Practical Training in Vascular Ultrasound as a Strategy to Enhance the Accuracy and Safety of Duplex Scanning

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ABSTRACT

Vascular ultrasound plays a relevant role in the noninvasive assessment of arterial and venous diseases, but its clinical usefulness depends not only on the available technology but also on the competence of the professional performing and interpreting the examination. This article discusses practical training in duplex scanning by integrating theoretical foundations, guided observation, supervised performance, interpretation, and critical review. Through a narrative review of the literature and professional guidelines, a five-axis conceptual model—understand, observe, perform, interpret, and review—is proposed to organize training progression without replacing institutional protocols, professional certifications, or formal competency criteria. The proposal emphasizes that standardization and autonomy are not opposing goals: protocols reduce avoidable variability, while supervision and feedback develop the ability to recognize limitations, adapt the examination, and relate imaging findings to the clinical question.

Keywords: Vascular ultrasound. Duplex scanning. Medical ultrasound. Medical education. Clinical competence. Supervised training.

1 INTRODUCTION

Vascular ultrasonography has become an important tool in the noninvasive assessment of various arterial and venous conditions. By combining two-dimensional imaging, color Doppler, and spectral analysis, duplex scanning makes it possible to visualize structures and obtain hemodynamic information, contributing to diagnosis, treatment planning, and patient follow-up (EIBERG et al., 2019; BANDYK, 2019).

Advances in equipment, however, have not made the examination independent of its operator. Acquisition quality remains linked to decisions made in real time, including patient positioning, selection of the acoustic window, transducer orientation, and adjustments to gain, scale, frequency, and insonation angle (SHEEHAN; ZIERLER, 2018).

This characteristic has direct implications for training. Knowledge of anatomy and physical principles is essential, but it is not enough to ensure consistent performance with real patients. Clinical practice involves anatomical variations, restricted mobility, edema, pain, wounds, and difficult acoustic windows (EIBERG et al., 2019).

For this reason, learning duplex scanning should not be reduced to memorizing a sequence. Protocols are essential for organizing the examination and reducing omissions, but competence becomes evident when the

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professional understands why each step is necessary and recognizes when additional investigation is required (BANDYK, 2019; SOCIETY FOR VASCULAR ULTRASOUND, 2026).

Training also involves learning to recognize one's own errors. An image may appear visually satisfactory and still be insufficient to answer the clinical question. Without review and feedback, technical inadequacies may be repeated until they become habits (SHEEHAN; ZIERLER, 2018; SHEEHAN et al., 2019).

This article analyzes practical training in vascular ultrasonography and proposes a five-axis framework: understand, observe, perform, interpret, and review. Its purpose is not to introduce a new diagnostic technique, but to organize educational elements that bring theoretical knowledge, technical performance, and clinical judgment closer together.

2 METHODOLOGY

A narrative literature review was conducted focusing on training, competence, and standardization in vascular ultrasonography and in ultrasound training fields presenting comparable educational challenges. This design was selected to integrate concepts and guidelines rather than quantitatively estimate the effects of a single intervention.

Priority was given to documents issued by professional societies, indexed publications, and texts addressing supervised training, technical competence, examination standardization, interpretation, and performance assessment. The Society for Vascular Ultrasound (SVU) was used as an institutional reference because it maintains specific performance guidelines (SOCIETY FOR VASCULAR ULTRASOUND, 2026; ACC et al., 2021).

The SVU Professional Performance Guidelines describe minimum essential elements of performance and explicitly state that they do not replace individual laboratory protocols. This distinction separates professional standardization from automatic adherence to a fixed procedure and recognizes the need for local adaptation (SOCIETY FOR VASCULAR ULTRASOUND, 2026).

The analysis also considered literature on technical training in vascular surgery and ultrasonography. Studies of skills education reinforce the need to establish competence for independent practice, while ultrasound studies demonstrate the value of supervised exposure, repetition, and assessment (EIBERG et al., 2019; BANDYK, 2019; JAFFER et al., 2015).

After reading and comparing the materials, recurring educational components were grouped into five categories: conceptual foundations, guided demonstration, supervised performance, interpretation, and review. Organizing these categories produced the conceptual model presented in this article.

The model is an educational proposal and should not be confused with a previously validated method. No patient data were collected and no comparative tests between groups were conducted; the inferences are conceptual and require future assessment through prospective studies.

3 OPERATOR DEPENDENCE AND THE CHALLENGE OF TEACHING

The expression operator-dependent is associated with ultrasonography because part of the diagnostic information is generated during image acquisition itself. In duplex scanning, the operator selects imaging planes, performs maneuvers, and adjusts parameters while observing the findings (SHEEHAN; ZIERLER, 2018).

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This dynamic means that acquisition errors may precede any interpretation. An inappropriate spectral Doppler angle, poorly performed compression, or failure to document a relevant segment may limit the usefulness of the examination (SHEEHAN; ZIERLER, 2018; JAFFER et al., 2014).

The challenge is greater because patients do not reproduce the ideal conditions described in a manual. Body habitus, scars, edema, dressings, pain, and positioning restrictions change the approach. Competence includes preserving the examination objectives despite these variations.

In this context, demonstration by an experienced professional becomes more valuable when it is not silent. Explaining why a parameter was changed or why a particular segment deserves attention makes visible reasoning that may appear intuitive to the expert (EIBERG et al., 2019; BANDYK, 2019).

Students need to begin performing examinations early, but with progressively increasing responsibility. If the instructor resolves every difficulty, the examination may improve at that moment, but the student loses the opportunity to develop independent strategies. Supervision should provide protection without eliminating the space needed to attempt and correct procedures (JAFFER et al., 2015; SHEEHAN et al., 2019).

Teaching vascular ultrasonography therefore means teaching both technique and decision-making. Manual skill without understanding tends to be rigid; theoretical knowledge without execution tends to remain abstract. Their intersection is where training begins to produce autonomy.

4 STANDARDIZATION, PROTOCOLS, AND CLINICAL JUDGMENT

Protocols play a central role in vascular laboratories because they establish a minimum pathway for performing examinations. They organize the segments assessed, documentation, measurements, and technical criteria, contributing to consistency and communication (COLERIDGE-SMITH et al., 2006; SOCIETY FOR VASCULAR ULTRASOUND, 2026).

The SVU defines its Professional Performance Guidelines as minimum essential performance elements and presents them as a basis for creating or updating each laboratory’s procedures. The organization also states that the guidelines are reviewed periodically (SOCIETY FOR VASCULAR ULTRASOUND, 2026).

For a professional in training, a clear sequence reduces the initial cognitive load. Rather than deciding everything simultaneously, students have a roadmap guiding acquisition and documentation while their manual coordination and familiarity with the equipment are still developing (BANDYK, 2019).

The risk emerges when protocols and reasoning are treated as synonymous. Completing every step does not, by itself, guarantee that the clinical question has been answered. An unexpected finding may require additional images, comparison, or an expanded study (COLERIDGE-SMITH et al., 2006).

For this reason, teaching protocols should include the rationale for each component. Knowing that a measurement must be obtained differs from understanding what it represents, which factors can distort it, and under which circumstances it needs to be repeated.

Mature standardization controls avoidable variability without obstructing judgment. It establishes a shared technical baseline, while experience and supervision help professionals recognize when they must go beyond the prescribed sequence.

5 FIVE-AXIS CONCEPTUAL TRAINING MODEL

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The proposed model organizes training into five axes: understand, observe, perform, interpret, and review. This division is didactic; in practice, the components overlap and recur in successive cycles as professionals encounter more complex examinations (EIBERG et al., 2019; SHEEHAN; ZIERLER, 2018).

Understand refers to developing a conceptual foundation. Vascular anatomy, hemodynamics, ultrasound physics, Doppler principles, indications, limitations, and diagnostic criteria must precede autonomy.

Observe means following the examination with focused attention. Demonstration is more useful when the instructor verbalizes decisions and acknowledges uncertainties. Students move beyond merely watching movements and begin to perceive the logic behind changes in positioning and parameters.

Perform progressively transfers responsibility to the learner. Students must handle the equipment, confront real difficulties, and attempt corrections. Supervision provides protection and feedback rather than permanently replacing initiative (EIBERG et al., 2019; JAFFER et al., 2015).

Interpret connects the image to physiology and the clinical question. Even when another professional is responsible for reporting, understanding the significance of the information being acquired improves the ability to document findings and recognize deficiencies.

Review completes the cycle. Inadequate images, discrepancies, subsequent correlations, and difficulties encountered should feed back into training. Review transforms the number of examinations performed into reflective experience and enables learning from limitations (SHEEHAN et al., 2019).

Figure 1 — Conceptual Model of Training Progression in Vascular Ultrasound

1	2	3	4	5
Understand	Observe	Perform	Interpret	Review

Source: Prepared by the author (2026). Conceptual representation, without empirical data. The five stages describe training progression and do not represent quantitative competency scores.

6 SUPERVISED PRACTICE, FEEDBACK, AND AUTONOMY

Supervised practice is the point at which knowledge and execution cease to be separate compartments. With real patients, students must coordinate communication, positioning, the transducer, equipment, and interpretation (EIBERG et al., 2019; BANDYK, 2019).

During initial encounters, frequent instructor interventions are expected. As training progresses, however, the nature of supervision should change. Instead of indicating every movement, the instructor can ask what is inadequate and which alternatives the student is considering (SHEEHAN; ZIERLER, 2018).

This change matters because autonomy is not simply the absence of an instructor. It involves the ability to detect problems, formulate technical hypotheses, and correct one’s own performance. Someone who requires instruction whenever an examination deviates from the standard has not yet achieved full independence.

Feedback must be specific. Saying that an image is poor provides less learning than identifying the element compromising its usefulness and demonstrating how to correct it. Feedback delivered close to the time of performance helps connect action, image, and consequence (SHEEHAN et al., 2019).

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The number of examinations performed should also be interpreted cautiously. Volume increases exposure but does not guarantee that errors are identified. A consistent training pathway combines repetition with quality review and progressively greater difficulty (SHEEHAN; ZIERLER, 2018; ACC et al., 2021).

Therefore, decisions about autonomy should consider demonstrated performance, not merely time spent training or the raw number of examinations. Objective criteria and case review may make this transition more transparent, although their validation requires specific research (NØRGAARD et al., 2020; ACC et al., 2021).

7 FROM IMAGE ACQUISITION TO CLINICAL INFORMATION

The purpose of duplex scanning is not to produce visually attractive images but to generate information useful for a clinical question. This distinction changes how the examination should be taught: technical quality must be linked to the ability to address the problem that prompted the investigation (COLERIDGE-SMITH et al., 2006; BANDYK, 2019).

Acquisition may follow the protocol and still be insufficient if a relevant finding is not investigated. Likewise, difficult conditions may prevent ideal images without necessarily invalidating the examination, provided the limitations are recognized.

This supports bringing acquisition and interpretation closer together during training. When students understand the significance of an observed pattern, they can adjust the investigation more purposefully. The image ceases to be an isolated product and becomes part of a sequence of questions and answers (EIBERG et al., 2019).

Experience with different cases broadens this repertoire. Anatomy, disease, and technical limitations vary, and no set of teaching images can anticipate every possible combination. Supervised clinical exposure makes it possible to discuss how general principles operate outside ideal scenarios (SHEEHAN; ZIERLER, 2018).

Subsequent review may include correlation with other examinations, procedures, or clinical evolution when such data are available. This feedback helps identify correct assessments and discrepancies and creates opportunities to improve acquisition criteria.

Professional maturity emerges when performance and reasoning become integrated. Part of the technique becomes sufficiently consistent to free attention for the patient and the findings, without abandoning vigilance regarding the quality of the examination itself.

8 CONTINUING EDUCATION AND MAINTENANCE OF COMPETENCE

Completing a course does not end learning in vascular ultrasonography. Equipment changes, recommendations are updated, and new applications emerge. Competence must be maintained through regular engagement with practice, literature, and assessment mechanisms (SOCIETY FOR VASCULAR ULTRASOUND, 2026; ACC et al., 2021).

Periodic updates to SVU guidelines illustrate this need. In 2026, the organization reported approval of updates to several Professional Performance Guidelines, including changes aimed at clarity, consistency of wording, and examination times (SOCIETY FOR VASCULAR ULTRASOUND, 2026).

Accumulated experience is valuable, but it can also entrench habits. Experienced professionals benefit from reviewing protocols and comparing their routines with current recommendations. Continuing education should not be viewed merely as a formal obligation.

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Services can incorporate learning into everyday routines through case discussions, audits, diagnostic correlations, and examination reviews. These activities help transform the laboratory into a continuous educational environment (ACC et al., 2021).

Instructors must also remain up to date. Teaching requires specialists to explain decisions they may already make intuitively. This exercise can reveal practices that need justification, review, or adaptation in light of new evidence.

Maintaining competence therefore depends on a culture in which review is not interpreted as punishment. The ability to recognize limitations and discuss errors in a structured manner is part of professional safety.

9 DISCUSSION

The proposal presented in this article is based on the understanding that competence in vascular ultrasonography is multidimensional. Knowledge, technical coordination, visual perception, interpretation, communication, and recognition of one's limitations all contribute to performance (SHEEHAN; ZIERLER, 2018; NØRGAARD et al., 2020).

This explains why exclusively lecture-based strategies have limited reach. A class can teach the physical principle underlying a phenomenon but cannot fully reproduce the difficulty of obtaining information from a patient experiencing pain, edema, or restricted mobility (JAFFER et al., 2015).

The opposite also deserves attention. Repeating examinations without understanding the foundations may produce operational familiarity but limit adaptability. When a situation no longer matches a memorized pattern, the professional must rely on understanding (EIBERG et al., 2019; BANDYK, 2019).

The understand–observe–perform–interpret–review model seeks to integrate these dimensions. Its value lies in making explicit stages that often appear informally in the instructor–student relationship and in allowing identification of the stages at which a particular learner encounters greater difficulty.

The figure presented in Section 5 should be interpreted as a conceptual representation of this progression, not as a quantitative result. The five levels do not express competency scores or differences in effect; the figure visually organizes the transition among components.

The main limitation is the lack of prospective validation of the model. Future studies may translate the five axes into observable indicators, test inter-rater reliability, and investigate retention, autonomy, and technical quality (NØRGAARD et al., 2020; JAFFER et al., 2014).

CONCLUSION

Vascular ultrasonography demonstrates that technological development and human competence are not competing forces. More sophisticated equipment expands possibilities, but the quality of information remains linked to how professionals conduct acquisition and recognize the limitations of the study (EIBERG et al., 2019; SHEEHAN; ZIERLER, 2018).

For this reason, training should not end with the transmission of theoretical foundations. Anatomy, hemodynamics, and ultrasound physics must be translated into concrete decisions at the patient's bedside, and this translation requires practice accompanied by supervision and feedback (BANDYK, 2019; EIBERG et al., 2019).

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Protocols remain indispensable. They organize examinations, reduce omissions, and establish shared references. However, their best use occurs when professionals understand the reason for each step and can recognize situations in which the investigation needs to be adapted (SOCIETY FOR VASCULAR ULTRASOUND, 2026; COLERIDGE-SMITH et al., 2006).

Supervised practice serves as a bridge between knowledge and autonomy. By allowing attempts, correction, and repetition in a protected environment, it helps prevent technical errors from becoming entrenched and supports the development of independent criteria for assessing quality (JAFFER et al., 2015; SHEEHAN et al., 2019).

The five-axis model—understand, observe, perform, interpret, and review—seeks to organize this progression without attempting to replace existing curricula, certifications, or guidelines. Its contribution is to integrate elements that are often taught separately.

Review deserves particular emphasis because it distinguishes mere exposure from reflective experience. Performing many examinations may increase familiarity, but learning becomes more consistent when professionals can compare results, identify failures, and return to practice with specific objectives (SHEEHAN et al., 2019).

This work has important limitations. The proposal is conceptual, has not undergone an educational trial, and does not support claims of superiority over other models. Validation will require objective instruments, learner follow-up, and outcome assessment.

Ultimately, training a competent duplex scanning professional means teaching someone to understand what they are looking for, produce technically appropriate information, recognize when that information is insufficient, and know how to improve it. It is at this intersection of knowledge, supervised practice, and critical review that technology can fulfill its role in vascular care.

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