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ELSEVIER

Evaluation of the Learning Experience after Ultrasound-Guided Percutaneous Arteriovenous Fistula Placement Workshop Utilizing the Ellipsys Vascular Access System

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Objectives: Excellent ultrasound skills are crucial for planning and creating a percutaneous arteriovenous fistula (AVF). This study presents the findings of a workshop focused on training healthcare professionals in ultrasound-guided puncture techniques for percutaneous AVF (pAVF) placement using the Ellipsys vascular access system (Medtronic, Minneapolis, MN, USA). Emphasizing the importance of ultrasound guidance in enhancing accuracy and safety, the workshop aimed to equip participants with the necessary skills to perform this procedure effectively.

Methods: The workshop consisted of didactic lectures, hands-on training sessions, and case-based discussions. Before and immediately after the workshop, the participants completed a paired, anonymous pre and postworkshop written survey. The workshop was conducted over a 1-day period 4 times over 13 months at a conference center in Bavaria, Germany. Twenty-one healthcare professionals (18 male and 3 female) from 14 tertiary and 7 secondary hospitals attended the workshop. Participants included vascular surgeons, nephrologists, and interventional radiologists.

Results: Participants significantly enhanced their knowledge about percutaneous endovascular AVF creation, with average knowledge scores increasing from 4.24 preto 2.33 postworkshop ($P = 0.02$). Participants demonstrated significant improvement in confidence of measuring vessels (1.71−1.38, $P = 0.01$). Further improvements reported were in ultrasound knowledge (2,10−1,90), confidence in identifying arteries (1,29 to 1,24) and veins (1,33−1,19), as well as confidence in depicting vessels in both transverse (1,29−1,10) and longitudinal (1,43−1,24) projections. These changes were not statistically significant. Feedback surveys indicated a high level of satisfaction with the educational content and hands-on training sessions, with scores for various aspects such as the achievement of personal learning goals (1.08), informativeness of teaching materials (1.09), and overall recommendation of the training (1.0).

Conclusion: The workshop provided participants with valuable hands-on experience and demonstrated significant improvement in their knowledge about ultrasound-guided AVF creation.

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INTRODUCTION

The arteriovenous fistula (AVF) is the lifeline for patients with end-stage renal disease. These patients depend on obtaining safe and functional vascular access to hemodialysis. As endovascular techniques have further developed, it is now possible to create an AVF without open surgical procedures.

Percutaneous AVF (pAVF) creation offers a minimally invasive additional option beside traditional surgical approaches, reducing procedural complications and improving patient outcomes.[1,2] The two at the time commercially available systems for endovascular creation of AVF are the Ellipsys Vascular Access System by Medtronic (Santa Rosa, CA, USA) and the WavelinQ EndoAVF System by Becton Dickenson (Franklin Lake, NJ, USA). Especially the Ellipsys system gained recognition for its role in revolutionizing vascular access procedures with durable results during the long-term follow-up.[3] Central to the success of both techniques is the utilization of ultrasound guidance for detailed preoperative estimation of the vessel conditions (vein mapping) and suitability for these techniques. While the WavelinQ system is fluoroscopy based, the vessel localization and puncture for the Ellipsys system is exclusively controlled by ultrasound. Consequently, ultrasound education and training have become essential skills for medical professionals performing pAVF creation. The consideration of technical aspects of the Ellipsys System has already been published.[4] Besides the technical aspects, ultrasound skills are crucial for planning and performing pAVF creation. Therefore, structured hands-on training is necessary to execute the procedure safely and successfully. To the best of our knowledge, this workshop is the first to equip healthcare professionals with theoretical knowledge and practical expertize in pAVF creation using the Ellipsys system.

METHODS

Setting

The 1-day workshop, organized by the Department of Vascular and Endovascular Surgery of a tertiary university hospital in Bavaria, Germany, was conducted 4 times between February 2023 and March 2024. Figure 1 represents an overview of the important facts about the workshop. The workshop took place in a conference room featuring a central seating area with a podium and a large display screen for the lectures. Furthermore, 4 ultrasound hands-on work stations with the possibility to train vascular puncture and closure and pAVF creation were set up (Fig. 2). The workshop was divided into 2 main sessions as follows: Into a ''basic course'' covering fundamental ultrasound skills and knowledge about vascular puncture and the utilization of puncture closure systems, followed by the ''Ellipsys intensive training'' focusing on pAVF creation. Table I provides an overview of the entire program.

For the basic course, participants were introduced to essential ultrasound principles and techniques relevant to vascular access procedures. Participants received instructions and hands-on training in puncture models to gain a comprehensive understanding of the techniques necessary for successful pAVF creation. A silicon model with gelatine sticks (Nephro-Xperts, Limeshain, Germany) or prosthetic grafts was used for training the vascular puncture. The ultrasound-guided puncture was trained in longitudinal and transverse views (Fig. 3). At each ultrasound station, pairs of participants worked together and were supervised by a trainer. Furthermore, we offered the possibility to train different vascular closure device for example Perclose ProGlide (Abbott, Chicago, Illinois), AngioSeal (Terumo Corporation, Tokyo, Japan), or QuikClot Interventional Hemostatic bandage (QCI) (Z-Medica, Wallingford, CT, USA).

In the specialized session, participants were taught in necessary material and currently available data about the Ellipsys system. Furthermore, each participant received hands-on training to identify eligible anatomical conditions and created an anastomosis using the Ellipsys device on the lifelike simulation model (LifeLike Biotissue, London, ON, Canada) (Fig. 3). This model was designed to replicate real-life vascular anatomy and provide a realistic simulation environment for the ultrasound-guided pAVF placement technique.[5] At the end, a recorded live case was shown.

All participants have given their consent for their questionnaires to be used for scientific evaluation.

Table II outlines the main objectives of the workshop.

Development of Participant Background and Evaluation Questionnaires

The participants' background questionnaire was designed to gather comprehensive demographic and professional information to better understand

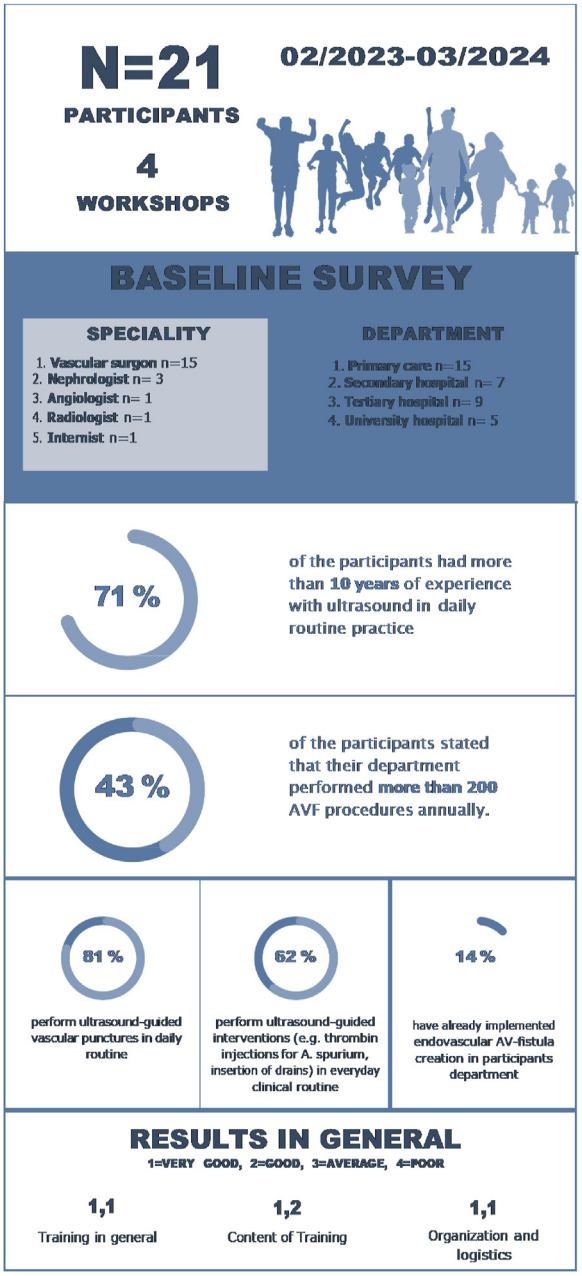

Fig. 1. Facts about the workshop- an overview of participants' demographics and baseline survey results.

their expertize and training needs. Key areas covered in the questionnaire included their area of specialty and details about their experience in the field of ultrasound-based diagnostics, procedures, and AVF creation (Supplementary Table 1). This detailed questionnaire allowed for an understanding of the participants' baseline skills and knowledge, as well as variations in experience levels and institutional practices, which were considered when analyzing the workshop's effectiveness.

Fig. 2. Training area- an overview of the workshop training area, featuring lecture area and ultrasound stations.

An evaluation of workshop effectiveness was conducted through specific questions assessing knowledge acquisition and skill proficiency before and immediately after completing the specialized training session. The questionnaire included a mix of multiple choice questions, both theoretical knowledge and familiarity with the step-by-step workflow, for creating an endovascular AVF using the Ellipsys system. Participants rated their confidence in ultrasound skills and self-perceived expertize on a Likert scale. To better capture the nuances in participant responses and to address the specific context of each question, we used a 5-point Likert scale for some questions and a 6-point Likert scale for others (1 = very good or very confident, 5/6 = poor orno skills). (Supplementary Table 2). The format ensured a focus on knowledge directly relevant to the workshop objectives, with a combination of basic and advanced topics.

Additionally, feedback surveys were administered to gather qualitative insights into participant satisfaction and perceived educational value (Supplementary Table 3).

Analysis

Statistical analysis of workshop outcomes and participant feedback was conducted using Excel (Microsoft Office Professional Plus 2016 for Windows; Microsoft 365) and GraphPad Prism 10.2.3 (GraphPad San Diego, USA). Participants' answers were described by mean and standard deviation (SD) or tabulated by frequencies and percentages (of correct answers). Wilcoxon signed-rank test was used to compare the before and after results. *P*

Table I. Workshop program ultrasound-guided vascular puncture and Ellipsys intensive training

Session	Activity
Basic course	Basics and introduction to ultrasound diagnostics Overview of materials for vessel puncture Presentation of closure systems Shunt puncture Practical ultrasound-guided puncture exercises on models - Ultrasound-guided vascular puncture - Puncture of vascular prostheses - Handling closure systems
Ellipsys intensive training: the endovascular shunt placement	Introduction to the Ellipsys system Materials Presentation of current literature Proper screening Discussion on screening Practical exercises on models Maturation procedures Edited life case

values less than 0.05 were considered statistically significant.

RESULTS

Demographics of Participants

A total of 21 professionals completed the workshop (18 male and 3 female). Fifteen (71%) of the participants were from surgical specialities (vascular surgeons or vascular-, visceral- and thoracic surgeons). The rest of the participants were 3 nephrologists, 1 radiologist, 1 internist, and 1 angiologist. Among the participants 15 (71%) were senior physicians, 4 (19%) heads of departments, and 2 (10%) residents.

Institutional and Departmental Profiles of Participants

The study included participants from a diverse range of departments. Out of these, 14 were tertiary care institutions, including 5 university hospitals, while 7 were secondary care institutions. Additionally, 47% of the departments have a residency program for vascular surgery. As for departments focused on AVF creation, 24% of them were independent, while the rest, which make up 76%, were integrated into another department. 62% of the participants responded that their hospital performs between 50 and 100 AVF interventions per year. Only one department performed more than 300 AVF interventions per year.

Three of the departments were certified by ClarCert (Neu-Ulm, Germany) as a regional AVF center, 9 were certified as a reference AVF center and 9 were not certified.

During the workshops, it was noted that only 3 departments (14%) had implemented endovascular AVF creation. Two of the hospitals used the Ellipsys system, while 1 utilized the WavelinQ system (Becton Dickinson, Franklin Lakes, NJ, USA).

Professional Experience in Ultrasound Handling

The majority[6] of the participants have over 10 years of experience in dealing with ultrasound and have pursued further education and training through courses. In everyday practice, 81%[7] of participants perform ultrasound-guided vascular puncture, with 62%[8] also performing ultrasound-guided interventions. Half of the participants reported using only the transverse projection for puncture, while the remaining half used both transverse and longitudinal projections. It's also worth noting that a considerable number of participants[6] are actively involved in performing interventions related to shunt stenosis.

Figure 1 showcases various aspects of the participants' diverse professional backgrounds.

Questionnaire Results before and after Ellipsys Intensive Training

The workshop significantly enhanced both the knowledge and confidence of participants in various aspects of ultrasound and endovascular procedures. Participants rated their knowledge of ultrasound with an average score of 2.10 ± 0.9 prior to the workshop, which improved to 1.90 ± 0,8 after the workshop (with 1 being the highest and 6 the lowest possible score). Confidence in diagnosing vascular pathologies improved from 1.95 ± 1 before the workshop to 1.67 ± 0.8 afterward, which was statistically significant ($P = 0.03$). Additionally, there was a significant improvement in the knowledge of endovascular AVF placement, with average scores rising from 4.24 ± 1.2 before the workshop to 2.33 ± 0.9 after ($P = 0.02$). Confidence in identifying arteries improved slightly from 1.29 ± 0.5 to 1.24 ± 0.4, and confidence in identifying veins increased from 1.33 ± 0.6 to 1.19 ± 0.4. When it

Fig. 3. Ultrasound training participants undergoing ultrasound training, learning to assess vascular anatomy and navigate the needle using both transverse **(A)** and longitudinal **(B)** projections. **(C)** and **(D)** show training on pAVF simulation model with 3 vessel pairs, embedded in hydrogel inlay, LifeLike Biotissue (London, ON, Canada).

came to depicting vessels in the transverse projection, participants' confidence improved from 1.29 ± 0.5 to 1.10 ± 0.2, and in the longitudinal projection, confidence scores increased from 1.43 ± 0.6 to 1.24 ± 0.5. Confidence in measuring vessels also saw a significant improvement, with scores going from 1.71 ± 0.8 before to 1.38 ± 0.7 after the workshop ($P = 0.01$) (Fig. 4).

The knowledge of necessary materials for Ellipsys significantly improved from 20% to 70%, understanding of anatomical requirements increased from 17% to 70%, and knowledge of procedural steps improved from 33% to 100%. The knowledge of the type of created anastomosis improved from 81% to 100% for the Ellipsys system and from 62% to 100% for the WaveLinQ system. Understanding of Endo AVF systems' position in the AVF placement algorithm remained consistent at 76% (Fig. 5).

Overall, the average number of correct answers to specific endo AVF questions increased significantly from 14.69 preworkshop to 19.31 postworkshop, with a statistically significant difference ($P = 0.002$).

Evaluation of the Workshop

Participants gave highly positive feedback on the workshop's training in general,[1] content of training,[1,2] and organization and logistics.[1] Figure 6 shows the evaluation of each category.

Table II. Workshop aims

Workshop aims	Focus areas
1. Improving ultrasound skills	**Assessment of vascular anatomy**: Correct identification and measurement of vascular structures
	Ultrasound-guided techniques: Ensuring that participants are adept at both transverse and longitudinal projections and puncture, crucial for performing procedures like pAVF creation
2. Hands-on training	**Practical application:** Providing participants with opportunities to handle materials and equipment extensively
	Simulation practice: Allowing each participant to practice creating an anastomosis using the Ellipsys device on a simulation model
3. Enhancing practical skills	**Mutual screening**: Conducting prior mutual screening among participants for endo AVF to better understand practical applications
4. Knowledge improvement	**Informative sessions:** Providing extended information about endovascular shunt placement procedures, literature review, and sharing own experiences
5. Evaluation of workshop benefits	**Assessment via questionnaires**: Measuring pre and postworkshop improvements in knowledge and confidence

pAVF, percutaneous AVF; AVF, arteriovenous fistula.

DISCUSSION

This workshop addresses the need for training in new endovascular techniques, like the minimally invasive AVF fistula creation. Numerous benefits, including faster recovery time and lower complication rate, compared to open surgical methods were already described in the literature.[9] Hence, the procedure is performed only via ultrasound guidance; mastering ultrasound skills is crucial for achieving successful AVF procedures. A precise identification of vascular structures is fundamental to performing ultrasound-guided procedures successfully.[10] As detailed in Isaak et al.'s ''Practical Guide of Vascular Ultrasound in Arteriovenous Fistulae,'' mastering ultrasound techniques is also vital for identifying suitable patients.[11] One important initial step is to use ultrasound guidance to accurately puncture the vessel. The focus on training of ultrasound-guided vessel puncture is particularly relevant given the increasing reliance on minimally invasive techniques in vascular surgery.[12] These procedures require precision and skill, which can be effectively achieved through targeted training.[13] Moreover, studies such as those by Piton et al.[14] and Denadai et al.[15] reinforce the importance of structured ultrasound training to enhance success rates and reduce complications in vascular access procedures.

The results of the current workshop align with the findings of previous studies by demonstrating that targeted ultrasound training significantly increases both knowledge and confidence among participants.[8,16] Participants initially rated their ultrasound knowledge with an average score of 2.10, which improved to 1.90 after the workshop. The progress may seem modest, but it represents an enhancement in understanding over a short period. Confidence in ultrasound-based diagnostics of vascular pathologies also increased, with scores improving from 1.95 to 1.67. Confidence in identifying arteries and veins showed slight but important improvements. For arteries, scores increased from 1.29 to 1.24, and for veins, from 1.33 to 1.19. These marginal gains emphasize that there is always room for improvement through training, even in basic skills. At this workshop, the confidence in measuring vessels improved significantly from 1.71 to 1.38. This finding highlights the fact that structured hands-on practice can enhance the proficiency of healthcare providers, including experienced professionals, as recently found in other surgical hands-on simulation workshop.[6]

Participants from 14 tertiary care institutions, including 5 university hospitals and 7 secondary care institutions, guaranteed a diverse range of perspectives and experiences. The diverse backgrounds of the participants, including vascular surgeons, nephrologists, and colleagues from various departments, led to a comprehensive exchange of experiences. 81% of participants regularly perform ultrasound-guided vascular punctures in their daily routine, clearly demonstrating the incomplete adoption of ultrasound guidance in routine clinical settings. On the other hand, 62% of participants incorporate ultrasound-guided interventions into their practice, while 71% perform interventions on patients with relevant AVF stenosis. This reflects a strong integration of advanced ultrasound techniques in their daily practices. Nevertheless, there is still potential for physicians to improve their

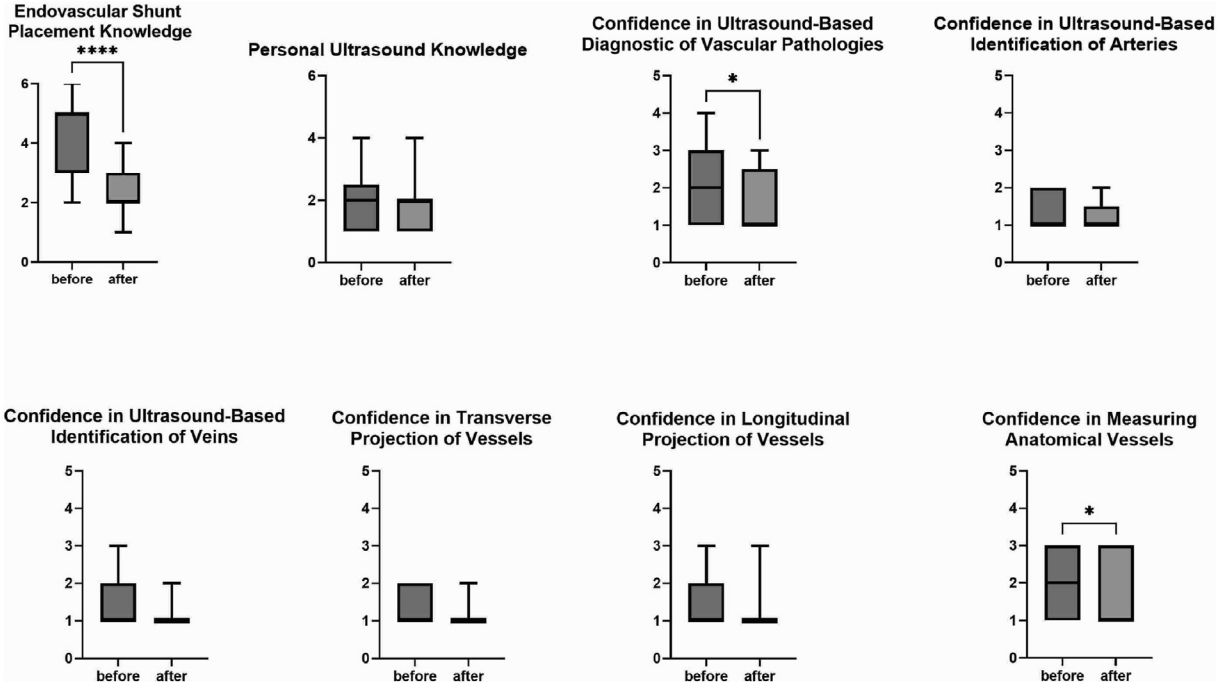

Fig. 4. Pre and postworkshop self-assessment *, **** Statistically significant outcomes (P value < 0.05) between comparisons (before vs. after workshop), as determined by Wilcoxon matched-pairs signed-rank test rating scale questions 1–2: 1 = very good, 2 = good, 3 = satisfactory, 4 = sufficient, 5 = insufficient, 6 = poor rating scale questions 3–8: 1 = very confident, 2 = confident, 3 = satisfactory 4 = insecure 5 = no skills.

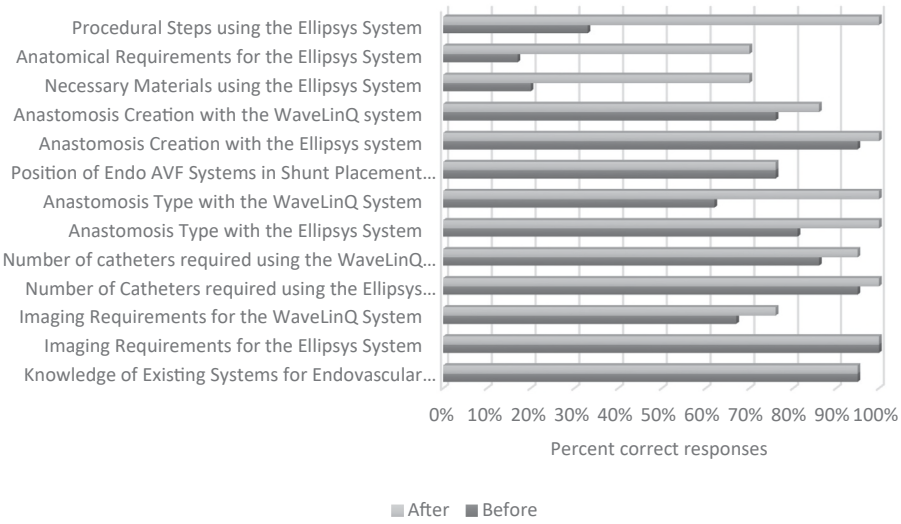

Fig. 5. Pre and postworkshop knowledge comparison of endovascular shunt creation (percent correct responses). Detailed results of individual correct answers of the specific questions assessed before and after the workshop.

personal ultrasound skills, and the current workshop addressed these physicians.

Another point of discussion is the preferred projection when performing ultrasound-guided puncture. Both projection, transverse and longitudinal, were trained in the workshop, and the participant's confidence in depicting vessels in transverse projection improved from 1.29 to 1.10, in

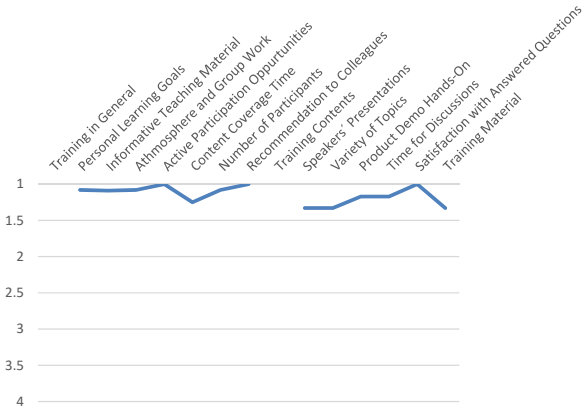

Fig. 6. Workshop evaluation rating scale: 1 = very good, 2 = good, 3 = average, and 4 = poor. Color should not be necessarily used for the figures in print. pAVF: percutaneous AVF; AVF, arteriovenous fistula.

longitudinal projection, from 1.43 to 1.24. It is commonly stated that the transverse (out-of-plane) projection is easier to master and quicker to learn,[17] while the longitudinal (in-plane) approach is considered a more advanced technique and also superior for needle visualization.[7] The fact that half of the participants reported that they puncture only in transverse and half of them in both longitudinal and transverse projection can be attributed to the fact that the cohort consisted of more experienced practitioners. To create an AVFwith Ellipsys, the user must skilfully switch between transverse and longitudinal projections.[18] Therefore, training in both projections is essential for performing the procedure. The workshop's ability to improve confidence in both projections indicates that it effectively catered to enhancing both basic and advanced skills among the participants.

After the workshop, there was a significant improvement in knowledge about EndoAVF creation and the technology involved. The knowledge scores related to endovascular AVF placement improved from 4.24 to 2.33, which show that there was still a lack of knowledge about the creation of endovascular AVFs. Before the workshop, participants had an average of 14.69 correct answers, which increased to 19.31 correct answers postworkshop. This improvement is statistically significant, with a *P* value of 0.0020. This included understanding the type of anastomosis, catheters, materials, procedural steps, and anatomical considerations. The results align with those of other training programs for improving procedural competencies.[19]

The workshop not only provided theoretical knowledge but also increased practical confidence. Published experiences with the Ellipsys device show that expertize in ultrasound for assessing vascular anatomy and knowledge of clinical techniques are crucial for performing pAVF procedures. The study results from major centers with experienced practitioners who gathered substantial expertize during the establishment of the procedure are excellent, also, the long-term resultswere good,[3] and the procedure was performed extremely quickly,[1] whereas centers with less experience, characterized by a smaller number of procedures per practitioner, demonstrate slower and less consistent results. Therefore, the workshop placed great emphasis on providing participants with practical opportunities to become familiar with the use of required materials. Additionally, participants underwent peer screening under supervision. Finally, performing a procedure on lifelike models was found to have a significant impact on the personal skills.[13] The focus on practical, real-world applications aimed to ensure that participants could directly translate their learning into clinical practice. The stability of knowledge regarding the patient's life plan algorithm suggests that the participants were already well-versed in this aspect, and the workshop's main impact was likely on practical and procedural skills rather than on altering their understanding of AVF's role in patient care.

In summary, participants reported high satisfaction with the training, achieving personal learning goals and finding the teaching materials informative. The atmosphere and opportunities for active participation were also rated highly, suggesting that the workshop's interactive and collaborative format was well-received. Especially the hands-on product demonstrations and the time for discussions were rated very positively (rating 1.17), indicating they were considered very appropriate. The content coverage time received a slightly lower score (1.25), indicating room for minor adjustments in pacing. Every participant indicated they would recommend this training to colleagues, with a perfect rating of 1.

Overall, the workshop provided a successful comprehensive training demonstrated by improved practical self-assurance and highly positive feedback. Thus, the aim of determining whether the workshop provided a benefit to the participants was achieved.

Limitations

The main limitation to this study is that the evaluation focused on self-reported knowledge and confidence rather than directly measuring practical skills. Objective assessments could provide a more reliable measure of the gain in competencies. Furthermore,

the study did not include a long-term follow-up to assess whether the training was translated into clinical practice. In addition, participants presented varying levels of preexisting knowledge and experience related to ultrasound-guided procedures and also belonged to different specialties. This heterogeneity can lead to differences in learning outcomes and may confound the results. After all, the relatively small number of participants limits the statistical power of the study. Nevertheless, the study was meant to be the first structured comprehensive training with the Ellipsys vascular access system, covering very specialized, as well as fundamental areas of ultrasound-guided procedures. Future studies should include more standardized or stratified baseline of participants' skills as well as objective measurement of practical skills. Longitudinal studies could provide valuable information on the durability of the workshop's impact and its real-world clinical benefits.

CONCLUSION

The workshop effectively enhanced participants' knowledge and confidence in both general ultrasound skills and endovascular AVF creation. Following the workshop, the participants demonstrated significant improvement in their knowledge about ultrasound-guided AVF creation. The feedback surveys revealed that they were able to respond to technical questions about the procedure correctly, indicating an enhanced understanding of the ultrasound-guided AVF creation process. Overall, the workshop contributed effectively to the improvement of knowledge in this area.

These results highlight the value of comprehensive training programs in improving both the theoretical knowledge and practical skills of healthcare professionals. The value of workshops extends beyond teaching new technologies to also improving existing skills for better patient outcomes.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Viktoria Peters: Data curation, Formal analysis, Project administration, Validation, Visualization, Writing — original draft, Writing — review & editing. **Sebastian Zerwes:** Project administration, Visualization, Writing — review & editing. **Hagen Kerndl:** Writing — original draft, Writing — review & editing. **Alexander Hyhlik-Dürr:** Conceptualization, Project administration, Resources, Supervision, Writing — review & editing. **Dominik Liebetrau:** Conceptualization, Data curation, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing — original draft, Writing — review & editing.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.avsg.2025.01.023.

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