A Brief History of Medullary Nailing, New Mexico Perspective

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My orthopaedic fracture journey began as a medical student at the University of Missouri in Orthopaedics in 1978 when a patient presented with a transverse femur shaft fracture. The residents were very excited because this was a "nailable" fracture which we proceeded to do. My role was under the table with a crutch pushing on the thigh. I could not see a thing and had little idea what was going on above me. There was blood dripping down onto my head soaking my scrubs. Periodically I would hear a request for "valgus" or some such word. I wasn't sure what that meant or how to achieve it but I would push harder on the crutch and there would be more grunting and hammering from above. After a couple of hours I emerged to see a patient with a stable straight thigh and the orthopaedic surgeons congratulating themselves. At the end of the day we retired to Katy Station for libations and I was hooked on orthopaedic fracture care.

Subsequently I honed that interest during Orthopaedic residency at the University of Vermont and fellowship in trauma and sports medicine at the University of Iowa. I then put what I had learned to work here at the University of New Mexico in 1986 where I've practiced ever since. Over the course of that 34 years I've seen a lot of progress in fracture care and this manuscript will report some of those changes.

General fracture treatment

Clearly the main change in fracture treatment between 1978 and 2012 is the change from closed treatment to operative stabilization as the standard. In general, that has been associated with improvement in quality of reduction at the time of healing, acceleration of return of motion and probably function, prevention of post-traumatic arthritis in many patients with displaced intra-articular fractures, and the saving of lives in multiple trauma patients. Complication rates from operative treatment have also been reduced over that time period.

Intramedullary nails

Dr. George Omer spent a large portion of his military career in the 1960s adjusting the traction on patients with femur shaft fractures. It was like washing the windows on the Empire State Building. By the time the last window was finished the first was already dirty and the window washer needed to start over again. His day was spent adjusting the traction on a 40 patient ward and when he came back the next day the traction had to be adjusted again. Plus 2 new patients came in who had to be put in traction and 2 patients had healed sufficiently to be taken out of traction and put into a cast brace or the like. The next day the whole process would be repeated. Patients stayed in the hospital for 2 to 4 months or longer.

Against this backdrop, the reamed closed medullary nail was gaining popularity. I had been introduced to it in medical school and developed technical skills in residency. I was now applying it to patients at the University of New Mexico (UNM) Hospital where my predecessor, Dr. Fred Hensal, had started the process. There were considerable hurdles to overcome at the time, including operating room access, anesthesia availability, and fluoroscopy technology.

1935-1945

Intramedullary nailing was developed for femur shaft fracture treatment by Gerhard Kuntscher in Germany in the late 1930s. At that time, there was not much transfer of scientific medical knowledge between the United States (US) and Germany. Various stories of the first recognition of this operative treatment exist, including Polish radiologists seeing radiographs of femurs with metal nails in them and escaped American POW's returning with metal nails. Some thought these nails were some sort of German torture device. Kuntscher was actually successfully providing this treatment to regular German patients as well as military injuries for both Allied and Axis soldiers. He kept meticulous notes and drawings of over 2000 patients.

1945-1955

At the end of World War II, Kuntscher was accused of war crimes for experimenting on American POWs with these surgical implants. However, it was discovered that these were placed as treatment for femur shaft fractures and that the patients were doing very well, even better than the English and American treatment of the time of traction followed by casting. Kuntscher was exonerated and his techniques were thought to be of sufficient promise to attempt to utilize them in the US.

The military commissioned an English version of Kuntscher's cumulative work on medullary nailing by Colonel Albee. Centers were chosen in Boston, Baltimore and the Campbell Clinic in Memphis to try these techniques. They could not make the techniques work and the whole concept of medullary nailing fell into disrepute.

Copies of the English translation of Kuntscher's work were crated up and placed in military storage, reminiscent of the final scene in *Indiana Jones and Raiders of the Lost Ark*. They were rediscovered in the late 1990s when the Stryker Corporation started a project to commemorate the 100th anniversary of Kuntscher's birth by translating his works into English. They found that this translation had already been done by Colonel Albee and actually found the original copies in military storage. They arranged to have more copies made and disseminated those to interested surgeons. I discovered that Colonel Albee had retired to Farmington, New Mexico. Unfortunately, I was never able to talk with him as he had died the year before his work was rediscovered.

1955-1965

I refer to this as the Dark Ages of medullary nailing in the United States (US) and certainly New Mexico. The lack of successful implementation of Kuntscher's techniques in the US and poor results with operative treatment of fractures in general made closed treatment the standard of care. No one knows why techniques that worked well for Kuntscher and subsequently worked well for the rest of the world were not effective or accepted at this time. It is a pattern often seen in medical progress. It is also a phenomenon somewhat peculiar to surgical techniques that seems to have escaped the attention of "evidence-based medicine." It may be impossible to conduct effective randomized controlled trials of surgical techniques because of the variability inherently present in surgical treatment, including surgeon skill and experience, availability and effectiveness of adjunctive technology, variability of pathophysiology in trauma, and biological variability in healing response. How many "controlled" trials actually control for surgeon experience? Almost none. It may be impossible, as the surgeon's experience, by definition, changes over the course of the trial.

1965-1975

I refer to this decade as the Renaissance of medullary nailing. Kuntscher and his colleagues had continued their work in Germany. The Arbeitsgemeinschaft für Osteosynthesefragen (AO) group developed effective techniques for operative treatment of fractures in Switzerland. Their approach emphasized rigid plating of fractures, including femur shaft fractures but success raised interest in operative treatment of femur shaft fractures. They initially rejected medullary nailing as violating 2 of their principles, including non-anatomic reduction and non-rigid fixation. Hanson and Street in the US developed solid, fluted nails that were placed after open reduction and were effective for transverse midshaft femur shaft fractures.[1]

1975-1985

This decade featured the rediscovery and implementation of Kuntscher's techniques with particular emphasis on hollow nails that could be placed over guide rods. Kuntscher had also developed medullary reamers over guide pins to allow for the placement of larger diameter nails. These nail characteristics, combined with the development of fluoroscopic radiographic techniques, allowed percutaneous nail placement without opening of the fracture site with associated soft tissue disruption. Kuntscher had also placed an anterior bow to match the natural bow of the femur, in contrast to the straight Hanson Street nails, resulting in easier nail placement and improved alignment and better functional outcomes. Kuntscher nails were slotted and relied upon endosteal contact for control of rotation and length. As the large diameter nail was driven into a tight medullary canal, the endosteal bone would squeeze the slot slightly closed. The natural recoil of the nail to its original shape created friction between the bone and nail which resisted the tendency toward shortening or rotation of the bone around the nail with weight bearing. This expanded the indication for medullary nailing to fractures that were farther from the isthmus or more comminuted. However, the amount of friction that could be obtained was severely limited and only the minority of femur shaft fractures were of a pattern and location to be "nailable." These techniques were introduced to New Mexico by my predecessors, including Drs. George Omer, Jr., Moheb Moneim, and Fred Hensal. Also during this decade, flexible nails were developed by Hans Ender of Austria and gained widespread use for a variety of long bone fractures. Unfortunately they were not very length stable

Figure 1. I've learned many things from my partners and residents. Clever types of fixation tend to be associated with interesting problems.

and become more prominent at complications conference than indications conference.

1985-1995

This was the decade of locking nails, which expanded indications for nailing to almost all femoral shaft factures, not merely nearly transverse fractures near the isthmus. Proximal locking of the nail by placement of a screw through holes in the nail by a nail-mounted guide was developed and provided good fixation of the nail to the proximal fragment. This did not provide a lot of resistance to rotation or shortening as the distal fragment still relied upon friction to resist motion. Brooker Wills developed a system of distal locking.[2] After nail placement, deployable fins were placed inside slots in the nail proximally and passed down the nail from the entry site at the hip. There were slots in the nail distally at 90° from the longitudinal (medial and lateral to the posterior longitudinal slot) and with gentle rotation and tapping the fins would deploy into the distal metaphysis. This provided rotational and length control. Although effective at expanding the indications, there were a myriad of problems encountered. The nail would tend to twist during insertion and the fins could deploy anteriorly and posteriorly and pentrate the cortex and impinge on important soft tissues (Figure 1). The fins could jam and not deploy or not retract, making extraction difficult.

An alternative technique that eventually supplanted fins was the placement of screws through holes in the nail distally by Klemm and Schleman in Germany and Grosse and Kempf in France. The problem with this technique was hitting the hole in the nail with a drill bit placed from the lateral side of the thigh. A variety of techniques were attempted with some success and some problems. Proximal nail-mounted guides were not sufficiently accurate and could not control for the rotational deformation of the nail that occurred during placement. Free-hand fluoroscopically controlled drilling was successful but required a lot of radiation exposure to surgeons and everyone in the operating room. However, with surgical experience and training this technique was eventually successful and gained widespread acceptance both here in New Mexico and around the country.

Also during this time, the AO accepted the utility of medullary nails and "perfected" the technique of Kuntscher with the introduction of partially slotted nails. The closed section proximally allowed use of a threaded introducer, a stronger cylinder to allow proximal locking holes without nail breakage and a thinner walled device to allow a more lateral entry hole, and a more flexible nail to reduce frequency of fracture comminution during nail insertion. AO also had "Herzog wires" for tibia nails that were similar to Brooker Wills fins in that they were passed down the nail from proximally and out through slots in the side of the nail distally to achieve better maintenance of length and rotation.

Intramedullary nails were also developed by a variety of surgeons and manufacturers for other long bones. For closed tibia shaft fractures, nonoperative treatment (cast and bracing) was the standard and good results were achieved. These patients were typically immediately ambulatory and weight bearing, in contrast to patients with femur shaft fractures. The advantages of medullary nailing over nonoperative treatment were not nearly as great in the tibia as femur. For open fractures, the standard alternative was external fixation, as the incidence of infection with nailing was considered too great. Even when medullary nailing was recommended there was considerable debate between reamed and unreamed nails and solid versus cannulated nails and closed section versus open section nails. Reamed nails were thought to have a higher complication rate in open fractures due to disruption of the medullary blood supply to the cortex which had already had its periosteal blood supply disrupted by the trauma. It was thought that the bone could tolerate injury to one, but not both of its primary blood supply. We participated in the decade-long debates of nailing versus closed treatment of tibia shaft fractures as well as reamed vs. unreamed nailing of the tibia.

Early in the decade I recall performing about 2 dozen cast changes for slight malalignment of a college football player with a tibia shaft fracture who went on to heal with good alignment in 14 weeks, had a successful senior year, and a 10 year National Football League (NFL) career. I also recall a Lobo basketball player who was 6 feet 9 inches tall with a grade 1 open tibia shaft fracture sustained when coming down with a rebound during a game at the Pit. We felt he would benefit from nail treatment but the length of his tibia was much longer than any available tibia nails. We overcame this technical problem with a femoral nail custom bent to achieve a proximal (Herzog) curve. He healed without infection. He had excellent function and completed his college basketball career the following year. This case illustrates the need to have special equipment and implants and techniques to successfully treat athletes who tend to be at the extreme end of human anatomy.[3]

There were two Highland High School football players with tibia shaft fractures. The first was an All-State running back who sustained a closed tibia shaft fracture during the final regular season game. He developed a compartment syndrome and was successfully treated with 4 compartment fasciotomy. We debated closed treatment versus external fixation or medullary nailing and eventually selected delayed nailing. His bone and soft tissue healed and he went on to a successful NFL career. This case illustrates the frequency of compartment syndrome associated with tibia fractures in football as well as the potential advantage to the soft tissue of bony stabilization.[3]

Another Highland High School football player was a 300 pound lineman who sustained a grade 3A open tibia shaft fracture when hit by a car while changing a flat tire. He was treated with debridement and external fixation. His soft tissue healed but he had a delayed union with possible indolent infection that persisted for 9 months. A variety of treatment alternatives, including bone resection and transport, medullary nailing, plating, casting, and external fixation were considered. He was in good alignment and the radiographs looked as if he were trying to heal. The soft tissue envelope was sufficiently worrisome that operative treatment was not appealing. I elected to treat him with 3 more months in a long leg cast and he healed solidly. After a year out of football, he was recruited and successfully played 3 years of college football. This case illustrates the importance of recognizing the inherent healing potential of patients and that it is not always necessary or optimal to aggressively operatively treat every situation, even if you have a variety of operative tools at your disposal.[3]

Both antegrade and retrograde nails were developed for humerus shaft fractures. Antegrade nails were more effective but did cause entry site shoulder problems and were not associated with the excellent healing rates and return of function seen with nailing of long bones of the lower extremity. Plating also had its problems, including radial nerve palsy and nonunions. We participated in another decade-long debate regarding nail versus plate for humerus shaft fractures.

During this decade, a high rate of complications was noted with flexible nailing of Ender, particularly problems with loss of reduction and malunions from relatively unstable fixation. As Dr. Richard Miller noted, "The only time I hear about flexible nails is at our M&M conference." Flexible nails generally passed out of favor except for pediatric femur shaft fractures.

This decade also saw the introduction of retrograde femoral nailing. My first case of retrograde femur nail was a young man with a patella fracture, a comminuted femur shaft fracture, and extensive abrasions about the hip. I needed to make an incision at the knee to stabilize his patella and wanted to stabilize his femur but did not think it safe to make a hip incision through the abrasions. There were no femoral nails available with the necessary bend for retrograde insertion so I utilized a long tibia nail. This was also prior to the development of locking holes but there were slots in the tibial nail for longitudinal wires. The patient was placed in the supine postion without use of a fracture table. This was much easier and quicker than standard nailing where positioning on the fracture table took an hour or more.

The distal femur was visualized through an anterior approach and the displaced patella fracture and an intercondylar entry hole was established. A ball-tipped guide was introduced into the medullary canal of the distal femur. With gentle traction the femur reduced easily and the ball-tipped guide placed across the femur shaft fracture under fluoroscopic control. Again, this occurred much easier and faster than typically occurs with antegrade nailing. The medullary canal was reamed and the reamings were removed from the knee joint under direct visualization. The tibia nail was inserted and a transverse Kirshner wire was placed transversely through the distal femur medial and lateral cortex and the slots in the nail to maintain position of the nail in the distal fragment and prevent the nail backing into the knee joint. The proximal fragment had friction interference with the nail in the isthmus of the femur. Locking screws and holes had not yet been developed. The patella was then fixed with tension band wiring.

The patient was placed in a supportive knee brace and allowed to ambulate. Initially, he was non-weight bearing with no knee motion. He progressed to partial and then full weight bearing with active assisted range of motion and then progressive resistance knee motion and healed with excellent function. One year later he had removal of the patellar implant. At that time he also underwent arthroscopic removal of the nail. The insertion site had sealed over with scar tissue and the knee joint surface and internal anatomy looked normal. The nail was removed through a 1.5 centimeter incision in the patellar tendon utilizing the previous skin incision. He was part of a 2 to 10 year follow up of retrograde nailing of femur shaft fractures reported in 2000.[4] At 10 years, he was functioning normally, with equal limb length and no degenerative changes to his knee joint despite the patella fracture retrograde nailing.

This was important information because there was concern at that time that retrograde nailing would cause all sorts of knee joint problems. This case also suggested that retrograde nailing might be easier and quicker than antegrade nailing. This case stimulated work on a more general use of retrograde femoral nailing for femur shaft fractures and we participated by providing some of the earliest cases, techniques, and long term followup.

There are numerous disadvantages to antegrade nailing that can be overcome with retrograde technique and are particularly important in special situations. First it was necessary to develop a good technique. We settled on placement of the nail through the inter-condylar notch in line with the medullary canal and anterior to the femoral attachment of the cruciate ligaments. Although covered by articular cartilage, this area does not contact the patella or tibia and is accessible from an anterior incision. A 10 millimeter (mm) hole in the non-articulating portion of the distal femur compared favorably to the 2 (1 tibia, 1 femoral notch) 10 mm holes placed for ACL reconstruction. These graft tunnels were not thought to be associated with a high rate of articular injury and deterioration.

Success with this entry site was also seen with retrograde nails for distal femur fractures introduced by Green, Seligson, and Henry (GSH nail). These were short nails with multiple transverse locking screws based on Huckstep nails from Australia. We were among the first to utilize the GSH nail for distal femur fractures proximal to total knee replacements with good results and published results with Drs. Jabczenski and Crawford that are still referenced today.[5] We also studied the mechanics of nail versus plate for distal femur fractures with Drs. Behzadi and Firoozbakhsh which are also commonly referenced today.[6]

1995-2005

During this decade, the Russell-Taylor nail became available and commonly used. This was a closed section nail with proximal and distal locking holes. The proximal holes allow two fixation options, either from the greater trochanter to the lesser trochanter or “reconstruction” mode from the lateral cortex into the femoral head and neck. The technique of over-reaming with use of smaller diameter statically locked nails became standard. We no longer relied upon friction interference of the nail with the endosteum. Nails were slid or tapped into place rather than being forcefully driven into place. There was less tendency for the nails to deform during insertion and distally locking was easier. It became recognized that statically locked nails did not always cause nonunion, and typically healed without dynamization or locking screw removal. Static locking became standard for nearly all femur shaft fractures and resulted in improved results with more precise restoration of length, rotation, and alignment than had been achieved previously.

The Alta nail system was also used during this decade. It incorporated the new technology of titanium, allowing an implant which was stronger but less stiff than stainless steel. It was also a closed section nail with proximal and distal transverse locking. Titanium nails were particularly attractive for use in the tibia where a small diameter nail could be placed in the tight medullary canal with less endosteal reaming, but with sufficient strength without too much stiffness to avoid nail breakage with nonunion.

During this decade, we participated in the debates of operative versus non-operative, plate versus nail, unreamed versus reamed nails, and nail versus external fixation for open fractures. Reamed nailing became accepted treatment for closed tibia shaft fractures as well as grades 1 and 2 open tibia shaft fractures. External fixation retained a role for more severe open tibia shaft fractures and there are selected indications for unreamed nails, plates, and nonoperative treatments.

For the humerus shaft, a variety of problems with nails persisted. The distal medullary canal is not very long or wide, especially from anterior to posterior (AP), in contrast to the long bones of the lower extremity, femur and tibia. Most of the nails were the same diameter proximally and distally and did not match the anatomy of the humerus medullary canal, which was large proximally and small distally. This resulted in nails that were too tight in the distal fragment. A variety of problems ensued, including distraction at the fracture site and nonunion since the nail would not advance into the distal part of the distal fragment. Distal cortical penetration also occurred anterior due to the small AP canal diameter. Thermal injury from cortical damage from reaming occurred.

At the same time, plates were enhanced by locking technology. This was important in the humerus, which has less cortical bone than the lower extremity long bones. Humerus shaft fractures are also more common than femur or tibia in elderly patients where osteoporosis is common. Plates became preferred to nails in the upper extremity long bones in general and for the humerus shaft in particular.

Femur shaft fractures in the elderly were the focus of a UNM report demonstrating that medullary nails were effective but that there is a high rate of mortality similar to that seen with proximal femur fractures in the elderly.[7] This mortality rate previously had not been prominent in the orthopaedic literature.

Removal of medullary nails has been a controversial issue that was addressed in a *Journal of Trauma* article from UNM written with Dr. Miller.[8] We demonstrated that there were significant risks with nail removal, including postop hematoma formation, refracture, and a low but significant incidence of infection. It was also difficult to objective demonstrate an improvement in subjective symptoms like pain with cold weather after nail removal. Over the course of the decade, removal of nails went from being performed in 90% of cases and routinely indicated to being done with much more selectivity. This article is commonly referenced to support that change. We now leave in the majority of nails.

If nails are going to be removed, it is much easier to do so between 12 and 24 months. After that, bony remodeling and incorporation may make nail removal extremely difficult and associated with a very high rate of complication. Incarcerated (unable to be extracted) nails, equipment breakage, and even bone extraction have been encountered. Specialized equipment to extract nails becomes increasingly hard to recognize and acquire. One of my patients with an Alta nail with a torx head screw and nail cap returned to England where surgeons twice attempted to remove the nail and were unsuccessful.

The first time they did not recognize the need for specialized equipment and were unsuccessful. The second time they had the torx head screwdriver but could not get access due to bony overgrowth. The patient did return to me where I recommended nail retention but she very much wanted it out and I agreed to make an attempt with the understanding that I would stop if the bone destruction was going to be too great. With appropriate preparation, torx headed screwdrivers, osteotomes and bone removal devices, fluoroscopy, adequate soft tissue dissection and visualization, and patience we were able to remove the nail and locking screws without too much bone injury. She recovered and was happy.

This case illustrates that nail removal should be selectively done in the window between 12 and 24 months after implantation and only after adequate preparation and planning.[9] It also illustrates that no one looks good removing implants and that surgeons should always consider the potential difficulties of future removal when placing orthopedic implants, especially if there are unusual features like a new type of screw head.

During this decade the short retrograde nails (GSH) were demonstrated to have problems with instability and passed out of favor. Locking plates have largely supplanted them for distal femur fractures, although long retrograde nails have been shown to be efficacious.

Retrograde nailing of femur shaft fractures gained acceptance during this decade, almost equal to antegrade nailing in reports from a variety of centers, including UNM.[4] Retrograde nailing has been shown to be easier and faster than antegrade nailing, although both give excellent long term outcome. In certain situations retrograde nailing may be better than antegrade nailing. These include ipsilateral acetabular fractures where it is important to maintain a pristine soft tissue environment for operative approaches to the acetabulum. Associated spine fractures that preclude positioning on a fracture table are another indication for retrograde nailing. Very large patients may be difficult to position on a fracture table and proximal obesity may make access to the greater trochanter so difficult that retrograde nailing is preferred.

There is less pelvic radiation with retrograde nailing and this may benefit pregnant patients with femur shaft fractures. Bilateral femur shaft fractures typically require 2 different positions for antegrade nailing but can be achieved through a single supine position for retrograde nailing. In general, antegrade technique is preferred for fractures of the proximal third of the shaft and retrograde technique for fractures of the distal third of the shaft. Middle third fractures can be treated with either technique.

Entry site problems occur with both antegrade and retrograde techniques in about equal frequency. With antegrade technique there is scar and occasional heterotopic bone formation in the gluteal muscles, some reports of gait disturbance from hip muscle dysfunction, and hip pain from nail prominence over the greater trochanter. For retrograde techniques there can be knee pain or stiffness and injury to the articular surface of the femur or patella from aberrant entry site or nail prominence.

The objection that retrograde nailing somehow "ruins" the knee has been overcome with decades of experience. Malreduction can occur if it is not recognized that fracture reduction must be obtained prior to drilling the entry site. This is particularly true for more proximal fracture (subtrochanteric) with antegrade nails and more distal fractures with retrograde nails. There were some reports of a slightly higher rate of delayed union with retrograde nails but this was at a time when typical retrograde nails were smaller diameter than antegrade. With equal diameter nails the union rate appears equal in the 2 groups.

The optimal location and pattern of proximal locking has also been a concern with retrograde nailing. There was widespread concern for injuring the femoral artery with an anterior to posterior proximal locking screw. With Dr. Brown, we were able to demonstrate and publish the location of the femoral artery relative to proximal locking screws for retrograde femoral nails and the safe corridor for their placement.[4] As Dr. Moed said, "You are more likely to poke yourself in the eye with the drill bit than to injure the patient's femoral artery." Our publication demonstrated there was a wide safe corridor for screw placement. That, combined with extensive nationwide experience with retrograde femoral nailing over 2 decades has virtually eliminated that particular objection to retrograde femoral nailing.

Nailing for trauma reconstruction includes femoral shortening and de-rotations. Dr. Winquist developed an intramedullary saw that can cut the femur from inside the medullary canal by sequentially hand rotating a transverse saw blade. A cam mechanism progressively increases the diameter of the saw while the operator simultaneously spins the blade within the medullary canal. A notch is cut in the endosteum and progressively expanded to a transcortical cut until the bone is osteotomized. De-rotation can then be performed to correct deformity and a nail placed to maintain reduction and provide stability during healing. Femoral shortening can also be performed by making two cuts at predetermined sites, splitting and displacing the intercalary piece, shortening the femur, and stabilizing it with a medullary nails. I have used both of these techniques to good effect. Femoral de-rotation and shortening with intramedullary saw and nail provide a good alternative to open osteotomies and plating or other more complicated techniques for limb length equalization like Ilizarov lengthening with distraction osteogenesis.

Indications for nail removal evolved during this decade. In an article co-authored with Dr. Miller, we reported the results of nail removal in the *Journal of Orthopaedic Trauma* that is widely cited.[8] Previously 90% of implants were removed mostly for theoretical future "risks" and the thought that the implant inherently caused pain. More recently, 90% of implants are retained with removal indicated for specific situations such as infection with healed fracture or prominence of implant causing symptomatic irritation of overlying soft tissue.

2005-2012

In the last 7 years, reamed medullary nailing of tibia shaft fractures has moved from accepted to standard treatment. However, we should not forget that tibia shaft fractures tend to heal biologically and can be successfully treated non-operatively. The advantages of operative treatment are a more reliable and probably better reduction that probably has some benefit to patients generally. There is also an earlier return to function, as it is far easier to mobilize and return to work earlier with a nail. There is a recognized incidence of knee pain although this tends to improve once the fracture heals. Suprapatellar nailing has been suggested to reduce this problem as well.

Although nails are successful at achieving adequate reduction and reductions generally superior to closed treatment there are still some problems. Gross malreductions do still occur, especially with more proximal or distal fractures of the tibia shaft treated by nailing. A variety of techniques to overcome this tendency have gained acceptance, including nailing in a semi-extended position, use of reduction clamps and temporary plates prior to nailing, and use of blocking screws. A small amount of distraction in a statically locked nail is well tolerated in the femur but may result in a nonunion in the tibia and should be avoided. I believe there is a role for dynamization of statically locked nails demonstrating delayed union, especially in the tibia. I recommend it to most patients who I see referred with delayed or nonunions as a simple outpatient procedure that often results in healing. It does not seem to be generally standard, based on the number of patients I have seen referred with delayed unions who have undynamized locked nails. There is also under-utilization of the dynamic locking slot available in many nail systems.

Subtle malreductions occur commonly, as we generally recommend restoration of length, rotation, and alignment for medullary nails and not true anatomic reduction. Some orthopaedists believe these subtle malreductions are the source of significant patient morbidity. I know of one orthopaedic traumatologist from this camp who had his own closed tibia shaft fracture treated with a Taylor Spatial frame in order to achieve a more anatomic reduction. Time will tell if the problems of knee pain and subtle malreduction are sufficient to move the pendulum away from medullary nailing as the standard treatment of tibia shaft fractures.

Medullary nailing of open tibia shaft fractures has now gained widespread acceptance and use of nails in more severe Grade 3 B and C fractures continues to grow. The infection rate appears to be no higher, and possibly lower, than external fixation (XF) and other alternatives. Staged reconstruction with initial external fixation converted in a few days or weeks to nails is a common protocol. In 2012, nails and XF are both reasonable options for skeletal stabilization of severe open tibia shaft fractures, although the trend is toward nails and away from fixators.

The last 7 years have shown a recognition of a role for damage control orthopaedics in some severely injured patients with multiple trauma, including femur shaft fractures. It has always been recognized that there was pathophysiology associated with placement of a medullary nail, including blood loss, soft tissue dissection and injury, and displacement of medullary contents into the blood stream with pathological implications for remote organs, including the heart, lungs and brain. It was thought these processes were tolerated by most patients and the benefits of long bone stabilization in restoring an upright chest and early ambulation more than offset the physiological costs. There may be some patients who are severely injured who cannot tolerate these effects and medullary nailing will push them beyond their physiological tolerance, increasing the rate of pulmonary compromise and death. For these patients, damage control orthopedics is recommended.

It has followed principles developed in general surgery for multiply-traumatized patients. For these patients, initial treatment of the femur shaft fracture may be an external fixator which restores mechanical stability of the thigh with minimal soft tissue dissection, blood loss, time, or medullary disruption. After a few days or weeks of general support, when the patient's condition is more stable, the fixator can be changed to a medullary nail. Other techniques of damage control orthopaedics might be the use smaller diameter nails to minimize reaming and blood loss and delayed placement of distal locking screws to shorten the operative time of initial stabilization. Retrograde rather than antegrade nailing can be achieved in less time with less blood loss and may be preferred in the multiply traumatized patients. Delayed treatment of less important injuries and prioritization of injury stabilization are tenets of damage control in contrast to total early care.

Another use of medullary nails for reconstruction is lengthening over a nail or the intramedullary skeletal kinetic distractor (ISKD). With this technique, an intramedullary osteotomy is performed with the intramedulary saw developed by Winquist described earlier. A medullary nail with distal and proximal telescoping components is placed. With torque applied a one way ratchet allows the nail to progressively lengthen which pulls the bone apart at a slow rate and creates a distraction osteogenesis gap that fills with bone and lengthens the femur. The nail then serves to stabilize the construct, maintain alignment, and allow ambulation during consolidation phase of the regenerate. Lengthening over a nail can be a good alternative to lengthening with an external fixator, especially when there is no need to simultaneous correct angular deformity.

Intramedullary nails work so well they have gained worldwide applicability, including third world countries with limited technical infrastructure. The Surgical Implant Generation Network (SIGN) nail project has been particularly effective in dissemination of medullary nailing techniques throughout the world.

Conclusion

It is interesting to note that the first half of my career was spent as an advocate for operative treatment for a variety of fractures against the setting of non-operative treatment being prevalent to the point of ubiquitous. The latter half of my career has been spent advocating "rational" operative treatment and consideration for less aggressive interventions in certain situations, when the most popular approach seems to be operative treatment of nearly everything. As Dr. Brown, my former partner and fellow Iowa alum said, "They should give a funeral for non-operative treatment of fractures." I replied, "No one would attend."

Intramedullary nails have been a tremendous advancement in the care of trauma patients, and one of the greatest contributions from the field of Orthopaedics in the past 50 years. They are very effective at restoring length and alignment and early mobilization of the patient with low complication rates and excellent results in comparison to the alternatives. They were a harbinger of many important advances in orthopaedics, including operative treatment of fractures and minimally invasive surgery to minimize injury and facilitate functional recovery. Medullary nails are perhaps the best example of respect for biology of healing while overcoming the mechanical disruption that occurs with long bone fractures. It has been my good fortune to participate in the application of this technology to the trauma victims of the state of New Mexico and the southwest region over the past 25 years. That knowledge has also been shared with over 100 residents and fellows from our training programs, as well as other surgeons from continuing medical education courses and publications.

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