dans le fémur, dans 4 dans l'humerus et dans 2 cas dans le radius et le cubitus, respectivement. Le diamèetre du clou était de 10–16 mm dans les cas de non-soudure du tibia, de 11–16 mm dans ceux du fémur, de 11–14 mm dans ceux de l'humerus et de 6 mm dans ceux du radius et du cubitus. Une réduction ouverte a été pratiquée dans les cas de non-soudure du tibia, excepté pour trois dans lesquels un enclouage fermé a été réalisé. Dans 17 cas, l'osteosynthèse a été complétée par une greffe autogène d'os spongieux. La complication la plus courante a été l'apparition d'une infection, constatée dans 10 cas. Dans 9 cas, la soudure s'est effectuée malgré l'infection. La méthode semble convenir parfaitement dans les cas de non-soudure du corps du fémur et du tibia, elle permet la mobilisation et le support du poids du corps très rapidement après l'operation. La méthode convient moins bien dans le cas de non-soudure de l'humérus parce que le clou ne reste pas fixé et que la tête du clou peut causer une irritation et une rigidité de l'articulation de l'épaule. Une soudure saine a été réalisée dans tous les cas de non-soudure du fémur et dans 16 des 17 cas de non-soudure du tibia.

ZUSAMMENFASSUNG

Das Material umfasst 35 Fälle von Pseudarthrose der langen Röhrenknochen, die im Orthopädischen Krankenhaus der Invalidenstiftung mit einem dicken Marknagel behandelt wurden. Siebzehn Pseudarthrosen der Tibia, zwölf des Femurs, vier des Humerus, eine der Ulna und eine des Radius wurden genagelt. Der Durchmesser der Nägel, die bei Tibiapseudarthrosen angewandt wurden war 10–16 mm, bei Femurpseudarthrosen war er 11–16 mm, bei Humeruspseudarthrosen 11–14

mm und bei Pseudarthrosen der Ulna und des Radius 6 mm. Eine offene Reduktion wurde in allen Fällen mit Ausnahme von drei Fällen von Tibiapseudarthrose gemacht. In den drei Fällen wurde eine geschlossene Nagelung ausgeführt. In siebzehn Fällen wurde die Osteosynthese mit der Applikation eines autogenen Knochentransplantates kombiniert. Die gewöhnlichste Komplikation war ein Aufflackern einer alten Infektion, was in zehn Fällen auftrat. In neun Fällen wurde eine Konsolidation trotz einer Infektion erreicht. Die Methode scheint für die Behandlung von Pseudarthrosen der Diaphysen des Femurs und der Tibia gut geeignet zu sein, und erlaubt frühzeitige Mobilisation und Belastung. Für das Humerus ist die Methode weniger geeignet da Lockerung des Nagels und Irritation und Versteifung des Schultergelenks gesehen wurde. Knöcherne Heilung wurde bei allen Fällen von Femurpseudarthrose und in 16 von 17 Tibiapseudarthrosen erreicht.

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