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ORIGINAL RESEARCH

Intraoperative Hip Arthrography During Closed Reduction for Developmental Dysplasia of the Hip in Infants: A Comparative Study of Surgical Decision-Making and Secondary Intervention Risk

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ABSTRACT

This study evaluated whether intraoperative hip arthrography performed during closed reduction for developmental dysplasia of the hip (DDH) in infants provides prognostic information regarding treatment failure and the need for secondary surgery and examined the influence of patient age. This retrospective comparative study included 88 hips in 79 patients aged ≤1 year who underwent closed reduction followed by hip spica casting. Patients were grouped according to intraoperative assessment method: fluoroscopy alone (Group 1) or fluoroscopy combined with arthrography (Group 2). The primary outcome was treatment failure, defined as secondary open reduction for redislocation in Group 1 and intraoperative conversion to open reduction due to nonconcentric reduction in Group 2. Secondary outcomes included avascular necrosis (AVN), acetabular index (AI) at 24 months, and lateral center–edge angle (LCEA) at 5 years. Subgroup analyses were performed for patients aged ≤6 months and 6–12 months. Overall failure rates were similar between groups (18.8% vs 20.0%, p=1.000). However, the timing of failure differed: failures in Group 2 were detected and managed intraoperatively, whereas those in Group 1 presented later and required additional surgery. Radiographic outcomes and AVN incidence were comparable (p>0.05). Failure rates were substantially higher in patients older than 6 months. Although arthrography did not reduce overall failure or improve radiographic results, it enabled early identification of nonconcentric reduction and immediate definitive management, thereby supporting intraoperative decision-making and potentially reducing delayed secondary procedures.

Level of evidence: III, retrospective comparative study.

Keywords: Closed reduction. Developmental dysplasia of the hip. Hip arthrography. Open reduction. Treatment failure.

Bebeklerde Gelişimsel Kalça Displazisinde Kapalı Redüksiyon Sırasında İntraoperatif Kalça Artrografisi: Cerrahi Karar Verme ve Sekonder Müdahale Riski Açısından Karşılaştırmalı Bir Çalışma

ÖZET

Bu çalışma, bebeklerde gelişimsel kalça displazisi (GKD) için kapalı redüksiyon sırasında yapılan intraoperatif kalça artrografinin tedavi başarısızlığı ve sekonder cerrahi gereksinimi açısından prognostik bilgi sağlayıp sağlamadığını değerlendirdi ve hasta yaşının etkisini inceledi. Bu retrospektif karşılaştırmalı çalışmaya, kapalı redüksiyon ve ardından kalça spika alçısı uygulanan ≤1 yaşındaki 79 hastaya ait 88 kalça dâhil edildi. Hastalar intraoperatif değerlendirme yöntemine göre gruplandırıldı: yalnızca floroskopi (Grup 1) veya floroskopi ile birlikte artrografi (Grup 2). Birincil sonuç ölçütü tedavi başarısızlığı olup, Grup 1'de yeniden çıkık nedeniyle sekonder açık redüksiyon ve Grup 2'de konsantrik olmayan redüksiyon nedeniyle intraoperatif olarak açık redüksiyona geçilmesi şeklinde tanımlandı. İkincil sonuç ölçütleri arasında avasküler nekroz (AVN), 24. ayda asetabular indeks (AI) ve 5. yılda lateral merkez–kenar açısı (LCEA) yer aldı. ≤6 ay ve 6–12 ay yaş grupları için alt grup analizleri yapıldı. Genel başarısızlık oranları gruplar arasında benzerdi (%18,8'e karşı %20,0, p=1,000). Ancak başarısızlığın zamanlaması farklıydı: Grup 2'deki başarısızlıklar intraoperatif olarak saptandı ve yönetildi, oysa Grup 1'deki başarısızlıklar daha geç dönemde ortaya çıktı ve ek cerrahi gerektirdi. Radyografik sonuçlar ve AVN insidansı benzerdi (p>0,05). Her iki grupta da 6 aydan büyük hastalarda başarısızlık oranları belirgin olarak daha yüksekti. Artrografi genel başarısızlık oranını azaltmadı veya radyografik sonuçları iyileştirmedi, ancak konsantrik olmayan redüksiyonun erken saptanmasını ve derhal kesin tedavinin uygulanmasını sağladı; böylece intraoperatif karar vermeyi destekledi ve gecikmiş sekonder girişimleri potansiyel olarak azaltabilecektir.

Anahtar Kelimeler: Gelişimsel kalça displazisi. Kapalı redüksiyon. Kalça artrografisi. Açık redüksiyon. Tedavi başarısızlığı.

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Developmental dysplasia of the hip (DDH) results from abnormal hip development and presents during infancy or early childhood with a spectrum ranging from mild acetabular dysplasia to complete dislocation of the hip joint. It is one of the most common developmental disorders of the hip in childhood, and when not recognized and treated early, it may lead to persistent acetabular insufficiency, gait abnormalities, and an increased risk of early-onset osteoarthritis in adulthood. The primary goal of treatment is to promote joint remodeling by achieving a stable and, as much as possible, concentric reduction of the femoral head within the acetabulum. Although abduction orthoses such as the Pavlik harness are particularly effective in young infants, closed reduction under general anesthesia followed by hip spica casting (CRSC) remains a widely preferred treatment option in cases with significant dislocation or failure of conservative management[1–6].

However, outcomes following CRSC are heterogeneous, and early loss of reduction (recurrence/redislocation), persistent residual acetabular dysplasia, and avascular necrosis (AVN) remain among the most critical concerns. A prospective multicenter cohort study reported that, even when an initially stable closed reduction is achieved, early failure and AVN rates may reach levels substantial enough to influence clinical decision-making[4]. Furthermore, population-based data indicate that the need for secondary surgical intervention after closed reduction is not negligible[7].

Although the primary determinant of success in CRSC is the quality of reduction, intraoperative fluoroscopy and early postoperative radiographs provide limited information regarding soft tissue obstacles and the concentricity of the femoral head within the joint. In this context, intraoperative hip arthrography allows dynamic assessment of intra-articular structures such as the limbus/labrum morphology, pulvinar tissue, and ligamentum teres, as well as the femoral head–acetabular relationship. This technique can facilitate real-time evaluation of reduction quality and support the decision to proceed to open reduction during the same session when necessary. The medial dye pool (MDP) measured during arthrography has demonstrated a strong correlation with postoperative magnetic resonance imaging (MRI) findings, and the identification of specific threshold values indicative of adequate reduction suggests that it may serve as a practical and reliable intraoperative parameter[2,8–10]. In this context, hip arthrography has been recognized as an important guide for evaluating femoral head reduction during closed treatment of DDH, and its prognostic value has been highlighted through reported associations with clinically relevant outcomes such as residual acetabular dysplasia and AVN[11,12].

On the other hand, it has been suggested that in patients with DDH treated with closed reduction (CR), reductions that are not fully concentric at the initial stage may become concentric over time; therefore, the prognostic value of early-stage, single-session imaging may not be uniform across all cases[6]. Within this framework, the present study aimed to clinically determine whether intraoperative arthrography performed prior to closed reduction and hip spica casting in patients younger than one year with DDH provides predictive insight for clinicians regarding disease prognosis, including recurrence and the need for secondary surgical intervention. Additionally, the study sought to evaluate potential differences between age subgroups (0–6 months and 6–12 months).

Materials and Methods

Study Design

This study was conducted as a retrospective review of medical records and imaging data of patients who were treated with closed reduction and hip spica casting for developmental dysplasia of the hip between September 2012 and January 2024. The study was carried out in accordance with the ethical principles of the Declaration of Helsinki (1964). Approval was obtained from the Institutional Ethics Committee of our hospital (No: 2025.05.124).

Study Population and Patient Selection

The target population consisted of patients aged ≤1 year who were diagnosed with DDH, treated with CRSC under general anesthesia, and had a minimum follow-up of one year. The following cases were excluded: patients who had previously undergone CRSC or prior surgery on the affected hip; those with teratologic hip dislocation, syndromic conditions, or

neuromuscular disorders; cases in which reduction failure was detected intraoperatively or during the casting period; patients with poor compliance to treatment or follow-up; and hips with high-grade dislocation (Tönnis grade 3–4). Tönnis classification was determined on preoperative radiographs based on the position of the femoral head ossification center[13].

Syndromic, teratologic, and neuromuscular hip dislocations were excluded because these non-idiopathic etiologies differ from idiopathic DDH in terms of underlying pathoanatomy, soft-tissue characteristics, and clinical behavior, which may influence reducibility and post-reduction stability. Including such cases could introduce etiologic heterogeneity and confound the interpretation of closed reduction outcomes in an otherwise homogeneous infant DDH cohort. This approach is consistent with prior literature distinguishing idiopathic from non-idiopathic hip instability in terms of management and prognosis[13–15].

Group Allocation and Treatment

Patients were divided into two main groups based on whether intraoperative arthrography was performed: those treated without arthrography (Group 1) and those who underwent intraoperative arthrography (Group 2). Patients were also stratified into two age-based subgroups: ≤6 months and 6–12 months.

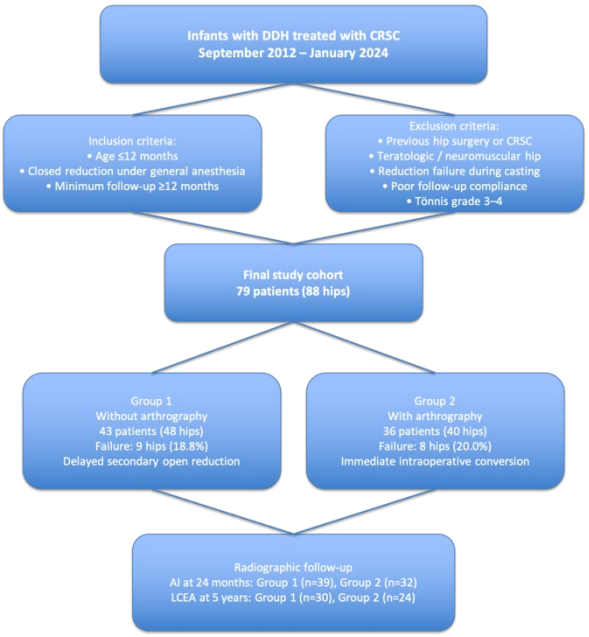
Within these groups, patients were managed according to the routine clinical practice of two different pediatric orthopedic surgeons who were unaware of each other's treatment approach. The surgeons had comparable casting positions, treatment durations, and follow-up protocols. The only difference between them was that one surgeon assessed reduction quality using intraoperative arthrography, whereas the other relied on fluoroscopic evaluation alone without arthrography. Group allocation was not influenced by patient characteristics or disease severity. Patient selection, exclusion criteria, and group distribution are summarized in the patient flow diagram (Figure 1).

Intraoperative Assessment

In all cases, reduction was performed under general anesthesia in the operating room with fluoroscopic guidance. Reduction stability was assessed dynamically with the hip positioned in flexion and abduction. Adductor tenotomy was performed when maximum abduction was <60° and the safe zone was <30°.

Intraoperative Percutaneous Hip Arthrography Protocol

With the patient in the supine position and the hip in flexion and abduction, the hip joint was accessed percutaneously via a posterior approach to the adductor muscles. Under fluoroscopic guidance, 1.0–1.5 mL of contrast material (iohexol) was injected. At this stage, the femoral head was reduced under traction, and the positional relationship between the femoral head and the acetabulum, as well as the distribution of the contrast medium, was dynamically evaluated using fluoroscopy (Figure 2). Arthrography was performed within the same fluoroscopic session used for reduction assessment, adding only a few minutes to operative time and not requiring additional postoperative radiographs. Reduction quality was assessed by measuring the MDP within the joint space[8,16,17]; in cases of inadequate reduction, the procedure was converted to open reduction.



Flowchart illustrating patient selection, inclusion and exclusion criteria, group allocation, and radiographic follow-up throughout the study period.

Abbreviations: DDH, developmental dysplasia of the hip; CRSC, closed reduction and hip spica casting; AI, acetabular index; LCEA, lateral center–edge angle.

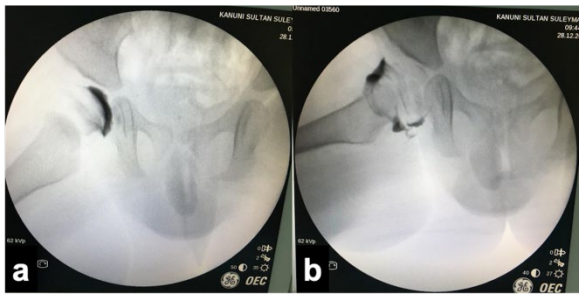
Figure 1.
Patient flow diagram of the study.

Closed Reduction and Hip Spica Casting

When reduction was considered acceptable based on arthrographic and/or fluoroscopic findings and stability assessment, immobilization was achieved with a hip spica cast applied in the human position, with the hip maintained at 90°–110° of flexion and approximately 45°–60° of abduction.

Within 24 hours after cast application (early post-casting period), computed tomography (CT) was performed for confirmation (Figure 3). In our institution, early post-casting CT is routinely obtained in all patients following closed reduction and hip spica casting. In accordance with ALARA (As Low As

Reasonably Achievable) principles, imaging is performed using a low-dose pediatric protocol and is limited to a focused cross-sectional study of the treated hip joint only, encompassing the acetabulum and femoral head rather than the entire pelvis. The primary aim of this imaging is to verify concentric and stable femoral head positioning within the spica cast during the early postoperative period, particularly in situations where plain radiographs may be limited by cast overlap. The use of cross-sectional CT to confirm reduction has been widely described in the literature and reported as common practice in many centers[18–21].

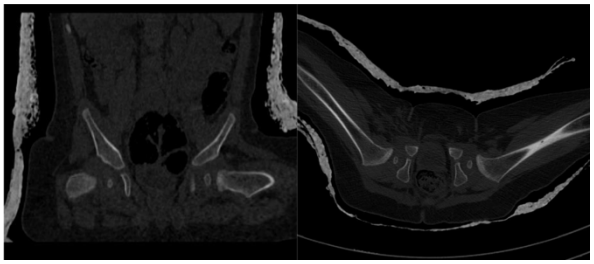


Fluoroscopic images obtained after intra-articular contrast injection demonstrating dynamic evaluation of reduction quality.

(a) Before reduction, contrast pooling medially indicating increased medial dye pooling.

(b) After closed reduction, restoration of concentric alignment between the femoral head and acetabulum with disappearance of medial pooling and improved assessment of intra-articular structures.

Figure 2.
Intraoperative hip arthrography for assessment of reduction.



Computed tomography obtained within the early post-treatment period demonstrates concentric and anatomical positioning of the femoral head within the acetabulum, confirming adequate reduction.

Figure 3.
Early post-casting computed tomography after closed reduction and hip spica casting.

Hip spica treatment consisted of two consecutive cast applications, each lasting 1.5 months (a total of 3 months of casting). Following the second casting period, a brace was used for 12 hours per day for an additional three months.

Failure of CR was defined as dislocation or subluxation of the femoral head within the cast, confirmed by cross-sectional CT obtained during the early post-casting period and by anteroposterior (AP) pelvic radiographs during follow-up.

Imaging Protocol and Radiological Measurements

Imaging evaluation included preoperative radiographs, early postoperative radiographs and cross-sectional CT scans, as well as pelvic radiographs obtained at 12, 18, and 24 months and at the fifth year of follow-up. Radiological assessment comprised the continuity of the Shenton–Menard line, measurement of the acetabular index (AI), and documentation of the position of the ossification center according to the Tönnis classification[13]. AVN was evaluated using the Kalamchi–MacEwen classification[22]. In patients with a follow-up of five years or longer, the lateral center–edge angle (LCEA)[23] was measured on AP pelvic radiographs[24].

During follow-up, measurements were performed on standardized AP pelvic radiographs. The radiographic parameters obtained were considered indirect indicators of reduction success and acetabular remodeling. Recurrences were recorded and managed according to standard stepwise treatment protocols, and patients were analyzed according to their initial group allocation.

Outcome Measures

The primary outcome measures were the development of recurrence (redislocation/instability) during follow-up and the presence of nonconcentric reduction identified intraoperatively. Failure was defined as the requirement for open reduction, irrespective of timing. In Group 2, this corresponded to intraoperative conversion to open reduction following identification of nonconcentric reduction, whereas in Group 1 it manifested as delayed redislocation necessitating secondary open reduction. Accordingly, these outcomes reflect different temporal manifestations of reduction inadequacy rather than fundamentally distinct clinical endpoints.

Secondary outcome measures included the presence of AVN, AI values, and radiographic improvement assessed by the continuity of the Shenton–Menard line on 24-month radiographs, as well as LCEA patterns on fifth-year radiographs.

Blinding and Reliability

To minimize observer bias, all radiographic evaluations were independently performed by two observers who were blinded to the treatment groups. Interobserver reliability was assessed using intraclass correlation coefficients. Demographic characteristics, including sex, age at treatment initiation, affected side, and associated risk factors, were recorded to ensure comparability between groups. Post hoc adjustments

were performed using multivariable logistic regression to account for potential confounding variables. Although the study did not include randomization, methodological rigor was maintained through comprehensive data analysis to reduce potential bias.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, Version 28.0 (IBM Corp., Armonk, NY, USA). The normality of continuous variables was assessed using the Shapiro–Wilk test. Continuous variables were presented as mean ± standard deviation (range), and categorical variables as frequencies and percentages.

Comparisons between the arthrography and non-arthrography groups were performed for the overall cohort. In age-based subgroup analyses (≤6 months and 6–12 months), group comparisons were limited to failure outcomes. Continuous variables were compared using the independent-samples Student's t test or the Mann–Whitney U test, as appropriate. Categorical variables were analyzed using the chi-square test or Fisher's exact test.

Among the 79 patients included in the study, 9 (11.4%) had bilateral involvement. In these cases, both hips were analyzed as independent observations. No additional sensitivity analysis using clustered or mixed-effects modeling was performed to account for potential within-patient correlation.

All statistical tests were two-tailed, and a p value <0.05 was considered statistically significant.

Results

Patient Characteristics

A total of 88 hips from 79 patients were evaluated. Group 1 included 48 hips from 43 patients, whereas Group 2 comprised 40 hips from 36 patients. The patient selection process and final cohort distribution are illustrated in Figure 1.

In Group 1, there were 30 females and 13 males; Group 2 included 23 females and 13 males (p=0.635). Regarding the side of the treated hip (left/right), the distribution was 26/22 in Group 1 and 24/16 in Group 2 (p=0.667).

Baseline Clinical Characteristics

The mean age at treatment initiation was 5.92±2.65 months (range, 2–11) in Group 1 and 6.74±2.09 months (range, 3.5–11) in Group 2 (p=0.097). The pre-treatment acetabular index measured 36.48±3.90° (range, 31–46) in Group 1 and 37.55±3.30° (range, 31–45) in Group 2 (p=0.091).

The distribution of sex, affected side, and baseline clinical characteristics was comparable between the groups, with no statistically significant differences observed in demographic variables (Table I).

Table I. Baseline characteristics of the study groups

	Group 1 (Without arthrography)	Group 2 (With arthrography)	p-value
▪ Patients, n	43	36	
▪ Hips, n	48	40	
▪ Patient Sex (Female/Male), n	30/13	23/13	0.635[a]
▪ Hip Side (Left/Right), n	26/22	24/16	0.667[a]
▪ Risk factors			
Family history	24	21	
Breech presentation	17	14	
Multiple birth	2	1	
▪ Pre-treatment AI (°)	36.48 ± 3.90 (31–46)	37.55 ± 3.30 (31–45)	0.091[b]
▪ Age at treatment initiation (months)	5.92 ± 2.65 (2–11)	6.74 ± 2.09 (3.5–11)	0.097[b]

AI, acetabular index
[a] Fisher's exact test; [b] Mann–Whitney U test

Post-treatment Radiological Outcomes

On the pelvic radiograph obtained at month 24, AI measurements were available for 39 hips (81.25%) in Group 1 and 32 hips (80%) in Group 2. The mean AI was 22.92±4.93° (range, 13–31) in Group 1 and 21.50 ± 4.27° (range, 15–34) in Group 2, with no statistically significant difference between groups (p=0.170).

Pelvic radiographs at age 5 were available for 30 hips (62.5%) in Group 1 and 24 hips (60%) in Group 2, and these hips were included in the LCEA analysis. The mean LCEA was 26.03±4.77° (range, 17–35) in Group 1 and 24.13±3.99° (range, 16–30) in Group 2, with no significant intergroup difference (p=0.123) (Table II).

Table II. Radiological outcomes

	Group 1 (Without arthrography)	Group 2 (With arthrography)	p-value
▪ AI at 24 months (°)	22.92 ± 4.93 (13–31)	21.50 ± 4.27 (15–34)	0.170[b]
▪ LCEA at 5 years (°)	26.03 ± 4.77 (17–35)	24.13 ± 3.99 (16–30)	0.123[c]

AI, acetabular index; LCEA, lateral center edge angle
[b] Mann–Whitney U test; [c] Independent samples Student's t-test

Complications and Recurrence

During follow-up, AVN was identified in three hips in Group 1 (one Grade I, one Grade II, and one Grade III), corresponding to an incidence of 7.69%. In Group 2, AVN was observed in two hips (one Grade I and

one Grade III), representing an incidence of 6.25%. There was no statistically significant difference between the groups in terms of AVN incidence (p=1.000) (Table III).

Table III. Avascular necrosis (AVN) incidence during follow-up

	Group 1 (Without arthrography)	Group 2 (With arthrography)	p-value
▪ AVN, n/N (%)	3/39 (7.69%)	2/32 (6.25%)	1.000[a]
▪ AVN			
Grade I	1	1	
Grade II	1	0	
Grade III	1	1	
Grade IV	0	0	

[a] Fisher's exact test (two-sided)

Treatment failure was defined as the need for open reduction: delayed secondary open reduction for redislocation during follow-up in Group 1 and immediate intraoperative conversion to open reduction due to nonconcentric reduction in Group 2.

In the overall cohort, the failure rate was 18.8% (9/48 hips) in Group 1 and 20.0% (8/40 hips) in Group 2, with no significant difference between the groups (p=1.000). However, the pattern of failure differed between the groups: failures in Group 1 occurred during follow-up and required secondary open reduction, whereas failures in Group 2 represented immediate intraoperative conversion to open reduction.

In age-stratified analysis, among patients aged ≤6 months, the rate of recurrence/secondary intervention was 8.0% (2/25 hips) in Group 1, whereas the rate of intraoperative conversion to open reduction was 5.6% (1/18 hips) in Group 2, with no significant intergroup difference (p=1.000). In patients aged 6–12 months, failure rates were 30.4% (7/23 hips) in Group 1 and 31.8% (7/22 hips) in Group 2, again without a significant difference between groups (p=1.000). Failure rates were markedly higher in patients older than 6 months in both groups (Table IV).

Table IV. Distribution of Failure by Age Group and in the Overall Cohort

	Group 1 (Without arthrography)	Group 2 (With arthrography)	p-value
▪ Total Hips	48	40	-
▪ Failure (n, %)	9 (18.8%)	8 (20%)	1.000[a]
▪ Failure rate ≤6 months	2/25 (8.0%)	1/18 (5.6%)	1.000[a]
▪ Failure rate 6–12 months	7/23 (30.4%)	7/22 (31.8%)	1.000[a]

[a] Fisher's exact test

All failed cases were managed according to standard stepwise treatment protocols. No cases of femoral nerve palsy or other major complications were observed.

Discussion and Conclusion

In the present study, the effect of intraoperative hip arthrography on clinical and radiological outcomes was evaluated in patients younger than one year with DDH treated with closed reduction and hip spica casting. The principal finding is that intraoperative arthrography enables direct assessment of reduction concentricity and allows modification of the treatment strategy within the same session when necessary, suggesting that it may play a meaningful role in the intraoperative decision-making process.

In our study, the absence of intergroup differences in AI at 24 months and LCEA at 5 years suggests that acetabular remodeling and mid-term femoral head coverage are driven primarily by the maintenance of a stable, concentric reduction and growth-related remodeling rather than by the intraoperative imaging modality itself. Studies on acetabular development after closed reduction have shown that AI improvement depends largely on sustained reduction with adequate femoral head coverage and that hips initially considered successful may later progress to residual dysplasia[1,25]. Studies evaluating center–edge angles at mid-term follow-up have similarly reported that successfully treated hips may approach near-normal coverage over time, whereas hips requiring secondary surgery tend to demonstrate less favorable early coverage characteristics[26,27]. Accordingly, arthrography should be interpreted less as a tool that directly improves AI or LCEA values and more as an intraoperative aid that identifies clearly nonconcentric reductions and supports timely escalation of treatment when needed.

Although the overall failure rates were similar between the groups (18.8% vs 20%), our findings indicate an important distinction in the timing and clinical implications of failure. In the arthrography group, failure primarily reflected intraoperative detection of nonconcentric reduction with immediate conversion to open reduction during the same session. In contrast, in the non-arthrography group, failure manifested later as redislocation or recurrence requiring secondary open reduction during follow-up. This difference suggests that the principal value of arthrography may lie not in reducing the overall failure rate, but in enabling early identification of inadequate reduction and guiding timely selection of the appropriate treatment, thereby reducing delayed secondary surgical intervention.

The critical determinant of success in CRSC is the achievement of a truly concentric and stable positioning of the femoral head within the acetabulum. Because fluoroscopy relies primarily on osseous contours, it may fail to accurately demonstrate intra-articular reduction quality. Arthrography allows intraoperative assessment of reduction concentricity and helps identify reductions that appear acceptable but are not truly concentric, enabling immediate conversion to open reduction and avoiding delayed failure. A recent review similarly emphasizes the role of arthrography in intraoperative decision-making[9].

Recent evidence suggests that certain arthrographic parameters may be associated with outcomes such as residual dysplasia or AVN. Tan et al. reported correlations between intraoperative arthrographic findings and radiographic outcomes, supporting the role of arthrography in guiding intraoperative decision-making, particularly in borderline cases[11].

On the other hand, the literature has demonstrated that, due to the so-called "docking" phenomenon, reductions that are not fully concentric initially may become more congruent over time. A study using serial MRI to evaluate the femoral head docking process showed that mild early incongruity does not necessarily indicate a poor prognosis[6]. This observation suggests that not every borderline finding on arthrography should be considered an automatic indication for open reduction. However, in the presence of clearly nonconcentric reduction, early definitive management may be more rational than awaiting a delayed recurrence. In our cohort, the main clinical contribution of arthrography was the intraoperative recognition of nonconcentric reductions and immediate conversion to open reduction, thereby preventing a clinical course that would otherwise require secondary intervention during follow-up.

The effect of age was evident in our findings, with failure rates increasing markedly in patients older than 6 months in both groups. A recent systematic review and meta-analysis on closed reduction failure reported that the risk of failure increases particularly with greater dislocation severity, with an overall failure rate of approximately 20%, consistent with our results[28]. Arthrography may be particularly valuable in more severe dislocations by improving the accuracy of intraoperative decision-making and potentially reducing the need for secondary surgical intervention.

The lack of a difference in AVN rates between groups suggests that AVN is more closely related to post-reduction biomechanical and vascular factors than to the use of intraoperative arthrography. Previous studies have identified patient age and the degree of hip abduction in the cast as important risk factors[29], along with variables such as dislocation severity and epiphyseal development[30]. Therefore, rather than directly reducing AVN risk, the role of arthrography appears to be providing decision support to ensure an adequate reduction and to guide appropriate treatment when necessary.

Strengths of this study include the homogeneous cohort of patients younger than one year, standardized treatment protocols, blinded radiographic assessment, and mid-term follow-up to age 5.

The limitations of this study include its retrospective design and lack of randomization, which may introduce selection bias; potential variability in surgical decision thresholds related to individual surgeon practice; and the possible clustering effect resulting from the analysis of bilateral hips as independent observations. Furthermore, because bilateral hips were analyzed as independent observations, no formal sensitivity analysis using clustered or mixed-effects modeling was performed; therefore, a residual intra-patient correlation effect cannot be entirely excluded. No post hoc power analysis was conducted, and the sample size may have limited the ability to detect small differences in failure or AVN rates.

Intraoperative hip arthrography allows objective assessment of reduction concentricity during closed reduction and hip spica casting and makes it possible to proceed to open reduction in the same session when nonconcentric reduction is identified. This approach may help prevent delayed recurrence and reduce the need for secondary surgical intervention. Its decision-making value may be greater in higher-risk patients, particularly those older than 6 months. Prospective multicenter studies with standardized indications are needed to confirm these findings.

Researcher Contribution Statement:
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