FROM THE ORTHOPEDIC CLINIC OF THE KAROLINSKA INSTITUTE, STOCKHOLM. CHIEF: PROFESSOR STEN FRIBERG

NON-UNION IN FRACTURES OF THE LONG BONES

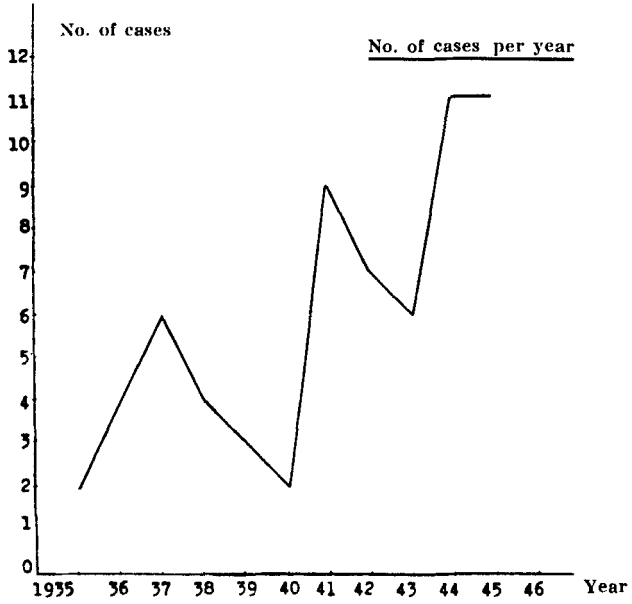
BY

CARL HIRSCH

The incidence of pseudoarthrosis in large series of fractures varies from ½ to 5 %. (Böhler, Sorudder, Hey Groves, Starr, etc.). The causes of non-union of fractures in certain cases are not fully understood, but it appears that they are many and varied, both systemic and local. It is surprising that the incidence is highest in strong healthy individuals, and that it is commoner among men than women (Böhler). As possible causes of non-union one must consider, on the one hand, general diseases, diseases of bone, reduced local circulation following thrombosis or impaired arterial supply, and local and general disturbances of calcium and phosphorus distribution or poor phosphatase formation; and, on the other hand, inadequacy of treatment. Poor or no contact between the bone ends, interposition and incomplete immobilisation may disturb the formation of granulation tissue in the fracture haematoma or prevent the conversion of granulation tissue into callus. If the blood of the coagulated haemotoma leaks out through a break in the surrounding muscle wall, or the clot is disturbed by infection or surgical interference, callus formation will be poor (Watson-Jones, Böhler, Perkins, Starr, etc.). Further, large series of fractures suggest that some fracture sites are more favourable to non-union than others (Böhler, Starr, Blmenfeld). However one must always remember that "non-union of fractures is due to the failure of surgeons much more than to the failure of osteoblasts" (Watson-Jones).

When a pseudarthrosis has developed the medullary cavity is closed by a sclerotic plug of bone, both bone ends are atrophic and conical and there is a gap between them. In transverse fractures the proximal fragment often shows a periosteal outgrowth which makes a cup for the distal fragment. The distinction between delayed union and pseud-

Table no. 1



arthrosis (non-union) is made from the radiograph. If a sclerotic plug of bone fills the medullary cavity a pseudarthrosis is established (Böhler) and surgery is the only solution.

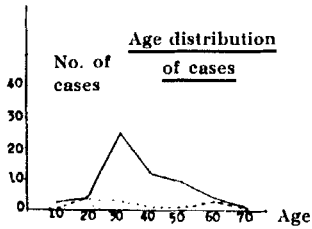
The material given below consists of 67 cases of uninfected pseudoarthrosis of the long bones treated in this Clinic from 1935-46. All the cases were originally treated at other hospitals. Table 1 shows the number of cases treated in the Clinic in each year.

56 men and 11 women were operated upon. Table 2 shows that, among men, pseudarthrosis occurred most frequently be-

tween the ages of 21 and 40. However, as not all cases in our area come to this clinic, conclusions as to age and sex distribution cannot be drawn from this material, though the figures agree with those of larger series (Starr).

All surgical procedures for the treatment of pseudarthrosis aim to break down the sclerotic barrier and produce hyperaemic decalcification by a new trauma. By removing the pseudarthrosis tissue, including the sclerotic bone, conditions are made favourable for the development of granulation tissue with new vessels and osteoblasts from the surrounding tissue.

Table no. 2



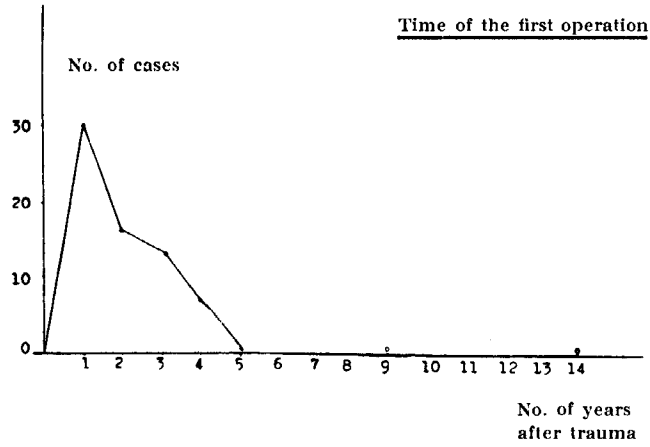
Age	Men	Women
1—10	2	0
11—20	4	4
21—30	24	3
31—40	12	1
41—50	9	1
51—60	4	2
61—70	1	0

If there is good contact between the bone fragments and little movement between them, some form of bone perforation, e.g. Beck's drilling, is sufficient, but usually a bone graft is preferable.

The first bone graft on man was performed by Ollier in 1858, and for many years the main method in use was Albee's inlay graft. The function of the transplant was both to stabilise the fracture and to contribute to the osteogenesis. For a long time the behaviour of the transplant, whether it remained as it was, or whether cells penetrated it, was disputed; and there was also considerable discussion on the value of the periosteum of the transplant. Gallie and Robertson after an extensive investigation made a valuable contribution to the surgery of pseudarthrosis; the presence or absence of the periosteum of an autogenous transplant does not affect the activity of the sub-

periosteal osteoblasts and has no practical clinical value. The periosteum is important to living bone because it carries vessels. In an autogenous transplant the cells on its outer surface live on the surrounding tissue fluids, while those within it disappear within 2-3 weeks. The cells proliferating on the surface and coming either from the transplant or from the surrounding bone replace the dead cells. The whole transplant is vascularised and the old bone is replaced by new,

Table no. 3



made up of fine trabeculae. During the first 2 months absorption is more rapid than replacement. Heterogenous transplants give the same results as autogenous by the ingrowth of cells from the graft bed. However, our experience has not as yet encouraged us to rely greatly on heterogenous transplants.

The time of the operation is not important for a satisfactory result. Table 3 shows the distribution of the cases with respect to the time interval between the trauma and the first operation for pseudarthrosis.

69 pseudarthroses have been operated upon in 67 cases. Operations for combined pseudarthroses of both radius and ulna in the same arm have been counted as one operation.

Table no. 4
Distribution of pseudarthrosis material

Bone	Beck's drilling		Osteosynthesis with wire		Inlay graft		Onlay graft		Küntscher nail		Intramedullary peg graft		Total no. of operations	
	1st op.	Re-op.	1st op.	Re-op.	1st op.	Re-op.	1st op.	Re-op.	1st op.	Re-op.	1st op.	Re-op.	1st op.	Re-op.
Humerus					1				1		1		3	0
Radius	2	1			1	1		1	2				5	3
Ulna	2		1		5					1	1		9	1
Radius and Ulna	1				1			1	2				4	1
Femur		1	1		5			1	1	2			7	4
Tibia	13	1		1	25	2			1		2		41	4
Total	18	3	2	1	38	3	0	3	7	3	4	0	69	15

There have been 13 re-operations, giving a total of 82 operations (see Table 4). 41 of the 69 (60 %) pseudarthroses occurred in the tibia, and this figure agrees with Henderson's. The sites in the other cases in this material are too few to allow any conclusions on their frequency. In larger series the remaining diaphyses have been affected about equally.

Table 4 shows which surgical procedures were used. Beck's drilling and inlay grafts have been used most; they were the routine procedures in this Clinic at the beginning of the period covered by the investigation. From 1944 to 1946 we tried Küntscher nailing and also began to use onlay grafts fixed with vitallium screws, though only in a few cases, because of shortage of material at that time. In the last few years we have used onlay grafts more frequently.

70 % of the cases united after one operation, and a further 13 % after a second operation (Table 5). Beck's drilling gave union in 83 %, and inlay grafting in 71 %.

The drilled cases showed an average consolidation time of 5.4 months. It must be mentioned, however, that the cases selected for this operation were considered to be favourable for osteogenesis, with good contact and only moderate sclerosis. Cases treated with inlay grafts showed an average consolidation time of 7.2 months. The less satisfactory results of Küntscher nailing are notable. In spite of resection of the sclerotic tissue and fixation with a long intramedullary nail, only 4 out of 7 patients showed union after the first operation and the consolidation time was 14 months, more than twice as long as the time for the other cases. Apart from the technical difficulties sometimes encountered due to narrowing of the medullary cavity over much of its length and the consequent impossibility of inserting a sufficiently thick nail into it, the nail does not give the stability one would expect. While a graft gives increasing stability after several months, nailed cases often develop some movement due to osteolysis round the stainless steel, and some only unite after the loose pin has been removed.

Table no. 5
Results of operations

	No. of cases	%	Method											
			Beck's drilling		Osteosynthesis with wire		Inlay graft		Onlay graft		Küntscher nail		Peg graft	
			No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Total no. of operated cases	69		18		2		38		0		7		4	
United after one op.	48	70	15	83	2	100	27	71	0		4	56	0	0
United after re-op.	9	13	3				3				3		0	
Time required for union in months			5,4		4,5		7,2				15		—	
Ununited cases	12	17												

SUMMARY

In the years 1935-46, 69 pseudarthroses of a diaphysis have been treated by operation: 18 by Beck's drilling (83 % united), 38 by inlay grafting (71 % united) 7 by Küntscher nailing (56 % united), and 6 by various other methods. In all, 70 % of cases united after one operation and 13 % after a second. The average consolidation time was 5.4 months for Beck's drilling, 7.2 months for inlay grafts, and 15 months for Küntscher nailing. 54 % of all the cases were men between the ages 21 and 40. In 60 % of the cases the pseudarthrosis occurred in the tibia.

RESUME

Pendant les années 1935 à 1946, 69 cas de pseudarthroses du diaphyse ont été traités opératoirement : 18 par le forage Beck (consolidation dans 83 %), 38 par implantation de greffe (consolidation dans 71 %), 7 par clou Küntscher (consolidation dans 56 %) et 6 cas par différentes autres méthodes. Dans l'ensemble, on a obtenu la consolidation dans 70 % des cas après une opération et dans 13 % après une deuxième opération. La durée moyenne de la consolidation s'est étendue sur 5,4 mois pour le forage Beck, 7,2 mois pour l'implantation de greffes et 15 mois pour l'opération un clou Küntscher. 54 % des cas étaient des hommes âges de 21 à 40 ans. Dans 60 % des cas la pseudarthrose était logée dans le tibia.

ZUSAMMENFASSUNG

In den Jahren 1935—46 wurden 69 Pseudarthrosen der Diaphysen operativ behandelt: 18 mit der Beck'schen Bohrung (83 % vereinigt), 38 mit Einpflanzung einer Spange (71 % vereiningt), 7 mit Küntscher-Nagelung (56 % vereinigt) und 6 mit verschiedenen anderen Methoden. Insgesamt wurden 70 % der Fälle nach einer Operation und 13 % nach einer zweiten Operation vereinigt. Die durchschnittliche Konsolida-

tionszeit betrug 5,4 Monate bei der Beck'schen Bohrung, 7,2 Monate bei der Einpflanzung von Spangen und 15 Monate bei der Küntscher-Nagelung. 54 % aller Fälle waren Männer im Alter von 21 bis 40 Jahren. In 60 % der Fälle trat die Pseudarthrose in der Tibia auf.

LITERATURE

Albee, F. H.: Bone Graft Surgery. Saunders Company 1917.

Blumenfeld, I.: Pseudarthrosis of the Long Bones. J. Bone Jt. Surg. Vol. 29, No 1, 1947.

Böhler, L.: The Treatment of Fractures. John Wright & Sons Ltd., Bristol 1935.

Gallie, W. E. and *Robertson, D. E.:* The Repair of Bone. The British Journ. of Surg. Vol. VII, No 26, 1919-20.

Geckeler, E. O.: Fractures and Dislocations for Practitioners. Baillére, Tindall and Cox, London 1940.

Harris, H. A.: Bone Growth in Health and Disease. Oxford University Press, Humphrey Milford, London 1933.

Henderson, M. S.: Journal of Bone and Joint Surg. Vol. 20, 1938.

Hey, Groves: From Blumenfeld, J. Bone Jt. Surg. Vol. 29, 1947.

Key, J. A. and *Conwell, H. E.:* The Management of Fractures, Dislocations and Sprains. S:t Louis, The C. V. Mosby Company, 1946.

Klingworth, C. F. W. and *Dick, B. M.:* Textbook of Surgical Pathology. J. A. Churchill Ltd., London 1938.

Ollier: From Albee: Bone Graft Surgery 1917.

Perkins, G.: Fractures. Oxford University Press, Humphrey Milford, London 1940.

Robinson: Bone Phosphatase. Ergebnisse d. Enzymforschung. Vol. 1, pp. 280, 1932.

— From Harris: Bone Growth in Health and Disease 1933.

Scudder, C. L.: The Treatment of Fracture. W. B. Saunders Company 1939.

Sinclair, M.: Fractures. Constable and Company Ltd., London 1931.

Starr, K. W.: Delayed Union in Fractures. Butterworth and Company, London 1947.

Stimson, B. B.: A Manual of Fractures and Dislocations. Columbia University, New York. H. Kimpton, London 1947.

Walton, J. A.: Fractures and Separated Epiphysis. Edw. Arnold, London 1910.

Watson-Jones, R.: Fractures and Other Bone and Joint Injuries. 1941.

Wilson, Ph. D.: Management of Fractures and Dislocations. J. B. Lippincott Company 1938.