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Evaluation of antenatal point-of-care ultrasound training workshops for rural/remote healthcare clinicians: a prospective single cohort study

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Abstract

Background: There is limited access to life-saving antenatal ultrasound in low-resource rural and remote settings worldwide, including Australia, mainly due to shortages in skilled staff. Point-of-care ultrasound (PoCUS) offers a viable solution to this service deficit, however, rural clinicians face many barriers accessing training and professional development critical to advancing their clinical practice. Standards for PoCUS training and competency assessment are unclear. Regulation is lacking globally, allowing untrained and inexperienced clinicians to practice PoCUS clinically.

Methods: This prospective single cohort study aimed to evaluate antenatal PoCUS training workshops for General Practitioners (GPs) and Midwives/Nurses (M/Ns) from rural/remote Australia, assessing the impact of the training on trainees' knowledge, confidence and translation of PoCUS into clinical practice. Two-day antenatal ultrasound workshops were delivered at the University of South Australia (UniSA) in 2018 and 2019 to 41 rural/remote clinicians . The training was designed and evaluated using the New world Kirkpatrick Evaluation Framework. Sixteen GPs and 25 M/Ns with mixed prior ultrasound experience were funded to attend. The course consisted of lectures interspaced with hands-on training sessions using high-fidelity simulators and live pregnant models. Pre- and post-knowledge assessments were performed. Post-workshop evaluation and follow-up surveys (3- and 6-month post-training) assessed the workshops and changes to trainees' clinical practice. A 2-day follow-up training session was conducted 12 months after the workshops for 9 trainees.

Results: Pre/post knowledge testing demonstrated a 22% mean score improvement (95% CI 17.1 to 27.8, $P < 0.0001$). At 6 months, 62% of trainees were performing PoCUS that had assisted in patient management and clinical diagnosis, and 46% reported earlier diagnosis and changes to patient management. 74% of trainees had increased scanning frequency and 93% reported improved scanning confidence.

Conclusion: This study demonstrated intensive 2-day workshops can equip clinicians with valuable antenatal PoCUS skills, offering a viable solution to assist in the assessment and management of pregnant women in the rural/resource-poor setting where access to ultrasound services is limited or non-existent. Geographical isolation and lack

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of onsite specialist supervision poses an ongoing challenge to the continuing professional development of remote trainees and the implementation of PoCUS.

Keywords: Medical education/training, Obstetrics and gynaecology, Ultrasound (US), Sonography, Point-of-care- ultrasound (PoCUS), Antenatal, Training, Rural, Remote, Low-resource setting

Background

Since the first ultrasound images of the fetus were published in the Lancet in 1958 [1], ultrasound has advanced to become the primary imaging modality in pregnancy [2–5]. In addition to estimating due dates, monitoring fetal growth and well-being, detecting anomalies and guiding specialist referral, antenatal ultrasound can facilitate the early detection of life-threatening complications such as ectopic pregnancy, fetal malpresentation, multiple pregnancies, placenta praevia and placental abruption [4, 6–8]. The International Society of Ultrasound in Obstetrics and Gynecology (ISUOG) have published guidelines recommending women receive two antenatal ultrasound examinations during a normal low-risk pregnancy [3, 9, 10], and The World Health Organization (WHO) recommend one antenatal ultrasound before 24 weeks of pregnancy [6]. However, studies into service accessibility in low-resource settings and rural regions throughout the world, where higher maternal and fetal mortality rates are reported [11–14], indicate women are not receiving this recommended care [15–17]. Over 90% of maternal deaths worldwide are estimated to occur in low-resource settings, and most are considered to be preventable [13, 14]. There is a global shortage of trained sonographers in these regions. Skills shortages have been reported in rural Australia for over a decade, where many remote medical centres have no onsite sonographer and rely on visiting professionals available as infrequently as one day per month [15, 18, 19]. Years of study and training are required to produce qualified sonographers in Australia. Available courses, most university conferred, are expensive and include a clinical practice component of which there are insufficient and declining placement opportunities [18, 20, 21]. Once trained it is challenging to entice professionals to relocate and remain in rural locations [18, 20, 21]. Upskilling the rural workforce in antenatal Point-of-Care ultrasound (PoCUS) is a viable solution to assist with this deficit and can offer substantial benefits to these under-resourced communities [22].

Defined as ultrasound imaging performed and interpreted by the healthcare provider at the bedside, PoCUS provides targeted scans to assist procedures or direct care and specialist referal [23]. Within the field of obstetrics, PoCUS can assist clinicians in the accurate estimation of due dates and early detection of potentially life-threatening complications, allowing for appropriate and timely pregnancy care planning and referral, which is crucial for remotely located women who may need days of travel to access specialist obstetric services [7, 15, 24]. Antenatal PoCUS does not replace formal ultrasound imaging performed by a trained sonographer. The Australian Department of Health (ADH) recommends a pre-planned schedule of antenatal visits, including up to four formal ultrasound examinations for a healthy low-risk pregnancy (8–14 week ultrasound to determine gestational age, 11–14 week fetal anomaly/nuchal translucency screening ultrasound, 18–20 week morphology ultrasound, and 36 week ultrasound for suspected non-cephalic presentation). In Australia, for women with access, these are performed most often in an imaging department by a trained sonographer using high-resolution ultrasound equipment and reported by a qualified radiologist or sonologist. Unlike formal ultrasound imaging, PoCUS can be performed anywhere by any healthcare worker, often using portable ultrasound equipment. While capable of producing high-quality images, this equipment does not provide the resolution and quality of a standalone ultrasound unit from an imaging department. However, their affordability and advantage of portability has helped establish PoCUS in many medical fields [2, 25].

Published literature and our research has shown many rural women do not present for antenatal care or ultrasound imaging until late in pregnancy or not at all [26–28]. A strength of PoCUS in the rural and low-resource context comes from its being, in some cases, the only imaging option available. For example, a rural clinician being able to establish gestational age in the first-trimester (when it is most accurately estimated) using PoCUS can allow for accurate timing of formal ultrasound imaging and scheduling of pregnancy care. Gestational age and estimated due date can also assist in detecting fetal growth disorders such as intrauterine growth restriction and macrosomia, and lead to confident identification of pre-and post-term labour critical to remote patients who may require considerable time and logistical planning for an assisted delivery. High-risk pregnancies (e.g. multiple pregnancy, placenta previa) can also be identified by rural clinicians using PoCUS, allowing for increased monitoring, triage and timely referral for advanced pregnancy management.

Despite the advantages offered by PoCUS, access to an ultrasound machine is insufficient for reliable service delivery; as a highly-skilled, operator-dependent modality, ultrasound requires appropriate and ongoing training of experienced healthcare professionals for safe and effective implementation into clinical practice. The WHO advocates all countries adopt a standardised curriculum and competency assessment for teaching PoCUS to improve the safety and quality of antenatal services and obstetric care [6]. However, training and competency assessment guidelines remain varied [29], and in many countries, including Australia, healthcare workers may perform PoCUS with little or no training, experience or formal accreditation. This lack of regulation may allow inexperienced and untrained practice, which represents a potential risk to patients and ensuing financial burden to healthcare systems in cases of misdiagnoses and unnecessary specialist referrals or patient transfers [18, 29–32]. However, given the urgent need for these skills and the difficulty accessing training in remote areas, regulation should be implemented carefully to preserve the time and financial advantages offered by PoCUS training.

The only certified pathway for PoCUS in Australia is through a 'Certificate in Allied Health Performed Ultrasound' (CAHPU) [33] or for doctors a 'Certificate in Clinician Performed Ultrasound' (CCPU) [34] which are managed by the Australasian Society for Ultrasound in Medicine (ASUM). This accreditation is not required to practice but is necessary to claim remuneration for PoCUS scanning performed in rural/remote areas through the government's Medicare Benefits Schedule. Rural clinicians face additional barriers accessing this accreditation pathway which stipulates attendance at approved training courses (mostly city-based) and a proportion of required assessments be performed under direct supervision of an expert with educational feedback provided.

Published literature on Antenatal PoCUS training report generally positive findings, supporting the upskilling of health professionals in low-resource settings [35]. However, widely varying training and competency assessment methods are described and study quality is mixed. Only 1 Australian study on antenatal PoCUS training has been published in the last decade [36]. Our preliminary research included a national survey on ultrasound access and use in rural and remote Australia, which identified a lack of trained staff and inaccessibility of ultrasound equipment as key barriers to PoCUS in these communities. Rural clinicians face many obstacles to accessing training opportunities needed to safely perform PoCUS, including geographical isolation (distance from training courses), heavy clinical caseloads and lack of locum staff to cover absences to attend training [37, 38]. In response to this service and skills deficit, this mixed methods prospective pilot study (The Healthy Newborn Project-HNP) was designed to deliver 2-day antenatal PoCUS training workshops to rural and remote Australian Midwives/Nurses (M/Ns) and General Practitioners (GPs). This paper describes the delivery and evaluation of the workshop model. It investigates the impact on trainees' knowledge and confidence, and the translation of PoCUS into clinical practice (PoCUS use and indications). Challenges to workshop delivery and barriers to training and PoCUS use are described with potential solutions. Findings may make a valuable contribution to obstetric PoCUS education in the rural/low-resource setting, and help guide curriculum development and health policy to increase the uptake and safe integration of this vital skill by rural healthcare workers, and improving healthcare services for rural women.

Methods

Two-day antenatal PoCUS training was provided in 2018 and 2019 to a convenience sample of 25 Midwives/Nurses (M/Ns) and 16 General Practitioners (GPs) at the University of South Australia's (UniSA) Adelaide city campus in a simulated ultrasound laboratory. Eligible trainees were working in rural/remote areas (see Fig. 1 for clinic locations), providing care to antenatal patients with access to ultrasound equipment. No prerequisite ultrasound training or experience was required. Outreach funding from The Hospital Research Foundation (THRF) paid participant travel, accommodation and training costs.

The workshop's design and content were based on years of experience delivering PoCUS workshops in under-resourced regions in Australia and developing countries, and have been adapted to suit the Australian rural context. The training model aligns with ASUM's 'Guide to providing an ultrasound workshop' [39] and antenatal PoCUS syllabus [33, 34]. Additional Table 1 [39] of supplementary material summarises these workshop requirements, and Additional Table 2 [40, 41] lists methods for PoCUS competency assessment.

Three workshops provided training to a total of 41 participants in groups of 12–16. Participants with varied previous ultrasound experience were trained together in multidisciplinary groups. Instructors were accredited sonographers with 3 to 14 years experience teaching in UniSA's Postgraduate Diploma in Medical Sonography; one instructor had specialist obstetrics and gynaecology medical training and extensive experience delivering outreach PoCUS workshops in rural Australia and developing countries. Pre-reading resources were sent several weeks in advance of the workshops. The training and material provided at the 3 initial workshops were identical and delivered by the same facilitators. Didactic

Fig. 1 Clinic locations of trainees (GPs, M/Ns) attending antenatal PoCUS training workshops

sessions (7 hours total) were interspaced with the practical sessions (6 h total), allowing demonstration on the equipment following theoretical content delivery and immediate practice of techniques. Course content and practical skills covered during training and trainee-to-faculty ratios are outlined in Table 1.

CAE Vimedix OB-GYN high-fidelity simulators [42] (mannequin, high-definition monitor, dedicated computer and simulated transducer) were used initially for learning probe manipulation and manual scanning technique. Live pregnant models (12 per workshop) of varying second and third and 3-trimester gestations were also used for practical training. Only healthy women with low-risk pregnancies and prior normal first-trimester formal ultrasounds were eligible to volunteer, each limited to a total of 30 min scanning time. Sonosite Edge-II and Sonosite M-Turbo portable units and Phillips iU22xMatrix standalone ultrasound units were used in practical sessions. Participants were encouraged to bring their own portable ultrasound equipment for training.

Assessment and evaluation

A pre-workshop survey was performed to collect trainee demographics, including clinical role, years of experience, and prior PoCUS training and scanning experience. This preliminary survey also explored current use and indications for PoCUS, and areas of antenatal PoCUS training theclinicians felt would benefit their practice to assist in curriculum design. Identical pre- and post-training knowledge assessment was conducted on ultrasound principles/physics,

Table 1 Course content and practical skills checklist

Course content	Practical skills checklist		
Two-day training schedule	**Instrumentation**	**First-trimester**	**Second / Third-trimester**
DAY 1	- Power	- Fetal heart trace	- Fetal heart trace / M-Mode
- Acknowledgment to country and introductions			
- Course requirements/objectives, materials, practical skills checklist	- Time gain compensation (TGC)	- Gestational sac	- Fetal presentation
- Pre-course baseline knowledge assessment		- Yolk sac	
Lecture 1- Basic scanning principles, transducer manipulation, transducer and image orientation, knobology and ergonomics	- Gain	- Crown to rump length (CRL)	- Amniotic Fluid Volume
Lecture 2- Fetal lie, placental position and amniotic fluid volume (AFV)-Maximum Vertical Pocket	- Depth		
Practical session- 2 simulator stations and 2–3 pregnant volunteer stations	- Zoom	- Adnexae	- Placenta
Lecture 3- First-trimester ultrasound and pregnancy dating		- Free fluid	- Estimated due date
Lecture 4- Fetal viability & cardiac M-mode assessment	- Focus		
Lecture 5- Second and third-trimester biometry-			
- Scanning requirements	- Calliper use		Biometry: - BPD - HC - AC - FL
- Measurements-Biparietal Diameter (BPD), Head circumference (HC), Abdominal circumference (AC), Femur length (FL)	- Annotation		
- Measurement interpretation	- Image storage		
Practical session- 2 simulator stations and 2–3 pregnant volunteer stations			
DAY 2			
Lecture 6- Miscarriage, pregnancy of unknown location, ectopic pregnancy			
Lecture 7- Multiple pregnancy			
Practical session- 2 simulator stations and 2–3 pregnant volunteer stations			
Lecture 8- Communication and documentation- report writing and medicolegal considerations			
Practical session- 2 simulator stations and 2–3 pregnant volunteer stations			
- Post-course knowledge assessment			
- Anonymous post-course training evaluation			

Faculty-to-trainee ratio during practical sessions ranged from 1:2 to 1:4 with periods of 1:1 supervised practical instruction and assessment. A 1:3 ratio or less of trainees-to-ultrasound workstations was maintained for all 4 workshops

image optimisation, biometry measurements, obstetric anatomy and pathology, patient communication and image review. Anonymous post-workshop evaluations (Post-workshop evaluation form available in supplementary material) were completed by all trainees immediately following training to rate course content (theoretical and practical), design, instructors, and highlight areas for improvement. Online follow-up surveys were conducted at 3- and 6-months (6-month follow-up survey form available in supplementary material) following the workshops to investigate scanning application and frequency of use, self-reported confidence, change in clinical practice/behaviour and the clinician's perception of impact on patient outcomes.

All surveys were developed by a multidisciplinary research team and included a mix of multiple choice, multiple response, Likert scale and free-text formats. The immediate post-workshop evaluation and 3- and 6-month follow-up surveys were adapted from forms used by UniSA's medical sonography program to evaluate workshop design, content, presenter and impact. These established evaluation tools have been in use since 2008, with all validity and reliability tests performed at that time. Content validation was performed by healthcare professionals external to the research project. Individual trainee responses collated from the pre-workshop, 3- and 6-month surveys were compared for reliability and internal consistency.

Follow-up training and support

Two online group mentoring/teaching sessions were provided 5 to 7 months after the training sessions, and an online forum was setup for trainees to network and access all course materials, which were also provided on USB. A

2-day follow-up training workshop was held 12 months after the initial training workshops for 9 trainees who were provided with the opportunity to request teaching content. This workshop reviewed important concepts building on the trainees' previous knowledge and skills, explored case studies/images, and dedicated more time to practical training. Learning was evaluated using an identical pre- and post-course knowledge test, and a post-course Objective Structured Clinical Exam (OSCE) practical assessment was administered (First and Second-trimester OSCE assessment forms available in supplementary materials 5 and 6). All assessments were adapted from validated tests used in the University's sonography teaching program. First-trimester OSCE assessment was performed on high-fidelity simulator and second-trimester on live models. Each case-based 6–7 part examination assessed patient communication, scan technique and accuracy of measurements with an overall 'satisfactory' or 'not satisfactory' grading. Anonymous post-workshop evaluation and 3- and 6-month follow-up surveys were conducted. Figure 2 provides a flowchart of antenatal PoCUS training, assessments and surveys conducted.

Analysis

Microsoft Excel 16.0 and IBM SPSS statistics 27 were used to generate data tables and analyse means and frequencies. Paired t-test analysis of trainees' pre- and post-test results was performed with stratification by profession/role and previous training/experience, and graphs presented using Graphpad Prism 8 software. Qualitative data was compiled using Excel spreadsheets, and a thematic analysis performed using Nvivo (2020) to explore the qualitative responses and guide a narrative review of concepts. The PoCUS workshops were appraised using the New World Kirkpatrick Evaluation Framework (NWKEF), an updated version of an established outcome-focused model for clinical education assessment [43–45]. Additional Fig. 1 of supplementary material shows the HNP workshops against the NWKEF.

Endorsement for the workshops was received from ASUM and ISUOG, with ethics approval from UniSA's Human Research Ethics Committee (Project ref: 201,543). This study and manuscript followed the equator network 'Strengthening the Reporting of Observational Studies in Epidemiology' (STROBE) guidelines for reporting observational studies [46].

Results

Table 2 details each workshop group, including trainee profession/role and percentage with previous ultrasound training/experience. Detailed trainee demographics are provided in Additional Table 3 of supplementary material.

Table 2 Workshop Participants- number, role, previous ultrasound experience/training

Workshop	GPs	M/Ns	Total	Previous ultrasound training/ experience
Workshop 1	6	6	12	9/12 (75%)
Workshop 2	4	9	13	7/13 (54%)
Workshop 3	6	10	16	11/16 (69%)
Total all 3 workshops	**16**	**25**	**41**	**27/41 (66%)**
Follow-up/Refresher Workshop 4	1	8	9	All attended one of the initial workshops 1–3

One respondent who only attended 1 day of training and failed to complete the 3-month survey was removed from all post-training analyses. Responses from 2 other trainees, one who did not complete the 3-month survey and one who did not complete the 6-month survey, were removed from the frequency of ultrasound use analysis.

Pre-workshop survey

The pre-workshop survey indicated 44% (18/41) of all participants were performing ultrasound clinically before the training (1–5/week, average 2/week). Indications for PoCUS use reported in order of frequency were: estimating gestation, referral for care, determining fetal presentation, assessing fetal viability, fetal growth assessment, PV bleeding, confirmation of pregnancy and patient request. Previous training programs had been attended by 54% (22/41) of participants, and 63% (26/41) reported having used ultrasound clinically in the past. Only 3 participants (7%) were performing ultrasound clinically with no prior formal training, and 7 (17%) had completed training but were not currently performing ultrasound at their clinic. Ninety percent (37/41) of trainees had patients who were required to travel out of their community for ultrasound services, travelling between 1 to 8 hours (Average 3.8 h) and distances of 70 to 3000 kilometers, some requiring flights and 1–2 nights' accommodation away from home and family.

Pre-post course knowledge assessment

Theoretical knowledge assessment performed before and after training demonstrated significant improvement in mean test scores of 22.4% for the initial workshops ($p < 0.001$). Both pre-and post-test scores were higher for GPs, but greater improvement was seen in the M/Ns cohort. Those with no prior ultrasound experience had the lowest pre-test scores but showed the greatest improvement overall (30.4%). Figure 3 a and b display

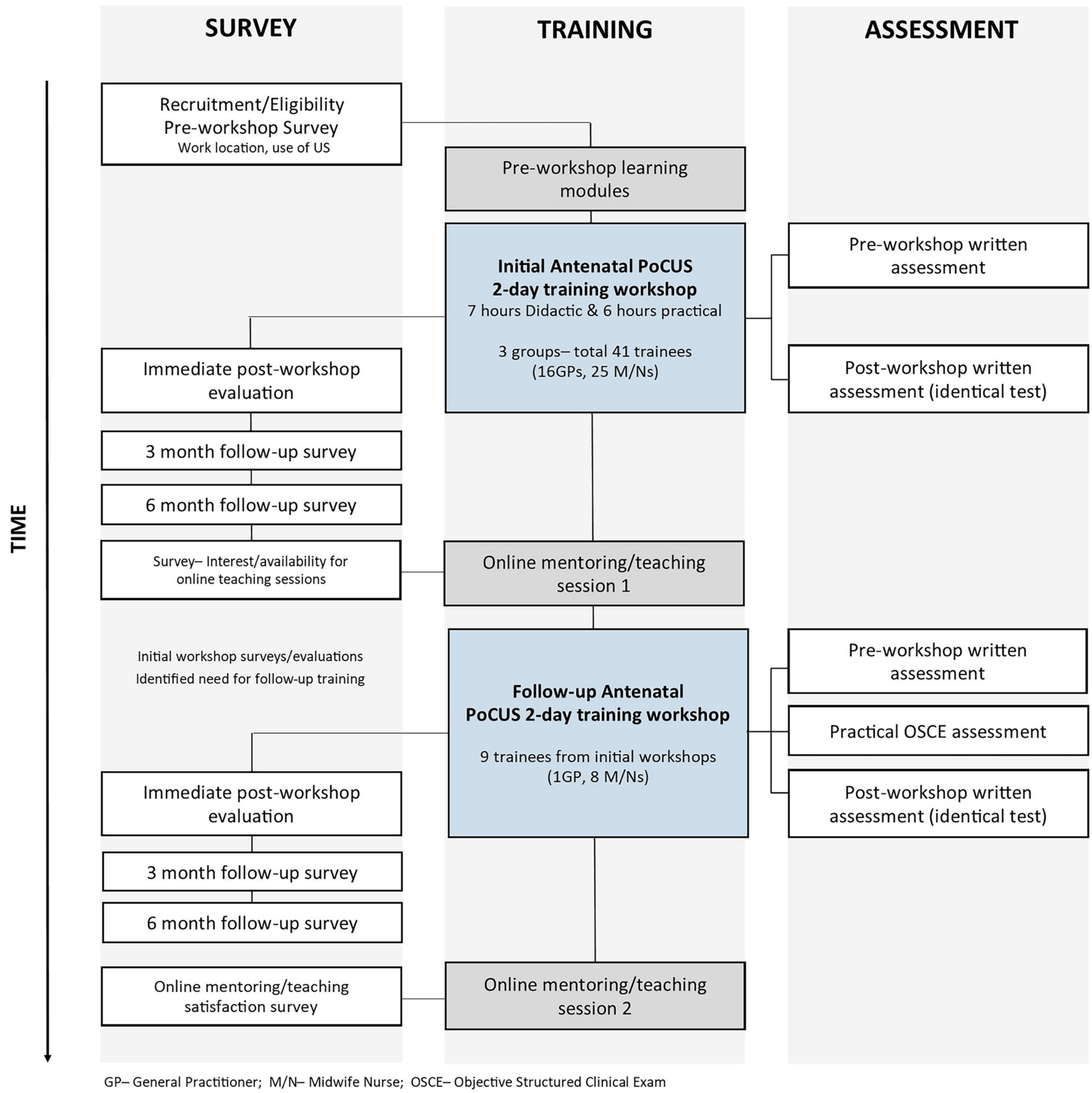

Fig. 2 Flow chart of antenatal PoCUS workshops- Training, assessment and surveys

trainees' mean pre-and post-test results with stratification by role and previous ultrasound experience/training. Additional Table 4 of supplementary material provides the mean test results, with confidence intervals and *p*-values, of all workshops and stratified groups.

Follow-up workshop practical OSCE assessment

For participants (9) who attended the follow-up training session (Workshop 4), pre-and post-test scores were significantly higher compared to the initial workshops ($p < 0.008$), demonstrating retention of knowledge and an increased understanding of concepts following clinical scanning experience, but showed the smallest improvement between tests (9.2%). Of the 9 trainees, 2 were unable to satisfactorily complete the first-trimester OSCE. Second-trimester OSCE assessment proved more difficult for trainees, with 5 failing to perform at a satisfactory level. This may reflect the more complex requirements for second-trimester scanning and the complexity of

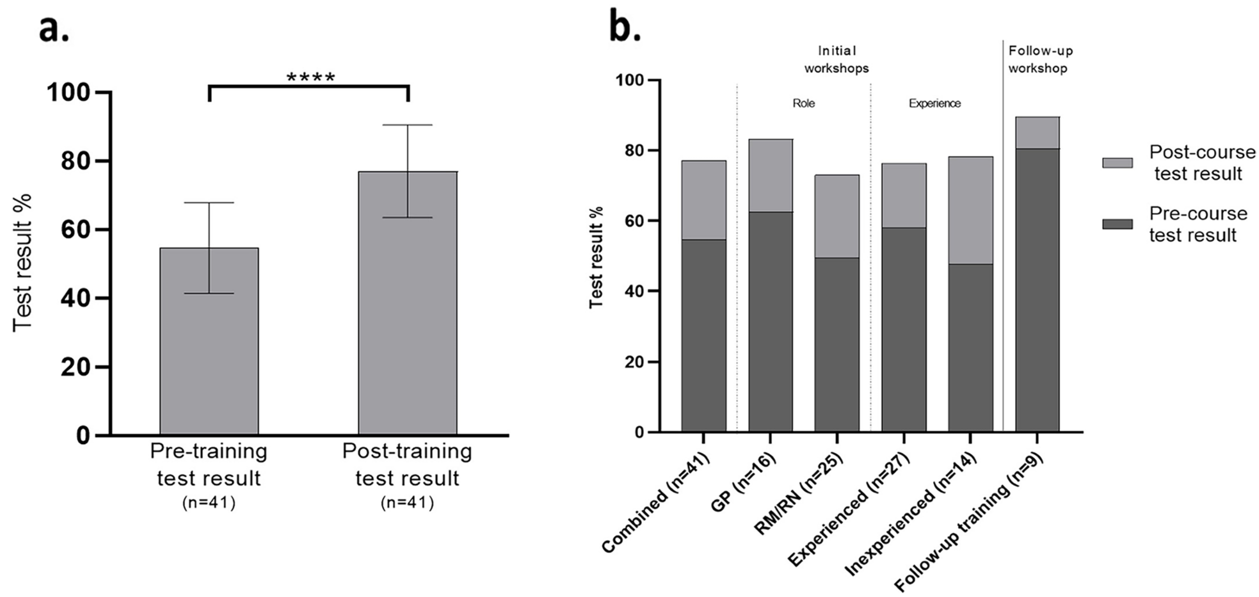

Fig. 3 **a** Pre- and post-test results for initial training workshops ($n = 41$) showing significant improvement in mean test scores ($p < 0.001$). **b** Pre-and post-test results stratified by trainee role and previous ultrasound experience

scanning real patients over the simulated (Vimedix) first-trimester OSCE.

Post-workshop evaluation

All trainees found the training valuable and relevant to their role, highly rating the workshop content, design, activities and facilitators, and indicated increased scanning confidence after learning. Trainees either strongly agreed or agreed that the difficulty level was appropriate and they would be able to utilise what they had learnt in clinical practice. The Vimedix simulators and live pregnant models were reported as the most valuable aspect of the training by 95% (39/41) of participants.

3- and 6- month post-workshop survey

At 3 months, 11% (4/38) of participants were not performing PoCUS, and 5% (2/38) were not scanning at 6 months. Reasons provided for never or rarely using PoCUS following training included: broken equipment, sub-optimal equipment, no/few antenatal patients seen clinically, and working mainly non-clinically in management/administration. Scanning frequency before training and at 3 and 6 months post-training for initial and follow-up workshops are provided in Fig. 4.

At 6 months after the workshop, trainee/self-reported data indicated 87% (34/39) of trainees had applied knowledge gained from the training to clinical situations, and 74% (29/39) reported having observed an impact on patient outcomes. As a result of attending the workshop, 62% (24/39) reported performing scans that had assisted in patient management and diagnosis, with earlier diagnosis and changes to patient management reported by 46% (18/39) of trainees. The main change to trainees' clinical practice/behaviour reported by 69% (27/39) of trainees was increased confidence in skills and ability to perform antenatal PoCUS. Additional Table 5 of supplementary material reports areas of improved confidence and practical skill by frequency of trainee response. Practise and follow-up training was named by 78% (28/36) of trainees as necessary to consolidate skills and further increase confidence and frequency of PoCUS use.

Discussion

This prospective single cohort study of 41 rural/remote clinicians demonstrated a statically significant improvement in knowledge-based test scores following the delivery of 2-day antenatal PoCUS training workshops in Adelaide, Australia. Trainees attending a second round of refresher training scored higher on pre-and post-test scores demonstrating retention of knowledge and increased understanding of concepts following 12 months of clinical scanning experience. The quantitative test data demonstrated the greatest test score improvements in Midwives/Nurses (M/Ns) and the ultrasound inexperienced cohorts. This result may reflect the fact that 81% (13/16) of the General Practitioners (GPs) had prior ultrasound training and experience (higher pre-course baseline knowledge) compared to 56% (14/25) of M/Ns. This trend is reflected in the literature, with ultrasound training

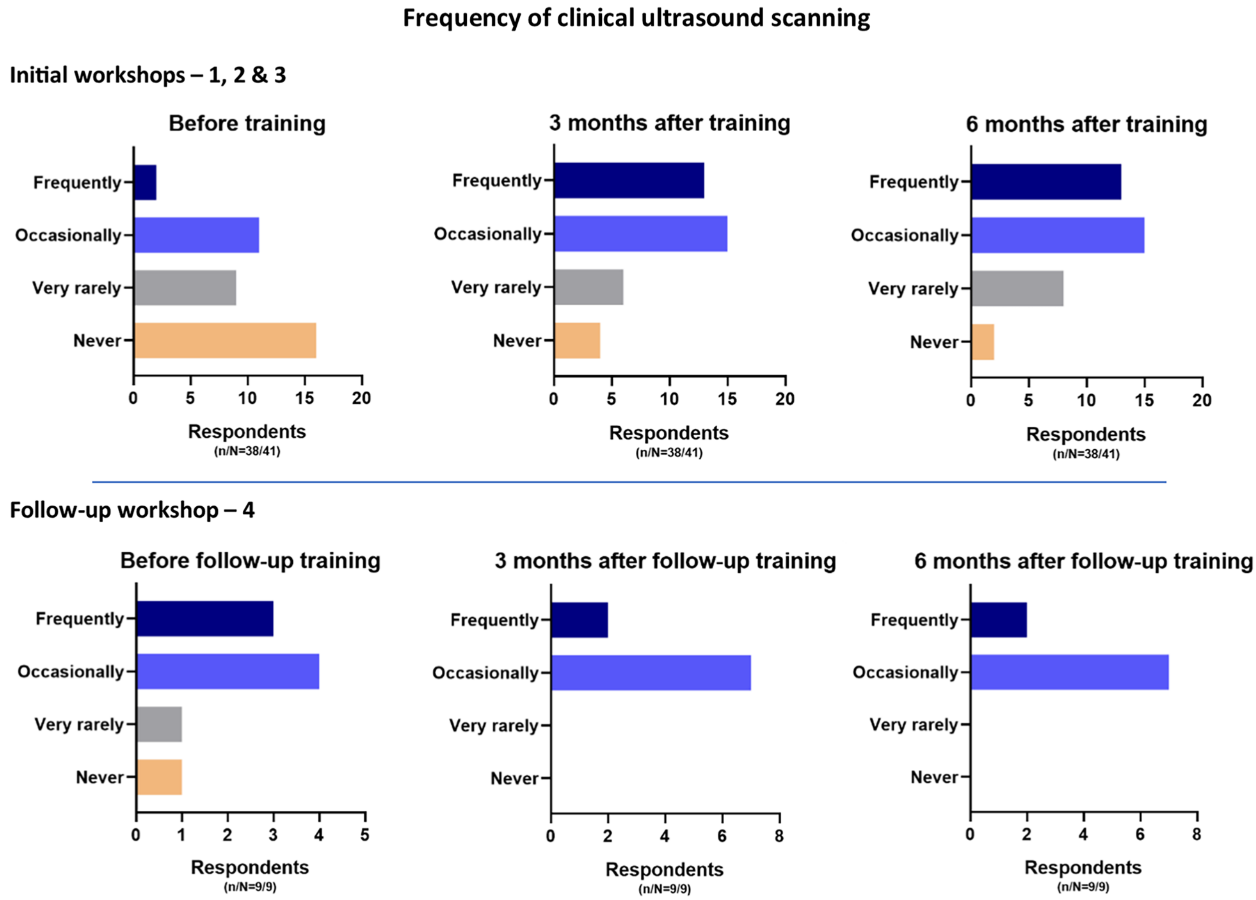

Fig. 4 Frequency of ultrasound scanning before training and at 3- and 6-months after training.*3 respondents censored due to incomplete data (3 or 6 month survey not completed)

being increasingly incorporated into undergraduate medical curricula and on-the-job training [47, 48], but less established in non-physician (nursing and midwifery) education programs and scope of practice [49, 50]. In most developing countries and low-resource settings, antenatal care is provided primarily by midwives and nursing staff, which presents an opportunity upskill these essential workers [48, 51–55].

Course evaluation and later follow-up showed trainees found the program relevant to their roles in rural health, and either 'agreed' or 'strongly agreed' that the difficulty level was appropriate and they would use what they had learnt in their clinical practice. Workshop content, design, activities, and facilitators were highly rated, with the Vimedix simulators and live pregnant models reported by 95% of participants as the most valuable aspect of the training. This supports the benefits of designing a program with an emphasis on practical hands-on training, which the program interspaced with theoretical content to consolidate learning and transfer theory into practice. Increased confidence, scanning frequency and impact on patient outcomes and management (as perceived by the clinicians) were described by the trainees as a result of the training; improvement in patient management and clinical diagnoses was reported by 62% of trainees, and earlier diagnoses and changes to patient management was reported by 46% of trainees. Other studies evaluating obstetric PoCUS training report similar improvements in pre-post course testing [56–59], trainee confidence [60–63], and knowledge retention [36, 56, 64].

The existing body of evidence evaluating antenatal PoCUS training stems largely from developing resource-poor countries. However, parallels in service access and health outcomes can be drawn between developing countries and rural and remote regions in developed nations [65, 66]. These studies commonly suffer limitations inherent to research conducted in remote settings, including low participant numbers, convenience samples, and loss to follow-up [32]. Our own systematic review [22] of PoCUS training evaluations in published literature highlighted a lack of comparable high-quality studies needed to establish a stronger evidence base for antenatal PoCUS. However, findings were generally positive, with improved knowledge and competence being reported despite the varying course durations (3 h to spanning several years). Variation in competence assessment and duration of trainee follow-up was also observed, with 11 of the 27 identified studies not surpassing the Kirkpatrick Evaluation Framework levels 1 or 2 which assess immediate reaction to training and knowledge gained. Almost half the studies investigated patient outcomes (KEF Level 4), several going further to ascertain if PoCUS changed the patient diagnosis and if this impacted their management, providing the most robust evidence for the impact of PoCUS. Kolbe et al. [48] found 52% of patients had a new diagnosis following antenatal PoCUS, of which 48% led to a change in patient management. In Rominger et al. [55] 34% of patients had a PoCUS directed change in diagnosis, with 78% leading to a modification of clinical management.

Multidisciplinary mixed experience groups

Delivering a training program to meet individual learning needs in a multidisciplinary mixed experience group, like those trained in this study, is challenging. The workshop evaluations revealed some opposing opinions on course content. For example, one trainee felt *"Basic physics- frequency of sound waves* etc." was the least valuable content of the workshop, while another stated they wanted *"to learn more about basic physics"*. The scope of practice between M/Ns and GPs and those with prior training compared to novice practitioners may be reflected in the comments from some trainees who appreciated the coverage of ectopic pregnancy and requested more detail in future workshops, while others found this content to be beyond their scope of practice. Running basic and advanced workshops separately was considered during the workshops design, however recruiting sufficient numbers of similarly experienced trainees with the same availability was not feasible. Allocating trainees to separate sub-groups with curricula and objectives catered to their experience and skill level could mitigate this problem but may exclude the advantages of interdisciplinary collaboration and learning [49]. This approach is also difficult to accomplish when delivering didactic content to small groups with a single trainer common to remote settings. A 'flipped classroom' pedological approach through the provision of pre-reading materials and learning modules, as used in this study, is an effective technique for teaching task-based skills like PoCUS [49, 67, 68], helping minimise the knowledge gap between experienced and inexperienced trainees and enabling faster transition through basic concepts. Preliminary knowledge testing prior to course entry to ensure understanding of assigned pre-course learning was not performed but has been reported in the literature [49, 51, 52, 59, 69].

Simulators and models

In this study, first-trimester ultrasound and clinical pathology that were unavailable for demonstration on live models were instead demonstrated using high-fidelity simulators, which provided a safe, patient-free learning environment, and were highly rated/commended by the training participants. Ideally, training should utilise both simulated and real-life patients with strictly limited scanning times for pregnant volunteers and heavier reliance on phantom models and virtual/simulation technologies in early training [70–72] as recommended by the ISUOG [41]. This reduces reliance on pregnant volunteers and provides the opportunity to scan simulated first-trimester pregnancies, often lacking in training courses due to the early gestation of the fetus and associated risk of identifying an unexpected abnormality in volunteers who are yet to receive formal scanning. A limitation of the simulators highlighted in feedback was the lack of controls (e.g. gain and focus) representative of an actual ultrasound unit. Other disadvantages of high-fidelity simulated technologies include the absence of the complexities of fetal movement and patient interaction, as well as the cost of implementing such systems, which could be prohibitive in low-resource settings [71, 73, 74]. Many trainees stated being able to train on their own equipment and become more familiar with the controls would have been beneficial, and despite being encouraged to bring their portable ultrasound units to the workshop, only 2 trainees were able due to active clinical use of the equipment and transport/insurance concerns.

Change in practice and patient outcomes

Seventy-four percent of trainees reported an impact on patient outcomes resulting from their training (as perceived by the clinician), demonstrating the practical benefits of the 2-day workshop. Qualitative responses indicated this stemmed from their ability to: better plan pregnancy care and refer where appropriate, increase patient engagement and antenatal care compliance, more accurately estimate gestation early in pregnancies, provide reassurance and patient education, and reduce unnecessary travel.

Identifying high-risk pregnancies in remote settings, where co-morbidities (e.g. obesity, diabetes, substance abuse) are more prevalent [75, 76], is important for antenatal care planning. This includes frequent monitoring, specialist referral and establishing the potential need for pre-term-delivery; a logistical challenge for remotely located women. One Trainee reported *"I have been able to identify twin fetal heart activity in first trimester confirming pregnancy and increasing ANC visits accordingly... I have had an obese diabetic pregnant woman with a difficult abdominal palpation in remote community and was able to identify lie and position of fetus."* Another *stated "Being able to provide anultrasoundat a woman's first visit is hugely helpful in planning and coordinating care, especially when they have chronic diseases such as T2DM."*

For some trainees, being able to offer PoCUS increased patient attendance at their clinic and provided earlier more accurate dating scans that are often missed in remote settings, and allowed for opportunistic scans on patients who would otherwise receive limited or no antenatal imaging throughout their pregnancy. Many instances of patients no longer needing to travel, some for days, to have a basic early dating scan where last menstrual period is unknown (required to plan antenatal care and schedule formal ultrasound imaging) were described. Gestational dating, most reliably assessed in the first-trimester, was the most frequent application for ultrasound use reported following training. Accurate estimation of due dates for delivery planning is crucial for remotely located women who may need days of travel to access obstetric care [7, 15, 24]. The early detection of problems and reduction of unnecessary travel/transfers can also provide direct economic benefits to healthcare systems. One respondent provided the example of a patient "*for whom it was not possible to find a fetal heart with the doppler unit. We were able to use the PoCUS unit to rapidly detect a fetal heart and live active fetus which saved a transfer, hospital resources and maternal anxiety*."

A sample of qualitative responses on PoCUS application and patient impact (as perceived by the clinicians) with clinical examples are provided in supplementary material- Additional Table 6a: Application of learning/PoCUS to clinical practice and Additional Table 6b: Impact of training/PoCUS use on patient outcomes.

Barriers to training and continuing professional development (CPD)

The most common barriers to accessing training and CPD opportunities raised by the trainees in order of frequency was: cost (course and travel); distance/remoteness; time for training; lack of relief staff; limited employer support; lack of onsite supervision/mentorship; availability and timing of courses; time to practise new skills with competing clinical duties/heavy workloads; no local/remote-setting courses available; poor internet access; and lack of credentialing opportunities. The training was scheduled on weekends due to lower staffing requirements at rural/remote clinics which often operate with minimal permanent staff and limited accessible relief staff [37]. Online mentoring and follow-up teaching was offered, with trainees surveyed to establish availability to accommodate work schedules. Many were unable to participate due to varying schedules, heavy clinical workloads and no or poor internet access (some conducting outback 'bush' visits). Of those who did attend (12), anonymous feedback was positive, with case study discussion and image review reported as the most helpful aspects by the majority, followed by networking with other clinicians.

Continuous access to a quality ultrasound machine was also reported as a barrier to trainees performing PoCUS upon return to work. In some cases, portable ultrasound machines were shared between numerous clinics and could be taken out to bush communities for days at a time. Several trainees reported equipment failure, one unable to scan due to the poor quality of their mobile ultrasound unit. While resources may be limited, a false economy may ensue where cheaper portable imaging equipment is purchased. A high-end portable ultrasound unit capable of providing high quality resolution can be purchased for around $40,000 (AUD). Cheaper units under $10,000 (AUD), including hand-held devices that can be adapted to a mobile phone or tablet, are available and the technology is improving but may not provide adequate resolution, particularly on obstetric patients with a higher Body Mass Index [77, 78].

Despite the above scheduling measures and coverage of travel and course costs by THRF, a theme which emerged from the trainees qualitative responses was the desire for onsite/workplace training to exclude the need to travel and reduce time away from work and family. A small number of the participants felt a lack of confidence scanning patients on returning to work due largely to lack of onsite supervision and assistance. To better address these identified barriers, the next round of HNP training provided remote-setting/onsite antenatal PoCUS workshops to 23 outback clinicians in Alice Springs in May and June of 2022. This format allowed the trainees to use and become more proficient on their own ultrasound equipment. Additional online group support/teaching sessions were held and access to trained sonographers for one-on-one consults and image review/feedback were offered to all past HNP training participants. Trainees were also encouraged to consider formal accreditation in PoCUS. The ASUM accreditation pathway provides clinicians with ongoing supervision and mentorship with longitudinal formative and summative assessment, and is the only means to claim remuneration through the Medicate Benefits Schedule in Australia. ASUM specifies half of the required assessments may be completed in a non-clinical environment, but under direct supervision with educational feedback provided. Teleultrasound may provide an alternative, allowing rural clinicians to be supervised and assessed by a distance city-based ultrasound expert. Making the accreditation pathway more accessible to rural clinicians could incentivise greater uptake of PoCUS training opportunities and better support clinicians practicing remotely.

While face-to-face teaching is optimal when learning a practical skill like US, online teaching and mentoring offers rural clinicians a means of support otherwise unavailable in their remote settings. Within our study, the use of a basic online meeting platform with the option of cursor control and screen sharing with trainees was well received. *"The online session was brilliant, I think it is very motivating to have sessions like that, it refreshed our memories. I particularly liked looking at the images and explaining what we were looking at…the ability to communicate by using the mouse at our end was great!".* Advancements in Teleultrasound systems now make it possible for an experienced clinician/instructor to communicate from a distance via live video and text message with the trainee/clinician, view the ultrasound monitor, images and probe position, and even take control of the ultrasound machines functions, all in real time [79]. Augmented reality simulated technologies with similar capabilities are also emerging as a viable tool for distance education and support [80, 81]. While such systems require significant funding and infrastructure (quality internet), they do offer considerable advantages for remote supervision and support of trainees and may see greater utilisation in the future.

Limitations

A small convenience sample of healthcare practitioners were recruited for the training. The total number of trainees was determined by available funding. While checklists of practical tasks were completed under instructor supervision, no formal practical assessment was conducted for the initial 3 workshop groups. At follow-up, 3- and 6-month surveys focused on trainees' use/application of PoCUS, confidence, and changes in clinical practice behaviour, i.e. follow-up practical and knowledge assessments after a period of clinical scanning were not conducted for the initial three workshops (Workshops 1–3). Only the Follow-up/Refresher training group (Workshop 4) was assessed for practical scanning competence and learning retention at 12 months. Practical scanning improvement was unable to be measured/quantified for this group however as baseline practical assessment was not conducted at initial training. Several trainees were not scanning patients following training and 3 failed to complete either the 3 or 6 month survey.

Image quality on return to clinical practice was not evaluated. Expert image review is a useful measure for quality assurance and competence assessment, particularly where direct onsite supervision is not possible, as it may be performed asynchronously and remotely. Trainees were offered ongoing access to qualified trainers/sonographers and invited to send images for critique but no trainees took up this offer. While assessing actual patient outcomes would provide the most robust evidence of PoCUS impact, the scope of this pilot study and its limitations (funding and study duration) excluded the collection of patient clinical outcomedata. This study only assessed impact on patient management and outcomes from the clinician's perspective.

Future direction

The ultimate goal of the HNP is to establish an evidence-based, accessible and sustainable training program for rural clinicians. With extended funding, our future training iterations will see the delivery of antenatal PoCUS workshops directly to clinicians in their local communities (following the pilot training conducted in Outback Australia this year). We will also be working in consultation with ASUM towards making the formal accreditation pathway for PoCUS more accessible to rural clinicians in Australia.

Quality studies on antenatal PoCUS with a focus on patient outcomes data, longer-term competency assessment, trainee support/supervision on return to practice and economic utility are needed to provide more robust evidence of the value of PoCUS in the rural healthcare setting and its impact on patients and healthcare services. Researcher and clinical educators looking to implement or evaluate their own PoCUS courses should ensure attention is given to the challenges and barriers unique to rural and low-resource settings at all stages of development, implementation and evaluation.

Conclusion

Intensive training workshops can equip clinicians with valuable skills and the confidence to perform PoCUS, presenting a viable solution to the ultrasound service access and skills shortage in rural and resource-poor settings. In this study, significant improvement in ultrasound knowledge and scanning confidence was evident following the delivery of 2-day antenatal PoCUS training workshops, with retention of knowledge demonstrated at 12 month follow-up assessment. Increased scanning frequency and changes to clinical behaviour impacting patient management and outcomes were described, with increased antenatal care attendance and compliance with care directives reported.

Interest in advancing skill-sets to take advantage of expanding technologies like ultrasound is evident amongst rural Australian clinicians. The future of healthcare and its education is moving towards a more cooperative interdisciplinary culture [82], providing the opportunity to use trainees' unique experiences and individual strengths to enhance course design and foster collaborative practice. Providing clear objectives and varying curricula in breakout groups tailored to participants' experience levels would benefit a multidisciplinary PoCUS training cohort. However, barriers to accessing training opportunities, as well as formal accreditation pathways and ultrasound equipment exist. Geographical isolation and lack of onsite expert supervision pose an ongoing challenge to the development of remote trainees' PoCUS skills. Creative solutions for distance training and supervision are needed, such as those offered by telehealth technologies.

This paper may serve to guide educators of PoCUS in the development of training programs directed at rural practitioners, and inform policy for clearer standardised training and competency assessment guidelines needed to ensure safe clinical practice. Government initiatives to support rural clinicians accessing PoCUS training, equipment and formal accreditation is vital to strengthening workforce capacity in these under-resourced communities, and improving health outcomes for rural mothers and babies facing significant inequities in healthcare access.

Abbreviations

AFV: Amniotic Fluid Volume; AC: Abdominal Circumference; ANC: Antenatal care; ASUM: Australasian Society for Ultrasound in Medicine's; BPD: Biparietal Diameter; CPD: Continuing Professional Development; CRL: Crown to Rump Length; FL: Femur Length; GP: General Practitioners; HC: Head Circumference; ISUOG: International Society of Ultrasound in Obstetrics and Gynecology; M/N: Midwife/Nurse; NWKEF: New World Kirkpatrick Evaluation Framework; OSCE: Objective Structured Clinical Exam; PoCUS: Point-of-care ultrasound; PV: Per Vagina; STROBE: Strengthening the Reporting of Observational Studies in Epidemiology; T2DM: Type 2 Diabetes Mellitus; TGC: Time Gain Compensation; THRF: The Hospital Research Foundation; UniSA: University of South Australia; US: Ultrasound; WHO: World Health Organization.

Supplementary Information

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Additional file 1: Table 1. General workshop requirements defined by ASUM.

Additional file 2: Table 2. Methods for assessing PoCUS competency.

Additional file 3. Post-workshop evaluation form.

Additional file 4. 6-month follow-up survey form.

Additional file 5. First-trimester OSCE assessment form.

Additional file 6. Second-trimester OSCE assessment form.

Additional file 7: Figure 1. New World Kirkpatrick Evaluation Framework (NWKEF) [45] for training evaluation and the Healthy Newborn Project workshops.

Additional file 8: Table 3. Trainee demographics (role, clinical experience, clinic remoteness area, pre- and post-workshop test results, previous ultrasound experience and ultrasound unit used).

Additional file 9: Table 4. Pre-post test scores for all workshops, and initial workshops by position/role and previous ultrasound experience.

Additional file 10: Table 5. Areas of improved confidence and practical scanning.

Additional file 11: Table 6a. Application of learning/PoCUS to clinical practice: Qualitative responses from 3- and 6-month follow-up surveys. **Table 6b.** Impact of training/PoCUS use on patient outcomes: Qualitative responses from 3- and 6-month follow-up surveys.

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Authors' contributions

The authorship conforms with the journal's authorship policy. The first author (AB) drafted the manuscript. Second and third authors (EB and NP) contributed substantially to the conceptualisation of the manuscript and subsequent revisions. All authors have approved the final version for publication and agree to be accountable for all aspects of the work. Concept and design: AB, EB, NP. Acquisition, analysis, or interpretation of data: AB, EB, NP. Drafting of the manuscript: AB. Critical revision of the manuscript: AB, EB, NP. Administrative, technical, or material support: UniSA.

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Availability of data and materials

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request. Additional data referred to but not included in the main manuscript is provided in supplementary material as 'Additional Tables' and 'Additional Figures'.

Declarations

Ethics approval and consent to participate

Ethics approval was granted by The University of South Australia's Human Research Ethics Committee (Project ref: 201543). All study participants and volunteer models provided informed signed consent.

Consent for publication

Not applicable. No individual or identifiable details are included in the manuscript or associated data.

Competing interests

The authors declare they have no competing interests.

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