Reduction Techniques for Trochanteric- and Subtrochanteric Fractures of the Femur: a Practical Guide

Technika repozice u trochanterických a subtrochanterických zlomenin femuru: praktický průvodce

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SUMMARY

Trochanteric intramedullary nailing has gained widespread acceptance and popularity among orthopedic trauma surgeons. Whereas some simple fracture patterns are easily reduced and nailed, others may present a major challenge for the surgeon. Anatomical reduction and optimal placement of the intramedullary implants are the most important factors for fracture healing and good functional outcome. Closed anatomical reduction is to be achieved before the nail is inserted. However, especially in inter- and subtrochanteric fractures, a limited open or even open reduction technique may be necessary to achieve an adequate reduction. This article focuses on a structured and practical approach to various reduction techniques based on characteristic displacement patterns. The authors describe in detail their favored reduction techniques with tips and tricks for problem-solving. Furthermore, a non-systematic review of the current literature is provided with a critical appraisal of the described techniques and alternative methods.

Key words: trochanteric, subtrochanteric femur, fracture, reduction, cephalomedullary nail.

INTRODUCTION

Although fractures of the proximal femur are among the most common fractures, they may still remain a challenge for the treating surgeon. Trochanteric- and subtrochanteric fractures are encountered with a wide range of different fracture patterns, ranging from undisplaced simple pertrochanteric fragility fractures in the elderly to severely displaced multifragmentary subtrochanteric fractures in young patients with high-velocity trauma. There are different treatment options available such as screw- and side-plates, blade-plates, locking plates or intramedullary nails. Cephalomedullary nails have several biomechanical advantages such as increased rigidity and stiffness of the implant, a shorter lever-arm and better load sharing. Thus, they have gained wide-spread acceptance for fixing unstable trochanteric and subtrochanteric fractures. Today, cephalomedullary nailing is the preferred technique for many orthopedic trauma surgenons surgeons (18). Although these fractures can be treated in supine or lateral position on a flat radiolucent table, the use of a traction table allows indirect fracture reduction and maintenance of reduction throughout the procedure. Thus, closed reduction and intramedullary nailing using either a short or long proximal femur nail antirotation (PFNA; DePuy Synthes, Oberdorf Switzerland) on a traction table in supine position is the standard of care for unstable trochanteric- and subtrochanteric fractures in our institution.

In the following, we describe a structured approach to these fractures focusing, on our favourite reduction techniques on a traction-table prior to insertion of a cephalomedullary nail. Furthermore, alternative reduction methods and crucial aspects regarding nail insertion are described and discussed.

Analysis of the fracture pattern and characteristic deformities

Defined muscular forces, depending on fragment sizes and fracture pattern, are responsible for characteristic deformities (Fig. 1). The abductor muscles may pull the proximal fragment into varus (abduction) whereas the iliopsoas causes a flexion deformity. The iliopsoas and the short external rotators are responsible for external rotation of the proximal part of the femur. Gravitation may cause a dorsal displacement of the distal main fragment. On the traction table with the injured leg extended, the femoral shaft may also be pulled into an extension deformity by the gastrocnemi. Shortening and medialisation of the femoral shaft may occur due to the force of the adductor muscles. This muscle group is also responsible for an external rotation of the distal fragment.

Fracture deformities are to be addressed with specific reduction maneuvres to facilitate the insertion of a cephalomedullar implant. Inserting a nail without prior adequate reduction may be hazardous leading to insufficient fracture alignment, bad implant positioning and remaining instability. As a consequence, secondary fracture displacement, malunion or nonunion and implant failure may occur. Thus, a profound understanding of the fracture with its characteristic displacement pattern due to the different muscle force vectors is mandatory. With this understanding, well targeted reduction maneuvers can be chosen in order to avoid further damage and to preserve remaining soft tissue attachments and blood supply to the bone fragments.

AO 31-A1 fractures

These fractures are simple two-fragment fractures with the fracture line running through the greater trochanter. Displacement typically consists of shortening and external rotation of the proximal fragment. Closed reduction on the traction table with traction and mild internal rotation usually is successful for this fracture type.

AO 31-A2 fractures

In contrast to A1 fractures, the fracture line also runs through the lesser trochanter. Therefore, the medial column may collapse. Without this medial support, these fractures tend towards varus displacement. External rotation, shortening and flexion deformity usually occur. The lesser trochanter may migrate proximally due to the pulling forces of the iliopsoas muscle. Depending on the exact fracture pattern, the proximal main fragment may also present in flexion deformity. In fractures with a comminuted greater trochanter or involvement of its lateral wall, there is an increased risk for a subsequent extensive collapse with lateralisation of the head-neck fragment once weight bearing is started. A2 fractures are considered unstable. Sometimes, fragments are trapped in the fracture itself, making additional reduction maneuvers necessary. Intramedullary stabilization, using a short PFNA, is the standard of care for these fracture patterns in our institution.

Fig. 1. Muscular tension forces and deformities in trochanteric and subtrochanteric fractures.

AO 31-A3 fractures

Type A3 fractures are defined as reverse trochanteric fractures (intertrochanteric fractures) with involvement of the lateral metaphyseal cortex. These fractures are considered highly unstable and difficult to reduce. The medial and lateral column is fractured. This fracture pattern typically presents with varus, flexion and external rotation deformity of the short head-neck-trochanter-fragment. The force of the adductor muscles on the femoral shaft results in a shortening, medialization, adduction and external rotation of the distal main fragment. Furthermore, dorsal displacement of the distal main fragment may occur. Inadequate reduction and implant positioning may increase the risk for a secondary loss of reduction and fixation failure. In these fractures, a long cephalomedullary nail is usually used for increased stability in our institution.

AO 32A-C subtrochanteric fractures

The subtrochanteric region is defined as the zone between the distal border of the lesser trochanter and the junction of the proximal and middle third of the femur. It typically involves a segment of about 5 cm (25). However, subtrochanteric fractures may extend into the femur shaft or into the trochanteric region and femoral neck. Although the subtrochanteric region is defined to be part of the femoral shaft (AO 32) in the AO classification system, its treatment differs from shaft fractures due to the short proximal main fragment and its biomechanical characteristics as described above. The typical displacement pattern is similar to A3-fractures: varus, flexion and external rotation of the proximal fragment and adduction, medialization, external rotation and dorsal displacement of the shaft fragment. Since the subtrochanteric zone mainly consists of cortical bone in contrast to the well-vascularized metaphyseal bone of the trochanteric region, bone healing is usually slower and delayed union is frequently observed. Comminution of the posteromedial cortex in subtrochanteric fractures increases the stress on the implant, leading to increased risks for hardware failure and nonunion (9). Inadequate reduction with some remaining varus malalignment is associated with even higher rates of these complications. Similar to A3 fractures, long cephalomedullary nails are generally recommended. However, alternative fixation devices such as blade plates or other implants are used as well.

General considerations regarding closed and open reduction maneuvers

According to the AO principles for internal fixation, a fracture has to be reduced to restore functional anatomical relationships followed by a stable fixation which allows early mobilization of the patient. The blood supply to the soft tissues and bone has to be respected and preserved (15). Gentle closed reduction with minimally invasive and stable internal fixation, followed by immediate postoperative mobilization with full weight bearing, is the highest goal of modern operative fracture treatment. However, this goal may not be achieved in many patients due to various factors related to the patient, the fracture pattern, the soft tissue conditions, the chosen implant or the surgical technique used. Closed reduction may be superior to open techniques if correctly applied. However, repeated forceful and undirected closed reduction maneuvers may compromise the soft tissues and the blood supply to the bone more than a well planned and performed open approach. The remaining soft tissue attachments to the bone and the periostal blood supply have to be respected. Whereas closed reduction is preferrable over open techniques, one must not hesitate to escalate from closed to percutaneous– and limited open reduction techniques. Sometimes, a complete exposure of the fracture can be necessary to achieve a good reduction result.

In many fractures, closed reduction maneuvers may successfully be performed. Thus, we usually attempt closed reduction on a traction table with fluoroscopic guidance before the patient's skin is desinfected in the vast majority of our patients. In some patients with fracture patterns considered unsuitable for closed reduction, the surgeon may proceed to more invasive reduction methods. However, independent of the applied technique, the reduction needs to be maintained throughout the intervention till the implant is finally placed. If the fragments are not held in the reduced position during reaming, eccentric reaming with consecutive malalignment may occur during the passage of the nail (1). This rule can not be overemphasized! Attempts to reduce a fracture by inserting a nail and stringing the displaced fragments onto the nail, are associated with unpredictable and bad results (3, 9, 17, 23, 26). Once the trochanteric region is reamed and a nail is placed, adequate correction of malalignment is rarely possible. Before the nail is inserted, the patella should be in a horizontal position with an antetorsion of 10–15^{0} of the femoral neck to exclude significant malrotation. The correct antetorsion of the femoral neck is controlled by fluoroscopy. Therefore, a true AP view of the femoral neck is obtained. Now, the C-arm is rotated 90^{0} to confirm a proper antetorsion of the neck (10–15^{0}), (9). To facilitate optimal placement of the guide wire in the axial view, the C-arm is rotated back 10–15^{0} to place the femoral neck in line with the femoral shaft. Sometimes, subtrochanteric fractures with long oblique or spiral fracture pattern re-displace ("spring open") once the reduction tool is released after final placement of the nail (1). In these situations, we prefer to apply a cerclage wire to achieve and maintain the previous reduction. In a biomechanical study, Mueller et al. demonstrated an increased stability of intramedullary nail fixation of subtrochanteric fractures when the medial collumn was stabilized with an additional wire cerclage (16). Accurate fracture reduction allows the femur to share the load with the cephalomedullary nail. Studies have shown that this concept improves bone healing and reduces implant failure (16, 24).

Patient positioning on the traction table and closed reduction techniques

The use of a traction table has become very popular among orthopedic trauma surgeons as it does not only allow indirect fracture reduction but also maintenance of reduction by providing consistent traction throughout the procedure. Studies have shown that the use of a traction table reduces surgical and anesthesia time (5). Thus, the traction table is used by default for trochanteric and subtrochanteric fractures in our institution. In the

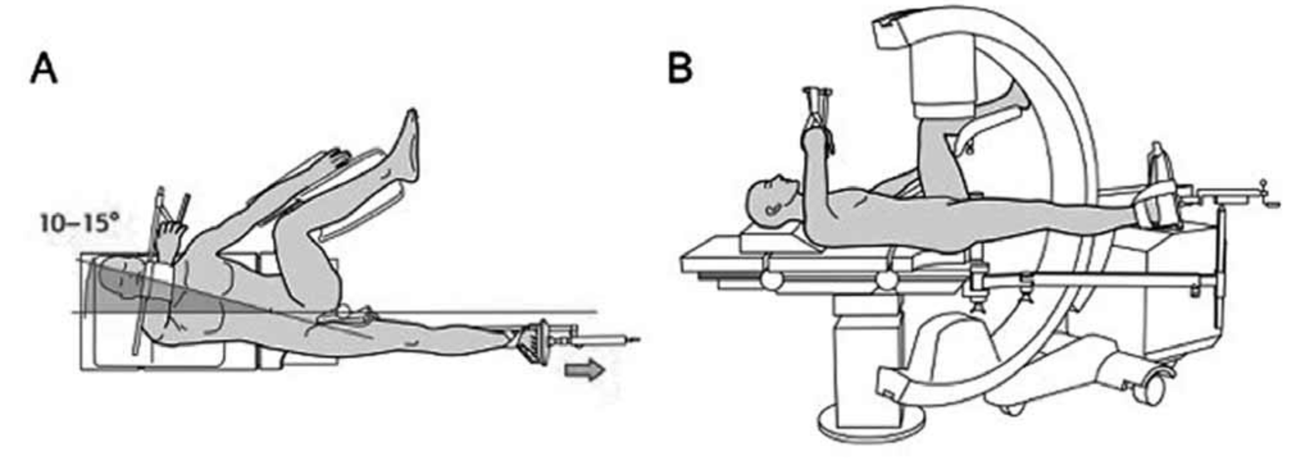

Fig. 2. A and B – traction table and patient positioning (with friendly permission by AO Publication).

following, proper patient positioning on the traction table is described. This is a key element for facilitated reduction maneuvers and good access for nail insertion.

The patient is placed supine on the traction table with a perineal post. The contralateral leg is placed in the hemilithotomy position (Fig. 2). This position allows good access for the C-arm to obtain adequate AP and axial views of the proximal femur. A "banana" position of the torso (bent 10-15^0 away from the affected limb) is important to facilitate access to the tip of the greater trochanter for an unobstructed insertion of the trochanteric nail. If necessary, slight elevation of the torso (flexion of the lumbar spine) and flexion in the hip releases some traction of the iliopsoas. This maneuver usually facilitates the correction of a flexion deformity of the proximal fragment. Traction of the injured leg combined with some adduction and slight internal rotation are the typical maneuvers for a successful closed reduction in various fracture patterns.

The use of a traction table is usually safe. However, serious complications have been reported in the literature associated with prolonged operation time, insufficient padding or excessive traction. Pudendal nerve palsy, which occurs as a compression neuropathy due to pressure between the perineum and the countertraction post, is reported with an incidence up to 27.6% (22). The hemilithotomy position on the traction table may cause sciatic and peroneal nerve injury and compartment syndrome of the uninjured leg (5). Thus, the healthy leg has to be sufficiently padded and only fixed as little as possible with straps. Forced abduction and flexion of the hip is to be avoided. We usually try to use as little traction as possible. Once an adequate reduction is achieved, the traction is released stepwise under fluoroscopic guidance to the minimum traction level at which the reduction is still maintained. Before the distal locking bolt is inserted, the traction is completely released to relieve the soft tissues and to allow any existing fracture gaps to close before distal locking is performed. Overreduction of a varus deformity into slight valgus may be corrected with this maneuver as well. Furthermore, the hemilithitomy position of the contralateral leg is lowered as soon as the implant is finally placed and the fluoroscopy is completed.

Surgical approaches

The approaches to the proximal femur are standardized and well described in the literature (7). Beside stab incisions for percutaneous reduction techniques, which may be applied at different locations of the tigh, lateral and posterolateral approaches to the proximal femur are usually used. In general, three short incisions are necessary. Access to the tip of the greater trochanter to insert the nail is gained through the most proximal incision whereas the more distal incisions are used for the femoral neck implants and the distal locking bolt, respectively. The location of these incisions is guided by the aiming device which is attached to the nail. The nervus gluteus superior may be in danger if the proximal incision is placed too proximally. Damage of the nerve can lead to gluteal muscle insufficiency (2). However, an anatomic study did not show a higher risk for superior gluteal nerve injury when a more proximal incision is used to the piriformis fossa (13).

Percutaneous reduction techniques represent the first step of escalation when closed reduction is considered inadequate. Although stab incisions are considered minimally invasive, the underlying anatomical structures have to be respected in order to avoid serious complications. Thus, the localization of stab incisions and the trajectory of the instruments from skin to bone require meticulous considerations and knowledge of the anatomy.

If closed reduction and percutaneous techniques through stab incisions fail, a limited open approach is our preferred option. Therefore, the incision, used for the insertion of the PFNA blade, is extended as required. One should keep in mind that usually no incisions have been performed until this moment when escalation from closed to a more invasive reduction method is considered. Successful reduction should be performed prior to implant placement! However, for most fracture patterns, the incision used for a limited open reduction is also used to insert the blade once adequate reduction is achieved. We usually perform a posterolateral approach. The vastus lateralis is gently mobilized and retracted anteriorly (7). Meticulous hemostasis is important to prevent bleeding from perforating vessels. It has been shown that ligation of the lateral intermuscular septum vessels does not alter the periosteal perfusion of the femur (6). Access to the femur by splitting the vastus lateralis fibers has also been described (7). However, this approach may be associated with denervation of the dorsal portion of the vastus lateralis (21). Thus, we prefer the more anatomical posterolateral approach posterior to this muscle as described above.

In more complex fracture patterns, such as subtrochanteric fractures with superior or inferior fracture extension, a limited open approach my not be sufficient to control the main fragments. In these situations, the lateral incision may be extended as required by the fracture pattern. The length of the incision is the only difference between a limited open- and an open approach. In rare cases, the approach may be extended for a full exposure of the fracture including the incision for the nail insertion at the greater trochanteric tip. Preservation of blood supply to the bone is crucial for timely fracture healing, extensive deperiostation and damage the soft tissues must be avoided. Thus, the surgical handling is more important than the length of the skin incision. Special care is given to avoid any further lesion to the insertion of the abuctors.

Favorite reduction techniques based on specific fracture displacement patterns

Abduction deformity

Abduction (varus) deformity may be corrected by simple traction. If the reduction remains insufficient, we prefer to apply pressure from lateral by using the assistant's fist or a hammer. Direct pressure onto the bone by using a percutaneous ball spike is an option if closed measures fail. A bone hook, inserted from lateral, may be used to realign the the head-neck fragment by pulling the greater trochanter laterally and distally (Fig. 3), (23). For reversed fracture types and oblique subtrochanteric fractures, the lateral spike of the proximal fragment may be reduced with a ball spike. The reduction may then be maintained by bone forceps. Alternatively, we frequently use a collinear reduction clamp.

Cerclage wiring may be applied to either support the reduction or for permanent augmentation of intramedullary nailing (8, 27). Historically, cerclage wiring was associated with impaired bone blood supply resulting in delayed- and nonunion. Recent research shows that the periostal vascularisation is circumferential, rather than longitudinal. Thus, non-union following open cerclage wiring may rather be caused by extensive soft tissue damage and wide dissection of the periosteum than due to strangulation of bone blood supply (10, 12). More sophisticated cerclage systems have been introduced in recent years which can be applied without extensive devascularisation of the affected bone (8). We use a cable system, consisting of a cable with crimp and specific instruments (Synthes Cable System; DePuy Synthes, Oberdorf Switzerland) which allows minimally invasive application for either temporary reduction support or permanent fracture fixation (Figs 4A–E). When the wires are passed around the bone, the surgeon must try to stay as close to the bone as possible in order to avoid further damage to the soft tissues, in particular to nerves and blood vessels.

In comminuted subtrochanteric fractures, the application of cerclage wires may overreduce the fracture fragments, resulting in a blocked medullary canal. Using reduction clamps may not be feasible in this situation due to the same reasons. To overcome this problem, one can maintain reduction of the main fragments by applying small plates (2.0/2.4mm) with monocortical screws ("hemi-cerclage") without compromising the passage of the guide wire and nail (Fig. 5).

Fig. 3. AO 31-A1 fracture. Correction of abduction deformity with a hook. Pulling the head-neck fragment laterally and distally, rotates the fragment from abduction into an anatomical position.

Fig. 4. AO 31-A3 fracture. A – multifragmentary fracture with varus deformity and shortening; B – good alignment was achieved by closed reduction techniques; C – limited open reduction, using a permanent cerclage cable, was applied for improved stability; D – lateral view.

Fig. 5. AO 31-A3 fracture. A – varus deformity with a multi-fragmentary fracture pattern; B – reduction was achieved and maintained with two mini-plates (2.0mm) with monocortical screws. Nail insertion was performed without obstruction.

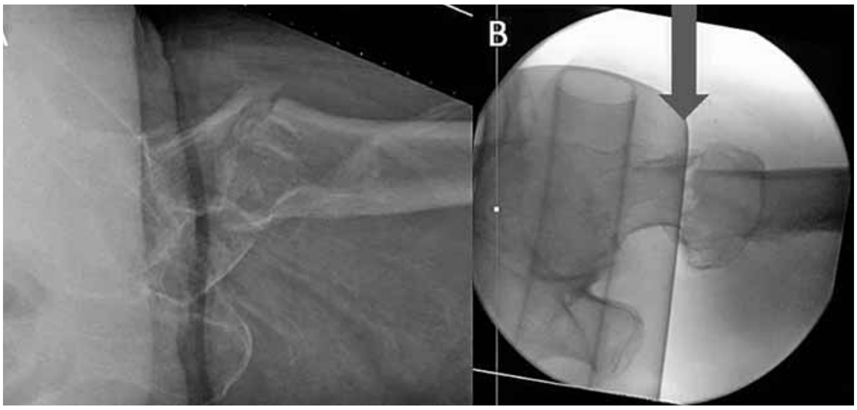

Fig. 6. AO 31-A2 fracture. A – flexion deformity; B – correction of the deformity was achieved by applying pressure from anterior onto the head-neck fragment in combination with some traction.

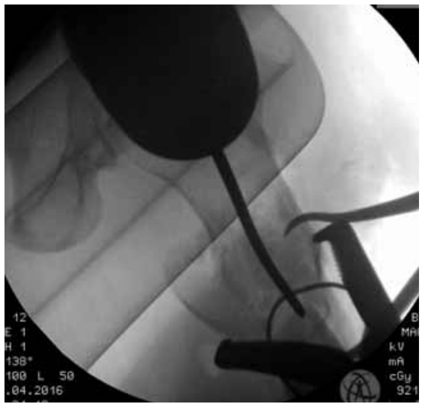

Fig. 7. AO 32-A3 fracture. Limited open reduction of a flexion deformity, using bone forceps and cerclage wiring, before the guide wire is placed.

Bone hooks, introduced through a small incision on the lateral aspect of the tigh, are ideal to realign medialization and adduction deformities of the shaft fragment. A long medial spike of the proximal fragment may be reduced as well in A1.3 fracture types. However, hooks should be used in a careful manner. We strongly advise against the use of any reduction tools on the medial aspect of the proximal femur superior to the lesser trochanter in order to avoid damage to the blood supply of the femoral head.

Flexion deformity

Slight traction, adduction and internal rotation on the traction table often reduce this deformity. Residual flexion may be reduced by appling blunt external pressure from anterior onto the proximal fragment. The fist of an assistant or a hammer may be used (Figs 6A and B). Additional support can be gained by slight elevation of the patient's torso or flexion of the hip to relieve the traction of the iliopsoas.

A Cobb elevator or other instruments like Hohmann retractors may be inserted through a limited open approach from lateral to neutralize the flexion deformity. Pointed reduction clamps, Verbrugge forceps or other bone forceps may be applied through a limited open or open approach to reduce the fracture, as well as maintaining the reduction (Fig. 7), (1, 3, 14). However, further devascularisation of the bone fragments is to be avoided. A ball spike, inserted percutaneously from anterior to correct the flexion deformity of the proximal fragment, can be useful because it leaves the medullary canal unobstructed, and reduction may be maintained till the nail is placed (4, 23, 26). Alternatively, percutaneous Schanz screws can be used as percutaneous joysticks to manipulate the fragments (11). However, they may obstruct the passage of a guide wire or nail insertion. We therefore rarely use them for fracture reduction.

Park describes a percutaneous technique to reduce abduction, external rotation and flexion deformity in one maneuver, using a long hemostatic forceps (19). A stab incision is performed at the level of the lesser trochanter, 1–2 cm posterior to the longitudinal axis of the femur. The forceps is advanced along the anterior cortex of the femur with the curved tip pointing posteriorly under fluoroscopic guidance. When the tip reaches the lesser trochanter, the handle of forceps is elevated anteriorly, using the lesser trochanter as a fulcrum. According to the authors, this technique usually corrects all deformities with one maneuver. In some cases, the distal main fragment has to be manipulated as well, using established techniques to achieve a proper alignment of the fracture.

External rotation deformity

Whereas the external rotation of the distal fragment is easily corrected by simple internal rotation of the leg on the traction table, the correction of this deformity of the proximal fragment is much more challenging. A combination of different techniques may be necessary for an adequate reduction. When the proximal fragment is pushed upwards from posterior to anterior, internal rotation of the head-neck fragment occurs. This maneuver can either be convieniently performed with the surgeon's fist or a hammer again (Figs 8A, B and 9). A percutaneous technique, using a ball spike from posterior, is another option with better direct control of the bone. However, whereas reduction might quite easily be achieved with these techniques, maintainance of reduction is more challenging. Once the external rotation and the other accompanying deformities are corrected, careful stepwise release of traction may "lock" the reduction. However, this is not always possible and sometimes release of traction leads to a loss of reduction. To overcome this problem and to avoid a more invasive approach, we often use a small, padded and draped height-adjustable instrument table which is placed underneath the proximal fragment. When the height of the table is increased, the proximal fragment is pushed anteriorly and rotates internally. Leaving the table in this position maintains the achieved reduction till the nail is placed.

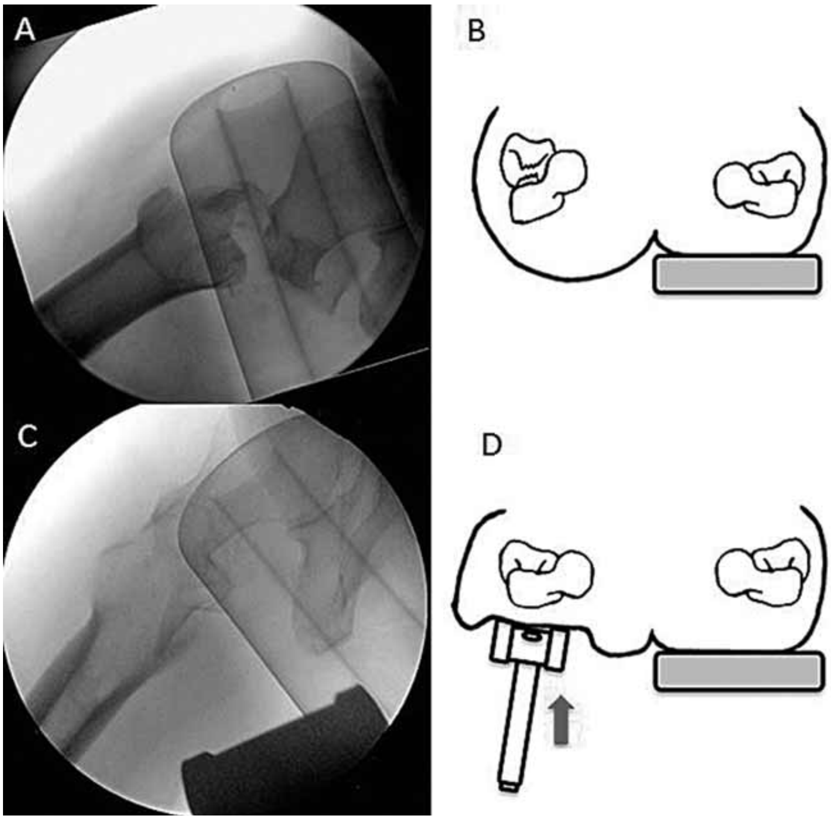

Fig. 8. AO 31-A1 fracture. A and B – extension deformity in combination with external rotation of the head-neck fragment; C and D – reduction was achieved with traction and a hammer applying pressure from posterior into an anterior direction.

Fig. 9. Closed reduction was performed by applying pressure from posterior into an anterior direction with a hammer to correct external rotation deformity.

A percutaneous technique which reduces abduction, flexion and external rotation deformities with a long hemostatic forceps in one simple move of has already been described above (19).

Extension deformity

Extension deformity of the head-neck fragment is rare. It may occur in rather simple pertrochanteric fractures (AO 31-A1) with the intact insertion of the iliopsoas at the distal fragment. The traction of the short external rotators can provoke a combined extension and external rotation deformity of the proximal fragment (Fig. 8 A). All the reduction techniques, usually used to correct the external rotation deformity of the proximal fragment, can be applied for extension deformities in a similar manner.

The nail entry point and reaming of the trochanteric area

For trochanteric nails the manufacturers usually recommend an entry point right at the tip of the greater trochanter between the anterior third to the posterior two thirds of the greater trochanter (23). The correct entry point is crucial. Using a wrong entry point may result in significant varus or valgus malalignment and flexion/extension deformity. Furthermore, a wrong entry point for the nail may also render a good center-center positioning of the femoral neck implant impossible. In a cadaveric study, Ostrum et al. (17) demonstrated that slight medialization of this entry point may be preferred. Furthermore, slight medialization of the entry point also protects the abductor insertions from further damage (20). However, a lateral entry point must be avoided, as it results in a varus deformity. When the guide wire is placed, its position has to be checked meticulously by fluoroscopy in both AP and lateral views before the trochanteric bone is reamed.

The correct entry point is difficult to identify in fractures with comminution of the greater trochanter. If the nail is pushed through the comminuted greater trochanter, the head-neck fragment may be pushed medially due to the intact bone of the most lateral aspect of the femoral neck (Figs 10 A and B). In these situations, careful reaming of this area is strongly advised to avoid varus deformity (23). In this situation, we prefer to use a cannulated cutter with an oblique blade to open the trochanteric bone instead of a reamer. The cutter is introduced over the guide wire. The medial aspect of the entry point (the most lateral aspect of the femoral neck) is opened first (Fig. 10 C). Once the cannulated cutter has gained purchase of the medial bone, the opening is completed by rotating the instrument. With this technique, the risk for a too lateral opening or lateral migration during the opening is minimized. When the reamer or cannulated cutter is introduced through a comminuted

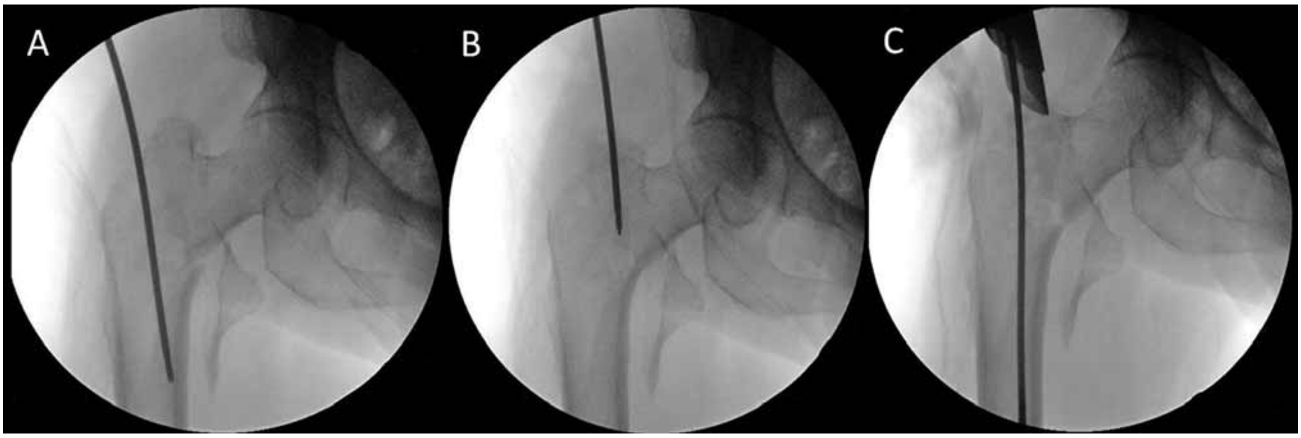

Fig. 10. AO 31-A2 fracture. A – introducing the guide wire through the fracture comminution at the greater trochanter's tip led to varus deformity of the proximal fragment; B – a more medial entry point was chosen; C – with the cannulated cutter, the medial aspect of the bone was opend first to avoid lateral migration of the cannulated cutter during the opening process.

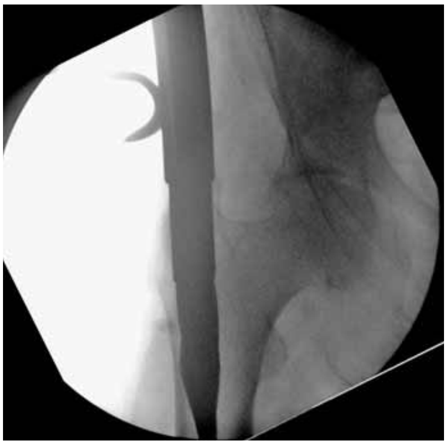

Fig. 11. AO 31-A2 fracture. Lateral pressure is applied onto the sleeve of the reamer with a Roux retractor to avoid further weakening of the lateral wall in this obese patient. However, the entry point is not ideal in this example, a slightly more medial entry is preferred.

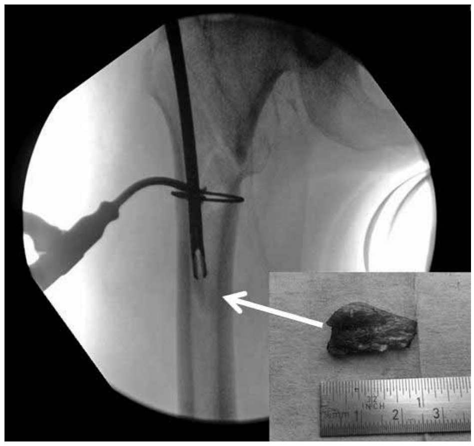

Fig. 12. AO 31-A3 fracture. A fragment was trapped in the medullary canal obstructing the insertion of the cephalomedullary nail in this nicely reduced fracture. Without releasing the reduction, the fragment was retrieved with a long grasping forceps.

greater trochanter, the surgeon should be careful to preserve the lateral wall. Weakening the lateral wall may increase the risk for a subsequent extensive collapse with lateralisation of the head-neck fragment once weight bearing is started. In particular in obese patients with a comminuted greater trochanter, the soft tissues may push the guide wire and reamer laterally. Ignoring this problem may end up in a too lateral nail position with resulting varus deformity. Lateral pressure onto the sleeve of the reamer, while opening the medullary canal, is necessary to keep the reamer in the desired position (Fig. 11).

Obstruction of the medullary canal

Small bone fragments, which obstruct the medullary canal, may render the passage of the nail impossible. We strongly advise against the use of a hammer to force advancement of the nail. Such a maneuver may lead to a loss of reduction, or even worse, iatrogenic fractures. We usually remove the nail, but reduction remains maintained. The fragment is then removed with a long grasping forceps before the nail is reinserted (Fig. 12). Alternatively, a guide wire with a hoke-shaped tip, which is usually used for nail extraction, can be tried as well.

Case presentations

In the following three cases are presented (Figs 13–15) to demonstrate stepwise escalation of different reduction maneuvres, starting with closed measures on the traction table, followed by percutaneous- and open techniques.

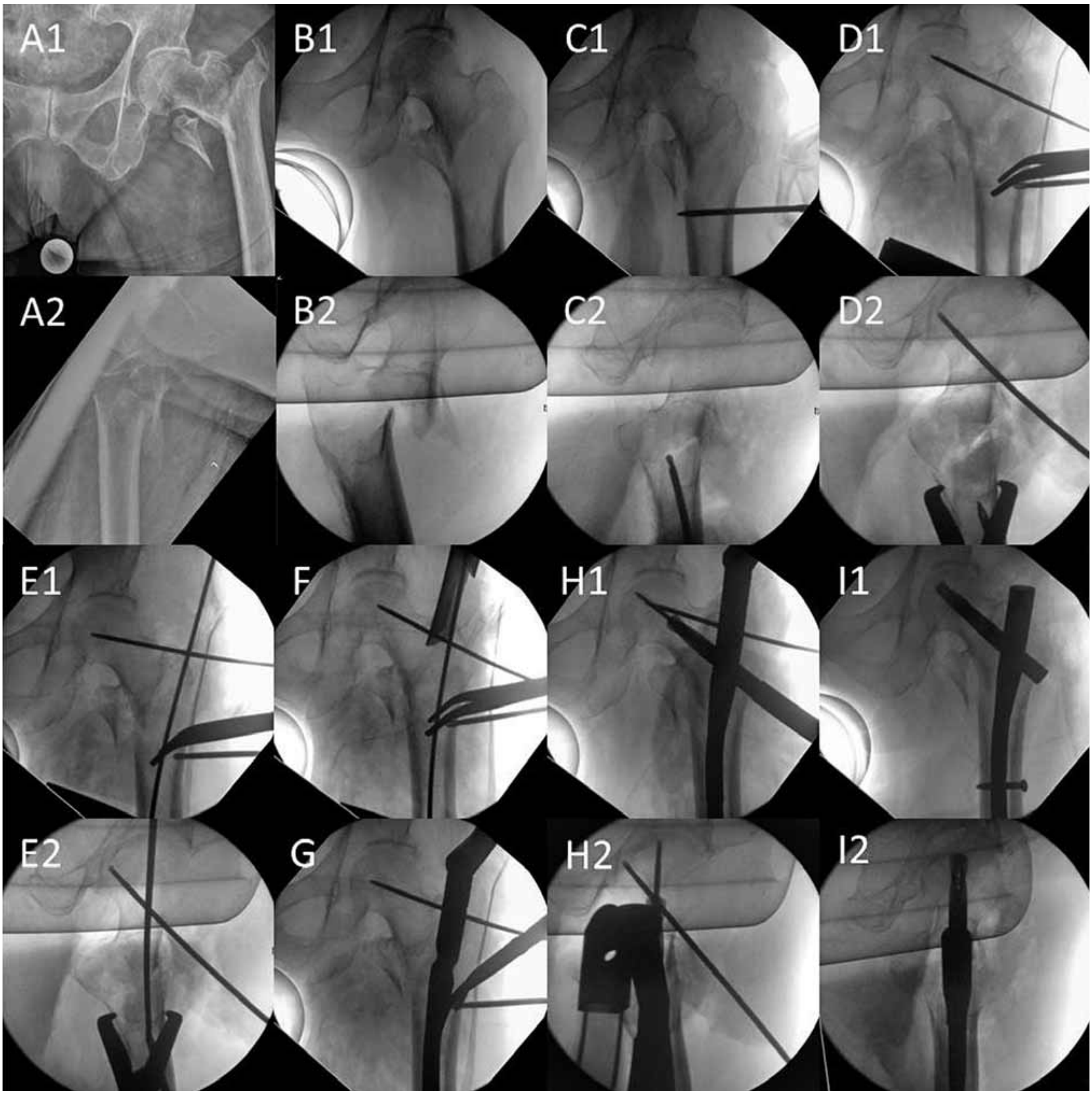

Fig. 13. Case presentation of an 89-year-old female patient. The stepwise escalation of reduction techniques to master reduction and stabilisation of this isolated highly unstable trochanteric fracture is demonstrated. A1 and A2 – preoperative AP and lateral view. AO 31-A2 fracture. B1 and B2 – AP and lateral view. Closed reduction techniques on the traction table failed to achieve a good result. Remaining dorsal displacement of the shaft fragment. C1 and C2 – AP and lateral view. The distal main fragment was reduced with a percutaneous Schanz screw and additional support was provided by a height-adjustable instrument table, placed underneath the shaft fragment. However, reduction could not be maintained in this highly unstable situation. When the guide wire was inserted through the comminuted tip of the greater trochanter, external rotation of the head-neck fragment occured. Stepwise release of traction also failed to „lock" the fracture. D1 and D2 – AP and lateral view. A limited open approach was performed and a K-wire was drilled into the head-neck fragment from anterolateral, avoiding the distal fragments. The Schwanz screw was withdrawn to the lateral cortex and a reduction clamp applied to maintain reduction. Thus, control of the proximal fragment was gained without interfering with following guide wire and nail insertion. E1 and E2 –AP and lateral view. The guide wire was inserted while the K-wire prevented external rotation/displacement of the head-neck fragment. F – AP view. Careful opening of the trochanteric bone with a cannulated cutter. The medial cortex was engaged first to avoid lateral migration of the cutter. G – AP view. Placement of a short proximal femur nail antirotation (PFNA; 200/10mm, 1250) without losing reduction. H1 and H2 – AP and lateral view. Placement of the guide wire centrally into the femoral head, followed by insertion of the blade. Before the blade touched the joy stick in the femor head, the K-wire was retrieved just enough to allow passage of the blade. Once the blade was in its final position, the K wire was removed. I1 and I2 – AP and lateral view. Final X-rays after insertion of the distal locking screw demonstrated an adequate fracture reduction and correct position of the implants. Full weight bearing was allowed postoperatively.

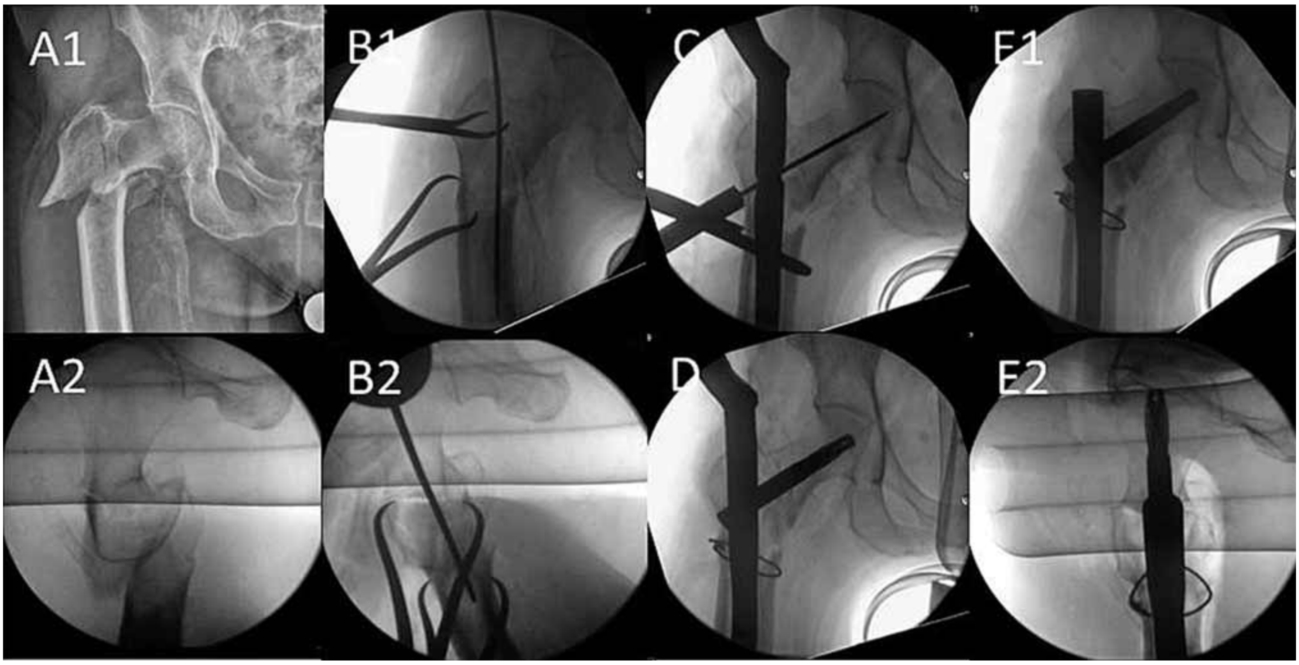

Fig. 14. A1 and A2 –preoperative (AP) and intraoperative (lateral) view. Isolated AO 31-A3 fracture. A limited open approach was performed from the start to address the lateral spike of the proximal fragment. Preoperative planning included a cable cerclage to augment the nail osteosynthesis in this unstable situation. B1 and B2 – AP and lateral view. The fracture was reduced with two pointed reduction clamps before insertion of the guide wire. Note the rather medial insertion point of the guide wire to avoid later varus malalignment. C – AP view. Application of a collinear reduction clamp to maintain the reduction during insertion of the long PFNA and blade. D – AP view. The traction was released to close the remaining fracture gap on the medial aspect of the femur before the cable was finally tightened. E1 and E2 – AP and lateral view. Final X-rays after insertion of the dynamic distal locking screw demonstrated an adequate fracture reduction and correct position of the implants. Partial weight bearing for six weeks was recommended.

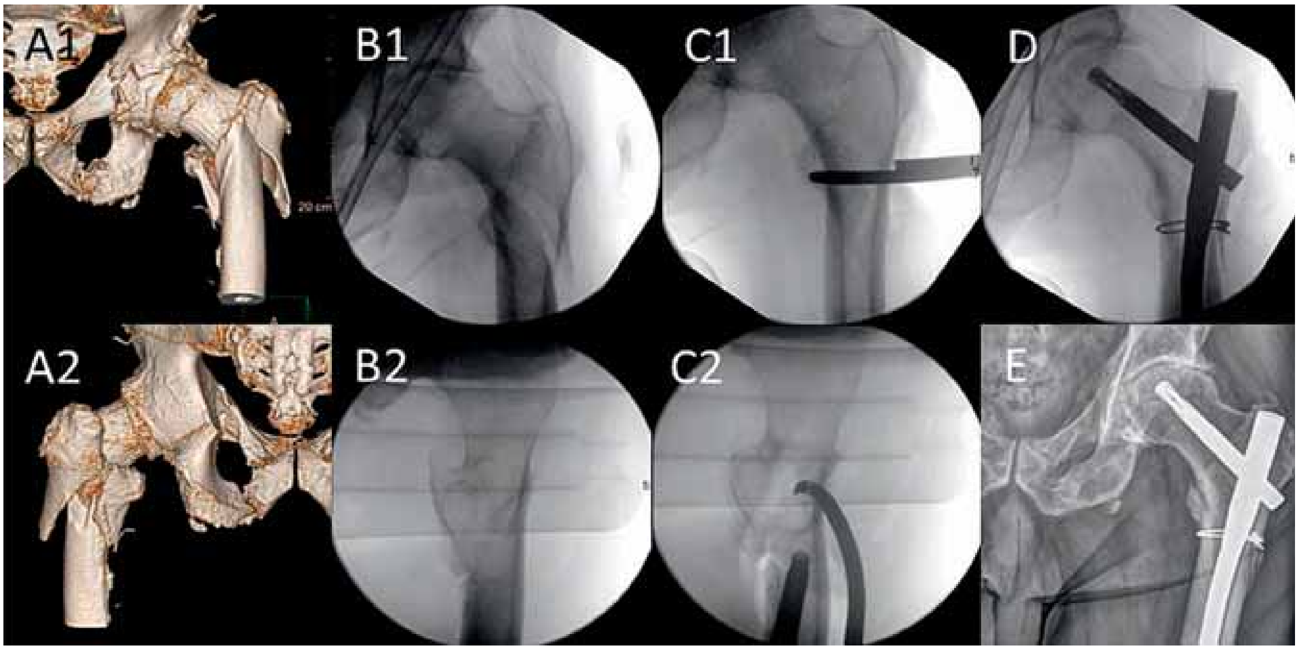

Fig. 15. Case presentation of a 70-year-old male patient who sustained a multiple trauma including injuries to the chest with multiple rib fractures and a pneumothorax, a pelvic ring fracture (sacrum and anterior ring) with involvement of the left acetabulum (undisplaced fracture) and a displaced unstable fracture of the left proximal femur. A1 and A2 – 3D-CT reconstructions, views from anterior (A1) and posterior (A2). AO 31-A3 fracture. B1 and B2 – AP and lateral view. Careful closed reduction on the traction table in order to avoid displacement of the fractures of the pelvic ring and acetabulum. C1 and C2 – AP and lateral view. A limited open approach was performed and a collinear reduction clamp applied to reduce the remaining varus deformity. No instruments were used proximal to the lesser trochanter to avoid damage to the blood supply of the femoral head. D – AP view. The long PFNA was introduced and the colliear reduction clamp replaced with a cable to augment stability of the osteosynthesis. E – AP view. Follow-up after 3 months of partial weight bearing showed progressive osseous consolidation of the fracture without secondary displacement.

CONCLUSIONS

Surgical management of trochanteric and subtrochanteric fractures can be challenging. A profound knowledge of the anatomy and the different fracture patterns is essential. The sugeon must be familiar with a variety of different reduction techniques, their advantages and potential complications. The crucial points are:

- Proper preoperative analysis of the fracture pattern is mandatory.
- Correct patient positioning on the traction table is the first step of fracture reduction.
- Adequate fracture reduction must be achieved before insertion of the cephalomedullary nail.
- Try closed reduction maneuvers first.
- Confirm the correct anteversion of the femoral neck by fluoroscopy.
- Reduction must be maintained until the nail is finally placed.
- If closed reduction fails, escalate according to appropriate invasiveness.
- Respect the soft tissues, an open reduction may be less damaging than repeated forceful closed reduction maneuvers.
- The correct entry point is slightly medial to the trochanteric tip. Avoid a too lateral entry point.
- Do not use the nail to reduce trochanteric fractures.
- Cerclage wires/cables may be used for reduction support as well as for improved stability particularly in oblique intertrochanteric- and subtrochanteric fractures.
- Release the tension and the lower the uninjured leg as soon as possible.

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