IJHS

Original Article

Avascular necrosis of the femoral head: Assessment following developmental dysplasia of the hip management

Ahmed F. Al Faleh[1,2], Ayman H. Jawadi[1,3,4,5], Samir Al Sayegh[1,3,4,5], Bander S. Al Rashedan[6], Mohammed Al Shehri[1], Abdullah Al Shahrani[7]

[1]Department of Orthopedic Surgery, King Abdulaziz Medical City, National Guard Health Affairs, Ar Rimaya, 2869, Riyadh 14611, Saudi Arabia, [2]Department of Surgery, King Abdullah Bin Abdulaziz University Hospital, Princess Nourah Bint Abdulrahman University King Khalid International Airport, Riyadh 13412, Saudi Arabia, [3]Department of Surgery, King Abdullah Specialized Children Hospital, National Guard Health Affairs, Ar Rimaya, 2869, Riyadh 14611, Saudi Arabia, [4]Department of Surgery, King Saud Bin Abdulaziz University for Health Sciences, King Abdullah Specialized Children Hospital, National Guard Health Affairs, Ar Rimaya, 2869, Riyadh 14611, Saudi Arabia, [5]King Abdullah International Medical Research Center, National Guards Health Affairs, Riyadh 11426, Saudi Arabia, [6]Department of Surgery, King Saud Medical City, Ulaishah, 7790 Al Imam Abdul Aziz Ibn Muhammad Ibn Saud, Riyadh 12746 3617, Saudi Arabia, [7]Department of Surgery, Al Qassim University, Almulidah, 6688, Qassim, Al Qassim, Buryadh, Saudi Arabia

Address for correspondence:
Ahmed F. Al Faleh, Department of Orthopedic Surgery, King Abdulaziz Medical City, National Guard Health Affairs, Ar Rimaya, 2869, Riyadh 14611, Saudi Arabia. Phone: 00966500691381. E-mail: a.alfaleh90@gmail.com

WEBSITE: ijhs.org.sa

ISSN: 1658-3639

PUBLISHER: Qassim University

ABSTRACT

Objectives: Avascular necrosis (AVN) of the femoral head is a major complication following treatment for developmental dysplasia of the hip (DDH). It is caused by excessive pressure over the femoral head, which compromises its blood supply. The rate of AVN following DDH treatment ranges from 6% to 48%. This study aimed to analyze the rate of AVN in DDH patients following different standard surgical treatments.

Methods: A retrospective cohort study was performed on patients diagnosed with DDH between January 2007 and December 2013. All idiopathic DDH patients who underwent standard surgical treatments were included in the study. Neuromuscular and teratologic patients and patients with previous surgical treatment outside the institute were excluded from the study.

Results: Overall, 204 hips in 143 pediatric patients were included in the study. The majority (84.8%) of the patients were female. Most patients (82.2%) received single treatment. The most commonly used surgical treatment was open reduction with pelvic osteotomy (82.8%). Type 4 Tonnis classification of DDH was found in 62.3% of patients. AVN was found in 14.3% of our study population. The majority (57.1%) of diagnosed AVN patients showed Grade 1 (Kalamchi) AVN classification. Patients who underwent closed reduction and hip spica showed a significantly higher rate of AVN compared to other treatments (14.3%, $P = 0.044$).

Conclusion: Close follow-up of patients treated with closed reduction is mandatory as these patients have the highest risk of AVN. We recommend the introduction of national screening programs targeting all newborn children and including systematic follow-up at well-baby clinics during the early years of life.

Keywords: Avascular necrosis, closed reduction, developmental dysplasia of the hips, hip spica, open reduction, ossific nucleus, pelvic osteotomy

Introduction

Avascular necrosis (AVN) of the femoral head is considered one of the most devastating complications occurring after treatment for developmental dysplasia of the hip (DDH).[1] The main pathology of AVN is excessive pressure over the femoral head, which causes compression or occlusion of the blood supply.[1] The incidence of AVN following DDH treatment ranges from 6% to 48%.[2] Common risk factors of AVN are the degree of hip abduction in the cast, the age of the patient at the time of surgery, and the need for multiple surgeries following failed closed reduction.[3] Reports suggest that immobilizing patients with an abduction brace in more than 60° of abduction increases the risk of AVN.[4,5] One study found that open reduction alone without concomitant osteotomies has a lower risk of AVN compared to open reduction with concomitant osteotomies.[5] Patients requiring secondary surgery have a 14-fold increase in the risk of developing AVN compared to patients who only require single surgery.[5] Moreover, studies have shown that advanced age alone was not considered as a risk factor for AVN, but all patients who required multiple surgeries in those studies were older patients.[5] One study suggested that the appearance of the ossific nucleus (ON) at the time of surgery decreases the rate of AVN.[6] Other studies

concluded that the ON does not play any role in the occurrence of AVN.[7,8] The age of the patient plays an important role in determining the type of treatment since most older children will require open reduction with pelvic osteotomy with or without the need for femoral shortening.[9-11]

The aim of this study was to analyze the rate of AVN in DDH patients following different standard surgical treatments.

Methods

This was a retrospective cohort study of patients diagnosed with DDH between January 2007 and December 2013. We included all DDH patients who underwent standard treatment methods: (1) Closed hip reduction under general anesthesia and hip spica application, (2) open hip reduction, (3) open hip reduction with pelvic osteotomy, and (4) open hip reduction with pelvic osteotomy and femoral shortening osteotomy. In our institute, closed reduction is performed under general anesthesia in the operating room and proper reduction is confirmed by performing arthrography with dye pooling of <5 mm on the medial side of the femoral head. The safe zone of Ramsey was identified and in cases where it was narrow, adductor tenotomy was performed.[12] Patients were kept in hip spica for 3 months and the cast was checked in the 6th week after application. The cast was maintained at 90° of flexion and abduction of no more than 50°. Pemberton pelvic osteotomy was the only osteotomy included in the current study since it was the treatment of choice during the study period. This surgical technique involves changing the coverage of the femoral head by hinging and rotating the acetabulum roof forward, downward, and outward providing lateral and anterior acetabular coverage.[13]

Neuromuscular and teratologic patients, as well as patients who underwent previous surgical treatment outside the institute, were excluded from the study. The data and radiograph results were retrieved from medical records and the electronic medical record system (best-care). The radiological parameters that were investigated were as follows: (1) Tonnis classification of DDH,[14] (2) the presence of the ON at the time of surgery, and (3) the Kalamchi and MacEwen AVN classification.[4] The senior authors reviewed all radiographs. The minimum follow-up was 18 months. The study was approved by the Institutional Review Board at King Abdullah's International Medical Research Center. The requirement for informed consent was waived due to the retrospective nature of the research.

Data were entered into Microsoft Excel (Version 16.12; Microsoft, Redmond, CA) spreadsheets and then managed with SPSS (Version 22.0. IBM Corp., Armonk, NY). Data were presented as frequencies and percentages for categorical data and mean and standard deviation for continuous data. The scores for coping strategies were analyzed as continuous variables. To examine the associations between baseline demographic and clinical characteristics in the diagnosis of AVN, fisher's exact test (as appropriate) was used to examine categorical variables. All *P*-values were two-tailed, and $P < 0.05$ was considered statistically significant.

Results

In this study, 204 hips of patients diagnosed with DDH were reviewed. The majority (84.8%) of the patients were female. The average age at the time of the first visit was 18.0 ± 10.0 months (range 0–56 months) and the average age at the time of management was 25.3 ± 13.9 (range 0–67 months), with an average of 8.9 ± 9.3 months between diagnosis and management [Table 1]. At the time of management, 17.6% of the hips belonged to children in their 1st year of life, 36.3% belonged to children in their 2nd year of life, 30.4% belonged to children in their 3rd year of life, and 15.7% belonged to children in their 4th year of life or greater. The left hip was affected in 52.9% of cases, while the right hip was affected in 47.1% of cases. When both sides were combined, the majority (62.3%) of the hips showed a radiological classification of Tonnis Type 4 followed by Type 3 (27.5%) and then Types 1 or 2 (10.3%). ON of the femoral head appeared in 88.7% of the hips at the first clinical presentation.

The majority of hips (82.2%) received a single type of treatment, while 17.8% received more than one type of treatment. The most common (82.8%) treatment used was an open hip reduction with a pelvic osteotomy, followed by closed hip reduction and hip spica application in 20.6%, open hip reduction with pelvic osteotomy and femoral shortening in 10.8%, hip abduction brace in 2.9%, and finally, open hip reduction and hip spica application in 1.0% of cases.

Of 204 hips, 14 (6.9%) were diagnosed with AVN at the last follow-up [Table 1]. The unilateral right side was the most frequently affected side with AVN (50.0%) followed by the unilateral left side (35.7%) and then both sides (14.3%). Type I AVN, according to the Kalamchi and MacEwen classification, was detected in the majority of the treated hips (57.1%), while Type VI was found in 28.6%.

Table 1: AVN according to Kalamchi and MacEwen classification

Characteristics	*n* (%)
Diagnosis of AVN	14 (6.9)
Side of AVN	
Right side	7 (50.0)
Left side	5 (35.7)
Both sides	2 (14.3)
AVN (All)	
Grade 1	8 (57.1)
Grade 2	1 (7.1)
Grade 3	1 (7.1)
Grade 4	4 (28.6)

AVN: Avascular necrosis

There was a trend toward a more frequent AVN diagnosis among those aged 1 year or less at the time of the first visit compared with those aged older than 1 year at the time of the first visit (13.9% vs. 5.4%, $P = 0.077$) [Table 2]. Similarly, the age at the time of the first visit tended to be younger in those who developed AVN at the follow-up (14.2 ± 10.6 vs. 18.3 ± 9.9, $P = 0.084$). On the other hand, there were no significant associations between the diagnosis of AVN and gender, age at the time of management, affected side, Tonnis classification, or the presence of ON in the femoral head [Table 3]. AVN was significantly more prevalent in patients who underwent closed hip reduction and hip spica application (14.3%) compared to other treatment modalities ($P = 0.044$) [Table 4]. On the other hand, AVN was not detected in our patients who received hip abduction brace treatment, open hip reduction and hip spica application, or open hip reduction with pelvic osteotomy and femoral shortening.

Table 2: Association of AVN with the age of the patient at the time of treatment

Characteristics	AVN *n*=14	*P*-value
Age at treatment (mean±SD, months)		0.173
Age at treatment (months)		
0–12	5 (13.9)	0.077
>12	9 (4.5)	
Age at treatment (mean±SD, months)	20.9±14.3	0.173
0–12	5 (13.9)	0.356
13–24	4 (5.4)	
25–36	4 (6.5)	

AVN: Avascular necrosis, SD: Standard deviation

Table 3: Association of AVN, Tonnis classification, and appearance of the ON

Characteristics	AVN *n*=14 (%)	*P*-value
Tonnis classification of DDH		
Type 1	0 (0.0)	0.736
Type 2	1 (11.1)	
Type 3	4 (7.1)	
Type 4	9 (7.1)	
ON at time of treatment		
Absent	1 (4.3)	>0.90
Present	13 (7.2)	

AVN: Avascular necrosis, DDH: Developmental dysplasia of the hip. ON: Ossific nucleus

Table 4: Association of AVN and type of treatment

Characteristics	AVN *n*=14 (%)	*P*-value
Hip abduction brace	0 (0.0)	
Closed reduction and hip spica application	6 (14.3)	0.044
Open reduction and hip spica application	0 (0.0)	
Open reduction with pelvic osteotomy	10 (5.9)	0.268
Open reduction with pelvic osteotomy and femoral shortening	0 (0.0)	

AVN: Avascular necrosis, DDH: Developmental dysplasia of the hip

Discussion

Complications that follow treatment for DDH treatment vary from minor to severe.[15] AVN is considered one of the major complications following surgical intervention for DDH.[16] The incidence of AVN varies from 0% to 74%, and it varies depending on the age of the patient at surgery and the type of surgical intervention.[15,17] Some surgeons will delay their surgical intervention until ON appears on radiographs to reduce the risk of AVN.[16] In our study, we examined the different types of DDH management reported in the literature and studied the presence of AVN at the last follow-up, which was more than 18 months after surgery.[15] Types of management included closed reduction, open reduction, open reduction with pelvic osteotomy, and open reduction with pelvic osteotomy and femoral osteotomy. Some patients underwent multiple surgical interventions; others received abduction brace treatment before their surgical intervention.

The average age at the time of surgery was 25.3 ± 13.9 months compared to 18.7 ± 2.25 months in a study which was undertaken in Turkey.[18] Another study showed that the mean age at surgery was 25 months.[19] The majority (62.3%) of the patients had Tonnis Type 4 DDH. This finding is different compared to another study, which showed that the majority of their cases were Type 3 followed by Type 4.[18] The main reason could be late presentation to the clinic, leading to higher dislocation and older age at the time of surgery. National screening programs should be implemented to target all newborn children and include systematic follow-up at well-baby clinics during the early years of life.

There were no significant associations between the diagnosis of AVN and gender, age at the time of surgery, affected side, Tonnis classification of DDH, or the presence of ON in the femoral head. Chen *et al*. showed in a meta-analysis that the presence of ON, age at the time of the reduction, and reduction method did not influence the development of AVN.[20]

The most used surgical treatment for DDH was open reduction with a pelvic osteotomy (82.8%). The majority (82.2%) of patients received a single type of treatment, while 17.8% received more than one type of treatment. One important reason why open reduction with pelvic osteotomy is the most common surgery performed is late initial presentation to the clinic. Although most of the patients with AVN underwent single surgical treatment, the AVN rate was not significantly different in patients who underwent single treatment and those who underwent multiple treatments ($P > 0.90$). The surgical treatment that was most frequently associated with AVN was closed reduction and hip spica application (14.3%), and this difference was statistically significant ($P = 0.035$). In a systemic review of seven papers, which included studies that

focused on AVN after closed reduction performed on 538 hips, the incidence of AVN was 10% over a follow-up of 7.6 years (5–18.8 years).[3] Another study of patients treated with closed reduction with a follow-up of 5 years (range 2–19 years) showed that the incidence of AVN was 35%.[21] The higher incidence rate of AVN in this study compared to ours may be related a longer follow-up period.

Conclusion

There were several limitations to our study. First, this study was retrospective and performed in a single center. Second, there was some missing documentation and some patients were lost to follow-up following surgery.

Since most of our study population was diagnosed late after the age of 3 months, early recognition of DDH would help prevent further surgical interventions. This may reduce the risk of AVN and we recommend the implementation of a national screening program. Close attention must be paid to closed reduction (CR) techniques and cast application so that the risk of AVN is minimized.

Study setting

This study was conducted at King Abdullah Specialized Children's Hospital.

Funding and Conflicts of Interest

No funding was received for this research and the authors declare that they have no conflicts of interest.

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