Simultaneous Biplanar Fluoroscopy for the Surgical Treatment of Slipped Capital Femoral Epiphysis

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Background: The current standard of care for treatment of slipped capital femoral epiphysis (SCFE) is in situ placement of a single, cannulated screw across the physis under direct fluoroscopic guidance. Previous studies have reported the theoretical advantages of shorter operative time and improved accuracy of screw placement when 2 fluoroscopy units are used simultaneously.

Methods: A retrospective review was performed to compare the use of 1 versus 2 C-arms in the surgical stabilization of SCFE. Data analysis, including demographics, surgical setup times, operative times, and precision of screw placement was performed in 77 consecutive hips (69 patients).

Results: No significant differences were found between the single and dual C-arm techniques with respect to operating room setup and surgery times. Center-center positioning of the screw was more precise when using the simultaneous dual C-arm technique. Surgical times were longer in obese children, irrespective of the number of C-arms used.

Conclusions: Efficient operating room setup time for the dual C-arm technique is possible. Precision of screw placement is improved when using simultaneous biplanar fluoroscopy for the in situ pinning of SCFE.

Level of Evidence: Level IV.

Key Words: SCFE, fluoroscopy, hip, obesity

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Slipped capital femoral epiphysis (SCFE) is one of the most common adolescent hip disorders.[1] Although a specific etiology has not been elucidated, most cases seem to have a multifactorial origin. Obesity, a positive family history, and endocrine abnormalities are known risk factors that predispose patients to SCFE.[2,3] The goal of treatment for SCFE involves stabilization of the femoral epiphyses on the metaphysis to prevent further slippage and potentially worsening deformity.[4]

Before the 1980s, the standard of care for the surgical treatment of SCFE was in situ fixation with multiple pins.[5] With the widespread availability of intraoperative fluoroscopy and recognition of inadvertent pin penetration into the joint, the standard of care for treatment of this condition became in situ placement of a single, cannulated screw across the physis and into the center of the epiphysis.[6,7] Using fluoroscopic guidance, a single wire is placed into the femoral epiphysis followed by placement of the cannulated screw. Nguyen reported that there is a single axis in which a screw can be placed in both anteroposterior (AP) and lateral planes that perfectly bisects the femoral epiphysis.[8] Previous studies have demonstrated complications associated with poorly placed screws such as chondrolysis and avascular necrosis. Persistent intraarticular screw placement may lead to chondral damage and chondrolysis.[7] Placement of the screw tip into the superior head can lead to damage of the intraosseous blood supply of the weight-bearing portion of the femoral head.[9] In the treatment of an unstable SCFE, multiple pins or screws may provide increased shear strength compared with a single screw construct. However, placement of multiple screws may increase the risk of poorly placed screws and potential joint penetration.[10–14]

Previous studies have reported the theoretical advantages of shorter operative time and improved accuracy of screw placement when 2 fluoroscopy units are used simultaneously.[15,16] Since 1997, our institution has used simultaneous AP and lateral fluoroscopic imaging using 2 fluoroscopic units to treat SCFE's using a single, cannulated screw technique. Using a historical cohort from our institution, the current study was performed to compare the use of 1 versus 2 C-arms in the surgical stabilization of SCFE.

METHODS

The current study is a retrospective review of a consecutive case series. The study was reviewed and approved by our institution's research review committee. Patients were identified using the electronic surgical log database. All patients who underwent operative treatment for a diagnosis of SCFE between 1990 and 2006 with complete medical record and radiographic data were included in the study. Patient demographic identifiers collected included age, sex, race, side of affected hip, height, and weight. The patients' height and weight at the time of surgery were used to calculate the body mass index (BMI).[17]

The Surgical Services record was used to calculate the operating room (OR) setup time and the OR surgical time. The OR setup time was defined as the time interval from when the patient entered the operating room until the time of surgical incision. The OR surgical time was defined as the time from surgical incision until completion of skin closure.

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Surgical times for patients who had additional procedures (eg, arthrograms, ipsilateral second screw placement, and contralateral hip screw placement) during the same surgical setting were excluded from analysis.

Radiology records from the time of procedure were used to identify the number of C-arms used during the index procedure. Radiographic measurement of screw placement was performed on plain-film AP and frog lateral radiographs obtained during the immediate postoperative period. Radiographic measurement was performed by a single reviewer (A.W.C.), and the accuracy of screw placement relative to perfect placement was determined by the method described by Blasier et al.[18] In this method, the precision of screw placement is estimated by measuring the deviation from ideal center placement on postoperative plain radiographs in both AP and lateral planes. The amount of deviation is expressed as a percentage with ideal placement expressed at a value of 0%. Optimal screw placement was defined to be within 10% deviation from the perfect center axis in both the AP or lateral planes. Greater than 10% deviation from the perfect center axis in either plane was defined as at-risk screw placement.

Surgical Technique

All patients were treated using a standard fracture table for leg positioning. For the 1–C-arm group, the fluoroscopy machine is placed between the legs, and the C-arm is rotated to obtain orthogonal views. For the 2–C-arm group, the placement of units is similar to that described by Killian et al.[15] With this method, the patient is placed supine on the fracture table (Fig. 1). The arm of the affected side is secured with an over-the-chest binder. The arm of the unaffected side is secured to an attached arm board. The proximal joint of the affected side leg holder is bent toward the midline so as to provide an unobstructed AP view of the hip. The leg holder for the unaffected extremity is abducted through the proximal joint approximately 45 degrees from the midline. A thigh support is placed under the unaffected extremity to provide room for the lateral-view C-arm to be positioned. Once the patient is positioned, the table is shifted toward the affected side, placing the affected hip in slight adduction. The lateral-view C-arm is placed first between the legs and rotated 90 degrees from the vertical to a plane that is parallel to the floor. The C-arm is then inverted 20 degrees away from the table to provide adequate space for the AP-view C-arm. The C-arm for the AP view is positioned lateral to the unaffected limb and enters from across the abdomen. Once both C-arms are positioned, scout images are obtained to confirm adequate visualization of the hip in both planes. The C-arms are then locked into position and do not need to be moved for the remainder of the case. The monitors are placed distal to the feet so that they can be seen by the surgeon when standing to the side of the affected hip.

The location of the skin incision and orientation of the guide wire are determined by the method reported by Lindaman et al.[19] A single guide wire is placed in the center-center position, measured, and overdrilled. A cannulated screw of appropriate length is placed over the wire, and the wire is retrieved. After placement of the screw, the affected leg is removed from the fracture table and gently ranged through a complete arc of motion under continuous fluoroscopy.[20,21] This is done to confirm overall position of the screw and verify the absence of inadvertent pin penetration into the hip joint.

Statistical Analysis

Statistical analysis was performed between the 2 groups using Student t test for means and the χ^2 test for proportions. Statistical significance was assigned to $P < 0.05$.

RESULTS

From 1990 to 2006, 77 hips in 69 patients were treated for a diagnosis of SCFE with in situ cannulated screw fixation. Of the 77 hips, 70 were diagnosed as stable slips, with the remaining 7 diagnosed at unstable slips.[22] All patients were treated within 48 hours of presentation with in situ screw fixation. Cases performed before 1997 were performed with the use of a single C-arm. Cases performed after this time were performed with the use of dual C-arms. Of the 77 hips, 42 were treated using a single C-arm (group 1), and the remaining 35 were treated using dual C-arms (group 2). In group 1, 4 cases were excluded from the time analysis because an arthrogram had been performed to improve visualization of the hip. The remaining 38 hips were available for OR time analysis. In group 2, 8 hips in 4 subjects were excluded from the time analysis due to treatment for bilateral SCFE at the same operative setting. An additional 2 cases were excluded from the time analysis due to an arthrogram (1 hip) and ipsilateral second screw placement (1 hip). The remaining 25 hips were available for OR time analysis.

Of the 77 hips, 76 were treated with a single in situ cannulated screw. The remaining hip was treated with a second ipsilateral screw during the initial procedure and was excluded from radiographic analysis.

Patient Demographics

The mean age of the subjects in group 1 was 13.0 years (SD, 1.3; range, 11–16). The mean age of the subjects in group 2 was 12.0 years (SD, 2.0; range, 6–15). This difference in age was statistically significant ($P < 0.05$). In group 1, there were 27 (67.5%) whites, 11 (27.5%) African Americans, and 2 (5.0%) others. In group 2, there were 17 (58.6%) whites, 9 (31.0%) African Americans, and 3 (10.3%) others. The mean BMI of the subjects in group 1 was 28.2 (SD, 5.6; range, 16.7–43.3). The mean BMI of the subjects in group 2 was 30.4 (SD, 4.8; range, 19.8-43.3). The number of patients with a BMI greater than 30 was 13 (32.5%) in group 1 and 14 (48.3%) for group 2. The differences between groups 1 and 2 for race, mean BMI, and subjects with BMI greater than 30 were not statistically significant.

OR Setup Time and Surgical Time

For group 1, the mean OR setup time was 38.2 minutes (SD, 10.0; range, 15–55). For group 2, the mean OR setup time was 37.8 minutes (SD, 12.8; range, 15–60). This difference in mean OR setup time was not statistically significant ($P = 0.90$). For group 1, the mean OR surgery time was 39.5 minutes (SD, 22.0; range, 15–125). For group 2, the

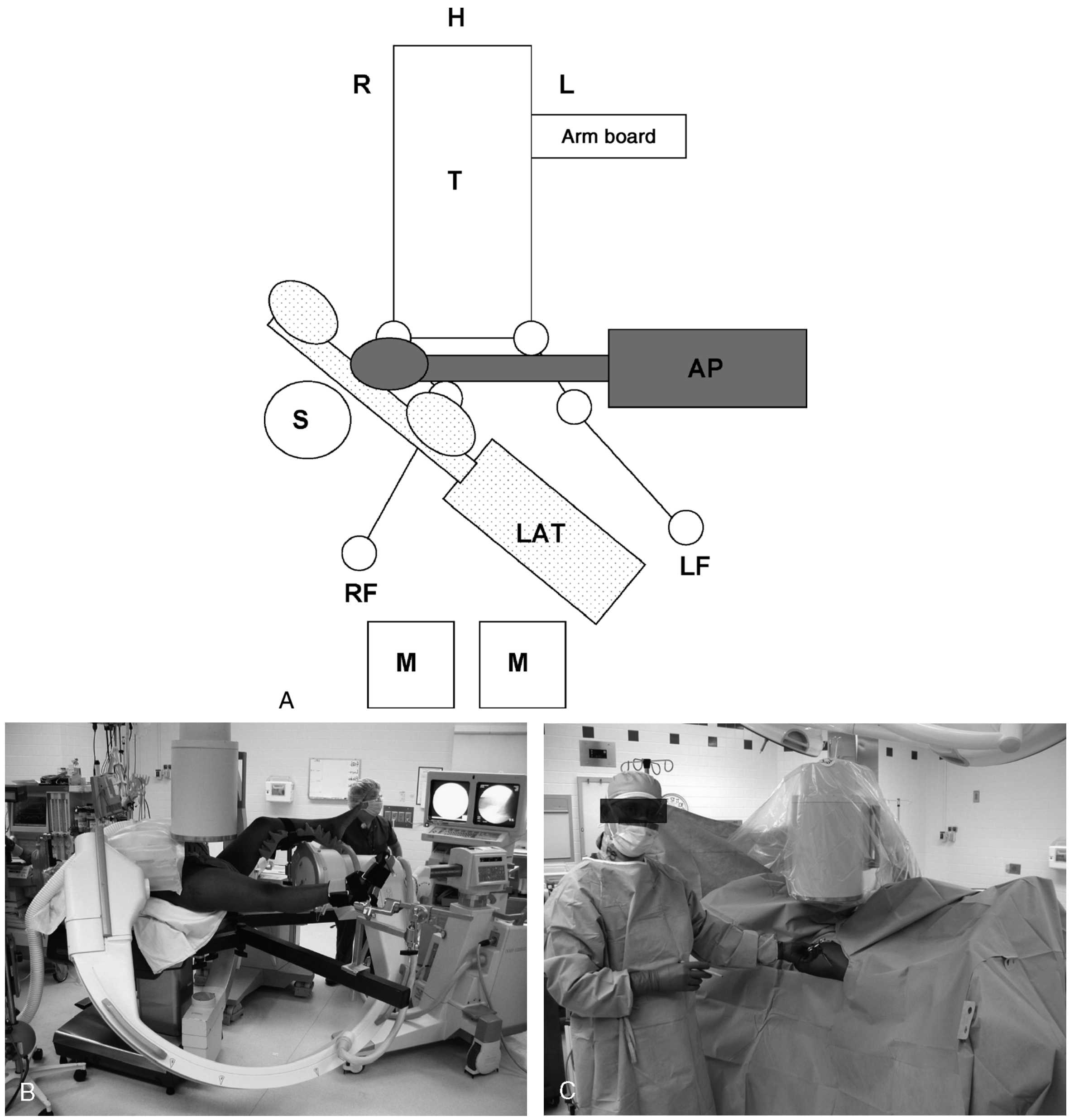

FIGURE 1. Technique for the use of simultaneous biplanar fluoroscopy for the in situ pinning of SCFE. A, Diagram of patient and fluoroscopy C-arm set up. The view is from above, and the right hip is the affected side. AP indicates fluoroscope positioned to image the right hip in the anteroposterior plane; H, head; L, left; LAT, fluoroscope positioned to image the right hip in the lateral plane; LF, left foot holder of fracture table; M, fluoroscope monitor; R, right; RF, right foot holder of fracture table; S, surgeon; T, fracture table. B, Clinical photograph of a patient positioned for in situ pinning of a SCFE of the right hip using simultaneous biplanar fluoroscopy. The monitors are positioned to allow the surgeon to see the screen while aligning and advancing the guide wire. C, Clinical photograph of the same patient completely prepped and draped before in situ pinning of the right SCFE. The surgeon has easy access to the right hip and thigh area without moving the 2 C-arms.

mean OR surgery time was 47.0 minutes (SD, 23.8; range, 20–105). This difference in mean OR surgery time was not statistically significant ($P = 0.21$).

Accuracy of Screw Placement

In group 1, the mean deviation of screw placement in the AP plane was 6.8% (SD, 4.7; range, 0–18.5). In group 2, the mean deviation of screw placement in the AP plane was 3.9% (SD, 3.2; range, 0–12.1). This difference in mean deviation of screw placement in the AP plane was statistically significant ($P < 0.05$). In group 1, the mean deviation of screw placement in the lateral plane was 7.0% (SD, 6.1; range, 0–26). For group 2, the mean deviation of screw placement in the lateral plane was 4.9% (SD, 3.6; range, 0–20). This difference in mean deviation of screw placement in the lateral plane approached statistical significance ($P = 0.07$).

In group 1, optimal screw placement was achieved in 29 of 42 hips (69.1%). In group 2, optimal screw placement was achieved in 30 of 34 hips (88.2%). This difference in precision of screw placement between groups 1 and 2 was statistically significant ($P < 0.05$).

Effect of Obesity on OR Times

The effect of obesity, as defined by a BMI of 30 or greater, was determined for OR times. For this analysis, 17 hips in 9 patients were excluded because additional procedures (arthrograms, contralateral hip pinning) were performed at the time of the index procedure. The remaining 60 patients were available for analysis of the effect of obesity on surgical times. Thirty-six patients had a BMI of less than 30 (not obese), and the remaining 24 patients had a BMI of 30 (obese) or greater. For those patients with a BMI of less than 30, the mean OR setup time 37.5 minutes (SD, 10.4; range, 15–60). For those patients with a BMI of 30 or greater, the mean OR setup time was 38.3 minutes (SD, 12.4; range, 15–55). This difference in mean OR setup times was not statistically significant ($P = 0.79$).

For the patients with a BMI of less than 30, the mean OR surgery time was 36.5 minutes (SD, 19.2; range, 15–105). For those with a BMI of 30 or greater, the mean surgery time was 51.3 minutes (SD, 26.6; range, 20–125). This difference in mean OR surgery time was statistically significant ($P < 0.05$).

Effect of Obesity on Accuracy of Screw Placement

The effect of obesity, as defined by a BMI of 30 or greater, was determined for the accuracy of screw placement. In patients with a BMI of less than 30, the mean deviation of screw placement in the AP plane was 4.9% (SD, 4.1%; range, 0%–16.7%). In those with a BMI of 30 or greater, the mean deviation of screw placement in the AP plane was 5.7% (SD, 3.8%, range, 0%–14.8%). This difference in the mean deviation of screw placement in the AP plane was not statistically significant ($P = 0.45$).

For those hips in patients with a BMI of less than 30, the mean deviation of screw placement in the lateral plane was 6.9% (SD, 6.0%; range, 0%–26%). For the hips in patients with a BMI of 30 or greater, the mean deviation of screw placement in the lateral plane was 4.5% (SD, 3.1%, range, 0%–15.9%). This difference in mean deviation of screw placement in the lateral plane was statistically significant ($P < 0.05$).

In patients with a BMI of less than 30, optimal screw placement was achieved in 32 of 42 hips (76.9%). In patients with a BMI of 30 or greater, optimal screw placement was achieved in 23 of 27 hips (85.2%). This difference in optimal screw placement was not statistically significant ($P = 0.36$).

Outcomes With Obesity Controlled

For this analysis, 17 hips in 9 patients were excluded because additional procedures (arthrograms, contralateral hip pinning) were performed at the time of the index procedure. Of the patients with a BMI of less than 30, 24 hips were treated using the single–C-arm fluoroscopy technique, and 12 hips were treated using the dual–C-arm technique. In these nonobese patients, the mean OR surgery time for the single–C-arm group was 32.9 minutes (SD, 16.5; range, 15–85). The mean OR surgery time for the dual–C-arm group was 43.8 minutes (SD, 22.9; range, 20–105).

In patients with a BMI of 30 or greater, 12 hips were treated using the single–C-arm fluoroscopy technique, and 12 hips were treated using the dual–C-arm technique. In these obese patients, the mean OR surgery time for the single–C-arm group was 52.5 minutes (SD, 28.0; range, 25–125). The mean OR surgery time for the dual–C-arm group was 50.0 minutes (SD, 26.2; range, 20–105). When controlling for the factor of obesity, there was no significant difference in mean OR surgery times between the groups using single– or dual–C-arm techniques ($P = 0.49$).

Of the 42 hips in patients with a BMI of less than 30, 27 were treated using the single–C-arm technique, and 15 were treated using the dual–C-arm technique. In nonobese patients whose hips were treated with the single–C-arm technique, optimal screw placement was achieved in 19 of 27 hips (70.4%). In nonobese patients whose hips were treated with the dual–C-arm technique, optimal screw placement was achieved in 13 of 15 hips (86.7%). This difference in optimal screw placement in nonobese patients was not significant ($P = 0.23$).

Of the 27 hips in patients with a BMI of 30 or greater, 13 hips were treated using the single–C-arm technique, and 14 hips were treated using the dual–C-arm technique. In obese patients whose hips were treated with the single–C-arm technique, optimal screw placement was achieved in 10 of 13 hips (76.9%). In obese patients whose hips were treated with the dual–C-arm technique, optimal screw placement was achieved in 13 of 14 hips (92.9%). This difference in optimal screw placement in obese patients was not significant ($P = 0.24$).

Complications

In group 2, 1 patient underwent a repeat procedure 1 month after the index pinning because of concern regarding the possibility of inadvertent intra-articular screw placement. The accuracy of screw placement after the initial surgery was rated as optimal, with deviation in the AP plane of 2.8% and deviation in the lateral plane of 3.0%. However, on follow-up radiographic analysis, the screw was felt to be placed too close to the margin of the femoral head. For this reason, the child was taken back to surgery, and the screw was withdrawn by approximately 3 mm. The patient subsequently did well, and no further complications were appreciated.

DISCUSSION

Although mini-incision, in situ pinning with a single screw is the current accepted procedure for the surgical management of SCFE, a variety of surgical and imaging techniques have been described. Killian[15] was the first to describe the use of simultaneous biplanar fluoroscopy, noting improvement in both surgical time and fluoroscopic time. In his review, operative times ranged from 15 to 35 minutes using a single C-arm and 4 to 9 minutes using dual C-arms. No statistical analyses were performed on the study cohort.

He concluded that continuous biplanar fluoroscopy provided a significant cost savings secondary to reduced surgical theatre time and a significant reduction in the necessary radiation exposure for treatment of SCFE. Klug et al[16] described a similar technique using 2 C-arms for the in situ pinning of SCFE. From a review of 6 cases, a 34% reduction in fluoroscopy time was noted. It was concluded that the use of dual C-arms reduced the maneuvering needed to reposition a single C-arm and may therefore reduce the risk of contamination during the procedure. Neither study presented sufficient data or statistical analyses to support the perceived benefits associated with the dual–C-arm technique.

Other patient positioning and imaging techniques for the treatment of SCFE have been described. Blasier et al[18] evaluated surgery time and accuracy of screw placement in comparing the use of a radiolucent surgical table with a standard fracture table when performing in situ pinning for SCFE. On the radiolucent table, the C-arm was left stationary, whereas the extremity was rotated to obtain orthogonal views. Conversely, when using the fracture table, the extremity was secured and the C-arm rotated to obtain orthogonal views. The mean surgery time in the study was greater with the use of the fracture table (38.6 minutes) as compared with the use of the radiolucent table (24.8 minutes). Neither operative table provided an advantage in accuracy of screw placement.

In the current study, patients with SCFE treated with the use of a single C-arm were compared with a similar group of patients treated with the use of dual C-arms. In both techniques, the patient is first positioned on the fracture table, and the C-arm(s) are used to confirm adequate visualization of the hip before establishing the sterile field. With the single–C-arm technique, the C-arm is continually repositioned between the AP and lateral planes throughout the procedure. With the 2–C-arm technique, once adequate imaging is obtained in each plane, the C-arms can be locked into place for the remainder of the case.

In the current study, we could not demonstrate any difference between the single– and dual–C-arm techniques with respect to OR setup and surgery times. The comparable OR setup times indicate that, although the 2–C-arm technique requires the placement of more imaging equipment, it can be done quickly once the staff become familiar with the standard positions of the fracture table and the 2 C-arms. We did not appreciate shortened OR surgical time with the 2–C-arm technique, as described by previous investigators. The OR surgical times at our institution were 2 to 3 times greater than those reported by Killian et al, perhaps reflecting the fact that all of the cases were performed by orthopaedic residents in a training program under the supervision of the attending pediatric orthopaedists.

The placement of a screw in the ideal center-center position in the head is critical to reduce the risk of inadvertent joint penetration and potential joint destruction. The precision of screw placement during in situ fixation was significantly better with the dual–C-arm than with the single–C-arm technique, with optimal screw positioning achieved in 88% of hips in the 2–C-arm group and 69% of the hips in the 1–C-arm group ($P < 0.05$). With the dual–C-arm technique, the guide pin can be inserted slowly under simultaneous biplanar visualization, allowing the surgeon to confirm optimum pin position. With the single–C-arm technique, optimum position and visualization of the guide pin can easily be lost, particularly in the lateral plane, during the repeated transitions of the C-arm under the surgical drapes between orthogonal planes.

The method of Blasier et al for assessing accurate screw placement was used to determine optimal screw position. However, this method does not allow assessment of overall screw length, nor its proximity to the joint. The approach-withdraw technique is routinely used at the time of surgery to evaluate screw length and confirm that the screw does not violate the articular surface of the hip joint. Plain radiographs obtained in the postoperative period were used in this study to determine overall accuracy of screw placement. Unless the postoperative radiographs were tangential to the screw, measurements regarding length of screw and proximity to the joint would be considered inaccurate. We were unable to determine if there were any differences between the 2 techniques regarding screw length, proximity to the articular surface, and joint violation.

Obesity is a common comorbidity associated with patients presenting with a diagnosis of SCFE.[2,3] It has been our clinical impression that patient positioning and accurate visualization of the hip, particularly on the lateral view, are more difficult in children with SCFE who are obese. In the current study, the obese children (BMI $\geq$30) had similar OR setup times and significantly longer OR surgical times compared with the nonobese children (BMI <30). Precision of screw placement was comparable between the 2 groups. When the statistical analysis controlled for obesity, we were not able to demonstrate a significant advantage to the use of dual–C-arm technique relative to the single–C-arm technique. The obese patients in both treatment groups demonstrated no significant differences with respect to OR setup times, OR surgical times, and precision of screw placement.

Previous reports documented improved fluoroscopy times with the use of dual C-arms.[15,16] After review with a radiation physicist, it was determined that our data set did not allow for adequate determination of patient radiation exposure based upon the available fluoroscopy times and exposure settings of the fluoroscopy machine. With the dual–C-arm technique, optimal alignment and visualization of the hip in both planes are achieved and maintained throughout the procedure. It has been our clinical impression that the repeated positioning of the C-arm when using the single-C-arm technique frequently required multiple imaging attempts to achieve visualization, particularly in the lateral plane. This would result in greater radiation exposure to the patient and staff during surgery. Precise calculation of radiation exposure is complex. Multiple factors contribute to the overall radiation exposure in the operating room. To determine radiation exposure for a single individual would require knowledge of the distance of the C-arm gantry to the patient, the decay of the radiation as it travels to the patient, and the diminished efficiency of x-ray transmission from the C-arm as the x-ray tube ages. For these reasons, we were not able to accurately calculate the relative radiation exposures associated with the single– versus dual–C-arm techniques.

The increased cost of using an additional C-arm during an operative procedure is unknown. When 2 C-arms are used, the same radiation technologist operates both units without the need for additional personnel and staff. Our institution is a nonprofit charity hospital in which no payments are required from the patient, patient's representatives, or patient's third-party payor for services rendered. In this setting, the costs are fixed, with no additional cost to the patient or institution if dual C-arms are used. Other institutions, specifically those in which payment is expected for services, may have a different policy.

The use of simultaneous biplanar fluoroscopy for the in situ pinning of SCFE was introduced at our institution in 1997. Once the OR staff became proficient at placement of the 2 C-arms, it has become the preferred technique for all 6 attending pediatric orthopaedists who have been on staff at our institution during the study period. No attending surgeon who has used this technique has chosen to return to the single–C-arm technique for the in situ pinning of SCFE. The current study confirms that efficient OR setup time for the 2–C-arm technique is possible, and that the precision of screw placement is improved when using simultaneous biplanar fluoroscopy for the in situ pinning of SCFE.

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