Computerized Navigation for Treatment of Slipped Femoral Capital Epiphysis

Yoram Weil, MD · Andrew Pearle, MD · Meir Liebergall, MD ·
Naum Simanovsky, MD · Shlomo Porat, MD · Rami Moshieff, MD

Published online: 24 June 2006
© Hospital for Special Surgery 2006

Abstract In situ pinning with a single screw is the treatment of choice for symptomatic slipped capital femoral epiphysis (SCFE). Some technical features are critical and include proper screw entry point, screw direction in relation to the epiphysis, and the length of screw. These are complicated by the deformity created as a result of the posterior slip of the epiphysis. Fluoroscopic based computerized navigation system can increase precision in screw placement while performing the surgical task, and markedly reduce radiation. By using real fluoroscopy-based navigation, the screw can be placed with only two fluoroscopic images. Entry point, length, and precise direction can all be easily determined through this technique.

Key words slipped capital femoral epiphysis · computerized navigation · in situ pinning

Introduction

Single screw fixation for slipped capital femoral epiphysis (SCFE) has proven to be as biomechanically stable as multiple screw fixation, but with a much lower complication rate [1–4]. In situ pinning with a single screw is now believed to be the treatment of choice for a stable slip, and may be appropriate in some cases of unstable slips [5]. This technique has the potential for serious iatrogenic complications [6, 7], and some technical features are essential for the success of the procedure. These include a

proper screw entry point, precise screw direction in relation to the epiphysis, correct screw positioning in the subcondral bone, and avoiding penetration of the hip joint [8].

According to Morrisy [9], the screw should be perpendicular to the epiphysis in both anteroposterior (AP) and lateral projections. As a result of posterior displacement epiphysis (or anterior displacement of the neck), the starting point should be anterior and on the femoral neck, as opposed to screws placed laterally in hip fractures. A skin line geometric technique, used to preplan the screw entry point had, been described by Canale [10]. Several authors have described mathematical formulas and radiographic templates to ensure correct screw placement [9, 11, 12]. Recently, Rooks et al. [11] recommended the tip of the screw to be positioned 8 mm from the subchondral bone or within one third of the femoral head radius—whichever is closest. Thus, placing a single screw perpendicular to the slipped epiphysis is a technically demanding task that requires meticulous technique and a significant amount of fluoroscopy.

Fluoroscopic based computerized navigation systems have recently emerged in orthopedic trauma and joint replacement surgery. These techniques have three potential advantages over conventional fluoroscopy: precise positioning of surgical instruments and implants, simultaneous multiprojection view while performing the surgical task, and markedly reduced amount of radiation. The entry point can be predetermined prior to the skin incision. The screw's direction, length and diameter can be precisely planned prior to insertion.

These advantages can render the procedure safe and easy, while reducing the amount of radiation to the pelvis in the adolescent child. This study describes the surgical technique for the fixation of slipped capital femoral epiphysis.

Surgical technique

The “ION” Treatment Guidance Platform by Medtronic (Surgical Navigation Technologies, Louisville, CO, USA)

Y. Weil, MD (✉) · A. Pearle, MD
Orthopedic Trauma Service,
Hospital for Special Surgery,
535 East 70th St., New York, NY 10021, USA
e-mail: yoramweil@gmail.com

Y. Weil, MD · M. Liebergall, MD · N. Simanovsky, MD ·
S. Porat, MD · R. Moshieff, MD
Department of Orthopedic Surgery,
The Hadassah University Hospital, Jerusalem, Israel

Fig. 1. (a) The patient is positioned on a fracture table. A reference array (arrow) is drilled into the iliac crest. (b) The drill guide, with its IREDs, is placed on the patient's skin to preplan the entry point

enables surgical navigation based on real-time acquisition of fluoroscopic data. A calibration target with affixed infrared emitting diodes (IREDs) is attached to a C-arm fluoroscope. The ION guidance platform is used to trace the fluoroscope and two trackers—the first is affixed to the patient's bone and the second is attached to a surgical instrument.

The patient is positioned on a fracture table and the bone tracker array is fixed to the patient with two 3-mm threaded wires inserted percutaneously (Fig. 1a). The bone tracker can be fixed to the iliac crest because the patient lies motionless and secured to a fracture table. In this scenario, no hip joint movement occurs and accuracy is not compromised. This was proven by a recent accuracy study for navigated fixation of femoral neck fractures [13].

Anteroposterior and lateral views of the hip are acquired and stored in the system's memory while the surgical team is at a safe distance from the radiation source. If needed, two oblique views can also be acquired. The navigation process uses a cannulated screw system. The guide

wire is assembled and passed through a cannulated tracked drill guide containing four IREDs that transmit infrared radiation to an optical IR camera. The camera detects each point of light during triangulation, locates its position, and transfers the data into the system. During surgery, the guide as well as the estimated length and diameter of the screw are simultaneously displayed on all previously acquired images with no need for further fluoroscopy. An extrapolation of the guide can be drawn on the screen prior to the incision so that it can be preplanned (Fig. 1b).

A small incision is then made and the cannulated guide is placed on the femur until the desired direction in all radiographic views is achieved (Fig. 2). The trajectory of the guide is measured so that the desired length and diameter are estimated on the registered images (Fig. 2). These eventually become the final screw length and diameter. After the successful positioning of cannulated guide, the wire is drilled into the femur. The self-tapping screw is advanced on the wire into the epiphysis. Final AP and lateral verification views are taken (Fig. 3a and b). The

Fig. 2. Desired AP and lateral hip registered image with the trajectory of the drill guide can depict direction length and diameter of the screw

Fig. 3. (a) AP and (b) lateral true fluoroscopic images of the screw after its insertion

reference array is then removed and the wound is irrigated and closed. The accuracy of the system can be verified by superimposing the navigated image on the actual guide wire image (Fig. 4).

Patients

This technique was used in six patients. The additional set-up time to utilize navigation was approximately 5–15 min. Although direct dosimetry was not performed, it is estimated that fluoroscopy time was somewhere between 10 and 15 s per screw, including an initial AP and lateral images for the image acquisition phase, and 2–4 additional images for verification. All screws were located within the center of the femoral head and no screw penetration occurred.

Discussion

Fixation of slipped femoral capital epiphysis is a technically demanding procedure. Numerous studies have exam-

ined the most effective surgical technique and have investigated methods of fixation (either pins or screws), number of screws/pins, positioning of the patient (fracture vs. radiolucent table), determination of entry point, and the exact positioning of the screws [2, 9, 10, 14]. In a recent paper reviewing a large series (241 patients), the method producing the least complications (avascular necrosis, chondrolysis) was in situ pinning with a single cannulated screw [12]. In this procedure, the precise aiming of the cannulated screw in all planes in a deformed proximal femur remains technically challenging. The narrow safe zone available for the screw requires utmost precision to avoid deleterious complications [11, 14–16]. By using computerized navigation, the lateral view as well as they AP and additional oblique views are constantly available while the screw is being inserted. Therefore, by aiming to the center of the femoral head on all views simultaneously, readily done by navigation, this complication can be avoided. We used computerized fluoroscopic navigation in a similar fashion with percutaneous fixation of pelvic fractures [17], and found the technique to be helpful in planning the exact route of the screw in a three-dimensional, anatomically complex structure with a very limited “safe-zone.” Also, correct estimation of the screw’s length can prevent penetration, and direct measurement of distances on the computer screen can be carried out. However, a virtual exact image of the screw is still not available commercially, although such systems are under development and investigation. This modification will also enable the surgeon to visualize the threads of the screw and their relation to the physal line.

The navigation system can also help the surgeon preplan the incision site because the tracked drill guide is approximated to the femoral shaft on the patient’s thigh prior to skin incision. The displayed virtual image can guide the surgeon to the correct starting point and therefore to the incision. Soft tissue dissection and skin incision are minimized. This is especially beneficial for obese children who constitute the majority of patients with slipped femoral capital epiphysis.

The amount of radiation is significantly reduced with the new technique. Essentially, only four images are needed for the surgery regardless of the number of screws placed. These

Fig. 4. A “registered” image of the hip with the actual guide wire in the femur together with the “virtual” line (green) demonstrating accuracy

include the two images for registration and two final verification images. Reduction of radiation to the pelvis is extremely important, considering the characteristic adolescent age group of patients. Several studies had measured intraoperative radiation while performing similar tasks, and demonstrated the benefit of these systems on several applications [18, 19]. Although gonadal shielding may prevent some of the radiation delivered, the amount of radiation delivered to the human pelvis in 1 min of fluoroscopy amounts to 40 mSV, which is equivalent to 250 chest x-rays [20]. Therefore, we believe that this is an important advantage of the system. Use of navigation does not significantly lengthen operative time because the system can be set up while the patient is being prepped and draped.

Computer-aided orthopedic surgery (CAOS) is gaining popularity and allows for precise minimally invasive techniques and increases the accuracy of implants placement. We think the percutaneous screw fixation of slipped femoral capital epiphysis is an excellent implementation of the technique because it requires utmost precision, narrow safe zone, and minimal amount of radiation. This is one of the first steps in implementing this technique in pediatric orthopedic surgery.

References

1. Aronson DD, Carlson WE (1992) Slipped capital femoral epiphysis: a prospective study of fixation with a single screw. *J Bone Jt Surg* 74A:810
2. Blanco J, Taylor B, Johnston CE: Comparison of single pin versus multiple pin fixation in treatment of slipped capital femoral epiphysis. *J Pediatr Orthop*
3. Kibiloski LJ, Doane RM, Karol LA et al (1994) Biomechanical analysis of single-versus double-screw fixation in slipped capital femoral epiphysis at physiological load levels. *J Pediatr Orthop* 14:627
4. O'Beirne J, McLoughlin R, Dowling F et al (1989) Slipped upper femoral epiphysis: internal fixation using single central pins. *J Pediatr Orthop* 9:304
5. Mooney JF 3rd, Sanders JO, Browne RH, Anderson DJ, Jofe M, Feldman D, Raney EM (2005) Management of unstable/acute slipped capital femoral epiphysis: results of a survey of the POSNA membership. *J Pediatr Orthop* 25(2):162–166 Mar–Apr
6. Goodman WW, Johnson JT, Robertson WW (1996) Single screw fixation for acute and acute-on-chronic slipped capital femoral epiphysis. *Clin Orthop* 322:86
7. Laplaza FJ, Burke SW (1995) Epiphyseal growth after pinning of slipped capital femoral epiphysis. *J Pediatr Orthop* 15:357
8. Walters R, Simon SR (1980) Joint destruction: a sequel of unrecognized pin penetration in patients with slipped capital femoral epiphysis of the hip. In: *Proceedings of the Eighth Open Scientific Meeting of the Hip Society*, St Louis, Mosby
9. Morrissy RT (1989) Principles of in situ fixation in chronic slipped capital femoral epiphysis. *Instr Course Lect* 38:257
10. Canale ST (1989) Problems and complications of slipped capital femoral epiphysis. *Instr Course Lect* 38:281
11. Rooks MD, Schmitt EW, Dravacic DM (1988) Unrecognized pin penetration in slipped capital femoral epiphysis. *Clin Orthop* 234:82
12. Seller K, Raab P, Wild A, Krasue R (2001) Risk–benefit analysis of prophylactic pinning in slipped capital femoral epiphysis. *J Pediatr Orthop B* 10(3):192–196 Jul
13. Ilisar I, Weil Y, Joskowicz L, Mosheiff R, Liebergall M (2005) Table-mounted vs. bone-mounted reference frame attachment in computer-assisted orthopaedic surgery—an assessment of accuracy. *Proc. CAOS—Int. Annual Meeting*, Helsinki
14. Lee FY, Chapman CB (2003) In situ pinning of hip for stable slipped capital femoral epiphysis on a radiolucent operating table. *J Pediatr Orthop* 23(1):27–29 Jan–Feb
15. Tokmakova KP, Stanton RP, Mason DE (2003) Factors influencing the development of osteonecrosis in patients treated for slipped capital femoral epiphysis. *JBJS Am* 85-A(5):798–801 May
16. Orr TR, Bollinger BA, Strecker WB (1989) Blind zone determination of the femoral head. *J Pediatr Orthop* 9:417 18(2):1106–1114 Feb
17. Mosheiff R, Khoury A, Weil Y, Liebergall M (2004) First Generation of fluoroscopic navigation in percutaneous pelvic surgery. *J Orthop Trauma* 18(2):106–111
18. Suhm N, Messmer P, Zuna I, Jacob LA, Regazzoni P (2004) Fluoroscopic guidance versus surgical navigation for distal locking of intramedullary implants. A prospective, controlled clinical study. *Injury* 35(6):567–574
19. Collinge C, Coons D, Tornetta P, Aschenbrenner J (2005) Standard multiplanar fluoroscopy versus a fluoroscopically based navigation system for the percutaneous insertion of iliosacral screws: a cadaver model. *J Orthop Trauma* 19(4):254–258
20. Kahler DM (2004) Image guidance: fluoroscopic navigation. *Clin Orthop* (421):70–76.