

Avascular Necrosis of Femoral Head Following Closed Reduction in Cases of Developmental Dysplasia of the Hip Among Infants

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ABSTRACT

Background: Avascular necrosis (AVN) of the femoral head is a serious complication following treatment for developmental dysplasia of the hip (DDH) in infants. Although several risk factors have been proposed, there remains uncertainty regarding the role of patient age, sex, hip side, and treatment technique in AVN development. This study aimed to determine the incidence and associated risk factors for AVN in infants undergoing closed reduction for DDH. **Methods:** A retrospective descriptive study was conducted on 124 infants (5–12 months old) treated for DDH at two specialized centers in Duhok City, Iraq, between January 2019 and December 2023. Patients underwent closed reduction with or without adductor tenotomy and with or without pre-reduction traction. All were followed clinically and radiographically for at least two years. AVN diagnosis was based on Salter criteria and graded using the Bucholz–Ogden and Kalamchi–MacEwen classifications. Categorical variables were compared using the Chi-square test, with $p < 0.05$ considered statistically significant. **Results:** The overall incidence of AVN was 18.5%. AVN rates did not differ significantly between the 5–8 month group (18.3%) and the 9–12 month group (18.8%, $p = 0.06$), nor by sex or side of involvement. Adductor tenotomy was associated with a significantly lower incidence of AVN (11.2% vs. 46.1% without tenotomy, $p = 0.001$). Pre-reduction traction also reduced AVN risk (9.1% vs. 41.6% without traction, $p = 0.001$). **Conclusion:** In this cohort, age, sex, and side were not significant predictors of AVN after closed reduction for DDH. The use of adductor tenotomy and pre-reduction traction markedly reduced AVN incidence, highlighting the importance of soft-tissue management and gentle, tension-free reduction techniques.

Keywords: Developmental Dysplasia of The Hip, Avascular Necrosis, Closed Reduction, Tenotomy, Traction, Infants.

Article Information

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INTRODUCTION

Developmental dysplasia of the hip (DDH) is a prevalent pediatric orthopedic condition, affecting approximately 1 to 3 per 1,000 live births globally, with considerable variation across populations (1,2). It is characterized by abnormal development of the hip joint, specifically involving the femoral head and acetabulum (3). DDH ranges from mild acetabular dysplasia to frank dislocation and predisposes to early hip osteoarthritis if not addressed promptly (4). The standard of care for infants aged 5–12 months with DDH is closed reduction followed by spica casting (5). While effective, this intervention carries a substantial

risk of avascular necrosis (AVN) of the femoral head, a serious complication that impairs hip growth, causes deformity, and may necessitate future reconstructive surgery (6). Reported rates of AVN after closed reduction vary widely, from approximately 4% to over 30%, depending on patient characteristics and treatment protocols (7).

Despite advances, the predictors of AVN post-reduction remain ambiguous (8). Recent evidence has highlighted several influential factors, especially surgical technique and preoperative management (9). For instance, Yong et al. (2023) found that pre-reduction traction reduced the odds of postoperative AVN

by nearly two-thirds, while higher severity of DDH, based on classification systems like IHDI or Tönnis, increased risk (10). Similarly, Tang et al. (2024) reported an AVN incidence of 9.8%, 25.3%, and 38.2% for IHDI grades II, III, and IV respectively, underscoring the impact of dislocation severity (11).

Moreover, Pang et al. (2024) revealed that ossific nucleus volume measured by MRI does not significantly predict AVN; instead, severe DDH (IHDI grades 3 and 4) increases risk nearly sevenfold (12). Early postoperative MRI with contrast appears promising for predicting AVN. Cheon et al. (2021) identified globally reduced femoral head enhancement as a strong predictor (13). However, such imaging modalities are often not accessible in resource-limited settings, reinforcing the relevance of surgical prevention strategies.

Among these, adductor tenotomy, performed when hip abduction is limited—facilitates a tension-free reduction and may preserve femoral head vascularity (14). In parallel, pre-reduction skin traction may gradually relax soft tissues and protect the femoral blood supply (15). Yet, high-quality evidence is still emerging. Some studies note reduced AVN rates when tenotomy and traction are used, but these associations have not been universally validated.

This study retrospectively analyzes 124 infants diagnosed with DDH who underwent closed reduction, with or without adductor tenotomy and/or traction, at two orthopedic centers. The aim of this study is to quantify the incidence of AVN and assess the impact of soft-tissue management strategies, specifically tenotomy and traction, on the risk of AVN in light of existing evidence. This approach attempts to clarify actionable factors that facilitate safer management of DDH and enhance long-term outcomes.

METHODS

Study Design

This was a retrospective descriptive study designed to evaluate the incidence and potential

risk factors for avascular necrosis (AVN) of the femoral head following closed reduction in infants diagnosed with developmental dysplasia of the hip (DDH). The research was conducted across two major pediatric orthopedic facilities: the Early Detection of Childhood Disability Center and the Emergency Training Hospital in Duhok City, Kurdistan Region, Iraq.

Study Period and Follow-up

The study covered all eligible patients treated between January 1, 2019, and December 31, 2023. Each patient was monitored for a minimum follow-up duration of two years to ensure sufficient time for the development and detection of AVN and to evaluate long-term treatment outcomes.

Participants

The study included 124 infants between five and twelve months of age at the time of reduction. All patients had DDH confirmed through both clinical evaluation and radiographic imaging. Only cases managed with closed reduction, with or without adductor tenotomy and with or without pre-reduction traction, were included.

Inclusion and Exclusion Criteria

Inclusion criteria consisted of infants aged 5–12 months, a confirmed diagnosis of DDH, treatment performed via closed reduction techniques, and complete clinical and radiological follow-up for at least two years. Exclusion criteria were previous surgical intervention for DDH, teratologic dislocations, neuromuscular disorders, or incomplete documentation and follow-up records.

Treatment Protocol

Closed reduction was performed under general anesthesia using standardized operative techniques in both centers. When intraoperative findings showed restricted hip abduction or excessive tension on the femoral head, an adductor longus tenotomy was performed to allow a tension-free and stable reduction. If a stable reduction was possible without significant force, tenotomy was omitted. In selected cases, pre-reduction skin traction was

applied for two to three weeks before surgery to relax periarticular soft tissues, reduce muscle contracture, and facilitate a gentle reduction.

Data Collection

Information was extracted from institutional records, including age group at reduction (5–8 months or 9–12 months), sex, side of involvement, use of pre-reduction traction, performance of adductor tenotomy, and occurrence of AVN.

Outcome Measures

AVN was diagnosed radiographically according to the Salter criteria, focusing on changes in the ossific nucleus and growth disturbances. The severity of AVN at final follow-up was graded using the Bucholz–Ogden and Kalamchi–MacEwen classifications. Radiographic evaluations were performed pre-treatment, periodically during follow-up, and at the two-year assessment.

Ethical Considerations

Ethical clearance for this study was obtained from the Kurdistan Regional Government, Iraq, Ministry of Health/Duhok Directorate General of Health/Directorate of Planning Scientific Research Ethics Committee (Protocol No: XYZ/2020). Written informed consent was secured from the parents or legal guardians of all participants before data collection and analysis.

Statistical Analysis

Data were analyzed using SPSS version 14 (IBM Corp., Armonk, NY, USA). Categorical variables were compared with the Chi-square test, and statistical significance was set at a p-value of less than 0.05.

RESULTS

Incidence of Avascular Necrosis by Age Group

Across the total study sample of 124 hips treated with closed reduction, the incidence of avascular necrosis (AVN) was just under one in five cases. Stratification by age at the time of reduction showed that both infants aged 5–8

months and those aged 9–12 months experienced a similar proportion of AVN cases. Although the incidence in the older group was slightly higher, statistical testing revealed no significant difference between the two age categories ($p = 0.06$). The detailed distribution of cases by age group and AVN status is presented in Table 1, which confirms the numerical similarity between these two patient subgroups.

Gender and AVN Occurrence

Within the study population, developmental dysplasia of the hip was considerably more prevalent among female patients, consistent with the well-documented female predominance of this condition. However, when examining the occurrence of avascular necrosis after closed reduction, male patients demonstrated a noticeably higher proportion of AVN cases compared to females. Despite this numerical difference, statistical analysis indicated no significant association between patient sex and the likelihood of developing AVN ($p = 0.8$). A summary of these findings is presented in Table 2, which details the distribution of AVN occurrence by sex.

Side of Hip Involvement

Analysis of AVN occurrence based on the laterality of the affected hip revealed no meaningful difference between right- and left-sided cases. The proportion of hips developing AVN was comparable across both sides. The full distribution of AVN cases in relation to hip side is presented in Table 3, which confirms the absence of a statistically significant relationship between laterality and AVN risk.

Effects of Secondary Procedures on AVN Risk

Secondary procedures, specifically adductor tenotomy and pre-reduction traction, showed a significant impact on the incidence of avascular necrosis following closed reduction for DDH. Adductor tenotomy was associated with a markedly lower rate of AVN. Hips that underwent tenotomy demonstrated an AVN incidence of 11.2%, compared with 46.1% in

hips treated without tenotomy ($p = 0.001$). This supports the principle that soft-tissue release facilitates a tension-free reduction, reducing stress on the femoral head and better preserving its vascular supply. Similarly, pre-reduction traction significantly reduced the likelihood of AVN. Hips managed with traction had an AVN

rate of 9.1%, whereas those without traction showed a substantially higher rate of 41.6% ($p = 0.001$). Traction likely contributes to gradual soft-tissue relaxation and more atraumatic reduction, thereby decreasing the risk of vascular compromise (Table 4).

Table (1): Relationship between age at reduction and AVN risk (unit: hips).

Age group	With AVN No. (%)	Without AVN No. (%)	Total No. (% of cohort)	P value
5–8 months	11 (18.3%)	49 (81.7%)	60 (48.4%)	0.06
9–12 months	12 (18.8%)	52 (81.2%)	64 (51.6%)	
Total	23 (18.5%)	101 (81.5%)	124 (100.0%)	

Table (2): Relationship between gender and AVN risk (unit: hips).

Gender	With AVN No. (%)	Without AVN No. (%)	Total No. (% of cohort)	P value
Male	8 (30.7%)	18 (69.3%)	26 (20.9%)	0.8
Female	15 (15.3%)	83 (84.7%)	98 (79.1%)	
Total	23 (18.5%)	101 (81.5%)	124 (100.0%)	

Table (3): Relationship between side and AVN risk (unit: hips).

Side	With AVN No. (%)	Without AVN No. (%)	Total No. (% of cohort)	P value
Right	9 (14.3%)	54 (85.7%)	63 (50.8%)	0.08
Left	14 (23.0%)	47 (77.0%)	61 (49.2%)	
Total	23 (18.5%)	101 (81.5%)	124 (100.0%)	

Table (4): Effect of Secondary Procedures on AVN Risk.

Secondary Procedure Status	With AVN n (%)	Without AVN n (%)	Total n (%)
With secondary procedures (<i>tenotomy and/or traction</i>)	15 (12.4%)	106 (87.6%)	121 (97.6%)
Without secondary procedures (<i>neither tenotomy nor traction</i>)	8 (100%)	0 (0%)	8 (2.4%)
Total	23 (18.5%)	101 (81.5%)	124 (100%)

DISCUSSION

Developmental dysplasia of the hip is a common pediatric condition where the hip joint doesn't develop properly, potentially leading to dislocation or instability (16). While closed reduction is a primary treatment for late-detected DDH (17), it carries a significant risk of AVN, a condition where bone tissue dies due to lack of blood supply (18). This study was conducted to determine the incidence of AVN following closed reduction in infants aged 5 to 12 months and to identify factors that may affect its occurrence, specifically age, sex, laterality, severity of dislocation, and procedural adjuncts including adductor tenotomy and pre-reduction traction.

In our cohort of 124 hips, the overall incidence of AVN was 18.5%, which is consistent with the 10–30% range reported in recent studies (6,19). This figure shows that, despite advancements in technique, AVN continues to be a significant postoperative complication. The lack of a statistically significant correlation between age group, sex, or hip side and AVN risk aligns with the findings of Bian et al. (2022), who observed comparable non-significant associations in a substantial multicenter cohort (19). Our findings indicate that patient demographics alone are inadequate predictors of AVN risk and should not determine the timing of intervention during the first year of life.

In this study, we did not assess DDH severity using standardized grading systems such as the Tönnis or IHDI classifications; therefore, no conclusions can be made regarding the impact of dislocation severity on AVN within our cohort. Nevertheless, previous reports have suggested that more severe dislocations may increase the risk of vascular compromise during reduction (12). This variable may be valuable to include in future investigations.

Our data also indicate a significant protective effect of adductor tenotomy, demonstrated by a substantial decrease in AVN rates (11.2% vs. 46.1%; $p = 0.001$). This corresponds with the physiological rationale that soft-tissue release alleviates mechanical compression of the femoral head during reduction, a principle corroborated by previous meta-analyses and case series (10). Similarly, pre-reduction traction markedly decreased the risk of avascular necrosis (9.1% vs. 41.6%; $p = 0.001$), supporting recent prospective studies by Yong et al. (2023) (10) and Chen et al. (2024) (15), which highlighted traction's effectiveness in alleviating femoral head strain and promoting a more gradual reduction.

While we did not use postoperative MRI, study by Cheon et al. (2021) indicates that early vascular compromise may be identified through contrast-enhanced imaging, potentially facilitating timely intervention. Such imaging could improve AVN risk assessment even more if it is included in prospective protocols in the future (13).

LIMITATIONS

This study has several limitations. It was conducted at a single regional center, which may limit its applicability to other populations or surgical practices. We excluded contrast-enhanced MRI, which could have detected vascular disease early and changed treatment. Finally, while adequate for AVN detection, the follow-up period may not capture long-term sequelae like growth disturbance or early osteoarthritis.

CONCLUSION

Our findings indicate that 18.5% of infants aged 5–12 months have AVN after closed reduction for DDH, regardless of age, sex, or laterality. The severity of dislocation, lack of adductor tenotomy, and lack of pre-reduction traction increased AVN rates.

Ethical approval

This study was approved by the Ethics Committee of the University of Duhok and the Duhok Directorate General of Health (Approval Number: 13062022-7-17). As this was a retrospective study using archival material, informed consent was waived.

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