SIGN Hip Construct Surgical Technique and Early Clinical Experience

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Summary: The Surgical Implant Generation Network (SIGN) Hip Construct was developed to treat patients with intertrochanteric hip fractures without the aid of fluoroscopic imaging. It is an intramedullary device inserted through the tip of the greater trochanter, using a lateral incision. Fracture fixation and compression are achieved using a single proximal interlocking screw and 2 compression screws inserted along the anterior and posterior walls of the greater trochanter into the femoral head. Beta sites have been established for clinical use of the SIGN Hip Construct and early clinical outcomes are promising. Each procedure is reported to the SIGN database with x-rays, which allows for immediate feedback and progressive innovation.

Key Words: SIGN—hip construct—hip technique—plate—screws—hip fractures.

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here were an estimated 1.7 million hip fractures globally in 1990, which is predicted to increase up to 4-fold by 2050.1–3 Hip fractures are recognized as a problem of high-income countries, but the largest growth in incidences are predicted to occur in Asia, Africa, and Latin America.4 This is largely due to the aging population and the associated rise in osteoporosis.5 Although much of the datum are speculative and fundamental epidemiologic studies establishing the incidence of hip fractures in developing countries are lacking, we have recognized the need for a suitable implant through direct observation of crowded wards with patients in skeletal traction for these injuries.

The development of the Surgical Implant Generation Network (SIGN) Hip Construct (SHC) was a 3-year process to address this need. Details are in a separate article in this issue. In brief, the SHC uses a 300-mm intramedullary nail inserted through a trochanteric entry point. Proximal fixation is achieved through a single interlocking screw and 2 compression screws. Distal fixation is accomplished using either the “fin nail” or a single distal interlocking screw. The final design is shown in (Figs. 1A, B).

After an iterative process that included extensive biomechanical testing, the SHC was felt ready for clinical use. The next step was to determine whether the surgical technique could be taught and accomplished without C-arm or a fracture table. In the experience of the senior author, surgeons in developing countries by necessity have a well-developed tactile sense that makes them well-suited to learn to use the SHC. In addition, the implant was designed such that misplaced screws would cause less damage than devices like the sliding hip screw that rely on a large centrally placed lag screw. In the current article, we describe the step-by-step operative technique for the SHC and follow this with a summary of the early clinical experience using the implant.

Significance: The rising incidence of hip fractures in developing countries must be addressed.

SURGICAL TECHNIQUE

General Considerations

The usual patient counseling and consent for surgery should be obtained. The surgeon must weigh the risks and benefits of open reduction and make the appropriate recommendation. Unlike the US hip fracture population, it is not uncommon for there to be a significant delay between injury and presentation, which is an important consideration in determining treatment. Irrespective of implant, reducing an intertrochanteric fracture is much easier within 10 days of the injury. An additional consideration for the SHC is the placement of the compression screws, which rely on hand-made pilot holes. Proper positioning of the pilot holes relies on tactile feedback, which is much easier when the drill passes through native cancellous bone rather than a partially healed fracture. For these reasons it may be better to pin an old hip fracture in situ rather than attempt reduction. Surgery should be avoided altogether in cases where the old displaced fracture is stable.

Significance: Treatment must be adjusted to allow for the age of the fracture.

Although many young people have fractured hips in developing countries, the elderly patient with significant comorbidities must also be treated. A thorough preoperative evaluation is therefore very important and should include washing the extremity the night before surgery.

The SHC template and preop x-rays are used to determine the length of compression screws, interlocking screw and approximate angle of the compression screws. This should be done using images of the unfractured hip bearing in mind that x-ray tube to cassette distance may not be standardized in all settings. The canal diameter should be measured to determine whether the fin nail can provide adequate distal fixation or an interlocking screw is indicated. Fatigue testing has demonstrated that distal fixation is important for overall stability of the construct; therefore, the fin must interdigitate solidly in the femoral canal. In equivocal cases, the distal interlocking screw is preferred.

In certain subtrochanteric fractures, the surgeon has the option to use a standard SIGN nail with 2 proximal interlocking

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L.G.Z., founder and president of SIGN. The patent on SIGN long bone surgical technique is in his name, and is listed as an inventor on the pending patent on SIGN SHC which is assigned to SIGN, and he receives no salary or expenses from SIGN.

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screws rather than the SHC. The level of proximal involvement where the SHC becomes the preferred method of fixation will be determined by clinical studies. At a minimum there should be sufficient bone in the proximal fragment to accommodate 2 proximal interlocking screws. If this cannot be determined using preoperative plain films, this is an intraoperative decision.

**Significance:** The choice of implant is estimated using a template and preoperative x-rays, but the final decision is made during surgery.

**Reduction**

A regular operating table can be used because C-arm is usually not available. The lateral position is suitable and has the added benefit that one does not have to worry about the posterior sag of the fracture fragments. An incision is made over the lateral aspect of the greater trochanter that starts 1 cm proximal to the vastus ridge and extends to 4 cm below. Reduction is accomplished by traction and rotation. The surgeon’s finger is inserted under the anterior border of the vastus lateralis to feel the fracture site on the anterior cortex of the greater trochanter and femoral neck. The surgeon must appreciate the forces that cause the intertrochanteric fracture are tension on the anterior side and compression on the posterior side. The anterior side therefore has less comminution and the quality of the reduction can be judged best by palpating the fracture line in this area.

**Significance:** Tactile sense is used to evaluate quality of reduction.

The posterior clamp is applied first to maintain the reduction. We have found that applying the anterior compression clamp first causes some displacement of the fracture due to differences in the anatomy of the anterior and posterior aspects of the greater trochanter and neck. To avoid interference with placement of the compression screws, the clamp is applied superior to the vastus ridge (Fig. 2). These reduction clamps have undergone 2 design iterations since the clamp shown in Figure 2.

**Anterior Compression Screw**

A 3.5-mm drill bit is used to make a hole in the cortex 1 finger breath below the vastus ridge in-line with the anterior
femoral canal. After enlarging the hole with the step drill, the pilot drill is used to make the track for the compression screw. The pilot is a manual device designed to be pushed and rotated through the bone (Fig. 3). The trajectory in the coronal plane is estimated using the Z angle finder, which has a 130 degree angle relative to the lateral cortex. The screw should pass as close as possible to the anterior cortex of the trochanter and femoral neck. In addition to the preoperative template, depth can be estimated by the resistance encountered with the pilot, which increases as it passes into the higher density bone of the femoral neck and ultimately subchondral bone. Screw length is determined by marks on the pilot drill, and the anterior compression screw is placed accordingly. Both compression screws are threaded proximally at a higher pitch than the distal threads. As a result, compression begins when the proximal threads enter the lateral cortex. It is important not to apply too much force to the screw as it is being advanced. It must follow the track of the pilot. Care should be taken to stop when the head of the screw reaches the cortex or the proximal threads will be stripped and compression lost. With a well-placed anterior compression screw the reduction clamps can usually be removed.

**Significance:** The anterior compression screw provides stability to the reduced fracture.

### Nail Insertion

The nail is introduced through a hole created slightly lateral to the tip of the trochanter at the junction between the posterior and middle third. The reaming technique depends on whether the surgeon chooses to use the fin nail or the standard interlocking nail, which are both 10 mm in diameter. The fin nails (Fig. 4) are underreamed distally to 9 mm so that the fin engages the canal tightly. In contrast, the standard nail (Figs. 5, 6) is reamed up to 12 mm distally. Both nails are reamed to 14 mm in the proximal 4 cm of the femur. The target arm should be attached to the nail during insertion and oriented to direct the interlocking screw into the femoral head (Fig. 5). This can be estimated by the position of the posterior aspect of target arm, which should be parallel to the posterior cortex of the femur. In our experience, the construct is more stable if the nail is placed proud with the top of the nail slightly higher than the cortex of the superior trochanter.

### Placement of Distal Interlock

If the SHC nail designed for distal interlock is chosen, be sure to use the SHC specific target arm for placement (Fig. 5).
The technique is otherwise as described previously for the tibia. When the fin nail is chosen, under-ream distally as described above and ensure that there is good interference fit between the fin and cortex, then proceed to proximal interlocking (Fig. 6).

Placement of Proximal Interlock

The proximal interlocking screw is placed using technique similar to what has been described previously for the tibia. However, because the screw passes into the femoral head rather than through a second cortex, the pilot drill is used to create the screw hole.

Similar to its purpose with the compression screw, the pilot drill provides greater tactile feedback to determine position and allows measurement of screw length. If the fracture involves the lateral wall of the trochanter, the connector rod or plate is placed over the screw before it is inserted. Because the interlocking screw used for the SHC is larger than the cannula, the target arm must be removed before the screw is inserted into the pilot hole.

Placement of Posterior Compression Screw

It is critically important for the surgeon to understand the differences in anatomy between the anterior and posterior aspects of the femoral neck and trochanter. Unlike the anterior wall, the posterior cortex of the trochanter does not form a continuous plane with the posterior cortex of the femoral neck. Furthermore, the close proximity of the medial circumflex artery requires careful consideration during this portion of the procedure.

The posterior compression screw is placed 1 finger breadth distal to the anterior compression screw. The 130 degree Z angle finder is used to determine the insertion angle, which should be slightly steeper than the anterior screw. After making a small hole and enlarging it with the step drill, the pilot is again used to make the track for the compression screw. This screw should have a slightly anterior trajectory. The length is determined by the marks on the pilot.

If these screws strike one another when inserted, back the proximal interlocking screw out and allow the posterior compression screw to seat fully. Screw in the proximal interlocking screw once the compression screw is seated. The threads must pass each other or the compression screws must be redirected.

Significance: A clear understanding of the anatomy of the proximal femur is needed because the relationship between the trochanter and the femoral head facilitates placement of the anterior and posterior screws.

ANCHORING THE PLATE

Anchoring the Plate

If there is a fracture in the greater trochanter, the connector plate is placed parallel to the wall of the anterior femoral cortex. The small drill bit and step drill are used to make the hole and the screw is inserted. Depending on the fracture pattern, this can serve as both a buttress and a tension band screw (Fig. 7).

CLINICAL EXPERIENCE

Preliminary results from a series of patients treated with the SHC in Afghanistan, Myanmar, and Cambodia are promising. The first clinical use was done in Afghanistan. We felt that this was fitting because the inspiration to complete the device was accelerated after we were told that 20 patients with fractured hips were in traction at Wazir Akbar Khan Hospital, the largest civilian hospital in Afghanistan. It is a unique setting with 12% of patients arriving after taking at least part of their journey by donkey cart. Both SIGN trips to Wazir Akbar Khan were during the very cold winter. The electricity was on for about 4 hours per day, which meant that we shared the cold with the Afghans. We were told that patients with fractured hips spent 3 weeks in traction before being placed in a body cast and discharged to homes that typically lack electricity.

Although the sliding hip screw might have been affordable for some cases, it cannot be placed safely without C-arm. Furthermore, several of the patients with unstable fractures would have been at high-risk for uncontrolled collapse.\(^6\)\(^-\)\(^8\)

The first case was a 42-year-old man with a 3-week-old unstable intertrochanteric fracture. He was placed in the lateral position on a fracture table. Because of his age and delayed presentation, we needed additional traction. Unfortunately, the fracture table was missing pieces and the traction mechanism had to be improvised.

After approaching through a lateral incision, we evaluated the initial reduction by feeling along the anterior wall of the trochanter and femoral neck. We benefited from knowing that fractures often occur with tension on the anterior side and compression on the posterior side. We felt the fracture reduction on the anterior side, and were satisfied that it had closed adequately during the traction and rotation maneuver.
The anterior compression screw was placed next. We were impressed by how well it compressed and stabilized the fracture site. The fin nail and interlocking screw with the connector rod attached were inserted as described in the technique above. We noted that there was a longitudinal fracture in the posterior trochanteric wall and therefore we could not place the posterior compression screw. Fortunately, we tested the reduction and it seemed stable. The patient was able to stand the next day, and the x-ray 3 months later showed healing in good position.

Significance: Be prepared to deal with longitudinal fractures in the lateral greater trochanteric wall, which are frequently not visualized on plain x-ray.

It is important to instruct the patient’s family on weight-bearing postoperatively. In many countries, it is the norm to lie down if you are sick. The idea of protective weight-bearing is used in all of our programs. We allow most patients to bear weight as tolerated using the principle of autoprotection. This has been recommended by Koval et al.9

Trips to Cambodia and Myanmar were scheduled to start 2 more beta sites for the SHC. The only fracture in one hospital observed was over 5-weeks-old. We took the fracture down, reduced it, but found that when we removed the callus that was holding the femoral neck and head in varus, little cancellous bone was left. We terminated the procedure early because of a fall in blood pressure and therefore were unsure of the reduction. We were gratified to receive an e-mail 4 months later that the patient was walking without pain. This demonstrates that the power of healing in that optimal stabilization is not always needed. The other surgery in Cambodia at the military hospital performed very well. There is definitely a learning curve to the procedure. The screws were all a little short, because we were concerned about penetrating the hip joint.

In Myanmar, the first patient had shattered the femur throughout the proximal 6 inches down the shaft including the greater trochanter. We were very happy to see how well the fracture reduced and was stabilized by the SHC. In this trip, we used the fin nail because the canals in Cambodia and Myanmar are small, and the fin provides good distal fixation.

The following are the lessons learned from Afghanistan, Myanmar, and Cambodia.

1. When you take down an old intertrochanteric fracture, you remove many of the healing elements. The callus should be preserved as much as possible.
2. The pilot works very well, but we were too cautious in worrying that we would penetrate into the hip joint so that the screws were short in most instances.
3. A fracture table is not necessary. An assistant can provide traction and rotation.
4. Our reduction clamps must be improved. We are working on a new design, which will be much better.

Africa–Tanzania, Uganda, and Kenya

We have multiple programs in these countries and chose the most active programs as beta sites. The many pre- and postop x-rays submitted in the reports show good surgical technique and judgment. In addition, during my prior visits, these surgeons demonstrated that they are able to think and adapt in the operating room as the surgery is being performed. This is very important because their education and primary school are by rote memory.

We prepared for this trip by making new reduction clamps. The canals are wider in Africa, so we redesigned and manufactured a new hip nail with a slot to accommodate a distal interlocking screw. A new target arm was designed and manufactured to direct placement of the distal interlocking screw.

Lessons Learned During the Africa trip

1. African bone is very hard. Drilling the holes for the screws should be done in such a way that it does not allow the drill bit to become dull. Steady pressure without progress through bone heats the drill bit, which predisposes to it becoming dull. Drill bits should be retracted periodically to allow them to cool. Our drill bits are not disposable and we hope they will last for many surgeries. Drilling at higher speeds causes less heat and saline irrigation diffuses the heat generated. We also emphasized that metal should not hit the cutting edge of a drill bit, step drill or reamer, or they will become dull.
2. Intertrochanteric fractures that are over 4 weeks old become...
osteoporotic. The senior author had read that subchondral bone is not as affected as the femoral neck by osteoporosis, which suggested that we should be able to feel the denser bone as the pilot is placed. These studies were done in postmenopausal osteoporosis and may not apply to disuse osteoporosis.

3. We penetrated the hip joint on one occasion. We had templated prior to the surgery, but unfortunately the distance of the x-ray tube from the cassette is not always consistent so we could not use the 15% magnification rule. We have considered this and made a 1.5 degree bend in the distal pilot. This will give greater tactile feedback to the surgeon. We are using the same principle as the 1.5 degree bend in the standard SIGN nail, which also gives more tactile feedback to the surgeon. The new pilot has been sent to Muhimbili Hospital in Dar es Salaam for trial.

4. A 30-mm standard cortical screw works better than the unicortical screw. This does not have threads in the screw head so it can be placed adjacent to the hole in the plate. This will give bicortical fixation.

5. Our bench testing has shown that the connecting rod is not necessary if there are no transverse fractures in the lateral trochanteric wall. We have applied this principle and it will be studied in future surgeries reported to the database.

6. We learned not to completely take out the healing process and to approximate the cortical wall. To date the reductions in older patients have held. We still have a lot to learn.

7. There are often unrecognized longitudinal fractures in the lateral trochanteric wall. When these are in the area where we want to place a compression screw, the procedure becomes problematic. We will work to develop a device that stabilizes the screw even when it is placed in the crack of a pre-existing fracture.

8. The SHC can be taught and learned by surgeons in developing countries. I have the highest respect for their ability.

9. It is difficult to determine preoperatively with a single anteroposterior x-ray whether the standard SIGN nail or the SHC will provide better fixation. It is the senior author’s personal opinion that if 2 screws can be placed in the proximal fragment, the standard SIGN nail will provide adequate fixation without the cost and complexity of the SHC. This has been well documented in many previous cases on the SIGN database.

We must now design stabilization devices for femoral neck fractures, which are a true unsolved fracture. The patients do not have the opportunity to receive total or hemiarthroplasty in developing countries.

We now have a special place on our website which only the hip surgeons can access. This allows a forum to discuss the surgery reports and x-rays and continue to make progressive improvements.
REFERENCES


