Incorporating 3D Multiplanar Reconstructed Images for Endovaginal Endometrial Assessment. Can We Improve Efficiency and Maintain the Sonography Role? A Pilot Study.

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Abstract:

A study was undertaken to evaluate the utilization of 3D Multiplanar Reconstructed (MPR) images to reduce the scan time for endovaginal studies, thereby potentially reducing sonographer strain and possibly improving patient workflow. The scope of the study was limited to evaluation of the endometrium. A group of 42 patients with dysfunctional uterine bleeding was selected for the study. After initial transabdominal examination on each patient, an endovaginal study of the endometrium was performed using 3D data collection; this was followed by a complete conventional 2D endovaginal scan. The scan times and endometrial measurements for 3D and 2D methods were compared. Staff members were interviewed for feedback on the experience and for future protocol recommendations.

Key words:

MPR, 3D, endovaginal, endometrium, coronal, MSI, WRMSD
Introduction:

Sonographers are all well aware of the high incidence of work related musculoskeletal disorder (WRMSD) rates among sonographers. These injury types and rates are well documented in multiple articles. Endovaginal scanning can be particularly uncomfortable due to the unsupported and abducted arm position required to perform the procedure. Sonography departments in Canada are also facing challenges to productivity from limitations in both facilities and human resources. A reduction in scanning time that could potentially reduce injury and/or improve workflow could obviously be of great benefit to both sonographers and department managers. Any technique that could reduce scan time while maintaining diagnostic imaging quality would be worth investigating.

To investigate this, a study design was proposed to the Providence Health Centre Innovations Committee at St Paul’s Hospital in Vancouver, B.C. Approval and funding were granted for the study which would investigate possible scan time reductions by utilizing 3D scanning rather than conventional 2D scanning in endovaginal assessment of the endometrium. Similar studies in other centers have demonstrated time savings by utilizing 3D imaging techniques. Staff sonographers would perform the offline 3D image manipulation on a workstation and select multiplanar reconstructed (MPR) images for review and comparison by a sonologist. While full 3D assessment and volume measurement of the endometrium has shown some promising results, only MPR images rather than the full 3D volume set were chosen for this study for two main reasons. The first was the greater ease of sending MPR images to a PACS server, which has been problematic for use of raw 3D data. The second was that the process would more closely replicate current department practice in terms of the involvement of the sonographers. Sonographers have historically been very involved in preliminary assessment of imaging data and it was determined to be important to preserve that role.
Materials and Methods:

A total of 42 pre- and post-menopausal patients referred to the sonography department for investigation of dysfunctional uterine bleeding were selected for the study. Only patients who were recommended for endovaginal scanning following a transabdominal pelvic sonogram were offered participation in the study. Although a full pelvic sonogram was performed on each patient, the data used for this study was limited to endometrial assessment and thickness measurement. There were two reasons for this decision: endometrial thickness assessment has well established clinical value\textsuperscript{15,16,17} and the measurement would be relatively easy to compare between the two techniques.

While a few of the initial study subjects were scanned on an Acuson Antares (Siemens, USA) using a 9-4 MHz endovaginal probe, the majority of the endovaginal portions of the scans were performed by staff sonographers on either an iU-22 or an HD-11 scanner (Philips Medical Systems, Bothell WA) using a 3D9-3v endovaginal probe. The 3D9-3v probe utilizes mechanical sweeping for collecting 3D information, allowing for accurate measurements to be conducted on images generated from the volume data\textsuperscript{18,19}. A total of eight (8) staff sonographers participated in performance of the scans. Sonographers were randomly assigned according to their availability.

Study-specific presets were created on the Philips scanners to aid in consistency. Following probe insertion, the midline of the uterus was located and positioned in the sagittal plane and two 3D sweeps of the uterus were performed. The first was to include the fundus, the second to include the cervix, although in most patients, the entire long axis of the uterus could included in the 130° angle of the probe. The uterus was not assessed in 2D prior to collecting the 3D information in order to reduce the effect the 2D knowledge gained while performing the 2D assessment might have on the
3D collection times. Additional sweeps of the adnexa and ovaries were also performed for use in future studies, but were not evaluated in this study. All of the 3D volume sets were sent to a Philips Q-lab 20 workstation for assessment. Because no labeling or other positioning information could be sent to the 3D workstation, strict protocols for imaging order were employed to aid in consistency and correct identification of structures.

Following the collection of the 3D volume sets, an endovaginal 2D study using the same probe was performed on each patient. No additional probe insertion was required on any patient. The endometrium was assessed in both sagittal and transverse planes and the endometrial thickness measured. Marker images were recorded at the start of each phase to help determine the time required for the various segments of the scan.

Staff members were introduced to the Q-lab workstation during individual orientation sessions with the department supervisor. Nine (9) sonographers, including one who did not participate in scanning any subjects, participated in evaluating the 3D data sets. Using the Q-lab workstation, 3D volume data sets on each patient were reviewed by two sonographers. The results were blinded from each other in order to test for inter-observer reliability. Sonographers did not review any studies that they had personally performed in order to reduce any impact from the additional information gained while performing the rest of the study. The 3D volume data sets were assessed employing multi-planar reconstruction (MPR) techniques. Image quality was adjusted with post-processing functions and sagittal, transverse and coronal 2D images were generated. Measurements of the endometrial thickness were made in the sagittal plane. The MPR images were saved in jpeg format and stored in a folder for radiologist review.
The stored MPR images were reviewed and compared to the original 2D endovaginal images by a sonologist to assess for image quality, inclusion of diagnostic information, value of the coronal plane and any artifacts unique to 3D as described by Nelson\textsuperscript{21}. The relative scan times for 3D and 2D scanning were compared and tested for significance. The endometrial measurements were compared between the two observers and also between those for the 2D and MPR images to test for inter-observer reliability and consistency.

In addition to the quantitative aspects of the study, a focus group was conducted with the participating sonographers to gain additional insights into the process and to obtain recommendations for future use of 3D in the department. The department supervisor was also interviewed to discuss some of the organizational and technical challenges encountered in administration of the study.
Results:

A total of 41/42 cases were included in the analysis. One case was excluded due to loss of the endovaginal image sets. The scanning times for 3D were demonstrated to be shorter than those for 2D and the difference was statistically significant with a p-value of .001. Because the distribution was symmetrical, the mean times were used. The mean 3D scan time was 69.34 seconds (SD 29.98) versus a mean 2D scan time of 115.98 seconds (SD 74.57), indicating a mean 2D scan time 46.64 seconds greater than that for 3D scanning. It should be noted that in 12/41 instances, the 3D collection time actually exceeded that of the 2D assessment. This occurred more frequently with the earlier cases in the study. No relationship was determined between the length of sonographer scanning experience and either the 2D or 3D scan times.

The MPR image endometrial thickness measurements between the two sonographers showed a very high degree of inter-observer reliability (graph 1). Two outlier measurements did exist, one due to data entry error, the second to disagreements in caliper placement due to poor image quality. The correlation was .77 with the inclusion of these two outliers, but increased to .93 upon their removal. The comparison of the measurements from the 2D and MPR images showed a very high correlation of .95 (graph 2). The measurements were then assessed in regard to placement in the < 5mm versus ≥ 5mm categories, which is an important clinical demarcation. The comparison of the average of each pair of MPR measurements to the 2D measurements demonstrated very high agreement with a Kappa coefficient of .83.

The sonologist review of the results yielded some interesting information. In 73.2% of the cases (30 of the 41 completed cases), the sets of MPR images were determined to display endometrial image quality equivalent to that of the 2D images. In 85.3% of the cases (35/41), the MPR images were
determined to contain acceptable diagnostic information. In two cases, polyps were identified in the MPR images that were not noted in the conventional 2D images (images 1 and 2). Evaluation of the coronal images indicated that in a total of four cases (9.8%), the coronal views aided in assessment of the endometrium (images 3 and 4). In one additional instance, the coronal view provided a superior view, but did not change or improve confidence in the diagnosis (images 5 and 6). No artifacts unique to 3D were noted. This could be due partly to the evenness of the mechanical sweep of the probe and also the unlikely observation of motion artifacts. However, in one case significant drop-out was noted at the lateral edges of the uterus in the transverse views and in another case drop-out was noted in part of the endometrium (image 7), possibly due to the proximity of the lateral borders of the uterus to the end points of the 3D sweep.

**Focus Group Results:**

The focus group discussion revealed information regarding the sonographers’ reflections on the study design, their opinions of the perceived strengths and challenges in using 3D and recommendations for future use. Some of the key data collection challenges faced by the sonographers included adhering to a strict and complicated protocol that was not a natural routine and adapting to ongoing software upgrades that altered instrumentation. They also felt hampered by having to collect the 3D data prior to doing a 2D assessment of the uterus.

In reviewing the data at the workstations, the staff felt limited by the lack of knowledge of the transabdominal and conventional endovaginal information. They also noted that the raw imaging data displayed by the workstations was often much darker than typical settings. This could be adjusted by post-processing, but was not consistently done due to lack of familiarity with the controls. They recommend that in future sonographers evaluate cases they had personally performed and do the 3D evaluation soon after the original 2D assessment.
The sonographers found that the coronal plane was helpful in assessing endometrial polyps, irregularly shaped endometria and septate uteri. This is consistent with findings of Benacerraf\textsuperscript{22}. They determined that the coronal plane was only helpful if the endometrium was thickened. The sonographers agreed that the usefulness on 3D imaging is limited to specific situations and does not replace 2D scanning. The more static nature of 3D imaging must be integrated with real-time 2D assessment to create a comprehensive evaluation. 3D could be best used for relatively small areas requiring thorough assessment, accurate angulation and multiple measurements. These might include ovarian follicle monitoring, endometrial polyps, septate endometria, irregular endometrial contour and measurement of multiple fibroids, which are situations also identified by Merz\textsuperscript{23} and Benacerraf\textsuperscript{24}.

In summary, the participating sonographers recommended that 3D endovaginal studies be performed only in cases where an abnormality is suspected or seen on the transabdominal images. Because 3D is subject to the same artifacts as is 2D, the area to be studied should be carefully assessed in 2D in order to optimize the window and technical settings prior to data collection. The evaluation of the 3D data sets should be conducted by the same sonographer who performed the 2D study and this should be done as soon as possible following that study.

**Supervisor Interview:**

An interview with the department supervisor, who was instrumental in both organizing and implementing the study, offered several recommendations and insights for any department considering introducing 3D into their protocols: In regards to instrumentation, software upgrades should be carefully tested prior to starting any 3D studies. Protocols should be reviewed regularly to determine any recommended changes to improve consistency and quality. Because no positional
labeling information currently transfers to the 3D workstations, in order to avoid location errors
protocols should be simple and consistent. Training time for staff sonographers and verification of
understanding of protocols is crucial for the collection of high quality data. Limiting the number of
staff initially involved should also help improve quality and consistency by reducing variables.
Having staff review their own imaging data and conducting that review immediately following
scanning is recommended for the best integration of information from 2D and 3D imaging.
Discussion:

The results indicated that the use of 3D data collection does appear to reduce scan times, even when implemented by relatively inexperienced users. A significant time saving was demonstrated by using 3D collection, although in 12/41 cases the data collection time for 3D actually exceeded that for 2D. No clear reasons were determined for this. In the majority of these cases, however, both 3D and 2D scan times were quite short, suggesting that these cases were quite easy to scan. In addition, the sonographer would have already determined the position and axes of the uterus while collecting the 3D images, which would have slightly reduced the time required for the 2D assessment. Further explanation for the longer 3D times could not absolutely be determined, but could be related to errors in timer markers or to operator inexperience with 3D scanning.

This time saving may be reduced if the target structure is assessed in real-time prior to collecting the volumetric data, as recommended by the sonographers participating in the study. The lack of assessment of the uterus prior to 3D data collection may have negatively affected the quality of the data, as is suggested by the fact that the reviewing sonologist deemed image quality of the MPR images to be comparable to that of the 2D in only 73.2% of cases, although the diagnostic information was contained in 85.3% of the MPR sets.

Although the image quality of the MPR images did not consistently equal that of 2D, the endometrial measurements were very consistent between the 2D and 3D methods and between the pairs of 3D evaluators, suggesting that measurement may be a valid use for 3D. The focus group suggestions for possible uses of 3D are consistent with this.
Conclusion:

3D ultrasound is an exciting technological advancement, the value and applications of which are still being discovered by clinicians. The time savings determined in this study are not large, but do serve as a model for possible applications in the clinical environment. A time saving was demonstrated even with very inexperienced users and this saving should logically increase with improved operator confidence and competence. Although this study design did not provide the opportunity to study the ergonomic impact of reduced scan times, it is reasonable to assume that a reduction in endovaginal scanning time would be a positive step in reducing WRMSD.

MPR images, which could be easier than full 3D files to incorporate into patient files, do appear to contain acceptably usable data for specific applications. The reliability of measurements from the 3D data appears to be very good and could be valuable in those procedures requiring multiple accurate measurements. The experience of the sonographers and the image quality of the MPR images indicate that best use of the technology does appear to require determination of optimal imaging windows by experienced practitioners prior to data collection.

Finally, and importantly, incorporating MPR images into gynecological scan protocols can not only potentially save scan time, but could also be a method of utilizing 3D technology while preserving the vital role of the sonographer in the diagnostic process.
Graph 1: MPR endometrial thickness measurements (mm) between observers

Graph 2: 2D versus average MPR endometrial thickness measurements (mm)
Image 1: Original conventional 2D image of endometrium

Image 2: MPR image of second polyp not seen on conventional 2D
Image 3: coronal image of polyp see in image 1 above

Image 4: coronal image of asymmetrical septate endometrium
Image 5: Conventional images of septate endometrium

Image 6: Coronal MPR image of septate endometrium above
Image 7: Ultrasound signal dropout on lateral aspects of uterus.
References:


