Special Case Report Series

CASE REPORTS

www.jorthotrauma.com

JOURNAL OF ORTHOPAEDIC TRAUMA

OFFICIAL JOURNAL OF

Orthopaedic Trauma Association
AOTrauma North America
Belgian Orthopaedic Trauma Association
Canadian Orthopaedic Trauma Society
Foundation for Orthopedic Trauma
International Society for Fracture Repair
The Japanese Society for Fracture Repair
CASE REPORT

Combined Open and Percutaneous Techniques in Complex Subtrochanteric Femur Fracture Nailing

Greg M. Osgood, MD

Summary: Subtrochanteric femur fractures are challenging cases that every on-call orthopaedic surgeon may encounter. Fracture features and patient features complicate the execution of the surgery and also challenge optimal reduction for healing. Poor surgical reduction often necessitates revision surgery for non-union or hardware failure. Anatomical reduction can be achieved if these specific fracture characteristics are recognized, proper positioning and reduction tools are selected, and the surgeon uses the appropriate implant to its optimal biomechanical capabilities.

Key Words: subtrochanteric femur fracture, cephalomedullary nail, reduction techniques

INTRODUCTION

Subtrochanteric femur fractures pose biological, mechanical, and technical complexity that challenge orthopaedic surgeons. Operative techniques and implants have evolved to counter the common complications of malunion, and delayed or nonunion.

The femur sustains some of the highest loads in the body during physiological activities due to angular deviation between its anatomical and mechanical axes. Cortical bone in the subtrochanteric region is subjected to the highest compressive and tensile forces of all regions in the femur. Due to the deviation of mechanical and anatomical axes in the femur, the bending moment on the femur is greatest in the subtrochanteric region when loaded along its mechanical axis, applying significant load to implants after surgery. As a result, when 100lb is loaded on the mechanical axis of the femur, 1200 lb/in² of compressive force is applied on the medial femoral cortex and 900 lb/in² of tensile force is applied on the lateral cortex in the subtrochanteric region. This force is nearly doubled when walking and tripled when running. Fracture fixation that does not account for these normal physiological loads predictably fail.

Deforming forces acting on the main subtrochanteric femur fracture fragments must also be accounted. Unopposed contraction of the gluteus medius hip short external rotators and iliopsoas muscles cause the characteristic flexed, abducted, and externally rotated position of the proximal fragment of subtrochanteric fractures, whereas contraction of the hamstrings and adductor group yield shortening, apex anterior, and varus fracture deformity through the diaphyseal fragment. These deforming forces complicate reduction and proper insertion of fixation, whether performed open or percutaneously. The case presented summarizes technical tricks and proper implant considerations that are imperative in preventing failures in treating a wide range of subtrochanteric fractures.

Case Report

The patient is a 34-year-old male motorcyclist struck by a motor vehicle on the left side who presented as a trauma activation at this Level I trauma center. He sustained an isolated proximal femur fracture. After following standard American College of Surgeons (ACS) evaluation, he was resuscitated and otherwise stable for surgery.

Radiographs of the left femur demonstrated a segmental subtrochanteric femur fracture (Fig. 1). The proximal fracture segment was flexed, abducted, and externally rotated. Fine-cut computerized tomography (CT) of the left femoral neck demonstrated a...
minimally displaced transcervical fracture only visible on CT (Fig. 2).

**SURGICAL TECHNIQUE**

The surgical plan was:

1. Anterior hip capsulotomy through a modified Watson-Jones approach
2. Open reduction of the femoral neck fracture directly through this anterolateral visualization
3. Temporary stabilization of the femoral neck fracture with wires
4. Preparation and reaming for antegrade piriformis start femoral nailing
5. Placement of definitive cannulated 6.5-mm (millimeter) screws anterior to the nail path
6. Intramedullary nailing with reconstruction proximal and static distal interlocking fixation

Secondary backup choices of internal fixation included isolated reconstruction nailing, proximal femoral locking plate, and angled blade plate fixation.

The patient was positioned laterally on a radiolucent flat-top table and stabilized with a bean bag with an axillary roll. The left lower extremity was prepped and free-draped from the 12th rib distally. A standard Watson-Jones incision was made on the lateral proximal thigh. Once the T-shaped capsulotomy was performed, there was minimal intracapsular hematoma, and the anterior femoral neck periosteum was intact. Multiple planes of intraoperative fluoroscopic images were used to further confirm the anatomical reduction of the femoral neck fracture.

Temporary internal fixation of the femoral neck fracture was achieved with 2 drill-tipped 2.8-mm Kirschner (K) wires for 6.5-mm cannulated screws. The entry for the parallel wires was on the anterolateral greater trochanter, aiming inferiorly and posteriorly toward the central femoral head, to compress the femoral neck perpendicularly while avoiding the piriformis nail path (Fig. 3). The fracture remained anatomically reduced visually and fluoroscopically as the wires were inserted. The position of these wires in the anterior femoral neck was confirmed on the lateral fluoroscopic projection.

Next, the piriformis entry point was accessed with the Femoral Recon Nail (FRN) entry wire (FRN; DePuy Synthes, West Chester, PA). Care was taken to direct the guide wire from the piriformis entry point anteriorly and laterally down the proximal femoral segment (Fig. 4). The opening reamer easily passed the anterior cannulated screw wires to the level of the lesser trochanter, aiming anterolaterally (Fig. 5); a percutaneous cannulated trocar was used to adduct the proximal segment during reamer insertion.

Reduction of the proximal subtrochanteric fracture was performed with a combination of direct and indirect techniques. In the lateral position, the distal extremity was easily brought anteriorly and rotated to match the flexed and externally rotated proximal femur. Additional direct manipulation of the proximal femoral segment through the Watson-Jones approach and percutaneous manipulation of the intercalary segment was performed using a Cobb elevator (Fig. 6). The ball-tipped wire was passed across the reduced intercalary segment. The distal fracture line was levered with a Cobb and reduced using similar percutaneous techniques. The ball-tipped wire was then advanced to a central intramedullary subchondral position on the anteroposterior (AP) and lateral fluoroscopic projections of the distal femur. The fractures were determined to be at anatomical length based on fluoroscopic reassessment, and the nail length was measured.

A near-anatomical reduction of the proximal subtrochanteric fracture was performed using a Collinear Clamp (Collinear Reduction Clamp; DePuy Synthes) inserted through the Watson-Jones approach to allow concentric reaming across this fracture line (Fig. 7). Sequential reaming was performed from 8 to 12.5 mm. Percutaneous tools maintained reduction throughout reaming to assure concentric preparation of the femoral canal.

After reaming, definitive compressive fixation of the femoral neck fracture was achieved by inserting 2 6.5-mm partially threaded cannulated screws over the previously placed guide wires.

An 11 × 420-mm piriformis entry FRN was inserted posterior to the cannulated screws. The fracture reductions were maintained as the nail was inserted (Fig. 8). The depth of insertion was selected to allow central position of a single cephalomedullary screw and distal insertion of a proximal diaphyseal interlocking bolt near the lesser trochanter. The radiopaque guide markers in the nail insertion handle were used to confirm central insertion of the cephalomedullary screw in the sagittal plane (Fig. 9). The second screw was percutaneously placed at the level of the lesser trochanter through the nail insertion handle.

The proximal subtrochanteric fracture line was held near-anatomically reduced with the Collinear Clamp until completion of all fixation. The femur was axially loaded manually along the nail axis to compress across the distal diaphyseal fracture line. At this fracture line, the interdigitation of the fracture line reduction and the cortical thickness of opposing fracture edges were clues to reduction accuracy.

Two distal interlocking bolts were inserted percutaneously using standard freehand technique. At the conclusion of the surgery, the patient was turned supine and the fracture rotational reduction was confirmed to be symmetric on bilateral internal and external rotational hip examinations, before extubation. Final radiographs demonstrated an acceptable reduction across all fracture lines (Fig. 10).

**DISCUSSION**

This patient sustained a complex proximal femur fracture with a minimally displaced fracture line in the femoral neck and segmental fracture of the subtrochanteric and diaphyseal region. Reduction of this fracture and stabilization of both the femoral neck and segmental elements require careful planning to minimize the risks of implant failure and other complications.
FIGURE 2. Axial CT scan demonstrates a minimally displaced transcervical femoral neck fracture.

Surgeons can mitigate risks of malunion, nonunion, and secondary surgery, common to subtrochanteric fracture treatment, by identifying predisposing patient and fracture characteristics and executing a biological surgical tactic with the appropriate implant. The bimodal distribution of subtrochanteric fractures reflects high-energy fractures in young patients and low-energy falls in elderly osteoporotic patients. The complexity of high-energy fractures in younger patients is balanced by favorable bone quality that supports forceful reduction maneuvers and anchors fixation well. Osteoporotic patients, however, can suffer from prolonged healing and impaired fixation of implants.

The Russell-Taylor fracture classification helps surgeons understand the challenges presented by the fracture pattern in obtaining a reduction and durable stabilization of the fracture until healing occurs. Type IA fractures have significant flexion-external rotation deforming force applied by the iliopsoas on the proximal fragment. Type IIA fractures add complexity in reduction due to piriformis extension of fracture lines. Type IB and IIB fractures lack medial cortical support in the critical calcar region; this results in maximal bending forces applied to the implant postoperatively, potentially leading to loss of fixation and catastrophic failure.

Other fracture features must be identified and countered during surgery to optimize reduction. Oblique and spiral fractures with short medial or posterior cortical faces on the proximal segment, as well as fractures with posterior and medial comminution, allow medial and posterior exit of guidewires and reamers during internal fixation, thereby predisposing to varus and apex anterior fracture deformity. Very short proximal fragments are difficult to control during instrumentation. Unopposed flexion, abduction, and external rotation impair access to the appropriate start point for nails and lead to medial and posterior trajectories of guide wires. This is accentuated by the large intramedullary diameter of short proximal segments, which allows even greater deviations of wires off the centromedullary axis. Varus malreduction has been associated with complications, delayed and nonunion, and increased length of hospital stay and delay in return to work.

Fracture reduction begins with patient positioning on the operating room table. Lateral positioning of the patient for surgery may allow the surgeon to flex the distal segment anteriorly and more easily to reduce it to the proximal segment, while applying traction and external rotational reduction. These maneuvers are more challenging in the supine position. Certainly, pharmacological paralysis must be considered when executing reduction maneuvers because the muscles discussed exert extraordinary deforming forces. The proximal fragment can be controlled through indirect methods (fracture table and traction), percutaneous methods (ball spike, bone hook, reduction clamp, Hohmann retractor, Schanz pin, external fixator, femoral distractor, and collinear clamp), or open techniques (direct visual reduction with clamp application).

Open reduction is underutilized as the often-rebuffed solution in modern biological reduction and fixation. When properly executed, however, open techniques often result in decreased surgical times and improved alignment. One series used open reduction of subtrochanteric fractures in 29% of cases and achieved 98% union, 2% revision surgery, and 98% acceptable alignment. A study of 58 patients found that open reduction correlated with complexity in fracture classification; more complex fractures required open reduction. Adjunctive cerclage wiring, once eschewed for its devascularizing potential, has been shown to aid reduction and obtain satisfactory result in some small series, when applied in a biologically supportive manner. In one series, outcomes (fracture displacement and distraction) were significantly worse if cerclage was not used; cerclage improved angulation and quality of reduction.

Implant insertion cannot be uncoupled from fracture reduction because the 2 steps are coincident and codependent. In these complex fractures, fracture reduction and implant insertion command the surgeon’s attention simultaneously as the instrumentation is anatomically directed across the aligned fragments. Intermittent fluoroscopy is required when using primarily percutaneous techniques. Key steps in instrumentation of subtrochanteric fractures include acquisition of the perfect starting point, direction of the insertion guide wire into the lateral anterior proximal fragment, and insertion of the starting reamer along this carefully defined trajectory. These initial steps in fixation account for the final quality of reduction in most cases. Insertion of a blocking wire or screw is sometimes helpful in assuring proper anterolateral wire placement in the short periacetabular proximal segment and in maintaining reduction as the anatomically designed implant is guided across the reduced fracture.

Historically, subtrochanteric fractures were universally fixed with fixed-angle extramedullary implants designed to resist varus deformity. The 95-degree OTA/AO condylar blade plate has been used with direct and indirect reduction techniques to achieve satisfactory rates of healing and alignment. The less technically challenging 95-degree dynamic condylar screw has also been used with excellent results, although sagittal plane control of the proximal fragment and medialization using this device are
compromised compared with the blade plate. Failure using these devices were increasingly attributed to surgical technique including iatrogenic soft tissue devitalization, and evolved toward the biological approach of vascular preservation and indirect reduction techniques.

The proximal femoral locking plate was introduced to allow 95-degree stabilization of subtrochanteric femur fractures while facilitating biologically sensitive surgical techniques. These plates demonstrated equivalent or superior bending stiffness compared with blade plates but less torsional stiffness. Early series of subtrochanteric fractures fixed with proximal femoral locking plates showed that this increased in vitro stiffness did not correlate with clinical results. Several series showed varus collapse and implant failure in up to 41%, leading to limited use of this product for subtrochanteric fractures.

Blade plates, condylar screws, and proximal femoral locking plates succeed when tension is applied to the implant, thereby loading opposing fracture surfaces in the proximal femur. In the absence of fracture loading, specifically in reduced fractures that lack posteromedial cortical contact, these extramedullary implants are subjected to extreme bending forces. For this reason, extramedullary fixation devices are not favored in unstable fracture patterns. Unlike the extramedullary implants discussed above, current intramedullary implants can provide similar stiffness in stable and unstable subtrochanteric fractures. Intradural implants, therefore, are increasingly important in stabilizing comminuted fractures of the subtrochanteric region.

Numerous biomechanical studies support intramedullary fixation of subtrochanteric fractures. Early statically locked intramedullary rods sustained loads of 3–4 times body weight, double the forces under which plating systems failed. Cephalomedullary fixation, in particular, sustains significantly greater loads for more cycles than blade plates and proximal femoral locking plates, and standard antegrade nailing. Clinical studies back up these in vitro protocols. Second-generation cephalomedullary nailing of subtrochanteric fractures results range from 2% to 5% nonunion, 2%–20% varus malunion, 9% reoperation, and 2%–7% nail revision. Comparison of piriformis and trochanteric starting points in a small series showed no difference in blood loss, incision, operative time, or immediate complications. Surgeons’ assessment of technical difficulty was similar in both groups. All fractures healed. Malunion was 12% in the piriformis entry cohort and 24% in the trochanteric start group, P > 0.05. Clinical outcomes of Harris Hip Score, range of motion, and return to work status were equal. The impact of starting point on malalignment is of significant concern, especially for subtrochanteric fractures. Although the piriformis entry point is collinear with the medullary canal, nails entering from the greater trochanter require a coronal plane bend to accommodate the trochanter’s offset in relation to the shaft. Deviations of 2–3 mm off the tip of the greater trochanter for these nails can result in 4–6 degrees of varus/valgus malalignment.

Ultimately, technical aspects of stabilization of the reduced fracture with intramedullary nailing can optimize results. The importance of nails with larger proximal diameter has been shown. The diameter of the proximal end of the nail plays an important role in fractures with very short segments, due to the mismatch between

**FIGURE 3.** Anterior–posterior (AP) and lateral fluoroscopic projections show anterior placement of cannulated screw wires to maintain reduction.

**FIGURE 4.** Anterior–posterior (AP) and lateral fluoroscopy show anterior and laterally directed starting wire in piriformis entry point.

**FIGURE 5.** Opening reamer passing femoral neck fixation wires.
nail diameter and medullary diameter in this area.\textsuperscript{45,47} Pugh demonstrated that Russell-Taylor reconstruction nail constructs restored 100\% of the stiffness and 60\% of the torsional stiffness of the subtrochanteric region while increasing the load to failure to 450\% of body weight.\textsuperscript{48} Two proximal screws are important in fixation of the proximal fragment. Nonparallel screws provide a biomechanical advantage by decreasing motion at the proximal segment and increasing stiffness under physiological load, compared with standard parallel cephalomedullary screws in reconstruction nails. The failure mode of fractures without cephalomedullary fixation also differs under cyclical loading, with fractures through the femoral neck.\textsuperscript{49}

This case exhibits fracture features that increase risk of subtrochanteric fracture treatment complications and execution of several key steps, outlined above, to mitigate these factors. Intramedullary fixation of this unstable fracture was planned to provide durable stiffness until healing. As shown to be successful in a clinical series of ipsilateral femoral neck and subtrochanteric fractures, this plan was altered to allow direct reduction and primary open reduction internal fixation (ORIF) of the femoral neck with compressive internal fixation before intramedullary nailing.\textsuperscript{50} As with other unstable fracture patterns, like those with posteromedial comminution or extension into the piriformis fossa, open reduction with extramedullary fixation was considered as a

\textbf{FIGURE 6.} Coronal and sagittal plane reduction of proximal subtrochanteric fracture using an elevator and percutaneous trochar, and passage of reaming wire.

\textbf{FIGURE 7.} Limited open collinear clamp (DePuy Synthes) reduction of proximal subtrochanteric fracture immediately before nail insertion.

\textbf{FIGURE 8.} Percutaneous reduction of the distal fracture segment for passage of the reaming rod and intramedullary nail.

\textbf{FIGURE 9.} Perfect lateral image of the proximal femur and nailing system shows alignment of the femoral head, neck, greater trochanter, and shaft, nail, and insertion handle. Radiopaque aiming guides in the insertion handle direct central positioning of proximal screws into femoral head.
secondary plan. Careful biological fixation during percutaneous reduction of the subtrochanteric region was essential. The perifemoral entry point allowed easy insertion of the guidewire into the centromedullary axis for reconstruction nailing. Recognition of the high medial fracture obliquity and its predisposition to varus malreduction guided our surgical tactic for initial steps in intramedullary nailing; percutaneous reduction techniques and frequent radiographic analysis allowed anatomical reduction during passage of the wire and reamers into the anterolateral proximal femur. Percutaneous reduction and careful reaming of the segmental distal fragments allowed near-anatomical final reduction. Nonparallel proximal interlocking screw fixation optimized the stiffness and micromotion of the proximal segment. Static distal interlocking was performed, recognizing the importance of smaller radius of curvature in preventing anterior nail penetration in the distal segment.51

CONCLUSION

Achieving optimal results in subtrochanteric fracture stabilization requires appreciation of the enormous physiological forces exerted in this area of the femur and careful assessment of fracture characteristics that challenge surgeons to achieve anatomical reduction and stabilization, especially in unstable patterns. Current intramedullary implants are capable of supporting forces exceeding normal physiological loading. A comprehensive understanding of reduction methods is essential in planning and executing such surgeries. Careful application of percutaneous and select open methods to counteract these forces throughout instrumentation minimizes the postoperative deformity and promotes successful union.

REFERENCES


Read the rest of the *JOT Case Reports* online on www.jorthotrauma.com. It’s the Grand Rounds series from the *Journal of Orthopaedic Trauma*, the official journal of the Orthopaedic Trauma Association.