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Original Article

Comparison of the results from simple radiography, from before to after Salter osteotomy, in patients with Legg-Calvé-Perthes disease☆,☆☆

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ABSTRACT

Objectives: To determine whether the clinical variables and preoperative classification of patients with Legg-Calvé-Perthes disease (LCPD) who undergo Salter osteotomy correlate with the radiographic result at the time of skeletal maturity.

Methods: In this retrospective cohort study, 47 individuals with LCPD who were treated using Salter osteotomy (1984–2004) were evaluated. The patients were evaluated according to sex, skin color, side affected and age at which osteotomy was performed. The preoperative radiographs were analyzed in accordance with the classifications of Waldenström, Catterall, Laredo and Herring. The radiographs obtained at the time of skeletal maturity were classified using the Stulberg method.

Results: The mean age at the time of surgical treatment was 82.87 months (6.9 years). The age presented a statistically significant correlation with the Stulberg grades at skeletal maturity ($p < 0.001$). Patients over the age of 6.12 years tended to present less favorable results. The variables of sex, skin color and side affected did not present any statistically significant correlation with the prognosis ($p = 0.425$; $p = 0.467$; $p = 0.551$, respectively). Only the Laredo classification presented a statistically significant correlation with the final result given by the Stulberg classification ($p = 0.001$). The other classifications used (Waldenström, Catterall and Herring) did not present any correlation between the time at which surgery was indicated and the postoperative result.

Conclusions: The age at which the patients underwent surgical treatment and the Laredo classification groups were the only variables that presented significant correlations with the Stulberg classification.

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Comparação entre resultados de radiografia simples, pré e pós-osteotomia de Salter, em pacientes portadores da doença de Legg-Calvé-Perthes

RESUMO

Objetivos: Determinar em pacientes com doença de Legg-Calvé-Perthes (DLCP) submetidos à osteotomia de Salter se as variáveis clínicas e as classificações pré-operatórias se correlacionam com o resultado radiográfico na maturidade esquelética.
Métodos: Neste estudo de coorte retrospectivo foram avaliados 47 indivíduos portadores da DLCP tratados com osteotomia de Salter (1984-2004). Os pacientes foram avaliados de acordo com sexo, cor, lado acometido e idade em que foi feita a osteotomia. As radiografias pré-operatórias foram analisadas de acordo com as classificações de Waldenström, Catterall, Laredo e Herring. As radiografias obtidas na maturidade esquelética foram classificadas segundo o método de Stulberg.
Resultados: A média da idade no momento do tratamento cirúrgico foi de 82,87 meses (6,9 anos). A idade apresentou correlação estatisticamente significativa com os graus de Stulberg na maturidade esquelética ($p < 0{,}001$). Pacientes acima de 6,12 anos tendem a apresentar resultados menos favoráveis. As variáveis sexo, cor e lado acometido não apresentaram correlação estatisticamente significativa com o prognóstico ($p = 0{,}425$; $p = 0{,}467$; $p = 0{,}551$, respectivamente). Apenas a classificação de Laredo apresentou correlação estatisticamente significante com o resultado final dado pela classificação de Stulberg ($p = 0{,}001$). As demais classificações usadas, Waldenström, Caterall e Herring, não apresentaram correlação entre o momento em que foi indicada a cirurgia e o resultado pós-operatório.
Conclusões: A idade em que os pacientes foram submetidos ao tratamento cirúrgico e os grupos da classificação de Laredo foram as únicas variáveis que apresentaram correlação significativa com a classificação de Stulberg.

Palavras-chave:
Doença de Legg-Calvé-Perthes
Radiografia
Classificação
Criança

Introduction

Since Legg-Calvé-Perthes disease (LCPD) was first described in 1910, it has always been a matter of great interest among researchers and has become one of the most-debated topics in the orthopedic literature. Several aspects of this clinical entity still remain unclear, especially regarding its etiology and treatment.

For a long time, almost all authors concentrated on analyzing the radiographic aspects of the disease. Its phase of evolution were first described by Waldenström,[1] whose classification was subsequently simplified and correlated with the anatomopathological findings by Jonsäter.[2] Evaluations on impairment of the ossification nucleus of the femoral head were systematized by Catterall[3] based on analysis of simple radiographs done during the phase of maximum fragmentation. With the aim of determining the proportions of the lesion during the initial phase and during necrosis, Salter and Thompson[4] demonstrated that the size of the subchondral fracture in the lateral view of the head precisely reflected the degree to which the proximal femoral epiphysis had been affected by the disease. More recently, Herring et al.[5] proposed a new classification based on the height of the lateral column of the femoral epiphysis.

Because the hips have a cartilaginous mold during the growth stage that is not visible on simple radiographs, Laredo[6] and Milani and Dobashi[7] demonstrated that arthrography would make it possible to detect alterations to the shape of the head and femoral extrusion before conventional radiographic examination would be able to recognize these features. These authors proposed an arthrographic classification composed of five groups. Among these, it would be possible to treat groups I and II using closed techniques, while arthrographic risk would be shown by the other groups, with the presence of extrusion and morphological alterations of the head, and surgical containment would be necessary.

Although LCPD treatment has for years been the subject of exhaustive discussions among orthopedists, there is still no clear evidence regarding the best therapeutic method. In relation to surgical treatment, the methods most used for providing improvements in the relationship between the proximal femoral epiphysis and the acetabulum are the so-called containment procedures, which can be divided into two major groups: (1) osteotomy of the proximal femur[8,9]; and (2) procedures involving the iliac bone. The latter group includes "shelf" surgery, medial displacement osteotomy[10] and Salter osteotomy,[11,12] which can be used during the active phase of the disease. In addition to the biomechanical aspects of the improvement through containment, it is believed that there is also a biological effect that gives rise to acceleration of the reossification process.[13–16]

This study aimed to compare pre and postoperative radiographs from patients with LCPD who underwent Salter osteotomy, with the aim of determining whether the clinical characteristics and the classifications of Catterall, Herring and

Laredo correlated with the radiographic result at the time of skeletal maturity and whether these might indicate the prognosis.

Materials and methods

The present study was submitted to evaluation by our institution's research ethics committee and was approved under report no. 0795/11.

We evaluated a retrospective cohort consisting of all the individuals with LCPD who were treated in our institution's department of orthopedics and traumatology between 1984 and 2004. Patients who fulfilled the following criteria were included: (1) individuals with LCPD who underwent Salter osteotomy to achieve containment of the femoral head; (2) who had reached skeletal maturity by the time of the last clinical assessment; and (3) for whom radiographs from before the operation and after reaching skeletal maturity were available.

Individuals presenting necrosis of the proximal femur with defined etiology and those with LCPD who underwent other types of treatment were excluded.

Forty-seven patients fulfilled the inclusion criteria. The following data were evaluated and extracted from the clinical medical files: sex, skin color, side affected and age at which osteotomy was performed.

The preoperative radiographs were classified in accordance with the following methods that have been described in the literature: (1) Waldenström,[1] as modified by Jonsäter[2]; (2) Catterall[3]; (3) Laredo[6,7]; and (4) the lateral pillar method of Herring et al.[5] The radiographs obtained after skeletal maturity had been reached were classified in accordance with the method of Stulberg et al.[17]

The radiographs from the preoperative examinations and those from the time of skeletal maturity were classified by the senior author at different times. This author also did not have access to the clinical data, so as to minimize the risk of bias.

The nominal variables were correlated using absolute and relative frequencies and the continuous variables, by means of summary measurements (mean, standard deviation, median, minimum and maximum).

The Stulberg grades were evaluated according to sex, skin color and side affected, using the Mann–Whitney test.[18] Spearman's correlation test was used to investigate whether there were any relationships between the Stulberg scale and the grades shown by the other scales, and with age and length of follow-up.[18]

The variables that presented some statistically significant relationship with the grades on the Stulberg scale were fitted into a multiple logistic regression model,[19] with grouping of grades I and II and grades III and IV. Only the variables that together had an influence on the grade on the Stulberg scale were kept in the final model. All the tests were performed taking the significance level of 5%.

Table 1 – Distribution of frequencies of the patients included, according to the variables of sex, skin color, side and the Waldenström, Catterall, Herring, Laredo and Stulberg classifications.

Variable	Frequency (*n*)	% Total	% Valid
Sex			
Female	10	21.3	21.3
Male	37	78.7	78.7
Subtotal	47	100	100
Color			
White	40	85.1	95.2
Others	2	4.3	4.8
Subtotal	42	89.4	100
No information	5	10.6	
Side			
Right	21	44.7	44.7
Left	26	55.3	55.3
Waldenström classification			
I	16	34.0	34.0
II	24	51.1	51.1
III	5	10.6	10.6
IV	2	4.3	4.3
Catterall classification			
II	2	4.3	4.3
III	23	48.9	50
IV	21	44.7	45.7
Subtotal	46	97.9	100
Unclassifiable	1	2.1	
Herring lateral pillar classification			
A	5	10.6	10.9
B	22	46.8	48
C	19	40.4	41.3
Subtotal	46	97.9	100
Unclassifiable[a]	1	2.1	
Laredo classification			
III	25	53.2	56.8
IV	15	31.9	34
V	4	8.5	9.1
Subtotal	44	93.6	100
Unclassifiable[a]	3	6.4	
Stulberg classification			
I	11	23.4	24.4
II	6	12.8	13.3
III	18	38.3	40.0
IV	10	21.3	22.2
Subtotal	45	95.7	100
Unclassifiable[a]	2	4.3	
Total	47	100	

[a] Patients were considered to be unclassifiable when the radiographs available were only from the remodeling phase, in which most of the methods cannot be applied.

Results

Table 1 summarizes the demographic data and all the variables gathered, with their respective distributions, including: sex, skin color, side affected, preoperative classification[1–7] and postoperative classification (Stulberg).[17]

The mean age at which the surgical treatment was performed was 82.87 months (range: 48–152) and the mean length of follow-up was 118.07 months (9.84 years) (Table 2).

An ROC curve was used (Fig. 1) to determine the best age cutoff point for distinguishing between hips that evolved to Stulberg III or IV, which represented the worst prognosis.

Table 2 – Summary measurements for age and length of follow-up among the patients included.

Variable	Mean	SD	Median	Minimum	Maximum	N
Age (months)	82.87	24.82	77	48	152	47
Length of follow-up (months)	118.07	22.76	119	67	158	47

SD, standard deviation.

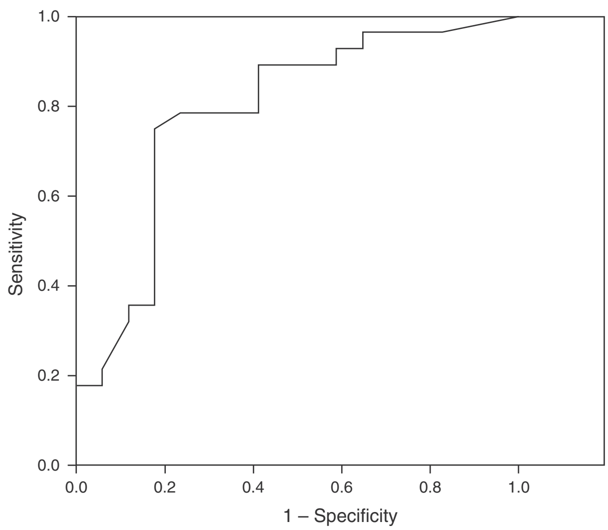

Fig. 1 – ROC curve relating to sensitivity and specificity of age in determining a worse final result characterized by Stulberg III or IV.

According to the analysis on the curve, 73.5 months (6.12 years) was the age that best distinguished between Stulberg III and IV, and this age showed sensitivity of 78.6% and specificity of 70.6%. This means that when treatment is instituted around this age, the prognosis is best. Age as a separate factor also showed a statistically significant correlation ($p < 0.001$) and indicated that the younger the age at which the patient undergoes corrective surgery is, the better the prognosis also is.

The variables of sex, skin color and side affected, as evaluated using the Mann–Whitney test, did not present any statistically significant difference regarding the prognosis ($p = 0.425$; $p = 0.467$; and $p = 0.551$, respectively).

Only the Laredo classification presented a statistically significant correlation with the final result given by the Stulberg classification ($p = 0.001$), according to Spearman's correlation test. The other classifications (Waldenström, Catterall and Herring) did not present any correlation between the time at which surgical treatment was indicated and the postoperative result, and were therefore not predictors regarding the treatment and prognosis. These data are summarized in Table 3.

Discussion

Salter osteotomy[11,12] has been used in our institution for surgical treatment of LCPD since 1979. This indication is made in cases with extensive impairment and especially in cases with alterations to the shape and size of the femoral head that are shown by arthrographic assessment of the hip in accordance with the Laredo classification.[6,7]

The classification methods that are most widely disseminated in the literature were used in this study. It was sought to establish which of them might have greatest prognostic value in relation to the final result after the disease had run its course. According to the Waldenström classification, most of the patients were in the phases of necrosis (34%) and fragmentation (51.1%), given that these are the best times for surgical intervention, before the remodeling process gets underway or is concluded.[20] Because this was a sample of patients who underwent surgical treatment consisting of Salter osteotomy, most of the individuals included presented hips with moderate to severe involvement, according to the radiographic classifications of Catterall[3] and Herring et al.[5]

Preoperative arthrography was performed on 44 patients. In all of these cases, there were important morphological alterations of the femoral head, especially in terms of extrusion and increased size. Thus, all of these 44 hips were included in the three arthrographic risk groups of Laredo, with predominance of groups III and IV.

Few studies in the literature have correlated the results from Salter osteotomy for treating LCPD with the Stulberg classification for grading the radiographic results.[21–23]

Ishida et al.[23] studied the results from Salter osteotomy for treating 32 patients (37 hips) at skeletal maturity and observed that the hips classified by Laredo as belonging to group III presented better results than those of hips in groups IV and V. This observation corroborates the concept that adequate coverage of the femoral head before severe deformity becomes established provides an improvement in hip biomechanics and favors the remodeling process over the course of LCPD.[15,16] Likewise, in our study, we observed that 47.8% of the patients classified in Laredo group III evolved to Stulberg type I or II. On the other hand, in the group of patients classified as Laredo groups IV and V, only 13.4% and 25% of the patients evolved to Stulberg type I or II, respectively.

These observations validate two facts: firstly, hip radiography in LCPD cases does not mirror the anatomical reality of the femoral head affected by the disease; secondly, it is precisely when a hip is classified as belonging to Laredo group III[6] that the head is considered to be leaving its protection zone at the acetabular bone rim. In such cases, if no cover is provided in time, the head will deform.[24]

In our study, we found a significant correlation between the age at which the surgical treatment was performed and the radiographic results at the time of skeletal maturity. We noted that patients above the age of 6.12 years presented a greater chance of evolving to Stulberg type III or IV,[17] thus giving rise to a worse prognosis. These findings are in agreement with what has been described in the literature, given that several authors have reported that independent of the type of

Table 3 – Correlation of the Stulberg classification with the variables of sex, color, side, age, length of follow-up and the Waldenström, Catterall, Herring and Laredo classifications.

Variable	Stulberg								Total	p
	I		II		III		IV			
	n	%	n	%	n	%	n	%		
Sex										0.425[a]
Female	3	25.0	0	0.0	5	41.7	4	33.3	12	
Male	8	22.8	6	17.2	14	40.0	7	20.0	35	
Color										0.467[a]
White	8	21.1	5	13.2	16	42.1	9	23.7	38	
Others	1	50.0	0	0.0	1	50.0	0	0.0	2	
Side										0.551[a]
Right	5	23.8	2	9.5	12	57.1	2	9.5	21	
Left	6	25.0	4	16.7	6	25.0	8	33.3	24	
Waldenström classification										0.052[b]
I	5	35.7	1	7.1	6	42.9	2	14.3	14	
II	6	25.0	5	20.8	9	37.5	4	16.7	24	
III	0	0.0	0	0.0	1	20.0	4	80.0	5	
IV	0	0.0	0	0.0	2	100.0	0	0.0	2	
Catterall classification										0.260[b]
II	2	100.0	0	0.0	0	0.0	0	0.0	2	
III	4	19.0	4	19.0	9	42.9	4	19.0	21	
IV	5	23.8	2	9.5	8	38.1	6	28.6	21	
Herring lateral pillar classification										0.243[b]
A	2	40.0	0	0.0	2	40.0	1	20.0	5	
B	6	30.0	4	20.0	6	30.0	4	20.0	20	
C	3	15.8	2	10.5	9	47.4	5	26.3	19	
Laredo classification										0.001[b]
III	7	30.4	4	17.4	11	47.8	1	4.3	23	
IV	1	6.7	1	6.7	7	46.7	6	40.0	15	
V	0	0.0	1	25.0	0	0.0	3	75.0	4	
Mean age ± SD	62.91 ± 19.32		80.5 ± 17.55		87.94 ± 21.4		97.8 ± 28.91		83.02 ± 25.08	<0.001[b]
Mean LF ± SD	121.55 ± 19.82		106 ± 18.01		120.17 ± 22.55		117.7 ± 28.88		118.07 ± 22.76	0.802[b]

LF, length of follow-up; SD, standard deviation.

[a] Result from Mann–Whitney test.

[b] Result from Spearman's correlation test.

treatment provided, patients over the age of six years tend to evolve with greater incidence of unsatisfactory results.[25,26]

The Catterall and Herring classifications have been widely used in the literature and in clinical practice for indicating treatment for LCPD. However, it has been reported in several studies that both methods present deficiencies in their capacity to predict the final clinical result.[27,28] Our data are concordant with these observations, since we found in our sample that was a significant dissociation between the gradings given by these classifications before the operation and the results at the time of skeletal maturity. For example, more than half ($n = 3$; 60%) of the patients classified as Herring type A evolved with hips of Stulberg classes III or IV. At the other extreme, five of the patients classified as Catterall type IV (23.8%) evolved with hips of Stulberg class I.

Several authors have pointed out that one of the problems of the radiographic classifications for Perthes disease, and notably in relation to Catterall, is the low to moderate inter and intra-observer concordance.[29–31] The stability of the Herring classification has also been questioned recently by Park et al., who noted changes from the initial grading in 40% of the patients with LCPD that they evaluated using serial radiographs.[32] These observations have important implications when some of these methods are used in clinical practice, given that the classifications should ideally dictate the treatment and prognosis.

Based on the data observed in this study, we believe that the Laredo classification[6,7] may provide the best substrate, in a systematized manner, for determining the prognosis of patients in whom surgical treatment is indicated. Thus, our data confirm the observations of Ingman[33] and Paterson et al.,[34] who found a close relationship between the presence of marked flattening of the femoral head on arthrography and occurrences of poor results from Salter surgery.

Conclusion

In the present study, we observed that the age at which the patient underwent surgical treatment and the groups of the

Laredo classification were the only variables that presented a significant correlation which the Stulberg classification. Thus, we conclude that the Laredo classification showed higher prognostic value than the Catterall and Herring classifications for treating LCPD by means of Salter osteotomy.

Conflicts of interest

The authors declare no conflicts of interest.

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