Two-dimensional (2D), three-dimensional static (3D) and real-time (4D) contrast enhanced voiding urosonography (ceVUS) versus voiding cystourethrography (VCUG) in children with vesicoureteral reflex.

Magdalena Maria Woźniak, Andrzej Paweł Wieczorek, Agata Pawelec, Agnieszka Brodzisz, Maria Małgorzata Zajączkowska, Halina Borzęcka, Paweł Nachulewicz

Department of Pediatric Radiology, Medical University of Lublin, Al. Rachackiego 1, Lublin 20-059, Poland
Department of Pediatric Nephrology, Medical University of Lublin, Al. Rachackiego 1, Lublin 20-059, Poland
Department of Pediatric Surgery and Traumatology, Medical University of Lublin, Al. Rachackiego 1, Lublin 20-059, Poland

ABSTRACT

Background: Two-dimensional (2DUS) contrast enhanced voiding urosonography has been used in the diagnosis and treatment monitoring of the vesicoureteral reflux in children for over 15 years. The opportunity of performing this examination with the use of three-dimensional static (3DUS) and real-time (4DUS) techniques opens up new diagnostic horizons.

Objective: To analyze if 3DUS/4DUS bring additional information leading to an increased detection rate or change in the grading of reflux compared to 2DUS and voiding cystourethrography.

Material and methods: We evaluated 69 patients (mean 4.1 years) who underwent 2DUS/3DUS/4DUS contrast enhanced voiding urosonography (ceVUS) and voiding cystourethrography (VCUG) for the diagnosis and grading of vesicoureteral reflux.

Results: 2DUS and 3DUS/4DUS urosonography diagnosed 10 more refluxes (7.25%) than cystourethrography and in 3 refluxes (2.17%) detected a higher grade. In 9 refluxes (6.52%) 3DUS/4DUS urosonography and cystourethrography diagnosed a higher grade than 2DUS. There was a statistically significant difference between cystourethrography and 3DUS/4DUS urosonography when the number of detected refluxes and differences in grading were compared. 4DUS enabled a better visualization of reflux than 3DUS.

Conclusions: 3DUS/4DUS techniques bring additional information leading to a change in reflux grading compared to 2DUS and a detect higher number of refluxes compared to cystourethrography.

© 2015 Elsevier Ireland Ltd. All rights reserved.

1. Introduction

Two-dimensional contrast enhanced voiding urosonography (2D ceVUS) has been used in the diagnosis and treatment monitoring of vesicoureteral reflux in children for over 15 years [1]. As early as 2001, it was shown that the application of contrast enhanced voiding urosonography could reduce by over one half the number of pediatric patients exposed to ionizing radiation during the diagnosis and treatment of vesicoureteral reflux [2]. Currently, it has a well-established position in the assessment of the urinary tract in children and the identification and grading of reflux [3–7]. Numerous reports indicate that urosonography with the use of sulfur hexafluoride contrast agent (SonoVue®, Bracco, Milan, Italy) is a highly sensitive and specific method, which can in many cases replace voiding cystourethrography (VCUG) or isotope cystography [3–6,8–11], and is also a very safe procedure [12,13]. Even the most frequently mentioned disadvantage of the modality, i.e., the difficulty to assess the urethra, especially in boys, has been overcome and is no longer a limitation of the technique [10,14–16]. Moreover,
the modality has recently been shown to be feasible for intraoperative use during the endoscopic treatment of vesicoureteral reflux in children [17].

Currently, the contrast enhanced voiding urosonography procedure is based on a two-dimensional ultrasound (2DUS) technique. However, with the rapid development of ultrasound technology, new opportunities are available to challenge previous methods and have led to continuous changes in paradigms and imaging algorithms. The latest technological innovations such as three-dimensional techniques in combination with contrast options have opened up new possibilities for contrast enhanced urosonography enabling the volumetric multi-dimensional detailed visualization of contrast within the pelvicaliceal system. Modern post-processing options available for three-dimensional static (3DUS) and real-time ultrasound (4DUS) enable the capture of very precise images showing details previously inaccessible in ultrasonography, which may potentially deliver clinically relevant information.

The purpose of this study was to analyze whether three-dimensional static and real-time ultrasound techniques (3DUS/4DUS) bring any additional information leading to an increased detection rate or a grading change in vesicoureteral reflux for contrast enhanced voiding urosonography compared to 2DUS and voiding cystourethrogram (VCUG) in children with vesicoureteral reflux.

2. Material and methods

The study group comprised 69 consecutive pediatric patients treated for vesicoureteral reflux referred to the Department of Pediatric Radiology, the Medical University of Lublin, Poland for follow-up examinations in order to monitor the effects of treatment (inclusion criteria). All the patients fulfilled the criteria to perform follow-up studies according to the referring physician. The exclusion criteria involved recurrent urinary tract infections for the confirmation or exclusion of vesicoureteral reflux, urinary incontinence, lack of consent for voiding cystourethrogram and coexisting abnormalities of the urogenital tract such as ureteroceles, ectopic ureters, posterior urethral valves and neurogenic bladder due to myelomeningocele.

The study was approved by the local ethics committee. The parents of all the patients were informed about the aim of the study, the advantages and disadvantages of the method, and the off-label use of the contrast agent (sulfur hexafluoride, Sonovue®; Bracco, Milan, Italy) in patients under 18 years of age. They provided written consent for these examinations in their children.

The study involved performing contrast enhanced voiding urosonography with Sonovue® (Bracco, Milan, Italy) using a combined approach of different sonographic techniques (2DUS, 3DUS and 4DUS) and anatomical accesses performed before, during and after intravesical contrast solution administration in all the patients. No special preparation was required before the examination. No sedation was used. The examinations were performed using a GE Voluson E8 ultrasound scanner (GE Healthcare, USA) lent for the purpose of the study by the Top Medical clinic, Lublin, Poland, with a pediatric micro convex real-time 4D transducer RNAS-9-D (5-9 MHz). Mid-quality or high-quality static (3D) and real-time (4D) ultrasound modes were selected to obtain optimal data at a sufficient resolution. Mid-quality mode was chosen for non-cooperating children, in such cases the images obtained were of middle quality, however the acquisition was relatively fast; in well cooperating children high-quality mode, characterized by longer acquisition and highest resolution of the images was chosen. For the vesicoureteral reflux imaging, an individual set-up protocol was created in the scanner using high frequency mid-quality (moderate acquisition speed) or high-quality acquisition (slow acquisition speed).

Every patient underwent an initial ultrasound examination of the urinary tract according to the procedural recommendations in paediatric uroradiology issued by the European Society of Paediatric Radiology (ESPR) [18]. The examination included a comprehensive two-dimensional and three-dimensional ultrasound from the transabdominal and transperineal approaches, with the use of B-mode, color doppler and harmonic imaging modes. The features studied above were not the subject of analysis in the current study.

Subsequently, contrast enhanced voiding urosonography (ceVUS) was performed in all the patients according to procedural recommendations on contrast enhanced urosonography based on the European Society of Paediatric Radiology (ESPR)/European Society of Urogenital Radiology using a standard two-dimensional technique [18,19]. The examination was then complemented by static (3DUS) and real-time (4DUS) imaging of the distal ureters and the kidneys in the case of vesicoureteral reflux, as well as by 3DUS and 4DUS transperineal scans of the urethra during voiding. The standard 2DUS contrast enhanced urosonography in dual image mode (simultaneous real-time images using both techniques, i.e., gray-scale (B-mode) and contrast-specific) was always implemented first for the identification or exclusion of the vesicoureteral reflux. Once the presence of reflux was diagnosed in the 2DUS, the 3DUS and subsequently the 4DUS mode were immediately started. Similarly, the urethra was assessed during micturition both in the 2DUS dual mode and subsequently in the 3DUS and 4DUS modes from the transperineal approach in girls and in boys via the suprapubic access and via the perineum/scrotum. The assessment of the urethra was not analyzed in the current study.

Examinations were performed with patients in the supine position. During micturition, neonatal patients were scanned in a supine position, while older patients were given a choice of micturating in the most convenient position for them (supine, sitting or standing). The subsequent stages of the examination were recorded as image files (JPG), video clips (AVI) and 3DUS/4DUS DICOM format files available for further post-processing if needed. On average, the examination lasted approximately 30 min.

Table 1

<table>
<thead>
<tr>
<th>Grades of vesicoureteral reflux</th>
<th>Number of refluxes detected by 2DUS ceVUS</th>
<th>Number of refluxes detected by 3DUS/4DUS ceVUS</th>
<th>Number of refluxes detected by voiding cystourethrogram VCUG</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRADE 0</td>
<td>70</td>
<td>70</td>
<td>77</td>
</tr>
<tr>
<td>GRADE 1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>GRADE 2</td>
<td>17</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>GRADE 3</td>
<td>29</td>
<td>28</td>
<td>22</td>
</tr>
<tr>
<td>GRADE 4</td>
<td>18</td>
<td>23</td>
<td>21</td>
</tr>
<tr>
<td>GRADE 5</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>TOTAL</td>
<td>138</td>
<td>138</td>
<td>138</td>
</tr>
</tbody>
</table>

Please cite this article in press as: M.M. Woźniak et al. Two-dimensional (2D), three-dimensional static (3D) and real-time (4D) contrast enhanced voiding urosonography (ceVUS) versus voiding cystourethrogram (VCUG) in children with vesicoureteral reflux. Eur J Radiol (2015). http://dx.doi.org/10.1016/j.ejrad.2015.11.006
Table 2
Concordance between VCUG and 3DUS/4DUS contrast enhanced voiding urosonography (ceVUS) in detection and grading of reflux. Green—number of refluxes detected by VCUG and missed by 3DUS/4DUS ceVUS. Red—number of refluxes detected by 3DUS/4DUS ceVUS and missed by VCUG. Blue—number of refluxes detected by both VCUG and 3D/4D ceVUS but graded differently by each method.

<table>
<thead>
<tr>
<th>Number and grading of refluxes detected by 3DUS/4DUS ceVUS</th>
<th>Number and grading of refluxes detected by voiding cystourethrography VCUG</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRADE 0</td>
<td>GRADE 1</td>
</tr>
<tr>
<td>GRADE 0</td>
<td>67</td>
</tr>
<tr>
<td>GRADE 1</td>
<td>1</td>
</tr>
<tr>
<td>GRADE 2</td>
<td>3</td>
</tr>
<tr>
<td>GRADE 3</td>
<td>5</td>
</tr>
<tr>
<td>GRADE 4</td>
<td>1</td>
</tr>
<tr>
<td>GRADE 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>77</td>
</tr>
</tbody>
</table>

Post-processing of the 3DUS and 4DUS volumes included rendering, zooming, rotating, sharpening and contrasting the image as well as removing artifacts, and was performed retrospectively directly after the examination during the time the patient was being dressed. Post-processing included the chosen best 3DUS or 4DUS acquisition for each kidney in the case of reflux. If 4DUS acquisition was selected for further post-processing, the 4DUS video clip was reviewed and the best frozen 4DUS image was further post-processed. The post-processed images of reflux were printed after the examination using a color printer and photographic paper, enabling high-quality documentation. The report included printed images and a detailed report on the ultrasound examination of the urinary tract and the results of the contrast enhanced voiding urosonography (detection and grading of vesicoureteral reflux on each side (if present)), as well as a description of the urethra (anatomical findings and assessment during voiding).

A modified five-grade classification of Darge and Troeger [7,20] was used to identify the grade of reflux in the voiding urosonography both in 2DUS and 3DUS/4DUS.

All the children underwent voiding cystourethrography (VCUG) according to the procedural recommendations of the European Society of Paediatric Radiology [18]; the vesicoureteral reflux was graded according to the international system [21].

Subsequently, for the purpose of this study a retrospective analysis of the 69 patients fulfilling the inclusion criteria was performed. This analysis included the assessment of the following features separately for the 2DUS, post-processed 3DUS/4DUS and cystourethrography images: (1) reflux grading and (2) morphological features of the visualized reflux such as an evaluation of the demarcation of the pelviccaliceal contours.

All the investigations and analyses were performed by a single investigator, a pediatric radiologist with 13 years of experience, specializing in pediatric ultrasonography and 3D/4D pediatric ultrasound, and who has performed contrast enhanced urosonography for nine years.

The statistical analysis was performed using Statistica® (StatSoft, Tulsa, USA) software, version 10.0. Descriptive statistics and a t-test and chi square test were used for the purpose of this study.

3. Results
The study group included 69 children; 48 girls and 21 boys (mean 4.1 years old, SD ± 2.5 years, range 1–13.7 years) examined between January 2013 and February 2015. All the patients underwent voiding cystourethrography followed by contrast enhanced voiding urosonography with the use of SonoVue® (Bracco, Milan, Italy) with a minimum time interval of 1 day and a maximum of 3 months between these examinations (mean 16 days).

Out of the 69 examined patients and 138 (100%) pelvi-ureteral units (PUU), voiding cystourethrography diagnosed reflux in 43 patients; in 25 unilateral and in 18 bilateral (61 refluxes; 44.2%), while 2DUS and 3DUS/4DUS urosonography diagnosed the presence of reflux in 49 patients; in 30 unilateral and in 19 bilateral (68 refluxes; 49.27%) (Table 1). Reflux was detected by all 3 methods in 41 patients and 58 (42.02%) pelvi-uretreal units (PUU).

Cystourethrography diagnosed 3 (2.17%) more refluxes (3 patients) than 2DUS and 3DUS/4DUS urosonography (Table 2). 2DUS and 3DUS/4DUS urosonography diagnosed 10 (7.25%) more refluxes (8 patients) than cystourethrography and in 3 (2.17%) refluxes (3 patients) they diagnosed a higher grade (Table 2). 3DUS/4DUS urosonography and voiding cystourethrography in 9 (6.52%) refluxes (5 patients) diagnosed a higher grade than 2DUS. There was a statistically significant difference (p > 0.05) between cystourethrography and 3DUS/4DUS urosonography when the number of detected refluxes and differences in grading were compared (13 refluxes; 9.42%); no statistical significances were found when calculating the detection rate and differences in grading separately. 3DUS/4DUS urosonography due to more detailed and three-dimensional visualization of the reflux enabled more accurate reflux grading resulting in changing the initial grade compared to 2DUS urosonography in 9 (6.52%) refluxes (5 patients) (Table 3).

Out of 68 (100%) refluxes diagnosed by 3DUS/4DUS urosonography, in 66 (97.06%) cases 4DUS acquisition and in 2 (2.94%) cases 3DUS acquisition were chosen for post-processing as better visualizing the reflux due to less amount of moving artefacts and more detailed visualization of the reflux. The difference was statistically significant (p > 0.005).

3DUS/4DUS urosonography and cystourethrography appeared statistically significantly better than 2DUS urosonography in the morphological assessment of reflux demonstrating demarcation of the renal pelvis and the caliceal contours in more details, with higher conspicuity and with higher contrast (p > 0.005).

4. Discussion
The results of our study show that there exists a statistically significant difference between voiding cystourethrography and 3DUS/4DUS urosonography when the number of detected refluxes and differences in grading were compared. 3DUS/4DUS urosonography detected 10 more refluxes than cystourethrography (Fig. 1).
Table 3
Concordance between 2DUS contrast enhanced voiding urosonography (ceVUS) and 3DUS/4DUS ceVUS in detection and grading of reflux. Green—number of refluxes diagnosed by both methods at the same grade. Yellow—number of refluxes graded differently by 2DUS ceVUS and 3DUS/4DUS ceVUS.

<table>
<thead>
<tr>
<th>Number and grading of refluxes detected by 2DUS ceVUS</th>
<th>Number and grading of refluxes detected by 3DUS/4DUS ceVUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRADE 0</td>
<td>70 GRAD E 0</td>
</tr>
<tr>
<td>GRADE 1</td>
<td>1 GRAD E 1</td>
</tr>
<tr>
<td>GRADE 2</td>
<td>13 24 GRAD E 2</td>
</tr>
<tr>
<td>GRADE 3</td>
<td>5 18 GRAD E 3</td>
</tr>
<tr>
<td>GRADE 4</td>
<td>18 GRAD E 4</td>
</tr>
<tr>
<td>GRADE 5</td>
<td>3 13 GRAD E 5</td>
</tr>
</tbody>
</table>

Fig. 1. Right-sided vesicoureteral reflux grade II in a three-year-old female patient treated for vesicoureteral reflux. a) Two-dimensional (2DUS) contrast enhanced voiding urosonography in dual mode, simultaneous real-time images using both techniques, gray-scale (B-mode) on the left side and contrast-specific on the right side. Blurred contours of a non-dilated renal pelvis and renal calyces (arrows). b) Three-dimensional real-time ultrasound (4DUS) contrast enhanced voiding urosonography post-processed volume image. Well demarcated contours of a non-dilated renal pelvis and renal calyces (arrows). c) Voiding cystourethrography performed in the same patient—no vesicoureteral reflux detected.

and in 3 refluxes it diagnosed a higher grade including grades I–IV, with a majority of grades II and III (together 10 refluxes). This may suggest that cystourethrography may potentially lead to false diagnosis even in cases with a relatively high grade of reflux. This finding is concordant with the literature showing that the predominance of urosonography over cystourethrography, as well as the higher
number of refluxes detected in urosonography, can be attributed to the more dynamic and longer duration of the examination as well as the enhanced depiction of microbubbles in a diluted anechoic ureter or pelvicaliceal system [10,15,22]. Cystourethrography diagnosed only 3 more refluxes than 3DUS/4DUS urosonography, and those were only grades I and II. Differences with the diagnosis of low-grade refluxes, particularly grade I by urosonography, is a limitation of this method. However, the missed diagnosis of low-grade reflux seems potentially less harmful than the missed diagnosis of high-grade reflux, particularly considering that low-grade reflux often resolves spontaneously, mostly in young patients, and the resolution is nearly 80% in reflux grades I and II [23].

Two-dimensional urosonography detected the same number of refluxes as 3DUS/4DUS but there were differences in grading in 9 (6.52%) refluxes where 3DUS/4DUS diagnosed a higher grade than 2DUS (Fig. 2). All 9 refluxes were evaluated as grade II (4 refluxes) or III (5 refluxes) by 2DUS, and as grades III or IV by 3DUS/4DUS, respectively. Considering that endoscopic treatment is an option for all children with low grades of reflux (I/III), while surgical correction should be considered in patients with persistent high-grade reflux (grades IV/V) [23], differences in grading between 2DUS and 3DUS/4DUS, despite being statistically insignificant, may influence the choice of treatment and thus may appear clinically relevant.

When number of patients was calculated the differences in number of detected refluxes and grading were not statistically significant, which is a limitation of this study. It may have resulted from the small number of recruited patients and from the retrospective character of the study. The authors have had difficulties in identifying patients who had been monitored by both voiding cystourethrography (VCUG) and 2D/3D/4D contrast enhanced
Fig. 3. Right-sided vesicoureteral reflux grade III in a five-year-old male patient treated for vesicoureteral reflux (same patient as Fig. 2). Three-dimensional real-time ultrasound (4DUS) contrast enhanced voiding urosonography post-processed volume image showing vesicoureteral reflux in time. a) Third second of the video file. b) Sixth second of the video file. c) Seventh second of the video file.

voiding urosonography (ceVUS) as usually the monitoring of treatment is performed by one of the methods, depending on the clinician and parents’ preferences and availability of the modalities. However, the aim of the study was to show the differences between the described imaging modalities in the diagnosis of vesicoureteral reflux thus the authors believe that the pelvi-ureteral unit (PUU)/reflux can be treated as the denominator of importance. Particularly considering that it is possible that one patient suffers from various grades of reflux which must be managed separately.

The results of the study show that 3DUS/4DUS urosonography is a technique that detects a higher number of refluxes compared to cystourethrography and delivers more detailed morphological image of the reflux than 2DUS, thus allowing for more accurate reflux grading. 3DUS/4DUS owing to post-processing options including rendering, sharpening, contrasting, zooming and rotating the image, as well as removing artifacts, allows the capture of much clearer images of the reflux, with highly visible margins of the pelvicaliceal system and ureter without artifacts and surrounding structures. Moreover, a multi-dimensional visualization of reflux inaccessible in 2DUS and cystourethrography enables a more precise and easier assessment of pelvicaliceal dilatation, thereby allowing a more accurate reflux grading that is much easier, more confident and faster than reflux identification using 2DUS or cystourethrography. This is particularly important in patients with normal renal rotation/position. Another considerable advantage of the 3DUS/4DUS technique possible thanks to the post-processing options, is the quality of the reflux documentation and the opportunity of its presentation in an analogous manner that is presented in voiding cystourethrography, e.g., in anatomical directions of the kidneys. This seems to be much more understandable and demonstrative for referring physicians and makes the report and image documentation more reliable and objective.

However, it is important to highlight that 2DUS urosonography still remains the basic ultrasound modality for reflux identification and grading, and cannot be skipped by going directly into 3DUS or 4DUS. Only when using dual mode 2DUS (simultaneous real-time images using both techniques, i.e., gray-scale (B-mode) and contrast-specific) is it possible to easily identify reflux, since dual mode helps to visualize the kidney. Also, when it comes to VUR grade I, 2DUS in dual mode often offers an easier visualization of reflux due to the simultaneous gray-scale presentation of the area of the distal ureter.

In our study the patients were examined with both the 3DUS and 4DUS techniques; however, the 4DUS technique appeared a modality more appropriate than 3DUS, enabling a better visualization of reflux in over 97%. Comparing these two options, the main limitations of 3DUS are its static character and higher susceptibility to artifacts. 4DUS, thanks to its real-time dynamic character, offers the possibility of a longer observation period allowing for imaging dynamic processes such as reflux (Fig. 3), which can sometimes be visualized only periodically, or during micturition or an assessment of the organ during periods of better acquisition quality. Thus, in cases of dynamic examination such as voiding urosonography 4DUS as a real-time technique is more useful than 3DUS. Real-time scanning is particularly advantageous in children when a lack of cooperation often creates difficulties in obtaining good quality...
acquisition. In this respect, the introduction of 4DUS can be compared to the introduction of a “cine loop” in B-mode. The real-time technique includes all the features of 3DUS and additionally offers further advantages being the dynamic modality thus there is no need to use both techniques as this only prolongs the procedure without adding any major benefits.

The limitations of the 3DUS/4DUS technique include the longer duration of the examination compared to cystourethrography and 2DUS urosonography, as 3DUS/4DUS techniques also require post-processing. The scarce availability of high-end ultrasound scanners equipped with 3DUS/4DUS contrast mode, as well as the relatively long learning curve of the technique, particularly regarding post-processing, are also disadvantages.

A review of the literature does not reveal any previously published studies using 3DUS or 4DUS in voiding urosonography; thus we cannot compare the obtained results with other authors. Pichler et al. used three-dimensional real-time ultrasound (4DUS) for the evaluation of the position of a bulking agent in children who had undergone endoscopic therapy of vesicoureteral reflux [24]. In their study only children with postoperative urinary tract infections and/or a non-orthotopic position of the bulking agent were referred for voiding cystourethrography. 4DUS seemed to be a sufficient protocol in the follow-up of children after endoscopic treatment of low-grade reflux [24]. Published articles on 2DUS voiding urosonography include comparisons of the technique with voiding cystourethrography in terms of reflux grading [4,15,20] proving its superiority over cystourethrography, support the safety of the procedure [13], and recently also report the reliable urethral assessment [15,22,25] and opportunity of intraoperative use [17]. We believe that the results of this preliminary study are a starting point for further studies on larger patient groups and hopefully will be supported by other researchers in the future.

The main limitations of this study include the non-blinded and retrospective character of the study, patient recruitment at a single institution, the relatively small number of patients, the involvement of a single pediatric radiologist, and a time interval of up to 3 months between urosonography and cystourethrography, which resulted from the retrospective character of the study. Thus, the need for further multicenter prospective controlled blinded studies comparing 2DUS with 3DUS and 4DUS voiding urosonography and voiding cystourethrography are necessary.

The results of the current study show that 3DUS/4DUS urosonography detects a higher number of refluxes compared to voiding cystourethrography and the same number of refluxes compared to 2DUS; however, the 3DUS/4DUS techniques diagnose higher grades than 2DUS. 3DUS/4DUS is the only modality offering multi-dimensional volumetric presentation of the reflux in an anatomical manner facilitating grading and increasing the quality of the documentation. 4DUS as a real-time dynamic modality visualizes reflux better than 3DUS, and thus can be used as the sole volumetric technique preceded by 2DUS.

5. Conclusion

In conclusion, our preliminary experiences indicate that three-dimensional static and real-time ultrasound techniques (3DUS/4DUS) bring additional information leading to a change in reflux grading for contrast enhanced voiding urosonography compared to 2DUS and detect a higher number of refluxes compared to cystourethrography in children with vesicoureteral reflux. The 4DUS technique can be used as the sole volumetric technique preceded by 2DUS.

Acknowledgments

This study was funded by a research grant from the Medical University of Lublin, Poland No DS427. The authors do not report any other financial or personal links with other persons or organizations that might negatively affect the content of this publication and claim authorship rights to this publication.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/ejrad.2015.11.006.

References


Please cite this article in press as: M.M. Woźniak, et al., Two-dimensional (2D), three-dimensional static (3D) and real-time (4D) contrast enhanced voiding urosonography (ceUS) versus voiding cystourethrography (VCUG) in children with vesicoureteral reflux. Eur J Radiol (2015), http://dx.doi.org/10.1016/ejrad.2015.11.006.