Does Acetabulum Remodel Following Varus Derotation Osteotomy for Perthes' Disease?

O acetábulo sofre remodelamento após a Osteotomia Derrotatória Varizante em pacientes com Doença de Perthes?

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Abstract

Objective We investigated the effect of disease stage, patient's age and final contour of femoral head on acetabulum contour following varus derotation osteotomy of proximal femur (VDRO) in unilateral Perthes's disease.

Methods The study is a retrospective analysis of case records of 23 children aged $\geq$6 years with unilateral Perthes' disease who underwent primary VDRO procedure for containment. Acetabular index (AI) and center edge angle (CEA) were calculated bilaterally in preoperative and follow-up radiographs and compared statistically.

Results There were 15 boys and 8 girls. Six hips were in Ib, 8 in IIa and 9 in IIb modified Waldenström stage while undergoing VDRO. The mean age at surgical intervention was 8.7 years. The mean follow-up duration was 3.5 years. All femoral heads were healed at final follow-up and the final Stulberg grades were I = 3, II = 8, III = 7, IV = 5. A significant acetabular dysplasia on the affected side was present preoperatively. At follow-up, the patients operated had significantly raised AI and reduced CEA. There was no significant acetabular remodeling of the affected hips at follow-up even in children operated at younger age ($<$ 8 years) or early stages (stage Ib or IIa). The acetabulum remodeling did not correspond to the final Stulberg grade as well.

Conclusion Acetabulum was found involved in early stages of Perthes' disease. Varus derotation femoral osteotomy for the diseased hip showed no significant improvement in acetabular dysplasia even when operated in early disease stages or younger age group. Residual acetabular changes were also noted even with favorable Stulberg grades.

Keywords
- acetabulum
- child
- hip joint
- legg-calve-perthes disease

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Resumo

Objetivo Investigamos o efeito do estágio da doença, idade do paciente e contorno final da cabeça femoral no contorno do acetábulo após a osteotomia derrotatória varizante (VDRO) do fêmur proximal na doença de Perthes unilateral.

Métodos O estudo é uma análise retrospectiva de prontuários de 23 crianças com idade $\geq$ 6 anos com doença de Perthes unilateral que foram submetidas ao procedimento primário de VDRO para contenção. O índice acetabular (AI) e o ângulo da borda central (CEA) foram calculados bilateralmente em radiografias pré-operatórias e de acompanhamento e submetidos à comparação estatística.

Resultados Os pacientes eram 15 meninos e oito meninas. À VDRO, seis quadris estavam no estágio de Waldenström modificado Ib, oito no estágio IIa e nove no estágio IIb. A média de idade à intervenção cirúrgica foi de 8,7 anos. A duração média do acompanhamento foi de 3,5 anos. Todas as cabeças femorais estavam consolidadas no último acompanhamento e os graus finais de Stulberg foram I = 3, II = 8, III = 7 e IV = 5. Havia displasia acetabular significativa do lado acometido no período pré-operatório. No acompanhamento, os pacientes operados apresentaram elevação significativa de AI e redução de CEA. Não houve remodelamento acetabular significativo nos quadris acometidos durante o acompanhamento, mesmo em crianças operadas em idade menor ($<$ 8 anos) ou estágios iniciais (estágio Ib ou IIa). O remodelamento do acetábulo também não correspondeu ao grau final de Stulberg.

Conclusão A VDRO do fêmur do quadril acometido não levou à melhora significativa da displasia acetabular, mesmo quando a cirurgia foi realizada nos estágios iniciais da doença ou em pacientes mais jovens. Alterações acetabulares residuais também foram observadas mesmo com graus de Stulberg favoráveis.

Palavras-chave

- acetábulo
- articulação do quadril
- criança
- doença de legg-calve-perthes

Introduction

There is ample evidence that acetabulum is significantly altered in addition to changes in proximal femur in Perthes' disease.[1–6] The acetabular changes begin early with abnormal growth of its cartilage and increased medial joint space. In late stages, a dysplastic lateral acetabulum is often seen associated with an enlarged, laterally displaced femoral head.[5]

A key treatment in Perthes' disease involves seating the femoral head as fully inside the acetabular socket so that it may retain its sphericity during the period of subsequent revascularization and remodelling.[7,8] Containment with proximal femur varus derotation osteotomy (VDRO) is one of the preferred surgical procedures recommended for this purpose. Many studies report the improvement in sphericity and radiological outcome of proximal femur following the use of VDRO procedure.[9–15] Since the acetabular changes closely follow the changes in femoral head morphology during the disease process, one might expect that a femoral containment osteotomy will also produce a congruent acetabulum at disease healing.[5] Others have raised concerns against this hypothesis since VDRO intervention is most commonly offered at a time when remodelling potential of the acetabulum is already limited.[5]

There is limited literature specifically evaluating acetabular remodelling following containment procedures in Perthes' disease in children.[1,3] We therefore conducted this study to further understand acetabular changes following VDRO intervention for Perthes' disease. Specifically, we investigated the effect of disease stage, patient's age and final contour of femoral head on acetabulum following the surgical intervention.

Methods

The retrospective study (2010–2020) was performed at a tertiary care pediatric center. Ethical clearance from Institutional Ethics Committee was obtained for the study and written informed consent was obtained from all patients and/or families. We included children $\geq$6 years with unilateral Perthes' disease in stages Ib to IIb (modified Waldenström classification) who underwent primary VDRO and trochanteric epiphyseodesis for containment.[8,16,17] We excluded patients with follow-up less than 1 year and inadequate records. Twenty-three children fulfilled above criteria and formed the subjects for this study.

According to the modified Waldenström classification for Perthes' disease, the femoral head fragmentation starts at IIa and progresses till stage IIb (late fragmentation).[8,16,17] The procedure of VDRO is generally indicated in stage I and II disease. With available evidence that there will be likely extrusion of the epiphysis and subsequent deterioration in children over the age of 7 years, the procedure is also recommended in patients without extrusion.[4,13,17,18] The practiced procedure of VDRO at our institute is an open

lateral wedge subtrochanteric osteotomy to achieve containment of femoral head with lower limit of final neck shaft angle of ~110–115 degrees, derotation of ~15–20 degrees and stabilized with a molded dynamic compression plate.[7]

Evaluation

The radiographic evaluation was based on anteroposterior plain X-rays. As above, initial stage and severity of hip involvement was determined using modified Waldenström classification.[8,16] Acetabular index (AI) and center edge angle (CEA) were calculated for both hips preoperatively.[19] In subsequent follow-up radiographs, hip was evaluated for the presence of acetabular dysplasia and sphericity. Acetabular dysplasia was radiologically assessed by AI and CEA. Overall head sphericity was assessed by Stulberg grade.[20]

The stage of disease at presentation, patient's age and final head sphericity are the key factors postulated to decide the final outcome in Perthes' disease.[2,7,8,14,21] Accordingly, to enable analysis of acetabular results, children were subgrouped into those with early (Ib and IIa) and late fragmentation (IIb) disease stage at presentation; age $\leq$8 and $>$8 years and those who achieved Stulberg grade upto 2 (considered as good results) versus those with grade 3 or more.

Statistical Analysis

Preoperative AI and CEA on both sides were compared using paired student *t*-test to determine the approximate dysplasia on affected side. The indices were again compared at follow-up to determine the residual acetabular dysplasia. P value of $<$0.05 was considered significant. The statistical analysis was done using online 'MedCalc' statistical software.[22]

Results

Twenty-three children comprised 15 boys and 8 girls. Six hips were in Ib, 8 in IIa and 9 in IIb stage before undergoing VDRO (►**Table 1**). The mean patient's age at surgical intervention was 8.7 (SD 1.5) years (range, 6.6–11.7 years). Lateral extrusion of the femoral head was present in 18 hips preoperatively. The mean duration of follow-up was 3.5 (SD 2.2) years and mean age at final follow-up was 12.2 (SD 2.4) years. All femoral heads were healed at final follow-up and of these, 48% hips were Stulberg grade I and II (Stulberg grade I = 3, II = 8, III = 7, IV = 5).

The preoperative radiographs showed significant acetabular dysplasia on the affected side compared with unaffected side. The affected hip showed a mean AI of 16.6 (SD 4.3) degrees and CEA of 25.8 (SD 4.8) degrees whereas for the unaffected side, the values were 11.7 (SD 2.4) degrees and 32.8 (SD 5.3) degrees respectively. Additionally, this dysplasia was also demonstrated in all analyzed subgroups (►**Table 2**).

Patients operated in both early and late fragmentation disease stages had significant persistent acetabular dysplasia on the affected side at follow-up (►**Table 2**). For disease stage Ib and IIa at presentation, AI on unaffected side was 12.8 (SD 3.9) degrees versus affected side 17.5 (SD 4.5) degrees ($p = 0.0004$). Corresponding CEA values on unaffected side were 37 (SD 6.5) degrees versus affected side 29 (SD 5.1) degrees ($p = 0.002$) (►**Fig. 1**). The observations for hips operated in late fragmentation stage IIb were similar (►**Fig. 2**). In the intergroup analysis, the acetabular dysplasia comparison of the affected side between the two groups (Ib/IIa and IIb), at the preoperative stage and at the final follow-up, was not significantly different ($p > 0.05$).

The acetabulum failed to remodel, and persistent dysplasia was present in both early (operated till 8 years) and late age groups (operated after 8 years) at final follow-up. Significant difference ($p < 0.001$) in AI and CEA values were noted between non affected and affected hips at follow-up. Also, the intergroup analysis between two age groups showed comparable AI and CEA for the affected hips, both preoperatively and at follow-up.

The acetabulum remodelling did not correspond to the final Stulberg grade as well. The hips with final Stulberg grade I and II group also had significantly altered acetabulum parameters compared with the unaffected side at follow-up. The degree of acetabular dysplasia showed no significant difference when observations of two groups (Stulberg I/II and $\geq$III) were compared both at preoperative stage and at follow-up.

Discussion

Perthes' disease is a disorder of childhood characterized by avascular necrosis of the femoral head. Acetabulum changes in Perthes' disease is a long recognized phenomenon.[1–6] Of the various morphological changes occurring in acetabulum, the most noted is acetabular dysplasia along with osteopenia of roof and irregularity.[5] The various factors analyzed in our study viz. initial stage of the disease, age of the child at surgical intervention and final radiological outcome have been a subject of much debate in Perthes' disease but the discussion is largely directed to the proximal femoral characteristics.[7,8] Our study focused on acetabulum relationship to these factors wherein patients were subjected to a uniform containment method i.e., VDRO. The study of acetabulum holds considerable importance because its incongruity persisting in older children after disease healing might cause early degenerative arthritis of the hip joint.[3,5]

Our study revealed presence of significant acetabular dysplasia even in early stages (stage I and II) of Perthes' disease or younger age children. Both AI and CEA were abnormal when compared with unaffected side preoperatively. This early dysplasia indicated that Perthes' disease is a global joint pathology rather than just proximal femoral involvement. It is therefore emphasized that the other side of hip joint may be given due consideration during the preoperative work up/ late reconstructions of Perthes' disease.

In the preventive intervention strategy for Perthes' management, as postulated by Joseph and associates, VDRO was typically indicated for stage IIa (stage of early fragmentation). However, in later research it was shown that VDRO was somewhat useful even for hips in late fragmentation (IIb).[8,14] Five out of nine (55%) patients with preoperative stage IIb

Table 1 Acetabular parameters preoperatively and at follow up

S.NO.	SEX	SIDE	AGE (MONTHS)	AGE AT F/U (YEARS)	F/U (MONTHS)	DISEASE STAGE	EXTRUSION	PREOPERATIVE PARAMETERS (DEG.)				FOLLOW UP (DEG.)				STULBERG GRADE
								UNAFFECTED	UNAFFECTED	AFFECTED	AFFECTED	UNAFFECTED	UNAFFECTED	AFFECTED	AFFECTED	
								AI	CEA	AI	CEA	AI	CEA	AI	CEA	
1	M	R	81	9	20	2b	PRESENT	12	28	22	23	15	30	22	27	II
2	M	R	132	16.6	120	2a	PRESENT	12	30	16	23	18	32	23	26	III
3	M	L	96	12.5	54	1b	ABSENT	11	34	15	26	6	42	12	37	III
4	M	L	122	14.5	51	2a	ABSENT	13	31	15	24	13	44	23	22	III
5	M	R	140	16	54	2b	PRESENT	15	27	16	26	15	36	24	6	IV
6	M	R	102	14.5	60	2b	PRESENT	14	30	16	14	14	30	21	8	IV
7	F	L	96	9.5	14	2b	PRESENT	11	38	15	32	10	39	14	39	II
8	F	R	108	14	55	1b	ABSENT	11	39	28	28	16	45	23	34	II
9	M	L	91	12.5	58	2a	PRESENT	12	33	15	34	15	39	21	22	II
10	F	L	76	10.5	49	2b	PRESENT	7	33	11	27	12	43	17	35	II
11	F	L	96	11.2	38	1b	PRESENT	16	32	20	25	19	32	19	24	III
12	M	R	120	12.6	32	1b	ABSENT	6	34	13	30	9	41	12	29	II
13	M	R	108	17	93	1b	PRESENT	12	30	22	21	11	45	21	30	III
14	M	R	96	12.7	51	2b	PRESENT	15	31	24	18	12	34	13	22	IV
15	M	L	132	14	34	2b	PRESENT	10	33	9	32	12	52	26	32	II
16	M	L	79	10	33	2a	PRESENT	13	34	18	24	6	31	14	32	I
17	F	L	120	11	14	2a	PRESENT	12	52	18	32	13	41	19	39	IV
18	M	L	96	10.5	22	2a	PRESENT	10	38	15	33	9	45	15	24	III
19	F	R	120	11	14	2a	PRESENT	12	26	15	24	16	29	12	34	I
20	M	L	115	11.5	36	1b	PRESENT	13	27	14	23	14	28	15	31	I
21	F	R	84	9.5	17	2b	PRESENT	14	32	20	23	15	26	24	17	II
22	F	L	103	10	17	2b	PRESENT	10	31	14	23	9	34	14	32	III
23	M	L	87	9.5	14	2a	ABSENT	9	32	11	28	11	30	11	26	IV

Abbreviations: AI, Acetabular Index; CEA, Centre Edge Angle; DEG.-Degrees; F, Female; F/U, FOLLOW UP; L, Left; M, Male; R, Right; VDRO, Varus Derotation Osteotomy.

Table 2 Comparison between various subgroups

Groups	Preoperative		Significance*	Preoperative		Significance*	Follow up		Significance*	Follow up		Significance*
	Unaffected AI (in degrees)	Affected AI (in degrees)		Unaffected CEA (in degrees)	Affected CEA (in degrees)		Unaffected AI (in degrees)	Affected AI (in degrees)		Unaffected CEA (in degrees)	Affected CEA (in degrees)	
Initial stage of disease												
Ib, IIa	11.6 (2.1)	17.1 (4.2)	0.0001	33.3 (6.1)	26.5(4.0)	0.0008	12.8(3.9)	17.5(4.5)	0.0004	36.9 (6.5)	29.1 (5.14)	0.002
IIb	12 (2.6)	16.3(4.6)	0.006	31.4 (3.0)	24.2(5.6)	0.002	12.7 (2.1)	19.4(4.8)	0.0007	36 (7.4)	24.2 (11.1)	0.008
Age at time of surgery												
≤8 years	11.8 (2.6)	16.9 (4.3)	<0.001	33.2 (2.9)	26.6 (4.9)	0.0001	11.8 (4.0)	16.5 (4.4)	0.0006	35.5 (6.3)	27.7 (7.0)	0.003
>8 years	11.6 (2.2)	16.3(4.5)	0.007	32.5 (6.7)	25 (4.9)	0.001	13.4 (2.6)	19.4 (4.7)	0.0001	38 (7.3)	27 (9.8)	0.005
Stulberg stage at follow up												
I andII	11 (2.4)	16.3(5.1)	0.004	32.4 (4.0)	27.2(4.0)	0.001	12.7 (3.1)	18.2(4.9)	0.003	36.6 (8.0)	30.2 (6.0)	0.027
III and IV	12.4 (2.1)	16.8(3.5)	0.0001	33.2 (6.2)	24.4(5.1)	0.0001	12.5 (3.6)	17.9(4.5)	0.0003	37.1 (5.7)	24.7 (9.5)	0.0008

Abbreviations: AI, Acetabular Index; CEA, Centre Edge Angle.
Standard deviation values expressed in brackets.
*Student *t*-test.

disease achieved a final Stulberg grade of II in our series and an overall congruent hip joint. However, the follow-up acetabular indices didn't normalize in these patients as healing occurred.

The age cut off of 8 years for better femoral outcomes as an indication for VDRO has been established by multiple series.[8,14,23] Yet similar findings were not replicated for acetabulum. A possible explanation for this observation may lie in the fact that even though triradiate cartilage may not be completely fused by 8 years, the remodelling capacity of acetabulum declines considerably by this time due to loss of biological plasticity or the disease process. Corroborative evidence to above postulate may be seen with the use of VDRO for pathologies other than Perthes'. Shore et al studied the effect of VDRO on 56 children (103 hips) with cerebral palsy operated at the mean age of 7.7 years and with mean follow-up of 7.8 years.[24] They found no significant improvement of AI in children older than 6 years and mean improvement of 2.3 degrees in children ≤6 years. Thus, modification of plan/ concomitant acetabular procedure is suggested as early as age 6 years in Perthes' disease, if there is significant preoperative dysplasia of acetabulum.

Lastly, the patients who had good radiological results (Stulberg grade I and II) at follow-up also had residual deformed acetabular configurations in our study. Similar observations were also noted by Kamegaya et al who demonstrated that position of femoral head determines the final acetabular cover at maturity rather than sphericity, shape of head or age of the child.[1] This study comprised 33 unilateral Perthes's hips out of which 29 hips were analyzed based on acetabular head index (AHI), sphericity of femoral head, age at primary healing and amount of subluxation. Only 13 hips (48.8%) had more than 10% improvement in AHI at healing. Overall, no significant correlation of AHI was found with femoral head sphericity or age at primary healing. It however, correlated to reduction of subluxation. Authors for this series however, recommended delaying acetabular procedures, if needed till maturity, as some of their patients showed acetabular remodelling. We found that changes in acetabulum in children who underwent VDRO after age of 6 years in Perthes' disease did not remodel significantly despite improved contour of femoral head.

Majority of our children were skeletally immature at final follow-up. According to observations of Shah et al, the shape of the femoral head and congruity of the hip was largely static post healing and further changes at achieving skeletal maturity were unlikely.[3] Thus, the possibility that final radiological results may change significantly at maturity is limited. Other limitations were a retrospective study design, different ages at which VDRO was performed, and the dissimilar follow-up period. Additionally, there were differences in preoperative Perthes' disease stages and severity of acetabular dysplasia. The plain radiographs formed the basis of both initial and final evaluation and had an inherent limitation as acetabulum has an overall complex shape. The statistical results need a careful interpretation being based on a relatively small number of patients and univariate analysis. However, our series cut down various biases of management,

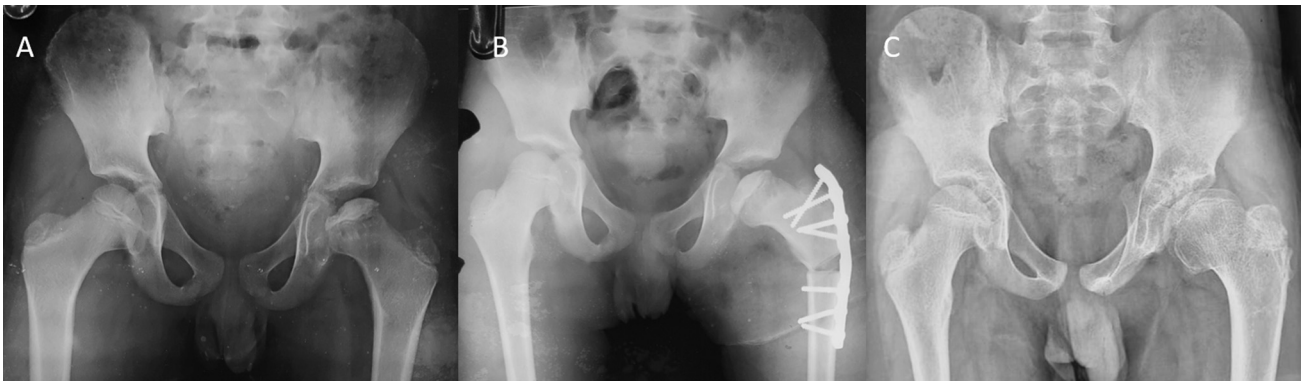

Fig. 1 (A) The 10.1 year old patient presented with Perthes' disease of left hip in stage 2a (patient 4); (B) The open wedge varus derotation osteotomy was performed to contain the hip; C) At follow-up 51 months, the disease healed. The head was enlarged and the final Stulberg grade was III. There was persistent acetabular dysplasia on the affected side (AI, 23 degrees) compared with unaffected (AI, 13 degrees).

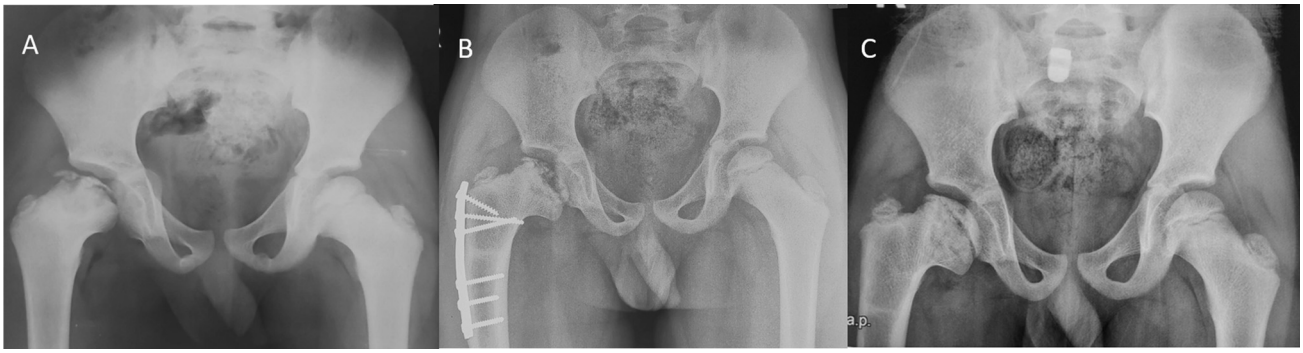

Fig. 2 (A) The 6.7 year old presented with stage 2b disease and extrusion of right hip (patient 1) with increased AI on affected side (22 degrees) compared with unaffected side 12 degrees); (B) The open wedge varus derotation osteotomy was performed to contain the hip; (C) At follow-up 20 months, the final Stulberg grade was II. There was persistent acetabular dysplasia on the affected side (AI, 22 degrees) compared with unaffected (AI, 15 degrees).

it being a uniform cohort of unilateral Perthes' cases operated upon with a common technique. Since a normal reference in form of unaffected acetabulum was available, both preoperatively and at follow-up for all comparisons, it accounted for physiological changes occurring in the acetabulum over the follow-up period. A follow-up till disease healing was available for all cases. We could quantitatively establish that acetabulum deformed early in Perthes' disease and its restoration was incomplete following VDRO possibly because of the limited remodelling potential at the time of performance of surgical procedure. Contrary to common belief, VDRO procedure performed in early disease stages may not always yield favorable acetabular outcomes. Finally, the acetabulum remodelling might not corroborate with the final femoral head shape at healing. We would however, like to suggest further studies on acetabular remodelling following VDRO with a larger number of cases and longer follow-up till skeletal maturity to decipher such changes with greater precision.

Conclusions

Acetabulum was found involved in early stages of Perthes' disease. Varus derotation femoral osteotomy for of the diseased hip showed no significant improvement in acetabular dysplasia even when operated in early disease stages or younger age group. Residual acetabular changes were also noted even with favorable Stulberg grades.

Authors' Contributions

Each author contributed individually and significantly to the development of this article: NBD: Methodology, investigation, writing original draft; AA: conceptualization, supervision, editing.

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Conflict of Interest

The authors have no conflict of interests to declare.

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