From the Small Animal Veterinary Clinic in Frankfurt/Main, Director: Volker Hach, Dr. vet. med.

Initial experience with the newly developed medullary stabilization nail (Trilam nail) in the osteosynthesis of diaphyseal fractures in dogs, cats, rabbits, birds and a monkey

Volker Hach

This paper reports on the treatment of fractures in small animals with a newly developed, rotationally stable intramedullary nail. Dogs, cats, rabbits, a bird and a monkey were treated for transverse, oblique, spiral and comminuted fractures in our veterinary clinic.

Summary
The Trilam nail is an elastic steel nail with 3 lamellae running along its length. After surgical exposure the fragments are „speared“ together with the pointed end of the nail. We treated 89 limb fractures by means of internal fixation. The type of fracture played a secondary role. Healing was achieved in all cases. Surgical correction had to be performed in one case due to telescopic instability. The advantages of the Trilam nail over alternative surgical procedures for osteosynthesis are that it is possible to treat fractures close to the metaphysis and ensure rotational stability as well as a reduction in the operating time. One disadvantage is the risk of infection resulting from exposure of the fracture, which is why the patient receives antibiotic cover.

Introduction
The surgical stabilization of fractures has a history that goes back over 100 years. It started in 1883 with Lister, who performed fixation of a patellar fracture with iron wire (cited from 35). In 1886, the traumatologist C. Hansmann attempted the first plate osteosynthesis at the St. George`s General Hospital in Hamburg and reported on his findings at the congress of the German Surgery Society in Berlin. The work was done by Lambotte (1907), Lane (1913) and Küntscher (1939) then formed the basis for the more familiar methods of osteosynthesis in practice today. Küntscher also produced intramedullary nailing into veterinary medicine in 1940.

The initial goal in treating a fracture of a large tubular bone involves providing pain relief at the site of the accident by splinting the extremitiy. The short-term goal of the definitive treatment is early mobility of the adjacent joints, with a long term goal of complete functional restoration of the traumatized part of the body (30). This requires reduction and fixation of the fracture (table 1). The application of bone traction or a plaster dressing is not sufficient to prevent fine motion in the fracture gap. Optimal splinting and compression of the fragments until healing is only achieved by osteosynthesis. Plate splinting and intramedullary nailing are the main methods available for this purpose. A single smooth intramedullary pin cannot achieve sufficient traction or rotational stabilility. Stack pinning enhances rotational stability and traction, but often times must be combined with other procedures (33). A positive assessment of these procedures was made by Dixon et al. (1994) on the basis of experimental investigations, and by Hackethal (1961) and by Brug et al. (1998) in human medicine.

A bone plate serves as an internal splint. Interfragmentary screws are used for compression of bone fragments while other screws lock the plate to the bone. This „locked“ plate bears the full load of weight bearing in unstable fractures or partial load in reconstructed fractures. However a plate is not generally capable of bearing the full force of a bone under strain for a long period of time without breaking. The load must be either shared by the bone fragments via their stable reconstruction or, in the case of an unstable „biological“ fracture osteosynthesis, a callus forms at an early stage and begins to share the load with the plate. A simple transverse fracture reacts very sensitively to micro-movements, and unstable osteosynthesis may exceed the strain tolerances of healing tissues resulting in non union. In a comminuted fracture, however, the limits of strain tolerance are not reached, since the strain is distributed over multiple larger fracture gaps; the minimal freedom of movement of the fragments then increases the induction of callus formation (30).

An intramedullary nail always acts like an internal splint. It assures a reasonable position of the bone fragments in the longitudinal axis, but displays a certain instability in torsion and in axial displacement (traction, compression). Its shortcomings become all the more apparent in treating fractures with short metaphyseal segments. This is why additional fixation by interlocking nailing was introduced (18,37,38). In contrast to a plate, an intramedullary nail is capable of supporting greater weightbearing on its own over a period of months. This lessers the disadvantage of delayed callus formation by secondary bone healing (30).

Intramedullary nailing has an advantage of a more atraumatic surgical technique (21). The soft tissue coat over the bone and fragments is preserved and a devascularisation in the area of the fracture is avoided. The nail leads to early stability under strain (36). Interlocking nailing leads to an extension by exposure of the fracture (17). The interlocking medullary nail was adopted by veterinary medicine (4,5,8,9,10,15,28) in order to solve the problem of rotational and telescopic instability of intramedullary nailing in the treatment of fractures close to the joint. Dueland et al. (1997) and others (2,6,31) have reviewed the biomechanics of interlocking nails in detail.

The principal disadvantage of osteosynthesis using an intramedullary nail is the necessity to ream the medullary cavity with the danger of destroying the medullary vessels and infarcting the medulla. Intramedullary nailing without reaming is advantadeous, especially in open fractures. A spontaneous loosening of the nail over the course of healing considered beneficial to the reconsturing of the bone (36).

Recently, we have developed an intramedullary nail that is better because: No ream, no collapse, no torsion, good bending strength, axial alignment, rotational stabilitity, verding and no telescoping. It can therefore be regarded as an optimal implant for osteosynthesis in fractures of the femur, tibia and humerus. Our experience so far covers the treatment of dogs, cats, rabbits, birds and a monkey.

Implant
Ihe Trilam nail is made of a stainless steel. It has a round basic form in cross-section, with three lamellae extending down ist length. The two ends are tapered to a point (Fig. 1).

The nail is supplied in four standard sizes with outer diameters of 3-6 mm and lengths of 110 to 150 mm and in five special sizes with diameters of 7 to 11 mm and lengths of 160 to 220 mm. These sizes are suitable for osteosynthesis in dogs, cats, rabbits, large birds and small monkeys.

Surgical technique
The use of the Trilam nail is indicated in all fractures of the long tubular bones in the central third of the diaphysis up to the metaphyseal border.

The ideal indication for the use of the Trilam nail is a transverse or short oblique fracture of the tibia, femur or humerus. It has been used successfully in long oblique fractures, three piece fractures and comminuted fractures. The Trilam nail can also been used successfully in pseudarthrosis on following an unsuccessful primary orthopaedic surgical procedure.

The appropriate size of the Trilam nail is determined from the x-ray image. It is a good idea to have a second nail of the same size at hand, in order to measure the length of insertion of the implanted nail during the operation.

The animal is placed in lateral recumbacey. The skin incision is made at the fracture site placed medially for tibial operations and laterally for fractures of the femur and humerus.

The proximal fragment is exposed, taking care not to disturb any soft tissue enveloping it, paying particular care not to traumatize the periosteum. The Trilam nail can be driven maximally into the medullary space with little resistance. The three lamellae of the nail must cut into the inner cortical bone to prevent rotation (Fig. 2). If too large a diameter nail is selected, there is a danger of splitting the bone. If one takes care to gauge the nail to the most narrow portion of the diaphysis these problems rarely arise. The extend to which anatomical variants play a role (34), has not been studied in animals.

Retrograde introduction of the nail results in perforation of the proximal bone fragment at its upper end. In the femur, the tip of the nail typically emerges between the greater trochanter and the femoral head, in the tibia at the tuberosity and the humerus above the greater tubercle. One must take care to flex the knee during tibial introduction so the pin exit does not damage the femoral condyles. During femoral introduction, the distal aspect of the proximal fragment should be held medially with the hip in extension to avoid damage to the sciatic nerve. Similary the proximal humeral fragment should be held medially with the shoulder in slight flexion to avoid joint damage upon pin exit. The protruding nail can be exposed through a seperate small incision.

In the second part of the operation, the distal end of the intramedullary nail is inserted into the distal bone fragment. Reduction is performed with the utmost care soas not to significantly disturb soft tissues. Once the long fragments are aligned, the nail is driven into the distal segment while observing the fracture gap. Comparison with the reference nail provides a good idea of how far to drive the nail.

The fracture gap should be minimal, with no tissue interposition. Any bone fragments in the vicinity can be placed in a favourable position towards the fracture site trying not to detach them from their soft tissue coatings. The fragment position may be facilitated by use of Dexon suture or wire cerlage. The operation is concluded by closing the soft tissues with knotted sutures and suturing the skin incision. The nail has to be cut as close as possible to the bone after closure.

Results

From 01.06.1997 to 15.04.1999, 89 limb fractures were treated with the Trilam nail in the veterinary Clinic for Small Animals in Frankfurt/Main, Germany. The animals treated were 25 dogs, 60 cats, 2 rabbits, 1 bird and 1 monkey (Tab. 2).

The majority of cases involved fractures of the tibia, followed by femoral fractures (Tab. 3).

The type of fracture played a subordinate role for the operation. Transverse midshaft diaphyseal fractures seemed to be most suitable for nailing (Tab. 4). However, comminuted fracuteres were most common in our patient population (Fig. 3 and 4). The greatest advantages of the Trilam nail over alternative osteosynthesis procedures were observed when the fractures extended up to the vicinity of the metaphyses (Tab. 5). In contrast to the use of interlocking nails, the Trilam nail was easier to apply and resulted in a shortening of the operation time. A stable fixation of a short proximal or distal metaphyseal fragment could be achieved (Fig. 5).

Reconstruction with the Trilam nail lasted an average of 25 minutes (15 to 45 minutes). The operation was easy to perform with the aid of a surgical assistant. Following surgery, all patients were discharged back home into their owner`s care. Postoperative followings was performed by the regular veterinarian.

The regular veterinarian was contacted on or around the 14th day postoperative, to obtain information on the operative outcome. Primary wound healing occurred in all cases. The animals were allowed full mobility after about four weeks. In two case, a 14-year-old and a 1-year-old cat, the nail migrated proximally and the fracture site collapsed as a result; reoperation then led to healing. A radiological follow-up was possible within 15 months in 44 of 49 animals. A stable anchorage of the Trilam nail was shown in all cases. In particular, no major areas of bone resorption on the outer edges of the lamellae could be detected during the observation period. The fractures had healed. There were no cases of pseudarthrosis as a late sequel of rotational instability. The nail was not removed routineley.

Discussion

In 1962, G. Küntscher wrote in the preface to his classical monograph The Practice of Medullary nailing: „The use of the intramedullary nail represented a completely new form of surgery. It requires very great experiences and practice. The obscurity and imprecision often to be found in medicine is not present here. The reason for failure is always clear to see, but meticulously precise work guarantees sucess.“
The biomechanical principle of the medullary nailing of fractures in long tubular bones is based on the splinting of fragments by a nail correctly placed in the medullary cavity. In contrast to static osteosynthesis with compression, minimal instability is always present in medullary nailing. This instability induces secondary bone healing. The strong callus formation and the stable implant in a transverse fracture ensures rapid an reliable loading of the injured limb. The advantages of osteosynthesis in man using medullary nailing according to Küntscher are to be found in the covered treatment of a closed fracture, in early functional stability and in favourable bone restructuring during the healing process (22,36).

In Küntscher nailing, the diameter of the nail slightely exceeds the diameter of the bone, thus ensuring a tight fit between the compressed nail and medullary contex. This friction creates boney stability by preventing the bones from twisting or sliding along the implant. These principles only apply to diaphyseal transverse, short oblique and short spiral fractures and to segmental fractures; there is an increasing loss of bone-implant stability as the diameter of the bone exceeds that of the implant, or the fracture becomes comminuted. This leads to various complications, such poor initial axial placement, and diminuished abelity to offset the forces of rotation and fracture collapse.

Another source of risk in classical nailing is to be found in reaming the medullary cavity (12,25,29). Küntscher summarized the complications under the term fat embolism, shock and infection. Rupture of the cortex, injury to adjacent joints or breakage of a jammed nail are further risks. A whole series of secondary injuries result from selecting the wrong direction of entry when inserting the nail into the medullary cavity of the femur and tibia. Damage to the soft-tissue coat is particularly prevalent in human and animal tibias.

Because animal bones are not long and straight, unlike in man, normograde nail placement is difficult. Retrograde placement of the nails in this study (following the conventionel techniques) did not result in any long term damage.

With the advent of interlocking nails, fractures previously best suited to plate on traction fixation techniques entered the of intramedullary nailing. In addition of interlocking screws neutralized problems nails rod with torsion and collapse. The interlocking technique has particular advantages in the osteosynthesis of fractures in the vicinity of joints (17).

The classical intramedullary nail is indicated in mid diaphyseal transverse or short oblique fractures.

According to the investigations conducted by Kempf (1991), rotational stability is dependent on the longitudinal fixation of the nail in the cortex on the interdigitation of the fractured bone ends. Dynamic proximal and distal interlocking doubled the rotational stability in transverse osteotomy. These principles can be applied to the majority of diaphyseal fractures today, including torsional fractures, segment fractures, comminuted and defect fractures, pseudarthroses, and osteotomy in reconstructive surgery.

Under unfavourable conditions, the nail itself may torque. Its torsional strength can be increased by blocking the slot, as in the Grosse-Kempf nail; in human medicine, it is particularly used in comminuted fractures, in severe osteoporosis and in tumor surgery.

The Steinmann nail is commonly used in veterinary medicine and does not offer the option of interlocking (27). For this reason, combinations were constructed with external fixation or with the Kirschner-Ehmer device.

A major problem of medullary nailing, rotational stability, is solved by the Trilam nail. If the diameters are measured correctly, the three lamellae cut into the bone fragments, thereby offsetting rotational forces. Another advantage is that reaming of the medullary cavity, with ist attendant risks, is not necessary. The longitudinal fixation of the nail is achieved by insertion into the metaphysis, especially in the distal fragment One disadvantage of the Trilam nail operation is the open surgical method, which increases the risk of infection (16,26). Short-term antibiotic treatment is therefore recommenden. The duration of the operation is shortened by the need to keep dissection in the area of the fracture to a minimum. Leaving small fragments in their tissue anchorage, maintaining the blood supply and preserving the fracture haematoma have a beneficial effect on primary bone healing.

The experience gained so far between 01.06.1997 and 15.04.1999 covers 89 operations on dogs, cats, 2 rabbits, 1 owl and one monkey. These included 22 fractures located in the transition to the metaphysis. In all cases, the Trilam nail achieved optimal longitudinal and rotational stability. The surgical technique is relatively simple and easy to learn. Serious complications were not observed.

The contraindications for use of the Trilam nail are the same as those that apply to all other surgical techniques used for osteosynthesis. The main one is general diseases that do not allow anaesthesia or surgical intervention. In the case of spontaneous fractures due to metastatic tumour disease, the prognosis must be discussed with the animal`s owner (11). The same naturally applies to fractures sustained in multiple trauma.

Heavily contaminated open fractures rule out medullary nailing of the risk of osteomyelitis. The extent to which medullary nailing may be considered at a later stage, once the situation has been stabilized using external fixation, can be considered from case to case.

The young age of an animal is not a contraindication. We did not see one case of premature groth plate closure. Neither is advanced age a contraindication. Old animals can walk again without impairment immediately after the operation, and secondary joint damage due to immobilisation or incorrect weight-bearing (fracture disease) is avoided.

Acknowledgements
The author would like to thank Dr. Timothy Lenehan for reviewing the manuscript.