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SYMPOSIUM: LEGG-CALVÉ-PERTHES DISEASE: WHERE DO WE STAND AFTER 100 YEARS?

Triple Innominate Osteotomy for Legg-Calvé-Perthes Disease in Children

Does the Lateral Coverage Change With Time?

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Abstract
Background Triple innominate osteotomy (TIO) is one of the modalities of surgical containment in Legg-Calvé-Perthes disease (LCPD). However, overcoverage with TIO can lead to pincer impingement.
Questions/purposes We therefore asked (1) whether TIO contained the femoral head in Catterall Stages III and IV of LCPD; (2) whether the center-edge (CE) angle, acetabular roof arc angle (ARA), and Sharp's angle changed during the growing years; and (3) what percentage of patients had radiographic evidence of pincer impingement beyond a minimum followup of 3 years.
Methods We identified 19 children who had 20 TIOs performed for Catterall Stages III and IV LCPD. Two blinded observers assessed sequential radiographs. Each observer made two sets of readings more than 2 weeks apart. Femoral head extrusion index, CE angle of Wiberg, ARA, and Sharp's angle were measured. Minimum followup was 3 years to document continued acetabular growth (mean, 3.8 years; range, 3–7 years).
Results All patients exhibited femoral head containment at last followup. Eleven of 20 hips demonstrated no radiographic evidence of pincer morphology beyond a minimum followup of 3 years (mean, 3.8 years). Patients with CE angle corrected to 44° or less and an ARA of greater than −6° after TIO did not demonstrate a pincer morphology at last followup.
Conclusions TIO resulted in femoral head containment in all cases. Lateral acetabular coverage changed during the growing years in all patients. Surgical correction beyond 44° of CE angle and −6° of ARA should be avoided to prevent pincer morphology later.
Level of Evidence Level IV, diagnostic study. See Guidelines for Authors for a complete description of levels of evidence.

Introduction

Legg-Calvé-Perthes disease (LCPD) involves an unexplained vascular insult to the capital femoral epiphysis with

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.
This work was performed at Rady Children's Hospital, San Diego, CA, USA.

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resulting avascular necrosis. Biologic sequelae include a chain of events with eventual revascularization leading to biologic plasticity of the femoral head [24] usually followed by femoral head shape change, flattening, and even subluxation in severe cases. These morphologic changes can be a precursor to premature hip osteoarthritis [3, 4, 23, 28, 34].

Important factors predicting long-term hip function in LCPD include age at onset and the extent of capital femoral epiphyseal involvement [3, 23]. Severe femoral head deformity and joint incongruity at skeletal maturity are two factors that predict reduced long-term hip function [4]. Surgical containment is intended to contain the femoral head and promote a spherical femoral head at skeletal maturity [9, 37]. Inadequate coverage can lead to iatrogenic hinge abduction in a subluxated head [23].

Treatment methods including Salter innominate osteotomy combined with a proximal femoral varus osteotomy [5, 33] and triple innominate osteotomy (TIO) [13, 35] have provided good results even in cases of more severe head involvement. TIO centers the femoral head within the acetabulum during the fragmentation and reossification phase, allowing the spherical acetabulum to serve as a mold to the biologically plastic femoral head during the healing (revascularization) phase. While TIO allows correction of acetabular orientation and femoral head containment [13, 35], it may also inadvertently cause overcoverage, leading to a pincer morphology and subsequent symptomatic femoroacetabular impingement (FAI), which is a prearthritic condition [1, 35].

We therefore addressed the following questions: (1) Does TIO contain the femoral head in Catterall Stages III and IV of LCPD? (2) Do the center-edge (CE) angle, acetabular roof arc angle (ARA), and Sharp's angle change in these patients with time and acetabular growth? And (3) what percentage of patients continue to have radiographic evidence of pincer impingement beyond a minimum followup of 3 years?

Patients and Methods

We searched the surgical database at our institution from 1995 to 2006 and identified 69 patients who had TIO performed at our institution (for all indications, including developmental dysplasia, LCPD, neuromuscular dysplasia, and avascular necrosis). Of these, we identified 26 patients with the following criteria: (1) patients with the diagnosis of LCPD; (2) patients younger than 12 years at the time of TIO; (3) patients of either sex; (4) patients with Catterall Stage III or IV LCPD at the time of surgery [8]; and (5) patients with a minimum followup of 3 years after TIO with adequate radiographs available. We excluded seven patients who did not have all preoperative and sequential postoperative radiographs or a minimum followup of 3 years. The exclusions left 19 patients who had 20 TIOs. There were 17 boys and two girls. The mean age at surgery was 8.3 years (range, 6–11 years). Eleven patients had surgery on the right side and seven on the left; one patient had bilateral procedures. Minimum followup was 3 years (mean, 3.8 years; range, 3–7 years). No patients were recalled specifically for this study; all data were obtained from medical records and radiographs. We had prior institutional review board approval.

Preoperatively, we obtained high-quality AP radiographs (of both hips with the feet pointing forwards) and frog lateral radiographs in all patients and classified them according to the Catterall classification [3]. There were 13 hips with Catterall Stage III LCPD and seven with Catterall Stage IV disease. The patient with bilateral disease had a Catterall Stage III hip on one side and Stage IV on the other.

Our surgical technique was similar to the method described by Carlioz et al. [2] described in 1982. The supraacetabular cut was as described by Salter [23]. Our superior pubic ramus cut was made through the medial groin incision because we found this approach was less risky since there was little or no retraction of the femoral neurovascular bundle. The groin incision was made in a transverse fashion distal to the groin crease, centering over the adductor longus tendon. The ischial cut was made just below the acetabulum. Our approach allowed all cuts to be made relatively near the acetabulum, which allowed free acetabular rotation, as noted by Tönnis and Heinecke [33]. In contrast to the Tönnis procedure, we avoided a separate posterolateral incision with our approach.

We performed the TIO in the following sequence: (1) iliac osteotomy, (2) pubic osteotomy, and (3) ischial osteotomy. The Salter-type iliac cut was made through a typical anterolateral incision. Intramuscular lengthening of the psoas was performed at the pelvic brim to decrease joint forces over the hip. Specially designed Rang retractors placed in the sciatic notch made passing the Gigli flexible wire saw easier. The pubic osteotomy was performed via a transverse medial groin incision (that can also be used for the ischial osteotomy) in most patients. A Foley urinary catheter can be placed (to decrease the risk for bladder injury during the pubic osteotomy) but is not routinely used in our center. A separate 2- to 3-cm transverse incision (parallel to the inguinal ligament) was used for the pubic osteotomy in very large patients with a subsequent separate ischial incision. The ischial osteotomy was usually performed through the single medial incision, which was extended posteriorly toward the ischial tuberosity. An assistant flexed the hip 90° to allow visualization and the adductor magnus origin was detached using electrocautery. A Cobb elevator was used to follow the ischium up to its base just below the acetabulum, with three Hohman retractors providing retraction. The ischial cut was made 1 to 2 cm below the acetabulum (confirmed by image intensifier) using a long osteotome (required because of depth).

Correct acetabular positioning was critical to the success of the operation. To guide the acetabular segment, a Schanz screw was placed in the ilium above the joint line with a ballpoint pusher placed in the pubic ramus just lateral to the pubic osteotomy. The pubis was pushed upward and medially with the ballpoint pusher while the Schanz screw was used to lever and rotate the acetabulum forward and laterally in the coronal plane. Care was given to avoid iatrogenic acetabular retroversion, which can create pathologic acetabular mechanics. Image intensifier views were carefully assessed to avoid creating retroversion, to provide an approximately 20° angle of the teardrop figure, and to create a horizontal sourcil.

A triangular wedge of bone was removed from the iliac crest and fashioned to fit tightly in the gap of the iliac osteotomy. The graft was smaller than that used for a Salter osteotomy because with a TIO rotation also occurs at the pubic and ischial cuts. The osteotomy was first fixed with temporary K-wires, with acetabular position checked by fluoroscopy to confirm containment and proper acetabular position. Two or three 4.5- or 3.5-mm fully threaded cortical screws were then placed to fix the iliac osteotomy. In younger children (or any patient with a small bone structure), threaded K-wires can be used as an alternative to screw fixation. In older children (or any very large patient), an oblique screw or a small reconstruction plate can be placed across the superior pubic osteotomy for more secure fixation. The wounds were closed in layers and a single-leg hip spica applied (in most cases for 6 weeks). In older children with adequate fixation, including fixation of the pubic cut, the spica cast can be avoided.

Intraoperative CE angle was determined using a Number 18 needle/K-wire placed fluoroscopically at the edge of the lateral-superior acetabulum. This helped to draw the angles on the picture archiving and communications system (PACS) that we had access to during surgery. Both pre- and postdisplacement TIO images can be measured with this method intraoperatively using fluoroscopy. All measurements were performed using AMICAS radiographic digital system and software (LightView™, AMICAS Vision™ Series PACS, v. 5.0; AMICAS, Inc, Brighton, MA, USA).

All patients had radiographs preoperatively, immediate postoperatively, at 6 weeks, 3 months, 6 months, 1 year, and yearly thereafter (Fig. 1). Two observers (ALM, HH) blinded to patient identity and clinical course independently reviewed all radiographs. Radiographic parameters and measurement of indices were carefully discussed and practiced before data collection to standardize the measurement techniques and parameters of the various data. Subsequently, these observers recorded the data independently (blinded and randomized by research coordinator) on two separate occasions at least 2 weeks apart.

The following parameters were measured (Fig. 2): (1) femoral head extrusion index [7]; (2) CE angle of Wiberg formed by the intersection of two lines radiating from the center of the femoral head, one passing through the point at the outer edge of the acetabular roof and the other a vertical line [36]; (3) ARA described by Tönnis and Brunken [31] as an angle formed between a line parallel to the weight-bearing dome (sourcil) and a line parallel to the interteardrop line; and (4) Sharp's angle formed by the intersection of a line that crossed the lateral edge of the acetabular roof with a line drawn bisecting the inferior tip of the teardrops [25]. Green et al. [7] initially developed the femoral epiphyseal extrusion index as a prognostic indicator in LCPD. This is the percentage of the width of the femoral head that is lateral to Perkins' line as determined from an AP radiograph of the pelvis. The amount of the ossific nucleus that is lateral to Perkins' line is measured in millimeters along a line perpendicular to Perkins' line. This distance is divided by the width of the opposite/normal femoral head as measured in millimeters along the epiphyseal plate. The quotient so obtained is multiplied by 100 to obtain the percentage of the femoral head that has been extruded from the acetabulum. Green et al. [7] noted 20% and less protrusion as a good prognostic indicator in LCPD cases. Tannast et al. [29] alluded to an extrusion index of less than 25% as normal, although they emphasized no study has defined a minimum extrusion. For the purpose of this study, we considered anything less than 20% of extrusion as good containment. Radiographic pincer lesions were considered as those with a CE angle of greater than 39° or a negative ARA or a Sharp's angle of less than 28° [19, 25, 29, 32]. We considered a Sharp's angle of more than 42° as evidence of dysplasia or undercoverage (ie, inadequate containment) [19, 25].

We computed intraclass correlation coefficients for mean measures to determine the interrater reliability between the two observers. Additionally, test-retest reliability was tested for repeated measures for the two observers using intraclass correlation coefficients for mean measures. Inter- and intrarater reliability coefficients were based on angles taken immediately after surgery. Our interrater reliability for CE angle, ARA, and Sharp's angle was 0.992 (95% CI, 0.984–0.996), 0.989 (95% CI, 0.979–0.994), and 0.970 (95% CI, 0.942–0.984), respectively. Our test-retest reliability for CE angle, ARA, and Sharp's angle was 0.991 (95% CI, 0.983–0.995), 0.989 (95% CI, 0.980–0.994), and 0.975 (95% CI, 0.951–0.987), respectively.

Descriptive statistics were generated for the various angles (femoral head extrusion index, CE angle, ARA, and Sharp's angle). Our goal was to determine differences between two groups in this cohort. Group 1 included patients meeting at least one radiographic criterion for pincer morphology (CE angle $> 39°$, ARA $< 0°$, Sharp's angle $> 28°$).

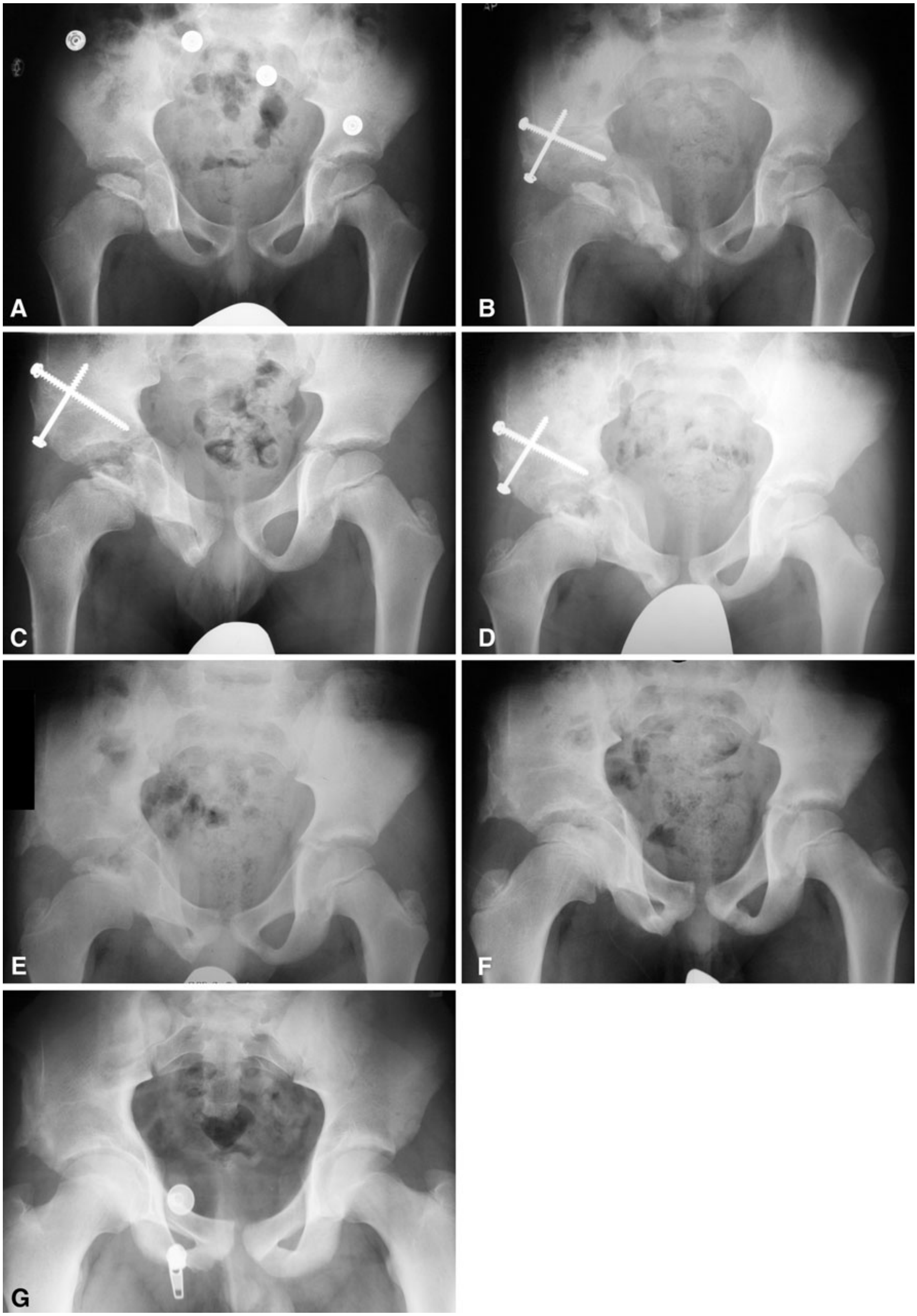

Fig. 1A–G Plain radiographs (AP view) illustrate the case of a 6-year-old boy with Catterall Stage III LCPD. Sequential radiographs (**A**) preoperatively and at (**B**) 2 months, (**C**) 6 months, (**D**) 9 months, (**E**) 1 year, (**F**) 3 years, and (**G**) 9 years after TIO demonstrate the process of remodeling after surgical containment until an eventual outcome of spherical congruity.

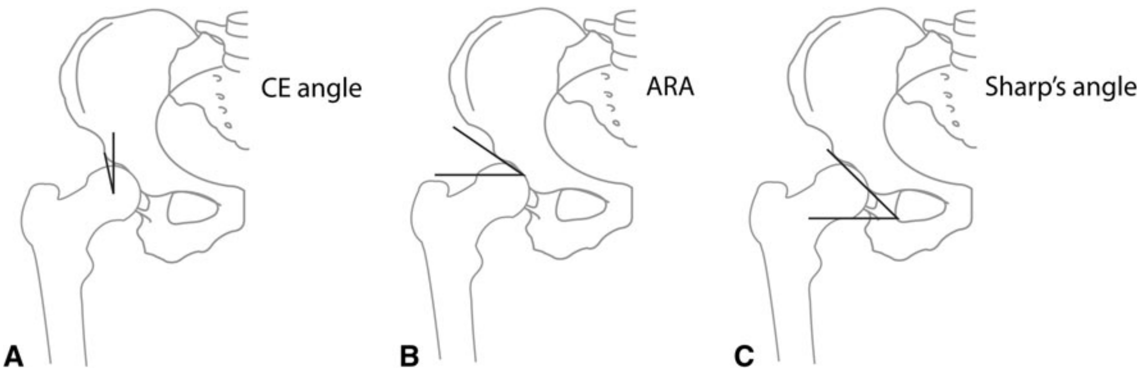

Fig. 2A–C Diagrams illustrate the measurement of (**A**) CE angle formed by the intersection of two lines radiating from the center of the femoral head, one passing through the point at the outer edge of the acetabular roof and the other a vertical line; (**B**) ARA formed between a line parallel to the weightbearing dome (sourcil) and a line parallel to the interteardrop line; and (**C**) Sharp's angle formed by the intersection of a line that crosses the lateral edge of the acetabular roof with a line drawn bisecting the inferior tip of the teardrops.

Radiographic parameters for good containment included femoral head extrusion of less than 20%, CE angle of greater than 25° (< 25° defined as dysplasia and undercoverage), and Sharp's angle of less than 42° (> 42° considered as dysplasia or undercoverage). Group 2 included patients not meeting these criteria. Femoral head containment was defined as good based on head coverage (femoral head extrusion index < 20%, CE angle > 25°, Sharp's angle < 42°). We plotted the CE angles, Sharp's angles, and ARAs on histograms and found they were not normally distributed. We therefore used the Wilcoxon signed-rank test to compare these angles. The Mann-Whitney U-test was used to compare continuous variables in cases where a between-groups test was required. We generated receiver operating curves (ROCs) to identify the following: optimal correction that would lead to a CE angle of 39° or less, an ARA of 0° or more, or a Sharp's angle of greater than 28° but less than 42° at last followup. We performed post hoc analyses to determine how well our optimal cutoff point predicted future deformity. In cases where the ROC was not possible due to small sample size, we manually reviewed the data to determine what the optimal cutoff point was where hips could remodel from the immediate postoperative period until last followup (ie, how much correction could be tolerated without deformity). We calculated all statistics using SPSS® Version 16.0 (SPSS Inc, Chicago, IL, USA).

Results

All patients (19 patients, 20 hips) had successful containment of the femoral head and no evidence of acetabular dysplasia or undercoverage at last followup. Mean extrusion index decreased ($p < 0.001$) from the preoperative (0.24) to the last postoperative film (0.07) for the entire cohort.

The CE angle, ARA, and Sharp's angle changed in all 20 hips with time and acetabular growth. Mean CE angle decreased ($p < 0.001$) from 44° in the immediate postoperative period to 38° at last followup (Fig. 3A). This represents a decrease of 6° (95% CI, 5°–7°). Mean ARA changed ($p < 0.001$) from a postoperative angle of −8° to −1° at last followup (Fig. 3B). This represents an increase of 7° (95% CI, −8° to −5°). Mean Sharp's angle changed ($p < 0.001$) from a postoperative angle of 27° to 32° at last followup (Fig. 3C). This represents an increase of 4.7° (95% CI, −5.7° to −3.7°). No patient corrected to a CE angle of 44° or less had a CE angle of greater than 39° at last followup. Our post hoc analysis of this curve suggested 43.5° would be the ideal maximum correction, with a sensitivity of 100% and a specificity of 69% (three patients who were corrected to greater than 44° remodeled to 39° or less). The mean postoperative CE angle was higher ($p < 0.001$) for patients with pincer lesions at followup (49°) than for patients without postoperative pincer lesions (40°). No patient with an ARA of greater than −6° postoperatively had a negative ARA at last followup. The mean postoperative Sharp's angle was lower ($p < 0.001$) for patients who were overcovered at last followup (Sharp's angle ≤ 28°) (24°) than for patients who were not overcovered at last followup (30°). Only one patient with a Sharp's angle of 26° or greater did not remodel sufficiently and ended up overcovered. All patients whose Sharp's angle was 26° or less postoperatively were overcovered at last followup. All patients had complete femoral head containment and no patient was labeled dysplastic at last followup (Sharp's angle > 42°).

Nine of the 20 hips had continued evidence of radiographic pincer morphology (with CE angle ≥ 39° [nine hips at last followup] or negative ARA [eight hips at last followup]) at the mean followup of 3.8 years.

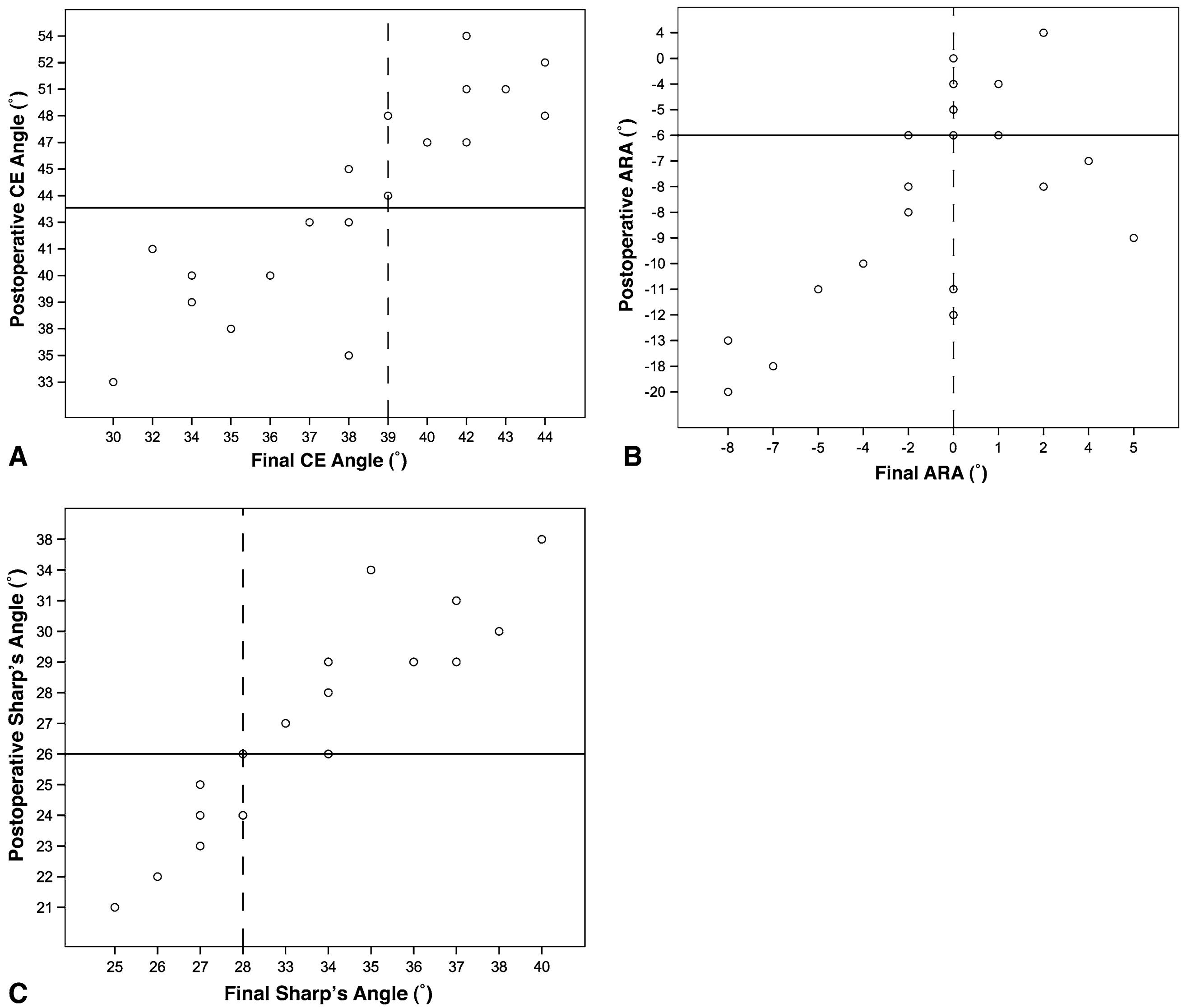

Fig. 3A–C Graphs show postoperative versus last followup (**A**) CE angle, (**B**) ARA, and (**C**) Sharp's angle. Dotted line = above which would constitute a pincer lesion. Solid line = maximum level of correction in our study. (**A**) Only one patient corrected more than the optimum remodeled to a level below the impingement line, and two remodeled to 39°. No patient corrected less than the solid line had a pincer lesion at last followup. (**B**) Only one patient had a negative ARA after surgery when the ARA was corrected to −6° or less, and four patients had a neutral ARA (0°) at this level. Less than ½ of patients corrected to 6° had a positive ARA at last followup. (**C**) Only one patient corrected to 26° or more (solid line) ended up overcovered at last followup (Sharp's angle ≤ 28°; dashed line). No patient was dysplastic at last followup (Sharp's angle > 42°).

Discussion

Although we have been aware of LCPD for 100 years, its etiology still remains unknown and treatment methods have empirically evolved over decades. Several studies have clarified brace treatment is not very effective, either due to brace design or poor patient compliance [16, 37]. Surgical methods of containment include proximal femoral osteotomy, innominate osteotomy, shelf acetabuloplasty, combined femoral varus with innominate osteotomy, and TIO [5, 13, 33, 35]. The intention of a TIO is to contain the femoral head and consequently allow the spherical acetabulum to serve as a mold for the growing biologically plastic femoral head in LCPD. TIO can lead to overcoverage in many cases. Overcoverage beyond a certain point leads to pincer morphology and as such can evolve into symptomatic FAI with time, which is a prearthritic condition [6, 11, 18, 29, 30]. Thus, surgical containment with TIO has a risk-benefit ratio. However, it is unclear whether and to what degree the acetabular coverage changes during the growing years and what is the potential for remodeling after TIO. We therefore conducted this study to answer the following questions: (1) Does TIO successfully contain the femoral head in Catterall Stages III and IV of LCPD? (2) Are there any changes in the CE angle, ARA, and Sharp's angle in these patients with time and acetabular growth? And (3) what percentage of patients continue to have radiographic evidence of pincer impingement beyond a minimum followup of 3 years?

We acknowledge several limitations of our study. First, it is a retrospective study with limited numbers, observer bias, selection bias, and measurement inaccuracies. Second, we included only Catterall Stages III and IV of the disease in patients younger than 12 years, and therefore the results cannot be extrapolated to the entire spectrum of LCPD. Third, we have utilized angle measurements on plain radiographs that are primarily designed for the adult hip. However, since these are the currently established standards for assessment of radiographic femoral head coverage and acetabular dysplasia, we had no options but to use these indexes. Furthermore, the definition of pincer morphology (as a subset of FAI) is also based on these same indexes, which happens to be one of the main questions addressed in this study. Fourth, acetabular coverage is three-dimensional while we assessed single-planar radiographs. Acetabular reorientation should ideally be evaluated three-dimensionally, likely with advanced imaging such as CT. We did have some patients who underwent CT, but these data were lacking for the entire cohort to do any meaningful assessment. Fifth, we lacked followup in 14 of the 19 patients up to skeletal maturity. We are aware the process of growth and remodeling of the acetabulum in LCPD continues to skeletal maturity [12, 15]. Our goals were to document changes in radiographic parameters in the growing age group and investigate whether iatrogenic overcoverage with TIO in LCPD leads to continued pincer morphology in all cases. With a minimum 3-year followup, most of the hips in our series remodeled (11 of 20) to a radiographically established nonpincer morphology. It is likely longer followup may cause further remodeling in the other cases. Finally, we cannot predict which of these patients with persistent radiographic pincer morphology will become symptomatic with time and develop symptomatic FAI, which is now considered a major cause of early osteoarthritis of the hip, especially in young and active patients [6, 11, 18, 29, 30]. It is characterized by an early pathologic contact between the acetabulum and the femur that limits the physiologic hip ROM, typically flexion and internal rotation. Based on clinical and radiographic parameters, two types of impingement are described. Pincer impingement involves the acetabular side and is characterized by focal or general overcoverage of the femoral head. Cam impingement is the femoral cause of FAI and is due to asphericity of the femoral head-neck junction. Most patients have a combination of both, which is called mixed pincer and cam impingement [1].

Pincer FAI is the result of linear contact between the acetabular rim and the femoral head-neck junction. The femoral head may or may not be normal in morphology, but in a pure pincer impingement, the abutment is a result of the acetabular abnormality. The acetabular abnormality may be generalized, as in patients with deep socket, or localized anterior overcoverage, as in patients with acetabular retroversion. The first structure to fail in this situation may be the acetabular labrum. Continued impact of abutment results in degeneration of the labrum. Eventual ossification of the rim leads to further deepening of the acetabulum and worsening of the overcoverage. In contrast to cam impingement, cartilage damage of the acetabular cartilage is restricted in pincer hips to a small thin strip near the labrum that is more circumferentially located. The persistent abutment (usually anterior) can lead to chronic leverage of the head in the acetabulum and over time can result in contre-coup chondral damage of the posteroinferior head and/or acetabulum resulting in central joint space narrowing.

Normally, general acetabular overcoverage is correlated with the radiographic depth of the acetabular fossa. A normal hip appears on an AP pelvic radiograph with the acetabular fossa line lying laterally to the ilioischial line. A coxa profunda is defined with the floor of the fossa acetabuli touching or overlapping the ilioischial line medially. Protrusio acetabuli occurs when the femoral head is overlapping the ilioischial line medially. Generally, a deep acetabulum is associated with excessive acetabular coverage that can be quantified with the lateral CE angle or the acetabular index [20]. A normal lateral CE angle varies between 25° (which defines a dysplasia) [19] and 39° (which is an indicator for acetabular overcoverage) [32]. In hips with acetabular overcoverage (such as coxa profunda or protrusio acetabuli), the acetabular index (also called acetabular roof angle) is typically 0° or even negative. Femoral coverage is also quantified based on the femoral head extrusion index [10], where normal extrusion index is defined as less than 25% [14].

Focal overcoverage can occur in the anterior or posterior part of the acetabulum. By carefully tracing the anterior and posterior acetabular rims, different acetabular configurations can be identified. A normal acetabulum is anteverted and has the anterior rim line projected medially to the posterior wall line [17, 22, 26, 27]. A focal overcoverage of the anterosuperior acetabulum causes a cranially retroverted acetabulum that presents as a figure-of-eight configuration also called the crossover sign.

Our initial goal was to assess whether TIO contained the femoral head in Catterall Stages III and IV of LCPD. Based on the radiographic criteria defined earlier, all patients had containment of the capital epiphysis in the immediate postoperative period and at last followup (femoral head extrusion index < 20%, CE angle > 25°, Sharp's angle < 42°). Surgical containment utilizing proximal femoral varus osteotomy or the Salter's innominate osteotomy may provide adequate containment in mild to moderate LCPD but can be problematic in more severe cases [35]. Proximal femoral osteotomy has the disadvantage of shortening an already short limb and producing a limp while Salter's innominate osteotomy may not achieve adequate acetabular rotation to cover the femoral head in patients with extensive necrosis [21]. Herring et al. [9], using the more standard osteotomies for containment in LCPD, ie, Salter innominate osteotomy or proximal femoral varus osteotomy, concluded patients with Lateral Pillar B or B/C disease older than 8 years at the time of onset had a better Stulberg class at skeletal maturity (Stulberg Classes I and II [61%] and Class III [29%]) with surgical containment compared to the nonoperative group (Stulberg Class I [36%] and Class II [18%]). They also noted patients with Lateral Pillar C disease at any age had poor outcomes, even when treated by femoral or Salter osteotomy [9] (8 years old or younger at disease onset: 64% had radiographic Stulberg Class III, IV, or V at skeletal maturity; older than 8 years old at disease onset: 100% had Stulberg Class III, IV, or V at skeletal maturity), and suggested surgical treatment could not help these patients. It is important to note that study did not include advanced containment methods [9]. We found advanced containment methods (TIO) can lead to satisfactory outcomes (radiographic Stulberg Class I, II, or III) in almost all Lateral Pillar B and some Lateral Pillar C patients [35].

Our second goal was to identify any changes in the CE angle, ARA, and Sharp's angle in these patients during the growing years. All patients in our study demonstrated changes in radiographic measurements during the growing years. All patients had successful femoral head containment. The overcoverage offered by the TIO remodeled to a radiographic nonpincer morphology in 11 of 20 hips at a mean followup of 3.8 years. Our findings may have biologic and treatment implications for patients with LCPD treated by TIO. From a biologic standpoint, we are aware any physis responds to mechanical forces during the growing years. The superior physis of the acetabulum contributes to most of the total acetabular growth. The intention of the TIO is containment of the femoral head with acetabular reorientation in a skeletally immature patient with LCPD with a purpose of obtaining a spherical femoral head. Remodeling during the growing years that permits change of the acetabular coverage to a nonpincer morphology while maintaining femoral head containment certainly assists in improving the risk-benefit ratio of this procedure. Based on our analysis, we recommend the acetabular coverage after TIO for LCPD (in Catterall Stage III or IV) should be limited to a CE angle of 44° or less and the ARA of not more than −6°, as we have noted this can still remodel to a nonpincer morphology during the growing years.

Our third and final goal was to identify what percentage of patients would continue to have radiographic evidence of pincer impingement beyond a minimum followup of 3 years. Eleven of the 20 hips evaluated in this study showed evidence of remodeling into a nonpincer morphology after a minimum followup of 3 years. Therefore, in patients who have pincer morphology but remain asymptomatic during the growing years, it may be prudent to continue observation as the acetabulum continues its remodeling toward completion of skeletal maturity. Aggressive intervention toward deimpingement may not be necessary unless the patient has severe symptoms.

TIO remains a good option for surgical containment of the femoral head in LCPD and provides containment even in severe stages of the disease. Radiographic pincer morphology seems to remodel during the growing years in most cases while maintaining the containment. We continue to use this approach because it can produce a surprisingly spherical head, even in older children.

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