International Orthopaedics (2019) 43:1405–1411
https://doi.org/10.1007/s00264-019-04315-z

ORIGINAL PAPER

Radiographic outcome of children older than twenty-four months with developmental dysplasia of the hip treated by closed reduction and spica cast immobilization in human position: a review of fifty-one hips

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Received: 2 August 2018 / Accepted: 15 February 2019 / Published online: 12 April 2019

Abstract

Purpose This study aimed to investigate the radiographic outcomes, rate of redislocation, and avascular necrosis of proximal femoral epiphysis (AVN) in patients aged 24 to 36 months with developmental dysplasia of the hip (DDH) treated by closed reduction (CR) and spica cast immobilization in human position.

Material and methods We reviewed the medical records of 39 patients (51 hips) aged 24 to 36 months with DDH treated by CR and spica cast immobilization in human position. The Tönnis grade, rate of redislocation and AVN, acetabular index (AI), centre-edge angle (CEA), and Severin radiographic grade were evaluated on plain radiographs.

Results Among the included 39 patients (51 hips), 15 hips (29.4%) were Tönnis grade II, 24 hips (47.1%) were grade III, and 12 hips (23.5%) were grade IV. In 47 hips (92.2%), the ossific nucleus was present at the time of CR. Stable reduction was achieved by CR in 39/51 hips (76.5%) and redislocation occurred in 12/51 hips (23.5%). Among the 12 hips that redislocated, 11 underwent open reduction and one repeated CR. Two out of 40 hips (5%) treated by CR developed AVN. Overall, 54.6% of the hips had satisfactory outcomes (39.2% Severin type I and 17.6% type II), while 45.4% had unsatisfactory outcomes (39.2% Severin type III and 3.9% type IV). Of the 40 hips treated by CR, 57.5% and 42.5% of cases had satisfactory outcomes and residual acetabular dysplasia, respectively. Six out of 11 hips (54.6%) treated by open reduction and pelvic osteotomy had satisfactory outcomes.

Conclusions Our study showed that stable CR could be achieved in 76.5% of patients aged 24 to 36 months with DDH at the time of index procedure. Satisfactory outcomes can be expected in 56.4% of the cases (5.0% AVN rate), although late acetabular dysplasia may develop in 43.6% of the hips.

Keywords Developmental dysplasia of the hip · Closed reduction · Redislocation · Avascular necrosis · Proximal femoral epiphysis · Age

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Introduction

The development of the hip joint is a complex phenomenon involving the growth cartilages of both the femoral head and acetabulum simultaneously [1]. Developmental dysplasia of the hip (DDH) is a disorder of the hip joint characterized by an abnormal anatomical relationship between the femoral head and the acetabulum [1–3]. The goal of treatment is to achieve stable reduction of the hip as early as possible and to avoid avascular necrosis of the proximal femoral epiphysis (AVN) [2–5].

Most authors agree that age is an important factor for the selection of treatment [1, 5–7] in patients with DDH. In early reports, several authors reported good outcomes in children with DDH treated by closed reduction (CR), even if children were three years or older at the time of index procedure [8–11]. On the other hand, recent literature, including textbooks, tends to recommend CR and spica cast immobilization in human position for DDH patients younger than 18 to 24 months [1, 4, 5, 7, 12].

However, controversy still exists regarding the effects of age at treatment on the outcome of DDH managed by CR and spica cast immobilization in human position. Some studies have shown that poor outcomes and increased rate of AVN are associated with older ages [13–17], while other reports found that age at treatment had no influence on the incidence of AVN [18–22]. Moreover, although some authors advocate open reduction in patients older than 24 months [7, 12], it has been reported that open surgery is a risk factor for AVN [19, 23, 24].

There is currently no study reporting the outcomes of DDH patients aged 24 to 36 months treated by CR and spica cast immobilization. The current retrospective study specifically reviewed the medical records of patients aged 24 to 36 months with late detected DDH treated by CR and spica cast immobilization in human position. The main objective was to investigate the radiographic outcomes of this patient population and to evaluate the rate of redislocation and AVN following closed treatment.

Materials and methods

After approval from the ethical committee of our institution (GZWCMC number 2015020904), we retrospectively reviewed the medical records of children aged 24 to 36 months with late detected DDH at the time of CR and spica cast immobilization from 2008 to 2015 in five institutions. This study is a retrospective observational study, which is part of our registered study on ClinicalTrials.gov (National Clinical Trial number 02163603).

The inclusion criteria were late-presenting DDH between the age of 24 and 36 months treated by CR and complete clinical and radiographic data with a follow-up for more than 24 months. We excluded the patients with incomplete radiological data and follow-up shorter than 24 months, those with a concomitant diagnosis, such as cerebral palsy, tethered cord syndrome, meningomyelocele, arthrogryposis multiplex congenita, or other neuromuscular diseases, and those whose hips could not be successfully reduced by immediate CR and required open reduction.

We attempted to perform CR in 51 patients (64 hips); 39 patients (51 hips) achieved successful immediate CR. Thus, these 39 patients (36 girls, 3 boys; 51 hips) met the inclusion criteria. There were 27 unilateral (69.2%) and 12 bilateral (30.8%) hip dislocations. The mean age was 26.8 ± 3.1 months (range, 24 to 35.9 months) and the mean follow-up time was 42.6 ± 27.1 months (range, 24 to 148 months). Detailed demographic and clinical data are shown in Table 1.

The modality of treatment was comparable among the five participating institutions. Prior to CR, all patients received longitudinal or overhead skin traction (1.0–1.5 kg) for two weeks. CR was performed under general anaesthesia and arthrogram of the hip was performed in all patients to assess reduction. Adductor tenotomy was performed if the adductor was considered to hinder CR (48 hips; 94%). After stable CR, a spica cast in human position was applied.

Table 1 Descriptive table summarizing the clinical and radiographic characteristics of hips according to outcome

		Value
Patients (hips)		39 (51)
Gender	F/M	36/3
Age (months)		26.8 ± 3.1 (24–35.9)
Follow-up (months)		42.6 ± 27.1 (24–148)
Side	Left	14 (35.9%)
	Right	13 (33.3%)
	Bilateral	12 (30.8%)
Pre AI (degree)		36.3° ± 4.6°
Tonnis grade	II	15 (29.4%)
	III	24 (47.1%)
	IV	12 (23.5%)
Redislocation	Yes	12 (23.5%)
	No	39 (76.5%)
Ossific nucleus	Yes	47 (92.2%)
	No	4 (7.8%)
Final AI (degree)		24.4° ± 7.9°
Final CEA (degree)		20.2° ± 11.0°
AVN	No AVN	47 (92.1%)
	Type II	3 (5.9%)
	Type III	0
	Type IV	1 (1.9%)

F, female; *M*, male; *AI*, acetabular index; *CEA*, center-edge angle of Wiberg; *AVN*, avascular necrosis of the proximal femoral epiphysis (AVN)

Table 2 Outcome according to Severin's classification

	Grade	Overall (%)	Closed reduction (%)	Open reduction (%)
Severin grade	I	20 (39.2)	19 (47.5)	1 (9.1)
	II	9 (17.6)	4 (10)	5 (45.5)
	III	20 (39.2)	16 (40)	4 (36.3)
	IV	2 (4)	1 (2.5)	1 (9.1)
Final outcome	Satisfactory	29 (56.8)	23 (57.5)	6 (54.6)
	Unsatisfactory	22 (43.2)	17 (42.5)	5 (45.4)

Anterior-posterior (AP) pelvis radiograph was performed in the operating room in order to assess the reduction of the hip. Our accepted standard of the reduction was the femoral head reduced into the acetabulum. Other factors, such as inversed labrum and width of medial pooling, were not taken into account. Moreover, in patients those we could not make sure whether the hip was reduced or not, Magnetic resonance imaging (MRI) or computed tomography (CT) was performed within 48 hour post operation to evaluate the position of the hip.

Cast immobilization was continued for three months but a cast change was done routinely after 6 weeks to adjust the cast and check the reduction of the hip. Then, the patients were placed into a rigid, custom-made, abduction brace with the hip flexed and abducted at 90° and 60°, respectively for another six months after cast removal (3-months full-time and 3-months night-time use only).

If redislocation occurred, open reduction was performed through an anterior incision (eight cases); if stable reduction could not be achieved, femoral shortening-derotation osteotomy with plate and screws fixation was added to pelvic osteotomy.

If there was residual hip dysplasia (Severin III/IV) after 2 years, patients were treated surgically.

Radiographic assessment

Patients were evaluated by AP radiographs in neutral position and frog views. Hip dislocation was classified according to Tönnis method [1]. The acetabular index (AI) was measured pre and post-reduction.

The following outcomes of the hips were evaluated on radiographs: (1) redislocation, (2) AVN of the femoral epiphysis, (3) AI, (4) centre-edge angle of Wiberg (CEA), and (5) Severin grade [25]. Redislocation was defined as a loss of initial reduction during follow-up. All measurements were assessed in the medical records and PACS system by two observers (TRY and LYQ) who were blinded to the final Severin classification. Radiographic measurements showed good to excellent inter-observer reliability for AI (intraclass correlation coefficient, ICC = 0.916) and CEA (ICC = 0.878).

AVN of the femoral epiphysis was determined according to the criteria described by Salter et al. [26] and was graded according to the method described by Bucholz and Ogden [27]. Two independent raters (FC and LYQ) evaluated AVN. We grouped type I AVN with the normal hip category because type I AVN is considered a transient ischaemia of the femoral head that can resolve completely [9, 25]. Severin grades I and II were considered satisfactory outcomes, while Severin grades III and IV were unsatisfactory outcomes. If the raters could not come to an agreement on the type of AVN, a discussion with at least three other senior paediatric orthopaedic surgeons was performed.

Statistical analysis

Data were expressed as frequencies and percentages, with the means and standard deviations as appropriate. Statistical analysis was carried out using Student's *t* test and statistical significance was established at $P < 0.05$. All statistical analyses were performed using the statistics package SPSS 22.0 (SPSS, Chicago, IL, USA).

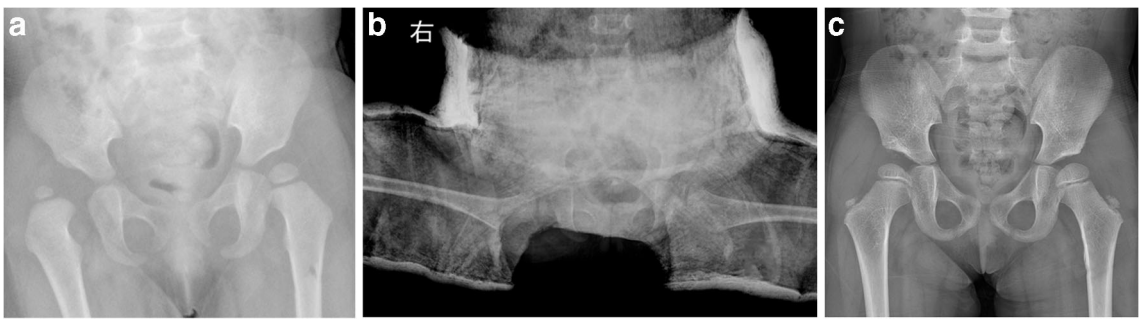

Fig. 1 Twenty-nine-month-old girl with right DDH treated by closed reduction (**a**, **b**). Final radiographic outcome is good (**c**)

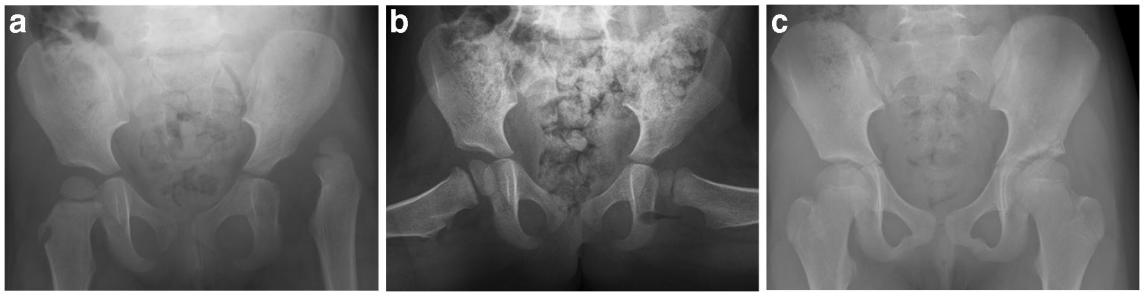

Fig. 2 Thirty-two-month-old girl with right DDH treated by closed reduction (**a**, **b**). Final radiographic outcome is good (**c**)

Results

Among the included 39 patients (51 hips), 15 hips (29.4%) were Tönnis grade II, 24 hips (47.1%) were grade III, and 12 hips (23.5%) were grade IV. At the time of reduction, ossific nuclei had appeared in 47 hips out of 51 (92.2%). The mean AI before CR was 36.3° ± 4.6° (Table 1).

During follow-up, redislocation occurred in 12 hips out of 51 (23.5%). At final follow-up, four hips (7.8%) developed AVN, including three type II and one type IV AVN. The overall mean AI was 24.4° ± 7.9° and the average CEA was 20.2° ± 11.0° (Table 1). Overall, 20 hips (39.2%) were graded as Severin type I, nine hips (17.6%) were type II, 20 hips (39.2%) were type III, and two hips (4%) were type IV. Thus, 56.8% of the hips had satisfactory outcomes, while 43.2% had unsatisfactory outcomes (Table 2).

Thirty-nine out of 51 hips (76.5%) were successfully treated by CR and remained located during follow-up. One redislocated hip (previous adductor tenotomy) underwent repeated CR and stable reduction was achieved. Of these 40 hips, one hip underwent secondary pelvic osteotomy to correct residual hip dysplasia (2.5%) (Fig. 3). AVN occurred in two hips (2/40; 5%). At the final follow-up, 19 hips (47.5%) were graded as Severin type I, four hips (10%) were type II, 16 hips (40%) were type III, and one hip (2.5%) was type IV (Table 2, Fig. 1, and Fig. 2).

Of the 12 hips that redislocated during follow-up (23.5%), 11 hips underwent open reduction: one hip underwent Salter osteotomy alone, two hips underwent Pemberton osteotomy alone, three hips underwent Salter osteotomy and femoral shortening-derotation osteotomy, and five hips underwent Pemberton osteotomy and femoral shortening-derotation (plate and screws fixation). Among the 11 hips that underwent open reduction, AVN occurred in two cases (18.2%). At the last follow-up, one hip (9.1%) was graded as Severin type I, five hips (45.5%) were type II, four hips (36.3%) were type III, and one hip (9.1%) was type IV (Table 2 and Figs. 3 and 4).

AVN rate ($P = 0.367$) and final radiographic outcome (satisfactory or unsatisfactory) ($\chi 2 = 4.256$, $P = 0.137$) did not significantly differ among participating institutions.

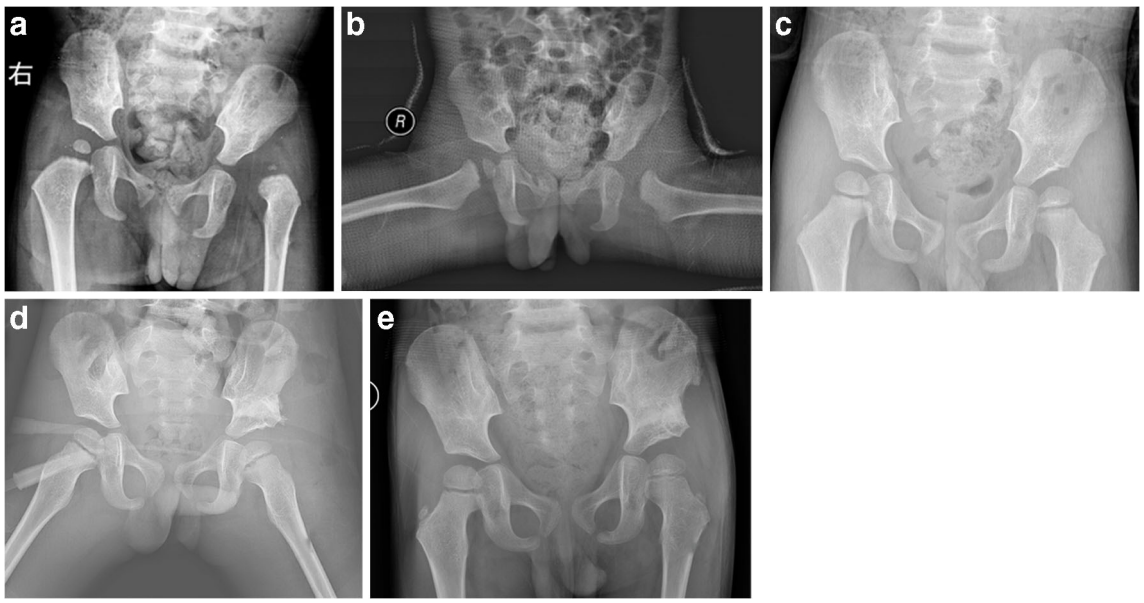

Fig. 3 Twenty-five-month-old girl with left DDH treated by closed reduction (**a**, **b**). Residual dysplasia treated by (**c**, **d**); final radiographic outcome is good (**e**)

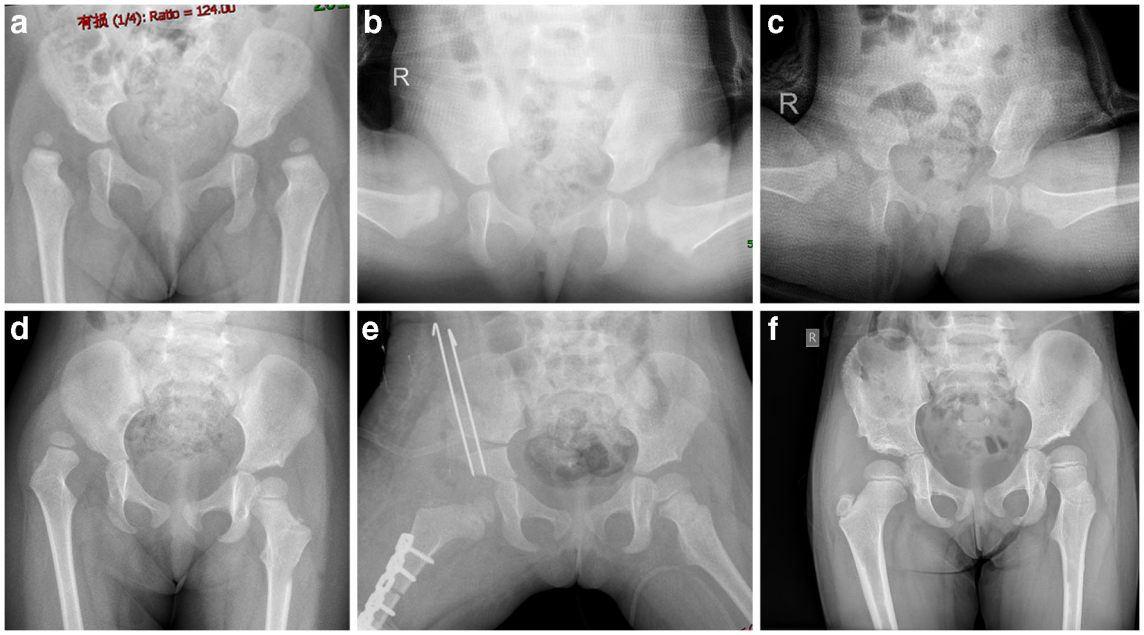

Fig. 4 Twenty-six-month-old girl with bilateral DDH treated by closed reduction (**a**, **b**). Redislocation occurred and cast removed, the left side achieved good reduction (**c**, **d**). Open reduction, pelvic osteotomy, and femoral shortening osteotomy were performed (**e**); Final radiographic outcome is good (**f**)

Discussion

In our present study, the AVN rate in children older than 24 months of age successfully treated by CR was 5%, which is similar to the AVN rate of previous reports, although the reported AVN rate range is variable, from 0 to 67% [3, 18, 28, 29]. However, some studies included large numbers of cases, which could make the reported rate of AVN more reliable. Their reported rate of AVN varies from 10 to 21% [21, 30–32] and the overall AVN rate was 15.8%, which was higher than the present study (7.8% for overall and 5.0% for CR). The overall AVN rate of these studies was 15.8%, which was higher than the present study (7.8% for overall and 5.0% for CR). Additionally, there is still controversy regarding older age as a risk factor for AVN. Although Sibiński et al. [16], Gage et al. [9], Kruczynski [31], and Gregosiewicz et al. [21] have reported that the age at onset of treatment is a risk factor for AVN and its severity, several other studies have found that an older age at reduction has no impact on the incidence of AVN [10, 18–22, 32, 33]. In particular, Kruczynski [31] and Gregosiewicz et al. [21] reported that although the incidence of AVN is higher in older patients, the incidence of more severe AVN is higher in patients younger than 6 months of age, when most of the hip joint is still cartilaginous and ossific nuclei may not have appeared yet [1, 5]. According to our data, it appears that children older than 24 months at the time of CR are not at higher risk of AVN. The lower incidence of AVN in patients older than 24 months may be attributed to the fact that the ossific nucleus has already appeared and had time to develop and increase. At the time of CR, the ossific nucleus was present in 92.2% of hips. Although controversies still exist for some clinicians, many studies show a protective effect of the presence of ossific nuclei on the incidence of AVN [33–35].

In our series of children older than 24 months at the time of CR, 76.5% of hips achieved stable reduction and 56.2% of them had satisfactory outcomes (Severin grades I and II). This means that about half of the patients older than 24 months could obtain benefit from CR without secondary surgery. At present, more authors have advocated for open reduction in all patients older than 24 months due to the reported poor outcomes in this age group [13, 14]. Some studies have shown that older age is a risk factor leading to poor outcomes [13, 14, 36]. In the study of Albinana et al. [36], they found that patients with poor outcomes (Severin III/IV) tended to be significantly older at reduction, regardless of the method of reduction (closed or open reduction). We agree that patients older than 24 months may have poor outcomes when compared with younger patients, but, in our opinion, this does not justify performing open reductions in all patients older than 24 months. Although poor outcome can be partially attributed to older age, age alone cannot explain alone all poor outcomes, as many other factor may influence outcome including amount of abduction and redislocation [3, 5, 33–35, 37]. First, we found that closed reductions in children with late detected DDH older than 24 months did not increase the incidence of AVN. Second, open reduction did not improve the final outcomes when compared with closed reduction. In particular, 11 patients underwent open reduction after failed CR, but only 58.4% of the hips had satisfactory outcomes, which was similar to the patients treated by CR. Third, patients successfully treated by CR are likely to require additional surgery to

address acetabular dysplasia. However, pelvic osteotomy without opening of the joint would provide acceptable clinical and radiological outcomes in most cases, thus reducing the extent of surgery, decreasing the risk of potential complications [37], and shortening the recovery period. In particular, among the hips that achieved stable reduction by CR, 43.6% had residual acetabular dysplasia (Severin grades III and IV), which is in agreement with previous studies. In the study of Albinana et al. [36] mentioned above, they found the prevalence of residual dysplasia increased with increasing age at reduction, and 64% of patients older than 24 months had residual acetabular dysplasia. However, for these patients, surgical correction could be performed using simpler osteotomies with more predictable outcomes [38, 39]. In a study of Chaker et al. [40], 31 patients (35 hips) with residual acetabular dysplasia of the hip were treated by Salter osteotomy alone and 88% of the hips had good outcomes. Similar results were also reported by Faciszewski et al. [41] and Fournet-Fayard et al. [42] and Li et al. [3]. Thus, although the number of secondary pelvic surgeries to address residual dysplasia is potentially higher in patients older than 24 months treated by CR, this does not mean poor functional and radiographic outcomes will always appear. Through secondary pelvic osteotomy, most of the hips can get satisfactory outcomes. However, it should be highlighted that these hips could be treated by closed means and the joints would never need to be opened, which may help to reduce the damages and complications of surgery and improve the function of the hip.

In conclusion, despite the limitations inherent to all retrospective studies, our study shows that stable CR could be achieved in 76.5% of patients aged 24 to 36 months with DDH at the time of index procedure. Satisfactory outcomes can be expected in 56.4% of cases (5.1% AVN rate). Although late acetabular dysplasia may develop in 43.6% of the hips, secondary pelvic surgery without opening the joint usually provides good outcomes in most patients, as reported by previous studies [3, 40–44].

Compliance with ethical standards

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

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

Informed consent No patients were involved. This is a retrospective study of patients' data, and an IRB approval was obtained (GZWCMC 2015020904).

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