# A Crossover Comparison of Standard and Telerobotic Approaches to Prenatal Sonography

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***Objectives***—To determine the feasibility of a telerobotic approach to remotely perform prenatal sonographic examinations.

***Methods***—Thirty participants were prospectively recruited. Participants underwent a limited examination (assessing biometry, placental location, and amniotic fluid; n = 20) or a detailed examination (biometry, placental location, amniotic fluid, and fetal anatomic survey; n = 10) performed with a conventional ultrasound system. This examination was followed by an equivalent examination performed with a telerobotic ultrasound system, which enabled sonographers to remotely control all ultrasound settings and fine movements of the ultrasound transducer from a distance. Telerobotic images were read independently from conventional images.

***Results***—The mean gestational age ± SD of the 30 participants was 22.9 ± 5.3 weeks. Paired-sample *t* tests showed no statistically significant difference between conventional and telerobotic measurements of fetal head circumference, biparietal diameter, or single deepest vertical pocket of amniotic fluid; however, a small but statistically significant difference was observed in measurements of abdominal circumference and femur length ($P < .05$). Intraclass correlations showed excellent agreement (>0.90) between telerobotic and conventional measurements of all 4 biometric parameters. Of 21 fetal structures included in the anatomic survey, 80% of the structures attempted across all patients were sufficiently visualized by the telerobotic system (range, 57%–100% per patient). Ninety-seven percent of patients strongly or somewhat agreed that they would be willing to have another telerobotic examination in the future.

***Conclusions***—A telerobotic approach is feasible for remotely performing prenatal sonographic examinations. Telerobotic sonography (robotic telesonography) may allow for the development of satellite ultrasound clinics in rural, remote, or low-volume communities, thereby increasing access to prenatal imaging in underserved communities.

***Key Words***—obstetrics (detailed fetal anatomy); obstetrics (second trimester); prenatal; telehealth; teleradiology; telerobotic; telesonography; ultrasound; ultrasound equipment and products

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Sonography is unique as it is an operator-dependent modality, and the skills of the sonographer, radiologist, or obstetrician generating images are critical for diagnostic examinations. As a result, sonography, including obstetric sonography, is not readily available in many communities across the developed and developing world because of a lack of on-site experts. In communities where obstetric sonography is not available, patients must often travel to another center for imaging or forego prenatal imaging altogether, potentially compromising maternal and fetal safety. For patients requiring referral for subspecialized obstetric sonography and residing in communities where basic sonography is available, travel to a tertiary care center may still be required, which burdens patients and their families and may delay diagnosis and management.

Telerobotic sonography (robotic telesonography) has emerged as a potential solution to provide greater access to care for patients in communities where basic or subspecialized sonography is not available, allowing patients to obtain these services in their home communities.[1,2] Telerobotic ultrasound systems allow sonographers or radiologists at a central location to remotely manipulate a transducer and generate images in real time via an Internet connection. Our group recently assessed a telerobotic ultrasound system to remotely perform adult abdominal examinations. Sonographers based at our academic health sciences center remotely scanned patients at an imaging clinic 2.75 km away.[2] We concluded that a telerobotic ultrasound system is feasible for performing adult abdominal sonographic at a distant location, with minimal training and setup requirements and a moderate learning curve.

An early telerobotic ultrasound system prototype showed promising results for obstetric sonography. Arbeille et al[3] investigated a telerobotic ultrasound system to assess biometric parameters, placental location, and amniotic fluid volume; however, the potential for the system to perform a fetal anatomic survey was not assessed. Additionally, this telerobotic ultrasound system did not allow users to remotely control settings such as gain or depth; rather, settings were controlled by an assistant at the patient's site.

Commercial-grade telerobotic ultrasound systems have now been developed, and a key prerequisite for widespread adoption of telerobotic sonography is a systematic assessment of the diagnostic capability and acceptability to users and patients.[1] In this study, the feasibility of using a telerobotic ultrasound system consisting of a robotic arm (MELODY system; Société AdEchoTech, Naveil, France), an ultrasound system (SonixTablet; BK Ultrasound, Richmond, British Columbia, Canada), and a videoconferencing system (TE30 All-in-One, HD Videoconferencing Endpoint; Huawei Technologies, Shenzhen, China) to perform routine prenatal sonographic examinations was assessed. An assessment of the acceptance of this system by users and patients was also performed.

## Materials and Methods

### *Patient Population*

This study was approved by our institutional Research Ethics Board. Patients 18 years and older scheduled for an obstetric sonographic examination at a local outpatient ultrasound clinic were prospectively recruited. Thirty patients (20 scheduled for a limited examination and 10 scheduled for a second-trimester fetal anatomical survey) were included in this study, including 1 patient with a twin pregnancy. Written informed consent was obtained from all participants.

### *Telerobotic System*

A clinic room (serving as the patient site/remote site) was equipped with the MELODY patient system, SonixTablet ultrasound system, and 5-MHz transducer. The MELODY system is a 3-degree-of-freedom robot designed to hold any standard ultrasound transducer and allows users to remotely control rotation, rocking, and tilting of the attached transducer.

An adjacent room (serving as the sonographer site/central site) was equipped with the MELODY Expert system, consisting of a mock transducer and an electronic control box. As sonographers manipulated the mock transducer in a manner similar to scanning conventionally, all fine movements of the mock transducer were reproduced by the scanning transducer at the patient site via the 3-degree-of-freedom robot. A touch screen monitor at the sonographer site displayed the identical ultrasound system interface as that displayed on the SonixTablet. Sonographers controlled all settings such as gain and depth and added image annotations using either the touch screen monitor or mouse and keyboard.

A videoconferencing system enabled communication between sonographers, patients, and patient site assistants. Gross placement of the robotic transducer holder and pressure of the transducer on the patient were adjusted by patient site assistants, who had no expertise in sonography, based on instructions from sonographers. A nondedicated Internet connection (50-Mbps download and 20-Mbps upload speeds) connected the two sites, with separate data flows for the sonographic video data, ultrasound settings, robotic control, and videoconferencing system (Figure 1).

### *Scanning Protocol*

All patients were initially scanned with a conventional ultrasound system (EPIQ 5; Philips Healthcare, Amsterdam, the Netherlands). Up to 7 days (mean, 2.0 days) after the conventional examination, patients were scanned by a different sonographer with similar experience and qualifications using the telerobotic system, who was blinded to the findings of the conventional examination. Based on the referring clinician's initial request, examinations included biometry (biparietal diameter, head circumference, abdominal circumference, and femur length), amniotic fluid volume, and placental location (n = 20) or a complete screening examination including fetal anatomy based on the Society of Obstetricians and Gynaecologists of Canada's clinical practice guideline, "Content of a Complete Routine Second Trimester Obstetrical Ultrasound Examination and Report" (n = 10).[4] The duration of each examination was recorded. Two sonographers performed all 30 conventional examinations (performing 14 and 16 examinations, respectively), and the same sonographers performed all telerobotic examinations (performing 16 and 14 examinations, respectively). There were 2 patient site assistants who assisted with 7 and 23 telerobotic examinations, respectively.

*Image Interpretation*

Images from telerobotic examinations were read independently from images from conventional examinations by a single board-certified radiologist, who was blinded to the findings of the corresponding examination. A standardized reporting form was used to assess whether structures could be sufficiently visualized on telerobotic and conventional examinations.

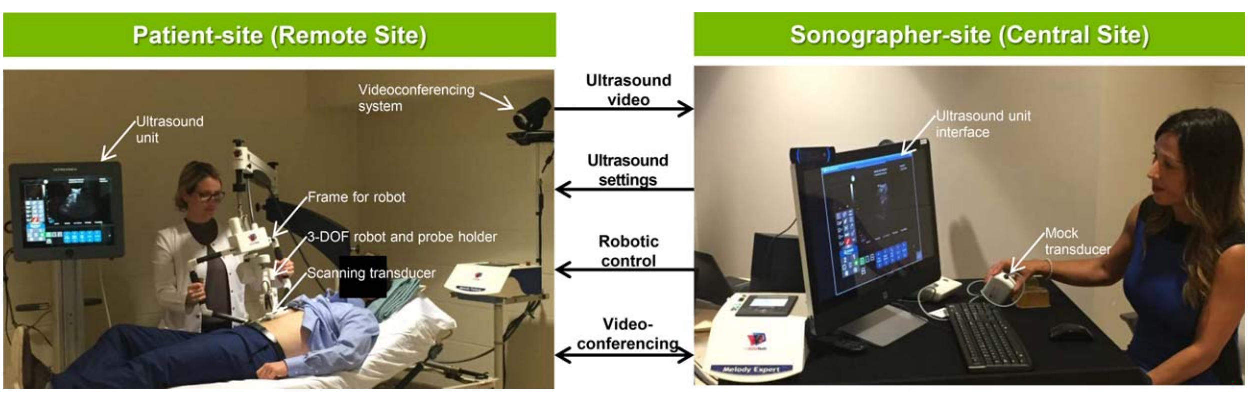
*Patient Assessment*

After completion of both scans, patients completed a survey based on that of Adams et al[2] regarding their experience with the telerobotic examination. Participants were asked to indicate their agreement with the following 4 statements using a 5-point Likert scale: (1) if in the future I required another sonographic study and sonography was not available in my community, I would be willing to have a robotic telesonography scan; (2) I felt comfortable communicating with the remote sonographer using the videoconferencing system; (3) I felt comfortable knowing that a person in a different room was controlling the ultrasound transducer; and (4) I felt less pressure on my abdomen during the robotic telesonographic study than I did during the conventional study.

*Sonographer and Patient Site Assistant Assessment*

Similarly, sonographers were asked to indicate their agreement with the following statements using a 5-point Likert scale after each telerobotic examination: (1) the audio was of sufficient quality to allow me to adequately communicate with the patient site assistant; (2) the patient site assistant and I were able to effectively communicate regarding transducer or patient positioning; and (3) manipulating the remote

**Figure 1.** At the patient site, an assistant holds the frame for a 3-degree-of-freedom (DOF) robot to which the scanning transducer is attached. A videoconferencing system allows the sonographer and the patient to communicate with each other and allows the sonographer to provide instructions to the patient site assistant regarding gross placement of the frame for the robot. At the sonographer site, a sonographer manipulates a mock transducer, and all movements of the mock transducer (rotation, rocking, and tilting) are directly replicated by the scanning transducer at the patient site. Real-time sonographic video data and a user interface identical to that of the ultrasound unit is displayed at the sonographer site, and the sonographer can remotely control all settings on the ultrasound unit. A nondedicated Internet connection connects the two sites, with separate data flows for sonographic video, ultrasound settings, robotic control, and videoconferencing.



ultrasound transducer resulted in less physical strain than scanning a similar patient using conventional sonography. Patient site assistants indicated their level of agreement with the following statements: (1) the audio was of sufficient quality to allow me to adequately communicate with the remote sonographer; (2) the sonographer and I were able to effectively communicate regarding transducer or patient positioning; and (3) holding the MELODY system caused moderate or severe physical strain (ie, I felt tired or sore as a result of holding the MELODY system).[2]

### *Statistical Analysis*

The statistical analysis was performed with SPSS Statistics version 23.0 software (IBM Corporation, Armonk, NY). Descriptive statistics, including mean values, standard deviations, and mean differences for continuous variables and frequencies and proportions for categorical responses, were determined. Measurements of structures from conventional and telerobotic examinations were compared by paired-sample *t* tests, and agreement was assessed with intraclass correlation coefficients. $P < .05$ was regarded as significant.

## Results

The mean gestational age of all participants was 22.9 ± 5.3 weeks (range, 15–36 weeks). The mean gestational age of the cohort of 10 patients scheduled for a second-trimester fetal anatomic survey was 20.2 ± 1.0 weeks (range, 19–23 weeks).

### *Image Assessment*

Paired-sample *t* tests showed no statistically significant difference between conventional and telerobotic measurements of fetal head circumference, biparietal diameter, or single deepest vertical pocket of amniotic fluid; however, a small but statistically significant difference was observed in measurements of abdominal circumference and femur length ($P < .05$). Intraclass correlations showed excellent agreement between telerobotic and conventional measurements of all 4 biometric parameters (Table 1). In 13 (43%), cases the relationship between the placenta and internal cervical os was not adequately shown on telerobotic images.

Of 21 fetal structures included in the fetal anatomic survey, 80% of all structures attempted across patients were satisfactorily shown on the telerobotic system (range, 57%–100% per patient), in comparison to 98.6% on conventional examinations (range, 86%–100% per patient). The cranium, stomach, bladder, abdominal umbilical cord insertion, upper extremities, and lower extremities were successfully shown on all telerobotic examinations; however, the cavum septi pellucidi and cardiac outflow tracts were shown on less than 50% of examinations (Table 2). All findings (2 echogenic foci within the left ventricle) identified on conventional sonography were also detected by sonographers using the telerobotic ultrasound system. Representative images from telerobotic and conventional ultrasound systems are presented in Figures 2 and 3.

### *Patient Assessment*

Most participants somewhat or strongly agreed that they felt comfortable communicating with the remote

**Table 1.** Comparison of Measurements as Determined by Telerobotic and Conventional Sonography

| Measurement | Telerobotic Measurement | Conventional Measurement | n[a] | Mean Difference (95% CI)[b] | $P^c$ | ICC |
|---|---|---|---|---|---|---|
| Biparietal diameter, mm | 54.9 ± 15.9 | 54.1 ± 16.4 | 31 | 0.8 (−0.01, 1.6) | .05 | 0.995 |
| Head circumference, mm | 204.5 ± 56.3 | 202.9 ± 58.3 | 30 | 1.6 (−1.3, 4.5) | .27 | 0.995 |
| Abdominal circumference, mm | 188.9 ± 64.7 | 184.6 ± 65.3 | 31 | 4.3 (0.7, 7.9) | .02 | 0.993 |
| Femur length, mm | 40.7 ± 14.0 | 39.1 ± 13.5 | 31 | 1.7 (0.9, 2.4) | <.001 | 0.990 |
| Amniotic fluid (single deepest pocket), mm | 49.0 ± 14.9 | 48.7 ± 11.4 | 24 | 0.21 (−5.2, 5.6) | .94 | 0.711 |

CI indicates confidence interval; and ICC, intraclass correlation coefficient.
[a]Number of paired robotic-conventional assessments.
[b]Robotic measurement – conventional measurement.
[c]Paired *t* test.

sonographer using the videoconferencing system, felt comfortable knowing that a person in a different room was controlling the ultrasound transducer, and perceived less abdominal pressure during telerobotic examinations than during conventional examinations (Table 3). Ultimately, 97% of patients agreed that they would be willing to have another telerobotic examination in the future if conventional sonography was not available in their communities.

### *Sonographer and Patient Site Assistant Assessment*

The mean duration of second-trimester fetal anatomic survey examinations performed telerobotically was $27.8 \pm 4.3$ minutes (range, 23–35 minutes), similar to

**Figure 2.** Representative sonograms showing equivalence of biparietal diameter (BPD) and head circumference (HC) measurements using the telerobotic ultrasound system (SonixTablet; **A**) and conventional ultrasound system (EPIQ 5; **B**).

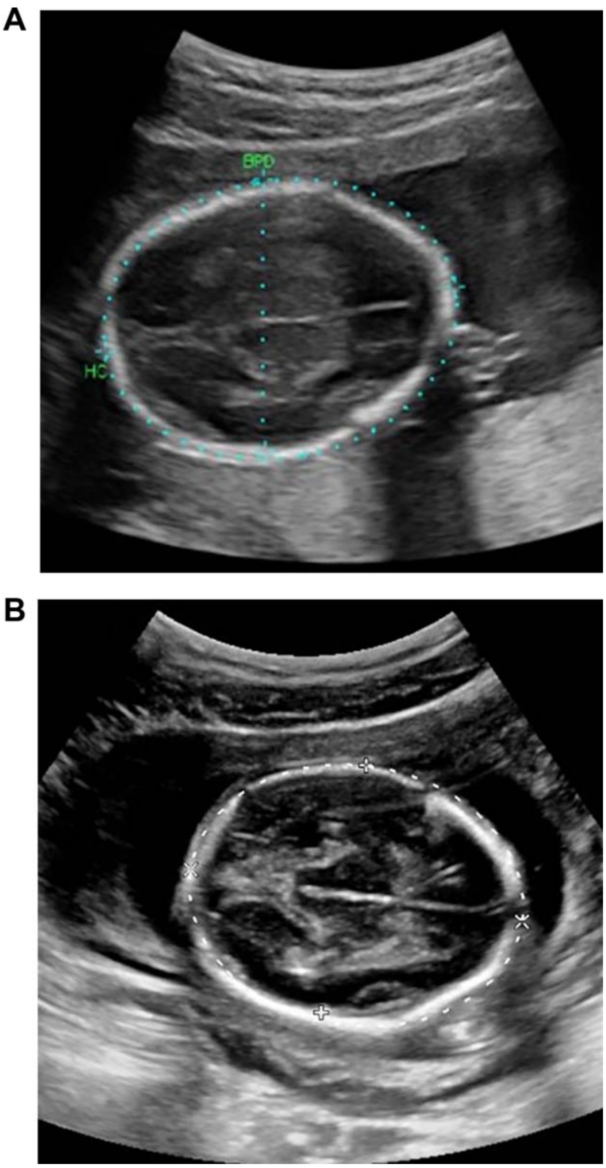
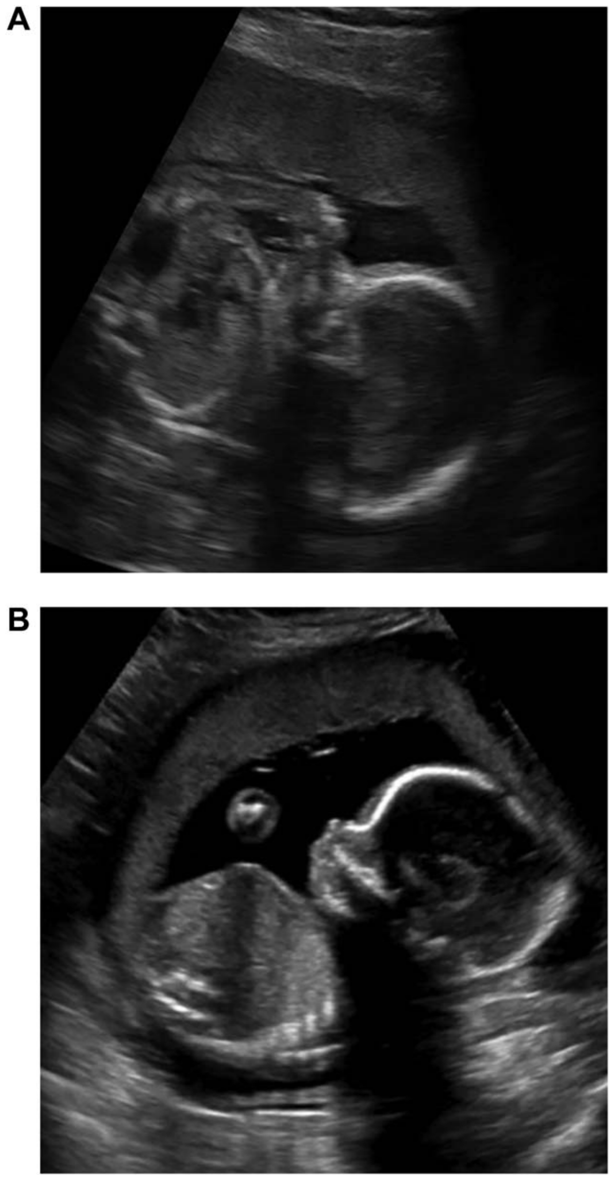



**Figure 3.** Representative sonograms showing a fetal profile on the telerobotic ultrasound system (SonixTablet; **A**) and conventional ultrasound system (EPIQ 5; **B**) at 20 weeks 4 days and 20 weeks 0 days, respectively.



that of examinations performed conventionally: 27.8 ± 7.9 minutes (range, 23–35 minutes). The audio quality using the TE30 All-in-One, HD Videoconferencing Endpoint system was sufficient to allow sonographers and patient site assistants to communicate regarding gross placement of the robotic transducer holder and patient positioning (Table 3). Strategies used to communicate with the patient site assistants regarding gross placement of the robotic transducer holder included using simple terms such as “up,” “down,” “right,” and “left” relative to the umbilicus or pubis and reorienting using the pubic symphysis as a landmark when contact was lost.

Sonographers generally reported that manipulating the mock transducer resulted in less physical strain than scanning a patient with a similar body habitus using a conventional ultrasound system. However, the patient site assistants reported that holding and grossly positioning the frame for the robotic arm caused moderate or severe physical strain in several cases (Table 3).

## Discussion

Access to prenatal imaging has been identified as an especially important need in communities that lack imaging facilities. As obstetric sonography is not available in many rural and remote communities, patients must travel or be transported to larger centers for imaging, resulting in additional transportation costs and delays in management. Due to the inconvenience and financial cost of transportation and loss of work time, many patients may forego prenatal imaging. In this study, we demonstrated the feasibility of using a telerobotic approach to remotely perform prenatal sonographic studies. Biometric measurements obtained during the telerobotic sonographic examination showed excellent agreement with conventional examinations. Patients readily accepted the technology and would be willing to have another examination performed telerobotically in the future. However, our study also demonstrated some limitations in the telerobotic ultrasound system’s ability to currently show all fetal anatomy

**Table 2.** Visualization of Fetal Anatomy Using Telerobotic and Conventional Sonography

| | Telerobotic | | | Conventional | | |
|---|---|---|---|---|---|---|
| **Structure** | **Sufficiently Visualized, n** | **Attempted, n** | **Visualized, %** | **Sufficiently Visualized, n** | **Attempted, n** | **Visualized, %** |
| Cranium | 10 | 10 | 100 | 10 | 10 | 100 |
| Cerebral ventricles | 8 | 9 | 89 | 10 | 10 | 100 |
| Cavum septi pellucidi | 3 | 9 | 33 | 10 | 10 | 100 |
| Midline falx | 9 | 10 | 90 | 10 | 10 | 100 |
| Choroid plexus | 9 | 10 | 90 | 10 | 10 | 100 |
| Cisterna magna | 9 | 10 | 90 | 10 | 10 | 100 |
| Cerebellum | 9 | 10 | 90 | 10 | 10 | 100 |
| Orbits | 9 | 10 | 90 | 9 | 10 | 90 |
| Lips | 5 | 10 | 50 | 9 | 10 | 90 |
| Spine | 5 | 9 | 56 | 10 | 10 | 100 |
| Chest | 5 | 8 | 63 | 10 | 10 | 100 |
| Cardiac 4-chamber view | 8 | 10 | 80 | 10 | 10 | 100 |
| Cardiac outflow tracts | 4 | 10 | 40 | 9 | 10 | 90 |
| Heart axis | 8 | 10 | 80 | 10 | 10 | 100 |
| Cardiac situs | 7 | 10 | 70 | 10 | 10 | 100 |
| Stomach | 10 | 10 | 100 | 10 | 10 | 100 |
| Kidneys | 5 | 9 | 56 | 10 | 10 | 100 |
| Bladder | 9 | 9 | 100 | 10 | 10 | 100 |
| Abdominal umbilical cord insertion | 10 | 10 | 100 | 10 | 10 | 100 |
| Upper extremities and presence of hands | 10 | 10 | 100 | 10 | 10 | 100 |
| Lower extremities and presence of feet | 9 | 9 | 100 | 10 | 10 | 100 |

required for a second-trimester fetal anatomic survey in some patients.

Although our analysis showed a statistically significant difference between measurements of the abdominal circumference and femur length when measured telerobotically compared to the reference standard, there is a lack of consensus on what defines a clinically meaningful difference. In a study comparing 3-dimensional sonographic measurements to those generated by traditional 2-dimensional sonography, a statistically significant difference was observed in measurements of head circumference, abdominal circumference, and femur length. However, the authors concluded that these did not represent meaningful, clinically relevant differences; this conclusion was supported by intraclass correlation coefficients indicating excellent agreement between the techniques.[5] Furthermore, it is established in the literature that there is high interobserver variability of measurements of the single deepest vertical pocket of amniotic fluid: for example, Sande et al[6] found interobserver variability of –51% to 52% (95% confidence interval), consistent with the greater variability between telerobotic and conventional measurements of this variable in our study.

Structures that were least effectively visualized telerobotically in our study included the cavum septi pellucidi, cardiac outflow tracts, spine, and kidneys. Furthermore, determination of cardiac situs was appropriately documented in only 70% of cases, as documentation of both an axial view of the upper abdomen and 4-chamber view of the heart were required for the assessment to be considered adequate. These views correspond to structures that are generally most difficult to satisfactorily show conventionally. For example, in a series of 98 patients at 18 and 22 weeks' gestational age, cardiac views were adequately obtained in only 80.6% to 83.7% of patients, and the spine was adequately shown in only 85.7% to 86.7% of patients on conventional sonography.[5] We hypothesize that in a clinical setting, where showing all fetal structures may be of critical importance for patient treatment, visualization scores may improve with additional time taken to show all fetal

**Table 3.** Survey Responses From Patients, Sonographers, and Patient Site Assistants After Telerobotic Examinations

| Item | Strongly Agree | Somewhat Agree | Neither Agree nor Disagree | Somewhat Disagree | Strongly Disagree |
|---|---|---|---|---|---|
| Patients | | | | | |
| (1) If in the future I required another sonographic study and sonography was not available in my community, I would be willing to have a robotic telesonographic scan. | 26 (90) | 2 (7) | 0 (0) | 0 (0) | 1 (3) |
| (2) I felt comfortable communicating with the remote sonographer using the videoconferencing system. | 25 (86) | 3 (10) | 0 (0) | 0 (0) | 1 (3) |
| (3) I felt comfortable knowing that a person in a different room was controlling the ultrasound transducer. | 23 (79) | 2 (7) | 3 (10) | 0 (0) | 1 (3) |
| (4) I felt less pressure on my abdomen during the robotic telesonographic study than I did during the conventional study. | 13 (45) | 11 (38) | 3 (10) | 2 (7) | 0 (0) |
| Sonographers | | | | | |
| (1) The audio was of sufficient quality to allow me to adequately communicate with the patient site assistant. | 21 (72) | 8 (28) | 0 (0) | 0 (0) | 0 (0) |
| (2) The patient site assistant and I were able to effectively communicate regarding transducer or patient positioning. | 11 (38) | 12 (41) | 1 (3) | 4 (14) | 1 (3) |
| (3) Manipulating the remote ultrasound transducer resulted in less physical strain than scanning a similar patient using conventional sonography. | 13 (45) | 13 (45) | 2 (7) | 1 (3) | 0 (0) |
| Patient site assistants | | | | | |
| (1) The audio was of sufficient quality to allow me to adequately communicate with the remote sonographer. | 20 (71) | 8 (29) | 0 (0) | 0 (0) | 0 (0) |
| (2) The sonographer and I were able to effectively communicate regarding transducer or patient positioning. | 15 (54) | 11 (39) | 0 (0) | 2 (7) | 0 (0) |
| (3) Holding the MELODY system caused moderate or severe physical strain (ie, I felt tired or sore as a result of holding the MELODY system). | 0 (0) | 6 (21) | 5 (18) | 13 (46) | 4 (14) |

Data are presented as number (percent).

structures. Due to the difficulty in visualizing the right and left ventricular outflow tracts, the addition of a 3-vessel and trachea view may be an especially important addition to telerobotic sonographic protocols. This view is generally easier to acquire in first-, second-, and third-trimester studies and has been reported to be helpful for detecting most ductal-dependent cardiac malformations.[7] Additionally, the use of 3-dimensional sonography, which allows a user to obtain a series of volumes that can later be displayed and reconstructed in any plane, may offer improved visualization of structures that are poorly visualized on 2-dimensional telerobotic scanning. Benacerraf et al[8] found that a standard fetal anatomic survey could be performed in 1.8 minutes by acquiring five 3-dimensional volumes (compared to 19.6 minutes for a standard 2-dimensional approach), with visualization of structures ranging from 92% to 100%. However, structures that were poorly visualized in our study, such as the cavum septi pellucidi and the cardiac outflow tracts, were some of the same structures that were least well visualized on 3-dimensional sonographic volumes.[8] Nevertheless, it is plausible that 3-dimensional volumes could be acquired in a short time remotely by using a telerobotic ultrasound system or by a trained patient site assistant; this approach may offer additional diagnostic information beyond that provided by 2-dimensional image acquisitions. Obtaining cine clips of structures that are difficult to capture may also allow for improved diagnosis by the radiologist. Furthermore, as the relationship between the cervical os and placenta was not consistently shown in our study because the robotic arm frame and pubic symphysis prevented the required angulation to be obtained, training the patient site assistant to manually scan this region with real-time, remote guidance from the sonographer may be a potential solution to improve visualization of this important relationship.

Most of the literature surrounding telesonography considers only the transmission of images generated directly at the patient's location for remote interpretation,[9–11] and there is limited literature describing telerobotic approaches for performing obstetric examinations.[12] Arbeille et al[3] found that in 93.1% of cases, biometric parameters, placental location, and amniotic fluid volume were correctly assessed with a telerobotic ultrasound system. Although visualization of additional fetal anatomic structures was attempted with the telerobotic ultrasound system, these were not included in the visualization score. Similar to our group's previous study evaluating telerobotic abdominal examinations,[2] Arbeille et al[3] found that the duration of telerobotic examinations was longer than that of conventional examinations (18 compared to 14 minutes). The relatively decreased time requirement for telerobotic examinations in this study (such that telerobotic and conventional examinations were of the same duration) may be attributed to sonographers' additional experience using the telerobotic system before the commencement of the patient recruitment, as well as the enhanced functionality of the telerobotic system, allowing the sonographer to remotely control ultrasound settings and annotate images, an improvement over the telerobotic ultrasound system used by Arbeille et al.[3]

This study also identified potential improvements to telerobotic ultrasound systems, including the ability for the sonographer to control translational movements and pressure of the transducer, modifications of the frame for the robotic arm to reduce strain for patient site assistants, and the development of a smaller base for the transducer holder, as sonographers noted that some angles were difficult to obtain because of the footprint of the transducer holder, which may be a reason that some structures such as the internal cervical os could not be sufficiently shown in all cases.

An alternative system consisting of a transducer outfitted with one motor to tilt the transducer and a second motor to rotate the transducer around its central axis has also been assessed by a group in France for telerobotic obstetric examinations. After 15 obstetric examinations, the authors reported that telerobotic images were of a similar quality as those generated by a robotic arm similar to the MELODY system; however, no formal evaluation methods were reported, and the scope of the obstetric examinations performed was unclear.[13]

The performance of sonographic studies by midwives has been identified as another potential solution to increase access to sonography in some communities, especially in countries with a greater number of midwives or nurses than sonographers. For example, a pilot project in Kenya trained midwives to perform basic obstetric sonography and then transmit images and preliminary reports from 3 clinics via a 3G mobile phone network for radiologists to review at a Kenyan hospital 20, 120, and 400 km away, respectively.[14] The study found excellent correlations between outcomes of the pregnancies and diagnoses based on preliminary reports generated by midwives. Although this approach represents a potential solution to increase access to sonography in some communities, the substantial training period required for midwives to gain competence in scanning (training 8 hours per day for 4 weeks) and the inability for radiologists to confirm findings by real-time sonographic video transmission or scanning themselves are drawbacks of this process. The role of midwives in performing ultrasound in developed countries is variable according to local laws, and it is considered within the scope of midwifery practice for midwives to perform point-of-care sonography.[15] However, midwives who perform advanced sonographic studies such as fetal anatomic surveys generally hold a sonographer designation,[15] and access to sonography remains limited in many communities.

Unique strengths of this study include that patients were recruited prospectively; sonographers were blinded to findings of the corresponding examinations; a standardized imaging protocol was used for all examinations; a full prenatal examination based on established clinical practice guidelines was performed; and all examinations were reported on a standardized reporting form. There were also some limitations to this study. All telerobotic examinations were performed after the conventional studies, resulting in situations in which some patients were not able to tolerate the entirety of the second scan because of time constraints or discomfort. In such cases, structures that were not attempted because of time factors were not included in the data analysis. Although 15 telerobotic examinations were performed the same day as conventional examinations, 15 telerobotic examinations were performed up to 7 days after the conventional studies, resulting in the potential for changes in the fetal position or lie, fetal growth, and changes in biometric parameters over that time. Finally, differences in diagnostic performance may partly be attributable to the quality of the ultrasound systems (EPIQ 5 and SonixTablet). Additional research using the SonixTablet for both telerobotic and conventional examinations may be helpful to differentiate differences due to the method of scanning (telerobotic or conventional) versus the quality of the ultrasound system. However, the design of this study allowed us to compare the telerobotic ultrasound system to a conventional system commonly used in larger centers, thus comparing it to a reference standard.

We plan to establish a pilot robotic ultrasound clinic in an underserviced remote community in northern Canada to provide obstetric and abdominal examinations. Establishing this service in a geographic area where there is a critical gap of obstetric sonography access will allow us to assess the impact of this technology in prenatal care. Our vision is to establish a network of telerobotic ultrasound systems in rural, remote, and low-volume centers, established in partnership with local communities, which will be serviced by central radiology groups. Ultimately, telerobotic sonography has the potential to provide increased access to imaging and greater equity in the delivery of health care services, enabling pregnant women to access prenatal imaging in their home communities.

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