SUBSPECIALTY PROCEDURES

INTRAOPERATIVE MONITORING OF EPIPHYSEAL PERFUSION IN SLIPPED CAPITAL FEMORAL EPIPHYSIS

SURGICAL TECHNIQUE

Tim Schrader, MD, K. Aaron Shaw, DO

Published outcomes of this procedure can be found at: *J Bone Joint Surg Am.* 2016 Jun 15;98(12):1030-40.

COPYRIGHT © 2017 BY THE
JOURNAL OF BONE AND JOINT
SURGERY, INCORPORATED

Introduction

Intraoperative monitoring of epiphyseal perfusion in slipped capital femoral epiphysis (SCFE) is a procedurally simple and readily accessible percutaneous technique to accurately guide decision-making and help to prevent osteonecrosis. Osteonecrosis of the femoral head is one of the most dreaded complications of slipped capital femoral epiphysis. It is hypothesized that increased intracapsular pressure results in disruption of the epiphyseal perfusion and the resultant development of osteonecrosis^{1,2}. The ability to intraoperatively assess the epiphyseal perfusion will allow surgeons to intervene in instances of absent perfusion in an effort to prevent osteonecrosis.

Epiphyseal perfusion assessment begins following reduction, if that is indicated, and placement of the guidewire for the appropriately selected cannulated screw for fixation. Once the pilot hole is drilled over the guidewire to the selected depth, the cannulated screw is inserted over the guidewire until approximately 3 screw threads have traversed the proximal femoral physis. At this time, the guidewire is removed, such that the cannulated screwdriver remains engaged onto the screw. An intracranial pressure (ICP) probe is then inserted down the shaft of the screwdriver to a depth just beyond the previously inserted screw. The ICP probe is then in a position to record the epiphyseal perfusion, which, when present, records as a waveform synchronous with the patient's heart rate. An absent waveform prompts the surgeon to perform an anterior hip capsulotomy, according to the desired technique, following which the epiphyseal perfusion is reassessed to confirm the return of perfusion (Video 1).

Video 1 Surgical technique for intraoperative assessment of epiphyseal perfusion using an ICP probe in a 12-year-old patient with an unstable SCFE.

Disclosure: The authors indicated that no external funding was received for any aspect of this work. On the **Disclosure of Potential Conflicts of Interest** forms, which are provided with the online version of the article, one or more of the authors checked "yes" to indicate that the author had a patent and/or copyright, planned, pending, or issued, broadly relevant to this work.

Indications & Contraindications

Indications

- Stable SCFE
- Unstable SCFE

Contraindications

- Patient size that would prevent the use of a 7.0-mm cannulated screw, as smaller screws are unable to accommodate the 3.0-mm intracranial probe.

Step 1: Patient Preparation and Positioning

Following anesthesia induction, position the patient and assess the physeal stability fluoroscopically to determine the need for a reduction.

- Place the patient supine, which is our preferred position, on either a Jackson table or a fracture table.
- Prepare and drape the entire affected leg in a sterile manner, especially in the setting of an acute SCFE, in which a reduction of the epiphysis to the chronic position is performed prior to guidewire placement.
- Perform fluoroscopic imaging to assess the physeal stability prior to introducing the guidewire. If there is any instability of the capital epiphysis with fluoroscopic imaging through a range of motion, a reduction maneuver is performed and maintained during guidewire placement.

Step 2: Guidewire Placement

Place a 3.2-mm threaded guidewire from the anterolateral aspect of the femur to provide initial stability of the slipped epiphysis.

- Once the physeal stability is assessed and the decision has been made to perform an in situ pinning or reduction and pinning, insert a 3.2-mm threaded guidewire.
- Insert the guidewire from the anterolateral aspect of the femur and aim at the center of the epiphysis.
- Following insertion, confirm the placement on fluoroscopic imaging in both the anteroposterior and lateral positions.
- Once satisfactory positioning has been confirmed, measure and overdrill the guidewire just past the level of the physis.

Step 3: Initial Screw Insertion

Insert a cannulated 7.0-mm stainless steel screw over the guidewire to a point just past the physis.

- Insert a fully threaded, cannulated 7.0-mm stainless-steel screw (Smith & Nephew). If a 2-screw construct is used, monitoring through only 1 screw should be sufficient for evaluating epiphyseal perfusion.
- Insert the screw past the level of the physis, with 2 to 3 screw threads traversing the physis in order to obtain stability while allowing for a minimum of 3 mm from the tip of the screw to the subchondral bone of the capital epiphysis for insertion of the ICP probe (Fig. 1).
- It is important to ensure that the screw is not fully inserted as this prevents the ICP monitor probe from extending beyond the tip of the screw and prevents adequate perfusion assessment.

Fig. 1

Fig. 1 Intraoperative C-arm anteroposterior image demonstrating insertion of the 3.2-mm threaded guidewire just past the physis.

Step 4: Preparation and Insertion of the ICP Probe

Once the screw has been inserted to obtain provisional stability of the physis, remove the guidewire and insert a sterile ICP probe down the screw shaft to assess the epiphyseal perfusion.

- Once provisional physal stability has been obtained, prepare and zero a sterile ICP probe (Integra Camino; Integra LifeSciences) (Fig. 2).
- Then remove the guidewire such that the screwdriver remains engaged on the screw head.
- Insert the ICP probe down the shaft of the screwdriver and the screw (Fig. 3) such that the tip of the probe, which is radiopaque, is present in the epiphyseal bone, beyond the tip of the screw (Fig. 4).
- Perform epiphyseal perfusion assessment, which is recorded in the form of a pressure and waveform.
- Waveforms of the epiphyseal perfusion should be synchronous with the patient's heart rate.

Fig. 2

Fig. 3

Fig. 4

Fig. 2 Photograph of the ICP probe system (Integra Camino; Integra LifeSciences). (Reproduced from: Schrader T, Jones CR, Kaufman AM, Herzog MM. Intraoperative monitoring of epiphyseal perfusion in slipped capital femoral epiphysis. J Bone Joint Surg Am. 2016 Jun 15;98[12]:1030-40.)

Fig. 3 Intraoperative photographs made before (**Fig. 3-A**) and after (**Fig. 3-B**) insertion of the ICP probe, showing the correctly positioned probe within the screw and screwdriver shaft. (Reproduced from: Schrader T, Jones CR, Kaufman AM, Herzog MM. Intraoperative monitoring of epiphyseal perfusion in slipped capital femoral epiphysis. J Bone Joint Surg Am. 2016 Jun 15;98[12]:1030-40.)

Fig. 4 Intraoperative C-arm anteroposterior image showing the screw inserted past the level of the physis with the probe tip seen in the epiphysis beyond the screw. (Reproduced from: Schrader T, Jones CR, Kaufman AM, Herzog MM. Intraoperative monitoring of epiphyseal perfusion in slipped capital femoral epiphysis. J Bone Joint Surg Am. 2016 Jun 15;98[12]:1030-40.)

Step 5: Hip Decompression

If a perfusion pressure and waveform cannot be obtained, perform decompression of the hip capsule by either aspiration or capsulotomy.

- When no perfusion pressure or waveform is obtainable, decompress the hip.
- Prior to decompression, remove the ICP probe and reinsert the guidewire.
- Perform the decompression by joint aspiration with an 18-gauge spinal needle or by carrying out a capsulotomy with either a Cobb elevator or Mayo scissors inserted along the anterior aspect of the femoral neck (Fig. 5). Our preferred approach is to perform a capsulotomy to minimize the risk of reaccumulation of the hemarthrosis.
- After the capsulotomy is performed, the effluence of the decompressed hemarthrosis will be seen at the level of the skin as a dark hematoma mixed with synovial fluid (Fig. 6).

Fig. 5

Fig. 6

Fig. 5 Intraoperative C-arm anteroposterior image showing a Cobb elevator as it is advanced along the anterior aspect of the femoral neck to decompress the joint. (Reproduced from: Schrader T, Jones CR, Kaufman AM, Herzog MM. Intraoperative monitoring of epiphyseal perfusion in slipped capital femoral epiphysis. J Bone Joint Surg Am. 2016 Jun 15;98[12]:1030-40.)

Figs. 6-A and 6-B Intraoperative photographs of the surgical site of a patient with an initial unstable SCFE in the left hip. (Reproduced from: Schrader T, Jones CR, Kaufman AM, Herzog MM. Intraoperative monitoring of epiphyseal perfusion in slipped capital femoral epiphysis. J Bone Joint Surg Am. 2016 Jun 15;98[12]:1030-40.) **Fig. 6-A** The initial unstable SCFE demonstrated no initial perfusion prior to joint decompression.

Fig. 6-B Following decompression, the decompressed hemarthrosis is visible at the level of the skin after percutaneous capsulotomy.

Step 6: Epiphyseal Perfusion Reassessment

Following the capsulotomy, reinsert the ICP probe and reassess the epiphyseal perfusion.

- Again remove the guidewire and reinsert the ICP probe down the screw shaft.
- Reassess the epiphyseal blood flow in the form of a pressure and waveform (Fig. 7).
- After confirming the epiphyseal blood flow, remove the ICP probe.

Fig. 7

Fig. 7 Monitor showing confirmation of epiphyseal blood flow following percutaneous capsulotomy of the hip joint.

Step 7: Final Screw Advancement

Once epiphyseal blood flow can be confirmed, reintroduce the guidewire to its previous depth and advance the screw to the final measured depth.

- Insert the guidewire back down the shaft of the screwdriver and screw it into its previous position in the epiphysis.
- Then insert the screw to the final depth across the physis and confirm its placement under fluoroscopic evaluation in orthogonal views (Fig. 8).
- Remove the screwdriver, followed by the guidewire. Complete the procedure by irrigating the surgical wound and performing suture closure.

Fig. 8

Fig. 8 Intraoperative C-arm anteroposterior image showing the screw advanced to the final depth. (Reproduced from: Schrader T, Jones CR, Kaufman AM, Herzog MM. Intraoperative monitoring of epiphyseal perfusion in slipped capital femoral epiphysis. *J Bone Joint Surg Am.* 2016 Jun 15;98 [12]:1030-40.)

Results

Utilizing this technique over a 5-year period, >35 patients were treated with the described technique, and 23 of them, including 29 hips, were included in our referenced prospective study³. In our patient cohort with SCFE, approximately 44% of the patients demonstrated an unstable SCFE. In all hips, we have been able to establish an epiphyseal waveform indicating perfusion. To date, none of our patients, including some with 5 years of follow-up and those in our study³ with a minimum follow-up of 2 years, have developed osteonecrosis. Recent studies have validated the use of the ICP probe in monitoring for epiphyseal perfusion in patients undergoing a modified Dunn procedure for unstable SCFE, finding it an effective technique for identifying patients who may go on to develop osteonecrosis^{4,5}.

Pitfalls & Challenges

- Depending on the length of the screwdriver shaft, the guidewire may not extend beyond the screwdriver in its fully inserted position. In this setting, the cannulated screw is inserted just beyond the physis so as to obtain physal stability. The screwdriver is then removed, and the guidewire is partially removed such that it continues to remain within the shaft of the screw. The screwdriver can then be reinserted down the guidewire to engage the screw head, followed by complete removal of the guidewire.
- If there are difficulties with obtaining pressure readings from the ICP probe, even after performing hip capsulotomy, this could be the result of incomplete connection of the ICP probe to the monitor, air within the screw shaft, epiphyseal hematoma, excessive screw advancement, or truly absent flow with complete vessel disruption, kinking, or stretching. The surgeon should proceed by first ensuring proper connection of the ICP probe to the monitor cable. If this does not return a reading, the probe should be removed from the screw and the shaft should be irrigated with normal saline solution to ensure that there is no air in the screw shaft or to evacuate any hematoma present in the epiphysis. The probe can then be reinserted and the

epiphyseal blood flow, reevaluated. If no reading is obtained, critical analysis of the screw placement should be performed to ensure that it has not been advanced too far, which can inhibit pressure readings.

- It is important to remember to remove the ICP probe and reinsert the guidewire prior to performing the hip capsulotomy. Failure to perform this step places the ICP probe at risk of breakage as well as runs the risk of dissociating the screwdriver from the screw head.

Tim Schrader, MD¹

K. Aaron Shaw, DO²

¹Children's Orthopaedics of Atlanta, Atlanta, Georgia

²Dwight D. Eisenhower Army Medical Center, Fort Gordon, Georgia

References

1. Herrera-Soto JA, Duffy MF, Birnbaum MA, Vander Have KL. Increased intracapsular pressures after unstable slipped capital femoral epiphysis. *J Pediatr Orthop*. 2008 Oct-Nov;28(7):723-8.
2. Loder RT. What is the cause of avascular necrosis in unstable slipped capital femoral epiphysis and what can be done to lower the rate? *J Pediatr Orthop*. 2013 Jul-Aug;33(Suppl 1):S88-91.
3. Schrader T, Jones CR, Kaufman AM, Herzog MM. Intraoperative monitoring of epiphyseal perfusion in slipped capital femoral epiphysis. *J Bone Joint Surg Am*. 2016 Jun 15;98(12):1030-40.
4. Jackson JB 3rd, Frick SL, Brighton BK, Broadwell SR, Wang EA, Casey VF. Restoration of blood flow to the proximal femoral epiphysis in unstable slipped capital femoral epiphysis by modified Dunn procedure: a preliminary angiographic and intracranial pressure monitoring study. *J Pediatr Orthop*. 2016 May 12. [Epub ahead of print].
5. Novais EN, Sink EL, Kestel LA, Carry PM, Abdo JC, Heare TC. Is assessment of femoral head perfusion during modified Dunn for unstable slipped capital femoral epiphysis an accurate indicator of osteonecrosis. *Clin Orthop Relat Res*. 2016 Aug;474(8):1837-44. Epub 2016 Apr 18.