



Prognostic Value of Hip Arthrography After Closed Reduction for Developmental Dysplasia of the Hip

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Abstract

The purpose of intraoperative arthrography is to assist in the acceptance of closed reduction, although the prognostic significance of femoral-head coverage, the medial dye pool, labral morphology, and the qualitative reduction is still uncertain.

The search of PubMed/MEDLINE and PubMed Central was carried out from the beginning up to 13 September 2026. A study on idiopathic DDH which had been treated by closed reduction was included if an intraoperative arthrogram parameter was associated with failed reduction, residual acetabular dysplasia, osteonecrosis, or the need for secondary surgery. The definitions of the predictors and the outcomes were prepared separately. A meta-analysis was not carried out when fewer than three cohorts that were compatible reported the same predictor-outcome relationship.

The study included fourteen cohorts. Femoral-head coverage was the most reproducible longterm predictor: in one cohort consisting of 139 hips, a threshold of 30% was identified, below which 81.8% of the cases developed late acetabular dysplasia, and another cohort with 110 hips gave an adjusted relative-risk estimate of 0.956 for each one-percentage-point increase. A cohort of 187 hips found that poor arthrographic delineation was a strong predictor of initial failure (adjusted RR 10.995, 95% CI 3.333-36.265) and noted a higher rate of failure when the medial dye pool was 6 mm or more. In a cohort of 182 hips, labral infolding was associated with both age and the severity of dislocation, but did not independently predict dysplasia or the need for secondary surgery; in another cohort of 110 hips, labral inversion was linked to osteonecrosis. Since the definitions and effect measures were too heterogeneous, a valid pooling could not be carried out.

In conclusion, femoral-head coverage is the best arthrographic predictor of residual dysplasia, but a coverage of 30% should be seen as a warning sign rather than as a definite indication for open reduction; poor visualization together with a large medial dye pool may indicate that the reduction is mechanically inadequate, and inversion of the labrum on its own has inconsistent independent prognostic value.

Keywords: Developmental dysplasia of the hip; Arthrography; Closed reduction; Femoral-head coverage; Medial dye pool; Residual acetabular dysplasia

1. Introduction

As soon as the hip has been manipulated the decision to be made is if the reduction is good enough and stable to allow it to be accepted and immobilized. Arthrography shows the cartilaginous femoral head, the shape of the acetabulum, the medial contrast pool, and the soft-tissue obstacles which cannot be seen on plain radiographs. However, the visual assessments and the numerical thresholds differ from one surgeon to another and from one institution to another.

Residual acetabular dysplasia, redislocation, and osteonecrosis are separate modes of failure. A criterion which can indicate inadequate containment might be used to predict dysplasia or early

Arthrogram predictors after closed reduction for DDH

mechanical failure without itself predicting vascular injury. It therefore follows that combining these endpoints can mask the clinical significance of each arthrographic parameter.

The systematic review looked at femoral-head coverage (FHC) as derived from an arthrogram, the medial dye-pool distance or ratio (MDP), labral or limbal inversion, and qualitative reduction. Its main aim was to find out which of these measurements predict residual acetabular dysplasia (RAD), while the secondary objectives were to examine failed reduction, osteonecrosis, and the need for secondary reconstructive surgery.

Methods

Design and reporting

The study carried out a systematic review combined with a structured prognostic synthesis in accordance with the PRISMA 2020 principles. The predictor-outcome pairs had been previously specified and were analysed separately. Attention was given to estimates that had been adjusted for both age and the severity of dislocation, as well as to distinguishing between initial failure and subsequent RAD and osteonecrosis.

Search strategy

The searches for PubMed/MEDLINE and PubMed Central were carried out from the beginning up to 13 September 2026. The search terms included developmental dysplasia or dislocation of the hip, arthrogram or arthrography, closed reduction, and femoral-head coverage, medial dye pool, labrum, limbus, reduction quality, prognosis, failure, dysplasia, or osteonecrosis. The reference lists of the eligible studies as well as those of recent technical reviews were examined.

Eligibility and outcomes

Children were included in prospective and retrospective cohort studies when they had an arthrogram-guided closed reduction for idiopathic DDH and at least one arthrographic measurement was associated with the initial failure, redislocation, RAD, osteonecrosis, or the need for later reconstructive surgery. Those studies which focused only on technique, anatomy, open reduction, or diagnostic correlation without including clinical outcomes were excluded from the prognostic synthesis.

Extraction and appraisal

The data contained information on age, the severity of DDH, the number of patients and hips, the length of follow-up, how the predictor was defined, the measurement reliability, the definition of the outcome, the effect estimates, and the adjustment variables. Judgments regarding the risk of bias were based on the QUIPS domains, with special attention given to cohort overlap, bilateral hip clustering, the derivation of thresholds, blinding, and confounding by age and IHDI or Tonnis grade.

Statistical approach

The effects associated with continuous FHC values were to be combined on a 10 percentage point basis and those related to MDP on a per millimeter basis. Binary thresholds could only be pooled if their definitions and endpoints were the same across at least three separate cohorts. Since this criterion was not satisfied, the results are given as structured syntheses specific to each predictor.

Arthrogram predictors after closed reduction for DDH

Results

Study selection and characteristics

The search electronically retrieved 76 records, with 18 of the reports being subject to a thorough eligibility assessment and 14 cohorts being included. The publication years spanned the period from 1978 to 2023, the sample sizes varied between 40 and 234 hips, and the follow-up period extended from the casting phase to skeletal maturity. In the older studies the term congenital dislocation was used together with qualitative limbus classifications; in the more recent studies measurement of FHC or the use of normalised MDP was more common.

Table 1. Principal Arthrogram Predictor Evidence

Study	Sample (n)	Arthrogram Predictor/ Variable	Outcome Assessed	Key Findings
Zhang et al. (2016)	139	FHC; arthrogram type	RAD	FHC: 51.2% recovered vs. 28.5% with RAD; $\leq 30\%$ predicted RAD in 81.8%; FHC was the sole adjusted predictor.
Zhao et al. (2023)	110	FHC, MDP, labral inversion, reduction type	RAD; AVN	FHC RR 0.956 per 1% (95% CI: 0.921–0.992); labral inversion was associated with AVN.
Zhang et al. (2020)	187	Delineation; MDP	Initial CR failure	Poor delineation adjusted RR: 10.995; MDP ≥ 6 mm was associated with failure.
Sankar et al. (2014)	23	Normalized MDP	MRI-confirmed concentric reduction	MDP ranged from 0.6% to 15.8% of head width in successful reductions; $\leq 16\%$ was proposed.
Talathi et al. (2022)	182	Infolded limbus	AI; surgery; AVN	Not independently associated with dysplasia, surgery, or AVN after accounting for severity.
Forlin et al. (1992)	72	Medialization ratio; limbus type	Overall result; AVN	Greater medialization was associated with good/fair outcomes; selected limbus shapes were associated with AVN.
Race and Herring (1983)	59	Qualitative reduction; joint widening	Outcome; AVN	Poor/indeterminate reduction: acceptable outcome in 5/23 cases and AVN in 57%.
Kaneko et al. (1999)	133	Soft-tissue interposition	Maturity outcome; surgery	Not directly related to final outcome or AVN; >3.5 mm predicted more secondary surgery.
Gulman et al. (2005)	85	Lateralization; inverted limbus	AVN	Lateralization >4 mm and inverted limbus were associated with AVN.
Leveuf-era comparative study (1978)	40	Inverted vs. nonobstructive limbus	AVN; surgery	AVN occurred in 3/20 cases in each group; surgery was performed in 17/20 vs. 11/20 cases.

Abbreviations: FHC = femoral head coverage; RAD = residual acetabular dysplasia; MDP = medial dye pool; AVN = avascular necrosis; CR = concentric reduction; AI = acetabular index; RR = relative risk; CI = confidence interval.

Femoral-head coverage and residual dysplasia

FHC was the most consistent of all the quantitative prognostic factors. In a group of 139 hips that were followed up for an average of 36 months, FHC varied by more than 20 percentage points between the group that recovered and the group that had dysplasia. A receiver-operating characteristic analysis established 30% as the threshold specific to the study, and 81.8% of the hips that had a value below this threshold went on to develop late dysplasia. In the later cohort of 110 hips, the mean FHC was 44.0% in the hips that recovered and 37.8% in those with RAD; the adjusted estimate was 0.956 for each 1-percentage-point increase, which is equivalent to about 0.64 for each 10-point increase if the log-linear model is valid.

Arthrogram predictors after closed reduction for DDH

The fact that the results are consistent suggests that FHC can be regarded as a useful marker of risk

but does not mean that it should be used as a standalone treatment requirement. The different definitions of RAD and the follow-up periods among the cohorts, together with the fact that the 30% cutoff was both derived and tested in the same sample, indicate a lack of external validation.

Medial dye pool and early failure

MDP included a greater variety of definitions. A study involving 23 hips showed that an arthrographic pool ranging from 0.6% to 15.8% of femoral-head width was compatible with MRI-confirmed concentric reduction, which led to the establishment of a normalised threshold at 16%. In a clinical group of 187 hips, failures were more frequently observed when the MDP was 6 mm or more. Older studies had stated that complications increased above 7 mm, but longer-term research found that soft-tissue interposition could be resolved and therefore should not automatically require open reduction.

Labrum, limbus, and qualitative reduction

In 20.3% of hips the largest group of dedicated limbus cases was found to have infolding, with a high level of agreement between observers. Infolding was associated with older age and with more severe IHD, and although it resulted in a minor difference in the acetabular index at two years, the severity of the condition still proved to be predictive after adjustments had been made and the differences had disappeared by four years. This finding is in favour of confounding rather than a direct independent effect.

There are other cohorts that contradict this view. A recent study has linked labral inversion with osteonecrosis, whereas earlier studies associated certain limbus shapes or lateralization with AVN. A matched comparison carried out in 1978 showed the same number of cases of AVN whether or not the limbus was inverted. Therefore, the evidence does not establish labral inversion on its own as a universal indication for open reduction.

The qualitative reduction still had clinical significance; a poor definition of the labrum and acetabular surface was a strong predictor of initial failure and, as has been reported by historical groups, poorer results followed poor or indeterminate reduction. These results probably reflect a combination of eccentricity, interposed tissue, and technical uncertainty rather than a single anatomical lesion.

Risk of bias and certainty

Most of the cohorts showed a moderate or high risk of bias due to retrospective selection, the use of data-derived cutoff points, incomplete adjustment, and inconsistent definitions of the outcome. Information regarding the reliability of the predictor measurements was rarely given, and the bilateral hips were usually treated as separate observations. The certainty of the findings was low when it came to FHC predicting RAD and was very low for specific MDP or labral thresholds.

Discussion

The main result shows there to be a hierarchy of usefulness: FHC provides the clearest evidence regarding long-term acetabular prognosis; poor arthrographic delineation and a large MDP are more closely associated with immediate mechanical adequacy; and labral inversion has an inconsistent independent prognostic value. Therefore, these factors should not be combined into a single general definition of a good arthrogram.

A hip joint concentration rate of 30% or lower indicates a high-risk situation, but the evidence does not show that each such case needs to undergo an open reduction. It is still necessary to take into account stability, the patient's age, the IHD grade, the ability to achieve a position within the safe zone, and to carry out cross-sectional imaging for confirmation. In a similar way, the MDP cutoff Arthrogram predictors after closed reduction for DDH

should be understood using the same units and in the same projection as those in which it was validated; millimetres and percentages of femoral-head width cannot be mixed together.

Clinical framework

Table 2. Suggested Interpretation of Intraoperative Arthrography

Arthrographic Finding	Suggested Interpretation	Clinical Implications
FHC >30% with concentric, stable reduction	Lower observed risk of RAD	Accept only if stability and safe positioning are satisfactory; continue radiographic surveillance.
FHC ≤30%	Potentially higher risk of RAD; threshold not externally validated	Reassess projection, obstacles, stability, age, and feasibility of improving reduction.

MDP $\geq$ 6 mm or 16% of head width	Possible eccentric or incomplete reduction	Confirm units and imaging view; reassess using dynamic arthrography or cross-sectional imaging.
Poor delineation of the labrum or acetabular surface	Higher risk of immediate CR failure	Do not rely on apparent bony alignment alone; repeat assessment and address potential obstacles.
Infolded or inverted limbus alone	Often correlates with severity; independent effect is inconsistent	Avoid using this finding as an isolated indication for open reduction.

Abbreviations: FHC = femoral head coverage; RAD = residual acetabular dysplasia; MDP = medial dye pool; CR = concentric reduction.

Limitations

The evidence was observational and clinically varied. The search was focused on the PubMed-indexed literature and involved citation chaining, without carrying out independent searches in Embase or Scopus. In several of the historical studies modern DDH grading was missing and the effect measures were frequently not available. Variations in projection, magnification, contrast volume, and the choice of landmarks made it difficult to achieve harmonization. Because of these limitations a reliable meta-analysis or HSROC model could not be carried out.

Conclusion

FHC is the most promising indicator of residual acetabular dysplasia following closed reduction for DDH; a figure around 30% points to a high-risk group, whereas poor definition and a large medial dye pool might indicate immediate mechanical inadequacy. Labral inversion by itself is not a consistent independent predictor. The prospective multicenter validation should standardize the method of acquisition, normalize the measurements, take into account the bilateral hips, and provide information on calibration and discrimination for separate clinical endpoints.

Declarations

There is no conflict of interest to declare. No funding was obtained. Ethics approval was not needed since it was a review of already published data. The data available consists of all the information that is contained in the cited publications.

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- Arthrogram predictors after closed reduction for DDH
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