MEDULLARY NAILING OF FRACTURES AFTER FIFTY YEARS

With a Review of the Difficulties and Complications of the Operation

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At the turn of the half-century surgeons have been inspired by the technique of intramedullary nailing. History will show that in the year 1950 many hundreds and perhaps thousands of case records of nailed fractures were reviewed critically but enthusiastically by surgeons in every part of the world. We ourselves know of the reviews that are taking place in Canada, America, Australia, Sweden, Spain and Great Britain, and there can be little doubt that there are others. No technique has been accepted, after long dormant years, so widely and with more sudden enthusiasm than that of intramedullary pinning of fractures by long nails. A form of internal fixation has been recognised that offers promise not only in the treatment of some recent fractures in which the external support of splints and plaster is minimised, but also in the treatment of fractures with delayed union which are capable of protection for many months without hardship to the patient, fractures with established non-union in which transplantation of iliac bone with medullary nail-fixation is often more satisfactory than onlay grafting with screws and plaster, pathological fractures which can be controlled more easily by this method than by any other, and even perhaps selected open fractures with wounds of soft tissues which may be immobilised—possibly without aggravation of infection—while abscesses are drained, granulating surfaces dressed and skin grafts applied.

Many surgeons believe that the operation is new, whereas it has in fact been developing steadily throughout the last fifty years. Küntsch er, whose name is often coupled with the technique, is no more than one of several surgeons who applied it recently in the circumstances of war. Details of the intramedullary fixation of bones were published by Nicolaysen in 1897, Delbet in 1906 and Lambotte in 1913. Delbet practised the internal fixation of fractures of the femoral neck by screws introduced under X-ray control. Lambotte's work was concerned mainly with the fixation of small bone fragments with thin nails; he nailed the neck of the femur (Fig. 1) and used two screws, one in the neck and one down the shaft, for subtrochanteric fractures of the femur (Fig. 2). The use of massive nails which filled the medullary cavity was introduced by Hey Groves (1916, 1918) in England nearly forty years ago. Not only did he experiment with four flanged nails and three flanged nails for fractures of the femoral neck long before Smith-Petersen but he introduced medullary nails through the greater trochanter for fractures of the shaft of the femur (Figs. 3 and 4), through the great tuberosity for fractures of the shaft of the humerus, and through the olecranon for fractures of the shaft of the ulna. He used three types of steel nail: solid nails, nails cruciform in section, and hollow tubes with perforations. He drove nails through the trochanter and across the fracture site into the distal fragment, and also tried the method of retrograde nailing—exposing the fracture site, driving the nail into the medulla of the proximal fragment until it emerged through the trochanter and then, after reducing displacement of the fracture, hammering the nail back into the distal fragment (Fig. 5). His words, written in 1918, may be quoted: “It occurred to me therefore to use a long internal peg or strut such as would render unnecessary
Figure 1—Fixation of fractured neck of femur by two nails. Figure 2—Subtrochanteric fracture fixed by a long nail introduced from the greater trochanter and two cross nails. (From Lambotte, *Chirurgie Opératoire des Fractures*, 1913, Paris: Masson et Cie. Reproduced by permission.)

Figure 3—Fracture of femoral shaft ununited after sixteen months. Figure 4—Fixation by a long steel rod introduced from the top of the great trochanter. (From H. Groves, in *British Journal of Surgery*, 1918. By permission of the Editor.)
any further fixation and would afford absolute rigidity. I have used pegs of various shapes, cylindrical, cross-sectioned and solid rods, and I am inclined to think that the last named are the best because they give the maximum strength . . . After preparing at least three or four inches of the distal fragment the proximal one is drilled by a special drill 12 inches long. This is driven right up through the trochanter, the top of which is exactly in a line with the axis of the femur. The tip of the drill is made to emerge against the skin of the buttock and then cut down upon. The drill is removed and the peg, 6 to 9 inches long, is then pushed up the proximal fragment until its upper end emerges from the buttock wound and its lower is left about half an inch from the bone end. The two fragments are now brought into apposition and into line, and the peg is hammered down until it engages the lower fragment by several inches.”

Many other forms of medullary splint were devised. Some were of metal but others were of ivory, beef bone or human bone (Hoglund 1917). Apart from the fact that they were

Hey Groves’s method of pegging the shaft of the femur. A—A metal rod has been passed upwards from the site of fracture through the top of the great trochanter. B—The peg is being pushed up into the upper fragment, driving the rod before it. C—Hammering the peg into position. (From Hey Groves’s On Modern Methods of Treating Fractures, 1921. By courtesy of the publishers, John Wright & Sons Ltd.)

seldom long enough to ensure adequate stability of the fracture they suffered the disadvantage that they were absorbed too quickly for initial fixation to be maintained. When metal was used, however, undesirable tissue reaction often occurred with loosening of the nail. Despite the pioneer work of Arbuthnot Lane (1893) in developing the treatment of fractures by applied plates and screws, metallic internal fixation of bone proved to be unreliable and intramedullary fixation as advocated by Hey Groves was not generally accepted.

Lane had always believed that resorption of bone round plates or screws was a consequence of infection and he declared that “rarelying osteitis in plain English means dirty surgery.” The non-touch technique he developed certainly gave him success far beyond that of others,
but bone still reacted to metal by resorption. In 1934 Ménégoux, Odette and Moïse suggested that bone resorption might be the result of electrolysis rather than toxicity or infection; three years later Venable, Stuck and Beach (1937) proved that bone was not resorbed if the metal were electrolytically inert. Hey Groves had been defeated by the imperfections of metals available in his time, and it was only after the development of biologically inert alloys such as 18/8 or 18/12 S.Mo steel and "vitalium," and the demonstration thereafter of the successful application of internal fixation to fractures of the neck of the femur by Smith-Petersen, Cave and Vangorder (1931), that interest in intramedullary fixation was revived. But when the merit of such fixation was proved in fractures of the femoral neck it was a simple step to apply it once more to fractures of the shafts of long bones and to explore again the possibility of introducing nails through the greater trochanter, the great tuberosity and the olecranon.

Intramedullary fixation by Kirschner wires was advocated in England by Lambrinudi (1940) (Fig. 6) and in Belgium by Danis (quoted by Soeur 1946). Steinman pins were driven into the medulla of long bones in America by Rush (1939). But these methods were never mechanically efficient (Watson-Jones 1943) and it was not until wide nails—fully engaging the medulla of the bone—were reintroduced in the Finnish war of 1942, that the technique commanded respect. In Europe it was seized upon with enthusiasm during the second world war when patients were necessarily discharged from hospital as quickly as possible. Moreover, in so far as intramedullary fixation was possible without operative exposure of the fracture, the technique of blind nailing was developed in an attempt to avoid the dangers of bone infection, which had been aggravated by lack of suitable hospital facilities and good nursing. Böhler, whose treatment of fractures has always been dominated by the fear of infection after operative exposure, became an enthusiastic exponent of blind intramedullary nailing.
under fluoroscopic control. He devoted the whole of one volume of his *Treatment of Fractures* to this method and although admitting that the procedure might go on for several hours, he said: “In fresh closed fractures open medullary nailing should not be performed because the risk of infection is very great... If this is done the greatest advantage of the closed medullary nailing, viz., minimisation of the danger of infection, the most precious virtue of the Kuntscher method, is lost.”

The wide application of intramedullary nailing as used in Germany has been reported to us by Le Vay who visited the Schleswig Clinic of Professor Kuntscher in 1948 and studied the work of his colleagues at the University Hospital of Kiel.

**INTRAMEDULLARY NAILING IN THE KÜNTSCHER CLINIC**

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In Germany intramedullary nailing of fresh fractures is the routine treatment in many large hospitals. It is regarded as the best method available for providing maximal function and at the same time maximal fixation; Kuntscher believes that in adults every closed fracture of a long bone, and indeed many compound fractures, should be nailed. He argues that since the nail lies in a longitudinal axis all shearing strains acting at the fracture site are converted into compression forces. The only absolute contra-indication is existing sepsis such as a boil or carbuncle, or poor general condition. Nailing is seldom used in children for here there is no economic urgency and no danger of non-union or stiffness despite long immobilisation. Only two children with nails were to be seen at Schleswig. One was a girl with osteogenesis imperfecta whose femora had been nailed as a protection against further fractures. The other child had a fractured femur in a limb so atrophied after poliomyelitis that delayed union was feared.

Kuntscher used only closed methods for nailing simple fractures, the nail being introduced through a small incision at one end of the bone under intermittent fluoroscopic control. If closed methods failed, the operation was abandoned in favour of traction or plaster. He was entirely opposed to exposure of the fragments at the site of fracture with direct or retrograde nailing as practised by other surgeons. The main types of nail used were straight ones, trefoil in cross-section for the femur and humerus (Fig. 7) and double-spread nails for the tibia designed to engage the expanded lower end of the bone (Fig. 8).

Infection appeared to occur in about 5 per cent of cases but was not necessarily regarded as a disaster. It was believed that if the nail were left in place it acted as a drain carrying pus to the surface and that by immobilising the bone it limited the inflammatory process. All that was then needed was drainage of the soft tissues at the site of introduction of the nail and possibly also at the fracture site.

*Nailing fractures of the femoral shaft*—In nailing the femoral shaft the patient was placed on the sound side with both hips flexed to a right angle against a short post at the groins, the fractured limb lying uppermost and being fixed to a traction stirrup. In this way the greater trochanter was thrown clear of the wing of the ilium which obstructs the insertion of a nail in conventional positions. The writer was impressed by the fact that once the necessary skill and experience had been acquired the insertion of a nail seemed to be a trivial procedure, often carried out by a surgeon single-handed with the help of the theatre sister. The shortage of equipment at that time was such that only the surgeon wore gloves, the sister handling all instruments and the nails themselves. Reduction was checked with two portable X-ray machines equipped for fluorescent screening. In the course of one operation attended by the writer there were twelve screenings, each lasting from two to five seconds; although this was more than usual it seemed plain that even with every precaution such casual screening would not be accepted in Great Britain. The risk of sepsis attendant
on the repeatedly dimmed lights and the manoeuvring of X-ray machines also seemed to be very real.

*Intramedullary nailing for trochanteric fractures*—For trochanteric fractures of the femur a "signal arm" arrangement of two interlocking pins was used and there was a great contrast between the mass of metal introduced and the two tiny incisions needed. The smaller cross-pin was sited with the help of an external guide (Fig. 9). The patient was allowed to walk within fourteen days. The Smith-Petersen pin has been abandoned for medial fractures of the femoral neck, a simple U-section nail being introduced almost vertically by feel alone, from a point well down the shaft, after a radiographic check of reduction. By aiming at continuous impingement against the opposite cortex from below upwards, central nailing was said to result automatically, and so prevent the need for either repeated radiographs or many nails of different length. Over-reduction, with a good ledge of neck supporting the head fragment, seemed to be a feature of these cases.

*Nailing infected fractures with delayed union*—There were very many cases of delayed union and pseudarthrosis of the femur and tibia after war injuries. Some had been nailed even in the presence of sinuses. Union was often secured, sometimes with persisting sinuses, but even then the gain was considerable because patients could walk without splints and mobilise adjacent joints. There was quite often a flare of infection after nailing but drainage paths already existed and—with the cover of penicillin—the risk did not seem to be great. Old compound fractures were never nailed until the temperature and sedimentation rate had been normal for some time. Sequestration sometimes occurred. One patient had a sliver of dead bone alongside the nail and well above the healed fracture in a quite inaccessible position.

*Intramedullary nailing for pseudarthrosis*—Nailing was regarded as the treatment of choice for pseudarthrosis; bone-grafting was done seldom. In the upper limb the bone was shortened to allow adequate freshening of the bone ends. In the forearm it was necessary...
to shorten both bones and to nail them both even when the fracture involved only one bone. No external immobilisation or splintage of any kind was used after nailing. Intramedullary nailing for arthrodesis and osteotomy—Intramedullary fixation was sometimes used after arthrodesis or osteotomy. The method has perhaps reached its height of ingenuity in arthrodesis of the knee joint. At the first operation a nail measuring thirty inches in length—an awesome weapon, seen for the first time—was inserted through the usual stab incision over the greater trochanter and passed through the femur, across the knee joint and down the tibia to just above the ankle (Fig. 10). A curved nail was preferred because it permitted some flexion at the knee. The patient was allowed up within a week or two. At a second-stage operation a chisel was inserted through short incisions at the medial and lateral sides of the knee and the articular surfaces were broken up thoroughly. The patient continued to walk "on the nail," which might be removed when fusion was sound. This long nail also proved valuable for the control of long-standing flexion deformity of the knee joint after prolonged bed-rest or in patients with rheumatoid arthritis. The flexion deformity was corrected by supracondylar osteotomy with immediate immobilisation by a nail passed across the joint.

For arthrodesis of the ankle joint a large tapering nail was inserted through the foot from below, traversing the calcaneum and talus. The second stage, as in the knee, consisted of blind destruction of the joint surfaces, but a drawback here was that the subtalar joint was left damaged by the passage of the nail or was of necessity also arthrodesed. In arthrodesis of the shoulder joint a "shepherd's crook" nail gripped the spine of the scapula and passed into the shaft of the humerus. Nailing was also employed after bone-shortening and bone-lengthening operations and in the treatment of pathological fractures of long bones from metastatic deposits.

General impressions of Küntscher's technique—It was clear that Küntscher disliked extensive open bone operations or any disturbance of the periosteum, and he stated that every such intervention delayed healing; he believed that the advantage of closed nailing lay in the avoidance of such disturbance and the fact that surgical intervention could be limited. All his procedures reflected this attitude—refusal to expose a simple fracture for nailing, avoidance of bone-grafting operations, dislike of plates and screws, and his very limited approach for arthrodesis of the knee joint. One was bound to conclude that such methods were evolved under the pressure of circumstances—the shortage of skilled nurses, the lack of penicillin, the need for immediate fixation without plaster and, above all, the total lack of certainty as to the duration of post-operative stay in hospital determined by the doubtful number of hospital beds that would be available. A virtue was made of necessity.

THE MERIT OF INTRAMEDULLARY FIXATION

In other parts of the world there has been less fear of operative exposure of the fracture and most surgeons have reverted to the technique of Hey Groves and introduced medullary nails under visual control, either by the direct method or by the technique of retrograde nailing. The very great merit claimed for medullary nailing is that the internal fixation is so much more efficient than that of circumferential wire, encircling bands, or plates and screws. The length of the nail controls angulation and the width immobilises the fragments without perforation of the bone cortex by screws and the consequent risk of secondary fracture; at the same time even massive nails can be removed easily at secondary operations through a two- or three-inch incision. In fractures of the upper shaft of the femur—which have always presented difficulty when treated conservatively—the technique has found one
of its most useful applications. Displacement of the fragments is controlled easily and protection can be maintained for long periods so that lateral angulation—which often occurred formerly during the third or fourth months—is prevented. The long nail can safely be left in the bone so that fractures with slow and delayed union consolidate without the hardship of plaster spicas or the annoyance of walking calipers. Malunited fractures and fractures with established non-union may be treated successfully by freshening and replacement of the bone ends, insertion of iliac bone chips and intramedullary fixation—usually with the added protection of a plaster spica for the first two or three months. In some pathological fractures of the femur, intramedullary nailing is the solution to the former problem of best giving comfort during the patient’s often brief survival.

In many other fractures the technique has solved difficult problems. Internal fixation of the fractured ulna in Monteggia fracture-dislocations, and of the fragments of a fractured humerus, particularly in cases of delayed union and non-union, are examples (Figs. 11 and 12). Displaced fractures of the neck of the humerus have been treated more easily than by some conservative means. The method has also been used for fractures of the shaft of the tibia, and for fractures of both bones of the forearm, although with much less certainty.

During the last few months this Journal has received from widely scattered sources many accounts of the complications of intramedullary nailing and the reports have been collated in this review. Nearly every writer in recording the complications has at the same time shown enthusiasm for the technique, and the contributions are valuable not only in reminding us of the difficulties but in suggesting how they may be overcome. Ivar Palmer of Sweden, whose review appears on page 721, has written of the difficulties and complications of
intramedullary nailing with some hesitancy because "it is not pleasant to speak only of the faults of a dear friend." Hugh Smith (1950) in presenting the report of the Committee on Fractures and Traumatic Surgery of the American Academy of Orthopaedic Surgeons wrote: "With experience we have become less timid and have applied intramedullary fixation to a great array of interesting lesions of the femur—namely, fresh fractures, cases of delayed union or non union, the bridging of defects, fractures through pathological bone in Paget's disease, dysplasia or extreme osteoporosis, and osteotomies to correct bowing of the femora from various pathological entities. As from January 1, 1950, 398 intramedullary pins have been inserted. To say that the results to date are encouraging would be an underestimate . . . For those who may be uncertain about proceeding with this technique we offer the following statement—given the proper indications, intramedullary fixation is the most effective form of therapy for many fractures of the shaft of the femur. That statement must now be modified a bit. This technique if applied to improperly selected cases, or if inefficiently or unskilfully carried out, offers more possibilities of trouble than any other."

Within the next few years there will almost certainly be increasing enthusiasm for the treatment of fractures by intramedullary fixation, and surgeons in many parts of the world will look to this operation for the solution of many problems. It is hoped that perusal of these case reports will emphasize that the operation is not always a simple procedure occupying ten or fifteen minutes; that sometimes it has demanded more than four hours of perilous anxiety; and that complications have arisen which have called for all the resources at the command of experienced surgeons. Thomas King of Melbourne writes: "Internal fixation introduces some special complications such as bending or breaking of plates, and the Kuntscher nail has a formidable list of complications. They include severe shock from hammering in a nail that fits too tightly in the medullary cavity, penetration of the bone and severance of the popliteal artery or sciatic nerve, splitting of the femur which means that the operation must be abandoned, and infection of the medullary cavity which is said to occur in 5 per cent of cases. In studying the case histories of more than 600 cases placed at my disposal at various hospitals I found an unbelievable number of complications."

The special purpose of this review is not to press the claims of medullary nailing but, on the contrary, to indicate the difficulties that often arise and to warn surgeons in advance of the dangers that may beset them.

**DANGERS OF MEDULLARY NAILING BY THE CLOSED METHOD**

The technique of intramedullary nailing of fractures by the closed or blind method under fluoroscopic control was developed by Kuntscher in circumstances of war when "a virtue was made of necessity." Le Vay refers to the dangers of X-ray screening which as practised in Germany "would not be accepted in Great Britain." We must indeed wonder how soon it will be before these surgeons or their assistants suffer amputation of the fingers or X-ray gangrene of the nose. Le Vay speaks also of the risk of sepsis from repeated dimming of lights and the manoeuvring of X-ray machines in the region of the wound. But true as it is that many radiographic screenings in the treatment of a single fracture would never be accepted in Great Britain or America, where the tragedies of X-ray burns of the hands and face are well known, the dangers of blind insertion of nails are at least as great to the patient as to the surgeon. We have heard of many disasters arising from attempts to nail fractures of the shaft of a long bone by the closed technique.

**Missing the distal fragment in fractures of the femoral shaft**—In a personal communication, Austin T. Moore (Columbia, South Carolina) describes the case of an elderly diabetic woman whose fracture was so little displaced as to appear to lend itself to blind nailing. Through a small incision the trochanteric fossa was located quickly and there was no trouble in driving a nail down the shaft. The resistance of the fracture line was encountered and then, with ease, the nail was felt to be driven on. Clinically the fracture appeared to be
immobilised completely. The surgeon as well as his assistants "smiled at the ease of the procedure," but when the radiographs came back they found to their chagrin that the nail was lying along the outer side of the lower fragment. The nail was withdrawn and reintroduced after exposure of the fracture.

**Severing the femoral artery**—The significant part of Austin Moore's communication is that he goes on to write: "Visiting a neighbouring hospital the following week I learned of a similar experience in an operation on a fractured humerus. I have since heard of a case where the nail missed the lower femoral fragment and divided the femoral artery. I have come to the conclusion that I will expose the fracture site in all cases in the future."

This is not the only case that has occurred of contusion or division of the femoral artery by the point of an intramedullary nail introduced blindly, even under fluoroscopic control. We know that other femoral arteries have been injured and that limbs have been amputated, but we have not yet been given permission to publish the details of these cases.

**Injury to the radial nerve**—Blind nailing is also dangerous in fractures of the shaft of the humerus where the radial nerve lies so close to the bone that it may be contused or severed. Palmer records two cases of injury to the radial nerve. In one fracture of the neck of the humerus a nail was introduced in retrograde direction through a hole in the shaft at the level of the deltoid insertion, but the nail penetrated the medial wall of the distal fragment and caused radial palsy. The other case was a fracture of the shaft of the humerus in which the nail took the wrong direction and made its way out into the soft parts at the level of the fracture. Injury to the radial nerve caused temporary paralysis.

**Summary of the dangers of blind nailing**—The dangers of nailing by the subcutaneous approach under fluoroscopic control include X-ray burns to the hands and face of the surgeon and his assistants, failure to engage the distal fragment of the fractured bone and injury to the main blood vessels and nerves of the limb. Palmer has independently reached almost identical conclusions from the analysis of 164 fractures treated by intramedullary nailing which he has contributed to this symposium. F. vom Saal of New York wrote a covering note to his invited contribution: "I hope that the necessity for open reduction of fractures before attempting the introduction of a nail has been emphasized sufficiently in this manuscript. Most of the complications could not have occurred with open operations." The consensus in Britain and America is that blind nailing is dangerous and that intramedullary nailing should be attempted only with direct visual control by exposure of the fracture, supplemented by the evidence of X-ray films but not of fluoroscopic screening.

**Impaction of the nail in one of the bone fragments**

What is a surgeon to do when half of a twelve-inch nail is sticking out through a wound and the other half is impacted so tightly that it can neither be driven farther into the bone nor be extracted from it? This is the situation with which many surgeons in all parts of the world have been faced in recent years. Böhler, in his book *Medullary Nailing of Küntscher* (1948), entitled one section: "How to proceed if a medullary nail can be neither driven in farther nor removed." Warren White of Greenville, South Carolina, in discussing a paper by Street (1950), said: "Any surgeon who has inserted a Küntscher nail and has not been able to pull it out has found himself in an embarrassing situation"; and the comment of Eaton of Baltimore was: "the use of too wide a nail may come close to being an unforgettable experience." These American comments show that the British are not alone in understatement. How embarrassing and how unforgettable the experience may be is illustrated in the reports published in this review; they include one in which there was not only impaction of a nail projecting through a wound in the trochanteric region but also impaction of a guide wire projecting through a second wound in the thigh—and neither nail nor guide wire could be moved! When was embarrassment greater? It will be agreed at once that surgeons should not only take careful pre-operative measurements of the medullary canal but that operations

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for intramedullary nailing should not be embarked upon until a sterilized hacksaw is on the instrument table, ready for use.

**Impaction in the shaft of the femur of a nail introduced from the fracture site**—O. J. Vaughan-Jackson (London, England). A woman aged thirty-two years sustained a transverse fracture of the mid-shaft of the right femur (Fig. 13) and fixation by an intramedullary nail was undertaken four days after the accident. Closed nailing was attempted and the first difficulty encountered. The guide wire, introduced at the upper end of the shaft, just medial to the tip of the greater trochanter, impinged against the inner cortex of the femur at the level of the lesser trochanter; despite repeated withdrawal and reinsertion it continued obstinately to follow its first path and impinge against the inner cortex of the femur. After much time had been spent in these unsuccessful attempts it was decided to expose the fracture site and pass the nail up the medullary cavity of the proximal fragment. The fracture was exposed and the blunt end of the nail was inserted and driven into the proximal fragment; but the nail was just too large for the medullary cavity and it jammed very firmly. The slot for gripping the nail with the extractor was of course inaccessible and all efforts at removal failed. Renewed efforts were therefore made to drive the nail on. With further heavy hammering the nail was driven upwards until its upper end was in the trochanteric region. The anaesthetist then announced an alarming fall in the patient's blood pressure. Fully half the length of the nail was still projecting through the wound at the fracture site. In these urgent circumstances, although no suitable instrument was available in the theatre, a hacksaw was obtained hastily from the workshops and sterilized; the end of the nail was cut off, leaving a short stub one and a half inches long which was manipulated into the medullary cavity of the distal fragment (Fig. 14). Apposition was thus ensured, and after closure of the wound the limb was placed in a Thomas's splint with skin traction.

**Comment**—Retrograde insertion of a medullary nail from the fracture site is a practicable and reasonable procedure. The modified nail designed by Burns is easier to insert in this
manner than standard nails but it is by no means indispensable. The primary mistake which led to all the trouble in the case described above was the failure to appreciate from the radiographs that in this slightly-built woman the medullary canal of the femur was unusually narrow. It is suggested therefore that if radiographs show a narrow medullary cavity, it would be a useful precaution to have an antero-posterior radiograph of the fractured bone with the selected nail strapped temporarily to the side of the limb. The magnification of the medullary cavity and of the nail would be approximately equal and measurements on the radiographs of their relative widths would indicate whether or not the nail would pass easily.

Impaction of a nail in the sclerotic bone of a fractured femur in Paget's disease—
E. A. NICOLL (Mansfield, England). A patient suffering from Paget’s disease sustained a spontaneous fracture of the upper third of the femur (Fig. 15). She had the typical flexion-abduction displacement of the upper fragment which is so difficult to control and which in normal circumstances is an indication for open reduction and intramedullary nailing. It

was decided to adopt this procedure and the open reduction proved quite simple. The nail was then introduced from above and was driven about an inch into the trochanter with some difficulty; it then jammed and after another five minutes of redoubled effort the nail had advanced about a quarter of an inch. Further efforts were evidently doomed to failure and were only making retreat more difficult. The nail, it was decided, should be taken out. This took half an hour and several extracting instruments were broken in the process. The fracture was finally fixed by a single oblique screw (Fig. 16), and fortunately the patient made a good recovery with no ill-effects from so much unnecessary trauma.

Comment—This case and another reported below, of a nail impacted in a fractured tibia, illustrate the difficulties caused by failure to understand that it is impossible to drive a blunt nail through sclerotic bone. When pre-operative radiographs indicate dense sclerosis encroaching on the medullary cavity, either in old fractures or in pathological conditions of the skeleton, intramedullary nailing should not be attempted.
Impaction in the shaft of the femur of a nail introduced through the trochanter—and later impaction of both a nail and a guide wire, the nail projecting through a wound over the trochanter and the wire through a wound in the thigh—Report by Hugh Smith (Memphis, Tennessee)—A patient aged twenty-five years sustained a transverse fracture of the upper shaft of the femur which was considered suitable for intramedullary fixation (Fig. 17). It was presumed that the intramedullary canal of an average adult would receive an eleven-millimetre nail without difficulty and a Hansen-Street diamond-section nail of this diameter was passed down the intramedullary canal from above. At twelve centimetres resistance was met. Every attempt, to drive the nail through the area of impingement was of no avail and it was decided to extract it. In this attempt all hooks on the extraction apparatus were quickly broken. A Steinmann pin was placed through the eye of the nail but the eye pulled open. An inlay driven into the medullary canal from below failed to dislodge the nail. Workshop equipment including a pair of vice-grip pliers was used and after great difficulty the nail was extracted. The operating time till then was two hours; blood pressure 130/86; pulse 84.

A review of the radiographs showed that the diameter of the canal diminished in a length of twelve centimetres of the proximal fragment. It was decided to use a narrower nail guided by a wire introduced through the fracture site and threaded backwards to the trochanter. Accordingly a guide wire was passed in retrograde direction through the proximal fragment and out through the upper wound. A nine-millimetre nail was threaded over it and driven into the bone. Very quickly it became impacted solidly in the femur and was compressed so powerfully that it also gripped the guide wire. We were then faced with the problem of a nail projecting through the proximal wound which we could neither drive on nor extract, and a guide wire projecting through the distal wound which we could not move. The trials and tribulations of the next hour and a half need not be detailed. Much equipment was wrecked but ultimately the nail and the guide wire were removed. The anaesthesia time was then three and a half hours; blood pressure 120/80; pulse 96; general condition remarkably good.

As the condition of the patient was so good and our endeavour had not yet been achieved, we went on to widen the medullary canal. By working from each end of the proximal fragment with a nine-millimetre burr we prepared a track through which a nail of similar diameter was inserted (Figs. 18, 19). The operation of intramedullary nailing was concluded successfully after four hours and fifty minutes.

Comment—Since this disastrous case we have done many intramedullary nailing of the femur without embarrassment of impacted nails. Measurement of the intramedullary canal in relation to the nail is made on the opposite femur by strapping a Konitscher nail on the lateral aspect of the thigh and taking radiographs on two films with a film distance of forty inches, from which the correct length and diameter of the nail can be calculated with some degree of accuracy. Nails in a much wider range of diameters are now made available before any operation is attempted, and include diameters from 7 to 11 millimetres. Moreover, care is always taken that perceptible progress is surely made with each blow of the hammer. If there is any sign of impaction the nail is at once withdrawn and exchanged for one of smaller diameter. In order to avoid gripping of the guide wire by the nail the wire is extracted as soon as the nail fully engages the intramedullary canal. Finally, special clamps with vice-grip pliers have been devised which are sufficiently strong to extract an impacted nail.

Pre-operative measurement of the intramedullary canal, and enlargement of the canal by reamers—In a recent personal note Hugh Smith reports that his own experience now includes some forty-five intramedullary nails for the femur; in reviewing the work of twenty-two investigators he has knowledge of well over 450 cases of nails in the femur. A more elaborate and accurate plan of measuring intramedullary canals has now been devised. In his report to the American Academy of Orthopaedic Surgeons (1950) he writes: "There is no formula for determining
the size of the canal in relation to the length of the bone. In general, young athletic individuals with very large bones usually have rather small canals—as little as 6 or 7 millimetres in diameter at the isthmus in the middle and upper thirds. The thick cortices encroach upon the canal. A small elderly woman, on the other hand, may have a very large intramedullary canal so that even an 11-millimetre pin may provide insecure fixation . . . Consultation with the Committee on Roentgenology of the National Research Council failed to divulge any very accurate method of determining the proper pre-operative measurement for the pins. The most accurate technique consists of a scanogram—that is, a full-length detailed picture of the normal femur—with a pin of known diameter and length strapped to the thigh parallel to the shaft of the bone . . . As an added precaution, after exposure of the fragments, reamers, 9, 10 and 11 millimetres diameter, can be introduced proximally and distally into the intramedullary canal. If the canal is not sufficiently large to take a reamer of the desired diameter it can be reamed out until it is so . . . No local or general untoward effects have been noted as a result of this method of enlarging the canal. A clearance of 1 millimetre provides a very tight fit; a clearance of 2 millimetres provides a medium fit.”

**Fig. 17**
Transverse fracture of femur before nailing (Fig. 17). Note narrow intramedullary canal (8 millimetres) of proximal fragment. Figures 18 and 19 show radiographic appearance one day after operation. Narrow canal was enlarged to 9 millimetres before an intramedullary nail could be introduced. The fracture united within three months.

**Impaction of an intramedullary nail in the sclerotic bone of a fractured tibia—**

E. A. NICOLL (Mansfield, England). In June 1948 a man aged forty-six years was admitted with an open fracture of the tibia and fibula with considerable skin loss which was replaced by split-skin grafting. Although the fracture was accurately reduced and was immobilised for eight months it failed to unite (Fig. 20). In normal circumstances a bone graft would have been performed at this stage, but before this could have been undertaken with safety, it would have been necessary to replace the split-skin graft by a pedicle flap. This procedure, together with the subsequent bone graft, would have meant two major operations and a
further twenty weeks' fixation in a man whose knee was already stiff. As the skin over the upper end of the tibia was normal it was decided instead to introduce an intramedullary nail and start mobilisation at once. This operation was done in about ten minutes without any difficulty. At six weeks the patient was able to walk without pain and he had a good range of knee movement; in three months he was back working full time (as a gardener) and had recovered almost normal movement of the knee. Recent radiographs show a well-united fracture (Fig. 21).

A few months later a similar problem was encountered (Fig. 22); in view of the success of the first case, it was decided to adopt the same procedure. The nail was driven along the medullary cavity without difficulty until it reached the level of the fracture. At this stage it jammed; no amount of hammering would induce it to go farther, nor could it be extracted; and in spite of reluctance to expose the fracture through a split-skin graft, there was finally no alternative. When this had been done the reason of the difficulty was at once appreciated: the lower cortex of the upper fragment was very sclerotic and encroached upon the medullary cavity. The point at which the nail was jammed had to be exposed by removing the overlying cortex and cutting a channel through which it could be guided into the lower fragment. In spite of forebodings the wound healed by first intention. All pain disappeared, recovery was complete and the patient went back to his work as a miner (Fig. 23). It is obvious that if the significance of the sclerosis been appreciated the considerable difficulty encountered at operation might have been foreseen and the whole plan of treatment altered.

**Other cases of impaction**—Further examples of impaction of a nail in the femur, tibia or humerus are reported by Palmer and by vom Saal in their independent reviews included in this symposium. In one of Palmer's cases the femur was split during a stubborn attempt to drive in too coarse a nail (page 723). In another case of fracture of the humerus impaction led to distraction of the fragments with delayed union (page 727). In vom Saal's case also, impaction of the nail was associated with distraction of the fragments, and contact was restored only after very considerable difficulty (Fig. 49, page 720).

**Summary of the complications arising from impaction of medullary nails**—Impaction of a nail so that it cannot be driven farther into the bone or be extracted from it presents very great difficulty. Forcible hammering may shatter the bone and cause myositis ossificans; and if the nail has already passed the site of fracture the fragments may be distracted and union delayed. It is therefore better to use every device for extraction of the nail with the object of introducing one of narrower dimension; then if these efforts fail, to saw off the projecting part. If the nail has been introduced in retrograde direction from the fracture site a short projecting stub should be left so that it can be angulated into the distal fragment and some fixation, however imperfect, be gained.

**EXTRUSION OF INTRAMEDULLARY NAILS FROM THE BONE**

Extrusion of three-flanged nails used for the fixation of fractures of the femoral neck has been attributed by many surgeons to resorption of bone at the site of fracture with consequent impaction of the fragments. It has often been claimed that such extrusion should not be prevented by the use of a cross-pin in the trochanteric region because impaction of the fragments was inevitable and if the nail were fixed in the distal fragment it would perforate the proximal fragment and enter the joint. Some of us have doubted this explanation. Penetration of the head of the femur by a nail occurs only when the bone is dead, and in these circumstances it occurs whether the nail is fixed by a cross-pin or not. Moreover, continued resorption of bone in the region of any fracture does not occur if there is complete immobility of the fragments. Finally, the length of nail extruded from the neck of the femur through the trochanter was often far greater than could be explained by the degree of resorption and impaction of the fragments. It has seemed more likely that extrusion was a positive expulsion, perhaps arising from the pressure of products of ionisation and foreign body.
Delayed union of a fractured tibia treated successfully by intramedullary nailing.

Figure 22—A similar problem to that shown in Figure 20. But when the nail had reached the site of fracture it could not be driven farther because of dense sclerosis. Efforts to extract the nail were unsuccessful and it was necessary to expose the fracture and cut a channel for the nail before it could be driven across the fracture. Figure 23 shows radiographs at the conclusion of treatment.
reaction accumulating between the nail and the bone. Certainly experience of intramedullary nailing of shaft fractures has shown that when a nail is extruded the length of metal expelled has no relationship at all to the impaction of fragments. In one case, personally communicated, a patient whose fracture of the shaft of the femur had been immobilised by a nail driven through the trochanter complained after several weeks of pain in his chest; it was found that the proximal end of the extruded nail was impinging against the ribs!

**Extrusion of intramedullary nail from the femur**—Reginald Watson-Jones (London, England). A man aged forty-seven years fell through a garage roof and sustained a comminuted fracture of the upper third of the shaft of the femur which was treated by immobilisation in a Thomas's splint with skin traction. After fifteen weeks, clinical tests suggested that union was sound enough to begin non-weight-bearing exercise and the splint was removed; but two weeks later it was evident that union was not consolidated and the fragments were bowing outwards. Instead of reapplying the Thomas's splint or immobilising the limb in a plaster spica an intramedullary nail was introduced through the trochanter (Fig. 24). Bed exercises were continued and weight-bearing was allowed after four weeks. After two months the patient complained of discomfort in the trochanteric region where the end of the nail could be felt; and after three months the pain was so severe that he was unable to walk. Serial radiographs showed progressive extrusion of the nail (Fig. 25). A short incision was made above the trochanter and when the scar tissue over the extruded nail was divided there was a spurt of clear, free fluid which was obviously under pressure. The nail was hammered back into the bone and a two-inch screw was driven through it (via a machine-drilled hole) at right angles to its long axis, into the lower part of the femoral neck (Fig. 26). Weight-bearing was then continued and the fracture consolidated soundly in good alignment. No further trouble
has arisen although five years have now elapsed, and the nail and cross-screw are still in the bone.

**Extrusion of medullary nail from the humerus with impingement against the acromion**—Reginald Watson-Jones (London, England). In 1947 a woman aged thirty-six years came to England from Israel with a fracture of the shaft of the humerus still ununited after thirteen years. So many operations had been performed that the patient had lost count of them; she thought that there had probably been sixteen, but was sure that seven bone-grafting procedures had been carried out with transplantation from both tibiae, one femur and both sides of the pelvis. All these operations had failed and there was a freely mobile pseudarthrosis of the lower shaft of the humerus with only 10 degrees of movement of the elbow joint and 80 degrees of shoulder-girdle movement. The fracture was exposed, the fragments freshened and a nail driven through the great tuberosity across the fracture site of the supracondylar level. Iliac bone chips were packed tightly between the bone ends and the limb was immobilised in a plaster spica for four months. Exercises were then begun but there was increasing discomfort in the shoulder. After seven weeks the end of the nail could be felt under the deltoid, with a fair-sized bursa in which it creaked. There was obvious impingement against the acromion process when abduction was attempted (Fig. 27). Union was not yet consolidated soundly enough to permit removal of the nail, particularly in view of the previous history of many grafting operations which had failed after apparent initial success. It was decided to excise the acromion (Fig. 28); this allowed continued mobilisation of the shoulder, but the nail continued to extrude very slowly and fifteen months after the original operation it was decided to remove it. By this time the end of the nail was lying almost subcutaneously and we expected the extraction to be completed within two minutes. In fact after twenty or thirty minutes of laborious effort I nearly fell backwards across the theatre as it was finally dislodged!
BENDING OR BREAKING OF THE NAIL

The complication of a nail bending or breaking is largely a technical problem that must be tackled by the manufacturers in consultation with orthopaedic surgeons. There can be no doubt that in many if not most of such cases the fault has been that the metal was too soft (Fig. 29) or that the cross-section was unsuitable. The bending forces acting at the site of fracture in a large bone such as the femur are much greater than is commonly understood. Charnley (1950) has calculated that in a person of average height and weight gravity alone may exert a tension force of 220 lb. at the cortex of the mid-femoral shaft when the limb is unsupported; and because the cross-section of an intramedullary nail is less than that of the femur the forces acting upon the nail are correspondingly more severe. When it is considered that to the force of gravity must be added the many extraneous stresses to which an unsupported limb is subject it is not surprising that from time to time there are reports that a nail has broken or bent.

In a personally communicated case of a woman aged sixty-three years whose left femur was nailed for an upper shaft fracture complicating Paget's disease, the nail began to bend two months after the operation; radiographs taken at the thirteenth week showed that the nail had broken about one inch below the level of the fracture, which was not yet united. Union was ultimately secured after a prolonged period of external splintage. In such a case, to extract the distal half of the nail would present such formidable difficulties that it would seldom be attempted.

Bending of a nail with angulation of a fractured shaft of the femur—DAVID TREVOR (London, England). A tailoress aged twenty-three years was admitted to hospital in March 1946 with a closed transverse fracture of the middle of the left femoral shaft with gross displacement, the result of a road accident. The fracture was considered suitable for fixation by means of an intramedullary nail; no difficulties were encountered in its insertion a week later. The fracture site was exposed through a small lateral incision and the guide was passed through a curved incision over the great trochanter and made to enter the medulla of the proximal fragment just to the medial side of the trochanter. When the guide had emerged at the fracture site the fragments were accurately reduced and the guide was driven into the medulla of the distal fragment. A suitable nail was threaded along the guide, which was then removed. Knee movements were encouraged from the beginning, walking was allowed ten days later, and at the end of four weeks the patient was discharged home.

Progress was satisfactory until three months after the accident when the patient fell into an empty bath during an epileptic fit. Examination on readmission revealed 30 degrees' angulation of the left femur (Fig. 30). The bent nail could not be extracted; it was therefore decided to attempt to straighten the nail and correct the deformity by closed manipulation although it was not known whether the nail would straighten or snap. With the operator's bent knee against the convexity of the deformity and counter-pressure applied with each hand at the upper and lower ends of the inner side of the thigh, good correction was obtained (Fig. 31). Because of the possibility of further epileptic fits external splintage by a plaster hip spica was considered advisable, and was continued until bony union was sound—seven months after the injury. The nail was then removed (Fig. 32). One year after the injury full function of the limb had been regained.
Figure 30—Angulation of nail and fracture caused by a fall during an epileptic fit three months after nailing. Figure 31—After straightening limb and nail by manipulation. Figure 32 shows union consolidated seven months after nailing.

Further instances of bending of the nail are reported by Palmer and by vom Saal. In Palmer’s series of forty-six fractures of the femur treated by nailing, there was bending in five; and he noted several cases of bending with angulation of the fracture after nailing of the radius and the ulna. Vom Saal emphasizes the importance of securing a snug fit of the nail in the bone; he has observed that when a nail fits loosely the risk of bending or breaking is appreciably increased.

**JOINT INJURY AND JOINT STIFFNESS**

Although the importance of driving the nail through a sufficient length of bone to secure rigid fixation is generally recognised, the accident of overdriving a nail through the articular cartilage into the adjacent joint cavity does not appear to be a serious hazard. In the selection of a nail of appropriate length the margin of safety is fairly wide; and with the additional safeguard afforded by control-radiographs, overdrive into the joint is easily avoided. When joint injury has occurred it was usually caused by a nail that penetrated the soft tissues and encroached upon the joint from outside the bone. Harm may be done without penetration: the point of a nail lying close to a joint may interfere with its function by setting up a local irritative reaction or by forming a mechanical block to joint movement.

**Penetration of the knee joint by a nail which perforated the anterior femoral cortex**—O. J. Vaughan-Jackson (London, England). A man aged twenty-three years had fractured the mid-shaft of the right femur while serving in the Army. Three months after the injury an anterior onlay bone graft had been applied and secured with six screws. Within a few weeks of the operation the graft had broken. The limb was immobilised in a plaster spica. Five months later he was allowed up with a walking caliper, and was finally discharged.
from the Army. He first attended the London Hospital sixteen months after the injury; there was gross forward bowing at the site of fracture and the limb was short by one inch. There was mobility at the site of fracture, which was painful. The patient was walking with the aid of two sticks. Radiographs showed an ununited fracture with forward angulation (Fig. 33). It was decided to explore the fracture, remove the screws, freshen the bone ends, immobilise the fracture with an intramedullary nail and pack cancellous bone chips around the site of fracture.

Some initial difficulty was met in removing the screws which were bent within the bone. The fracture ends were freshened and a small wedge of bone with the base anteriorly was removed to permit correction of the angulation and adequate apposition of the fracture ends. A small incision was made over the greater trochanter and a twelve-inch nail was passed down through the upper fragment to the site of fracture. The point of the nail was guided by eye into the lower fragment and the nail driven home. It was considered safe to do this as the length of the nail was chosen after the length of femur had been measured, and there seemed to be no risk of its point penetrating the distal end of the femur; moreover, the two fragments could be seen to be in accurate alignment. The wound was closed and only on the day after operation was a further radiograph taken to check the position of the nail. It showed that the end of the nail had emerged obliquely through the thin anterior cortex of the lower end of the femur (Fig. 34). The nail clearly had gone on to penetrate the suprapatellar pouch and come to rest against the upper pole of the patella. A further operation was undertaken. The trochanteric incision was reopened and the nail was withdrawn one inch (Fig. 35).

Comment—Though this was a comparatively minor mishap, it draws attention to the fact that, while the thick cortex of the upper two-thirds of the shaft of the femur can be relied on to retain the advancing point of the nail within the medullary cavity, the thin cortex of the lower end is not dependable. However perfect reduction may seem there must always

![Fig. 33](image1)

Ununited fracture of femur fourteen months after bone graft (Fig. 33). Open reduction and fixation with an intramedullary nail were performed, but subsequent radiographs showed that the point of the nail had penetrated the anterior cortex of the femur and was lying close to the upper pole of the patella (Fig. 34). At a second operation the nail was withdrawn till its point was flush with the cortex of the distal fragment (Fig. 35).

![Fig. 34](image2)

![Fig. 35](image3)
be—owing to the normal anterior curve of the femoral shaft—a risk of penetrating the anterior cortex of the distal fragment with the nail, which necessarily advances in the axis of the proximal fragment and at an angle to the axis of the lower fragment. No matter how confident the surgeon may feel, it is nevertheless essential to check the position of the nail by radiographs in two planes before closing the wound.

Mechanical interference with movement at the elbow joint by a nail introduced into the humerus from its distal end—J. G. Bone (London, England). A middle-aged woman had sustained a fracture involving the lower and middle thirds of the left humerus with separation of a "butterfly" fragment. There was associated paralysis of the radial nerve. Two months after the injury an intramedullary nail had been inserted from the lower end of the humerus and the distal fragment had been wired to it with two encircling loops. After the operation the limb was immobilised on an abduction splint. When she was first seen by the writer two months after the operation there was gross restriction of movement at the elbow joint, which was practically fixed at a right angle; the shoulder joint was markedly stiff also. There was no evidence of recovery of the radial nerve lesion. Radiographs showed that the fracture was not united. The lower end of the nail was very close to the elbow joint and appeared to form a mechanical block to extension (Fig. 36). A period of intensive rehabilitation was successful in restoring a useful range of shoulder movement, and during this time the nerve lesion recovered fully. The intramedullary nail was removed five months after its insertion and intensive efforts were made to mobilise the elbow. A range of 45 degrees was all that could be achieved and it soon became obvious that union at the fracture site was unsatisfactory. With continued use of the elbow a pseudarthrosis gradually developed, until it became clear that further operative treatment was necessary (Fig. 37). Accordingly the humerus was exposed through an antero-lateral incision, the fracture surfaces were trimmed and freshened into a step-cut formation and a plate was applied. Post-operative progress has been satisfactory to date.
NON-UNION FROM UNPROTECTED WEIGHT-BEARING

The experience of many surgeons has shown that in suitable cases intramedullary nailing can usually be relied upon to secure sound bone-union provided a careful technique is used and a rigid mechanical fixation is achieved. In most examples of delayed union or non-union that have come to our notice the failure has been attributable to the use of the method in unsuitable cases or to errors of technique. If the nail fits too loosely or is too short, fixation will be inadequate and rapid union cannot be expected unless immobilisation is aided by external splintage. An error that is less obvious, though perhaps no less important, is to permit distraction of the fragments during introduction of the nail. An example of this complication is recorded by Palmer in his contribution to this symposium.

**Non-union: absorption round nail from early unprotected weight-bearing**—Reginald Watson-Jones (London, England). A man aged forty-five years sustained a fracture of the shaft of the right femur in Switzerland in January 1947. Three days after the injury an intramedullary nail was introduced. Early weight-bearing was permitted. Two months later there was movement at the fracture site. A short thigh plaster was applied and he continued to take weight on the limb. When first seen by the writer fourteen months after the nailing operation the fracture was still mobile. Radiographs showed established non-union and there was evidence of absorption of medullary bone around the distal part of the nail (Fig. 38). Because of the absorptive changes further medullary fixation was considered impracticable. Onlay bone grafting gave sound bone-union within four months.

**Comment**—The fracture was well below the mid-shaft of the femur and the radiographs suggest that the distal part of the nail was gripped only by cancellous bone. Mechanical fixation was not sufficiently rigid to withstand the stresses of unprotected weight-bearing. If immobilisation...
Fragile bones in Paget's disease: multiple fractures after intramedullary nailing of a fractured femur
—H. Jackson Burrows (London, England). A woman aged sixty-eight, with Paget's disease, broke her right thigh at the junction of lowest and middle thirds, without violence, as she stepped from the Channel packet to enjoy a Continental holiday. From this beginning she sustained three more fractures in the course of treatment during the next five months. The original fracture of the right femur was treated with an intramedullary nail (Fig. 39); two months later, when she was getting out of bed, she broke the left femur; during an operation for nailing this (Fig. 40), the right patella became broken; two weeks before repatriation a "crack" occurred near the lower end of the right femur. It was all the fault of the patient: her "bones were like glass!"

REVIEW OF THE COMPLICATIONS IN INTRAMEDULLARY NAILING
Frederick vom Saal, New York, N.Y.

The widespread use of any new surgical method is always accompanied by more complications than any one surgeon could imagine possible. The same will be true of intramedullary nailing. No attempt will be made to cover the many possible complications but a few of the major pitfalls will be reviewed. Complications fall into two major groups: those caused by the carelessness of the patient and those caused by the carelessness of the surgeon. The latter group is much the larger and more important.

A properly done intramedullary nailing gives the patient such a complete sense of security that he may become careless. A young man standing at the front of a tram three weeks after nailing was thrown across a seat when the tram started abruptly. The femur was bent at the fracture site (Fig. 41). One of the advantages of intramedullary fixation is that most of one's difficulties can be resolved, and in this case the patient was anaesthetised and the nail straightened manually, using the post of the fracture table as a fulcrum. While the limb was steadied by an assistant, the upper incision was opened, the nail extracted and a new nail inserted (Fig. 42). The patient merely suffered the inconvenience of two days' stay in hospital and went back to his former routine. Union continued uneventfully. After such a complication one must not, however, make the mistake of straightening the nail and leaving it, because bending will probably recur.

Since six or seven nails are sterilized for each intramedullary fixation, it is possible for a nail to be repeatedly boiled and discarded until it softens, and then will bend quite easily after insertion. Since this has twice happened to the author it is now his practice not to boil the nails but to place them in antiseptic solution for several hours.

The malleable clover-leaf nail is preferred to the more rigid Hansen–Street pattern because it will adapt itself better to irregularities of the cortex, will not rotate during insertion and as it is less liable to shatter the bone can therefore be inserted snugly. It will bend to follow the normal anterior curve of the femur, and will even follow the marked curve seen so frequently in Paget's disease. This malleability has certain disadvantages as was pointed out above in the case of a nailed femur—and the same holds true for the forearm. The malleable square clavicle nail is much easier to insert, particularly into the radius, but may
There is occasional lead to trouble. Figure 43 shows the forearm of a thirty-two-year-old man. Notice in the post-operative radiograph (Fig. 44) how the nail, inserted from the distal end of the radius, has bent and slid down the canal. Five days after nailing the patient disappeared. He went back to truck-driving, taking care of his three children and even doing the family wash. He returned after six weeks with a bent forearm (Fig. 45), union, excellent function but permanent limitation of supination of 45 degrees. In uncertain cases, and to guard against a euphoric patient, it is better to use the more rigid V-nail in the ulna and to guard against double malleable nails only in patients who can be supervised.

After nailing of both bones of the forearm a difficult problem may arise when one bone unites more rapidly than the other. In fractures of the proximal part of the forearm first and then distract the ulna. Figure 46 shows a united radius holding apart the ulnar fragments with resultant non-union. It is advisable in this type of injury to lay bone grafts across the ulnar fragments, even in fresh fractures.

Because of its configuration the humerus is the least satisfactory bone in the body for intramedullary nailing. For shaft fractures the nested V-nail should be used. One is sometimes tempted to use a single nail because fixation seems adequate but consideration of the following two cases should serve as a reminder of the risk incurred. The first (Fig. 47) shows a transverse fracture of the mid-humerus which was exposed because of a radial nerve paralysis; nailing was done from below. Fixation seemed adequate, but the nail gradually slid distally out of the bone (Fig. 48)—presumably because of the forces of gravity and of movements of the arm. The fracture angulated a little but fortunately united. Some difficulty was experienced because the nail gradually worked its way out through the skin. If the nail comes out before union, all fixation is lost. This happened in the second case. The fracture was nailed from above in an attempt to overcome the gravity factor. Nevertheless the nail began to migrate down through the bone and some absorption took place around it. Fixation was therefore lost and non-union became established. The difficulty was overcome by the use of nested V-nails, the ends of the two nails being bent apart so that it was impossible for them to migrate or for the fragments to rotate. This method ensures adequate fixation in a fresh fracture. In non-union—because there is a distraction rather than an impaction factor in the humerus—the fracture may still fail to unite unless bone grafts are applied to the humerus. Full use can then be allowed and rapid union is the rule.

Carelessness in the selection of nails can easily bring disaster. When the nail is too short or too narrow rotation, bending or breaking happens easily. It is also possible to select a nail that is too large. This happened in one of our cases of femoral shortening (Fig. 49). The nail became impacted in the canal and, when it was hammered, simply drove the fragments apart at the site of osteotomy. So much force was used in trying to extract the nail that the end was broken off. The nail was finally pulled up and the fragments so brought back into
apposition; the end of the nail was then sawn off with a hacksaw. Fixation was adequate because the nail was tightly stuck in the canal, a much better condition than when a nail is too loose. In spite of the operative difficulty the patient did very well. Within fourteen days there was a large amount of callus around the osteotomy site. After seven months, when union was secure, the nail was removed without difficulty.

Inserting a nail that is too loose or too short is easier for the surgeon but a real danger to the patient. In a mid-femoral fracture the leverage on a loose nail may equal several thousand pounds. As a result the nail may easily bend or break (Fig. 50). If the nail is snug the force is markedly reduced. A loose or short nail may also allow rotation of the fragments. One must also remember that all intramedullary nails loosen. If the patient is kept off the foot, atrophy and absorption are hastened and the nail will loosen more rapidly; then, when weight-bearing is finally allowed, one has the same problem as in a poor loose insertion. Inferior metals may also break or bend. The nails should be made of 18/8 S.Mo steel and carefully tempered so that they are neither brittle nor too soft. A reliable manufacturer is important.

In one case of femoral shortening we encountered a complication peculiar to intramedullary nailing. The piece of bone removed for the shortening was cut up and part of it laid about the osteotomy site, but the grafts were not fastened. The patient was allowed out of bed in twenty-four hours with weight-bearing. Radiographs taken three days later showed that the early movement of the soft tissues around the osteotomy site had scattered the bone.
Extrusion of nail after intramedullary fixation of a fracture of the humerus.

Distraction of the fragments caused by hammering a nail which was impacted in the distal fragment.

Breakage of a nail that was too narrow. (Radiograph from a case of Dr. Arthur Thibodeau.)

Scattering of applied bone grafts due to early movement of the soft tissues surrounding the site of osteotomy.
grafs (Fig. 51). Although this did not slow down healing it did cause an undesirably large mass of callus. So it is better when using supplementary bone grafts after intramedullary nailing to fasten them to the shaft by means of circular chromic catgut, silk or wire. This was done in another case of femoral shortening, two grafts being fastened on with chromic catgut. Radiographs seven months later showed secure union. The patient had begun walking after twenty-four hours; at one month he was swimming and enjoying all sorts of exercise short of competitive sports. However, the case illustrates another point. The upper end of the femoral nail protruded a fair distance from the femur. This also is undesirable. There are two complications. First, the nail tends to hook under the glutei when the patient sits; and when he sits on a low chair he may not be able to get up. Second, the oscillation of the end of the nail causes the formation of a bursa: which may become calcified. After removal of the nail there were no symptoms from the calcification. The nail should not protrude more than one inch from the trochanter.

To sum up: there are many possible complications of intramedullary nailing, most of them springing from carelessness or lack of understanding of the principles of intramedullary fixation.

Conclusions—The fracture should be treated by open reduction. The nail selected must fit the canal snugly and be buried in cancellous bone at each end of the shaft. In the tibia and humerus, multiple nested V-nails should be used to prevent migration and rotation. Movement and impaction should be begun immediately with the upper extremity, and weight-bearing with the lower extremity. Each of the above points is a "must"; if they are rigidly observed, complications will be at a minimum and the surgeon will have at his command a method which provides the most rapid union with the least cost and the greatest return of function.

REVIEW OF THE COMPLICATIONS AND TECHNICAL PROBLEMS
OF INTRAMEDULLARY NAILING

Ivar Palmer, Stockholm, Sweden

The purpose of this paper is to summarize my experiences of the difficulties of intramedullary nailing. I do this with some hesitancy, for it is not pleasant to speak only of the faults of a dear friend. However, intramedullary nailing has proved itself to have so many true virtues that we can afford to discuss its negative qualities too. Few methods have given us so many happy surprises. The after-treatment of patients has been simplified, the stay in hospital has been shortened and, as our experience accumulates and our technique improves, so complications have grown increasingly rare. Success in intramedullary nailing depends to a great extent on the skill and experience of the surgeon. The operation should not be attempted by surgeons unaccustomed to bone and joint surgery or who have a limited fracture material at their disposition.

Many of the difficulties of the operation have been appreciated and remedied. But there is still room for improvement. Technical equipment has certainly not yet reached perfection. Among early errors I am inclined to include the original theory that fractures should be reduced by the closed method, either manually or with the aid of various types of reducing apparatus. The closed method does not always give sufficiently exact reduction to permit precise nailing; consequently the nail may escape into the surrounding soft tissues; renailing is often necessary; the operation may take an unexpectedly long time, and may entail numerous radiographic exposures, bringing the danger of X-ray burns to both patient and attendants. In the author's opinion it is as a general rule unwise to attempt closed reduction.
Every case of intramedullary nailing undertaken in my service during the period 1944 to 1950 has been reviewed. Nailing was performed for the following fractures:

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Total: 164 cases

The complications and technical problems that have developed in the treatment of these cases are not necessarily disclosed by the case reports, some surgeons undoubtedly preferring not to mention their difficulties. In the following paragraphs I shall therefore confine myself to the more striking complications from which lessons have been learnt. Errors and complications of the method may be placed in the following categories: 1) Technical errors that are manifested during the course of the operation. 2) Post-operative complications arising from some technical error during the operation or unsuitable post-operative treatment. 3) Post-operative complications not arising from technical errors or unsuitable post-operative treatment. Since the anatomical conditions—and consequently the technical problems—vary in the different groups of fracture, each type must be studied separately.

**Fractures of the Femur**

Forty-six patients were operated upon, one for open fracture. In the post-operative treatment no external fixation was used at all in some cases, walking on crutches being permitted after one week. In other cases fixation in the "snow-plough" splint was used—that is, a simple wooden splint supporting the limb in slight abduction and neutral rotation for two to six weeks. Fractures of the femur, like those of the ulna, are especially suitable for intramedullary fixation. A straight nail can be inserted from the apex of the bone (greater trochanter, olecranon) which is easily accessible.

**Operative difficulties. Indications**—The first problem is to decide whether the particular fracture is suitable for intramedullary nailing. The most suitable are transverse fractures of the shaft, unless they are moderately oblique or comminuted with small fragments, in which event the method is contra-indicated. The subtrochanteric abduction fracture is also well suited for intramedullary nailing, unless the trochanteric fragment is splintered. Supracondylar fractures may also be nailed provided the fracture line is almost transverse. Any fracture that is grossly comminuted is unsuitable for nailing; fixation is poor and union may be delayed because of defective vascularity of the intermediate fragments. If there is a large intermediate fragment, nailing and circumferential wiring may be combined to advantage. But under no circumstances should the intermediate fragment be dissected away from its soft-tissue attachments.

**Impaction**—The next difficulty is to choose a nail of the correct size. Radiographs give an estimate of the calibre of the medullary canal, but mistakes are easily made. Very often the nail has met resistance when being inserted; it has had to be extracted, occasionally with considerable difficulty, and replaced by a smaller nail. The opposite situation has also been encountered: the nail enters too easily, in which case it has to be extracted and replaced with a larger one.
In one case the nail became impacted before it reached the distal fragment and had to be sawn off and left where it was, the fracture then being treated with traction. In another, the shaft of the femur was split during a stubborn attempt to force in too coarse a nail; fortunately this did not interfere with the healing process. Rule—Force must never be used. The nail should be extracted and discarded if difficulty is encountered on insertion.

Finding the passage—Some experience is required to be able to locate the medullary canal when driving the nail in. The simplest way is to begin from the tip of the trochanter (Fig. 52)—not from the trochanteric fossa—and to determine the direction by localizing the distal end of the proximal fragment. A hole four to five centimetres long should be made in the correct direction with a strong pin-driver. The ring of the metal when the nail penetrates through the medullary canal will serve as guidance for the experienced operator. In at least three cases the surgeon unwittingly drove the nail through the neck into the medial soft parts (Fig. 53); fortunately no harm was done. Rule—The nail should be introduced from the tip of the trochanter and great care should be taken to determine the correct direction before driving the nail.

The nail passes alongside or penetrates the distal fragment—The nail is driven down through the proximal fragment until it is judged to have reached the level of the fracture. If it is inserted too far its withdrawal may be difficult (Fig. 54). The fracture is then exposed and is exactly reduced. The nail is driven in farther, but this time by an assistant while the surgeon sees to it that the reduction is maintained as the nail continues its progress. The nail has an amazing faculty for making its way out to the side of the distal fragment. The greatest care must be taken to reduce the fracture in exact alignment. If any angulation is allowed the position will be locked by the nail when it is inserted and the nail may force its way out and possibly penetrate the knee joint at the epiphysial line (Fig. 55). This has occurred in one case. Rule—The nail must be inserted only to the level of the fracture before the exploration. Apposition and alignment of the fragments must be exact.

Post-operative complications caused by technical errors. Distraction of the fragments; delayed union—In one case of transverse fracture, distraction of about half a centimetre developed during nailing. The post-operative course was characterised by delayed union and a tendency to pseudarthrosis. At a second operation the distraction was reduced and the nail reinserted. The fracture united. Rule—Avoid distraction of the fragments.

Bending of the nail—In five cases the nail bent post-operatively as a result of weight-bearing or muscular action or, in two cases, from accidental injury. If a nail bends there is little point in trying to straighten it. Its strength will be reduced, it will bend again and ultimately break. The very suggestion of a bend in the nail should cause the surgeon to change nails. This is both quick and easy. The bend is straightened gently by correcting the deformity in the extremity, the nail is extracted and a new and somewhat shorter nail is immediately inserted. The second nail should be larger, because the first one will have become loose in the canal.

If healing is delayed, which often happens in transverse fractures no matter how they are treated, it can be stimulated by exploring the fracture and packing the area around it with cancellous bone chips. Rule—If a nail bends it should be discarded immediately. Explore, and insert cancellous chip grafts if union is delayed.

One case of the five mentioned above caused trouble. The patient was a very obese fourteen-year-old girl. The nail had been badly bent in an accident. Extraction proved impossible because at the first operation the nail had been sawn off below the extraction hole; further, the obesity of the patient made it impracticable to drill a new hole. Ultimately the surgeon managed to straighten the nail and to withdraw it a short distance so that a sound section was brought to the level of the fracture. Rule—Never use improvised, unsuitable material. Make sure that the nail is the right length before driving it in. See to it that the nail always is provided with an extraction hole.
The nail should be introduced at the tip of the greater trochanter (Fig. 52). If it is introduced in the trochanteric fossa the nail may penetrate the medial cortex of the femoral neck (Fig. 53).

Nail has been driven too far before exploration of the fracture. It has missed the distal fragment and penetrated the soft tissues.

Angulation has not been adequately corrected. Nail has penetrated anterior cortex and entered the suprapatellar pouch.

Calcified bursa around the upper end of the nail.
Post-operative complications independent of technical errors. *Fat embolism*—It is difficult to decide whether fat embolism is more common with intramedullary nailing than with other methods. Lauritzen (1948) reported two cases of fatal fat embolism in a series of thirty-eight cases. My material includes two cases of pulmonary fat embolism, neither of which was fatal.

*Thrombosis* was seen in one case.

*Bursitis at the upper end of the nail*—Enough of the nail should be left free above the tip of the trochanter to enable it to be extracted. However, the end of the nail may irritate the tissues and give rise to a sometimes painful bursa formation. Occasionally the wall of the bursa will become calcified, in which case it can be seen clearly in the radiographs (Fig. 56). No case of infection was observed.

**Fractures of the Tibia**

Ten patients were nailed—two for open fractures. After operation, the patients walked immediately in an ordinary long leg plaster. Because of its shape the tibia is not well suited for intramedullary nailing: the profile of the medullary canal is like an hour-glass, which means that the nail easily becomes impacted in the narrow, middle part of the bone. The method is not advisable in these fractures.

**Operative difficulties. Indications**—We have confined the use of the method to transverse fractures in the middle and lower parts of the bone. Other types of fracture are better treated by alternative methods.

**Impaction**—The most suitable width of nail is more difficult to determine for the tibia than for the femur. For the tibia it should be as coarse as possible, otherwise fixation will be poor; but it must be narrow enough to pass through the constricted central part of the bone.

The nail became impacted in two cases. In one of them it had penetrated one centimetre into the distal fragment before it became impacted, and it therefore did some good (Fig. 57). In the other case it never reached the lower fragment. It had to be sawn off and left in place, after which the fracture was fixed by wiring. A few weeks later the nail was removed without difficulty as its track had become widened by decalcification.

**Wrong approach**—If an intramedullary nail is to be inserted from the side into the tibial shaft a very oblique entrance canal must be prepared and the tip of the nail must be slightly curved. In one case in which these two rules were not observed the nail showed a stubborn tendency to perforate the cortex at the level of the fracture where the resistance of the wall was decreased (Figs. 59 and 60).

**Post-operative complications caused by technical errors.**

**Distraction; delayed union**—In one case the nailing caused considerable distraction (Fig. 58) and greatly delayed union; nevertheless the fracture was consolidated after fourteen months. This patient was one submitted to intramedullary nailing for open fracture of the tibia.

**Bending of the nail**—In three cases the nail bent post-operatively and permitted angulation of the fracture which could only be partly
corrected. The complication develops from the nail being driven in from the side with so curvature. The risk of deformation is increased if the entrance canal is not made sufficient oblique.

**Complications independent of technical errors**—There were no cases of fat embolism, thrombosis or infection.

**Fractures of the Upper End of the Humerus**

Twenty-five patients were treated. After nailing, the arm was supported in slight elevation with neutral rotation and the hand suspended for the first week. Thereafter a sling was applied with a cushion for support. Exercises were begun on the first day.

Intramedullary nailing is very useful in displaced fractures of the neck of the humerus. The nail is introduced through an oblique canal beneath the deltoid tuberosity where:

![Image](Fig. 59)  
**Fig. 59**—The nail, the tip of which is not sufficiently curved, has been introduced incorrectly. It has penetrated the soft tissues at the level of the fracture.

![Image](Fig. 60)  
**Fig. 60**—The mistakes have been corrected and the final result is satisfactory.

![Image](Fig. 61)  
**Fig. 61**—Myositis ossificans after splintering of the upper end of the humerus by a nail driven in from below. The nail was withdrawn and reintroduced from above.

The shaft is directly beneath the skin. When it has reached the level of the fracture, the fracture is exposed through a deltoid-splitting incision. The long tendon of the biceps serves as a guide to avoid a rotatory displacement between the fragments during reduction. The nail is driven up through the head but penetration is avoided. The fracture immediately becomes stable.

**Operative difficulties. Penetration**—In one case the nail penetrated the head, but had been left where it was because of the smallness of the head fragment. It was extracted later. The complication had no ill effect.

**Post-operative complications due to technical errors. Splintering of the bone:** Myositis ossificans—In one case in which the nail used was too wide, the upper part of the shaft splintered when the nail was driven in. The old nail was extracted and a new one inserted in the opposite direction—that is, from the greater tuberosity downward. After the operation however, myositis ossificans developed at the site of penetration of the nail (Fig. 61).

Post-operative mobility in the shoulder joint was poor.
Wrong approach; radial palsy—In one case in which the nail penetrated the medial wall of the distal fragment, the patient had temporary radial palsy after the operation. The nail had obviously been in contact with the nerve cord.

Fractures of the Shaft of the Humerus

Thirty-two patients were operated upon. Three had open fractures. Post-operative treatment was the same as for fractures of the upper end of the humerus. The fracture may be fixed either from above with a straight nail driven in through the greater tuberosity, or from below through an oblique canal in the mid-line of the dorsal aspect of the humerus. We have used the latter method in order to avoid damaging the subacromial bursa of the shoulder joint. Operative difficulties. Wrong approach; radial palsy—In one case the nail took the wrong direction and made its way out into the soft parts at the level of the fracture. It apparently caused superficial damage to the radial nerve, for the patient had a brief attack of radial palsy after the operation.

Distraction—In one case distraction of the fragments was caused by the insertion of the nail. A transverse fracture of the humerus heals slowly and every effort must be made to create favourable conditions for consolidation. Re-nailing was successful.

Post-operative complications. Infection—A mild infection developed in one case but healed after removal of the nail. No case of pseudarthrosis was observed.

Fractures of the Upper Half of the Ulna with Dislocation of the Head of the Radius (Monteggia Fracture)

Ten patients were treated. One fracture was open and one had been neglected and had established non-union. Post-operative treatment was in a forearm plaster and sling.

It is a simple matter to drive a nail through the tip of the olecranon, reduce the fracture and achieve excellent fixation. At the same time the head of the radius also slips into position. Care should be taken, however, to avoid distraction of the fragments. If distraction does occur and cannot be corrected, the gap can be filled in with bone chips. There were no difficulties or complications connected with operation. All the cases united with good function in the elbow joint. In the patient with established non-union the radial head was later excised.

Fractures of the Shaft of the Radius with Subluxation of the Inferior End of the Ulna

Eight cases were treated, one for open fracture. Post-operative treatment was as described above. Nailing of fractures of the radius was done from the inferior dorsal part of the bone immediately above the wrist. The subluxation of the lower tip of the ulna was relieved automatically when the radial fracture was restored to its correct position.

Operative difficulties. Impaction—In one case in which a narrow Kirschner wire was introduced as a guide and an intramedullary nail then inserted beside it, both guide and nail became stuck and had to be left where they were. The guide gave a certain degree of fixation in the fracture. The nail and guide were removed six weeks later. No ill effects were noted. Post-operative complications. Shortening and radio-ulnar subluxation—In one case the radius united with shortening of the bone, and the subluxation of the lower end of the ulna reappeared. The lower end of the ulna was excised after consolidation of the fracture. The end-result was satisfactory.

Fracture of the Radius and Ulna with Gross Displacement

Twenty-eight cases were treated; five had compound fractures. The post-operative treatment was as described above. The material included eight cases of intramedullary
nailing of both radius and ulna, seven of nailing of the ulna alone and thirteen of the radius alone. In two cases intramedullary nailing was combined with wiring of the other bone.

The displaced double fracture of the forearm is a very difficult injury to treat, regardless of the method used. Intramedullary nailing presents many problems and with it we have encountered greater technical difficulties than with any other method. Difficulty is caused mainly by the small diameter of the medullary canal in the middle third of the shafts of the radius and ulna. Dr Kock, one of my assistants, has recently evolved a method which we call "retrograde medullary nailing." A relatively short nail is inserted first backward through the fracture surface in one fragment and then back again down through the other fragment to half its length. In this way the canal for the nail can be prepared in advance if the medullary space is narrow. The method is to be described by Dr Kock in a later communication.

**Operative difficulties. Impaction**—It has been impossible to determine from the case records exactly how often the surgeon encountered difficulty from the impaction or bending of nails. It was always possible, when necessary, to remove the nail and replace it with a new one during the course of the operation.

**Distraction**—In one case the first nailing was unsatisfactory and caused distraction of the fragments. Re-nailing was done.

**Post-operative complications. Poor material**—In three cases, because the medullary canal was very narrow, the fragments were fixed with a Kirschner wire of ordinary steel instead of with a nail. Post-operatively, local areas of bone absorption or decalcification, attributed to rust granuloma, were associated with some generalised osteoporosis (Fig. 62).

**Rule**—Never use anything but dependable stainless material.

**Bending of the nail**—In several cases the radial nail bent quite considerably after the operation. Union occurred in a position of angulation which led to a disabling block to pronation.

**Pseudarthrosis**—Pseudarthrosis developed in one of the bones in five cases, once in the ulna after double nailing, twice in the ulna after unlar nailing and twice in the radius after radial nailing.

The series is too small to permit definite conclusions, but it indicates that with the present technique the method is attended by too great technical drawbacks. We hope for better results with the "retrograde" method and a modified technique.

**The Metacarpus**

Retrograde nailing was successfully performed in three cases of displaced fracture of the metacarpus.

**The Clavicle**

Retrograde nailing was performed in three cases of greatly displaced fractures in which retention had been difficult. Union was rapid and the results satisfactory.

The entire series of 164 cases includes one case of death from encephalomalacia. This patient was a sickly sixty-six-year-old woman with a subtrochanteric fracture of the femur. The death cannot be attributed to the method.

Investigation of a very large series would be required to answer the question whether union is expedited by this method. The impression gained from the material studied was that the healing period was about neither shorter nor longer than is ordinary.

The stay in hospital, on the other hand, is appreciably shortened. This, together with the comfort and freedom of the post-operative treatment from the point of view of the patient, is undoubtedly the greatest advantage of the method.
Summary

One hundred and sixty-four cases of intramedullary nailing of the long bones have been studied with special reference to the difficulties and complications encountered.

There was one death not attributable to the method.

Two cases of pulmonal fat embolism and one case of thrombosis occurred, all in fractures of the femur.

The lessons we have learned from our mistakes can be summarised as follows:

1. The method requires technical experience and knowledge and is not suited to inexperienced surgeons or surgeons with little fracture material at their disposal.
2. Intramedullary nailing should only be used in fractures to which the method is suited. In general, comminuted fractures or fractures near a joint are unsuitable.
3. Open reduction is preferable to closed methods.
4. The nail should never be driven in with violence. It should be removed and replaced with a new one if difficulty is encountered when inserting it.
5. In fractures of the femur the nail should be driven in from the tip of the trochanter after careful determination of the direction.
6. The nail should be introduced only to the level of the fracture before exploring and removing the fracture.
7. Distraction of the fragments must be avoided.
8. If the nail bends it should be replaced by a new one, at least in femoral fractures.
9. If union is delayed, the fracture should be explored and chip grafts of cancellous bone placed around it.
10. Improvised nails or nails which are not made of absolutely reliable material should never be used.
11. Make sure that the nail is equipped with an extraction hole for removal.

REFERENCES


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