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# Open reduction after failed closed reduction following failed Pavlik harness treatment in developmental dysplasia of the hip: One- or two-stage?

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## Abstract

**Introduction** The current published evidence for the treatment of developmental dysplasia of the hip (DDH) with failed closed reduction (CR) following failed Pavlik harness (PH) treatment is still limited. This study aimed to determine whether an one-stage open reduction (OR) would lead to a similar outcome to a two-stage OR in these patients. Meanwhile, the occurrence of femoral head avascular necrosis (AVN) and further surgery (pelvic osteotomy, PO) within the follow-up period was investigated.

**Materials and methods** A consecutive series of DDH patients who failed CR following failed PH treatment and received OR finally between January 2008 and December 2020 were studied. The patients were divided into two groups. One group of which received OR immediately after failed CR (one-stage OR group, Group A), and the other received a delayed OR (two-stage OR group, Group B). The McKay's criteria, acetabular index (AI) and the degree of dislocation of the hips were evaluated for the final outcomes.

**Results** At the last follow-up, 54 (84.4%) of the 64 hips in Group A and 26 (83.9%) of 31 hips in Group B were in excellent or good condition. Comparison between the two groups revealed that there were no differences in terms of McKay grading ($P=0.950$), AI ($P=0.783$), incidence of AVN ($P=0.745$), and also incidence of PO ($P=1.000$). However, a significant lower mean AI was found in Group A, when the OR was performed in Group B ($31.06\pm4.45°$ vs. $33.87\pm4.12°$, $P=0.004$).

**Conclusion** Both of the one- and two-stage OR may acheive favorable outcomes. Moreover, one-stage OR is of without the general anesthesia risk associated with two-stage OR. We therefore advocate that an OR should be performed in appropriate DDH patients during the same session once a failed CR is detected.

**Keywords** Developmental dysplasia of the hip · One-stage open reduction · Two-stage open reduction · Avascular necrosis · Pelvic osteotomy

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## Introduction

Developmental dysplasia of the hip (DDH) is a common developmental deformity of the lower extremity and one of the leading causes of total hip arthroplasty in young people [1, 2]. It is currently accepted that, early detection and Pavlik harness (PH) treatment in infants less than 6 months of age can yield favorable outcomes [1, 3]. While failure of PH treatment are unavoidable. In these patients, a closed reduction (CR) of the dislocated hip is usually firstly considered for further treatment [2, 4]. Unfortunately, failure of CR is still encountered. Thus open reduction (OR) is indicated [1, 5, 6]. However, the timing of OR after failed CR is still not well established.

To our knowledge, previous reports regarding management after failed CR have focused on issues such as the occurrence of femoral head avascular necrosis (AVN), patient's age at intervention, the incidence of further surgery and so on, while few studies specially reported the timing of OR. Accordingly, the corresponding data is still limited. Therefore, in this study, we compared the clinical and radiographic outcomes of OR between two groups of DDH patients with failed CR following failed PH treatment, aiming to determine whether an one-stage OR would lead to a similar outcome to a two-stage OR in these patients. Meanwhile, the occurrence of AVN and further surgery (pelvic osteotomy, PO) within the follow-up period was investigated.

## Materials and methods

In our hospital, a CR is usually attempted in DDH patients with failed PH treatment. When the CR fails, an OR is usually performed during the same session (one-stage OR). Before CR, all legal guardians gave their formal consent for the treatment protocol they would accept after being explained the pros and cons and the potential complications of each method. For those who do not accept one-stage OR, a delayed (two-stage) OR is performed.

### Patients

After the Institutional Review Board approved this study, we retrospectively reviewed the medical records of all DDH patients who were treated with OR between January 2008 and December 2020. The study included a total of 95 consecutive DDH patients who failed CR following failed PH treatment and received OR finally. According to the time when OR was performed, the patients were divided into two groups. Of these patients, 64 cases underwent OR immediately after failed CR during the same operative session, and were designated as the one-stage OR group (Group A). Thirty-one cases underwent delayed OR after several months of consideration of the legal guardians following the failed CR, and were designated as the two-stage OR group (Group B). Inclusion criteria included: (1) diagnosis of DDH, (2) failure of previous CR and PH treatment, younger than 6 months (mean 4 months) when PH treatment started and the duration of treatment was not more than 1.5 months, (3) treated by OR in our hospital within 18 months of age. Exclusion criteria included bilateral DDH, presence of AVN before OR, genetic or neuromuscular disorders, and older than 18 months of age when OR is performed.

The operative techniques were similar as reported in previous studies [7]. Under general anesthesia, a CR combined with percutaneous adductor tenotomy was attempted in all cases, with the aid of arthrography and under fuoroscopic guidance. In Group A, when a concentric and stable reduction of the hip was not achieved, the CR was confirmed failed, and the procedure was immediately converted to OR during the same operative session through an anterior approach using the bikini incision. During the procedure, an iliopsoas tenotomy was routinely performed followed by a capsulorrhaphy including removal of the ligamentum teres and transection of the transverse acetabular ligament to create space for the reduction. Moreover, all of the soft tissue blockage in the acetabular fossa was removed so as to make the reduced hip more stable. In Group B, a delayed OR was performed after failed CR, and the operative techniques were the same as that used in Group A. All reductions were performed by one senior surgeon (J. S.).

After OR, the patients were immobilized in a 1.5 hip cast for six weeks, with the hips 30° fexion and 45° abduction. On postoperative day two, MRI examination was carried out to reconfirm the stable concentric reduction of the hips. After removal of the cast, the patients were required to wear a full-time (24 h/day) abduction orthosis for 12 weeks, and then to wear only at night time for 12 weeks. Patients were followed up regularly every 3-month interval within the first year, 6-month interval within the second year, and then yearly after the surgery up till skeletal maturity of the hips.

### Outcome measures

At the last follow-up, the clinical outcomes were evaluated according to McKay's criteria [8]. In all patiens, the antero-posterior X-ray films taken pre- and postoperatively till the final follow-up were evaluated for the acetabular index (AI), meanwhile, the degree of dislocation of the hips was categorized according to Tönnis grade [9] prior to OR. AVN of the femoral head was assessed using the Kalamchi and McEwen classification system [10], among which only grades II-IV were considered significant and included in the

**Table 1** General characteristics of the study population

| | Group A ($n=64$) | Group B ($n=31$) | F/x$^2$ | $P$ value |
|---|---|---|---|---|
| Age (months) | | | | |
| at failed CR | 8.19 ± 1.42 | 8.10 ± 1.33 | 0.061 | 0.767 |
| At OR | 8.19 ± 1.42 | 15.13 ± 2.08 | 5.711 | 0.000 |
| Sex (male/female) | 9/55 | 6/25 | 0.440 | 0.507 |
| Affected side (left/right) | 36/28 | 17/14 | 0.017 | 0.897 |
| Tönnis grade prior to OR | | | | |
| Grade I ($n$) | 0 | 0 | 1.147 | 0.564 |
| Grade II ($n$) | 11 | 7 | | |
| Grade III ($n$) | 30 | 11 | | |
| Grade IV ($n$) | 23 | 13 | | |
| follow-up duration (months) | 51.68 ± 18.79 | 49.36 ± 17.24 | 0.367 | 0.552 |

*CR* closed reduction, *OR* open reduction

**Table 2** Clinical outcomes evaluated according to McKay criteria

| | Group A ($n=64$) | Group B ($n=31$) | x$^2$ | $P$ value |
|---|---|---|---|---|
| Excellent ($n$) | 34 | 16 | 0.004 | 0.950 |
| Good ($n$) | 20 | 10 | | |
| Fair ($n$) | 9 | 4 | | |
| Poor ($n$) | 1 | 1 | | |

analysis. The incidence of PO were also observed within the follow-up period.

## Statistical analysis

Means and standard deviations were used for normally distributed continuous variables, and the medians were used for non-normally distributed continuous variables. Frequencies were used for categorical variables. Within groups, a paired $t$ test was applied to compare continuous variables, while an independent Student's $t$ test was applied between groups. The chi-square test or the Fisher's exact test was applied to compare categorical variables. A $P$ value less than 0.05 was considered statistically significant. All data were analyzed utilizing IBM SPSS 26.0 (IBM Corp., Armonk, New York).

# Results

All of the 95 unilateral DDH patients were followed. The median follow-up time was 51 months (range 25–93). There were 64 patients in Group A and 31 patients in Group B. No statistically significant differences between the two groups were found in terms of the mean age at failed CR, sex ratio, afected side, Tönnis grade prior to OR and follow-up duration ($P>0.05$). Detailed clinical information of the study population is shown in Table 1.

The clinical outcomes were evaluated according to McKay's criteria. At the last follow-up, 54 (84.4%) of the 64 hips in Group A and 26 (83.9%) of 31 hips in Group B were in excellent or good condition. The difference in the McKay classification between the two groups was not significant ($P=0.950$) (Table 2). At failed CR, the mean AI was 36.19 ± 4.07° and 36.23 ± 4.46° in Group A and Group B respectively, and the difference was found no significant ($P=0.967$). At the last follow-up, the AIs in both groups were significantly improved ($P=0.000$ in Group A and $P=0.000$ in Group B), and no significant difference was found between the two groups (21.13 ± 4.95° in Group A vs. 22.42 ± 4.75° in Group B, $P=0.229$). However, at the time when OR was performed in Group B, the mean AI in Group A was significantly lower than that in Group B (31.06 ± 4.45° vs. 33.87 ± 4.12°, $P=0.004$) (Table 3).

At the final follow-up, according to the Kalamchi and McEwen classification system, AVN of the femoral head was detected in 12 patients (12.6%). Among whom, nine (14.1%) cases in Group A (one case of grade II, four cases of grade III and four cases of grade IV) and in three (9.7%) cases in Group B (one case of grade II, one case of grade III and one case of grade IV). Seven patients (10.9%) in Group A and three patients (9.7%) in Group B underwent PO (Fig. 1). Although the incidence of PO and AVN in Group A were higher than those in Group B, no significant difference was found between the two groups ($P>0.05$). (Table 4).

**Table 3** Acetabular index in the two groups

| | Group A ($n=64$) | Group B ($n=31$) | F | $P$ value |
|---|---|---|---|---|
| At failed CR (°) | 36.19 ± 4.07 | 36.23 ± 4.46 | 0.278 | 0.967 |
| At the time when OR was performed in Group B (°) | 31.06 ± 4.45 | 33.87 ± 4.12 | 0.867 | 0.004 |
| At the last follow-up (°) | 21.13 ± 4.95 | 22.42 ± 4.75 | 0.128 | 0.229 |

*CR* closed reduction, *OR* open reduction

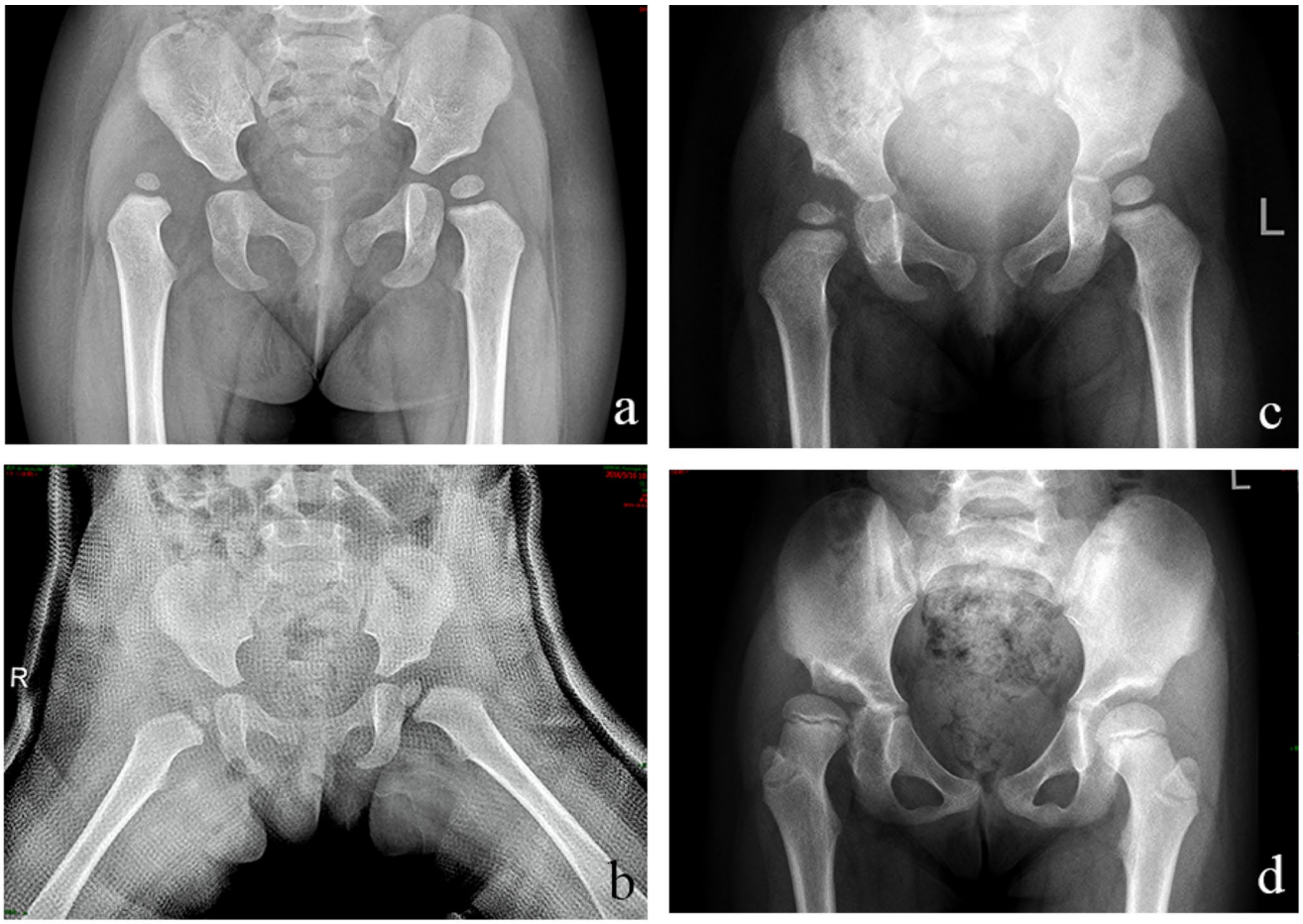


**Fig. 1** (**a**) A 17-month-old girl in Group B with right hip dislocation of Tönnis grade IV. (**b**) Image obtained 2 days after right hip open reduction. (**c**) Image obtained 6 months after open reduction showing AVN of grade I and acetabular dysplasia. (**d**) Follow-up images at 71 months of age showing right hip dysplasia

**Table 4** Occurrence of femoral head avascular necrosis and pelvic osteotomy in the two groups

| | Group A ($n=64$) | Group B ($n=31$) | $P$ value |
|---|---|---|---|
| Avascular necrosis (AVN) | | | |
| Yes ($n$) | 9 | 3 | 0.745* |
| No ($n$) | 55 | 28 | |
| Pelvic osteotomy | | | |
| Yes ($n$) | 7 | 3 | 1.000* |
| No ($n$) | 57 | 28 | |

* Compared using the Fisher's exact test

## Discussion

The fundamental principle of DDH treatment is to achieve a stable and concentric reduction of the hip, so as to provide an optimal environment and facilitate the normal development of all structures of the hip, while avoiding complications such as AVN and early osteoarthrosis [1, 2, 11]. The management for DDH is largely related to the age of the child and the degree of bone deformity. It is generally accepted that the treatment of DDH should be performed as early as possible. The early the reduction, the better outcome. Because younger patients may be associated with a higher remodeling potential of the hip, and that the potential may decline with age. When degenerative joint disease present radiologically, the opportunity for preventative measures has been lost, and surgical intervention is the only option [1, 12]. Studies also demonstrated that early treatment may lead to a less difficult reduction and optimized development of the hip, with less further surgery requirement [11, 13].

OR is the preferred treatment option when CR failed [1, 5, 6, 14]. For patients who failed CR following failed PH treatment, the pathologic changes become more complex with age. Meanwhile, the treatment becomes more difficult [15]. The general trend in the literature is that younger DDH patients may have better outcomes after OR [11, 15–17]. However, the current published evidence for the treatment is still limited, and the optimal protocol for these patients remains unclear. To the best of our knowledge, there have been no published data comparing the efficacy of one- with two-stage OR in these patients up to now.

At the last follow-up, the majority of the patients achieved satisfactory results in both groups. Comparison between the two groups revealed that there were no differences in terms of McKay grading ($P=0.950$), AI ($P=0.783$), incidence of AVN ($P=0.745$), and incidence of PO ($P=1.000$). We therefore concluded that the outcome of one-stage OR was similar to that of two-stage OR. The results were consistent with previous reports [7, 18], also with many other studies concerning one-stage OR with or without femoral or pelvic osteotomy [15, 19–21].

Many authors have demonstrated the remarkable remodeling potential of the hip at early age of life [1, 16, 22, 23], and AI has proven to be the best parameter for evaluating the development of acetabulum, meanwhile associated with the remodeling potential [1, 24]. In the present study, we found a significant lower mean AI in Group A, when OR was performed in Group B. Which may be explained by the improvement of acetabular development following relatively early reduction in the one-stage OR group.

Conflicting evidence exists regarding the timing of OR in relation to the occurrence of AVN. Some authors noted that OR in younger patients is associated with a higher rate of AVN [11, 25–27], while others reported opposite results [13, 28, 29]. Also, there have studies reporting that age at the time of reduction had no effect on the incidence of AVN [30, 31]. Although the optimal timing of OR remains ambiguous, there is an increasing number of surgeons apply OR to treat DDH patients with decreasing age. In a study by Alves and colleagues [32], which is the largest and most comprehensive one to date, surveying DDH evaluation and management preferences among paediatric orthopaedic surgeons, the authors reported that 32% and 13% of the Pediatric Orthopaedic Society of North America (POSNA) members set the minimum age of OR at six months and 12 months, respectively. The corresponding data were 16% and 15% for European Paediatric Orthopaedic Society (EPOS) members. Our results showed that, although no significant difference was found, the incidence of PO and AVN in Group A were higher than those in Group B. However, the overall incidence of AVN in our series was 12.6%, which was relatively lower than that reported by many authors [27, 30, 33–36]. The developmental mechanism of AVN is multifactorial. Besides, for patients who failed CR, it is difficult to accurately attribute the occurrence of AVN to OR [2]. Therefore, further standardized, high-quality evidence is still required to clarify this complex problem.

As is well known, persistent acetabular dysplasia can lead to degenerative joint disease at a young age, and an appropriately selected pelvic osteotomy before any irreversible cartilage damage occurs could provide a biomechanically sound hip joint while prevent premature osteoarthritis of the hip. Several months of consideration of the legal guardians led to a delayed OR in Group B. Our results showed no significant difference regarding the incidence of PO between the two groups. Furthermore, the clinical outcomes including walking function were similar. However, because that the follow-up duration was not long enough, further research will be necessary to ascertain the true association between the time when OR was performed and the eventual outcome.

There are several limitations to this study. First, this was a retrospective study. Second, the sample sizes of Group B was relatively small. Third, this study only included unilateral DDH patients.

In summary, despite the limitations, this is the first study comparing the efficacy of one- with two-stage OR in DDH patients with failed CR following failed PH treatment up to now. Our findings suggested that both of the treatment protocols may acheive favorable outcomes. Moreover, one-stage OR is of without the general anesthesia risk associated with two-stage OR. We therefore advocate that an OR should be performed in appropriate DDH patients during the same session once a failed CR is detected.

**Author contributions** All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Yong Liu, Lisheng Kan, Jie Huang, Jun Sun and Yapeng Zhang. The first draft of the manuscript was written by Lisheng Kan and Yong Liu commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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**Data availability** The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Declarations

**Ethical approval** The Research Ethics Committee of the Affiliated Provincial Pediatric Hospital of Anhui Medical University has confirmed that no ethical approval is required.

**Consent to participate** Written informed consent was obtained from patients.

**Consent to publish** The authors affirm that the parents provided informed consent for publication of the present study.

**Competing interests** The authors have no conflicts of interest to disclose.

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