Timing For Closed Reduction of Developmental Dysplasia of the Hip and Failure Analysis

Zhiqiang Zhang
Children's Hospital of Fudan University

Hao Li
Shanghai Sixth Peoples Hospital

Hai Li
Shanghai Jiaotong University School of Medicine Xinhua Hospital

Ziming Zhang (zhangziming@xinhuamed.com.cn)
Shanghai Jiaotong University School of Medicine Xinhua Hospital

---

Research article

Keywords: Developmental dysplasia of the hip, Closed reduction, Avascular necrosis Re-dislocation, Residual acetabular dysplasia

Posted Date: June 23rd, 2020

DOI: https://doi.org/10.21203/rs.3.rs-37192/v1

Version of Record: A version of this preprint was published on September 14th, 2020. See the published version at https://doi.org/10.1186/s12891-020-03635-1.

Abstract

Background

It remains controversial whether the older age at closed reduction (CR) of developmental dysplasia of the hip (DDH), the higher incidence of complications.The aim of this study is to evaluate theMid-term outcome of CR for DDHamongdifference age groups, and to analyze and identify risk factors for the failure of this procedure.

Methods

Clinical data of DDH patients, who received CR, were retrospectively reviewed. Hips were divided into three groups according to initial age (Group I: <12 months; Group II: 12 months to ≤18 months; Group III: >18 months). The presence of avascular necrosis (AVN),residual acetabular dysplasia (RAD), re-dislocation, further surgeries (FS)and failure of CR were observed. The risk factors were identified for those outcomes abovementioned. Receiver operating characteristics (ROC) curve analysis based on age, pre-op AI and post-op AI for failure was conducted.

Results

A total of 107 patients (156 hips) undergoing CR wereevaluated with a median age at initial reduction of 13.0 months(range, 4 to 28 mo). The incidence of AVN, RADand re-dislocationwas 15.4% (24/156), 17.3% (27/156) and 14.7% (23/156). For AVN, RAD and re-dislocation, the risk factors were pre-op IHDI IV(p=0.033), age≥18 months (p=0.012), and pre-op IHDI IV and walking (p=0.004 and p=0.011), respectively. The areas under the ROC curve of failure were 0.841 (post-op AI), 0.688 (pre-op AI)and 0.650 (age).

Conclusions

RAD is a complication that must be carefully considered for severepatients older than 18 months before CR. Re-dislocation is associated with pre-op IHDI IV and walking.Patients, who are older than 12.5 months or have a pre-op AI of 38.7° or a post-op AI of 26.4°, are more likely fail of CR.

Background

Developmental dysplasia of the hip (DDH) is the most common developmental malformation affecting children’s hips. The principle of management for DDH has been widely adopted that a concentric reduction should be obtained and maintained through the intervention as early as possible [1, 2]. Closed reduction (CR) of the hip is indicated in patients who failed to achieve stable reduction with Pavlik harness, and or as the primary treatment option for patients with late diagnosis [3, 4]. Although this procedure has achieved satisfactory outcomes, CR may also lead to a number of adverse complications, including iatrogenic avascular necrosis (AVN), re-dislocation and residual acetabular dysplasia (RAD), which might need further surgeries (FS) to address. Since, several articles reported that increased age at

the time of CR predicted a higher rate of complications or further corrective surgeries [5–7], while others not [8, 9]. Moreover, it still remains controversial whether CR or open reduction (OR) should be adopted for children approaching or older than 18 months at the first time, especially for the severe dislocated cases. Balancing advantages and disadvantages of treatment options, and evaluating the risks of complications, will help in bringing to a better outcome. The aim of this present study was to evaluate the effect of CR among different age groups, to identify the risk factors of complications of CR and to discuss the indications for unsuccessful CR, especially in controversial age abovementioned.

Materials And Methods

After institution Ethics Committee approval (XHEC-D-2020-014), a retrospective review was performed in 107 patients with the diagnosis of DDH from January 2011 to December 2013 successfully undergoing CR and cast fixation. The inclusion criteria were: 1) At least 36 months follow-up time and complete medical records. 2) Diagnosed with unilateral or bilateral DDH with International Hip Dysplasia Institute (IHDI), III, IV grade, or Tönnis III, IV grade, without any treatment before. 3) Successful CR at initial attempt. Patients were excluded if their follow-up time less than 36 months, pathological or other secondary hip dislocation, dysplasia of the hip without hip dislocation or unsuccessful CR initially (post-operative MRI indicating dislocation of the hip, including 11 patients).

CR under fluoroscopic guidance was performed under general anesthesia in all cases. After the percutaneous adductor tenotomy, close reduction was performed according to a routine manipulation. Namely, the hip was reduced by placing it in flexion nearly 100 degrees and gradually abducting it on the position of stability (nearly 45 to 65 degree). Then a hip spica cast was fixed in a human position with a gentle posterior mold. MRI examination was carried out under sedation within 24 hours postoperatively. The spica cast maintained 3 months. Plain radiography of the pelvis was taken every month. After three-month immobilization, the cast was removed and changed to application of an adjustable abduction orthosis for 7 months. The orthosis contained four holes with cap nuts and adjusted timely according to our protocol of 1-2-2-2-month (Fig. 1).

The medical data of patients were collected. Anteroposterior x-ray films were obtained pre-and post-operatively till the final follow-up. Radiological data were evaluated and included the ossification centers of femoral heads, AI and Tönnis and IHDI grade; Complications included re-dislocation, RAD and AVN. Re-dislocation: hip dislocated on MRI during casting time or on X-ray when finished the CR. RAD: evaluated by AI (AI > 28° 1 year following CR or > 25° two to four years after CR [10]).The presence or absence of AVN based on the final follow-up was determined by Salter et al.[11], with a simple “yes” versus “no” to reduce subtype variability. FS of open reduction (OR) and osteotomy were warranted when RAD or re-dislocation exist. Failure was defined as either an open reduction at any time and/or AVN at the final follow-up. All measurements and evaluations were made by 2 observers (HL and ZQZ) who didn’t get involved in the clinical care without knowing the outcome of the treatments.

Continuous variable was analyzed by Kolmogorov-Smirnov test to assess for normality. Comparisons of 3 groups in terms of AI, time of splint immobilization and follow-up time were performed by using ANOVA. The chi-squared test was used to compare categorical variables (i.e. walking, ossific nucleus, Tönnis and IHDI grade, AVN rate, RAD rate, re-dislocation rate and FS rate). Furthermore, univariable logistic regression was performed to evaluate the relationships among the prereduction factors, including age groups, walking, ossific nucleus, preoperative AI, Tönnis and IHDI grades. We then calculated the sensitivity and specificity of parameters (age, pre-op AI and post-op AI) based on thresholds detected for the ROC curve. An alpha level of 0.05 was used in all tests. The analysis would be done by hip affected. A p value < 0.05 was considered significant. Statistical analysis was performed using SPSS 19.0 (IBM, America).

Results

Total 107 children (95 girls and 12 boys) with DDH had been successfully received CR followed by plaster and splint fixation. There were 58 unilateral DDH patients and 49 bilateral DDH patients who at least present with one side hip dislocation. Mean age at initial treatment was 13.0 months, ranging from 4 to 28 months. Mean follow-up time in this study was 6.7 years (range, 3–8 years). A visible ossific nucleus of the femoral head was present in 103 hips (66.0%). Mean pre- and postoperative AI were 37.9° (range, 26.2°-49.7°) and 27.1° (range, 14.6°-37.6°), respectively. Subsequently, FS were performed on 52 hips (33.3%), of which 23 (14.7%) hips due to re-dislocation, 27 (17.3%) hips of RAD, and 2 (0.01%) of AVN. The incidence of AVN of femoral head was 15.4% (24/156). Figure 2

CR of DDH at Different Age Groups

The influence of age at the beginning of treatment for DDH with CR is presented in Table 1. There was no significant difference in the general characteristic (including sex, side, femoral head, splint time and Tönnis grade) among 3 groups. Compared with Group I, the pre-op IHDI grade was significantly difference with other Groups, while the pre-op Tönnis grade was not. However, postoperatively, no significant difference was found between IHDI and Tönnis grade. As for pre-op AI, there was no statistically difference, preoperatively, while post-op AI was significantly higher in comparison with Group I. Among the observed complications, only RAD in Group III was significantly higher than the other Groups. Moreover, significant difference was found between Group III and other groups in FS rate.

Table 1
Demographic data with reference to age when DDH management of CR was initiated

	Group I	Group II	Group III
No. of hips (cases)	71(45)	50(37)	35(25)
Age at present[0](months)	7(1.8)	15(1.6)	19(2.1)
range	4–10	12–17	18–28
Sex (girls: boys)	39:6	33:4	23:2
Side (unilateral: bilateral)	19:26	24:13	15:10
Walking	0	33 [b]	35 [b]
Femoral head (yes: no)	20:51	48:2	35:0
Orthosis time[0] (mons)	6.6(2.1)	5.9(2.1)	6.8(1.9)
Pre-op Tonnis	8	1	2
I	3	7	2
II	34	13	9
III	26	29	22
IV			
Pre-op IHDI	2	0 [b]	1 [b]
I	11	10	2
II	48	19	16
III	10	21	16
IV			
Pre-op AI[0]	36.9(6.9)	38.1(4.5)	39.2(5.8)
Post-op AI[0]	25.5(5.0)	27.9(5.1) [b]	29.6(5.5) [b]

Group I (< 12 months), Group II (12 months to ≤ 18 months), Group III (> 18 months);

AI: Acetabular Index, RAD: Residual Acetabular Dysplasia, FS: Further Surgeries, IHDI: International Hip Dysplasia Institute, AVN: avascular necrosis

[0] values of mean (SD)

[a] : $p < 0.05$ compared with Group II.

[b] : $p < 0.05$ compared with Group I.

	Group I	Group II	Group III
Post-op Tonnis	47	35	25
I	11	5	6
II	7	10	1
III	6	0	3
IV			
Post-op IHDI	45	34	22
I	11	8	9
II	11	8	4
III	4	0	0
IV			
AVN (%)	10(14.1%)	9(18.0%)	5(14.3%)
Re-dislocation (%)	9(12.7%)	8(16.0%)	6(17.1%)
RAD (%)	6(8.5%)	7(14.0%)	14(40%) [ab]
FS (%)	15(21.1%)	15(30.0%)	22(62.9%) [ab]
Group I (< 12 months), Group II (12 months to ≤ 18 months), Group III (> 18 months);			
AI: Acetabular Index, RAD: Residual Acetabular Dysplasia, FS: Further Surgeries, IHDI: International Hip Dysplasia Institute, AVN: avascular necrosis			
[0] values of mean (SD)			
[a] : $p < 0.05$ compared with Group II.			
[b] : $p < 0.05$ compared with Group I.			

Univariable Logistic Regression of Prognostic Factors for Different Outcomes

Univariable logistic regressions were used to develop models predicting the potential Odds Ratio (OR) (Table 2). For AVN, pre-op IHDI IV was found to be significant risk factor (OR: 2.524; CI:1.076–5.919; p = 0.033). Furthermore, by stratified analysis, early CR did not reduce the risk of AVN. For RAD, age ≥ 18 months was found to be significant risk factor (OR: 4.000; CI:1.361–11.755; p = 0.012). For re-dislocation, pre-op IHDI IV and walking were found to be significant risk factors (OR: 4.211; CI:1.585–11.245; p = 0.004 and OR: 3.551; CI:1.339–9.412; p = 0.011). The risk factor of FS was pre-op IHDI III (OR: 27.506; CI: 3.234-233.919; p = 0.002).

Table 2

Odds Ratio Estimates for Risk Factors of Several Outcomes

Outcomes	Risk Factors	Odds Ratio	(95%CI*)	P
AVN	Pre-op IHDI IV	2.524	1.076–5.919	0.033
Redislocation	Walking	3.551	1.339–9.412	0.011
	Pre-op IHDI IV	4.211	1.585–11.245	0.004
RAD	age ≥ 18months	4.000	1.361–11.755	0.012
FS	Pre-op IHDI III	27.506	3.234-233.919	0.002

AI: Acetabular Index, RAD: Residual Acetabular Dysplasia, AVN: Avascular Necrosis, IHDI: International Hip Dysplasia Institute, FS: Further Surgeries *CI: confidence interval

ROC curve of Failure

To assess sensitivity and specificity, we conducted ROC curve based on age, pre-op AI and post-op AI for failure. The greatest area under the curve (AUC) was found for the post-op AI with a cutoff of 26.4° (AUC: 0.841; Sensitivity: 78.3%; Specificity: 74.0%; p = 0.00), followed by the pre-op AI with a cutoff of 38.7° (AUC: 0.688; Sensitivity: 63.9%; Specificity: 70.0%; p = 0.00) and the age at 12.5 months (AUC: 0.650; Sensitivity: 65.1%; Specificity: 60.3%; p = 0.01) (Fig. 3).

Discussion

The principle of the treatment for DDH is to establish a stable, concentric reduction of the hip to enable the subsequent hip development as early as possible, given the well-established correlation between residual dysplasia and the age of reduction. CR plays an essential role during the process of DDH treatment, especially the young children, with high success rate and low complications. It has drawn more attention, in recent years, with various studies and researchers focusing on the topic that how to make a proper intervention strategy for DDH patients who are approaching or older than 18 months old, treatment could be CR followed by plaster casting, or performing OR as soon as possible once the diagnosis was established, since several articles indicated that older age might indicate poor outcome [5–7]. It is still a controversial issue among pediatric orthopedists. This study enrolled 107 children (156 hips) with DDH in a single center from 2011 to 2013 in order to evaluate the effect of CR among different age groups, to identify the risk factors of complications of CR and to discuss the possible indicators for failure of CR, especially in controversial age abovementioned.

Compared with Group II and III, Group I showed significant difference about IHDI grade, but not Tönnis grade. Moreover, the ossific nucleus was not present in 34% hips. Comparing IHDI classification to Tönnis classification, Both Miao and Brandon et al [12, 13] concluded that IHDI classification can be applied

more flexibly which can better reflect the severity of the conditions, especially for those cases without ossific nucleus of the femoral head.

Postoperatively, for all the measurements, the difference between Group I and Group II□III were statistically significant among post-op AI, which revealed that the older the child, the lower the potential for the normalization of AI. The decrease of AI indicated a sign of gradual normalization of acetabular morphological structures under the condition of concentric reduction of the affected hip. Shin et al [14] considered that an AI > 32° and CEA < 14° at the age of three years could serve as a guideline for osteotomy. Correspondingly, our results showed that if the post-op AI > 26.4°, CR was more likely to fail (84.1%). Pre-op AI also manifested with an obvious tendency to be fail if the value larger than 38.7° (68.8%). The ROC curve also showed that the predictor of failure DDH treated by CR was the initially age > 12.5 months (65%).

Several articles reported older age at the time of CR showing a higher rate of complications or further corrective surgeries [5–7], while others not[8, 9, 15]. RAD in group III was found to be significantly high, compared with Group I and II. Moreover, the result of univariable logistic regression manifested that age ≥ 18months was the only risk factor for the happening of RAD (OR: 4.000; p = 0.012). That is to say the prevalence of RAD increases with the age of hip reduction. Other researches have indicated that in the case of lateral hip subluxation, the pressure on the femoral head becomes concentrated along the medial aspect of the head as the hip hinges along the edge of the acetabulum. The acetabular growth cartilage fills the acetabular floor and arrests its lateral growth, forming a progressively shallower and more oblique acetabulum [16, 17]. Therefore, we thought that, for the dislocation patients, RAD was a complication that must be carefully considered for children older than 18 months, which might require FS to correct.

Although there was no influence of age at initiation of outcomes on AVN and re-dislocation in our study, some researches granted age as risk factor of AVN[11, 18, 19]. Similar to our results, age was not found to be the risk factor of AVN after CR also reported in other literatures [9, 15, 20]. The rate of AVN (18.6%) in this present study was similar to previously reported studies (10%-33%)[7] [21–24]. The most common cause is the immobilization in a position that places excessive pressure on the femoral head. Thus, Ramsey et al. [25] recommended creating a “safe zone” to prevent AVN. In certain situation, an adductor tenotomy will increase the safe zone by allowing for a wider range of abduction, especially for patients with high Tönnis grade. Madhu et al [26] collected nine articles and analyzed the data, found out the most critical element of AVN was extreme abduction angle, and the ossification of the femoral head was not associated with AVN, which was similar to this our result and other studies [7, 27]. AVN was not associated with age or other factors (sex, side, ossific nucleus etc.) in our cohort, but the IHDI IV was found to be the risk factor for AVN and re-dislocation resulting from univariable logistic regression (OR: 2.524, p = 0.033; OR: 4.211, p = 0.004). For severe patients, CR was difficult to perform when extreme abduction was warranted to stable reduction, which AVN might occur. The incidence of re-dislocation after CR was 23.1% in this study, which was similar to Sankar’s study [7]. Except from IHDI IV, the walking experience was also a risk factor about re-dislocation (OR: 2.524, p = 0.033). As the time went on,

especially after independent walking, a series of pathological changes of the affected hip would make CR more difficult, which, certainly, lowered the efficiency of CR [28, 29]. This is consistent with results in our present study, namely, walking ability should be an important evaluation at the time of treatment.

This study has a number of limitations. First, a longer follow-up until adult is necessary, which may lead to different results of AVN and FS rate. Second, all the included cases had successful CRs at the initial attempt, which might bring to a selection bias. Third, the study was retrospective and more randomized controlled trials or large-scale case-control studies are required for further validation.

Conclusion

In summary, treatment initiated > 18 months of age produced higher rate of RAD and FS. Re-dislocation is associated with pre-op IHDI IV and walking. Pre-op IHDI IV was also found to be the risk factor of AVN. The threshold age, pre-op AI and post-op AI values associated with an increased risk of failure are older than 12.5 months and lager than 38.7° and 26.4° and more, respectively. The parents of such children should be informed about the high risk of treatment failure and further surgeries.

Abbreviations

DDH
Developmental dysplasia of the hip
CR
closed reduction
OR
open reduction
AVN
avascular necrosis
IHDI
International Hip Dysplasia Institute
AI
acetabular index
RAD
Residual acetabular dysplasia
FS
further surgeries
AUC
area under the curve

Declarations

Ethics approval and consent to participate

This study was approved by the Research Ethics Committee of the Xinhua Hospital Affiliated to Shanghai Jiaotong University School of Medicine (XHEC-D-2020-014). Since the participants was children (< 14 years old), written informed consent from their parents to participate in the study had been obtained, and procedures were conducted according to the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Funding:

The project is sponsored by Natural Science Foundation of Shanghai. NO. 17411965800, in the design of the study, the collection, analysis, and interpretation of data and in writing the manuscript.

Author’s contributions

Study design and drafting manuscript: ZQZ, data collection and analysis: ZQZ,HL1, Revising manuscript content: HL2. Approving final version of manuscript: ZMZ

Acknowledgement

Not applicable.

References

1. Forlin E, Choi IH, Guille JT, Bowen JR, Glutting J. Prognostic factors in congenital dislocation of the hip treated with closed reduction. The importance of arthrographic evaluation. J Bone Joint Surg Am. 1992;74(8):1140–52.
2. Noritake K, Yoshihashi Y, Hattori T, Miura T. Acetabular development after closed reduction of congenital dislocation of the hip. J Bone Joint Surg Br. 1993;75(5):737–43.
3. Kotlarsky P, Haber R, Bialik V, Eidelman M. Developmental dysplasia of the hip: What has changed in the last 20 years? World J Orthop. 2015;6(11):886–901.
4. Vitale MG, Skaggs DL. Developmental dysplasia of the hip from six months to four years of age. J Am Acad Orthop Surg. 2001;9(6):401–11.

5. Schur MD, Lee C, Arkader A, Catalano A, Choi PD. Risk factors for avascular necrosis after closed reduction for developmental dysplasia of the hip. J Child Orthop. 2016;10(3):185–92.
6. Luhmann SJ, Bassett GS, Gordon JE, Schootman M, Schoenecker PL. Reduction of a dislocation of the hip due to developmental dysplasia. Implications for the need for future surgery. J Bone Joint Surg Am. 2003;85(2):239–43.
7. Sankar WN, Gornitzky AL, Clarke NMP, Herrera-Soto JA, Kelley SP, Matheney T, Mulpuri K, Schaeffer EK, Upasani VV, Williams N, et al. Closed Reduction for Developmental Dysplasia of the Hip: Early-term Results From a Prospective, Multicenter Cohort. J Pediatr Orthop. 2019;39(3):111–8.
8. Li Y, Xu H, Li J, Yu L, Liu Y, Southern E, Liu H. Early predictors of acetabular growth after closed reduction in late detected developmental dysplasia of the hip. J Pediatr Orthop B. 2015;24(1):35–9.
9. Novais EN, Hill MK, Carry PM, Heyn PC. Is Age or Surgical Approach Associated With Osteonecrosis in Patients With Developmental Dysplasia of the Hip? A Meta-analysis. Clin Orthop Relat Res. 2016;474(5):1166–77.
10. Li Y, Guo Y, Li M, Zhou Q, Liu Y, Chen W, Li J, Canavese F, Xu H. Multi-center Pediatric Orthopedic Study Group of C: **Acetabular index is the best predictor of late residual acetabular dysplasia after closed reduction in developmental dysplasia of the hip**. Int Orthop. 2018;42(3):631–40.
11. Salter RB, Kostuik J, Dallas S. Avascular necrosis of the femoral head as a complication of treatment for congenital dislocation of the hip in young children: a clinical and experimental investigation. Can J Surg. 1969;12(1):44–61.
12. Miao M, Cai H, Hu L, Wang Z. Retrospective observational study comparing the international hip dysplasia institute classification with the Tonnis classification of developmental dysplasia of the hip. Medicine. 2017;96(3):e5902–2.
13. Ramo BA, De La Rocha A, Sucato DJ, Jo C-H. A New Radiographic Classification System for Developmental Hip Dysplasia is Reliable and Predictive of Successful Closed Reduction and Late Pelvic Osteotomy. J Pediatr Orthop. 2018;38(1):16–21.
14. Shin CH, Yoo WJ, Park MS, Kim JH, Choi IH, Cho T-J. Acetabular Remodeling and Role of Osteotomy After Closed Reduction of Developmental Dysplasia of the Hip. J Bone Joint Surg Am. 2016;98(11):952–7.
15. Li Y, Lin X, Liu Y, Li J, Liu Y, Pereira B, Canavese F, Xu H. **Effect of age on radiographic outcomes of patients aged 6–24 months with developmental dysplasia of the hip treated by closed reduction**. *J Pediatr Orthop B* 2019:10.1097/BPB.0000000000000672.
16. Lee MC, Eberson CP. Growth and development of the child's hip. Orthop Clin North Am. 2006;37(2):119-v.
17. Siffert RS. **Patterns of deformity of the developing hip**. *Clin Orthop Relat Res* 1981(160):14–29.
18. Brougham DI, Broughton NS, Cole WG, Menelaus MB. Avascular necrosis following closed reduction of congenital dislocation of the hip. Review of influencing factors and long-term follow-up. J Bone Joint Surg Br. 1990;72(4):557–62.

19. Sibiński M, Synder M, Domzalski M, Grzegorzewski A. Risk factors for avascular necrosis after closed hip reduction in developmental dysplasia of the hip. Ortop Traumatol Rehabil. 2004;6(1):60–6.
20. Pospischill R, Weninger J, Ganger R, Altenhuber J, Grill F. Does open reduction of the developmental dislocated hip increase the risk of osteonecrosis? Clin Orthop Relat Res. 2012;470(1):250–60.
21. Bradley CS, Perry DC, Wedge JH, Murnaghan ML, Kelley SP. Avascular necrosis following closed reduction for treatment of developmental dysplasia of the hip: a systematic review. J Child Orthop. 2016;10(6):627–32.
22. Tiderius C, Jaramillo D, Connolly S, Griffey M, Rodriguez DP, Kasser JR, Millis MB, Zurakowski D, Kim Y-J. Post-closed reduction perfusion magnetic resonance imaging as a predictor of avascular necrosis in developmental hip dysplasia: a preliminary report. J Pediatr Orthop. 2009;29(1):14–20.
23. Gornitzky AL, Georgiadis AG, Seeley MA, Horn BD, Sankar WN. Does Perfusion MRI After Closed Reduction of Developmental Dysplasia of the Hip Reduce the Incidence of Avascular Necrosis? Clin Orthop Relat Res. 2016;474(5):1153–65.
24. Morbi AHM, Carsi B, Gorianinov V, Clarke NMP. Adverse Outcomes in Infantile Bilateral Developmental Dysplasia of the Hip. J Pediatr Orthop. 2015;35(5):490–5.
25. Ramsey PL, Lasser S, MacEwen GD. Congenital dislocation of the hip: use of the Pavlik harness in the child during the first six months of life. 1976. J Bone Joint Surg Am. 2002;84(8):1478–8.
26. Madhu TS, Akula M, Scott BW, Templeton PA. Treatment of developmental dislocation of hip: does changing the hip abduction angle in the hip spica affect the rate of avascular necrosis of the femoral head? J Pediatr Orthop B. 2013;22(3):184–8.
27. Luhmann SJ, Schoenecker PL, Anderson AM, Bassett GS. The prognostic importance of the ossific nucleus in the treatment of congenital dysplasia of the hip. J Bone Joint Surg Am. 1998;80(12):1719–27.
28. Kitano T, Imai Y, Morita M, Nakagawa K, Wada M, Sakai T, Eguchi Y, Kuroda T. New treatment method for developmental dysplasia of the hips after walking age: arthroscopic reduction with limboplasty based on the findings of preoperative imaging. J Orthop Sci. 2010;15(4):443–51.
29. Cai Z, Li L, Zhang L, Ji S, Zhao Q. Dynamic long leg casting fixation for treating 12- to 18-month-old infants with developmental dysplasia of the hip. J Int Med Res. 2017;45(1):272–81.

Figures

Figure 1

Orthosis used after cast removal The orthosis contained four holes with cap nuts and adjusted timely according to our protocol of 1-2-2-2-month

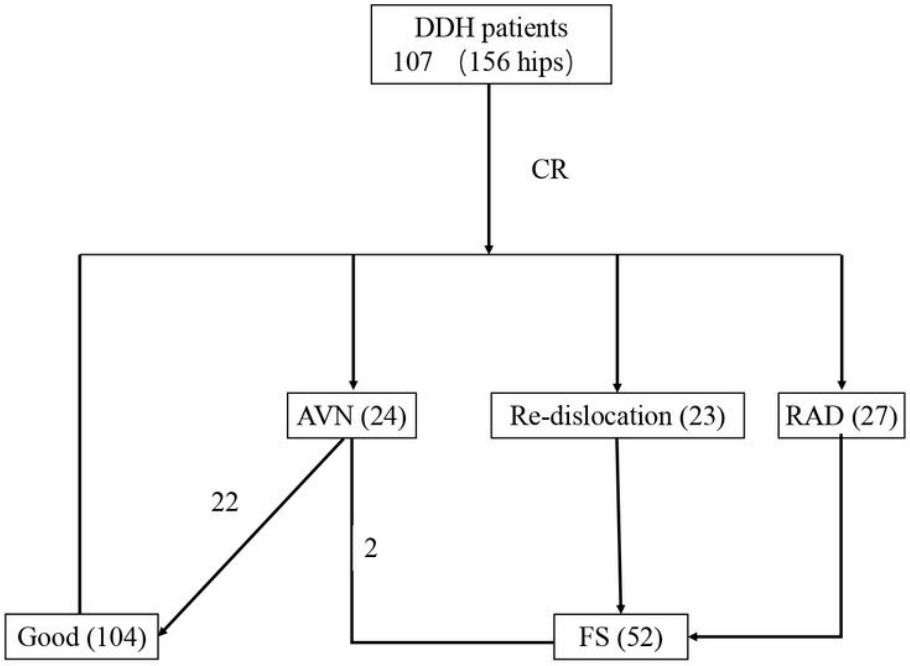

Figure 2

Flowchart of clinical outcomes of DDH patients treated by CR 107 children (156 hips) with DDH received CR. There were 104 hips achieved good outcome, FS were performed on 52 hips (33.3%), of which 23 (14.7%) hips due to re-dislocation, 27 (17.3%) hips of RAD, and 2 (0.01%) of AVN.

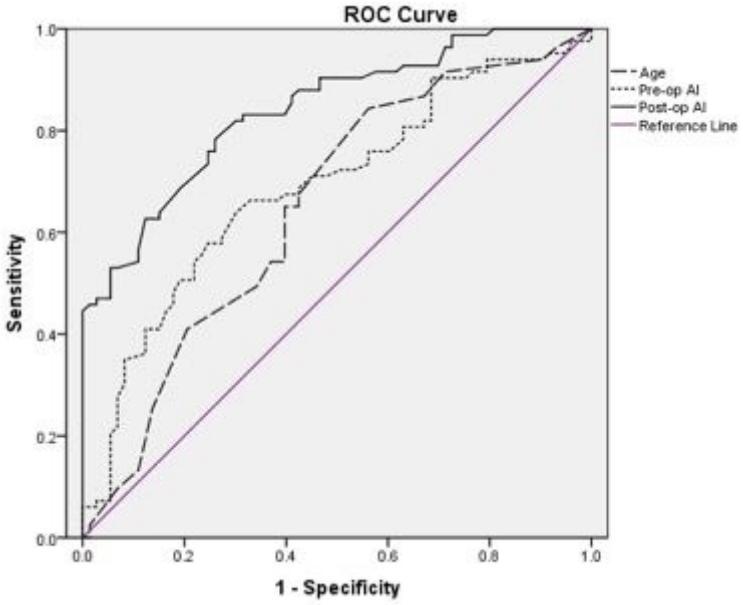

Figure 3

The ROC curves used to determine the predictive value for 1) the age, 2) pre-op AI, 3) post-op AI, are shown for detection of failure of CR. The area under the curve (AUC) was found for the post-op AI with a cutoff of 26.4°, followed by the pre-op AI with a cutoff of 38.7° and the age at 12.5 months.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- ETHICALREVIEW.pdf