ORIGINAL PAPER

Operative treatment and avascular necrosis of the hip development disorder

Ismet Gavrankapetanović · Amel Hadžimehmedagić ·
Adnan Papović · Elvir Baždar

Abstract

Purpose The purpose of this research was (1) to evaluate the consequences of an operative treatment of hip developmental disorder in children, (2) to evaluate the significance of hip vascular supply in children through indirect radiological signs, such as morphological changes on femoral head, and to classify them with standard classification methods, and (3) to analyse the research results and make a recommendation for the following treatment dilemma: when is the optimal time for an operative treatment of a hip development disorder?

Methods The research is a retrospective and observational analysis based on the classification of indirect radiological signs of local vascular disorder by the Bucholz-Ogden's scale. Materials used for this research are medical records of treated patients at the Clinic for Orthopaedics and Traumatology of the Sarajevo University Clinical Centre. Using a random selection, two groups of 30 patients with hip development disorder were formed. The first group was comprised of patients aged six to 18 months and the second group of patients aged 18–60 months. The medical records used for this research included all necessary anamnestic details and postoperative state treatments with clinical findings and regular radiological check-up findings that include the presence or absence of the ossification nucleus as well as its position. All patients underwent surgery with the same operative technique. Data analysis points include the state at the beginning of the treatment, the postoperative state, the state at discharge as well as control findings that followed the development of the proximal femoral part up to 72 months on average. The analysis covered data such as age, sex, family anamnestic data, clinical findings and radiological findings regarding the femoral head morphology (appearance, size, shape, position and indirect signs showing lack of vascular supply). In addition, data analysis included the types of any previous conservative or operative treatments, the duration of previous conservative treatments and repeated hospitalization.

Results In group 1, 86.6 % were female patients and 80 % in group 2. Family history was positive in 15.6 % in group 1 and 13.3 % in group 2. A total of 51.6 % of all patients started walking on time, while the rest had problems with verticalization. Of all patients, 47 % did not undergo any kind of prior treatment. Only 62.2 % of group 1 patients had ossification nucleus present, while the entire group 2 had it present. Results showed that 24.32 % of group 1 patients had none or minimal signs of avascular necrosis (AVN) while 39.47 % of group 2 had none or minimal signs of AVN; 60.52 % of group 2 patients had signs of AVN.

Conclusion The results of this study show that the performance of a surgical treatment during the age between 12 and 20 months is burdened by the highest percentage of avascular necrosis. Even though AVN can be noticed in other age groups, according to the results of our research, it seems that vascular supply of the hip is the most vulnerable in the period between 12 and 20 months.

I. Gavrankapetanović (✉) · A. Papović · E. Baždar
Clinic for Orthopaedics and Traumatology, Sarajevo University
Clinical Centre, Bolnička 25, 71000 Sarajevo, Bosnia and
Herzegovina
e-mail: ismetcap@ortotrauma.com.ba

A. Hadžimehmedagić
Heart Centre, Sarajevo University Clinical Centre, Bolnička 25,
71000 Sarajevo, Bosnia and Herzegovina

Introduction

Blood vessel branching of the proximal femur by its scheme differs from all other major joints. This scheme changes

during the individual's development, dynamically depending on age. Namely, the caliber, blood flow rate and dominance of certain arteries from the entire network of blood vessels that participate in hip vascularization are not equally expressed in all stages of development. In each successive stage, blood supply is dominated by a different artery that, after a certain period of time, shifts its major role to another artery [1, 2]. Anastomoses between individual arteries are not constant in all stages of development and they represent a great importance for compensatory mechanisms [2].

The disturbance of local arterial blood vessels, at a time when they dominate the blood supply and affect the quality of hip development and maturation, leads to reduced perfusion, and consequently, to the lack of development, ossification and possible osteonecrosis [3].

This study tries to emphasize that the vascularization of the proximal femur can be damaged by surgical and nonsurgical procedures with the aim of correcting the position of luxation of hip elements.

In most cases, the conservative treatment for a hip development disorder involves direct mechanical pressure to the femoral head. This pressure is, in fact, an unrecognized force acting on microcirculation and as such is not yet measurable. Immobilization positions such as internal rotation, abduction and flexion, which are used for bringing hip hinge elements in optimal physiological position in the critical period of development, can lead to permanent residual changes that are seen in advanced stages of life [4]. These changes are called "dormant" changes. Only later, in the period of rapid development, dormant changes become visible in the form of changes to the morphology. Forced positions that are the essence of

conservative therapy lead to changes in the blood flow angle, the permanent deformation of one or more arterial blood vessels, as well as its normal position. The lack of mobility or minimal movements that the child can perform in an immobilized therapeutic position does not contribute to the regional development of existing arterial network branching [5].

Knowing the nature of subluxation and the hip development disorder, as well as knowing the importance of vascularization of the proximal femoral part for vitality of the specific region and its successful development through childhood and adolescence, is a task in which the main problem remains to preserve vitality and functionality of cartilaginous and bone tissue [6, 7]. In addition, there are clear indications defined by orthopaedic standards in which patients select the surgical treatment of developmental hip dysplasia. At the same time, there is increasing debate on which age group surgery should be performed on and whether it should be done in one or two acts [8]. Hips that were supposed to be treated in early childhood, as well as hips treated with ignorance of this problem, often because of vulnerable vascular supply, after completion of growth are subject to the degenerative changes that are being compensated in youth, but in the further evolution represent a disabling factor.

Purpose

The purpose of this research was (1) to evaluate the consequences of an operative treatment of hip developmental disorder in children, (2) to evaluate the significance of hip

Fig. 1 Patient's pre-operative X-rays in *upper row* and postoperative in *lower row*
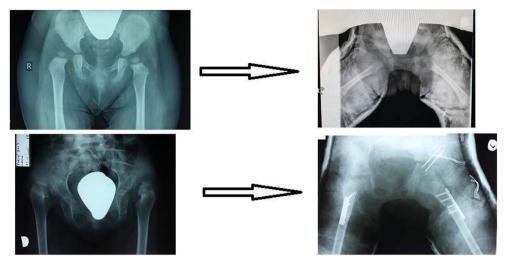
Fig. 2 Patient's X-rays—*upper row* representing preoperative state and state after bloody reposition, *lower row* shows pre-operative state and after operative treatment using an anterior approach

vascular supply in children through indirect radiological signs, such as morphological changes on femoral head, and to classify them with standard classification methods, and (3) to analyse the research results and make a recommendation for the following treatment dilemma: when is the optimal time for an operative treatment of a hip development disorder?

Methods

This research was a retrospective and observational analysis based on the classification of indirect radiological signs of a local vascular disorder based on the Bucholz-Ogden's scale. The Bucholz-Ogden system is a four-point classification system. Type 1 refers to an irregular ossification of the femoral head. No significant growth disturbance occurs and results in a good outcome. Occasionally growth arrest lines may be visualized in the metaphysic that demonstrates that growth is occurring. Type 2 refers to a lateral metaphyseal injury. The femoral neck and head grow in to a valgus position because of a premature lateral physeal closure. With a type 3 injury, the entire metaphysis is affected and the result is a shortened femoral neck. Type 4 refers to a medial growth plate injury where a radiolucent defect is observed along the medial

metaphyseal area. This type of injury results in a varus deformity of the proximal femur. Materials used for this research are medical records of patients treated at the Clinic for Orthopaedics and Traumatology of the Sarajevo University Clinical Centre. Using a random selection, two groups of 30 patients with hip development disorder were made. The first group was comprised of patients aged six to 18 months and the second group of patients aged 18–60 months. The study sample is made up of children with a basic disorder—a hip luxation without cardiac, hepatic, renal or other visceral blood insufficiency that could metabolically, or in other ways, affect eventual changes in bone structure of the femoral head. Medical records used for this research included all necessary anamnestic details and postoperative state treatments with clinical findings and regular radiological check-up findings that include the presence or absence of the ossification nucleus and its position. All patients underwent surgeries with the same operative technique. Operative treatment included bloody reposition and anterior approach to the hip (Smith-Petersen approach). For all patients in the age group between 18 and 60 months operative technique included bloody reposition, osteotomy of the proximal femoral part with abbreviation, varus correction and derotation, and for all of these patients Salter's pelvis osteotomy was performed (see Figs. 1 and 2) [9–11].

Table 1 Summarizing study sample by previous treatment

Risk factor	Group 1	Group 2
Previous treatment	Without previous treatment 36.6 %	Without previous treatment 53.3 %
	Wide diapering 26.6 %	Wide diapering 10 %
	Pavlik's belts 6.6 %	Pavlik's belts 30 %
	Immobilization 6.6 %	Immobilization 3.3 %
	Traction 3.3 %	Traction 3.3 %

Table 2 Classification by groups with presence of avascular necrosis (AVN) as a risk factor

Risk factor: Presence of AVN	Group 1	Group 2
No signs of AVN or mild and reversible signs of AVN	9	
(24.32 %)		
(39.47 %)	15	
Manifest signs of AVN	28	
(75.67 %)		
(60.52 %)	23	

As part of the pre-operative state, all patients underwent clinical examination, hip ultrasound and radiographic diagnostic and none of the patients underwent artrography during preparation state for the surgery [12, 13]. The data analysis includes the state at the beginning of the treatment, the post-operative state, the state at discharge and control findings where we followed the development of the proximal femoral part up to 72 months on average. Analysis covered data such as age, sex, family anamnestic data, clinical findings and radiological findings regarding femoral head morphology (appearance, size, shape, position and indirect signs showing lack of vascular supply). In addition, data analysis included, as well, the types of previous conservative or operative treatments, the duration of previous conservative treatments and repeated hospitalization.

Results

In total, there were 60 patients who underwent surgery for developmental dysplasia of one or both hips between the ages of six and 60 months. Out of 60 patients, only 10 (16.6 %) were male while 50 (83.3 %) were female (a ratio of 5:1). It seems that the use of sophisticated diagnostic and consequent criteria in assessing a child's general development contributes to the stabilization of data on the incidence of this disease.

Research showed that dislocation is predominantly a disease affecting female children, four to ten times more often than male children [14, 15]. Patients were divided into two groups—the first group classified children that underwent surgery between the ages of six and 18 months, while the other group included children that underwent surgery between the ages 1.5 and five years.

Family history refers to the occurrence of a similar or the same disease only among the closest relatives (a sister, brother, father or mother). From the total sample, there was a history in 15 % of the cases; or by groups it was positive in 16.6 % of cases in group 1 and 13.3 % of cases in group 2.

The type of birth and the intrauterine position were correlated with congenital luxation or the existence of a less valuable hip. According to research by Clausen and Nielsen, the breech position carries the risk of dislocation and dysplasia with a rate of 13.3 % [16]. This study addressed the time of delivery, but with incidence of 86.6 % in the first and 93.3 % in the second group on-time delivery dates; there was no statistical significance for further relation of date of birth and eventual development of avascular necrosis.

Starting to walk at an early age, the use of a walker or similar equipment are primary risk factors for the basic disease, but also indirectly affect the occurrence and severity of avascular necrosis due to mechanical movements of luxated joints that stretch the joint capsule, pull the string of iliopsoas muscle and compromise blood circulation in a direct way.

The previous treatment refers to the period between setting up the diagnosis and starting the surgical treatment (see Table 1). Senaran et al. [17] had a hypothesis in his study that the optimal treatment of developmental hip dysplasia can be achieved using Pavlick's belts during the first two months of life, and then, if conservative treatment fails to produce a good result, bloody reposition should be performed no later than three months of age.

All studies that have researched events on hips have registered the importance of the presence of an ossification nucleus
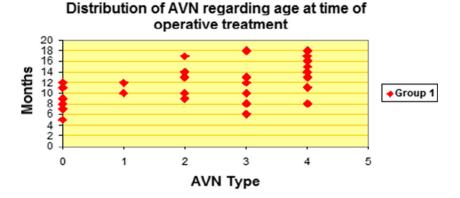
Table 3 Summarizing research sample by Bucholz-Ogden's classification

Type	Localization of compromising vascular supply	Group 1 (37 hips)	Group 2 (38 hips)
0	No noticeable change	No signs of AVN 6 (16.21 %)	No signs of AVN, 10 (26.31 %)
I	Temporary circumferential vascular occlusion	Irregular ossification in secondary centre, 3 (8.1 %)	Normal epiphyseal contour. Slightly reduced height of the head, 5 (13.15 %)
II	Primary occlusion spot exclusively on lateral side	Metaphyseal and epiphyseal irregularities, 7 (18.91 %)	Early fusion of lateral metaphysis and epiphysis, 8 (21.05 %)
III	Temporary circumferential vascular occlusion dominant laterally	Disproportional longitudinal growth of epiphyseal head, 9 (24.32 %)	Irregular formation of femoral head, 7 (18.42 %)
IV	Primary occlusion spot exclusively on medial side	Irregular longitudinal and curved growth, 12 (32.43 %)	Complete head deformity and early epiphyseal closure, 8 (21.05 %)

AVN avascular necrosis

Graph 1 Distribution of
avascular necrosis (AVN)
regarding age at time of operative
treatment in group 1

which indirectly indicates the existence of high-quality vascular supply or guaranteed conditions for progress in the development and maturation of the entire hip [17–19]. In the group of patients aged between 18 and 60 months, in which an ossification nucleus has been present at all stages of the follow-up (100 %), the group that includes patients of up to 18 months of age showed presence of the same in 62.2 %.

To evaluate the success of a surgical treatment of developmental hip dysplasia by Salter, there should be at least one year of postoperative follow-up for indirect signs of the vascular supply disorder of proximal femur to register signs of avascular necrosis (AVN). All patients in this study had a long enough follow-up period up to 72 months on average. Given that follow-up period, the first group of patients enjoyed longer and thus higher-quality follow-up period. From the total sample, there were 24 (32 %) cases with no signs of AVN or only mild and reversible signs of AVN (type 0 and type 1). However, 51 of them (68 %) had manifested signs of AVN at the end of the follow-up period (see Tables 2 and 3).
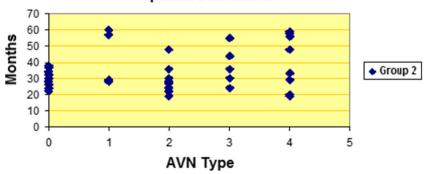
By observing the distribution of AVN in relation to age and time of the surgical procedure, in the first group, the concentration of the worst form of AVN (type IV) for patients who underwent surgery in a period between 12 and 18 months of age is evident (Graph 1). For patients in the second group, we did not form a significant concentration due to a wider range of variables (Graph 2).

Conclusion

Avascular necrosis of varying degrees can also be a complication of the treatment of developmental dysplasia of the hip, which in many cases is characterized by the subsequent development of premature osteoarthritis. Current literature records the frequency of these complications ranging from 0 to 73 %, compared to the variability of diagnosis. This variability has not changed since 1990 when the incidence ranged from 3 to 60 %, which directly depends on the authors, their protocols and the length of the follow-up period. In this study, postoperative complications of AVN were mostly found in children operated for developmental hip dysplasia in the age group between six and 18 months and as contrasted to the group aged between 18 and 60 months, a finding which answers our initial research dilemma—the optimal time for an operative treatment would be in the second group of patients because of their lower incidence of AVN, which is directly connected to the anatomic distribution of the hip vascular scheme. Even though AVN can be noticed in other age groups, according to the results of our research, it seems that vascular supply of the hip is the most vulnerable in the period between 12 and 20 months. The main reason for admitting patients so late is that during war time in Bosnia and Herzegovina there was no screening at all, and since 2004 screening is legally mandatory for all newborns. Also, in our practice it has been noted that

Graph 2 Distribution of
avascular necrosis (AVN)
regarding age at time of operative
treatment in group 2

wrong clinical examination as well as wrong ultrasound interpretation led patients to late admittance in our hospital.

References

1. Kalhor M, Horowitz K, Gharehdaghi J, Beck M, Ganz R (2012) Anatomic variations in the femoral head circulation. Hip Int 22(3): 307–12

2. Grose AW, Gardner MJ, Sussmann PS, Helfet DL, Lorich DG (2008) The surgical anatomy of the blood supply to the femoral head: description of the anastomosis between the medial femoral circumflex and inferior gluteal arteries at the hip. J Bone Joint Surg 90(10): 1298–303

3. Zlotorowicz M, Szczodry M, Czubak J, Ciszek B (2011) Anatomy of the medial femoral circumflex artery with respect to the vascularity of the femoral head. J Bone Joint Surg 93(11):1471–1474

4. Ganger R, Radler C, Petje G, Manner HM, Kriegs-Au G, Grill F (2005) Treatment options for developmental dislocation of the hip after walking age. J Pediatr Orthop B Vol 14(3):139–150

5. Gautier E, Ganz K, Kruegel N, Gill T, Ganz R (2000) Anatomy of the medial femoral circumflex artery and its surgical implications. J Bone Joint Surg 82(5):679–83

6. Hernigou P, Habibi A, Bachir D, Galacteros F (2006) The natural history of asymptomatic osteonecrosis of the femoral head in adults with sickle cell disease. J Bone Joint Surg Am 88(12):2565–2572

7. Drescher W, Li H, Lundgaard A, Bunger C, Hansen ES (2006) Endothelin-1-induced femoral head epiphyseal artery constriction is enhanced by long-term corticosteroid treatment. J Bone Joint Surg Am 88(3):173–179

8. Remmel E, Schraml A, Stauner K, Schuh A (2008) Long-term results after two-stage operative treatment of late developmental displacement of the hip. Int Orthop 33(4):1095–1100

9. Okano K, Yamada K et al (2009) Long-term outcome of Ludloff's medial approach for open reduction of developmental dislocation of the hip in relation to the age at operation. Int Orthop 33(5):1391–1396

10. Kamath SU, Bennet GC (2005) Re-dislocation following open reduction for developmental dysplasia of the hip. Int Orthop 29(3): 191–194

11. Gavrankapetanovic I, Cobeljic G et al (2007) Developmental dysplasia of the hip in cerebral palsy—surgical treatment. Int Orthop 31(4): 561–568

12. Sibinski M, Adamczyk E et al (2012) Hip joint development in children with type IIb developmental dysplasia. Int Orthop 36(6): 1243–1246

13. Rakovac I, Tudor A et al (2011) New "L value" parameter simplifies and enhances hip ultrasound interpretation in the detection of developmental dysplasia of the hip. Int Orthop 35(10):1523–1528

14. Staheli LT (2007) Developmental hip dysplasia in fundamentals of the pediatric orthopedics. Williams & Wilkins, Lippincot, pp 208–219

15. Williams H, Johnson KJ (2005) Developmental dysplasia of the hip. In: Imaging of the hip and bony pelvis. Birkhauser, pp 107–141

16. Clausen I, Nielsen KT (1988) Breech position, delivery route and congenital hip dislocation. Acta Obstetricia et Gynecologica Scandinavica 68(7):595–597

17. Senaran H, Bowen JR, Harche HT (2007) Avascular necrosis rate in early reduction after failed Pavlik harness treatment of developmental dysplasia of the hip. J Pediatr Orthop 27(2):192–197

18. Aaron RK, Dyke JP, Ciombor DM, Ballon D, Lee J, Jung E, Tung GA (2007) Perfusion abnormalities in subchondral bone associated with marrow edema, osteoarthritis and avascular necrosis. Ann NY Acad Sci 1117:124–137

19. Connolly P, Weinstein SL (2007) The course and treatment of avascular necrosis of the femoral head in developmental dysplasia of the hip. Acta Orthop Traumatol Turc 41(1):54–59