Controversies in intramedullary nailing

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Abstract

Early fixation of fractures contributes to lower morbidity and mortality in patients. Intramedullary fixation with locking nails with (minimal) reaming is currently biomechanically superior to all other operative procedures for the fixation of long bone fractures. The present report addresses several controversial issues related to intramedullary fixation such as the patient's position and type of table, priority of fixation, effect of intramedullary reaming in polytraumatized patients and in patients with specific injuries and conversion of external to internal fixation.

Introduction

The modern concept of intramedullary fixation changed the traditional approaches to treatment of long bone fractures in many ways. While in the past patients with long bone fractures had to rest in bed for months, "equipped" with various extensions and braces, nowadays immediate mobilization and rehabilitation are advised with intramedullary nailing even to patients with comminuted fractures. Entry points are far away from the fracture, blood loss is a lot lower because hemathoma is preserved above the fracture and no additional damage is done to the surrounding tissues (incisions), locking screws contribute to high stability of the fixation etc.. But some dilemas still remain, and new ones occur as we strive towards better management of long bone fractures and towards faster rehabilitation.

Controversies regarding the operation

Radiation

One of the biggest drawbacks to intramedullary nailing is the high level of exposition of the patient and the operating team to radiation (1-3). Modern big-screened X-ray monitors with computerized management of the signal and the rays reduce radiation significantly. The modern sub-dimensionized nails with a thick wall that are placed with the use of a guiding wire allow faster and easier placement with minimal use of an X-ray monitor. Special locking devices are used for practically all types of nails – IMHS, reconstruction nail (proximally), femoral antegrade and retrograde nail, humeral nail, tibial nail. Precise reposition, proper technique and detailed instructions allow us to fasten the locking screws almost without the use of an X-ray monitor altogether. All it takes is X-ray control of the final position, and correction of any incorrectly placed screws.

Operation table

Most long bone fractures (particularly femoral fractures) are treated on an extension table. The method allows indirect reposition with pulling, which can be performed over a cuff or over wires that were inserted into the bone before reposition (Steinman pins). The negative side to wires is the risk of infection (1-4). Pulling can also injure the pudendal or ishiadic nerve. Modern X-ray transparent (radiolucent) tables and modern distractors allow us IM fixation on this tables, too. This method is particularly useful in treatment of poly-traumatized patients, when other injuries are associated (chest or back injuries), and in treatment of simultaneous long bone fractures (for example femoral and tibial fracture at the same side or on both sides). We cannot operate on abdominal or chest injuries or on the pelvis on an extension table, therefore the patient has to be moved from one table to another during surgery. An operation on a radiolucent table therefore reduces the duration of surgery and of anaesthesia (5). It facilitates the process of determining the length of the injured extremity in comparison to the healthy one and its position (flexibility and rotation compared to the healthy extremity, reposition of the femoral neck anteversion in same projections). The position on a regular table does not give a good view over the hip area, but it does allow easier entry into fosa piriformis (esp. in over-weight patients or when the patient is laid on his side).

Order and choice of implants

In simultaneous tibial and femoral fractures we normally fixate the femur on an extension table by pulling through the condyles over the Steinman nail first, while the tibia hangs freely, immobilized with braces. If we are dealing with simultaneous fractures of the femur and the tibia on both sides, we perform traction of both femurs and first operate on one side, then we change the position and operate on the other. After fixating both femoral fractures, we treat both tibial fractures on a regular table. Any open fractures must be treated first. If we are dealing with simultaneous open tibial and femoral fractures, we treat the open tibial fracture first (on a regular table), while the femur is immobilized with a brace or with a distractor. Lately, the same order (tibia first, then femur) is recommended in closed fractures, too (5), especially if we use the radiolucent (flat) table.

The surgical procedures take a lot of time because we have to move the patient from an extension table to a regular table and back, which also means repeated preparation and disinfection of the operative field. If we use an X-ray transparent (radiolucent) table, we can prepare the operative field for fracture fixation on the whole extremity or even on both extremities at the same time. Normally the stabilization of tibial fractures is performed first, and then we can nail the femoral fracture through the same entry with a retrograde intramedullary nail. If we have associated femoral fractures (neck and diaphysis) they can be fixed with special nails (long IMHS or reconstruction nail on an extension table), we can fixate diaphyseal and distal fractures with a retrograde nail, and proximal femoral fractures with an IMHS or DHS nail or with a "miss-a-nail" technique with screws in femoral neck and head beside antegrade or even retrograde nail. This way we can place the optimal implants for individual fractures, and allow primary healing in up to 99% of cases (4, 5). Modern long retrograde femoral nails are getting closer and closer to reaching the good results that antegrade nails provide in long bone fractures treatment (5).

A distractor can also be used for temporary fixation or reposition. It provides sufficient stability of femoral fractures while simultaneous tibial fractures are treated in the operating room. Tibial fractures can temporarily be stabilized with a "pinless" fixator, before it is finally fixated with an IM nail. Schanz screws or a special handle can be used for reposition of fragments. The handle is placed into the fragments and the fragments are put on it in a row like with the use of a knitting-needle.

Effects of intramedullary reaming

Modern locking intramedullary nails provide primary healing in 95-99% of fractures (5, 6). With reamed intramedullary nails, the healing rate is even higher, but they can cause other complications. Reaming affects the endostal circulation. It can reduce the blood supply for up to 50%, reaming over the width of the medullary canal can reduce it even more (up to 83%) (see Chapter of biomechanical principles) (1). Therefore reaming can jeopardize the vitality of fragments in comminuted fractures, and this is why non-reamed nails have been developed. Non-reamed nails have a smaller impact on the endostal circulation (3). On the other hand, reaming accelerates the formation of callus and reparation of the bone as it increases circulation through the periost and soft tissues above the fracture and changes the direction of the blood stream. Normally 2/3 of the blood into the bone is supplied by endostal – intramedullary circulation. After reaming, this assignment is temporarily given to the periostal and soft tissue (extramedullary) veins. That is why the direction of the blood stream changes from inside-out to outside-in (centrifugal principle) (1, 5). The level of extramedullary blood supplies depends on the condition of surrounding soft tissues, and this is why we should avoid additional incisions above the fracture. Increased blood supply allows fast formation of callus and faster healing. The osteoinductive effect of mechanically embolized spongious particles during reaming also plays an important role here. The absence of this osteoinductive effect where non-reamed intramedullary nails are used results in a lower number of primary healed fractures than when reamed intramedullary nails are placed (1). Nowadays, sub-dimensionized locking nails with minimal reaming try to combine the advantages of both reamed and non-reamed nails: small influence on the reduction of blood supply and the osteoinductive effect that encourages the formation of callus and accelerates the healing process.

Controversies in treatment of poly-traumatized patients

Many studies show that early fixation of fractures contributes significantly to a lower frequency of complications, especially in poly-traumatized patients (1-5, 7). Intramedullary nailing with locking screws is considered as a method of choice in long bone fracture fixation (1-5). It is undisputed that reaming causes embolization of the content of the medullary canal. A question is raised here about whether this has a clinically important effect and whether it puts in danger patients with certain types of injuries – especially with chest injuries and damage to the central nerve system.

Numerous articles oppose the use of reamed intramedullary nails in patients with associated lung contusion and in unstable and poly-traumatized patients because the frequency of complications is higher when reaming is involved (1, 4, 5, 8). One of the first and most influential works in this field was done by Pape et al. (8), who analyzed a group of patients with simultaneous chest injuries and femoral fractures. They reported on a higher number of pulmonary com-

plications in patients whose fractures were fixed with reamed intramedullary nails within 24 hours after the injury in comparison to those who were treated after more than 24 hours after the injury. Although the numbers were not statistically relevant, the authors concluded that reaming contributes to pulmonary problems when it is associated with chest injuries. The same author also performed tests on animals and developed a hypothesis that embolization of the content of the medullary canal during reaming triggers other factors, such that cause the pulmonary permeability and pulmonary arterial pressure to change. This leads to lung failure (9).

On the other hand, numerous authors found no significant differences in patients with reamed or non-reamed nails and in experiments on animals with inducted pulmonary injuries (Charash et al., Bosse et al., Wozasek et al., ...) (1, 4, 5).

Thorough analysis of the researches and literature on this topic suggests that the crucial factor in development of complications is SIRS (*Systemic Inflammatory Respone Syndrome*) (4, 5). The level of hypoperfusion after the injury appears to be the most important factor which determines the magnitude of SIRS. Development of shock and reperfusion injuries are supposed to play an important role here (5). Special SIRS scales have been developed that show higher mortality and longer treatment in patients with higher values on the SIRS scale. The reason is supposed to be a more extensive inflammatory reaction. Released mediators and cascade reactions cause endothelial injury. This leads to pulmonary damage including post-traumatic ARDS (*Adult Respiratory Distress Syndrome*) (1, 4, 5). The main reason for endothelial injury is probably the release of free oxygen radicals of activated neutrophil granulocytes (5). Preliminary triggered cascade reactions can graduate to higher degrees with additional stimulations of embolization caused by reaming, which brings to further worsening and complications (5). That is why we must stabilize the patients and "normalize" the results of laboratory blood tests (the level of lactate and the acid-base balance (base excess) together with body temperature and coagulation seems to be important factors) before performing intramedullary fixation of fractures to be sure that no hypoperfusion is present in the patient. If the patient is hemodynamically unstable or if resuscitation procedures have not yet provided sufficient stabilization of the patient's general condition, intramedullary fixation must be delayed and the fracture is temporary fixated with a less invasive external fixator. So it seems the level of stabilization is the decisive factor in development of pulmonary complications during intramedullary fixation with reaming rather than the chest injury itself (5).

Similar can be said about patients with head injuries, associated with long bone fractures. Literature gives no proof that it is the fixation of fractures itself that leads to worsening of the condition of patients with intracranial injuries (5). Aggressive, immediate resuscitation and stabilization of the patient, associated with invasive monitoring, is crucial in the attempt to provide stable intracranial and systemic conditions. If the patient's condition allows it, the fractures are fixed internally (5, 10). If such condition cannot be achieved, external fixation is used as a definitive treatment of long bone fractures (5, 10).

Controversies concerning conversion from external to internal fixation

External fixator presents the ideal method for fracture fixation in difficult (even extreme) conditions when severe injuries and threatened extremities or the lives of multiple trauma patients are in question (1-5, 7). The advantages of an internal fixator lead us to convert from external to internal fixation whenever this is possible. The greatest disadvantage of external fixators is re-

lated to Schanz screws: infection ("pin infect") and the loosening of the screws (1, 2, 3, 11). We differentiate between superficial infection around the screws, and deep infection that can spread into the bone and the medullary canal. In cases of superficial infection the external fixator can still be preserved, whereas deep infection may lead to septic condition, therefore the fixator must be removed (2). According to literature, the risk of infection around the Schanz's screws is up to 7%, approximately 2% of cases require operative surgical treatment (11).

The modern external fixator is still biomechanically weaker in comparison to internal fixation. Dislocation of the fragments and deformity of the extremity can occur (2). Delayed union and pseudoarthrosis are also quite common (2). According to literature, pseudoarthrosis occurs in about 5% of closed tibial fractures, fixed with an external fixator (12). Level III open fractures where external fixation is performed most often, result in primary healing in only 23% of cases (1). At this point we must add that the criteria for comparison between external and internal fixation are not completely correct as additional injuries in this group of fractures do not even allow primary internal fixation. Despite that we can say that cases in which the external fixator is replaced by an internal fixator as soon as the patient's general and local condition allow such conversion heal in higher percentage than fractures that are only stabilized with an external fixator as a definitive form of fixation (1, 2, 10). Because of its construction, an external fixator can be very uncomfortable for the patient. Modern unilateral fixators are therefore much more patient-friendly. The construction of the external fixator also stands in the way of any necessary reconstructive procedures, the care for the soft tissue is obstructed as is providing aseptic conditions. All this contributes to the final result of fracture treatment (1, 2, 11).

Because of all these disadvantages of the external fixator, we try to convert the external fixation to internal one as soon as possible. The patient's general and local (esp. in case of open fractures) condition are crucial here. Risk of infection around the Schanz screws grows with each day, so the conversion should be done if possible within 5-7 days after surgery (5, 10). The conversion can still be performed safely within 2 (maximally 3) weeks after the injury. After this time, we either use the external fixator as the final form of fixation or we remove the fixator, place a temporary cast for immobilization (or a "pinless" fixator or a special brace), and care for the soft tissue to achieve complete recovery of surrounding soft tissues (implant free period principle) (1, 2, 12). Internal fixation is then performed associated with antibiotic prophylaxis. Despite all the measures mentioned above, infection can still occur. According to literature, infection occurs in up to 20% of cases of later conversion (1). That is why internal fixation should be performed as soon as possible. The percentage of infections in primary internal intramedullary fixation of closed fractures and level I and II open fractures (where internal intramedullary fixation is most common) is 0-7% (12). One third of these lead to deep infection (12). If any signs of infection occur around the Schanz screws, we do not convert to internal fixation (2). If the infection progresses, we must remove the fixator and prescribe parenteral antibiotic treatment. During this time we never perform internal fixation because of high risk of infection or even sepsis (2, 12). The fracture is stabilized with a cast or with another external fixator with Schanz's screws in different positions, the infected areas around the removed screws must be cleaned (debrided) during the operation.

The modern microvascular technique allows us to cover ample defects in open fractures, therefore we can tactically choose between temporary external fixation (converted to internal within 5-7 days) and immediate internal fixation with non-reamed intramedullary nails. Level

I, II and sometimes even IIIA open fractures are often stabilized primarily with non-reamed (or minimally reamed) nails nowadays (2). The defect can be covered with skin substitutes (in either internal or external fixation) and then with suitable flaps (free) as soon as possible. Microvascular work is obstructed by external fixators. Internal fixation also provides a more stable support and better results in terms of fracture reparation. Additional osteoinduction with transplants of autologous bone tissue is often performed, either primarily or at a later time, which also improves the results of fracture treatment even in the most complicated cases (2).

Conclusion

Despite certain controversies intramedullary fixation of fractures with locking intramedullary nails with minimal reaming is considered as a method of choice in management of long bone fractures.

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