Received July 8, 2025, accepted January 6, 2026, publication date for online-first March 2, 2026.

Original Research Article

Genitourinary System Imaging with Low-Cost Portable Ultrasound Device in the Context of Telemedicine Implementation

Afroza Naznin[1,2], Muhammad Abdul Kadir[1,*], Fatima Begum[3], Khondkar Siddique-e Rabbani[1]

[1] Department of Biomedical Physics and Technology, University of Dhaka, Dhaka, Bangladesh.
[2] Institute of Nuclear Medicine & Allied Sciences, Sir Salimullah Medical College & Mitford Hospital, Bangladesh Atomic Energy Commission, Dhaka, Bangladesh.
[3] National Institute of Nuclear Medicine & Allied Sciences, Bangladesh Atomic Energy Commission, Dhaka, Bangladesh.
[*] Corresponding Author Email: kadir@du.ac.bd

ABSTRACT

Background: The integration of digital diagnostic tools is essential for strengthening telemedicine infrastructure, particularly in remote and resource-limited settings. Ultrasound is a promising imaging modality because of its noninvasive disposition, absence of ionizing radiation, and ability to provide rapid, real-time diagnostic information. Among the wide range of ultrasound systems, cost-effective and portable devices with acceptable diagnostic performance are needed to improve accessibility. This study aimed to evaluate the performance of a commercially available low-cost portable ultrasound device, with a specific focus on imaging the genitourinary (GU) system. **Methods:** This cross-sectional study was conducted between December 2022 and July 2023 and included 169 participants. Each participant underwent ultrasound examinations using both a low-cost portable ultrasound device and a conventional ultrasound machine, which served as the reference (gold) standard. The assessment included measurement of organ sizes and detecting pathological conditions in the kidneys, urinary bladder, uterus, ovaries, and prostate. **Results:** The portable ultrasound device demonstrated high diagnostic accuracy for detecting renal cysts (98.7%), uterine masses (97.2%), polycystic ovaries (98.7%), and adnexal cystic lesions (96.3%). Relatively lower accuracy was observed for the detection of renal parenchymal disease (93.7%) and ovarian enlargement (91.5%). Agreement between the portable and conventional devices for organ size measurements showed moderate to strong correlations. The coefficients of determination (r^2) for bipolar lengths of the right and left kidneys, uterine length, and uterine anteroposterior diameter were 0.5907, 0.6345, 0.8637, and 0.8444, respectively. **Conclusion:** These findings suggest that low-cost portable ultrasound devices can provide acceptable performance for imaging of the GU system. Their integration into telemedicine and tele-ultrasound services could enhance diagnostic capabilities and improve access to essential imaging in resource-limited and underserved populations.

Keywords—*Telemedicine, Tele-ultrasound, Portable ultrasound, Genitourinary system, Low-cost device, Low resource settings.*

INTRODUCTION

Telemedicine enables patients to receive timely consultations, diagnoses, and treatments from healthcare professionals without the need to travel, reducing both costs and barriers to care. Telemedicine has become an integral part of modern healthcare, especially in the wake of the COVID-19 pandemic[1–3], bridging gaps in healthcare access in both urban and rural settings, particularly in low-resource environments.[4] A critical component of telemedicine infrastructure is the integration of diagnostic tools that allow for remote evaluation and monitoring. Among available imaging modalities, ultrasound is especially well-suited for telemedicine because of its real-time capability, portability, relative affordability, and minimal infrastructure requirements, compared to computed tomography (CT) or magnetic resonance imaging (MRI). The concept of tele-ultrasound, wherein ultrasound images and videos are transmitted for remote interpretation, has been successfully deployed in diverse settings, including emergency medical services[5,6], conflict zones[7,8], and remote expeditions[9], demonstrating its broad applicability and clinical value. Even the International Space Station has implemented tele-ultrasound as a cost-effective tool for onboard medical diagnostics, underscoring its versatility and global utility.[10]

In low-resource settings, indigenous innovations, such as tele-stethoscopes and tele-electrocardiograms (ECG), have already improved the quality of telemedicine consultations by enabling real-time transmission of basic diagnostic data.[11] Building on this progress, incorporating tele-ultrasound systems into telemedicine could be a pivotal step forward in enhancing remote healthcare. While high-end ultrasound machines provide exceptional detail, their high costs and need for skilled technicians limit accessibility, especially in rural and underserved areas. As a result, there has been a growing interest in the use of low-cost portable ultrasound devices to address these limitations. However, concerns remain regarding the trade-off between cost and diagnostic performance in low-cost portable ultrasound systems. Previous studies have explored the accuracy of low-cost portable ultrasound scanners, compared to more sophisticated standard devices in various applications, including pregnancy profiling[12], detection of pneumothorax, abdominal pathologies, and imaging of knee structures. These findings suggest that portable ultrasound technology holds potential to strengthen telemedicine in multiple areas.

Genitourinary (GU) conditions, including kidney stones, bladder abnormalities, and prostate disorders, are common and require timely and accurate diagnosis to prevent complications and improve patient outcomes. The use of portable ultrasound devices for GU imaging has been explored in various studies, with promising results for their diagnostic accuracy and practicality. Lavi et al. evaluated kidney length measurements using a portable ultrasound scanner and reported a difference of approximately 0.8 mm, compared to conventional ultrasound systems.[13] This is a very small difference when considering the full length of the kidney, which is about 110 mm. Stock et al. demonstrated that a pocket-size ultrasound device achieved a sensitivity of 79% and specificity of 100% for detecting renal cysts.[14] Portable ultrasound devices are also investigated for urinary bladder (UB) imaging. Multiple studies have concluded that these devices provide sufficient accuracy to enhance clinical decision-making.[13,15,16] Prostatic evaluation with portable ultrasound remains underexplored, although Lavi et al. demonstrated no significant difference ($p = 0.46$) in prostate volume measurements between portable and standard devices in a small prospective observational study involving 25 urology patients.[13] For uterine and ovarian imaging, portable devices have shown good agreement with high-end systems in detecting pathologies, such as uterine mass lesions and adnexal abnormalities. Toscano et al. conducted a pilot study on 40 subjects, finding substantial agreement (Cohen's Kappa > 0.7) in evaluating uterine position, the presence of myomas, and adnexal pathologies.[17] A recent study reported good to excellent agreement (Cohen's Kappa = 0.68 – 0.84) for measurements, such as uterine length, volume, endometrial thickness, and the diameter of uterine myomas as well as ovarian volume.[18] Toscano et al. also quantified the diagnostic performance of handheld ultrasound devices for uterine mass lesions, reporting sensitivity of 80%, specificity of 93.1%, positive predictive value (PPV) of 80%, and negative predictive value (NPV) of 93.1%.[7] For intracavitary content detection, Araujo et al. reported a sensitivity of

12.5%, specificity of 99.3%, accuracy of 90.3%, PPV of 66.7%, and NPV of 90.8% using a handheld device.[18]

Despite these encouraging findings, many of the studies to date have been pilot in nature, involved limited sample sizes, and a narrow focus on specific GU pathologies. Importantly, most of these studies relied on portable devices with 128-element arrays, typically costing around US$5,000. Although such devices are less expensive than conventional high-end ultrasound systems, their cost remains prohibitive for large-scale deployment in low- and middle-income countries, where thousands of units are required to serve widespread populations. Moreover, little evidence exists regarding the clinical performance of ultra-low-cost portable ultrasound probes with fewer elements and reduced bandwidth, which are increasingly marketed for use in resource-limited settings. The diagnostic reliability of these devices is not studied to a sufficient degree. The present study aims to address these issues by evaluating the performance of a low-cost portable ultrasound device with only 80 elements, resulting in lower image resolution, lower bandwidth, and costing less than US$1,000. The device was assessed across a broad range of GU conditions, including the kidneys, UB, uterus, ovaries, and prostate. Given the high prevalence of GU disorders and the frequent presentation of GU symptoms in telemedicine consultations, a dependable and affordable portable ultrasound solution could bridge critical healthcare gaps and improve patient outcomes, particularly in underserved populations.

MATERIALS AND METHODS

Study Design

This cross-sectional study was conducted from 01 December 2022 to 30 July 2023 to assess the diagnostic accuracy of a low-cost portable ultrasound device with 80 elements (Sunbright SUN-P1, costing approximately US$900; Sunbright, Shanghai, China; more information is provided in Table 1) for imaging the GU system. Participants were selected randomly from patients who presented to the hospital with symptoms suggestive of kidney, UB, prostate, uterine, ovarian, or adnexal abnormalities. Additionally, the study included apparently healthy individuals who were referred for GU ultrasonography as part of a routine health check-up. A total of 169 patients, aged 15–76 years (mean ± SD: 34.5 ± 13.7 years), were included in this study. The cohort consisted of 63 males and 106 females. Inclusion criteria required that patients had non-emergency stable conditions to ensure that imaging could be performed safely and systematically. Individuals presenting with any urgent or life-threatening conditions were excluded to maintain consistency in the study's non-emergent focus and to avoid compromising patient safety. Each selected patient underwent imaging using the portable ultrasound device. The findings were then compared with measurements performed on the same patients using a standard, high-end ultrasound machine (Samsung Medison Accuvix A30, 192 elements; Samsung Medison, South Korea, more information is provided in Table 1), which served as the reference standard. This comparison allowed for evaluation of the portable device's accuracy, sensitivity, and specificity in detecting various GU pathologies.

Specifications of Ultrasound Machines

The portable handheld ultrasound device (Sunbright Sun-P1, Shanghai, China) features a wired convex probe that connects to a smartphone, tablet, or personal computer (PC).[19] This device was chosen for its affordability (about US$900), commercial availability, Conformité Européenne (CE) marking indicating conformity with applicable European Union regulatory requirements as declared by the manufacturer, and its ability to transfer data to both PCs and smartphones. For the present study, a tablet or PC was used to acquire and display ultrasound images. Data obtained from the portable device were compared with the results from a high-end conventional ultrasound machine (Samsung Medison Accuvix A30), which is widely used in hospital settings.[20] Technical specifications of the two devices are summarized in Table 1.

TABLE 1. Comparison of the technical specifications of both conventional and portable devices.

Feature	Conventional Device	Portable Device
Model	Accuvix A30	SUN-P1
Manufacturer	Samsung Medison, South Korea	Sunbright, Shanghai, China
Number of elements	192	80
Frequency	2–6 MHz	2.5–4.5 MHz
Fractional bandwidth	100%	57%
Maximum scanning depth	35 cm	24 cm
Maximum frame rate	30	20
Gray scale level	256	256
Display resolution	1920 × 1080	1024 × 768
Power supply	100–220 V, 50/60 Hz, 1100 VA	5 V USB powered, 1 W
Price	US$30,000	US$900

Most previous studies evaluating portable or handheld ultrasound devices[13–15, 21] for point-of-care or telemedicine applications relied on probes with at least 128 transducer elements and wide fractional bandwidths, typically exceeding 80%. The technical parameters of representative probes used in such studies are summarized in Table 2. These hardware configurations provide improved beam-forming capability, shorter pulse lengths, and better axial and lateral resolution. In contrast, the low-cost device evaluated in this study employs an 80-element convex probe with a narrower fractional bandwidth. From a physical standpoint, the reduced element count limits spatial sampling and beam-steering flexibility, while the narrower bandwidth increases spatial pulse length, both of which are expected to degrade image resolution and contrast, compared to higher-end portable systems. The aim of this study is to assess whether such a low-cost probe can nevertheless provide clinically relevant diagnostic information for common GU conditions with acceptable accuracy.

TABLE 2. Technical specifications of portable ultrasound probes previously evaluated for point-of-care applications.

Device / Probe	No. of Elements	Frequency Range (MHz)	Fractional Bandwidth (%)
GE Vscan Air (convex)	128	2–5	90
Siemens Acuson P10	64	2–4	67
Philips Lumify™ C5	128	2–5	75
Sunbright SUN-P1 (present study)	80	2.5–4.5	57

Data Collection

After obtaining informed consent, each subject underwent two ultrasound scans: the first using a low-cost, tablet/PC-based portable, and handheld device, and the second using a high-end, sophisticated scanner operated by the same sonologist. To minimize bias, a sufficient time interval (minimum 1 h) was maintained between the two scans so that the sonologist forgets the measured values in the previous scan. The scans focused on evaluating the size, structural characteristics, and pathological changes in the kidneys, UB, uterus, ovaries, and prostate. Specific measurements and observations were made for each organ system as follows:

Kidney Assessment

For each kidney, length was measured as the longest longitudinal diameter along the bipolar axis. Parenchymal echotexture was categorized as normal, echogenic, or hypoechoic, and corticomedullary differentiation was classified as intact, reduced, or poor. The pelvicalyceal system was evaluated for dilation, and the presence or absence of focal lesions, including cysts, masses, or stones, was recorded.

Urinary Bladder Assessment

The urinary bladder wall thickness was classified as normal or increased, and wall regularity was noted as either regular or irregular. The presence or absence of any intraluminal structures was documented.

Uterus Assessment

Uterine size was documented as normal, smaller, or enlarged. The presence or absence of any mass lesion within the myometrium was recorded, and the endometrial cavity was assessed for the presence of material, with endometrial thickness measured where applicable.

Ovary Assessment

Each ovary was evaluated for size and classified as normal or enlarged. The presence or absence of focal lesions, such as cysts or masses, was documented.

Prostate Assessment

The prostate gland was assessed for size, categorized as normal or enlarged, and echotexture was noted as homogeneous or heterogeneous.

Measurements of organ diameters and lengths were taken using electronic calipers integrated into each device, with each measurement repeated thrice. The arithmetic mean of these measurements was calculated and recorded for final analysis. Statistical analysis was performed to evaluate concordance between the two devices, focusing on parameters such as organ measurements and the detection of pathologies. Sensitivity, specificity, PPV, and NPV were calculated to determine the diagnostic performance of the portable device relative to the conventional system.

Analysis and Presentation

Statistical analyses were conducted using the SPSS software and Microsoft Excel to evaluate accuracy and agreement between portable and standard ultrasound devices. Scatter plots were initially constructed to visually assess the overall correlation between the measurements from both devices. Agreement on categorical variables, such as parenchymal echotexture and the presence or absence of specific pathologies, was assessed using Cohen's Kappa statistics[22], which measure the degree of agreement beyond chance. For continuous variables, including organ measurements such as kidney length and endometrial thickness, a Bland–Altman plot was used to evaluate agreement by illustrating mean differences and limits of agreement between the two devices. Additionally, a paired *t*-test was applied to identify any statistically significant differences between measurements from portable and standard devices, with a significance level set at $p < 0.05$.[23]

RESULTS

Ultrasound scans were performed according to the referral request. The patients' age ranged from 15 to 76 years (mean ± SD: 34.5 ± 13.7 years). The number of scanned organs and the gender distribution of the subjects are summarized in Table 3.

TABLE 3. Number and distribution of study subjects.

Scanned Organ	Number of Patients	Male	Female
Kidney	80	57	23
Urinary bladder	125	30	95
Uterus and adnexa	83	-	83
Prostate	7	7	-

Some representative ultrasound sonography (USG) images of different organs are shown in Figures 1–3, which demonstrate both normal and pathological states of organs as captured with both devices in this study. Figure 1 illustrates two distinct renal pathologies captured by both standard and portable ultrasound devices. In the upper row, a cystic lesion is visible in the lower pole of the kidney, while the lower row displays a renal stone casting a characteristic distal acoustic shadow, effectively detected by both devices.

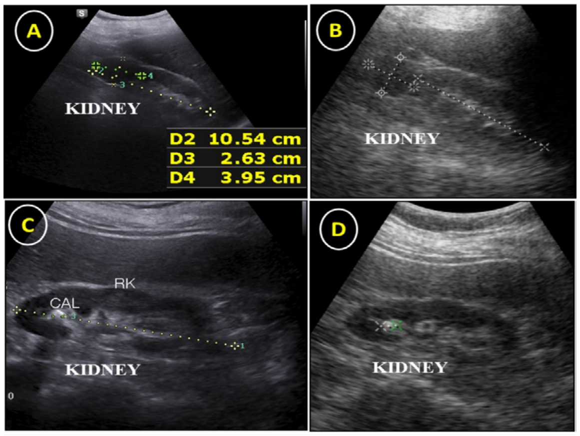

FIGURE 1. Ultrasound scan images of the kidneys captured with both devices. (A) and (C) are from the standard USG unit, while (B) and (D) are the corresponding images from the low-cost device. The upper row demonstrates a cystic lesion in the lower pole of the kidney, while the lower row shows a renal stone casting distal acoustic shadow, detectable in scans from both devices.

Figure 2 presents comparative images of UB and prostate obtained using the standard ultrasound device (left) and the portable device (right). Both scans demonstrate comparable structural details, highlighting the devices' capability to identify key anatomical features of these organs.

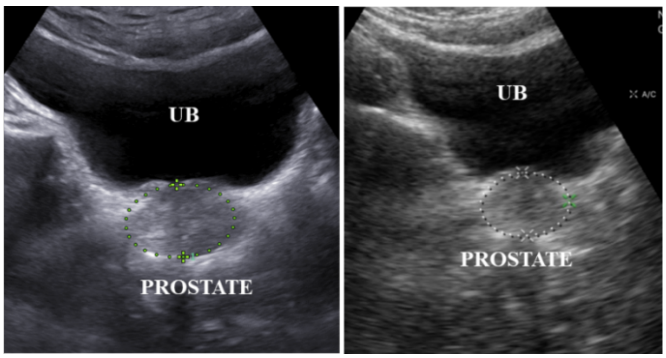

FIGURE 2. Ultrasound scan images of the urinary bladder and prostate captured with the standard device (left) and the portable device (right).

Figure 3 showcases ultrasound images of the uterus and ovary captured with both the standard and portable devices. Images 3A and 3C correspond to scans from the standard device, while images 3B and 3D are their counterparts from the portable device. The upper row images depict a normal anteverted uterus with clear delineation in both devices. In contrast, the lower row focuses on the right ovary. While the standard device provides a well-defined image, the ovary is less distinct in the portable device scan, as indicated by the white arrow, reflecting a limitation in its resolution for small or less echogenic structures.

Kidney Evaluation

Bipolar length of the right kidney, as measured by portable and conventional machines show moderate positive correlation as plotted in Figure 4. The squared correlation coefficient (r^2) is 0.5907. Bland–Altman plot in Figure 5 shows that overall, the mean value given by the portable device was only 0.1 cm greater than that obtained using the conventional device. The plot also shows that 95% of the measurements using the portable device remained within +1.8 cm and −1.5 cm range of the actual values.

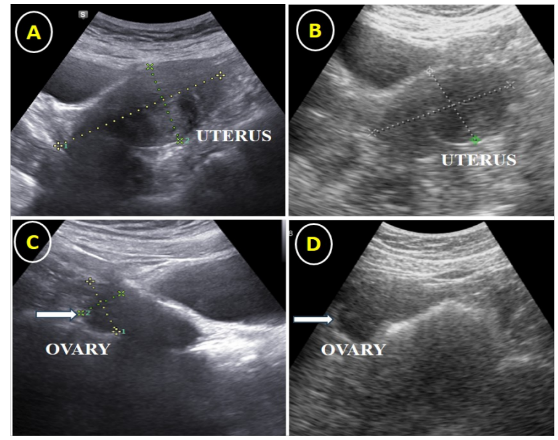

FIGURE 3. Ultrasound scan images of uterus and ovary captured with both devices. (A) and (C) are images from the standard USG unit, while (B) and (D) are the corresponding scans from the low-cost device. The upper row shows a normal anteverted uterus, while the lower row depicts a right ovary, which is difficult to delineate in the portable device scan (white arrow).

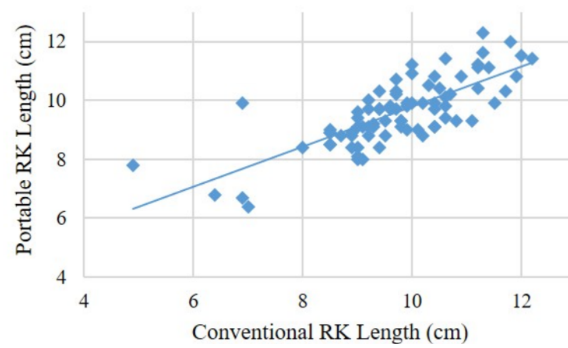

FIGURE 4. Scatter plot showing correlation between right kidney bipolar length measurements taken with the two devices. The squared correlation coefficient (r^2) = 0.5907.

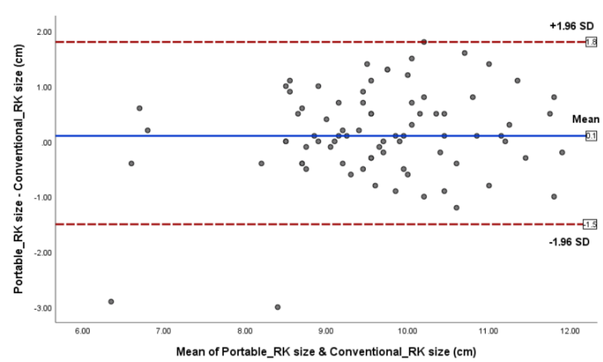

FIGURE 5. Bland–Altman plot showing the difference of the two paired right kidney (RK) length measurements plotted against the mean of the two measurements. There is no remarkable tendency toward under- or overestimation by the portable device.

Performance of the low-cost device in evaluating different pathologies involving the right renal parenchyma is summarized in Figure 6. The portable device could detect normal parenchymal echogenicity accurately, but about 33.3% of echogenic kidneys and 66.6% of hypoechoic kidneys were perceived as normal. The overall agreement between the portable and standard devices was substantial, with a Cohen's Kappa value of 0.715.

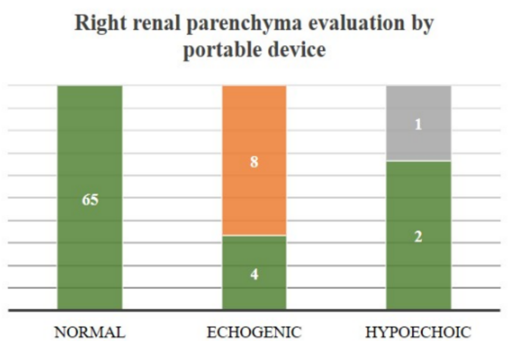

FIGURE 6. Distribution of right renal parenchymal change detection with the portable device plotted against the conventional USG unit. The Kappa value was 0.715, indicating substantial association.

Performance of the low-cost device in evaluating right renal lesions is summarized in Figure 7. It is observed that, except for one case of cortical cyst, the portable device performed accurately. Kappa value was 0.852, indicating a very good association.

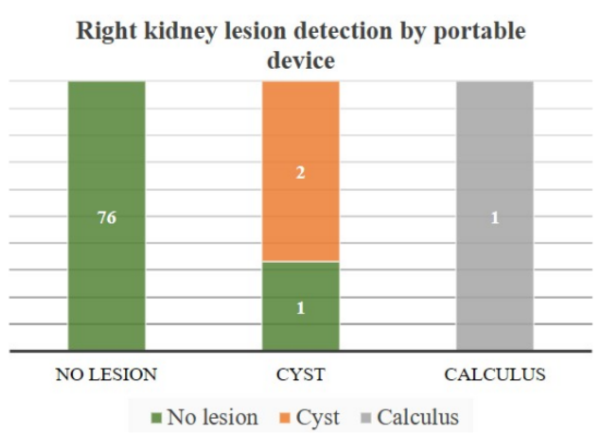

FIGURE 7. Distribution of right renal lesion detection with the portable device plotted against the conventional USG unit. The Kappa value was 0.852, indicating a very good association.

The bipolar length of the left kidney, as measured by both portable and conventional ultrasound devices, demonstrated a moderate positive correlation, as depicted in Figure 8.

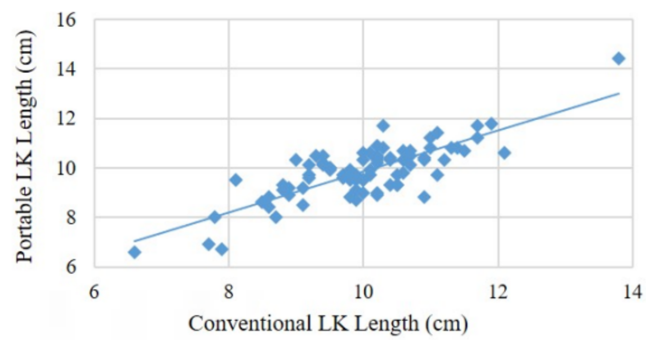

FIGURE 8. Scatter plot showing the correlation between left kidney bipolar length measurements taken with two devices. The squared correlation coefficient (r^2) = 0.6345.

The squared correlation coefficient (r^2) was 0.6345. The Bland–Altman plot in Figure 9 further illustrates the agreement between the two devices, showing that the mean measurement obtained with the portable device was only 0.14 cm greater than that obtained from the conventional device. Additionally, 95% of the measurements using the portable device were within a range of +1.55 cm-1.27 cm, compared to the gold standard.

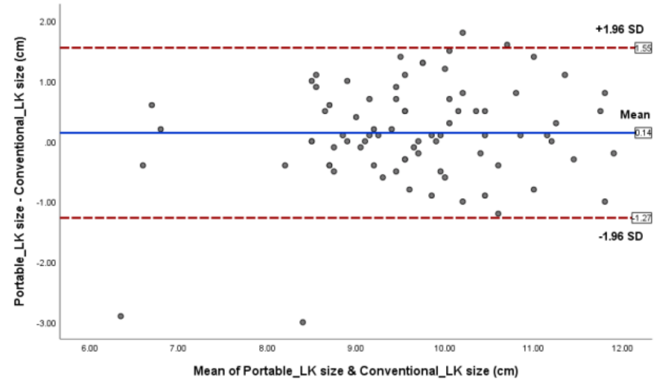

FIGURE 9. The Bland–Altman plot shows the difference of the two paired left kidney (LK) length measurements plotted against the mean of the two measurements. No remarkable tendency toward under- or overestimation by the portable device.

The performance of the portable device in detecting various pathologies affecting the left renal parenchyma is summarized in Figure 10. While the portable device accurately identified normal parenchymal echogenicity, 50% of cases with increased echogenicity and approximately 66.6% of cases with hypoechoic kidneys were misclassified as normal. The Cohen's Kappa value for agreement between the two devices was 0.595, indicating a moderate level of association.

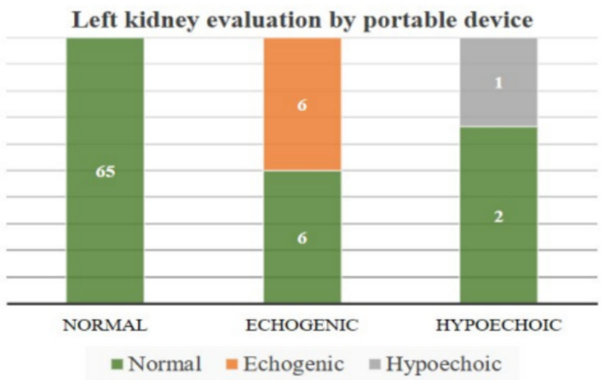

FIGURE 10. Distribution of left renal parenchymal changes detected by the portable device compared to the standard USG unit. A Cohen's Kappa value of 0.595 indicates moderate agreement.

Performance of the low-cost device in evaluating left renal lesions is summarized in Figure 11. Except for one case of cortical cyst, the portable device performed accurately. Kappa value was 0.662, indicating a substantial association.

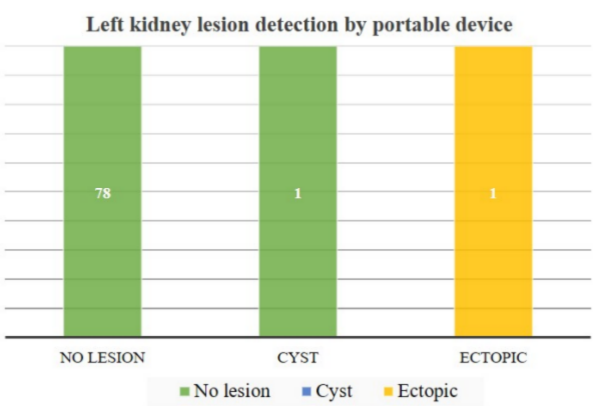

FIGURE 11. Distribution of left renal lesion detection by the portable device compared to the conventional USG unit. A Cohen's Kappa value of 0.662 indicates substantial agreement.

Urinary Bladder Evaluation

A total of 126 patients underwent UB examinations. Among these, 82.5% of UB cases were optimally filled, 13.5% were partially filled, and approximately 4% were empty. Regarding wall thickness, 82.5% of the examined UB cases exhibited normal thickness, while the remaining showed abnormal thickening. Both portable and conventional ultrasound devices demonstrated perfect agreement in assessing the level of UB filling and wall thickness, with a Cohen's Kappa value of 1. This indicates complete concordance between the two devices for these parameters.

The uterine length and anteroposterior (AP) diameter measurements obtained using the portable and conventional ultrasound devices demonstrated good positive correlations, with correlation coefficients of 0.8637 and 0.8444, respectively, as shown in Figures 12 and 13. Bland–Altman plots in Figures 14 and 15 show that there is no remarkable tendency toward under- or overestimation by the portable device in case of uterine size measurements.

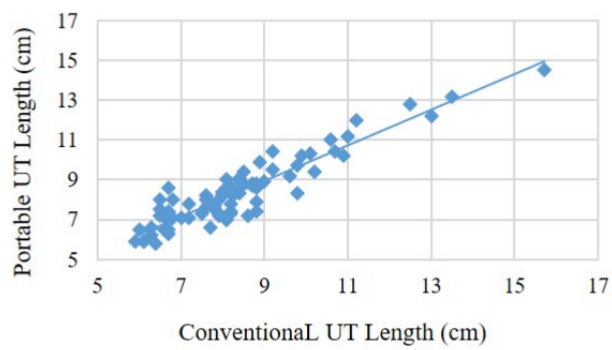

FIGURE 12. Scatter plot showing correlation between uterine length measurements obtained by using both portable and conventional ultrasound devices. The squared correlation coefficient (r^2) is 0.8637.

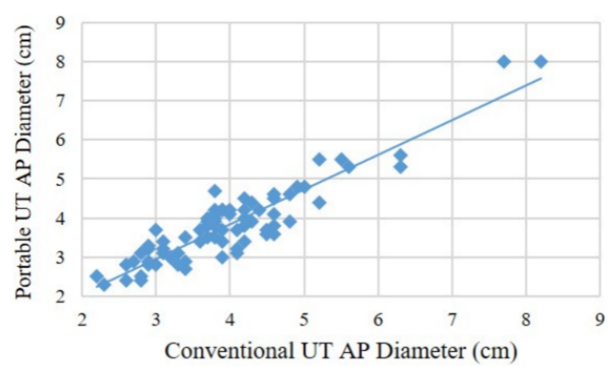

FIGURE 13. Scatter plot showing correlation between uterine A/P diameter measurements obtained using the portable and conventional ultrasound devices. The squared correlation coefficient (r^2) = 0.8444.

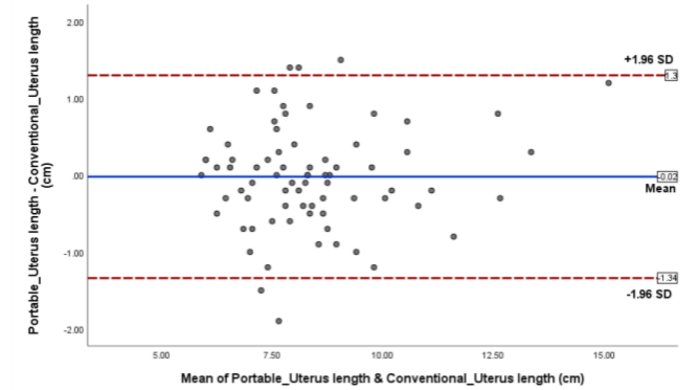

FIGURE 14. The Bland–Altman plot for the two paired uterine length measurements. The mean value from the portable device was only 0.02 cm lower than that of the standard device. Additionally, 95% of the values from the portable device were within the range of +1.30 cm−−1.34 cm, compared to the reference.

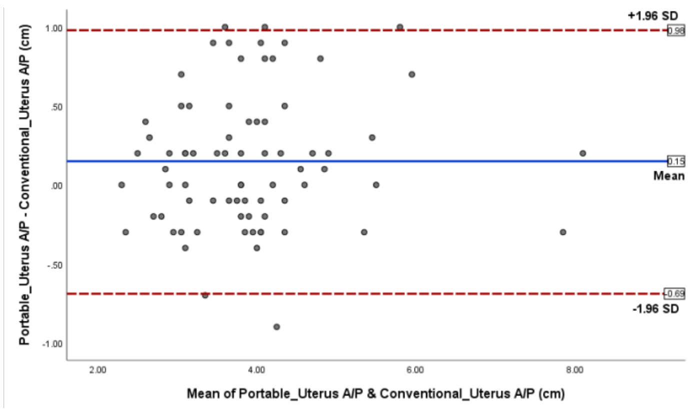

FIGURE 15. The Bland–Altman plot for the two paired uterine A/P diameter measurements. The mean value from the portable device was only 0.15 cm higher than that of the standard device. Additionally, 95% of the values from the portable device were within the range of +0.98−−0.69 cm, compared to the reference.

Performance of the low-cost device in evaluating the myometrium is summarized in Figure 16. The portable device had difficulty in differentiating solid lesions, inhomogeneous texture, and myometrial calcification from a normal myometrium, resulting in a Cohen's Kappa value of 0.710. The portable device could accurately identify normal myometrium. However, about 25% of the solid lesions, 66.7% of the inhomogeneous texture, and myometrial calcification could not be distinguished.

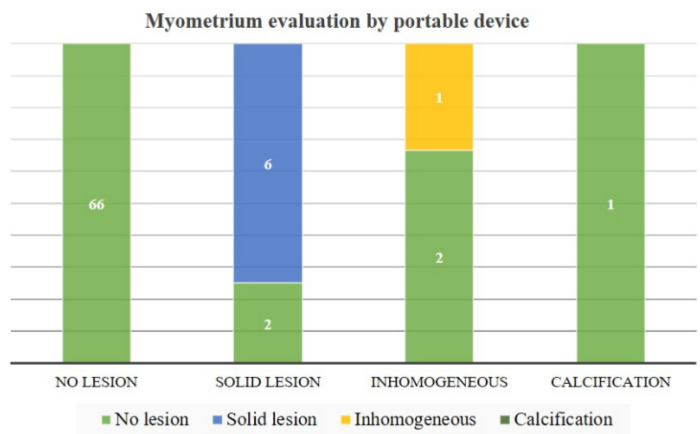

FIGURE 16. Bar chart showing the distribution of myometrial pathology detection using the portable device, compared to the standard USG unit. The portable device accurately identified normal myometrium but failed to detect 25% of solid lesions and 66.7% of cases with inhomogeneous texture and myometrial calcifications.

Performance of the low-cost device in evaluating the endometrium is summarized in Figure 17. Inhomogeneous endometrium and most endometrial collections were misdiagnosed with the portable device. Cohen's Kappa value was 0.696, indicating a substantial association.

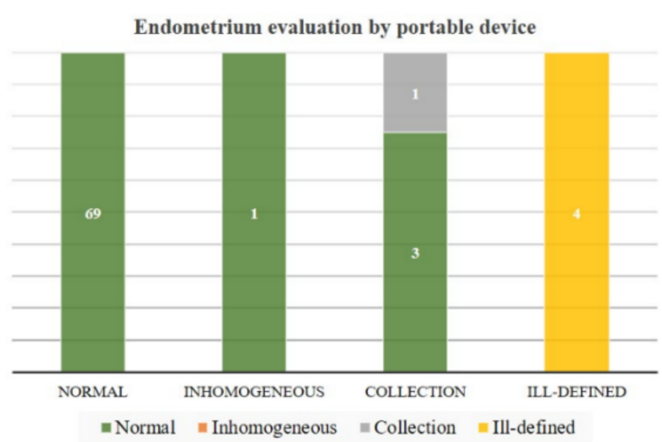

FIGURE 17. Bar chart showing the distribution of endometrial pathology detection using the portable device, compared to the standard USG unit. The Kappa value was 0.696, indicating a substantial agreement.

Ovary Evaluation

The performance of the low-cost portable device in evaluating ovarian size is summarized in Figure 18. While the device accurately identified normal-size ovaries, approximately 53.8% of enlarged ovaries were misclassified as normal. Cohen's Kappa value for agreement with the conventional device was 0.740, indicating substantial association. Notably, among the subjects, six had no ovaries because of surgical removal, and the portable device detected this in all cases. Figure 19 illustrates the device's performance in detecting ovarian and adnexal lesions. The portable device accurately identified non-pathological ovaries; however, it misclassified 14.2% of polycystic ovaries and 27.2% of adnexal cysts as normal. Despite these limitations, the device showed good agreement with the standard system, with a Cohen's Kappa value of 0.854.

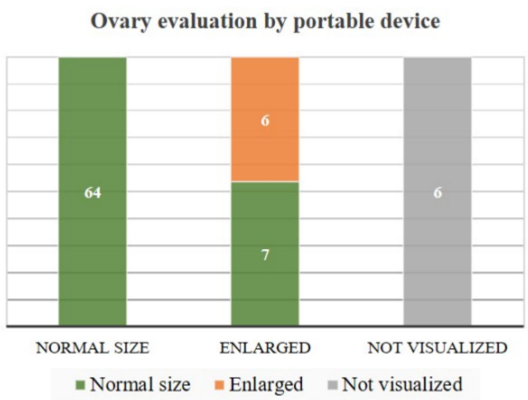

FIGURE 18. Bar chart showing ovarian size assessment findings using the portable device, compared to the standard USG unit. The portable device accurately identified normal-sized ovaries. The Kappa value was 0.740, indicating a substantial agreement.

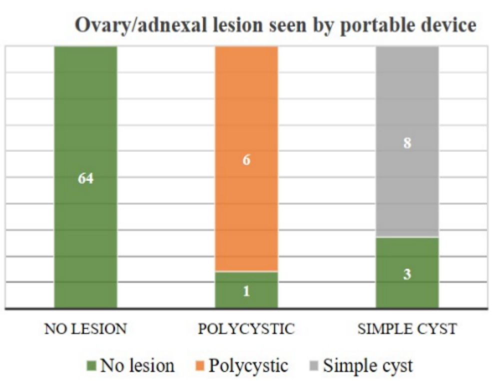

FIGURE 19. Bar chart showing findings from ovarian/adnexal lesion assessment using the portable device, compared to the standard USG unit. The Kappa value was 0.854, indicating a good association.

Prostate Evaluation

Figure 20 shows the performance of the low-cost device in evaluating the prostate. Except for one case of a small prostatic cyst, the test device was accurate. Cohen's Kappa value was 0.611, indicating a substantial association.

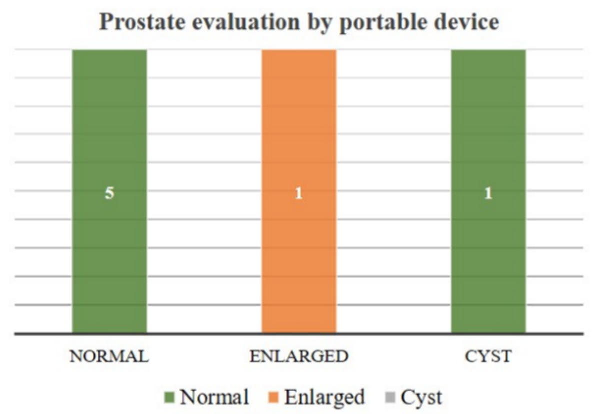

FIGURE 20. Bar chart showing findings from prostate assessment using the portable device, compared to the standard USG unit. The Kappa value was 0.611, indicating a substantial association.

Diagnostic performance of a method/device to detect a pathology is usually described in terms of sensitivity, specificity, accuracy, PPV, and NPV. Table 4 summarizes these findings for the portable device in case of some commonly found pathologies of GU system.

TABLE 4. Diagnostic performance of portable device in statistical terms.

Pathology	Number of subjects	Sensitivity (%)	Specificity (%)	Accuracy (%)	Positive predictive value (PPV) (%)	Negative predictive value (NPV) (%)
Chronic kidney disease	80	58.3	100	93.7	100	93.1
Acute kidney injury	80	33.3	100	97.5	100	97.4
Renal cyst	80	50	100	98.7	81.2	98.5
Bulky uterus	78	92.8	95.3	94.8	100	97.1
Uterine mass	78	75	100	97.2	100	97.3
Inhomo-geneous myometrium	78	33.3	100	97.2	100	96.0
Endometrial collection	78	25	100	95.8	100	90.9
Enlarged ovaries	83	46.1	100	91.5	100	98.6
Polycystic ovaries	83	85.7	100	98.7	100	95.9
Adnexal cyst	83	72.7	100	96.3	100	98.9

DISCUSSION

This study evaluated the accuracy and agreement of a low-cost portable ultrasound device (80 elements, US$900) with a high-end conventional system (192 elements, US$30,000) for imaging the GU system. The evaluation focused on organ size measurements and the detection of pathological changes in the kidneys, UB, uterus, ovaries, and prostate. While the portable device demonstrated satisfactory performance for basic measurements, its lower resolution limited its ability to detect fine anatomical details and subtle textural changes, as illustrated in Figures 1–3.

Ultrasound is a valuable tool for kidney evaluation, leveraging the distinct echogenicity of the renal parenchyma, and the ability to detect architectural distortions caused by pathology.[24] In this study, the portable device provided renal bipolar length measurements within 1 mm of the conventional device, corroborating the findings of Lavi et al. in a comparison study, who reported a 0.8 mm difference.[13] However, the portable device exhibited reduced sensitivity for detecting parenchymal diseases, misclassifying 33.3% of echogenic kidneys and 66.6% of hypoechoic kidneys as normal for the right kidney, with a Cohen's Kappa value of 0.715 (Figure 6). Similar limitations were observed for the left kidney, yielding a Cohen's Kappa value of 0.595 (Figure 10). These findings appear to match those obtained by Zúñiga et al., who reported challenges in the left kidney evaluation because of its posterior position despite using a device with more elements (128) and higher price in a prospective observational study.[25] Despite these issues, the low cost portable device performed well in detecting renal cysts and stones, achieving Cohen's Kappa values exceeding 0.8 for the right kidney and 0.6 for the left kidney (Figures 7 and 11). The device's sensitivity (50%) and specificity (100%) for cyst detection were partially comparable to Stock et al., who reported a sensitivity of 79% and specificity of 100% in another comparison study using a pocket-size device[14], again with a greater number of elements.

For UB evaluation, the portable device achieved perfect agreement with the conventional device in assessing bladder filling and wall thickness, with a Cohen's Kappa value of 1. This aligns with previous studies demonstrating the accuracy of portable devices for UB evaluation, supporting their integration into clinical workflows.[13,15,16] Uterine size measurements showed a very strong correlation ($r^2 > 0.8$ for both longitudinal and anteroposterior diameters), with mean differences of only 0.02 cm and 0.15 cm, respectively (Figures 12–15). The portable device effectively identified normal myometrium but struggled to detect inhomogeneous textures and calcifications, yielding a Cohen's Kappa value of 0.710 (Figure 16). The sensitivity, specificity, PPV, and NPV values for detecting uterine mass lesions were 75%, 100%, 100%, and 97.3%, respectively, exceeding the results reported in a pilot study conducted by Toscano et al.[17]

For endometrial evaluation, the portable device demonstrated a Cohen's Kappa value of 0.696, indicating a substantial agreement with the conventional device (Figure 17). However, misdiagnoses occurred for inhomogeneous endometrium and some endometrial collections. Sensitivity was 25%, while specificity, PPV, and NPV were 100%, 100%, and 90.9%, respectively, the results that were consistent with the findings reported by Araujo et al. in a prospective accuracy study.[18]

Ovarian size evaluation showed substantial agreement, with a Cohen's Kappa value of 0.740 (Figure 18). However, 53.8% of enlarged ovaries were misclassified as normal. For adnexal lesions, sensitivity ranged between 72% and 85%, with specificity and PPV at 100% (Figure 19). The portable device performed well in identifying cystic adnexal lesions but had limitations in detecting subtle ovarian enlargements. Prostate assessments demonstrated excellent agreement with the standard device, highlighting the portable device's potential for evaluating this organ (Figure 20). However, the sample size for prostate evaluations was limited.

Overall, the portable device was comparable to similar devices tested in previous studies, as it also showed higher specificity and lower sensitivity (Table 3), indicating its ability to report fewer false negatives than false positives. The ease of use and accessibility of portable diagnostic tools often come with such trade-off between sensitivity and specificity, which, in turn, affects their accuracy. However, for large-scale screening programs, or to avoid unnecessary intervention, a tool with higher specificity is worth considering.

The high cost of sophisticated ultrasound machines (US$20,000–50,000) limits their use in telemedicine for rural areas of LMICs. Even portable models from reputed brands (about US$5,000) remain expensive for such settings. This study focuses on an even lower-cost device (about US$900) with only 80 elements probe and a narrower fractional bandwidth. Despite these inherent technical constraints, our results demonstrated that clinically relevant diagnostic information for common GU conditions could still be obtained with acceptable accuracy. This finding suggests that, although image quality is compromised relative to higher-element, wider-bandwidth devices, the performance of an ultra-low-cost ultrasound system may remain sufficient for targeted diagnostic tasks in telemedicine. While a smartphone or tablet/PC (around US$200) is needed to operate the device, the existing personal devices may suffice. Portable units are far more power-efficient (1 W vs. 1000 W for conventional systems), can be recharged via solar power, and require minimal maintenance, because most controls are software-based. Although repairs may be challenging, the low price makes replacement feasible, enhancing affordability, scalability, and suitability for rural healthcare delivery.

Limitations

The inclusion of patients with routine or nonurgent complaints resulted in a low prevalence of abnormal findings. In addition, emergency cases were excluded due to their inability to stay for prolonged evaluations, meaning the device's performance in critical care settings was not assessed. Scans were performed by the same person using both devices; therefore, inter-observer agreement could not be evaluated. Involving multiple observers and a larger patient pool would help to address these limitations in future studies. Furthermore, as a single-center study, the findings may not be generalizable. Future multicenter trials are recommended to validate these results and assess the device's performance in diverse clinical settings, including critical care.

Historically, several factors have hindered the widespread adoption of tele-ultrasound, including the complex challenges of transducer positioning, patient body posture, device settings, and image quality and clarity. Additionally, the process requires sophisticated medical software and secure transmission protocols to ensure patient privacy. However, advances in wireless network technology and increased cell phone accessibility are making tele-ultrasound an increasingly viable option. Challenges such as probe handling, orientation, and machine settings can be mitigated through adequate training of remote operators. Beyond traditional teaching methods, approaches such as tele-learning, augmented reality tools, and tele-guided ultrasound can further enhance operator proficiency.[26]

CONCLUSION

This study evaluated the diagnostic accuracy of a low-cost portable ultrasound device for GU system imaging and found it effective for detecting renal cysts, uterine masses, polycystic ovaries, and adnexal cystic lesions. However, its accuracy was lower for diagnosing renal parenchymal diseases and ovarian enlargement. Pathologies affecting the parenchymal echotexture of solid organs should be interpreted with caution. The portable device exhibited high specificity but comparatively lower sensitivity, a common characteristic of such devices. For size measurements, it demonstrated reliable accuracy across most organs, reinforcing its utility in routine clinical settings. While the portable ultrasound device shows promise as a point-of-care diagnostic tool and holds potential for integration into telemedicine services, particularly in resource-limited areas, its limitations must be clearly understood. Adequate user training is essential to ensure safe and effective use. Additionally, efficient data transfer mechanisms are crucial to maximize its utility, especially in remote settings, such as refugee camps, hilly regions, and islands.

AUTHOR CONTRIBUTIONS

Conceptualization, K.S.R. and M.A.K; Methodology, A.N.; Validation, A.N.; Formal Analysis, A.N.; Investigation, A.N.; Writing–Original Draft Preparation, A.N.; Writing–Review & Editing, M.A.K., F.B. and K.S.R.; Supervision, M.A.K., F.B. and K.S.R; Funding Acquisition, M.A.K and K.S.R.

ACKNOWLEDGMENTS

Not applicable.

FUNDING

The authors acknowledge the International Science Programme (ISP) of Uppsala University in Sweden for financial support as a research grant (IPPS BAN:04). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

DATA AVAILABILITY STATEMENT

The data supporting the results are available online in Harvard Dataverse: https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/I1FGPG

CONFLICTS OF INTEREST

The authors declared they had no competing interests.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was conducted under the principles embodied in the Declaration of Helsinki and in accordance with local statutory requirements. Ethical approval was obtained from the National Research Ethics Committee, Bangladesh Medical Research Council (Registration No.: 457 13 12 2021, dated: 09/06/2022) for this study. The objectives and procedures were explained in details to the patients and their attendants. Written informed consent was taken from each subject preserving their rights, privileges and freedom. Written informed consent was obtained from the parent/guardian of each participant aged < 18 years.

CONSENT FOR PUBLICATION

Data and images were anonymized, and all analyses were conducted thereafter. Informed consent was obtained from the subjects to publish their anonymized data.

FURTHER DISCLOSURE

Not applicable.

REFERENCES

1. Busso, M., Gonzalez, M.P., Scartascini, C. On the demand for telemedicine: evidence from the COVID-19 pandemic. *Health Econ*. 2022;31(7):1491–1505. https://doi.org/10.1002/hec.4523.
2. Mann, D.M., Chen, J., Chunara, R., et al. COVID-19 transforms health care through telemedicine: evidence from the field. *J Am Med Inform Assoc*. 2020;27(7):1132–1135. https://doi.org/10.1093/jamia/ocaa072.
3. Chu, C., Cram, P., Pang, A., et al. Rural telemedicine use before and during the COVID-19 pandemic: repeated cross-sectional study. *J Med Internet Res*. 2021;23(4):e26960. https://doi.org/10.2196/26960.
4. Ishfaq, R., Raja, U. Bridging the healthcare access divide: a strategic planning model for rural telemedicine network. *Decision Sci*. 2015;46(4):755–790. https://doi.org/10.1111/deci.12165.
5. Trippi, J.A., Lee, K.S., Kopp, G., et al. Emergency echocardiography telemedicine: an efficient method to provide 24-hour consultative echocardiography. *J Am Coll Cardiol*. 1996;27(7):1748–1752. https://doi.org/10.1016/0735-1097(96)00042-3.
6. Su, M.J., Ma, H.M., Ko, C.I., et al. Application of tele-ultrasound in emergency medical services. *Telemed e-Health*. 2008;14(8):816–824. https://doi.org/10.1089/tmj.2008.0076.
7. Strode, C.A., Rubal, B.J., Gerhardt, R.T., et al. Satellite and mobile wireless transmission of focused assessment with sonography in trauma. *Acad Emerg* Med. 2003;10(12):1411–1414. https://doi.org/10.1197/S1069-6563(03)00547-5.
8. Huffer, L.L., Bauch, T.D., Furgerson, J.L., et al. Feasibility of remote echocardiography with satellite transmission and real-time interpretation to support medical activities in the austere medical environment. *J Am Soc Echocardiogr*. 2004;17(6):670–674. https://doi.org/10.1016/j.echo.2004.03.021.
9. Otto, C., Hamilton, D.R., Levine, B.D., et al. Into thin air: extreme ultrasound on Mt Everest. *Wilderness Environ Med*. 2009;20(3):283–289. https://doi.org/10.1580/08-WEME-BR-228R2.1.
10. Nelson, B.P., Melnick, E.R., Li, J. Portable ultrasound for remote environments, part I: feasibility of field deployment. *J Emerg Med*. 2011;40(2):190–197. https://doi.org/10.1016/j.jemermed.2009.09.006.
11. Rabbani, K.S., Al Amin, A., Tarafdar, Z., et al. Dhaka University telemedicine programme, targeting healthcare-deprived

rural population of Bangladesh and other low resource countries. In *HCI International 2019–Late Breaking Papers*, Proceedings of the 21st HCI International Conference (HCII 2019), Orlando, FL, USA, July 26–31, 2019:580–598. https://doi.org/10.1007/978-3-030-30033-3_45.

12. Naznin, A., Kadir, M.A., Begum, F., Rabbani, K.S. Comparative performance of low-cost portable scanner in pregnancy profile ultrasonography: a promising adjunct to telemedicine. *Global Clin Eng J*. 2024;6(3):26–36. https://doi.org/10.31354/globalce.v6i3.200.
13. Lavi, A., Tzemah, S., Hussein, A., et al. A urologic stethoscope? Urologist performed sonography using a pocket-size ultrasound device in the point-of-care setting. *Int Urol Nephrol*. 2017;49:1513–1518. https://doi.org/10.1007/s11255-017-1641-8.
14. Stock, K.F., Klein, B., Steubl, D., et al. Comparison of a pocket-size ultrasound device with a premium ultrasound machine: diagnostic value and time required in bedside ultrasound examination. *Abdom. Imaging*. 2015;40:2861–2866. https://doi.org/10.1007/s00261-015-0406-z.
15. Taus, P.J., Manivannan, S., Dancel, R. Bedside assessment of the kidneys and bladder using point of care ultrasound. *POCUS J*. 2022;7(Kidney):94. https://doi.org/10.24908/pocus.v7iKidney.15347.
16. Fröhlich, E., Beller, K., Muller, R., et al. Point of care ultrasound in geriatric patients: prospective evaluation of a portable handheld ultrasound device. *Ultraschall in der Medizin (Eur J Ultrasound)*. 2020;41(03):308–316. https://doi.org/10.1055/a-0889-8070.
17. Toscano, M., Szlachetka, K., Whaley, N., et al. Evaluating sensitivity and specificity of handheld point-of-care ultrasound testing for gynecologic pathology: a pilot study for use in low resource settings. *BMC Med Imaging*. 2020;20:121. https://doi.org/10.1186/s12880-020-00518-8.
18. Araujo, K.G., Adriana, Y., Machado, H.C., et al. Handheld ultrasound device in the assessment of the uterus and adnexa. 2024.https://doi.org/10.21203/rs.3.rs-4145952/v1.
19. SunBright. 2024. SUN-P1 type-C portable USB probes ultrasound. Available from: https://www.sunbright.shop/Factory-price-SUN-P1-type-C-portable-usb-probes-ultrasound-for-sale-8317?d=2.11.
20. Samsung. 2024. Accuvix A30. Available from: https://www.samsung.com/hk_en/support/model/USS-AV30F4U/WR/.
21. Le, M.P., Voigt, L., Nathanson, R., et al. Comparison of four handheld point-of-care ultrasound devices by expert users. *Ultrasound J*. 2022; 27(1):14. https://doi.org/10.1186/s13089-022-00274-6.
22. Barton, B., Peat, J. *Medical Statistics: A Guide to SPSS, Data Analysis and Critical Appraisal*. John Wiley: Hoboken, NJ; 2014, pp.317-328.
23. Watson, P.F., Petrie, A. Method agreement analysis: a review of correct methodology. *Theriogenology*. 2010;73(9):1167–1179. https://doi.org/10.1016/j.theriogenology.2010.01.003.
24. Tse, K.H., Luk, W.H., Lam, M.C. Pocket-size versus standard ultrasound machines in abdominal imaging. *Singapore Med J*. 2014;55(6):325. https://doi.org/10.11622/smedj.2014078.
25. Zúñiga, M.Á., Palomino, T.V., Toro, M.A., et al. Diagnostic capacity of pocket-sized ultrasound devices at point of care by a non-radiologist resident in patients with suspected abdominal pathology. *Ultrasound Med Biol*. 2020;46(2):263–268. https://doi.org/10.1016/j.ultrasmedbio.2019.10.019.
26. Recker, F., Höhne, E., Damjanovic, D.,et al. Ultrasound in telemedicine: a brief overview. *Appl Sci*. 2022;12(3):958. https://doi.org/10.3390/app12030958.