FROM THE ORTHOPAEDIC CLINIC, HÄRNÖSAND
(HEAD: NILS LINDSTRÖM)

OSTEOSYNTHESIS IN PSEUDARTHROSIS OF THE HUMERUS DIAPHYSIS

By

JAMES HINDMARSH and LARS UNANDER-SCHARIN

The principles of treatment for pseudarthroses of the long bones are well known to have been much debated and the number of methods employed are very great. Diaphysis pseudarthroses of the humerus are considered by many to belong to the more difficult types to treat. Good treatment results have nevertheless been reported. The results presented by *D'Aubigné* and *Solal,* 1950, belong to those more worthy of note. Using Küntscher nailing and tibia transplantation fixed by screws as an onlay graft, healing was obtained in 18 out of 19 cases = 94.7 %. Using fixation only with screwed-on tibia transplants following resection of the pseudarthrosis the same authors obtained healing in 12 out of 13 cases = 92.4 %. Lange reported in 1953 an incidence of 87 % healed in a series comprising 126 humerus pseudarthroses. A detailed account of the operative methods used is not given, although in general intramedullary osteosynthesis is recommended, with Küntscher nail + tibia bone graft as an inlay or onlay graft fixed with cerclage or screws. *Maatz* reported good results using the so-called "Markraumfeder".

During the years 1946–1959, at the Orthopaedic Clinic, Institute for Cripples, Härnösand, 18 cases of pseudarthroses of the humerus diaphysis and of diaphysis fractures of the humerus were operated on, the latter showing delayed healing. 15 cases have been considered as clear pseudarthroses. The period from initial injury to pseudarthrosis operation varied here between 10 months, and 5 years, averaging about 22 months. In the three cases designated as delayed healing the period between initial injury and operation was about 4 mths. in all cases. This may seem indeed a short time within which to define the cases as delayed healing, but after 4 mths. the possibilities of healing were judged radiologically to be extremely small and this was con-

firmed by the findings at operation. (There was interposition of soft tissue and complete instability after previously inserted osteosynthesis material was removed).

17 patients achieved healing (94.4 %), 4 of them, however, only after reoperation. With one exception, where the patient's primary injury was cared for at the Orthopaedic Clinic, the patients consisted of remission cases from various hospitals in Norrland, (North Sweden).

TABLE 1

Fixation method	Fracture type			
	Transverse	Double	Oblique	Comminuted
Intramedullary	9	1		1
Plate	1			1
Cerclage		1	1	3
Conservative	1			
Total	11	1	1	5

Table 1 reviews the type and treatment of the original injury. Transverse fractures were dominant, with 11 cases. 9 of these had Küntscher nailing, 1 was fixed by means of a plate and 1 was treated conservatively. A double fracture was fixed by nail + cerclage. A short oblique fracture was fixed with cerclage. 5 may be termed comminuted fractures. 1 of these had nailing, 1 was fixed with a plate and 3 with cerclage. Thus open reduction with inner fixation was performed in 17 out of the 18 cases. Only 2 of the fractures were open.

A more detailed analysis of the reasons why the pseudarthrosis arose could not be made since we did not have access to the fracture material of the hospitals. Probable contributory causes could, however, be traced in many cases. In a number of cases it was a question of severe, multiple injuries, so that a suitable fracture treatment was much delayed. In some cases the open reduction was, to judge from the available X-rays, not successful. In 2 cases which had Küntscher nailing, the bone cracked when the nail was struck home and a large intermediary fragment arose. 1 case had a large intermediary fragment which was removed at operation. Lack of fixation following operation was probably in the majority of cases a factor of significance. The patient was postoperatively treated as if a completely stable inner fixation was present, and this, judging from the evidence available, was not the case. For

example, out of those with medullary nailing only 2 were provided postoperatively with a thoracobrachial plaster. As a rule no more than an abduction splint was supplied, sometimes only an arm sling, although the nail did not fill the medullary cavity, so that it could have prevented rotation.

3 patients underwent pseudarthrosis operation before treatment at the orthopaedic clinic, with negative results. For 2 of them operation comprised freshening of the fracture ends and osteosynthesis with Küntscher nailing and bone chips packed in a canal sawn up to the medullary cavity. In the third case the osteosynthesis was performed with a tibia bone graft screwed above the fracture site following resection of the pseudarthrosis.

TABLE 2

Completed in connection with the injury + previous treatment.

	Radialispareses	Ulnarispareses	Comb. radialis- and ulnarispareses
Injury	4 (1)		
Op. treat.	2 (1)	1 (1)	2 (2 ulnp.)
Total	6 (2)	1 (1)	2 (2)

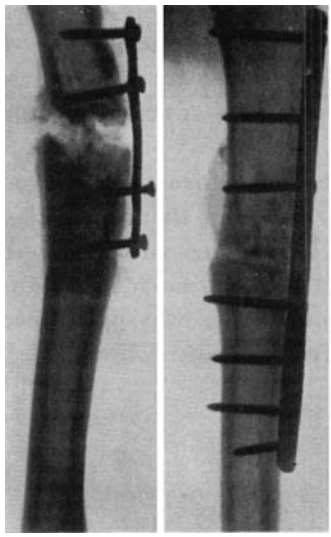
Figures in brackets state lasting pareses.

Table 2 shows the incidence of nerve injuries connected with the accident and the previous treatment. The figures in brackets state permanent pareses. These were present therefore in 5 cases. 1 patient had almost total lasting pareses of the ulnar nerve in other cases it was a question of slight pareses without any invalidising effect.

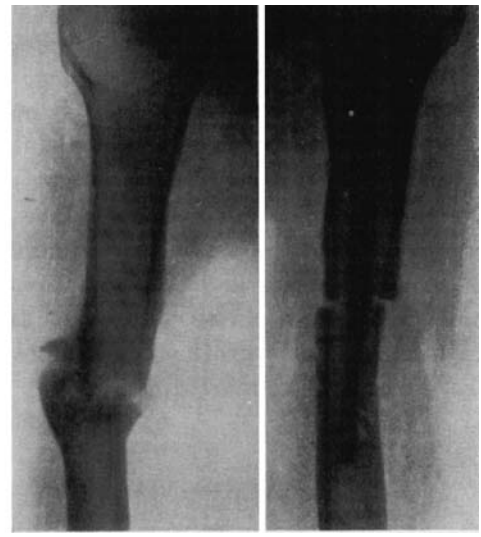
Our operative material is distributed between 14 men and 4 women, 8 right-sided and 10 left-sided cases. The average age at operation was 47.7 years, with the highest age 78 and the lowest age 20 years.

TABLE 3

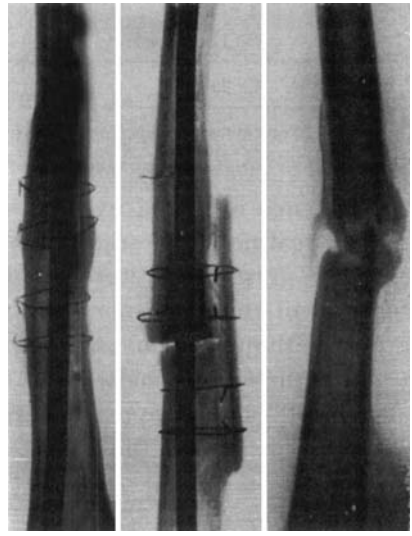
Op. method		*No. of cases*
I	Freshening of fracture ends + osteosynthesis with Egger's plate + bone chips in a chiselled canal. Figs. 1 a, 1 b	14
II	Freshening of fracture ends + osteosynthesis with free bone transplant (tibia bone graft). Figs. 2 a, 2 b	2
III	Freshening of fracture ends + osteosynthesis with Küntscher nailing + free bone transplantation (tibia graft as onlay graft fixed with cerclage). Figs. 3 a, 3 b, 3 c	2



Figs. 1 a and b.



Figs. 2 a and b.



Figs. 3 a, b and c.

The operative methods used are shown in table 3. In the operative technique of method I, quite long plates were employed as a rule and at least three screws were inserted on both sides of the pseudarthrosis. The screws were always inserted through both cortical layers. The canal was usually fully 1 cm. wide and extended 3 to 4 cms. along

each fragment. It entered the medullary cavity. Chips were taken from the ilium and consisted mainly of cancellous bone. In method II one end of the tibia bone graft was pushed into the medullary cavity of the proximal fragment and the other end was sunk in a chiselled canal of the distal fragment. All 3 methods always included exstirpation of fibrous tissue and freshening of the fracture ends. Sclerotic bone was resected so that bleeding bone was present on both sides. In some cases, reoperated on, this involved a not insignificant shortening. In cases of delayed healing, which were all operated on according to method I, only slight freshening of the fracture ends was carried out, however.

Outer fixation with thoracobrachial plaster was retained in principle until radiological consolidation arose. The fixation period varied between 2 and 10 mths. and was on average 4 mths.

TABLE 4

Method	No. primary op.	Primary healed	Reop.	Completely healed	No. of op.
I	14	11	2	13	16
II	2	0	0	0	2
III	2	2	1	3	3
IV	0	0	1	1	1
Total	18	13	4	17	22

Table 4 gives the results with the respective methods. With method I, 14 patients were operated on, 11 of which healed primarily. Of the remaining 3, 2 were reoperated on according to the same method with good results. The third would not undergo any further operation and so represents the sole definitive non-union in the series. In all, 13 out of 14 healed with this method after 16 operations. Method II gave depressing results with no primary union. Both patients were, however, reoperated on, using other methods, and then healed. One was operated on according to method III, and therefore with this method we had 3 healed out of 3 operations, since the two operated on primarily also healed. The other patient in method II was operated on by a method designated IV in the table: the pseudarthrosis was resected during transformation into an oblique fracture and was fixed with screws.

Of the 18 patients therefore, 13 healed primarily. Since the 4 reoperated also healed, this makes a total of 17 healed.

Throughout the operative series, comprising 22 pseudarthrosis operations, no complications were recorded in the form of nerve or blood

vessel injuries or of more severe infection, although there was one case of slight wound infection. It should be emphasised that aseptic pseudarthroses are involved. In no case were signs of infection present at operation.

16 patients were followed-up. 1 is dead and only some general information could be obtained from relatives concerning his working capacity following the operation. 1 patient was able to leave relatively detailed information about his condition by letter. The observation period in no case fell below 8 mths. and at its longest was 13 years.

Regarding the follow-up only, a few observations will be made here, which may perhaps be of some interest. We only saw a high degree of reduced strength in the arm in 3 patients, who had all undergone repeated pseudarthrosis operations. 6 patients had significant limitation of mobility in the shoulder and elbow joint, while 5 of these also had considerable limitation of movement at the time of the pseudarthrosis operation. In such a small series as this, coincidence may of course be present, but the circumstance still gives us cause to emphasise the importance of a patiently executed pre-operative course of treatment in mobility, which we believe is fundamental. For it appears as if the patient, in spite of the lengthy fixation, as a rule obtains approx. the same mobility as existed on the occasion of operation. In some cases we believe we would have obtained a better end result if the patients had been afforded a longer period of exercise before the pseudarthrosis operation. Shortening varied between 7 cms. and an amount too small to be measured with accuracy. We saw no reaction around the osteosynthesis material and this was never removed after healing.

TABLE 5

	Returned to work	Changed work	Incapable of work
Manual work	7	3	2
No manual work	3	0	0
Household work	2	0	0
Total	12	3	2

Table 5 gives a rough estimation of work capacity. Of the 12 manual labourers, 7 returned to the same work and 3 were changed to lighter work. 2 were not capable of work; the one owing to chronic uremia, from which disease he afterwards died, the other probably mainly owing to psychological reasons, since objectively the arm was fairly

satisfactory. Of the 3 who were white collar workers, 2 declared themselves capable in their leisure time of carrying out heavier manual work. Both housewives said that they could see to all household chores. One patient, aged 81 at the time of the follow-up, and who hardly had any work, was not included in the table.

DISCUSSION

As far as the principles defining pseudarthrosis are concerned, we followed those laid down by *Bertelsen, Birn, Christiansen* and others in the Danish Medical Bulletin, 1955; these are that a case may be designated pseudarthrosis within 12 mths., if 1) a defect exists, 2) plain sclerosis of the fracture ends and closure of the medullary cavity are found, or if 3) it can be confirmed at operation that muscle or tendon tissue are interposed.

Regarding the type of pseudarthrosis: the three cases previously submitted to pseudarthrosis operations and in whom resection had been performed, can be designated as defect pseudarthroses. On reoperation of the four cases where we did not achieve primary union, defects were also present, in that the previously inserted osteosynthesis material was removed. Thus there were 7 operations on defect pseudarthroses (in 5 of these operations method I was used, in one method III, and in one method IV). In the other operations no bone defect was present. This does not, however, mean that it was always a question of "contact pseudarthroses". This phrase refers chiefly to a pseudarthrosis in which the fracture ends are held together by a fibrous callus tissue in fairly good contact. Amongst our cases, however, there are also dislocated, loose pseudarthroses which therefore can neither be designated as contact or defect pseudarthroses.

Method I includes by far the majority of cases (14 cases, 16 operations) and therefore deserves further discussion. The results may here be considered as satisfactory with regard to the total number of healed cases (13 out of 14), but the fixation period of 4 mths. on average must be regarded as relatively long and from this point of view the method seems to be inferior to, e.g., that by D'Aubigné and Solal with nailing + tibia bone graft where only 1 mth. of outer fixation is necessary according to the information given.

In spite of the good results reported by Phemister in various pseudarthroses of the long bones, the majority of authorities seem to agree that a stable inner fixation is of essential importance in the healing of

pseudarthroses above all, those of the humerus and femur. Moreover, it is thought that a factor stimulating osteogenesis must be supplied as a rule in the form of a transplant. The method by which inner fixation is achieved varies very much on the other hand, (the screwing of or cerclage round the fracture ends, a bone graft screwed on, Küntscher nailing possibly after drilling, Rush-pin, various types of metal plates, "Markraumfeder", "Doppeldraht" according to Greifensteiner, Hoffman's instruments, etc.); the type of transplant varies also (cortical graft, chips, pure cancellous), likewise its application (onlay, inlay, sliding, intramedullary etc.).

No attempt will be made here at a more detailed evaluation of the different fixation methods. As far as Egger's plate is concerned, it may, however, be said that a sufficiently long plate gives good fixation of the humerus and that this is superior to that obtained with a bone graft alone, but probably not to that obtained by a technically complete intramedullary osteosynthesis. With the last method, however, it must be said that its general use is limited to a certain extent by the considerable technical difficulties, which increase further if a defect exists or arises on bone resection. In this connection it may naturally be wondered why we have always carried out bone resection. The majority of authorities (*D'Aubigné, Küntscher, Palmer, Phemister* etc.) do not recommend resection of bone for contact pseudarthroses. If we could adjust fresh bone surfaces to each other, however, and thus follow the old Lexer laws, we felt more secure, especially in the treatment of humerus pseudarthroses, where remission is particularly common, according to what is witnessed in many parts. A shortening of the humerus to a slight or moderate degree has no functional significance. Since the transplant is not needed to contribute to the fixation, cancellous bone, which has good inductive and conductive function, is preferred, and its insertion in the canal is regarded as hastening the process of bridging.

In connection with the series presented, the following points may be put forward:

1. In principle it seems advisable that open methods in the treatment of diaphysis fractures of the humerus should be restricted (out of 18 fractures, which afterwards became pseudarthroses, 17 were operated on).

2. If such methods are nevertheless indicated, regardless of the type of inner fixation, this ought to be supplemented by outer fixation in the form of thoracobrachial plaster.

3. In the treatment of diaphysis pseudarthroses of the humerus, the above-mentioned method I may be described as an acceptable alternative to D'Aubigné's or Palmer's methods, without being recommended as superior to these.

4. Patients with joint contractures ought to have time to exercise before the pseudarthrosis operation is undertaken.

SUMMARY

A series is reported, consisting of 15 pseudarthroses and 3 fractures with delayed healing located to the humerus diaphysis; these were operated on between 1946 and 1959 at the Orthopaedic Clinic, Institute for Cripples, Härnösand.

In 14 cases the osteosynthesis was performed with Egger's plate and bone chips inserted into a canal chiselled up to the medullary cavity (method I). In 2 cases the osteosynthesis was performed with a tibia graft (method II). In 2 cases the osteosynthesis was performed by means of medullary nailing and a tibia graft as an onlay graft, which was fixed above the pseudarthrosis with cerclage (method III). In all cases the bone had been resected so that fresh surfaces could be adjusted to each other.

17 of the 18 cases healed, 4, however, only after reoperation.

In the group operated on according to method I (14 cases), 13 healed (2 reoperations).

No complications in the form of nerve injury or more severe infection arose.

The fixation period in the thoracobrachial plaster was 4 mths. on average.

16 patients were followed-up and in the majority it was possible to confirm satisfactory function and work capacity. 6 patients had limited mobility to a considerable degree in the shoulder and elbow joints, although this was already present in 5 of these at the time of the pseudarthrosis operation. This emphasises the importance of a patiently executed, preoperative movement therapy.

Method I is discussed and is considered as an acceptable method alongside the intramedullary osteosynthesis procedure.

RESUME

Il est rapporté une série de cas comprenant 15 pseudarthroses et 3 fractures localisées à la diaphyse de l'humérus dont la guérison ne

s'était pas faite. Ceux-ci furent opérés entre 1946 et 1959 à la Clinique Orthopédique de l'Institut des Infirmes d'Härnösand.

Dans 14 cas l'ostéosynthèse a été réalisée avec la plaque Egger et des fragments osseux insérés dans un canal taillé jusqu'à la cavité médullaire (méthode I). Dans 2 cas, l'ostéosynthèse a été réalisée avec une greffe de tibia (méthode II). Dans 2 cas, l'ostéosynthése a été réalisée au moyen d'un enclouage médullaire et d'une greffe de tibia simplement posée et fixée autour de la pseudarthrose par cerclage (méthode III). Dans tous les cas, on a pratiqué une résection de l'os de manière à ce que des surfaces fraîches puissent être ajustées l'une à l'autre.

Sur ces 18 cas, 17 ont été guéris; pour 4 toutefois seulement après réopération.

Dans le groupe des malades opérés selon la méthode I (14 cas), 13 furent guéris (2 réopérés).

Il n'y a pas eu de complications sous forme de lésion des nerfs ou d'infection grave.

La période de fixation dans un plâtre thoracobrachial a été en moyenne de 4 mois.

16 malades ont été réexaminés et dans la majorité des cas on a trouvé la confirmation d'une fonction et d'une capacité de travail satisfaisantes. Chez 6 malades la mobilité était réduite à un degré considérable dans les articulations de l'épaule et du coude, mais pour 5 c'était déjà le cas au moment de l'opération de la pseudarthrose. Cela souligne l'importance de la thérapie pré-opératoire du mouvement chez les malades.

La méthode I est discutée et est considérée comme une méthode acceptable à côté du procédé de l'ostéosynthèse intramédullaire.

ZUSAMMENFASSUNG

Über eine Reihe von 15 Pseudarthrosen und 3 Brüchen der Humerusdiaphyse mit verspäteter Heilung wird berichtet. Diese Fälle wurden zwischen 1946 bis 1959 an der orthopädischen Klinik des Institutes für Krüppel in Härnösand operiert. In 14 Fällen wurde die Osteosynthese mit der Egger-Platte und Knochenspähnen, die in einen bis zur Markhöhle aufgemeisselten Kanal eingelegt wurden, ausgeführt (Methode I). In 2 Fällen wurde die Osteosynthese mittels einer Tibiaspange vorgenommen (Methode II). In 2 weiteren Fällen wurde die Osteosynthese mittels Marknagelung und einer angelegten Tibiaspange, die oberhalb der Pseudarthrose mittels Cerclage fixiert wurde (Methode III) aus-

geführt. In allen Fällen wurde Knochen reseziert so dass angefrischte Oberflächen aneinander gelegt werden konnten.

17 von den 18 Fällen heilten, 4 jedoch erst nach Reoperation. In der Gruppe, die nach Methode I operiert wurden (14 Fälle) heilten 13 (2 Reoperationen).

Keinerlei Komplikationen wie Nervenbeschädigung oder schwerere Infektionen traten auf.

Die Dauer der Ruhigstellung im Thorax-Armgips betrug im Durchschnitt 4 Monate.

16 Patienten wurden nachuntersucht und bei der Mehrzahl konnte eine Zufriedenstellende Funktion und Arbeitsfähigkeit festgestellt werden. 6 Patienten hatten eine bedeutende Einschränkung der Beweglichkeit im Schulter und Ellbogengelenk, doch war dieselbe bei 5 bereits zur Zeit der Pseudarthrosenoperation vorhanden. Dies zeigt die Wichtigkeit einer geduldig ausgeführten Bewegungsbehandlung vor der Operation an.

Methode I wird besprochen und wird zusammen mit der intramedullären Nagelung als eine brauchbare Methode angesehen.

REFERENCES

1. *Bertelsen, A.* and others: Treatment of pseudarthrosis of long bones in Denmark. Danish Medical Bulletin *2*: 1–7, 1955.
2. *D'Aubigné, R. M. & Solal:* Le traitement des pseudarthroses de la diaphyse humérale. Revue d'orthopédie *36*: 373, 1950.
3. *Fehr, A. M.:* Die Behandlung der Pseudarthrose und ihre Ergebnisse. (Diskussion M. Lange) Helvetia chirurgica acta *20*: 355, 1953.
4. *Fehr, A. M. & Rieben W.:* Weitere Erfahrungen mit der Phemisterplastik. Helvetia chirurgica acta *21*: 411, 1954.
5. *Jarry, L. & Uhthoff, H. K.:* Activation of osteogenesis by the "petal" technique. Journal of Bone and Joint Surgery *42-B*: 126–36, 1960.
6. *Küntscher, G.:* Fünfzehn Jahre Marknagel. Langenbecks Archiv *282*: 211, 1955.
7. *Küntscher, G.:* Der Wirkungsmechanismus des Phemister-Spanes. Der Chirurg *26*: 23–28, 1955.
8. *Küntscher, G.:* Pseudarthrose nach Marknagelung. Zeitschrift für Orthopedie (Stuttgart) *87*: 225, 1956.
9. *Palmer, I.:* A dualistic method of treating pseudarthrosis. Acta chir. scand. *107*: 261, 1954.
10. *Støren, G.:* The incidence of pseudarthrosis with different methods of treatment in a fairly large fracture series. Acta orthopaedica scand. *25*: 69–76, 1955.