SIGN Technique for Retrograde and Antegrade Approaches to Femur

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Summary: Although designed as a tibia nail, the Surgical Implant Generation Network system has been used frequently to stabilize fractured femurs. C-arm imaging is not necessary for placement of interlocking screws. Hand reaming decreases the morbidity associated with power reaming. The results are excellent for the contemplative surgeon.

Key Words: tibia, SIGN, IM nail, SIGN system, retrograde approach, antegrade.

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The history of retrograde approach to fractures of the femur is well described by Ricci et al. The early retrograde approaches were done for patients with ipsilateral hip and femoral shaft fractures, bilateral femur fractures, pregnancy, and fractured acetabulum. Indications have now been expanded to include all fractures of the distal and midshaft femur in our series. The knee must have 60 degree of flexion to insert a nail.

The first Surgical Implant Generation Network (SIGN) retrograde approach to the femur was done in 2000 in Vietnam. Many floating knee injuries occur due to motorbike accidents. The first patient treated by SIGN system stabilization of the tibia and a retrograde approach to the femur is shown in Figure 1, standing on the operated leg 6 weeks after surgery.

The ratio of retrograde versus antegrade SIGN nail, shown in Figure 2, is influenced by 2 factors. Retrograde was the first approach used for SIGN nail in the femur. Full knee flexion after surgery is the most important criteria for a successful operation in Southeast Asia. We found that we could usually obtain full knee flexion by manipulation of the knee to full flexion after the nail and interlocking screws were placed. This is particularly important when the patient presents with a knee flexion contracture before fracture stabilization. The resultant full knee flexion after retrograde approach has prompted surgeons in Southeast Asia to use this approach (Fig. 3).

Significance: A straight nail designed for the tibia can be used in retrograde approach to femur fractures.

TECHNIQUE FOR RETROGRADE APPROACH FOR FEMUR FRACTURES

Preop Protocol
The preoperative protocol is similar to that described for the tibia. We recommend that the traction pin be placed in the proximal tibia. At least 60 degree of flexion is necessary for insertion by retrograde approach.

Preparation in the Operating Room
The patient is placed in the supine position with the knee positioned at the break in the table. A bump is used to gain the necessary knee flexion. A knee bolster or a triangle can also be used.

Reduction—Closed
Closed reduction is relatively easy with a C-arm if the fracture is not over 10 days old. If C-arm is unavailable, open reduction can be used (Fig. 4).

Reduction—Open
Palpate the level of the fracture to locate the end of the proximal fragment. Once the skin incision has been made, use a periosteal elevator to longitudinally separate the muscle fibers of the vastus lateralis down to the fracture site. Use your finger to find the fracture. Free up the callus and soft tissue until you find the end of each fracture fragment. Preserve immature callus to fill the dead space. Do not curette the ends of the bone where the osteocytes lie. A common reduction method used to flex the fracture site to 90 degree, hook the edges of the posterior cortex together, and extend the fracture site. With persistence, the surgeon should never have to shorten the femur by removing bone. Line up the linea aspera on both sides of the fracture to accomplish rotational alignment. Accurate rotational alignment of the fracture site is an advantage of open reduction over closed reduction.

Significance: The linea aspera is used for rotational alignment.

In comminuted fractures, the femur may be shortened because of lack of bone continuity. Once reduction has been obtained, secure the reduction and assign maintenance of the reduction to an assisting surgeon. It is very important to maintain reduction during reaming and insertion of the nail and interlocking. Loss of reduction after drilling the hole in the near cortex will make placing the interlocking screw through the slot in the nail impossible.

Incision and Bony Entrance
When surgeons first attempt using the retrograde approach, we suggest using an incision medial to the patellar tendon. This incision can be elongated, and the knee flexed and extended for direct observation of the bone entrance point. As
the surgeon becomes more experienced, the incision can be decreased in length. Longitudinally incising the center of the patellar tendon is the shortest route. This approach can be used for both the tibia entrance and the femur bone entrance in floating knees. The entry point should be just anterior to the posterior cruciate insertion in the medial side of the femoral notch. It is made at the junction of the articular cartilage without damaging the posterior cruciate ligament attachment.

When using this approach for the first time, it is best to visualize the awl as it starts the bony entrance. If visualization is difficult, use the alignment pin to dimple the site of bony entrance and then feel the indentation before the awl is introduced. The flexion and the extension of the knee will improve visualization of the entrance hole. Use a curved awl to start the bone entrance and follow-up with the pointed reamers.

Significance: The bony entrance in the medial femoral notch can be determined visually by flexing and extending the knee.

Reaming of the Canal

Observe the fracture site to determine the direction of the reamers. Do not force the reamers. They will stop when they are against the cortex of the bone. It is important to rotate the reamers clockwise or the cutting edges will be dulled. Stabilize the distal femur fragment during penetration for bony entrance, reaming and insertion of the nail. The surgeon will feel the reamer pass through the metaphysis and into the proximal femur. Once the first reamer passes, use progressively larger reamers until chatter occurs for 4 to 6 centimeters longitudinally. The diameter of the nail chosen should be 2 mm smaller than the last reamer used.

Significance: Stabilize the distal fracture fragment during reaming and nail insertion.

Polytrauma Patients

The SIGN surgeon must often be the entire trauma team for his patients. The SIGN system is often used as the first implant for fracture stabilization in trauma patients. Other series have suggested external fixation as the first stabilization implant.1–2 We believe SIGN success in polytrauma patients is related to the speed of surgery (no frequent C-arm imaging) and the use of hand reamers. We believe that hand reaming is much safer than power reaming. Less complications may occur with the use of the reamer/irrigator/aspirator (made by Synthes) for similar reasons.2 Reaming allows a larger nail to be introduced. The interlocking screws can be inserted quickly using SIGN technique. A larger nail that has interlocking screws placed obviates the need for a second surgery and decreases possibility of nonunion and infection. Thermal necrosis is avoided by hand reaming, and the bone from the flutes of the reamer can be introduced into the fracture site. Higgins and Horwitz3 has suggested unreamed retrograde nail insertion for severely traumatized patients rather than initial external fixation followed by intramedullary (IM) nail later.

Significance: Hand reaming has many advantages over power reaming especially in polytraumatized patients. The bone from the flutes of the reamer can be used for bone grafting.

The conventional wisdom regarding selection of nail length has changed over the years. Whereas longer nails are important for stability, we studied 5 patients who had fractured their femur at the end of a retrograde nail. The majority of these fractures occurred when the end of the nail was 2 to 3 cm distal to the lesser trochanter, which is an area of high stress. The nail should end superior to or 6 cm distal to the lesser trochanter to avoid the high stress area. This is empiric observation. Further studies are needed.

Significance: There is a stress concentrator affect if the nail ends 4 inches below the lesser trochanter.

Fin Nail

Fixation of the distal end of the nail can be accomplished using the SIGN fin nail, shown in Figure 5.

The distal fin provides good rotational stability for transverse fractures, but should not be used in comminuted fractures with longitudinal instability. The technique for the fin nail includes reaming to chatter for 4 cm and then choosing the correct nail diameter. The proximal canal is underreamed at the level of the fin so the interdigitates with the bone in the canal. Marks on the reamers determine the distance each reamer is advanced to achieve this effect. The metaphysis of the femur is then over-reamed 3 to 4 millimeters to account for the 9 degree bend in the nail. The distal end of the fin nail should extend at least 10 cm back to the fracture site. It should be inserted with minimal rotation.

Significance: The fin nail provides adequate distal fixation for stable fractures.
Insertion of the Nail

The nail is inserted with the bend anterior. Observe the fracture site for orientation as you introduce the nail. There is a ring around the tube of the L-handle. Advance the nail until this ring is at the level of the articular surface. The nail will then be 2 mm below the articular cartilage. Do not force the nail—if necessary tap the nail while gently twisting 10 degree after every 2 taps.

Significance: The IM nail should not be inserted with great force.

Distal Interlock

The distal interlock in the retrograde approach refers to placement of the interlocking screws farthest from the L-handle near the hip. Distal interlocking screws are placed before proximal interlocking screws so that rotation can be used to find the slot in the nail. If the nail is struck heavily, it will bend to accommodate for the curve in the femur. We advise minimal force during nail insertion. If the nail does not progress, ream a larger diameter or use a smaller nail. If the end of the nail ends in the narrow part of the canal, the hole in the near cortex for insertion of the interlocking screw should be in the center of the cortex. The target arm determines the longitudinal location of this hole. If the slot in the nail is not readily found, remove the target arm and use the curved slot finder to find the slot. The interlock for the retrograde approach is placed from lateral to medial. This avoids possible damage to the femoral nerves and arteries, as opposed to anterior-posterior direction using C-arm imaging. Technique for placing the interlocking screw is same as the tibia. There is no radiation exposure as C-arm imaging is not required.

Significance: The distal interlock (nearest the hip) is oriented lateral to medial to avoid damage to the femoral nerves and arteries.

Compress the Fracture

If the fracture is transverse and there is a fracture gap, compress the fracture as described in the tibia. The amount of compression should be anticipated by adjusting the depth the nail is inserted into the femur before distal interlock.

Significance: Observe how deeply the nail is inserted before distal interlock and if impaction of the fracture is desired.

Proximal Interlocking

Proximal interlocking for the retrograde femoral nail is accomplished using the same technique used for the tibia. We
advise putting two interlocking screws so the nail will not protrude into the knee due to collapse at the fracture site.

Significance: We advise placement of 2 screws in the nail nearest the knee.

Manipulation of the Knee

The knee should be manipulated to full flexion after the nail and interlocking screws have been placed.

Postoperative Protocol

Range of motion of the knee should be maintained. The desired amount of weight imparted to the fractured leg depends on the stability of the fracture. This is an area for study. Certainly early full weight bearing can be accomplished in stable fractures. We have had few nails break after surgery. When failure has occurred, it is a fatigue fracture due to delayed or nonunion. It is possible that a more progressive weight bearing protocol than is commonly accepted would speed the healing process and actually decrease the number of broken nails.

Significance: Weight bearing is dependent on the stability of the fracture.

Antegradic Approach to the Femur

The nail is inserted through the greater trochanter with the patient in the lateral position. Interlocking screws are placed as in the tibia and retrograde approach to the femur technique.

Position of Patient

The lateral position makes it much easier to access the greater trochanter. It is also much easier to approach the fracture site if open reduction is necessary. Most of the fractures that reach SIGN programs have surgery ten days or more after injury. Open reduction is necessary in these cases. Fracture tables can be used if available.

Significance: Use lateral position if open reduction is done without using C-arm.

Reduction

The skin incision is made bearing in mind that the proximal fragment position is fixed whereas the distal fragment may be telescoped. After incising the skin and tensor fascia lata, a periosteal elevator is used to spread the muscle fibers longitudinally down to the bone. All soft tissue and callus is removed from around the bone fragments. Once the ends are freed, reduction can be accomplished using several methods including (1) reduction clamps, (2) stretching the tissues with a periosteal elevator between the 2 fragments, or (3) distracting the fracture site with the fracture fragments at 90 degree flexion and hooking the posterior cortex of each fragment followed by extension into reduction. It is essential to hold the reduction during reaming, insertion of the nail, and placement of interlocks.

If closed reduction is possible, standard technique with C-arm is used. It is important that the C-arm is calibrated yearly to control radiation exposure to surgeon and patient.

Nail Insertion

The difference of opinion between nail entrance at the piriformis fossa and the greater trochanter is noted. Considerations regarding the piriformis fossa include the following:

1. The piriformis fossa is directly in line with the proximal femoral canal and it is well-suited for a straight nail.
2. The straight line into the canal means that anterior or posterior translation of the bone entrance causes increased hoop stresses and perhaps bursting of the femur during nail insertion.
3. Piriforms approach requires a deeper soft tissue incision than a trochanteric approach.
4. Over-reaming to accommodate for the bend in the proximal nail may damage the blood vessels to the femoral head in piriforms approach.

Considerations regarding the trochanteric starting point:

1. Location is more superficial, so approach is easier.
2. The greater trochanter has more cancellous bone and therefore is more forgiving if the nail is placed anteriorly or posteriorly.

The proper bony entrance depends on nail design and technique. The SIGN nail has a 9 degree proximal bend and we advise over-reaming the metaphysis 4 mm to accommodate for this bend. This could damage the blood vessels to the femoral head if the piriforms approach is used. Hoop stresses will not occur if the surgeon does not force rotation as the nail is being inserted. The direction of the interlocking screws can be anterior to posterior or lateral to medial in both provide equal stability. The 1 degree to 1/2 degree bend at the distal end of the nail decreases the chance of penetration of the medial femoral condyle. C-arm imaging is not necessary if this technique is used.

This technique of interlocking was taught to me by Dr. Han Khoi Quang in Vietnam. Equal stability of the anterior-posterior and lateral-medial interlock has been confirmed by x-rays on the SIGN surgical database. This technique is easily demonstrated on a sawbones, which have variable anatomy of the femoral canal. As you are inserting the nail, rotate it and see how the hoop stresses torque the sawbones. This may be a cause of the femoral neck fractures, which are sometimes diagnosed later. These fractures may occur at a time of insertion or the hoop stresses plus walking creates a fracture of the femoral neck (Fig. 6).

Significance: The tip of the greater trochanteric approach is best for SIGN nail insertion.

A curved awl is used to make the bony entrance in the junction between the posterior third and middle-third of the greater trochanter. The reamers are then progressively introduced. We save the bone from the flutes of the reamers for placement into the fracture site if open reduction has been done. If more bone graft is needed, curettes can be used to remove bone from the greater trochanter. This bone is placed in a cup without contact with a sponge or saline. The bloody fluid is also retained in this cup. The surgeon must fill the entire circumference of the cutting edge of the reamer as it passes down the canal. This is a developed sensation and makes surgery much more interesting. The fracture must be stabilized in reduction during reaming and nail insertion.

Significance: Save the bone from the flutes of the reamer and the fluid that comes from the bony entrance for bone grafting.
The diameter of the nail is determined by the reamer size when chatter develops over 4–6 cm of canal. Drop back 2 mm for the diameter of the nail. The length of the nail depends on the level of the fracture. The nail should end at least 6 cm below the fracture site.

**Significance:** As the nail is inserted, allow it to assume rotation as insertion progresses. Proximal interlocking screws placed lateral to medial or anterior to posterior are equally stable.

**Distal Interlocking Considerations**

The distal interlock (fragment closest to the knee) is accomplished first. This allows the surgeon to rotate the nail to line up the slot in the nail with the hole in the near femoral cortex. The surgeon should consider the following advice:

1. If the nail is inserted forcefully, the nail may bend slightly. Even a bend of 1 degree is significant. The diameter of the canal at the level of interlock will also determine location of the slot.
2. If the nail ends in the narrow part of the canal, the hole for interlock should be placed in the middle of the bone, no matter where the target arm indicates.
3. Check to be sure the locking bolt is tightly engaged in the nail or rotation of the target arm may occur.
4. If the nail ends in the wider part of the femoral canal or metaphysis, the nail will rest in an anterior position.
5. The hole in the near cortex may have bone in the rim at the bottom of the hole and prevent insertion of the slot finder. This bone must be removed with the screw hole broach.
6. The hole in the near cortex may be misplaced longitudinally if reduction of the fracture is lost after the hole is drilled.
7. Rotation of the nail must be emphasized when the surgeon is searching for the slot in the nail. Often a slight rotation using the L-handle will allow placement of the slot finder.
8. The curved slot finder is very valuable in finding the slot in the nail. The target arm must be removed to use the curved slot finder.
9. If 1 screw is decided on, the screw should be placed in the slot nearest to the fracture. This puts less stress on the IM nail. The hole and slot in the proximal end of the nail should be filled with interlocking screws.

**Significance:** If the distal interlocking is difficult, consider the above possibilities.

**Distal Interlocking Technique**

The target arm is reattached to the L-handle and the bone exposed as described in the retrograde technique. This technique is the same as all SIGN interlocking screw techniques.

**Compress the Fracture**

Once the interlocking screw has been placed, consider the need for compression of the fracture site. The extractor connector can be applied in 10 seconds and backslapping done. This is done in stable fractures whenever compression will bring the fragments closer together. We routinely compress the fracture site in nonunions to stimulate healing.

**Significance:** The target arm orients the longitudinal position of the hole in the cortex; rotation of the nail will line up slots in the nail and hole in the cortex rotation.

**Proximal Interlocking Technique**

The direction of the interlocking screws may be in the anterior to posterior or lateral to medial direction. Both directions provide equal strength. This interlocking technique is described in the tibia chapter.

**Significance:** Use 2 interlocking screws for proximal interlock.

**Postsurgical Care**

Weight bearing may be done in a stable fracture the next day. The patient may bear weight depending on pain.
REFERENCES