Original Article
Waldenström classification: better evaluation for the intervention time of scottish rite brace treatment in legg-calve-perthes disease

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Abstract: *Objective:* To evaluate the outcome of the scottish rite brace treatment by classifications and if so in what phase the optimal intervention time is. *Methods:* We retrospectively reviewed 43 patients (48 hips), aged from 5-15, who had LCPD and accepted scottish rite brace treatment between December 1996 and October 2012. Mean follow-up is 5.75 years (range, 2.58-14.08 years). The radiographic images of osteonecrosis were evaluated in our institution. We investigated the potential prediction of several classification systems by *Kruskal-Wallis* rank sum test and *Nemenyi*test, including Catterall Grouping, Herring Lateral Pillar Sign, Waldenström classificationand so on. *Results:* The clinical effective rate in modified Stulberg classification (type I & II) was 85.4% and the excellent rate (ER) was 56.3%. The children younger than eight years old showed an ER of 80% compared to 45.5% in the elder ones. The cases of Catteralltype I & II group presented an ER of 77.8% which was higher than that of III & IV type group (43.3%). In Herring classification, ER of type A group was 100%, ER of type B group was 62.5% and ER of type C group was 25%. In osteonecrosis phase, the patients were proved to be better with an ER of 56.5% than those patients in the fragmentation phase (0%) and reossification phase (77.8%) (P < 0.05). Among them, the differences between A and C were statistically significant in Haring classification (P < 0.05); the difference between osteonecrosis phase and the repair phase in Waldenstrom' was not statistically significant (P > 0.05); but those two groups were significant different with fragmentation phase (P < 0.05). *Conclusions:* The scottish rite brace treatment used on particular phases of Perthes's in children are advised to have a better outcome. The fragmentation and necrosis phase showed a worse result than reossification one. The optimal intervention times are tended to be the earlier phases in the disease progress according to Waldenström's. Orthopedic surgeons can resort and refer to the optimal times mentioned above and make the most of scottish rite brace treatment, even if those indexes are required to be addressed infuture randomized trials.

Keywords: Legg-calve-perthes disease, scottish rite brace treatment, classification, waldenström, intervention time

Introduction

Legg-Calve-Perthes disease, resulted from interruption of blood supporting of femoral head, may lead to serious complications in early infancies or younger children, such as deformation of the femoral head and bonetemporarily dies to fragment [1-4], although the etiology of LCPD is complex and difficult to associate with multi-factors like genetic and environment [5, 6]. It is reported that the estimated rates of LCPD are 2.5‰ in the group below 6 years old and higher than 100‰ in the older group [7].

Problems related with LCPD are the majority in limitation range of hip joint. In clinical practices, the range of abduction and alternation are usually examined to be decreased. Pain are the greatest serious symptom children can not bear due to the necrosis growth femoral bone [8]. Multiple authors proposed their own classifications, including Catterall Grouping, Herring Lateral Pillar Sign, Waldenström classification and so on, to evaluate the long-term outcomes of LCPD [8-10]. Operation or non-operative-treatment of LCPD is controversial, even if they are all focus on relieving limitation joint motion and painsymptom, but also reshaping the con-

Table 1. Demographic data of the patients

Characteristic	Information
Cases (hips)	43 (48)
Gender (M/F)	37:5
Age (yr, mean, range)	9.39 (5-15)
Duration of final follow-up (years)	5.75 (2.58-14.08)

tainment of femoral head in hip acetabular [11].

No matter considering surgery or conservation treatment (non-surgery), there are various kinds of indication exiting for surgeons to scale, such as radiological signs, others on the age of the patient, range of motion and pain or other clinical symptoms. One other principle is the optimal intervention time. As for operation, the significantly better result had already been reported by many surgeons. For example, femur varus osteotomy had its distinct advantage in fragmentation stage as reported [12]. Pelvic osteotomy is claimed to be useful in older children with total necrosis head [13]. Surgical dislocation of the hip is regarded as benefit methods for patients in poor Stulberg grade [14]. Older than 8 years with subluxation is suitable for salter and varus osteotomy [15]. Admittedly, previous reviews were a lack of the optimal intervention time for conservation treatments, especially the commonly used methods. Furthermore, no assessment of the particular treatments had been obtained to realize the relationship between outcome and the optimal intervention time.

The purpose of this paper was to analysis the outcome of Perthes' disease after the Scottish rite brace treatment assessed by several classifications and finally to predict the optimal intervention time for treatment.

Materials and methods

43 children (48 hips) were included in the study who underwent Scottish rite brace treatment over four years. There were 37 males (83.4%) and 5 females (11.6%). The mean age at the discovery of LCPD to the last follow-up was 5.75 years (range, 2.58-14.08 years). The affected hip was the left in 14 (32.6%) cases, the right in 24 cases (55.8%) and 5 cases (11.6%) for both. All children are accepted in

the department of orthopedics of the first affiliated hospital of Guangzhou University of Chinese Medicine, from December 1996 to October 2012 (**Table 1**). They were contacted by telephone- or an out-patient clinic return visit in the follow-up study. The study was approved by the local ethics committee (ethics committee of the first affiliated hospital of Guangzhou University of Chinese Medicine) and informed consent was obtained from the patients. Patients were informed regarding other treatment options and their possible outcomes. They were allowed to reject any data taking at the beginning of or during the study. Inclusion criteria were radiographically confirmed LCPD. We excluded patients who suffer from developmental dysplasia of the hip, slipped capital femoral epiphysis, coxa plana at the onset, traumatic bone fracture and other surgeries which can put an adverse effect on the efficacy of study result.

All children underwent a standard physical examination and anteroposterior and frog-leg lateral radiographs. The pain level was measured by the visual analog scale defined from 0 to 10 (0 = no pain, 10 = maximum pain). The limitations in range of movement were classified according to Tönnis. All the children were classified according to the several classification systems in their initial diagnosis, including Catterall Grouping: 4 radiologic subgroups I to IV based on the site and extent of involvement of the femoral capital epiphysis; Herring Lateral Pillar Sign: A, B, and C types based on the status of the lateral pillar height; Waldenström classification: 4 phases based on the necrosis states of the femoral head, respectively. We obtained all data only from medical record review and hip radiographs.

All the followed-up children had the Scottish rite brace treatment performed by physicians in the department of orthopedics of the first affiliated hospital of Guangzhou University of Chinese Medicine. The detailed approaches were as follows: 1) In osteonecrosis or fragmentation phase, children are kept in the supine position and maintained the double hips for 35~45° abduction, 5~10° internal rotation, 15° flexion of the lower limbs; Materials: Scottish rite brace; Joints is covered by 5-7 layers and 3-4 layers to non-articular portion.

Table 2. Modified Stulberg result based on the initial diagnosis age

Age (years)	Modified Stulberg result			Total (hips)	Z	P
	I	II	III			
8	12 (80.0%)	3 (20.0%)	0 (0%)	15	-2.396	< 0.05*
> 8	15 (44.5%)	11 (33.3%)	7 (21.6%)	33		
Total (hips)	27	14	7	48		

*Patients classed by aged up or below 8 showed significant statistic different.

Table 3. Modified Stulberg result based on the Catterall classification

Catterall	Modified Stulberg result			Total (hips)	Z	P
	I	II	III			
I & II	14 (77.8%)	4 (22.2%)	0 (0%)	18	-2.556	< 0.05*
III & IV	13 (43.3%)	10 (33.3%)	7 (23.3%)	30		
Total (hips)	27	14	7	48		

*Patients classed by Catterall classification showed significant statistic different.
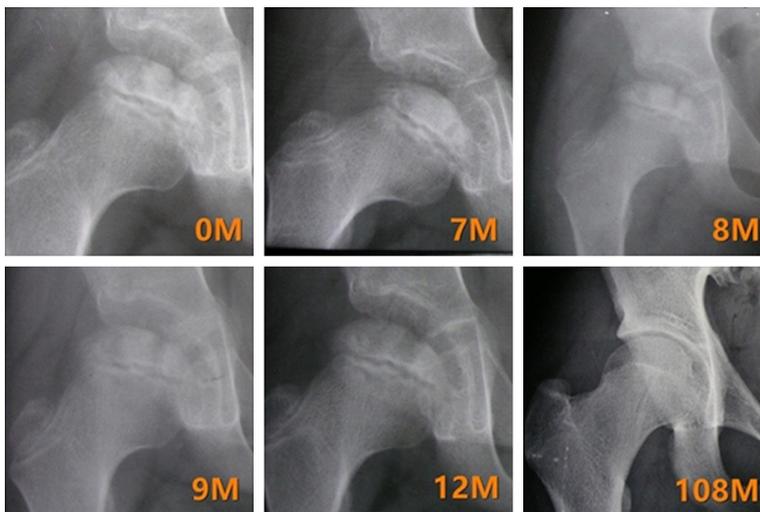

Figure 1. A 7-year-old boy with a LCPD in Catterall II type. a-h is examined at different times as marked in anterior-posterior position. The patients accepted the conservation treatment for 3 months. His disease has undergone from necrosis phase, fragmentation phase to reossification phase, and finally get a good Stulberg grade. (M = months).

Statistical analysis was calculated by SPSS 19.0, including the direct comparison of variables (i.e., initial staging classification vs. final Stulberg results), *Kruskal-Wallis* rank sum test and *Nemenyi* test, where appropriate. The significance level was set at $P < 0.05$.

Results

Total 43 children (48 hips) were studied. The age at presentation ranged from 5 years to 15 years with a mean age of 9.39 years. Male to female ratio was 37:5. All children with the active disease, multiple epiphyseal dysplasia, or history of developmental dysplasia of the hip, and all children lost to follow-up were excluded from this study. Based on the Stulberg classification, 27 hips were classed as good, 14 as media, 7 as worse. The relationship between age at onset of the disease and the resultant outcome was explored in *Kruskal-Wallis* rank sum test (**Table 2**).

According to Catterall classification, 14 hips (77.8%), defined as Catterall I or II, had a good outcome with hips classed Stulberg good level. 13 hips (43.3%) defined as Catterall III or IV are classed Stulberg good level and the 10 hips (33.3%) had a fair outcome. 7 hips (23.3%) are found to be the poor one. In the I & II group, contrasted to the III & IV group, there are only 4 hips (22.2%) to be the fair level and none of the hips had a poor result. Statistical analysis of the association between Catterall classification and outcome (**Table 3**) using *Kruskal-Wallis* rank sum test, produced a *P* value < 0.05 confirming the greater different of a favorable outcome between (**Figure 1**).

Patients accepted regular reexamination for checking the fixation and having a plain radiography one time, then modified the plaster bandage for every three months. Patients were required to avoid weight loading in fixation phase. 2) While developing into the reossification phase, children have imposed functional exercises instead of plaster bandage fixation. Patients are allowed to walk with or without the assistance of crutches.

Table 4. Modified Stulberg result based on the initial classification of Herring Lateral Pillar Sign

Herring	Modified Stulberg result			Total (hips)	Z	P
	I	II	III			
A type	4 (100%)	0 (0%)	0 (0%)	4	8.924	< 0.05
B type	20 (62.5%)	9 (28.1%)	3 (9.4%)	32		
C type	3 (25%)	5 (41.7%)	4 (33.3%)	12		
Total (hips)	27	14	7	48		

*Patients classed by Herring classification showed significant statistic different.

Figure 2. A 7-year-old boy with a LCPD in Herring B type. a-h is examined at different times as marked in anterior-posterior position. After accepted the conservation treatment for 3 months, the patients finally get a good Stulberg grade. (M = months).

Concerning the Herring Lateral Pillar Sign, 27 hips had a good outcome; classed Herring A and B, 4 hips (100%) and 20 hips (62.5%) were diagnosed as Modified Stulberg I respectively. Children classed as C type tended to present a poor outcome with only 8 hips (66.7%) classed Stulberg I or II and 4 hips (33.3%) classed Stulberg III. Statistical analysis of the association between Herring's and outcome (**Table 4**) using *Kruskal-Wallis*rank sum test, produced a P value < 0.05, which approve the greater different of a favorable outcome (**Figure 2**).

Children presenting in different pathological phase were placed into three groups using Waldenström classification at the time of initial diagnosis. Children classed as fragmentation phase got a poor outcome (0% in good) while the other two groups got modified Stulberg I as 56.5% and 77.8%. This varied in phases are obtained at unless 60 months after their initial diagnosis. The outcome of three example for each group at the different time was demonstrated (**Figure 3**). Statistical analysis of the association between Waldenström classification and Stulberg class, using *Kruskal-Wallis*rank sum test, produced a P value < 0.01 (**Table 5**).

We do a further Nemenyi test to compare among every type in Herring Lateral Pillar Sign classification and Waldenström classification by using *Nemenyi*test (**Table 6**). A and C type in the Herring Lateral Pillar Sign classification are demonstrated to have a statistic different.

Discussion

As for children with LCPD, multiple authors have shown that several conservation treatments, including Scottish rite brace, Newington brace, Toronto brace, Birmingham splint and broomstick plaster, used at disease onset are important measures to delay the progressive of the disease, and Scottish rite brace is the popular one. The goal of such treatments is to obtain a spherical femoral head and matched femoral head-acetabular relationship when skeletal developed [1]. As a self-limited disease, LCPD can obtain a better result when earlier conservational treatment operated [16].

For orthopedic surgeons, classifications were regarded as vital prognostic evaluation methods to clarified what stages the children are and direct to set up the suitable conservation treatments for the suitable ages patients. Many studies had already mentioned these aspects [17]. However, as we can observe, those studies had not addressed the really important aspect of what is the optimal time to have a conservation treatment. Regarding for this, our series tried to combine four usual classifications to evaluate the Scottish rite brace treatment and analyzed the outcomes, so as to guide clinical decision-making.
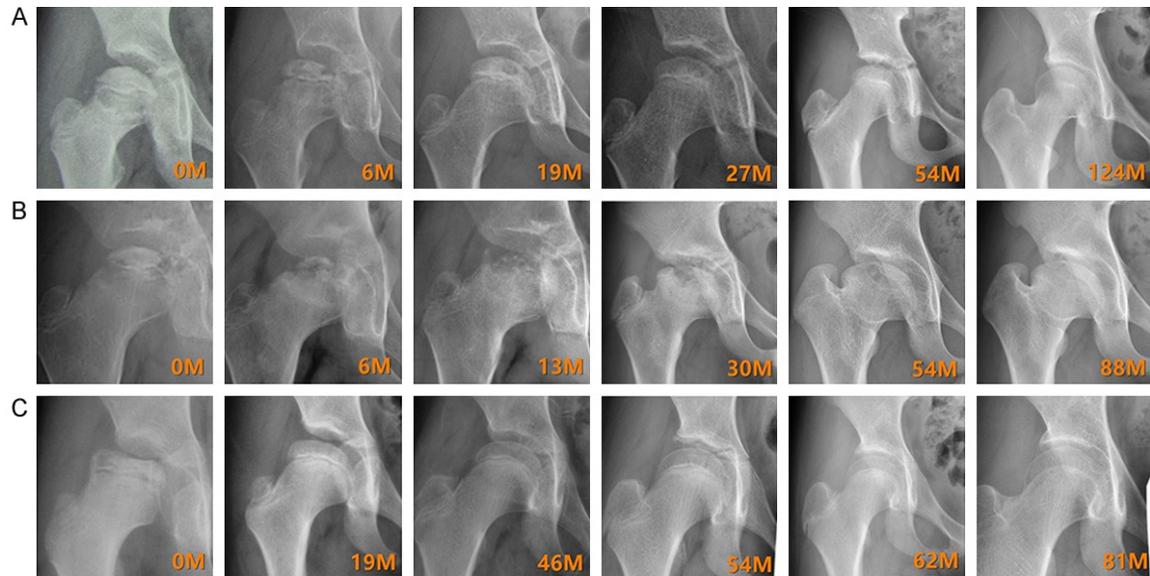
Figure 3. Three different children are defined as necrosis phase, fragmentation phase, re-ossification phase respectively according to Waldenström's. A. 5-year-old boy. Diagnosed as necrosis phase and got a good grade at 88 months; B. 7-year-old boy. Diagnosed as fragmentation phase and got a poor grade at 124 months. C. 8-year-old boy. Diagnosed as reossification phase and got a good grade at 81 months. (M = months; all photos is post by anterior-posterior position).

Table 5. Modified Stulberg result based on the initial classification of Waldenström

Waldenström	Final Stulberg result			Total (hips)	Z	P
	Good	Fair	Poor			
Necrosis	13 (56.5%)	10 (43.5%)	0 (0%)	23	23.349	< 0.01
Fragmentation	0 (0%)	0 (0%)	7 (100%)	7		
Reossification	14 (77.8%)	4 (22.2%)	0 (0%)	18		
Total (hips)	27	14	7	48		

*Patients classed by Waldenström classification showed significant statistic different.

Table 6. Comparison of prognosis based on different Herring and Waldenström classification

Classification		Z	P
Herring	A-B	1.718	> 0.05
	A-C	6.864	< 0.05
	B-C	5.835	> 0.05
Waldenstrom	Necrosis-fragmentation	16.813	< 0.01
	Necrosis-reossification	1.231	> 0.05
	Fragmentation-reossification	22.635	< 0.01

*Patients classed by Herring and Waldenström classification showed significant statistic different.

Firstly, by only considering the age of children, younger one may have a worse result. Studies had mentioned that when patients presenting above 8 years, they can result in a femoral head deformation if they haven't any intervention [7, 18, 19]. Many other studies also recognized that age is a more valuable index in the reossification phase than in the onset of the disease [2, 20]. As our studies shown, children below and above 8 years had 80% and 39.4% of good rate if they accepted the Scottish rite brace treatment. The good rate decreased when the children become older. That meant the Scottish rite brace treatment can fundamentally change the final result in an earlier age. Below 8-year-old may be one of the optimal time in LCPD treatment (**Figure 4**).

In addition, classifications are also needed to be involved. Generally speaking, there are various kinds of important prognostic signs exited. And these ones can be categorized into a number of categories: the osteonecrosis extent involving in the femoral capital epiphysis (Catterall Grouping), the height of lateral pillar (Herring

Figure 4. A boy, 7 years old, accepted scottish rite brace fixation in 40-50 abductionand have weight-bearing exercises in abduction position after brace-divested.

Lateral Pillar Sign), skeletal malformation and lost matched of the hip joint (Modified Stulberg classification) and so on. Besides, Waldenström classification system, based on the pathological stages, represents a dynamic process for LCPD [21]. Although lots of previous studies have already compared the Interobserver and intraobserver reliability of the above classifications in past years, it remains to be clarified which classification is the most efficient one to demonstrate the optimal intervention time for Scottish rite brace treatment. It has to be mentioned that Stulberg classification is utilized when epiphysis completely developed.

With a better reliability, Catterall classification is modified and divided into two group, I & II and III & IV [7]. In the first step of our study, 26% of hips, defined as Catterall I & II, had a good outcome. Only 19% of hips, defined as Catterall III or IV, are classed Stulberg good level while 11 hips had a fair outcome and 10 hips are found to be the poor one. As for Herring's, it got an insignificant different in our study. However,

both the classifications were used widely but there has been some criticism. Because they are focused on the fragment stage and the classification children belonging to is uncertain and changeable with the time passed. Some authors reported that at least 7 months are required from initial stage to fragment stage [22]. Besides, they consistent with many conditions, like the current morphology of femoral head epiphysis and the current height of lateral pillar. So, predicting the outcomes by such kinds of classifications in the exact time of the disease remains difficult. To our knowledge, the first classification of LCPD, also the only staging classification, was described by Waldenström, representing the natural course of the disease [21]. It is also clear that the duration of the fragmentation phase is one year and 3-5 for reossification phase [9]. Perhaps as a consequence, Waldenström's has its natural advantage. In our study, no children classed as fragmentation phase got good or fair outcome contrasted to the other two groups getting a graduate rate as 56.5% and 50%. This significant different demonstrated substantial to an almost perfect agreement between classification and final predicted result. These results indicate that the fragmentation and necrosis phase showed a worse result than reossification one. That might be explained by some authors that necrotic femoral head tends to develop worse in the fragmentation and necrosis phase while being better or worse or remaining unchanged in the reossification one.

There are also some limitations to our research. Our retrospective study could have limited power and may be of insufficient cases to demonstrate an actual difference between the outcomes we evaluated and the optimal intervention time. In addition, there is a potential selection bias, as more patients rejected to accepted other kinds of surgical treatments in the required stages, such as fragmentation stage, and reossification stage. And some patients are likely to confuse the follow-up study, which makes us lose some valuable cases.

Regardless of its unavoidable limitations, our paper is one of the most special research reported in the literature on LCPD patients with long time follow-up and it takes advantage of several kinds of classification in common use to evaluate what is the optimal intervention phase for the Scottish rite brace treatment. In

addition, a number of advises and questions about the classifications had been proposed above in order to predict the treatment clinical effect better. To sum up with, due to the statistically significant difference between different stage of the disease after treatment, we confirm that the suitable intervention in the suitable phase of LCPD is more useful to change the final results of the disease. Waldenström classification, based on a radiographic image, is more predictable in Scottish rite brace treatment selection than other kinds of classifications. To some extent, pathological stages and classification do have their predictive value, but not the absolute indexes.

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Disclosure of conflict of interest

None.

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