

Comparison of the superb microvascular imaging technique and the color Doppler techniques for evaluating children's testicular blood flow

L. KARACA¹, A. ORAL², M. KANTARCI¹, R. SADE¹, H. OGUL¹,
U. BAYRAKTUTAN¹, A. OKUR³, İ. YÜCE¹

¹Department of Radiology, Medical Faculty, Ataturk University, Erzurum, Turkey

²Department of Pediatric Surgery, Medical Faculty, Ataturk University, Erzurum, Turkey

³Department of Radiology, Medical Faculty, Bozok University, Yozgat, Turkey

Abstract. – OBJECTIVE: We have compared conventional Color Doppler (CD) and Power Doppler (PD) techniques, which are used for evaluating the testicular blood flow in small children, and the Superb Microvascular Imaging (SMI), which is a new technique. We have also investigated their contributions to testicular evaluations.

PATIENTS AND METHODS: We evaluated blood flow in testicles using a grading system with CD, PD and SMI techniques. We determined the average duration of the three techniques.

RESULTS: There was a statistically significant difference between the SMI and CD techniques for all patients ($p < 0.001$, $p = 0.001$). When we compared the PD and SMI, either as much or more vascular information was obtained ($p = 0.106$). There was a statistically significant difference between the application durations of the tests ($p < 0.05$).

CONCLUSIONS: Superb Microvascular Imaging yields more detailed vascular information in blood flow in testicles in small children, than either CD or PD. Furthermore, this technique decreases the duration of the examination at a significant level. Superb Microvascular Imaging may represent an alternative method that can be used safely for evaluating blood flow in the testicles of small children. Additional studies may increase the reliability of SMI.

Key Words:

Superb microvascular imaging, Testicle, Color and power Doppler.

cles of small children. Especially in acute cases such as torsion in children, evaluating blood flow may be extremely difficult in clinical practice. For this reason, clinically evaluating patients with acute scrotal pain is difficult, and frequent misdiagnoses may occur. It has been reported that misdiagnoses account for 7-10% of the work of pediatric urologists, and 45% among practicing physicians¹.

It has been reported in various studies that a Color Doppler examination (CD) is not sufficient for making a diagnosis, particularly in children^{2,3}. For this reason, it is important that the testicles be evaluated in a quick and accurate manner. Today, the gold-standard test for evaluating testicular blood flow is Color-power Doppler⁴⁻⁶. Contrast-enhanced magnetic resonance imaging or tomography may also be used for evaluating blood flow according to clinical cases. However, these techniques are both expensive and difficult to use with children.

The blood flow detected with the conventional CD technique yields information only about the macro blood flow in testicles, and does not provide information about micro blood flow. Contrast-enhanced ultrasonography (US) techniques have been used to evaluate micro blood flow, and it has been reported that these techniques yield useful information about blood flow in the testicles and have contributed to diagnoses^{7,8}. However, the use of contrast-enhanced US in children is limited.

Superb Microvascular Imaging (SMI) is a new Doppler sonography technique used to determine micro-vascular blood flow. The Doppler signal is formed both by the blood flow and the tissue movement. In the Doppler technique, the power-

Introduction

There are radiological imaging challenges associated with evaluating blood flow in the testi-

ful movement signals suppress the lower blood flow signals, and the primary image consists of high-velocity blood flows. In SMI, on the other hand, the tissue movement signals are decreased and the low-velocity blood flows are detected. As a result, both high-velocity and low-velocity flows constitute the image in SMI technology.

Since the CD techniques apply a filter to decrease movement artifacts and noise, low-velocity flows are not observed in CD. In other words, the CD technique cannot distinguish between low-velocity flows and movement artifacts. However, SMI is not influenced by artifacts, and the low-velocity flows constitute a component of the image.

It is extremely difficult to evaluate testicular blood flow in children because their testicles are small, and the flows in the testicles are low-velocity^{4,9}. Superb Microvascular Imaging is an innovative CD technique that has been developed to detect low-velocity flows. It is possible to visualize small vessels with this technique. To the best of our knowledge, there have been no clinical studies conducted thus far that have reported testicular blood flow in children using the SMI technique. The purpose of this study is to compare evaluations of blood flow in normal testicular tissues in children using conventional Doppler techniques and SMI.

Patients and Methods

Patients

This work was approved by the Ethical Board of our hospital, and all of the patients were informed about the examinations and the procedure, and their written consents were obtained.

Thirty prospective patients who visited the Pediatric Surgery Department with urinary system infection complaints between January 2015 and October 2015 were included in our study. The average age of the patients was 15 months (range: 2-84 month). None of the patients had complaints about their scrotum. The evaluation included testicular tissues that were detected as normal, and the entire ultrasound examination was conducted using Grayscale US, CD, PD (Frame Rate 10-15 Hz) and SMI (Frame Rate > 50 Hz). A TOSHIBA Aplio 500 (Toshiba Medical System Corporation, Tokyo, Japan) was used in the examination with high-frequency (14 Mhz) line array transducers.

To avoid intra-observer variability, all of the sonographic evaluations were performed by two independent radiologists MK (experienced in CD and Testicles Sonography for 15 years; 3 months' experience with SMI and; LK (experienced in CD and Testicles Sonography for 8 years; 2 months' experience with SMI). In each evaluation, focal zone, depth and time gain compensation were adjusted in the gray scale, and the parameters were not changed until the end of the study.

No image processing techniques were applied, and the preset values were preserved. Meanwhile, during the evaluation, no pressure was applied to the transducer to prevent the collapse of vascular structures. The examination was conducted when the patient was relaxing in a supine position and calm. The CD, PD and SMI vascular blood flow images were obtained by taking the same imaging area as the reference area for the testicular tissue. The images were evaluated by two radiologists in a qualitative manner and using the same grading system for each examination. A four-stage evaluation system was used for grading (Figure 1):

Grade 0: No vascularity.

Grade 1 (Minimal): There are one or two spots color encoding.

Grade 2 (Medium): There is one linear color encoding or several spots color encoding.

Grade 3 (Distinct): There are four or more spots color and one linear flow color encoding.

Both sonographers measured three different resistive indexes (RI) values using Color-power Doppler and SMI. To measure the RI value, the application continued until a spectrum with four successive smooth waves was obtained (Figure 2). When the RI value was obtained for each application, the other technique started. The time when the RI value was measured and the duration of each application were recorded in minutes since the beginning of the application. The time evaluation was recorded as the number of minutes. Patients whose RI values could not be obtained in the least 10 minutes were excluded from the study (Figures 3 to 5).

Patients whose testicular tissue could not be obtained at the US, who experienced testicular tissue protruding out of their scrotum, who had a pronounced difference in size between their two testicles, or patients with parenchymal lesions were excluded from the study.

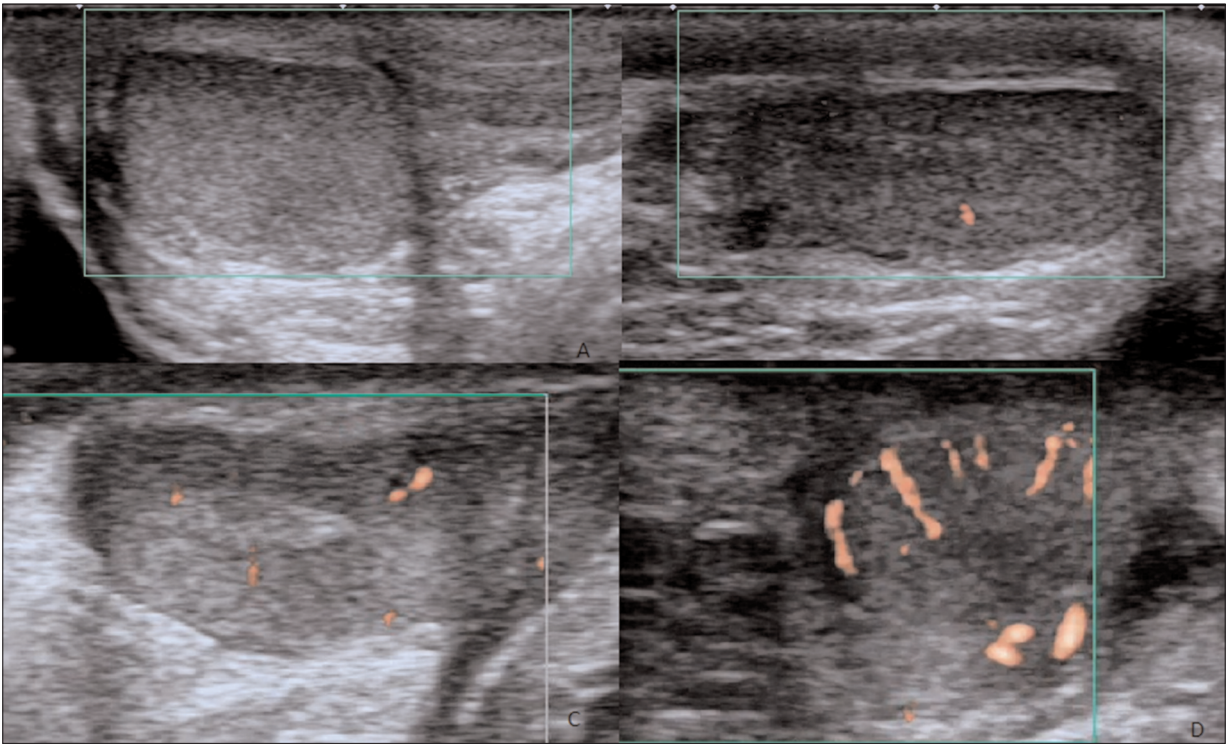


Figure 1. Qualitative evaluation of vascular blood build-up in the testicles. Grade 0 (*A*), Grade 1 (*B*), Grade 2 (*C*) and Grade 3 (*D*).

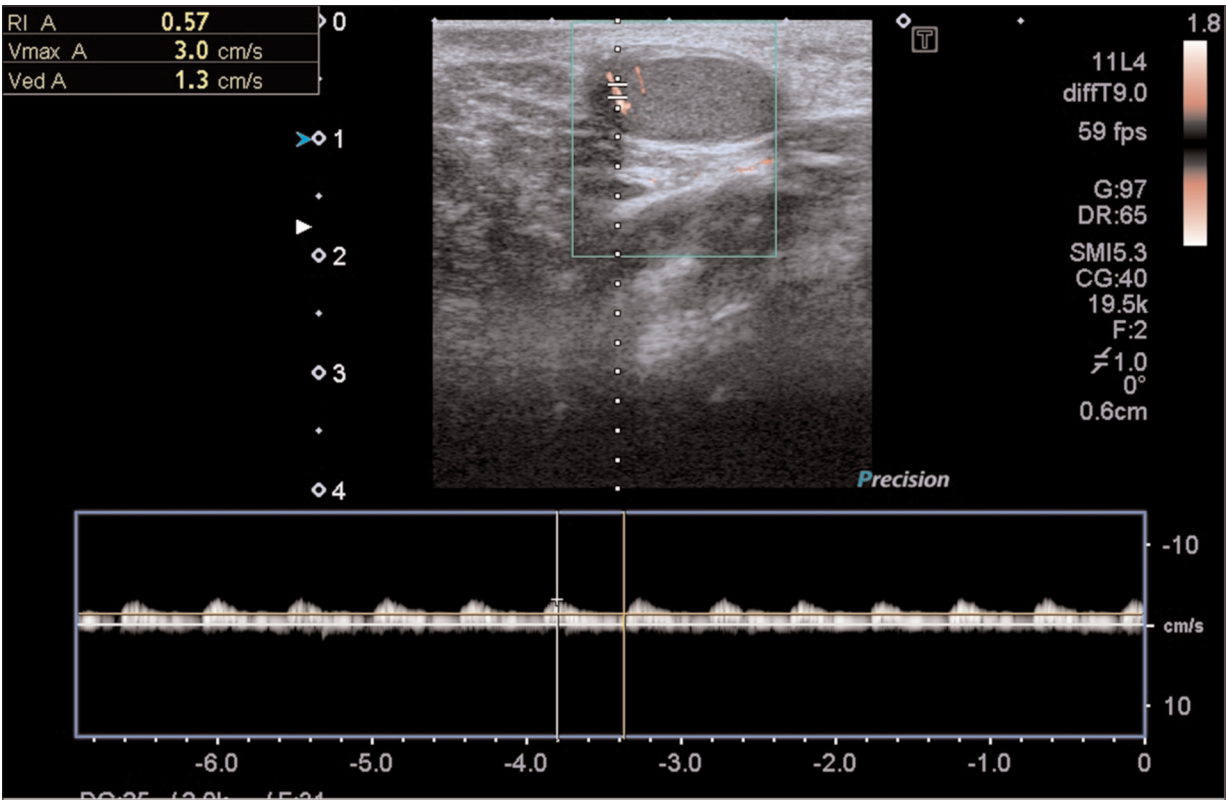


Figure 2. Four-year-old male child. Measurement of the RI value in the right testicle using the SMI technique.

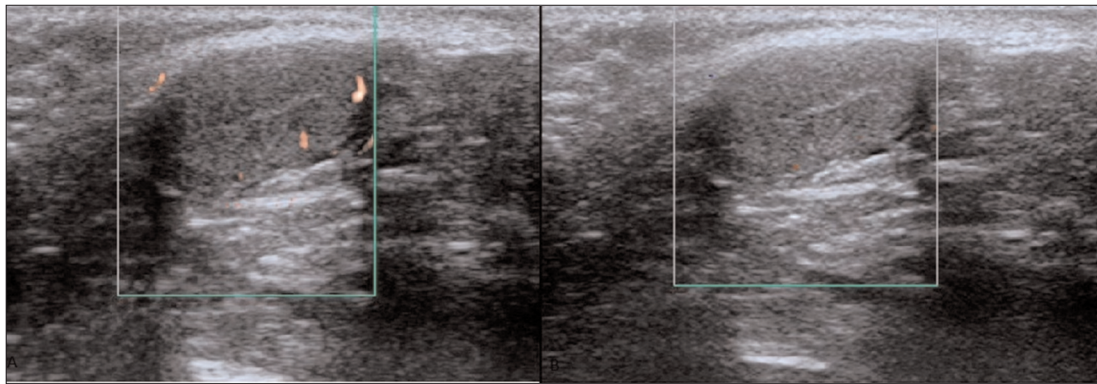


Figure 3. Evaluation of blood build-up in the testicles with SMI and CD in a 7-month-old child. Grading was grade 2 **(A)** with SMI and grade 1 **(B)** with CD vascular flow in the left testicle.

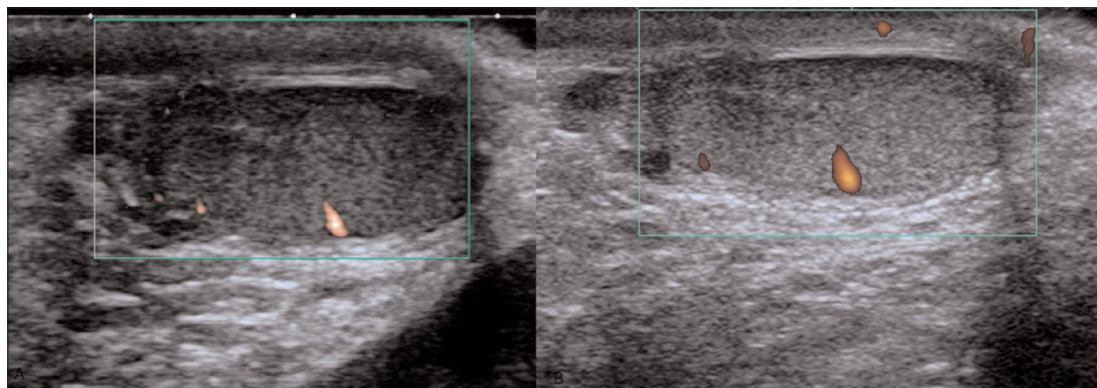


Figure 4. Evaluation of blood build-up in the testicles with SMI and PD in an 11-month-old child. The grading was grade 2 **(A)** with SMI and grade 2 **(B)** with CD vascular flow in the testicles.

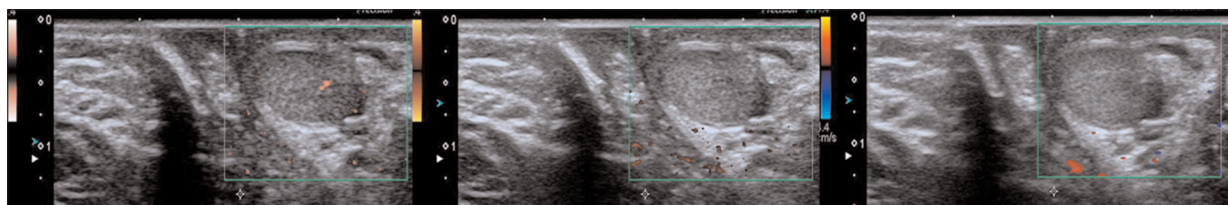


Figure 5. Evaluation of blood build-up in the testicles with SMI CD and PD in a 7-month-old child. The grading was grade 2 **(A)** with SMI and grade 0 **(B-C)** with CD and PD vascular flow in the testicles.

Results

Each sample of testicular tissue was evaluated using a qualitative grading method. The average blood flow using CD was found to be 1.2000 (SD: 0.22341); the corresponding value for PD was, 1.6500 (SD: 0.54695). In SMI, the average blood-flow was 2.3667 (SD: 0.55132) (Figure 6).

There were no statistically significant differences among the three evaluation techniques regarding blood-flow. However, there were significant differences among the CD, PD and SMI in terms of the average values observed by the two sonographers (Figures 7 and 8).

We compared the grading of the two doctors using the CD, PD and SMI techniques with the

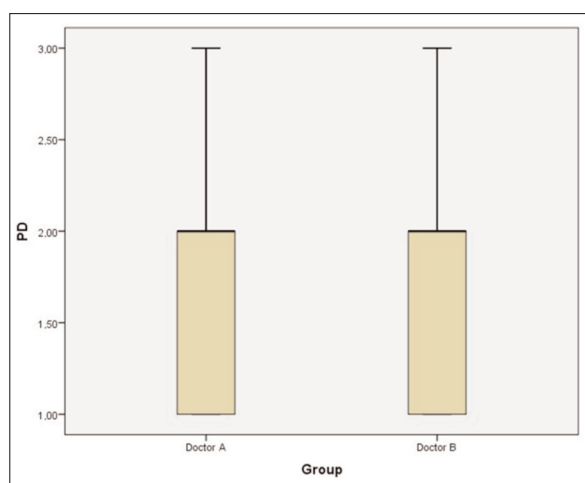


Figure 6. The average values obtained by two sonographer using CD.

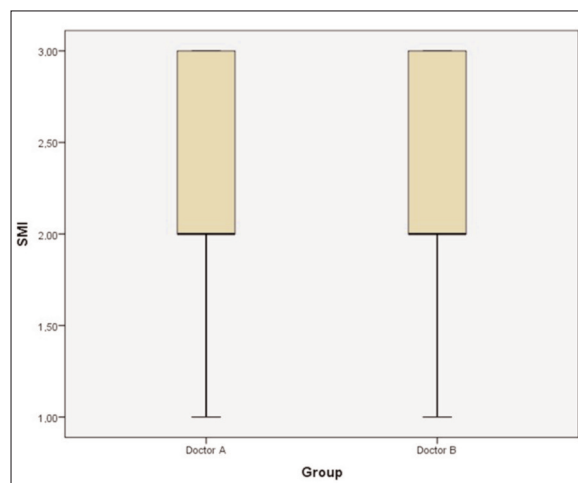


Figure 8. The average values obtained by two sonographer using SMI.

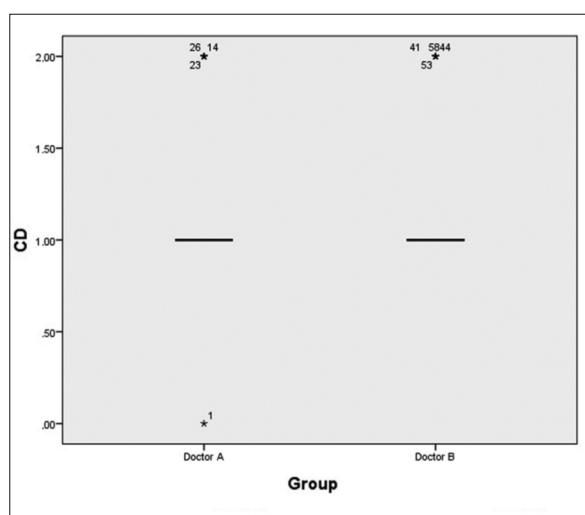


Figure 7. The average values obtained by two sonographer using PD.

Marginal Homogeneity Test (Stuart-Maxwell) because the category number of the two dependent groups was $k \geq 3$. In this context, there was a significant difference between the grading of the two doctors for the CD and SMI techniques ($p = 0.001$; $p < 0.001$, respectively); no differences were found between the evaluations of the doctors with the PD technique ($p = 0.106$).

When we considered the application times of the techniques, we observed that they exhibited a normal distribution ($p < 0.05$). No significant differences were found between the evaluation times of the doctors ($p > 0.05$).

We observed that there was a significant difference between the application durations of all of the techniques when we applied one-way variance analysis ($p < 0.05$) (Table I).

Table I. Variance analysis evaluation comparing the CD, PD and SMI durations.

		Sum of Squares	df	Mean Square	F	Sig.
CD time	Between groups	30.817	1	30.817	34.527	0.000
	Within groups	51.767	58	0.893		
	Total	82.583	59			
PD time	Between groups	4.817	1	4.817	9.385	0.003
	Within groups	29.767	58	0.513		
	Total	34.583	59			
SMI time	Between groups	2.400	1	2.400	5.495	0.023
	Within groups	25.333	58	0.437		
	Total	27.733	59			

Discussion

Ultrasound is an easily available and non-invasive imaging technique. Generally, the first technique requested given a pathology of the testicles is Doppler ultrasound⁴. Since conventional Doppler techniques do not reveal low-velocity flows and small vessels^{5,6}, the Doppler technique provides limited data, especially in small children.

There have been various studies reporting that conventional Doppler techniques have important limitations in evaluating testicle vascularity in 2 and 4-year-old children¹⁰⁻¹⁴.

There have been several studies in the literature on this topic; however, there have been few studies related to the testicles of very young patients^{15,16}. We believe that our study affords first-time, valuable data about this subject because the average age of our patients was low (15 months on average). Superb Microvascular Imaging yields more detailed vascular flow data in patients with lower ages, which are limited in conventional Doppler techniques; this technique accordingly ensures that many testicle pathologies are evaluated, and distinctive diagnoses are made.

Although conventional Doppler techniques provide valuable data for evaluating blood flow, they do not reveal low-velocity flow data. As a result, conventional Doppler techniques are associated with a loss of data due to movement artifacts. To prevent this loss, the contrast-enhanced Doppler applications have been employed; however, technical applications have been limited.

It has been reported in the literature¹⁷ that SMI is a technique that enables imaging of tissue vascularity without the need for contrast materials.

In our study, the differences among the CD, PD and SMI average values revealed that CD yields the least data about testicular blood flow, and PD and SMI provide more data in terms of evaluating vascularity (Figure 5). There have been various studies¹⁷⁻¹⁹ reporting that PD provides more data about testicular blood flow than CD. We found that PD provided more vascular data than CD, which is consistent with findings in the literature. Superb Microvascular Imaging provides more vascular flow data compared with CD in blood flow in the testicles. There have been several studies^{20,21} in this area conducted on tissues such as the thyroid and breasts.

According to our research, this study is the first conducted on testicles in children of young ages. Superb Microvascular Imaging provides

more detailed data about testicular vascular structure compared with the CD technique. When we compared SMI and PD in terms of the blood flow in testicles, we observed that the evaluated cases an equal or higher vascularity grade ($p = 0.106$). We believe that valuable data will be provided on this topic with a wider series of studies. Superb Microvascular Imaging provides more than data than PD for evaluating tissue vascularity of the testicles.

When we considered the duration of the applications of the three techniques, we are observed that the SMI technique ensured the fastest evaluation ($p < 0.05$). Since it is difficult to ensure patient agreement in small children, the SMI technique may yield important advantages because it ensures a fast evaluation.

There are several limitations to this paper. First off, the number of patients that we considered was relatively small. There is the need for additional studies. However, we evaluated the duration of the techniques, the conventional techniques were applied prior to the SMI. By doing so, the RI value measurement of the vascular structure may have provided an advantage in the SMI technique for the sonographer because it evaluates the same area, and SMI can measure the RI value faster.

Conclusions

We evaluated blood build-up in the testicles of small children using conventional Doppler technique and SMI. Our study revealed that SMI yields more data for evaluating blood flow in the testicles than the CD technique. At the same time, SMI can provide at least as much data as the PD technique for evaluating testicular blood flow. Superb Microvascular Imaging may also shorten the evaluation time of testicle sonography, which is a difficult examination in children. For this reason, it may contribute to vascularity evaluation of the testicles more than the conventional Doppler technique. Additional investigations conducted in the future pertaining to evaluating different disease groups may contribute to the wider use of Superb Microvascular Imaging in the future.

Conflict of Interest

The Authors declare that there are no conflicts of interest.

References

- 1) MELEKOS MD, ASBACH HW, MARKOU SA. Etiology of acute scrotum in 100 boys with regards to age, distribution. *J Urol* 1988; 139: 1023-1025.
- 2) MATTESON JR, STOCK JA, HANNA MK, ARNOLD TV, NAGLER HM. Medicolegal aspects of testicular torsion. *Urology* 2001; 57: 783-787.
- 3) DOGRA VS, RUBENS DJ, GOTTLIEB RH, BHATT S. Torsion and beyond: new twists in spectral Doppler evaluation of the scrotum. *J Ultrasound Med* 2004; 23: 1077-1085.
- 4) ATKINSON GO JR, PATRICK LE, BALL TI JR, STEPHENSON CA, BROECKER BH, WOODARD JR. The normal and abnormal scrotum in children: evaluation with color Doppler sonography. *AJR Am J Roentgenol* 1992; 158: 613-617.
- 5) MIDDLETON WD, SIEGEL BA, MELSON GL, YATES CK, ANDRIOLE GL. Acute scrotal disorders: prospective comparison of color Doppler US and testicular scintigraphy. *Radiology* 1990; 177: 177-181.
- 6) BURKS DD, MARKEY BJ, BURKHARD TK, BALSARA ZN, HALUSZKA MM, CANNING DA. Suspected testicular torsion and ischemia: evaluation with Doppler sonography. *Radiology* 1990; 175: 815-821.
- 7) BROWN JM, TAYLOR KJ, ALDERMAN JL, QUEDENS-CASE C, GREENER Y. Contrast-enhanced ultrasonographic visualization of gonadal torsion. *J Ultrasound Med* 1997; 16: 309-316.
- 8) LUNG PF, JAFFER OS, SELLARS ME, SRIPRASAD S, KOOIMAN GG, SIDHU PS. Contrast-enhanced ultrasound in the evaluation of focal testicular complications secondary to epididymitis. *AJR Am J Roentgenol* 2012; 199: 345-354.
- 9) INGRAM S, HOLLMAN AS. Color Doppler sonography of the normal paediatric testis. *Clin Radiol* 1994; 49: 266-267.
- 10) DOGRA VS, GOTTLIEB RH, OKA M, RUBENS DJ. Sonography of the scrotum. *Radiology* 2003; 227: 18-36.
- 11) BADER TR, KAMMERHUBER F, HERNETH AM. Testicular blood flow in boys as assessed at color Doppler and power Doppler sonography. *Radiology* 1997; 202: 559-564.
- 12) PATRIQUIN HB, YAZBECK S, TRINH B, JÉQUIER S, BURNS PN, GRIGNON A, FILIATRAULT D, GAREL L, DUBOIS J. Testicular torsion in infants and children: diagnosis with Doppler sonography. *Radiology* 1993; 188: 781-785.
- 13) DUNNE PJ, O'LOUGHLIN BS. Testicular torsion: Time is the enemy. *Aust N Z J Surg* 2000; 70: 441-442.
- 14) KALFA N, VEYRAC C, BAUD C, COUTURE A, AVEROUS M, GALIFER RB. Ultrasonography of the spermatic cord in children with testicular torsion: Impact on the surgical strategy *J Urol* 2004; 172: 1692-1695.
- 15) ZINN HL, COHEN HL, HOROWITZ M. Testicular torsion in neonates: importance of power Doppler imaging. *J Ultrasound Med* 1998; 17: 385-388.
- 16) BARTH RA, SHORTLIFFE LD. Normal pediatric testis: comparison of power Doppler and color Doppler US in the detection of blood flow. *Radiology* 1997; 204: 389-393.
- 17) WU L, YEN HH, SOON MS. Spoke-wheel sign of focal nodular hyperplasia revealed by superb microvascular ultrasound imaging. *QJM* 2015; 108: 669-670.
- 18) LUKER GD, SIEGEL MJ. Scrotal US in pediatric patients: comparison of power and standard color Doppler US. *Radiology* 1996; 198: 381-385.
- 19) MA Y, LI G, LI J, REN WD. The diagnostic value of superb microvascular imaging (SMI) in detecting blood flow signals of breast lesions: a preliminary study comparing SMI to color doppler flow imaging. *Medicine* 2015; 94: e1502.
- 20) FORSBERG F, MACHADO P, SEGAL S, OKAMURA Y, GUENETTE G, RAPP C, LYSCHCHIK A. Microvascular blood flow in the thyroid: preliminary results with a novel imaging. *Technique* 2014 IEEE International Ultrasonics Symposium Proceedings.