HIP ULTRASOUND: A PROSPECTIVE COMPARISON OF CONVENTIONAL GRAY-SCALE TECHNIQUE WITH HARMONIC IMAGING

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Summary

Aim: *This study aimed to determine whether tissue harmonic imaging, used for the assessment of infant hip in terms of examination, contributes or not to conventional gray-scale ultrasonography.*

Methods: *Nine anatomic regions were defined as standard views and assessed with the use of a scoring system (1: not seen, 2: seen uncertainly, 3: seen acceptably, 4: well seen, and 5: very well seen). Tissue Harmonic Imaging was compared with conventional gray-scale ultrasonography.*

Results: *When the overall average score was considered, tissue harmonic imaging was, in general, higher than conventional gray-scale ultrasonography in all anatomic regions. The highest score was obtained in promontorium and the lowest in cartilaginous acetabular rim. Tissue harmonic imaging was significantly better than the plain conventional gray-scale ultrasonography (P <. 001).*

Conclusion: *In the sonographic examination of infants between four and six weeks, it was found that conventional tissue harmonic imaging can provide better reproducibility and demonstrability than conventional gray-scale ultrasonography.*

***Key words*:** *Hip, scoring system, harmonic imaging, ultrasonography.*

Introduction

Although developmental dysplasia of the hip (DDH) is defined as abnormal development and abnormal size, shape or unsuitable alignment of femoral head and acetabulum or both, there is no consensus on a strict definition [1, 2, 3, 4]. Recently, frequency of DDH has been reported as 0,7 to 20 infants per 1000 births [2, 4, 5, 6] and these values can vary due to differences in diagnosis methods and examination time.

Premature degenerative changes, impaired walking and painful arthritis are predisposing factors in children with DDH. It is recommended not to delay the early diagnosis of DDH and when diagnosed, treatment must be started immediately [2, 7, 8, 9]. With this background, it has been reported that clinical screening programmes have an important role for the surgical treatment incidence which may be required in future.

Routine clinical screening for DDH in neonates and infants was first implemented by Ortolani, Von Rosen, while US utilization was introduced by Graf et al., Berman and Klenerman, Harcke et al., Clarke et al. [10, 17, 20]. Clinical tests that are used by Barlow and Ortolani are simple tests with high sensitivity, which can be conducted in short time for hip instability in neonates [1, 14, 15].

In several studies, clinical and ultrasonographic examination is recommended within several days following birth. However, it has been determined that ultrasonography (US) is the basic imaging method for infants younger than 3 months. During this period, conventional radiology cannot be used (as the femoral nucleus of ossification is not yet fully developed, thus it is necessary to wait until 3-4 months) [7, 16, 17].

US is a simple, reliable and non-invasive examination method in DDH [1, 9]. Additionally, when no abnormality can be found in clinical examination, it is also a useful and adjunctive examination method for detecting pathology [17, 18, 19, 20, 21, 22]. Accuracy is defined as over 90 % [23]. Moreover, the most significant advantages of US are lack of X-rays and the direct imaging of acetabulum and other structures [22].

Tissue harmonic imaging (THI) is a new sonographic technique relative to conventional sonography and it provides a potentially better image quality (24). Recently, THI is being widely used and there are also studies on several organs such as breast [25, 26], thyroid gland [27], liver [28], gall bladder [29], carotid arteries [27] and bile duct [30]. Kendi et al. suggested that THI has a positive contribution to the visualization of ligamentous structures such as scapholunate ligament [23]. Moreover, it presents no difficulty in use as it can be activated by pushing a single knob [31, 32]. Some advantages of THI are: improvement of signal-to-noise ratio, narrowing of the width of

the ultrasound beam and reduction of side-lobe and reverberation artifacts [29, 33, 34].

There are many studies suggesting that ultrasonography plays a fundamental role in assessing developmental dysplasia of the hip [1]. Additionally, there is a great number of studies about the potential of tissue harmonic imaging for improving the image quality. All these studies drew the conclusion that tissue harmonic imaging (THI) can provide a much better image quality than conventional gray-scale ultrasonography [25, 26, 27, 28, 29, 30].

The aim of the present study has been two-fold: first, to compare CUS and THI in the assessment of hip morphology and second, to assess the variation between examiners.

Methods

Several authors suggest that it would be appropriate to conduct ultrasonographic examination right after birth, whereas others consider that 4-6 weeks of age would be more suitable for ultrasonographic examination. In general, the most suitable period is reported as between 4 and 6 weeks of age, although additional studies are warranted on this issue [1, 35, 36]. Consequently, the patient group of the study consisted of healthy infants, with ages ranging between 4 and 6 weeks, who were admitted to pediatric outpatient clinic of Gulkent Hospital for general examination. All the patients had undergone physical examination for DDH and normal individuals were subjected to sonographic examination.

Sonographic examinations were conducted for 108 hips of the 54 infants (23 boys and 31 girls). The Graf technique was used in ultrasonographic examination of the hips. Each hip anatomic region was systematically assessed by using a scoring system.

During the examination, 9 anatomic structures, stated below as 'definition of anatomic region', were taken into consideration. These structures were first examined using conventional gray-scale ultrasonography (CUS) and then each anatomic region was scored according to the scoring system and their angles (alpha and beta) were measured. Later, assessments were made with the help of THI, following the same procedure. Consistent with these results, patients were categorized according to Graf classification. During this period, iliac bone and promontorium were examined and classified in terms of shape.

A single score between 1 and 5 points was obtained for each anatomic structure examined in the hip. Each hip was examined by 2 separate radiologists, who gave scores for anatomic structure in accordance with the predefined criteria.

All measurements were performed using a CDI set: Logiq S6 (GE Medical System, Milwaukee, Wisconsin, USA) with a 4.0-11.0 MHz multifrequency linear transducer.

Statistical methods

The statistical analysis was performed by Statistics Package for Social Science (SPSS) 13.0 computer software. A p value of < 0.05 was considered statistically significant. Data were presented as mean ± SD. When comparing means of the 9 anatomic structures in the hip (comparison of conventional gray-scale imaging with tissue harmonic imaging), the Mann-Whitney U test was used. When comparing means of the 9 anatomic structures separately (comparison of conventional gray-scale imaging with tissue harmonic imaging) the Independent Samples T test was used.

Definition of scores

1. Not seen: not even suggestive of a structure.
2. Seen uncertainly: suggestive of a structure, but structure cannot be clearly distinguished.
3. Seen acceptably: structure can be clearly distinguished.
4. Well seen: structure can be very well distinguished.
5. Very well seen: structure can be very well distinguished, no better visualization possible.

Definition of anatomic structures

1) Iliac bone (Baseline shape): Shape of the ilium was recorded in 3 types: straight, convex and concave. Image clearance of ileal perichondrium and periosteum was scored.

2) Promontory (Promontory of osseous acetabular rim): Edge of the superior acetabular rim is represented as the point at which the flat surface of the ilium meets the acetabular cavity. This was recorded in 3 types: angular or sharp, rounded or flattened and insufficient scan quality.

3) Acetabular rim of the iliac bone (Bony moulding): Evaluation of this structure was performed by the image clearance.

4) Triradiate cartilage: Examination was made in terms of image clearance.

5) Ischium: Judgement was made in terms of image clearance.

6) Cartilaginous acetabular rim (Hyalinized cartilage between the bony acetabulum and the limbus): Examination was made in terms of image clearance.

7) The Labrum acetabular (The limbus acetabular, Echogenic lateral limbus, Fibrokartilage of the limbus) and CLC (capsule-ligament complex): This is represen-

ted by the triangular echogenic structure extending laterally from the cartilaginous rim.

8) Gluteus minimus, gluteus medius, gluteus maximus and fibrofatty plane between these three muscle planes: Examination was made in terms of image clearance.

9) The ossific nucleus of the femoral head: It was recorded attributable to its positiveness or negativeness, as well as medial or lateral location of baseline.

Angle Measurement Criteria: The 'alpha' angle is located between the baseline and the osseous roof line, and the 'beta' angle is located between the baseline and the cartilaginous roof line.

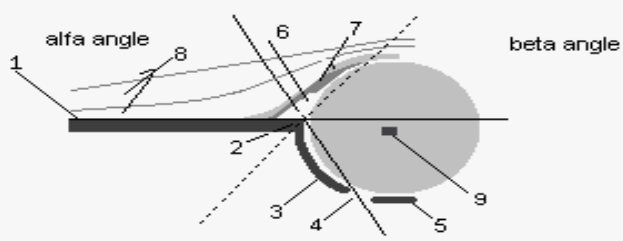

Figure 1. *Schematic drawing of the hip.*

Results

The mean age of the total of 54 infants (23 male and 31 female) was 34.22 ± 3.94 days.

When all anatomic structures in the hip were assessed in B-mode, the mean score (general mean) for the first operator was 3,30; among these anatomic structures the highest score was 3,56 for promontorium and the lowest score was 2,69 for cartilaginous acetabular rim (see table). When all anatomic structures in the hip were examined in B-mode, the mean score (general mean) for the second operator was 3,19; among these anatomic structures the highest score was 3,56 for promontorium and the lowest score was 2,53 for cartilaginous acetabular rim (see table). When B- mode examinations of the first and second operators were compared, no statistically significant difference was found (P = 0,599).

THI examinations of the first operator for all anatomic structures of the hip identified a mean score (general mean) of 3,92; among these anatomic structures the highest score was 4,31 for promontorium and the lowest score was 3,13 for cartilaginous acetabular rim (see table). THI examinations of the second operator for all anatomic structures of the hip identified a mean score (general mean) of 3,19; among these anatomic structures the highest score was 4,21 for promontorium and the lowest score was 3,01 for cartilaginous acetabular rim (see table). When THI examinations of the first and second operators were compared, no statistically significant difference was found (P = 0,529).

When CUS and THI means of the first operator were compared, a statistically significant difference was found between CUS and THI (P = 0,006). When CUS and THI means of the second operator were compared, a statistically significant difference was found between CUS and THI (P = 0,016).

When means of each anatomic structure for each operator were examined and compared (using the Independent Samples T test), a statistically significant difference was detected (for both operators, P < 0,05).

In accordance with the measurements of the first operator with tissue harmonic imaging, hip anatomy was more clearly visible in 65,4% of the cases. In the conventional gray-scale ultrasonography, it was more clearly visible in 33,8% of the cases and worse in only 3,6% (see table). According to the examination results of the second operator with tissue harmonic imaging, the anatomy was more clearly visible in 64,6% of the cases. In the conventional gray-scale ultrasonography, it was more clearly visible in 35,7 % of the cases and worse in only 2,5 % (see table).

Following the evaluation of all hips by both operators, the first operator classified 46 hips as Graf-Ia and 62 hips as Graf-Ib, while the second operator classified 48 hips as Graf-Ia and 60 hips as Graf-Ib. However, no difference could be found as a result of CUS and subsequent THI between the two operators.

When infants were classified in terms of risk, 6 infants had breech presentation and 24 infants were first child of the family.

Iliac bones were examined in all hips for baseline shape. 76 hips were straight, 24 were concave and 4 were convex. According to the shape of promontory, 58 were angular or sharp, 46 were rounded or flattened. Iliac bone evaluation results of both operators were the same in terms of promontory. Ossified nucleus was observed in 6 hips and both operators defined them as medial of baseline. When THI and CUS were evaluated with two operators, they suggested that THI provided better image in 6 hips.

Recently, two different methods are being used for hip US. The first one is a static technique suggested by Graf [11, 20] and the second one is a dynamic method defined by Harcke et al. [37, 38, 39]. The static method emphasizes morphology and classifies the status of the hip on the basis of angular measurements of alpha and beta angles [7, 21, 40]. The '*alphą*' angle (the bony roof) is formed by the intersection of the line parallel to the lateral wall of the ilium and the line parallel to the osseous

Tissue harmonic imaging compared with the B-mode ultrasonography

	Mean score				*THI and B-mode*					
	B-mode		*THI*		*Better*		*Same*		*Worse*	
	I	II	I	II	I	II	I	II	I	II
İliac bone	3,45	4,09	3,37	4,01	72	73	34	32	2	3
Promontorium	3,56	4,31	3,56	4,27	81	78	27	29	-	1
Acetabular rim	3,52	4,24	3,55	4,17	77	70	30	34	1	4
Triradiate cartilage	3,06	3,67	2,76	3,38	71	68	33	39	4	1
Ischium	3,54	4,12	3,29	3,91	69	72	32	32	7	4
Cartilaginous Acetabular rim	2,69	3,13	2,53	3,01	56	55	44	50	8	3
Labrum acetabular and CLC	3,23	3,80	3,05	3,69	64	70	42	37	2	1
Gluteus muscle	3,37	4,02	3,42	4,06	75	72	28	33	5	3
Nucleus of ossification	(3,33)	(4,33	(3,33	(4,33)	(6)	(6)	-	-	-	-
Average mean (score)	3,30	3,92	3,19	3,81	70,6 (65,4%)	69,8 (64,6%)	3,8 (31,3%)	55,7 (33,1%)	3,6 (3,3%)	2,5 (2,3%)

n: 54 infants (male: 23, female: 31) and 108 hips
Score 1: not seen, 2: seen uncertainly, 3: seen acceptably, 4: well seen; and 5: very well seen.
Tissue harmonic imaging is better, the same or worse compared with the B-mode

acetabulum. The '*beta*' angle (the cartilage roof) is formed by the intersection of the line parallel to the lateral wall of the ilium and the line parallel to the roof of the cartilaginous acetabulum [1]. In the Graf method, only a single appropriate coronal image is sufficient for the hip to be examined. The infant shall be in lateral decubitus position and the hip shall be in 35 degrees of flexion and 10 degrees of internal rotation. In this position, the morphological image of the hip can be examined and angle measurements can be conducted [1, 15, 41]. In the study, classifications are made by morphologic examination and angle measurements are performed with the help of the Graf method. According to the results obtained from both operators, there were differences only in 2 hips. However, in both hips, there were no changes following CUS and subsequent THI.

The rim of the bony acetabulum can be easily seen in neonates; however, it may not be possible to completely view image acetabulum in older children due to the ossified femur head [42]. Acetabulum was one of the structures which obtained the highest scores both in CSU and THI conducted by both operators. Cartilaginous acetabular rim (hyalinized cartilage) in hip is hypoechoic and is located between two echogenic structures such as promontory and fibrocartilaginous limbus [22, 42]. Cartilaginous acetabular rim was one of the structures which obtained the lowest scores both in CSU and THI conducted by both operators. The ossific nucleus of the femoral head can be seen as echogenic femur head associated with hypoechoic fields in other regions by US between 4-12 weeks in neonates [42]. In the study, only 6 hips could be imaged by both operators and it is observed that THI provides better image in all of them.

Conclusion

Breech presentation, female sex, positive family history, firstborn status and oligohydramnios can be included among the factors affecting DDH. Among them, intrauterine position, sex and positive family history are the most important risk factors [2, 4, 43, 44, 45]. None of our patients had family history. When examined in terms of sex, 31 were female infants. Six infants had breech presentation history and 24 infants were first child of the family.

The study investigated whether or not THI has a contribution to conventional gray-scale ultrasonography. It was found that, in anatomic structures defined by examination results of both operators in US examination of infant hip, THI provides better image quality than CUS. Although not significant, it was also found that both examination methods have a somewhat similar image quality. However, the striking point is that the imaging quality of THI was slightly worse than that of CUS in accordance with the results of both operators.

As a result, it was determined that, in general, THI is more useful for the evaluation of anatomic structures than CUS and it provides a significant contribution to image quality (figures 2a-2b).

We conclude that tissue harmonic imaging provides a considerably better image quality in the sonographic examination of the infant hip than CUS and, thus, it would be beneficial as an adjunction for CUS in sonographic examination.

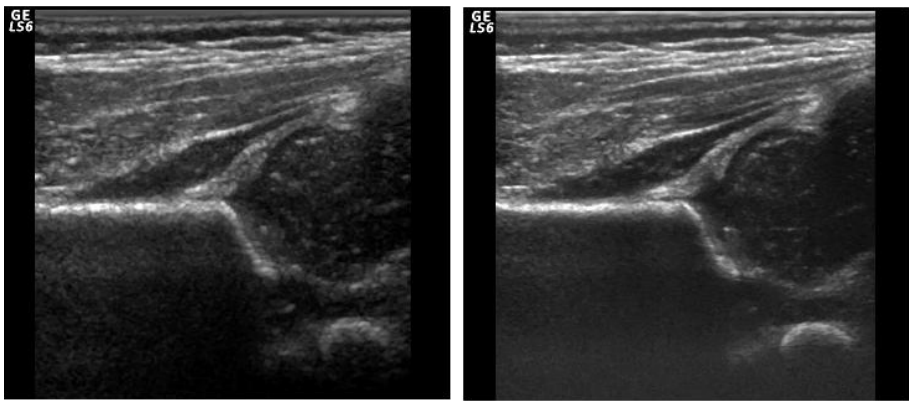

Figure 2. 3*4 days infant; B-mode (a) and tissue harmonic imaging (b), demonstrating better visibility with tissue harmonic imaging.*

Bibliography

1. Wientroub, S. and Grill, F. *Ultrasonography in developmental dysplasia of the hip*. J Bone Joint Surg [Am] 82:1004-1018, 2000.
2. Storer, S.K., Skaggs, D.L. *Developmental Dysplasia of the Hip*. Am Fam Physician. 2006; 74(8): 1310-1316.
3. Lehmann, H.P., Hinton, R., Morello, P., Santoli, J. *Developmental dysplasia of the hip practice guideline: technical report. Committee on Quality Improvement and Subcommittee on Developmental Dysplasia of the Hip.* Pediatrics. 2000; 105(4): 1-25.
4. Bialik,V., Bialik, G.M., Blazer, S., Sujov, P., Wiener, F., Berant, M. *Developmental dysplasia of the hip: a new approach to incidence*. Pediatrics. 1999; 103(1): 93–99.
5. Lowry, C.A., Donoghue, V.B., Murphy, J.F. *Auditing hip ultrasound screening of infants at increased risk of developmental dysplasia of the hip*. Arch Dis Child 2005; 90: 579–581.
6. Patel, H. *Canadian Task Force on Preventive Health C. Preventive health care, 2001 update: screening and management of developmental dysplasia of the hip in newborns*. CMAJ. 2001; 164: 1669–1677.
7. Terjesen, T., Holen, K.J., Tegnander, A. *Hip abnormalities detected by ultrasound in clinically normal newborn infants*. J Bone Joint Surg 1996; 78: 636-640.
8. Shipman, S.A., Helfand, M., Moyer, V.A., Yawn, B.P. *Review for the US Preventive Services Task Force Screening for Developmental Dysplasia of the Hip: A Systematic Literature*. Pediatrics 2006; 117; 557-576.
9. Engensaeter, L,B., Wilson, D,J., Nag, D., Benson, M.K.D. *Ultrasound and congenital dislocation of the hip (The importance of dynamic assessment)*. J. Bone Joint Surg 1990; 72: 197-201.
10. Graf, R. *The diagnosis of congenital hip-joint dislocation by the ultrasonic compound treatment*. Arch Orthop Trauma Surg 1980; 97: 117-133.
11. Castelein, R.M., Sauter, A.J. *Ultrasound screening for congenital dysplasia of the hip in newborns: its values.* J Pediatr Orthop 1988; 8: 666-670.
12. Tonnis, D., Storch, K., Ulbrich, H. *Results of newborn screening for CDH with and without sonography and correlation of risk factors*. J. Pediatr Orthop 1990; 10: 145-152.
13. Marks, D.S., Clegg, J., Al-Chalabi, A.N. *Routine Ultrasound screening for neonatal hip instability. Can it abolish late-presenting congenital dislocation of the hip?* J. Bone Joint Surg 1994; 76: 534-538.
14. Barlow, T.G. *Early Diagnosis and Treatment of Congenital Dislocation of the Hip*. J. Bone Joint Surg 1994; 44: 292-301.
15. Soboleski, D.A., Babyn, P. *Sonographic Diagnosis of Developmental Dysplasia of the Hip: Importance of Increased Thickness of Acetabular Cartilage*. AJR 1983; 161: 839-842.
16. Simona, E.A., Buergec, M., Glaabd, R., Roose, M., Kohlera, G. *Inter-observer agreement of ultrasonographic measurement of alpha and beta angles and the final type classification based on the Graf method*. Swiss Med Wkly 2004; 134: 671-677.
17. Berman, L., Klenerman, L. *Ultrasound screening for hip abnormalities: preliminary findings in 1001 neonates*. British Med. J. Clin. Res 1986; 293: 719-722.
18. Castelein, R.M., Sauter, A.J. *Ultrasound screening for congenital dysplasia of the hip in newborns: its value*. J. Pediat. Orthop 1988; 8: 666-670.
19. Graf, R. *New possibilities for the diagnosis of congenital hip joint dislocation by ultrasonography*. J. Pediat. Orthop 1983; 3: 354-359.
20. Harcke, H.T., Kumar, S.J. *Current concepts review. The role of ultrasound in the diagnosis and management of congenital dislocation and dysplasia of the hip*. J. Bone and Joint Surg 1991; 73: 622-628.
21. Terjesen, T., Bredland, T., Berg, V. *Ultrasound for hip assessment in the newborn*. J. Bone and Joint Surg 1989; 71: 767-773.
22. Dias, J.J., Thomas, I.H., Lamont, A.C., Mody, B.S., Thompson, J.R. *The Reliability of Ultrasonographic Assessment of Neonatal Hips*. J. Bone Joint Surg 1993; 75: 479-482.
23. Kendi, E.T., Gudemez, E. *Sonographic evaluation of scapholunate ligament: value of tissue harmonic imaging*. J. Clin Ultrasound 2006; 34(3): 109-112.
24. Shapiro, R.S., Wagreich, J., Parsons, R.B., Pasik, A.S., Yeh, H.C., Lao, R. *Tissue Harmonic Imaging Sonography: Evaluation of Image Quality Compared with Conventional Sonography*. AJR 1998; 111: 1203-1206.
25. Rosen, E.L., Soo, M.S. *Tissue harmonic imaging sonography of breast lesions: improved margin analysis, conspicuity, and image quality compared to conventional ultrasound*. Clin Imaging 2001; 25: 379-384.
26. Seo, B.K., Oh, Y.W., Kim, H.R., et al. *Sonographic evaluation of breast nodules: comparison of conventional, real-time compound, and pulse-inversion harmonic images*. Korean J. Radiol 2002; 3: 38-44.
27. Szopinski, K.T., Wysocki, M., Pajk, A.M., Slapa R.Z., Jakubowski. W., Szopinska, M. *Tissue Harmonic Imaging of Thyroid Nodules. Initial Experience.* J. Ultrasound Med 2003; 22: 5-12.
28. Hann, L.E., Bach, A.M., Cramer, L.O., Siegel, D., Yoo, H.H., Garcia, R. *Hepatic*

Sonography: Comparison of Tissue Harmonic and Standard Sonography Techniques. AJR 1999; 173: 201-206.
29. Hong, H.S., Han, J.K., Kim Y.H., Kim, J.S., Kim, T.K., Cha, J.H., Choi, B.I. *Ultrasonographic Evaluation of the Gallbladder Comparison of Fundamental, Tissue Harmonic and Pulse Inversion Harmonic Imaging*. J. Ultrasound Med 2001; 20: 35-41.
30. Dulia Ortega D., Burns, P.N., Simpson, D.H., Wilson, S.R. *Tissue Harmonic Imaging: Is It a Benefit for Bile Duct Sonography?* AJR 2001; 176: 653-659.
31. Desser, T.S., Jeffrey, R.B.Jr., Lane, M.J., Ralls, P.W. *Tissue harmonic imaging: utility in abdominal and pelvic sonography.* J. Clin Ultrasound 1999; 27: 135-141.
32. Treadwell, M.C., Seubert, D.E., Zador, I., Goyert, G.L., Wolfe, H.M. *Benefits associated with harmonic tissue imaging in the obstetric patient.* Am. J. Obstet. Gynecol. 2000; 182: 1620-1622.
33. Whittingham, T.A. *Tissue harmonic imaging*. Eur Radiol 1999; 9 [suppl]: 323-326.
34. Tranquart, F., Grenier, N., Eder, V., Pourcelot, L. *Clinical use of ultrasound tissue harmonic imaging.* Ultrasound Med Biol 1999; 25: 889-894.
35. Gardiner, H.M., Dunn, P.M. *Controlled trial of immediate splinting versus ultrasonographic surveillance in congenitally dislocatable hips*. Lancet 1990; 336: 1553-1556.
36. Rosendahl, K., Markestad, T., Lie, R.T. *Ultrasound screening for developmental dysplasia of the hip in the neonate: the effect on treatment rate and prevalence of late cases*. Pediatrics 1994; 94: 47-52.
37. Harcke, H.T., Clarke, N.M., Lee, M.S., Borns, P.F., MacEwen, G.D. *Examination of the infant hip with real-time ultrasonography.* J. Ultrasound Med 1984; 3: 131-137.
38. Harcke, H.T., Grissom, L.E. *Performing dynamic sonography of the infant hip.* AJR 1990; 155: 837-844.
39. Harcke, H.T. *Imaging in congenital dislocation and dysplasia of the hip.* Clin. Orthop 1992; 281: 22-28.
40. Graf, R. *Classification of hip joint dysplasia by means of sonography.* Arch Orthop and Trauma Surg 1984; 102: 248-255.
41. Exner, G.U. *Ultrasound screening for hip dysplasia in neonates*. J. Pediatr Orthop 1988; 8: 656-660.
42. Yousefzadeh, D.K., Ramilo, J.L. *Normal Hip in Children: Correlation of US with Anatomic and Cryomicrotome Sections.* Radiology 1987; 165: 647-655.
43. Wilkinson, J.A. *A post-natal survey for congenital displacement of the hip.* J. Bone Joint Surg Br 1972; 54: 40-49.
44. Omeroglu, H., Koparal, S. *The role of clinical examination and risk factors in the diagnosis of developmental dysplasia of the hip: a prospective study in 188 referred young infants.* Arch Orthop Trauma Surg. 2001; 121: 7–11.
45. Chan, A., McCaul, K.A., Cundy, P.J. et al. *Perinatal risk factors for developmental dysplasia of the hip.* Arch Dis Child Fetal Neonatal Ed. 1997; 76: 94–100.