



# Post-operative radiograph assessment of children undergoing closed reduction and spica cast immobilization for developmental dysplasia of the hip: does experience matter?

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## Abstract

**Purpose** Closed reduction and spica cast immobilization are routinely used for young patients with developmental dysplasia of the hip with reducible hips. Our primary objective was to assess the interpretation quality of immediate post-operative pelvis radiographs after treatment.

**Methods** A series of 28 randomly selected patients (30 hips) with pre- and post-operative pelvis radiographs and post-operative magnetic resonance imaging were included. Each was presented twice with an interval of two weeks, in alternating orders. Raters with different experience and specialties from different institutions rated the quality of reduction (hip in or out) after treatment.

**Results** Thirteen surgeons and three radiologists evaluated 30 hips (28 patients). Agreement was not satisfactory ( $\kappa = 0.12$ ). Experienced clinicians demonstrated similar agreement to inexperienced raters ( $\kappa = 0.04$ ). Consistency at a two week interval was moderate ( $\kappa = 0.48$ , percent of agreement at 82%). The mean number of errors from the two ratings were  $8.6 \pm 2.5$  and  $8.9 \pm 2.7$ , respectively ( $P = 0.72$ ). There was no significant difference between surgeons with different levels of experience; radiologists did better than surgeons, but the difference was insignificant. Raters from different institutions had similar performance in poor judgment.

**Conclusions** Our results show poor concordance between observers and ratings. Post-operative radiographs are unreliable for assessing the quality of hip reduction. The level of experience, subspecialty, and geographical origin do not impact the radiographic assessment. Based on the present findings, we recommend performing post-operative magnetic resonance imaging rather than anteroposterior pelvis radiograph to assess the hip. Compared to standard radiographs, magnetic resonance imaging allows more reliable interpretation while decreasing radiation exposure.

**Keywords** DDH · Closed reduction · Radiographs · MRI · Reliability

## Introduction

Closed reduction (CR) and spica cast immobilization are routinely used in the treatment of patients aged six to 18 months with developmental dysplasia of the hip (DDH) with reducible hips [1]. Some authors have shown that post-operative magnetic resonance imaging (MRI) is helpful in detecting hips that remain dislocated after CR and spica cast immobilization [2–5]. Moreover, it has also been shown that MRI correlates well with arthrography performed immediately prior to CR [6–8]. Despite the fact that several studies have highlighted the validity of MRI, none have focused on the reliability of plain radiograph assessment after CR and spica cast immobilization, notwithstanding the fact that radiograph interpretation can

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extensively affect the diagnosis and treatment of patients with DDH [8]. Additionally, the quality of plain radiograph interpretation can also be influenced by external factors, such as experience and subspecialty training, as has been shown by several studies performed on different sets of radiographs taken for other diseases [9–11].

The primary objective of this study was to assess the interpretation quality of immediate post-operative anteroposterior (AP) pelvis radiographs of children undergoing CR and spica cast immobilization for DDH. We aimed to evaluate intra- and inter-observer reliability among raters of different levels of experience, specialties, and institutions. We hypothesized that compared to less experienced raters, more experienced raters would score better regardless of subspecialty training or background.

## Materials and methods

After securing IRB approval from our institution (n. 2017102307), a series of 28 randomly selected patients (30 hips) with pre- and post-operative AP pelvis radiographs and post-operative MRI were included.

The inclusion criteria were (a) age between six and 18 months; (b) diagnosis of unilateral or bilateral DDH confirmed by pre-operative AP pelvis radiographs; (c) treatment by hip arthrogram, CR and spica cast immobilization; (d) an exploitable set of pre- and post-operative AP pelvis radiographs; and (e) a post-operative MRI performed no later than 36 hours after index surgery.

Patients not meeting all inclusion criteria (a through e) and those with teratologic, syndromic, or neuromuscular hip dislocation were excluded.

## Rater selection and grouping

Participants included 16 raters with different levels of experience and subspecialties (13 paediatric orthopaedic surgeons and 3 radiologists) from 2 different institutions, one from Asia and one from Europe. Paediatric orthopaedic surgeons were grouped according to their experience, per the number of years in clinical practice, and the geographical origin of their institution, Asia or Europe.

Raters from Institution 1 (Asia) were divided into three groups of three raters each: group A (raters 1, 2, and 3) included raters with less than five years of experience, group B (raters 4, 5, and 6) included raters with five to ten years of experience, and group C (raters 7, 8, and 9) included raters with more than ten years of experience.

Three paediatric radiologists with more than five years of experience and a special interest in musculoskeletal disorders

from institution 1 (Asia) were included in group D (raters 10, 11, and 12).

Four paediatric orthopaedic surgeons with more than five years of experience from institution 2 (Europe) were included in group E (raters 13, 14, 15, and 16).

## Radiographic assessment

The 28 selected AP pelvis radiographs (30 dislocated hips) were assigned to raters in random order. Each rater assessed hips on post-operative AP pelvis radiographs twice at a two-week interval, with radiographs presented in a different random order at each presentation ( $n = 60$  evaluations).

Each post-operative AP pelvis radiograph was presented together with a vignette stating the patient's age, gender, and diagnosis (i.e., 12-month-old female with left DDH) and with the pre-operative AP pelvis radiograph.

Raters were asked to rate each hip on post-operative AP pelvis radiograph as *in* (reduced) or *out* (dislocated).

MRI was used as the standard reference for the final assessment of hip joint reduction (*in* or *out*). All raters were blinded to MRI results during the rating process. Data were collected and analyzed by two researchers not involved in the care or imaging analysis of any of the included patients.

## Statistical analysis

Statistical analysis was performed using Stata software (version 13, StataCorp LP, College Station, TX, US). The tests were two-sided, with the Type I error set at  $\alpha = 0.05$ . Characteristics were presented as the mean  $\pm$  standard deviation or median [interquartile range] for continuous data (assumption of normality assessed using the Shapiro-Wilk test) and as the number of patients and associated percentages for categorical parameters. Generalized linear mixed models (logistic) were carried out to compare percentage of errors made by raters according to the rating (first or second) and to the level of expertise, the specialty, and the geographic origin of raters. In these models, raters and patients are considered as random-effects in order to model between and within raters and patients variability. The kappa coefficient for correlated data and proportion accuracy (%) were calculated in order (1) to measure the inter observer reliability at the first rating and intra-observer reliability between first and second ratings, then (2) to compare results between observer's evaluation and MRI at the first rating. According to the usual recommendations [12, 13], the concordance was examined as follows:  $< 0.2$  (bad),  $0.2\text{--}0.4$  (low),  $0.4\text{--}0.6$  (moderate),  $0.6\text{--}0.8$  (good) and  $> 0.8$  (excellent). Considering MRI as the

standard reference, sensitivity and specificity were calculated and presented with 95% confidence intervals.

## Results

Twenty-eight patients with unilateral (26 patients; 7 right, 19 left) or bilateral (2 patients) DDH, for a total of 30 dislocated hips, met the inclusion criteria. There were four male and 24 female patients with a mean age of  $12 \pm$  four months (range, 6–18). According to Tönnis classification, hips were rated as type 1 in one case, type 2 in eight cases, type 3 in 16 cases, and type 4 in five cases (Table 1).

Based on post-operative MRI findings, a total of 6 hips (6/30; 20%) were identified as out (dislocated) after arthrogram, CR, and spica cast immobilization.

## Radiographic assessment

A total of 60 hips (30 for each rating) were reviewed twice by each of the 16 observers, for a total of 1920 ratings.

Overall, on average, raters misdiagnosed  $8.6 \pm 2.5$  hips (range, 6–13) and  $8.9 \pm 2.7$  hips (range, 5–14) in the first and the second rating, respectively. No significant difference was found between the first and the second rating or among all raters ( $P = 0.72$ ). Table 2 shows the number and percentage of errors made by raters according to the level of expertise, specialty, and geographic origin of raters (Table 2). The level of experience (< 5, 5–10, and > 10 years of experience) and subspecialty training (orthopedic surgery versus radiology) of raters did not influence their performance, expressed as the number of errors/number of total ratings.

**Table 1** Demographic and clinical characteristics of patients in this cohort

Patient number	Hip number	Age (months)	Gender	Side of dislocation	Tönnis grade	Result of post-operative MRI	
						Left side	Right side
1	1	15	Female	Left	III	IN	IN
2	2	10	Female	Left	IV	IN	IN
3	3	7	Female	Right	IV	IN	IN
4	4	13	Female	Right	II	IN	IN
5	5	16	Female	Left	III	IN	IN
6	6	7	Female	Left	II	IN	IN
7	7	16	Male	Right	IV	IN	OUT
8	8	10	Female	Left	III	IN	IN
9	9	16	Female	Left	III	OUT	–
	10			Right	III	–	IN
10	11	6	Female	Left	II	IN	IN
11	12	14	Female	Left	II	IN	IN
12	13	16	Female	Left	III	OUT	IN
13	14	8	Female	Left	II	IN	IN
14	15	6	Female	Left	III	IN	IN
15	16	11	Female	Left	III	IN	IN
16	17	7	Female	Left	I	IN	IN
17	18	15	Female	Left	III	OUT	IN
18	19	15	Female	Left	II	IN	IN
19	20	18	Female	Right	III	IN	IN
20	21	10	Female	Left	III	IN	IN
21	22	18	Female	Left	IV	IN	–
	23			Right	IV	–	IN
22	24	9	Male	Left	III	IN	IN
23	25	13	Female	Left	III	IN	IN
24	26	14	Male	Left	III	OUT	IN
25	27	6	Male	Right	III	IN	IN
26	28	17	Female	Right	II	IN	OUT
27	29	10	Female	Left	III	IN	IN
28	30	11	Female	Right	II	IN	IN

**Table 2** Number and percentage of errors made by raters according to the level of expertise, specialty and geographic origin of raters

	1st rating	2nd rating	<i>P</i> value 1st rating vs 2nd rating
<b>Institution A</b>			
<i>Level of experience/specialty</i>			
<i>Resident/orthop. surgery (group A)</i>			
Rater 1, <i>n</i> (%)	7 (23)	6 (20)	
Rater 2, <i>n</i> (%)	6 (20)	10 (33)	
Rater 3, <i>n</i> (%)	9 (30)	14 (47)	
All raters, (%) [95% CI]	24 [16; 35]	33 [24; 44]	0.19
<i>Staff &lt; 10 years of experience/orthop. surgery (group B)</i>			
Rater 4, <i>n</i> (%)	6 (20)	5 (17)	
Rater 5, <i>n</i> (%)	6 (20)	7 (23)	
Rater 6, <i>n</i> (%)	10 (33)	9 (30)	
All raters, (%) [95% CI]	24 [16; 35]	23 [15; 33]	0.86
<i>Staff &gt; 10 years of experience/orthop. surgery (group C)</i>			
Rater 7, <i>n</i> (%)	8 (27)	10 (33)	
Rater 8, <i>n</i> (%)	6 (20)	8 (27)	
Rater 9, <i>n</i> (%)	10 (33)	9 (30)	
All raters, (%) [95% CI]	27 [18; 37]	30 [21; 41]	0.62
<i>Staff &gt; 5 years of experience/radiology (group D)</i>			
Rater 10, <i>n</i> (%)	6 (20)	5 (17)	
Rater 11, <i>n</i> (%)	7 (23)	5 (17)	
Rater 12, <i>n</i> (%)	13 (43)	11 (37)	
All raters, (%) [95% CI]	29 [20; 39]	23 [15; 33]	0.39
<b>Institution B</b>			
<i>Staff &lt; 10 years of experience/orthop. surgery (group E)</i>			
Rater 13, <i>n</i> (%)	12 (40)	13 (43)	
Rater 14, <i>n</i> (%)	12 (40)	12 (40)	
All raters, (%) [95% CI]	40 [28; 53]	42 [29; 55]	0.85
<i>Staff &gt; 10 years of experience/orthop. surgery (group E)</i>			
Rater 15, <i>n</i> (%)	12 (40)	9 (30)	
Rater 16, <i>n</i> (%)	8 (27)	10 (33)	
All raters, (%) [95% CI]	33 [22; 47]	32 [20; 45]	0.85
<i>P</i> value institution A vs B	0.02	0.13	
<i>P</i> value experience < 10 vs > 10 years	0.83	0.84	
<i>P</i> value orthop. surgery vs radiology	0.97	0.15	

Table 3 shows inter- and intra-observer reliability of the post-operative X-ray in DDH patients in terms of agreement (%) and Cohen's kappa. Agreement among all readers equals  $\kappa = 0.12$  at first rating. Clinicians with less than ten years of experience demonstrated a similar level of agreement to raters with more than ten years of experience ( $\kappa = 0.04$ ). Consistency was moderate when raters assessed hip reduction at a two week interval ( $\kappa = 0.48$ , percent of agreement at 82%). Overall, the sensitivity and specificity of post-operative AP pelvis radiographs with MRI as the standard reference were 32% [CI 23%–43%] and 81% [CI 77%–85%], respectively.

## Discussion

This article aimed to assess the quality and reliability of the interpretation of post-operative AP pelvis radiographs of children treated by CR and spica cast immobilization for DDH. This study forced raters to evaluate each hip as reduced (hip in) or dislocated (hip out) in a homogeneous set of radiographs.

Our findings demonstrate that AP pelvis radiographs taken after closed reduction and spica cast immobilization are frequently misjudged, regardless of the level of experience, subspecialty training, and geographic origin of the rater. In particular, the mean overall misjudgment rate was 29.3% (range,

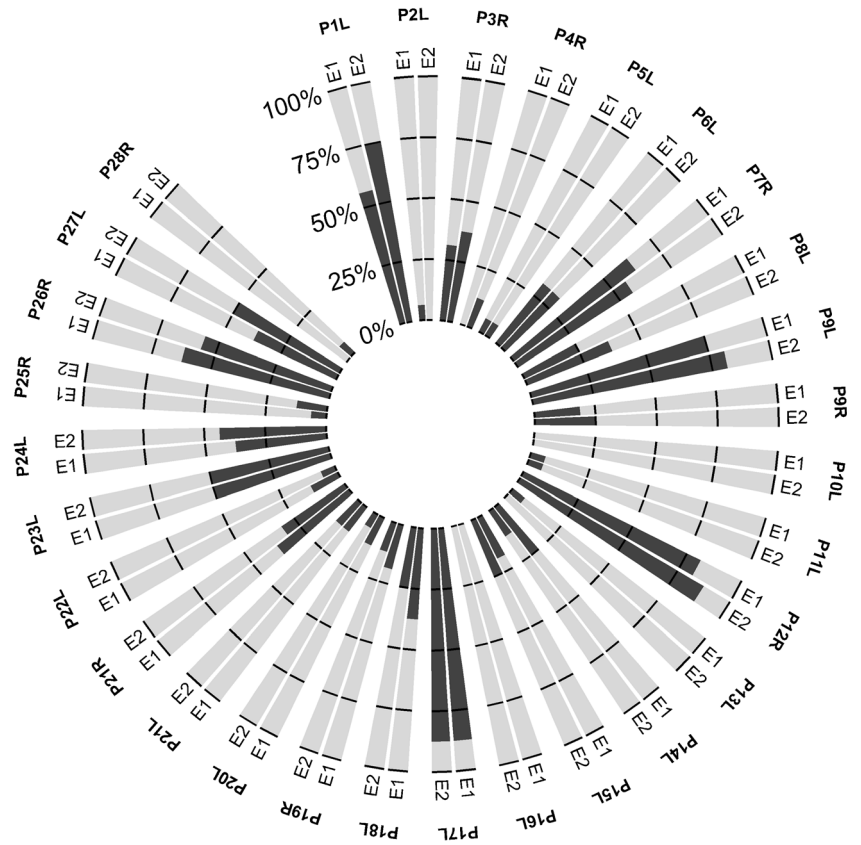
**Table 3** Inter- and intra-observer reliability of post-operative X-ray in DDH patients in terms of agreement (%), weighted Cohen’s kappa ( $\kappa$ ), sensitivity, specificity, and 95% coefficient interval (CI) according to MRI

	First rating				
	% of agreement/ kappa	Sensitivity (%)	Specificity (%)	Inter-observer reliability kappa	Intra-observer reliability % of agreement/kappa
All	71/0.13	32 [23; 43]	81 [77; 85]	0.12	82/0.48
Experience					
≤10 years of experience	71/0.08	27 [12; 46]	82 [74; 88]	0.04	84/0.47
≥10 years of experience	72/0.20	44 [30; 59]	79 [72; 84]	0.04	83/0.55
Specialty training					
Paediatric orthopaedic Surgeon	71/0.16	37 [27; 49]	80 [75; 84]	0.15	83/0.53
Radiologist	71/0.03	11 [1; 35]	86 [76; 93]	0.04	79/0.17
Institution					
Institution A	75/0.23	41 [28; 55]	83 [78; 88]	0.06	84/0.55
Institution B	63/0.00	29 [13; 51]	72 [62; 81]	0.09	80/0.49

16.7–46.7%). Additionally, the low sensitivity and moderate specificity of the post-operative radiographic assessment (with MRI as standard reference) pushed forward the idea that AP pelvis radiographs alone, taken after cast immobilization, are probably inadequate to consistently evaluate if the hip is well reduced or not. Thus, MRI must be used as the standard reference for hip reduction and is required to post-operatively assess patients undergoing CR for DDH (hip in or out).

Our data provide a basis to assert that hip radiographs that have produced previous discordant interpretations continue to produce discordance on secondary review, in all groups of raters. Some hips are likely at a higher risk of being wrongly rated. In particular, we found that among misjudged hips, 8 were consistently wrongly rated by at least eight out of the 16 raters (50%) on both ratings. Among these hips, five (62.5%) were rated as *in* (reduced) although they were posteriorly

**Fig. 1** Polar plot histogram showing the percentage of correct answers for all patients (P1 through P28), side (R or L), during the first (E1) and second evaluation (E2). Dark gray highlights percentage of incorrect answers (R software; CRAN R project; Vienna, Austria)



**Table 4** Hips consistently misjudged by more than 50% of raters

	Patient No. 1	Patient No. 7	Patient No. 9 (left side)	Patient No. 12	Patient No. 17	Patient No. 23	Patient No. 26	Patient No. 27
Errors (first rating)/16	9 (56%)	10 (63%)	12 (75%)	13 (81%)	14 (88%)	8 (50%)	10 (63%)	6 (38%)
errors (2nd rating)/16	12 (75%)	9 (56%)	13 (81%)	14 (88%)	14 (88%)	8 (50%)	9 (56%)	8 (50%)
Rater answer	Out	In	In	In	In	Out	In	Out
MRI results	In	Out	Out	Out	Out	In	Out	In

dislocated on MRI (out) (Fig. 1). The remaining three hips (37.5%) were interpreted as *out* (dislocated) although MRI proved them to be in (reduced) (Table 4) (Fig. 2). These findings lead to the conclusion that approximately one hip out of four is at risk of being wrongly rated, regardless of the experience, subspecialty training, and geographic origin of the raters (Tables 2 and 3) (Fig. 3).

Why is the error rate so high? One reason could be that AP pelvis radiographs provide only frontal plane images. Raters often missed posteriorly dislocated hips. It could be hypothesized that AP radiographs give raters the impression that the hip is reduced (hip in) in the frontal plane, although it is out in the coronal view. Moreover, if the hip is not perpendicular to the source of radiation, the projected image may lead the rater to a false interpretation. We feel that it is very difficult to place the hip perpendicularly to the source of radiation due to multiple factors, such as the amount of hip abduction and rotation, asymmetry of the spica cast, and positioning of the patient [14]. Hence, radiological signs of reduction, such as Shenton's line, medial pool distance, femoral head-acetabulum distance, and the axis of the femoral neck going to the triradiate cartilage may not be always reliable [15, 16]. In particular, in some patients, the axis of the femoral neck did not go through the triradiate cartilage centre in the radiograph: hips were rated as out although the MRI showed them to be in (reduced). Similarly, in other patients, Shenton's line was broken on AP pelvis radiographs, and the hip was rated as out although the MRI showed the hip to be in (reduced).

A second reason could be related to the amount of contrast used for the intra-operative arthrogram. It is possible that if contrast diffuses around the joint or if too much product is used, the radiographic assessment could be more challenging

and more prone to misjudgment. This seems to be particularly true when raters base their judgment on the femoral head-acetabulum distance, normally less than 4 mm [17, 18], and/or the “spur” sign, as described by Bowen [19]. Therefore, the quality of the arthrogram is important, and the amount of contrast should probably be standardized in order to avoid confounding post-operative radiographs.

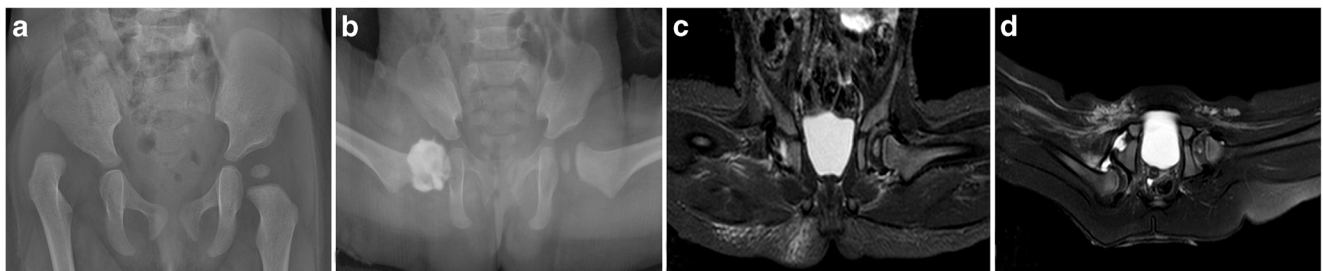
Moreover, if the cast is too thick and/or is not totally radio-transparent (i.e., plaster of Paris), it might create difficulties for raters to evaluate whether the hip is in or out. In this respect, 10 out of the 16 raters (62.5%) consistently misjudged a patient immobilized in plaster of Paris (patient 26; Table 1). It is well known that plaster of Paris can be well molded; however, synthetic material has the advantage of better transparency [20].

In summary, all of the above influence the quality of radiographs and their subsequent readability.

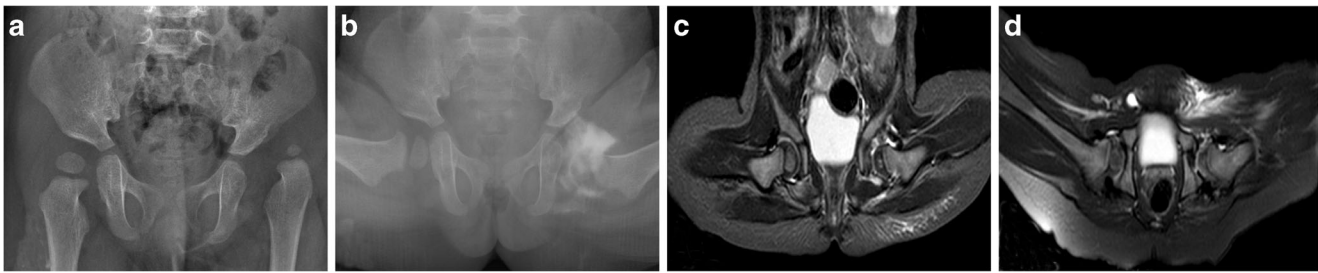
This study has some limitations. It is a preliminary study based on radiographs of patients presenting at a single institution. Moreover, the relatively low number of radiographs did not allow the inclusion of a balanced distribution of DDH configurations.

Despite these limitations, this is the first study documenting board-certified clinicians of different levels of expertise, subspecialties, and geographical origins having low agreement when assessing hip reduction on post-operative AP pelvis radiographs of children aged six to 18 months with DDH treated by CR and spica cast immobilization.

In conclusion, post-operative AP pelvis radiographs alone appear to be inadequate to assess if the hip is reduced (hip in) or dislocated (hip out). In contrast with our hypothesis, experience and subspecialty are not protective for avoiding errors.



**Fig. 2** Sixteen-month-old female with a right dislocated hip (a). Arthrogram image (b). Hip was rated as in (“reduced”) on the post-operative AP radiograph by most of the raters, although the post-operative MRI showed the hip being posteriorly dislocated (“out”) (c, d)



**Fig. 3** Fourteen-month-old female with a left dislocated hip (a). Arthrogram image (b). Hip was rated as out (“dislocated”) on the post-operative AP radiograph by most of the raters, although the post-operative MRI showed the hip being reduced (“in”) (c, d)

An MRI after closed reduction and immobilization is mandatory. Institutions without MRI equipment should be very cautious in treating such patients and should eventually refer them to tertiary medical centers with MRI.

Based on the present findings, we recommend performing post-operative MRI rather than AP pelvis to assess whether the hip is reduced or not. Compared to standard radiographs, MRI allows more reliable interpretation while decreasing radiation exposure.

### Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

**Informed consent** No patients were involved. This is a retrospective study of patient’s data, and an IRB approval was obtained (2017102307).

### References

- Malvitz TA, Weinstein SL (1994) Closed reduction for congenital dysplasia of the hip. Functional and radiographic results after an average of thirty years. *J Bone Joint Surg Am* 76(12):1777–1792
- Desai AA, Martus JE, Schoenecker J, Kan JH (2011) Spica MRI after closed reduction for developmental dysplasia of the hip. *Pediatr Radiol* 41(4):525–529. <https://doi.org/10.1007/s00247-010-1965-3>
- Dibello D, Odoni L, Pederiva F, Di Carlo V (2017) MRI in postreduction evaluation of developmental dysplasia of the hip: our experience. *J Pediatr Orthop* <https://doi.org/10.1097/BPO.0000000000001037>
- Ge Y, Cai H, Wang Z (2016) Quality of reduction and prognosis of developmental dysplasia of the hip: a retrospective study. *Hip Int* 26(4):355–359. <https://doi.org/10.5301/hipint.5000348>
- Starr V, Ha BY (2014) Imaging update on developmental dysplasia of the hip with the role of MRI. *AJR Am J Roentgenol* 203(6):1324–1335. <https://doi.org/10.2214/AJR.13.12449>
- Jaremko JL, Wang CC, Dulai S (2014) Reliability of indices measured on infant hip MRI at time of spica cast application for dysplasia. *Hip Int* 24(4):405–416. <https://doi.org/10.5301/hipint.5000143>
- Gans I, Sankar WN (2014) The medial dye pool revisited: correlation between arthrography and MRI in closed reductions for DDH. *J Pediatr Orthop* 34(8):787–790. <https://doi.org/10.1097/BPO.000000000000187>
- Aoki K, Mitani S, Asaumi K, Akazawa H, Inoue H (1999) Utility of MRI in detecting obstacles to reduction in developmental dysplasia of the hip: comparison with two-directional arthrography and correlation with intraoperative findings. *J Orthop Sci* 4(4):255–263
- Verma K, Sitoula P, Gabos P, Loveland K, Sanders J, Verma S, Shah SA (2014) Simplified skeletal maturity scoring system: learning curve and methods to improve reliability. *Spine (Phila Pa 1976)* 39(26):E1592–E1598. <https://doi.org/10.1097/BRS.0000000000000653>
- Zuckerman SL, Lakomkin N, Magarik JA, Vargas J, Stephens M, Akinpelu B, Spiotta AM, Ahmed A et al (2017) Evaluation of previously embolized intracranial aneurysms: inter- and intra-rater reliability among neurosurgeons and interventional neuroradiologists. *J Neurointerv Surg*. <https://doi.org/10.1136/neurintsurg-2017-013231>
- Reem J, Carney J, Stanley M, Cassidy J (2009) Risser sign inter-rater and intra-rater agreement: is the Risser sign reliable? *Skelet Radiol* 38(4):371–375. <https://doi.org/10.1007/s00256-008-0603-8>
- Fleiss JL, Cohen J (1973) The equivalence of weighted kappa and intraclass correlation coefficient as measures of reliability. *Educ Psychol Meas* 33:613–619
- Landis JR, Koch GG (1977) The measurement of observer agreement for categorical data. *Biometrics* 33(1):159–174
- Li Y, Guo Y, Li M, Zhou Q, Liu Y, Chen W, Li J, Canavese F, Xu H et al (2017) Acetabular index is the best predictor of late residual acetabular dysplasia after closed reduction in developmental dysplasia of the hip. *Int Orthop*. <https://doi.org/10.1007/s00264-017-3726-5>
- Herring JA (1982) Inadequate reduction of congenital dislocation of the hip. *J Bone Joint Surg Am* 64(1):153
- Race C, Herring JA (1983) Congenital dislocation of the hip: an evaluation of closed reduction. *J Pediatr Orthop* 3(2):166–172
- Dimeglio A, Canavese F (2011) Imaging in Legg-Calvé-Perthes disease. *Orthop Clin N Am* 42(3):297–302. <https://doi.org/10.1016/j.ocl.2011.04.003>
- Clohisy JC, Carlisle JC, Trousdale R, Kim YJ, Beaulé PE, Morgan P, Steger-May K, Schoenecker PL, Millis M (2009) Radiographic evaluation of the hip has limited reliability. *Clin Orthop Relat Res* 467(3):666–675. <https://doi.org/10.1007/s11999-008-0626-4>
- Forlin E, Choi IH, Guille JT, Bowen JR, Glutting J (1992) Prognostic factors in congenital dislocation of the hip treated with closed reduction. The importance of arthrographic evaluation. *J Bone Joint Surg Am* 74(8):1140–1152
- Bitar KM, Ferdhany ME, Ashraf EI, Saw A (2016) Physical and clinical evaluation of hip spica cast applied with three-slab technique using fibreglass material. *Malays Orthop J* 10(3):17–20. <https://doi.org/10.5704/MOJ.1611.008>