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The Rational Strategies for Detecting Developmental Dysplasia of the Hip at the Age of 4–6 Months Old Infants: A Prospective Study

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A B S T R A C T

Using ultrasound in evaluation of infant's hip development can reduce surgical procedures, hospitalization and late presentation of developmental dysplasia of the hip (DDH). The increasing incidence of DDH after ultrasound examination is observed and published by many authors. In a prospective study, radiograph of every single ultrasonographic positive hip in infants older than three months, was taken and analyzed in order to see whether it affects infants splintage rate in treating DDH. In a period of 30 months, clinical and simple static ultrasonographic examinations according to Graf were performed on 1430 consecutive infant hips in patients aged between 4 and 6 months. Sonographic positive hips were radiographed and acetabular index (AI) values on simple AP radiographs were analyzed. The sonographic DDH incidence was 51.75 per 1000 hips (51.75‰). After X-ray examination of all 74 ultrasonographic positive hips, only 44 remained abnormal and required treatment indicating a true DDH incidence of 30.77 per 1000 hips (30.77‰). The difference in incidence per ultrasonographic and X-ray positive hips is statistically significant p <0. 01 (t=5,536). The rational approach in detection of DDH in a child more than 3 months old is to do radiographic assessment of every sonographic positive hip.

Key words: *dysplasia, congenital hip, ultrasonography, radiographic, diagnosis*

Introduction

According to our experience, using ultrasound (US) in evaluation of infant's hip development can reduce surgical procedures, hospitalization and late presentation of developmental dysplasia of the hip (DDH). There are many reports in recent literature that general or selective ultrasound neonatal hip screening is the most effective way to detect DDH[1–6].

As our hospital, Clinic for Orthopaedic Surgery Lovran, has been not directly connected to the delivery unit in our region, we have been dealing with newborns in extremely rare cases.

Most infants that are referred from pediatricians to our outpatient clinics for hip assessment are between 3 and 6 months old.

In the evaluation of every infant's hip two methods are used: clinical and ultrasound examination. We have been using ultrasound as the imaging method in the diagnosis of DDH for many years. Very soon we have observed increasing number of DDH cases and splintage rate as well; especially Pavlik harness applications.

The increasing incidence of DDH after ultrasound examination is instituted, observed and published by many authors[7,8]. The basic problem is a potential damage of the hips that may be caused by overdiagnosis and subsequently overtreatment[7,9–11]. We must be aware of the psychological and financial aspects of such treatments as well[12].

There is a doubt that we are able to begin with the harness treatment on the ground of ultrasonographic hip findings alone or positive ultrasound hip findings need to be assessed by X-rays to be sure that the hip is not well developed.

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The aim of our prospective study is radiographic assessment of every single ultrasonographic positive hip in infants aged from 4 to 6 months in order to see whether it affects infant splintage rate in treating DDH.

Material and Methods

From March, 2003 until September 2005, 715 infants between 4 and 6 months of age were evaluated by single experienced clinician. They were referred by pediatricians to our outpatient clinic for additional hip assessment. Clinical and simple static ultrasonographic examinations according to Graf were performed on 1430 consecutive infant hips. For the purpose of our investigation we simplified Graf's method of infants hip sonograph interpretation[13] (Table 1).

After ultrasound evaluation, hips presented with alfa angle more than 60° and clearly sharp bony angle were classified as Graf I A and were dismissed as healthy hips requiring no further treatment or observation. Hips that were sonographically presented with no matter of absolute value of alfa angle but round or steep bony angle were classified in any of all other Graf? groups (I B–IV). These hips were suspected on DDH and were real subject of our study.

The decision for further hip diagnostic evaluation was based solely on ultrasound findings. Such sonographic positive hips were radiographed and acetabular index value (AI) on the simple AP radiograph was analyzed. If radiographic assessment of the hip confirmed ultrasonographic findings, infants were treated by Pavlik harness. Estimation of pathological border of AI varies according to literature[14,15,16]. In our study we considered values of AI of 30° and more measured on AP infants hip radiograph to be pathological (two standard deviations from average values of infants aged from 3 to 6 months old)[14]. As 30° is not generally accepted as the border angle important for treatment decision, we took into account also AI hips measuring of at least 31° and of at least 32° as well to see whether this fact could affect our treatment protocol. However, in our study, hips measuring 30° of AI and more were treated.

The correct position of the infant during the radiographic imaging is important for evaluating geometrical parameters of the hip joint and AI values as well[16].

Therefore, after radiographic hip assessment of all ultrasound positive hips (infants), two consecutive groups were formed: the group of sonographically DDH positive but X ray negative hips (infants) – named ultrasound DDH group; these hips (infants) were not treated but observed at least until the age of one year. Ultrasound and X ray positive hips (infants) formed the second group – named real DDH group; they were treated by Pavlik harness.

We calculated DDH incidences for ultrasound DDH and real DDH groups taking into accounts hips and infants separately. According to our experience and taking literature into consideration as well, when measuring alfa angle on the infant hip sonograph at least few degrees +/– can easily be mistaken[17]. For this reason we took four degrees like border values of alfa angle; an example: 48°, 49°, 50° and 51° were border angles important for differentiation between groups II and III. Calculating border sonographic alfa angles we tried to see how many hips could be classified in two border types or groups of hips at the same time.

In statistical analyses we compared all data obtained from the ultrasonographic screening hips (infants) and X ray examination hips (infants). STATISTICA version 6.1 (Stat Soft Inc.) was used for all calculation. The following tests were applied: descriptive statistic and difference between proportions. A level of $p<0.05$ was defined as the statistically significant item. Graphic presentations were performed by using Microsoft Excel.

Results

By ultrasonographic screening of 1430 hips we detected 74 instances of deviation from normal, indicating the sonographic DDH incidence of 51.75 per 1000 hips (51.75‰). After X-ray examination of all ultrasonographic positive hips (74), only 44 hips remained abnormal and required treatment indicating a true DDH incidence of 30.77 per 1000 hips (30.77‰). All others evolved into normal hips, and no additional instances of DDH were found on the follow-up throughout the period of 12 months. If we considered AI of at least 31° or 32° as pathological value, the incidence would be even lower (Figure 1).

The difference in incidence per ultrasonographic and X-ray positive hips (AI≥30°) is statistically significant

TABLE 1
SIMPLIFIED ULTRASONOGRAPHIC TYPING OF THE HIP-READINGS BY GRAPH (AT THE AGE OF 4 MONTHS AND MORE)

Type	Acetabular osseous formation	Osseous process (bone angle)	Acetabular cartilaginous roof	Alfa angle°
I A	good	sharp angle	narrow-covers femoral head	>60
I B	good	round	broad-covers femoral head	>60
II B	insufficient	round	broad-covers femoral head	50–59
II C	insufficient	round	broad-covers femoral head	43–49
III (decentred hip)	poor	steep	Pushed	<43
IV (dislocated hip)	poor	steep	Pushed	<43

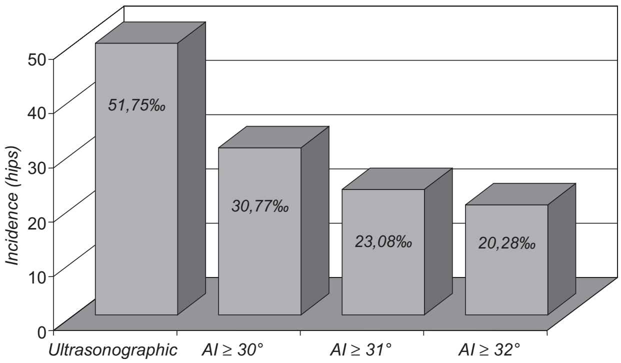

Fig. 1. The incidence of DDH based upon the ultrasonographic findings and various acetabular angles values (for hips).

p<0.01 (t=5.536). If AI of at least 31° is taken as pathological, the difference in incidence per hips is statistically significant t=6.5 p<0.01. If 32° is taken as pathological, the difference in incidence per hips is statistically significant t=6.82 p<0.01.

Observing patients on the ground of ultrasonographic findings only, we would have treated 41 patients – incidence 57.34 per 1000 (57.34‰). After X-ray evaluation we finally treated 28 patients – real incidence in our material was 39.16 per 1000 patients (39.16‰). If we considered AI of 31° or 32° as border pathological value the incidence would be even lower (Figure 2).

The difference in incidence per ultrasonographic and X-ray positive patients (really treated patients) is also statistically significant p=0.0001 (t=3.64). If AI of at least 31° is taken as pathological, the difference in incidence per patient is statistically significant t=4.297 p<0.01. If AI of at least 32° is taken as pathological, the difference in incidence per patient is statistically significant t=4.536 p<0.01.

The comparison of every ultrasonographic positive hip with its radiographic assessment value (all three AI values are considered to be pathological) is presented in Table 2. Ultrasonographic negative hips (Graf I A), which are radiologically examined by chance due to contralateral pathology, are also presented in Table 2.

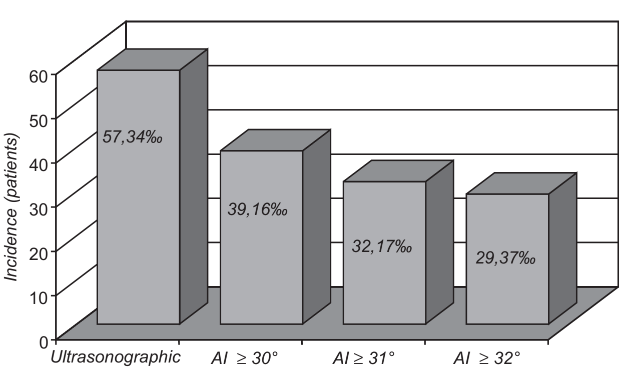

Fig. 2. The incidence of DDH upon to ultrasonographic findings and various acetabular angles values (for patients).

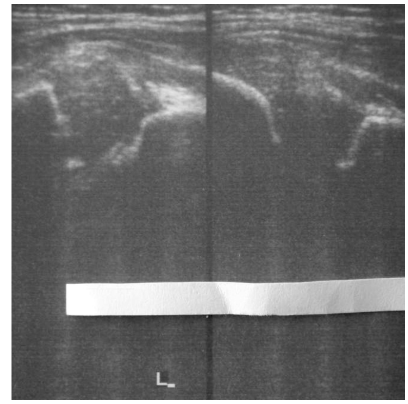

Fig. 3. Unexpected result: 4 months old girl a) Ultrasound – Graf 1 A dex, Graf II C sin (L) b) Radiograph – AI dex (D=34°, AI sin=42°.

From sonographic Graf I A group 8 hips (8 patients) were extracted and 2 of them were treated (25%). One of these treated cases is presented on the Figures 3a and b. From sonographic Graf I B group 28 hips were extracted and 10 of them were treated (35.71%). From sonographic Graf II B group 31 hips were extracted and 20 were treated (64.52%). From sonographic Graf II C group 9 hips were extracted and 7 were treated (77.78%). From sonographic Graf III group 6 hips were extracted and 5 were treated (83.33%). This untreated case is presented on Figure 4a and b.

If considered AI of at least 31° as pathological value of X-ray hip findings from sonographic Graf I A group 1 hip (12.5%), Graf I B 8 hips (28.6%), Graf II B 15 hips (48.4%), Graf II C 4 hips (14.4%) and from Graf III group 5 hips (33.3%) would be treated.

If considered 32° acetabular angle as border pathological value, number of hypothetically treated hips are as follows: 1 hip (12.5%) from Graf I A, 7 hips (25%) from Graf I B, 13 hips (41.9%) from Graf II B, 4 hips (44.4%) from Graf II C, and 4 (66.7%) from Graf III group. All these possibilities are presented on Figure 5.

There are 15 (25.42%) border α angle hips (58°, 59°, 60°, 61°) out of 58 (total number of hips in I B and II B);

TABLE 2
ULTRASONOGRAPHIC (US) HIP VALUES AFTER READINGS
BY GRAF ARE COMPARED WITH X-RAY FINDINGS FOR EVERY SINGLE US POSITIVE PATIENT

	Hip according to Graf(α°)	AI value/ °	AI ≥30°	AI ≥31°	AI ≥32°
1.	III(40) T	35	RT	T	T
2.	III(42) T	34	RT	T	T
3.	III(40) T	35	RT	T	T
4.	III(42) T	38	RT	T	T
5.	III(42) T	31	RT	T	N
6.	III(42) T	27	RN	N	N
7.	II C(49) T	28	RN	N	N
8.	II C(48) T	38	RT	T	T
9.	II C(48) T	30	RT	N	N
10.	II C(49) T	30	RT	N	N
11.	II C(49) T	36	RT	T	T
12.	II C(48) T	30	RT	N	N
13.	II C(47) T	27	RN	N	N
14.	II C(49) T	42	RT	T	T
15.	II C(49) T	34	RT	T	T
16.	II B(54) T	31	RT	T	N
17.	II B(53) T	28	RN	N	N
18.	II B(58) T	34	RN	T	T
19.	II B(59) T	26	RN	N	N
20.	II B(52) T	33	RT	T	T
21.	II B(52) T	33	RT	T	T
22.	II B(50) T	31	RT	T	N
23.	II B(58) T	30	RT	N	N
24.	II B(52) T	32	RT	T	T
25.	II B(54) T	32	RT	T	T
26.	II B(56) T	30	RT	N	N
27.	II B(50) T	36	RT	T	T
28.	II B(52) T	46	RT	T	T
29.	II B(52) T	30	RT	N	N
30.	II B(56) T	30	RT	N	N
31.	II B(54) T	24	RN	N	N
32.	II B(56) T	28	RN	N	N
33.	II B(58) T	24	RN	N	N
34.	II B(59) T	24	RN	N	N
35.	II B(50) T	24	RN	N	N
36.	II B(50) T	30	RT	N	N
37.	II B(54) T	30	RT	N	N
38.	II B(54) T	20	RN	N	N
39.	II B(50) T	37	RT	T	T
40.	II B(56) T	26	RN	N	N
41.	II B(54) T	36	RT	T	T
42.	II B(52) T	38	RT	T	T
43.	II B(58) T	34	RT	T	T
44.	II B(58) T	26	RN	N	N
45.	II B(56) T	37	RT	T	T
46.	II B(58) T	34	RT	T	T
47.	I B(68) T	25	RN	N	N
48.	I B(63) T	20	RN	N	N
49.	I B(63) T	20	RN	N	N
50.	I B(70) T	24	RN	N	N
51.	I B(68) T	18	RN	N	N
52.	I B(64) T	31	RT	T	N
53.	I B(64) T	21	RN	N	N
54.	I B(63) T	30	RT	N	N
55.	I B(60) T	22	RN	N	N
56.	I B(72) T	36	RT	T	T
57.	I B(62) T	19	RN	N	N
58.	I B(68) T	20	RN	N	N
59.	I B(68) T	18	RN	N	N
60.	I B(68) T	32	RT	T	T
61.	I B(68) T	22	RN	N	N
62.	I B(60) T	24	RN	N	N
63.	I B(60) T	30	RT	N	N
64.	I B(64) T	27	RN	N	N
65.	I B(61) T	26	RN	N	N
66.	I B(64) T	22	RN	N	N
67.	I B(66) T	22	RN	N	N
68.	I B(60) T	32	RT	T	T
69.	I B(60) T	32	RT	T	T
70.	I B(80) T	24	RN	N	N
71.	I B(74) T	23	RN	N	N
72.	I B(62) T	32	RT	T	T
73.	I B(62) T	34	RT	T	T
74.	I B(60) T	32	RT	T	T
75.	I A(68) N	21	RN	N	N
76.	I A(65) N	19	RN	N	N
77.	I A(74) N	22	RN	N	N
78.	I A(74) N	34	RT	T	T
79.	I A(70) N	30	RT	N	N
80.	I A(72) N	27	RN	N	N
81.	I A(74) N	20	RN	N	N
82.	I A(68) N	22	RN	N	N

N and T – hypothetically nontreatement and treatement according to ultrasound and different AI values (X-ray), RT and RN – hips that were really treated or not treated in our material

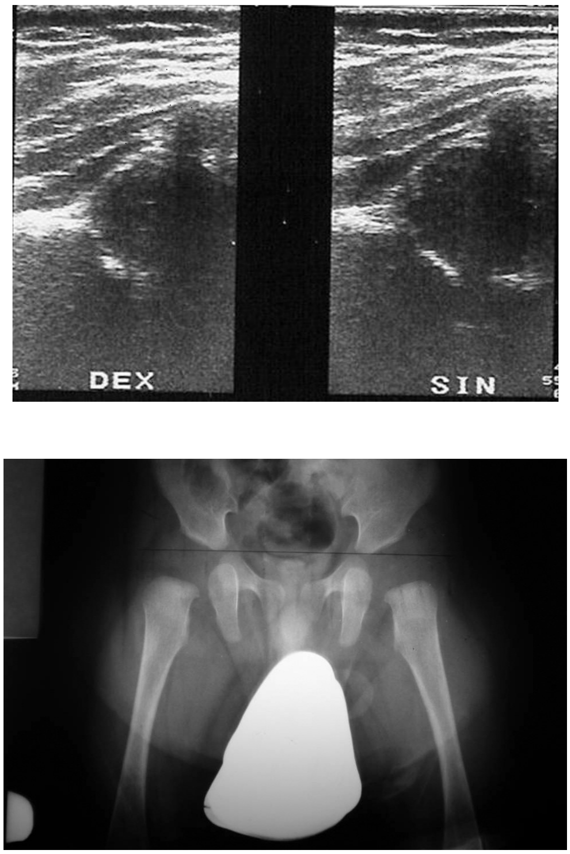

Fig. 4. Unexpected result: 4.5 months old boy a) Ultrasound – Graf III sin, Graf II B dex b) Radiograph – AI sin=27°, AI dex=26°.

13 (32.5%) hips with border α angle out of 40 (total number of hips in II B and II C) and 4 (26.67%) border α angle hips out of 15 (total number of hips in II C and III). The relationship between border α angle hips and other hips are shown on Figure 6.

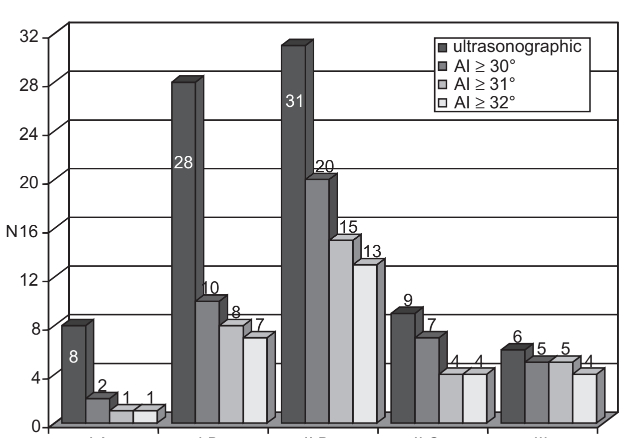

Fig. 5. Relationship between hips that are grouped according to Graf (ultrasound positive) and hips that would be treated according to different acetabular angle values (rtg positive). Red columns denote hips that were really treated. Hips that belong to Graf I A are found by chance (contralateral pathology).

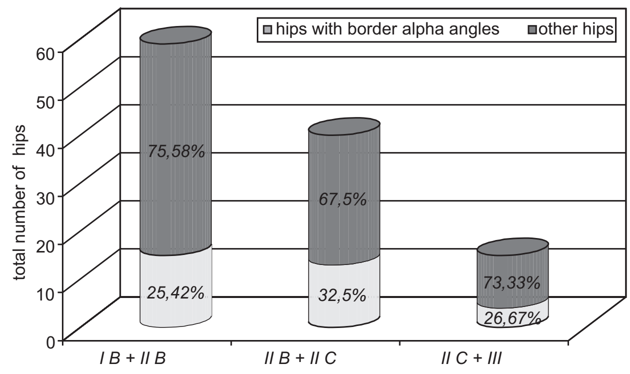

Fig. 6. Hips with border alfa angles.

Discussion

Generally speaking, the goal of DDH diagnostic strategy is to detect all cases at an early age and at reasonable cost without overdiagnosis[18]. Theoretically, the final result should be the elimination of the late cases that can be »disastrous« for the patient[19]. According to some authors, the general (nonselective) ultrasound neonatal hip screening will eliminate late presentation of DDH and failure in diagnosing the cases of DDH which may be considered as malpractice[20]. Nowadays, the general ultrasound neonatal hip screening is introduced as a standard procedure in many countries[8,21]. Furthermore, it is usual practice that ultrasound plays a key role not only for screening of DDH but for monitoring the whole harness treatment as well[22–25]. But there is another side of this »ideal« treatment that could eliminate late diagnoses of DDH. It is overtreatment[26] and the fact that late cases can not be eliminated so far[8,19,27–33]. Even more, the author of the recent study on this issue concluded that in spite of using current diagnostic techniques, the late presentation of DDH can be minimized but not eliminated[34].

The world widely accepted ultrasonographic infant hip evaluation method according to Graf is being used in our study. In spite of the original Graf's opinion that only I A type of hip is entirely well developed[13], some authors indicate harness treatment for infants hips that are typed according to Graf as II B or even II C and more severe developed hips[22,23]. The results of our study show that indication for harness treatment in infants older than three months should not be based exclusively on the ultrasonographic findings. We considered interpretation of Graf's classification as basic problem in every day orthopaedic practice because the indications for treatment, according to the same classification, are not clearly defined. In our opinion it is clear that drawing lines and angles measurement on the infant hip sonograph or radiograph is not geometry. It can not be precise on the infant hip sonograph particularly due to a lack of specific landmarks in the definition of bony angle. Graf's method is mostly based on measurement of the absolute size of alfa angle[1] and it is easy to measure it when bony angle (osseous process) is sharp (I A group). The question is how this measurement can be free from error when bony angle is less or more round (I B – all other groups)? For that reason the measurement of α angle value of few degrees more or less is likely, and it is understandable that some hips can be at the same time classified in different, border groups or types. It is of a great importance in everyday practice because, for example, the hip with measured α angle of 48° or 51° may be easily classified as II B or II C. The point is that such a hip is dysplastic or, in our opinion; suspected on DDH. Few research workers have confirmed our theses about the reliability of the ultrasonographic evaluation of infant hips[17,35,36].There was an unsatisfactory level of interobserver and intraobserver agreement that made different assessments and measurements on which Graf based his classification; according to these results, static scans cannot be used with confidence either for screening or for monitoring treatment[35]. Better repeatability and reliability on Graf's α and β angles were found in another study but their clinical relevance have been poor[17]; the similar conclusion of the third study is that the standard ultrasound measurements on the static infant hip sonograph do not correlate with the clinical and radiographic outcome[36]. Our results also suggest that the accuracy of Graf's classification into groups and types is at least questionable: according to the previously mentioned criteria in our material, there were many hips that could be classified at the same time in two adjacent groups (Figure 6).

We can not agree with authors who considered radiographic assessment of infants hips useless[37]; the results from our prospective study show the opposite: 44 hips after radiographic evaluation of 74 ultrasonographic positive hips were treated eventually; in other words, 30 hips did not need unnecessary treatment.

Recent literature shows that there are authors with similar approach: physical and ultrasonographic examination must be supplemented by radiographic evaluation of an infant's hip[2,34]. Radiographs are indicated when developmental dysplasia of the hip is suspected in any child more than three months old[38]; this suspicion was based solely on positive clinical findings. We agree that radiographic assessment of infant's hip, suspected on dysplasia, at that age is very important. In our material clinical examination of 74 ultrasonographic positive his revealed unilateral limited abduction in five hips and absence of all other relevant clinical signs. Further radiographic evaluations of all these five hips were positive on DDH. It confirms limited hip abduction, among all other clinical signs, to be the most significant in detecting DDH[39,40].

In our study we basically considered any infant hip sonograph that is not classified as I A according to Graf to be suspected on DDH. Our results definitely indicate that ultrasound is too sensitive method in detecting DDH. By ultrasonographic evaluation DDH incidence was 51.75‰ (per hips) and this was significantly diferent from the DDH incidence after radiologic assessment – 30.77‰ (per hips). If we considered AI of 31° or 32° as border pathological value, the incidence would be even lower (Figures 1 and 2). There is no high degree of conformity between sonographic and radiographic infant hip assessment in diagnosing of DDH in any Graf's sonographic group, except in group III. The highest level of agreement between two methods of infant's hip examination for group III has been found (83.33%) and the least for group I B (35.71%) (Figure 5). Reviewing literature we have found the similar result: some hips classified as II A, II B and II C was normal on radiographic examination[41].

Furthermore, eight hips that were found ultrasographically normal were incidentally submitted to X-rays because of contralateral pathology and two of them were positive. Radiographic analysis showed AI value for one hip 30° and for another 34°. We can assume that in some cases acetabular angle of 30° is not high enough for splintage treatment decision but in our opinion AI value of 34° could be high enough for everyone. This result is very interesting because hips that belong to Graf's group I A should be normally developed. We can say that these two hips (or one) were benefited and treated due to contralateral pathology but they would not be treated other ways. The question is how many hips were missed and not treated properly? Similar cases are also described in literature: hips that were normal on the initial ultrasound examination and followed pathology on one side were reassessed again, eventually deteriorated and required treatment[26]. In our material, 1358 hips in 674 infants are classified as ultrasographic Graf I A group and did not need additional X-ray evaluation. Could some of these hips some day become so called »missed« or »late« cases? This is accepted as crucial problem in prevention of DDH nowadays[42]. Naturally, we are aware that the possibility for detection of DDH on the ground of radiographic evidence would be extremely rare in general population or in infants whose hips are ultrasonographically negative (Graf I A) comparing it to the possibility to diagnose DDH on the contralateral side of the hip that is proven to be dysplastic (bilateral pathology). Although lately diagnosed DDH could be malpractice, there are more authors in the past, as well as today, who do not think that way. The authors of the study published twenty years ago considered that a failure to diagnose DDH on early screening is not evidence that a physician does the mistake[43]. The author of the recently published study found this matter even worse and estimated that approximately 15% of DDH at birth is not detectible, even by experienced examiners or ultrasonographers[34].

It seems that sonographic examination of infant's hip joint itself provides too many falsely positive diagnoses of DDH and subsequently overtreatment, too. How to prevent overtreatment by the use of ultrasonography in detecting DDH? Some authors propose variety of algorithms[18,44]. Others emphasize that the accuracy of the ultrasonographic examination is related to the skill and experience of the examiner[45].

In our opinion, better results in detecting and treatment of DDH could be achieved by optimization of everyone's approach by using clinical and ultrasonographic examination of infant's hip, but when infant is more than three months old radiographic assessment of every suspected infant's hip is necessary.

Conclusion

The rational approach in detection of DDH in a child older than 3 months is to do radiological assessment of every sonographic positive hip.

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RACIONALAN PRISTUP OTKRIVANJU RAZVOJNE DISPLAZIJE KUKA U 4–6 MJESECI STARE DOJENČADI: PROSPEKTIVNA STUDIJA

SAŽETAK

Upotreba ultrazvuka u procjeni razvoja dojenačkog kuka može smanjiti kirurške zahvate, bolničko liječenje i kasniji prikaz razvojne displazije kuka. Mnogi su autori zamijetili i objavili porast učestalosti razvojne displazije kuka nakon pregleda ultrazvukom. U ovom prospektivnom istraživanju učinjena je rendgenska obrada svakog kuka kod kojeg je ultrazvučni nalaz bio pozitivan u dojenčeta starijeg od tri mjeseca. Cilj istraživanja je utvrditi da li ovakav postupak mijenja broj djece koja se kasnije liječe od razvojne displazije kuka.

U razdoblju od 30 mjeseci jednostavnim, statičnim ultrazvučnim pregledom, metodom po Grafu, pregledano je 1430 kukova kod dojenčadi od 4 do 6 mjeseci starosti. Kukovi kod kojih je ultrazvučni nalaz pozitivan, radiološki su obrađivani i to tako da je učinjena anterioposteriorna snimka na kojoj je mjerena vrijednost acetabularnog indeksa. Učestalost razvojne displazije kuka dijagnosticirane ultrazvukom bila je 51.75 na 1000 kukova (51.75‰). Poslije radiološke obrade svih 74 kuka s ultrazvučno pozitivnim nalazom, samo kod 44 kuka je određeno liječenje; prema tomu stvarna je učestalost razvojne displazije 30.77 na 1000 kukova (30.77‰). Razlika u učestalosti razvojne displazije kuka u odnosu na navedene dvije metode dijagnosticiranja je statistički značajna $p<0.01$ ($t=5.536$). Racionalan pristup u otkrivanju razvojne displazije kuka u dojenčeta starijeg od 3 mjeseca je radiološka obrada svakog ultrazvučno pozitivnog kuka.