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Teaching neurological disorders with ultrasound: A novel workshop for medical students

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Abstract:

INTRODUCTION: The goal of this study was to assess if a neurological disorder ultrasound workshop for the first-year medical students significantly enhanced the students' ability to retain and apply concepts related to neuroanatomy and neurophysiology.

MATERIALS AND METHODS: We performed a prospective study to evaluate student performance before and after an optional ultrasound workshop. Data were collected through a within-population pretest–posttest design. Purposive sampling was used to recruit first-year medical students for this study. The six stations were transcranial doppler ultrasound, ocular ultrasound, ultrasound-guided external ventricular drain placement, high-intensity focused ultrasound for brain lesions, carotid artery scan with ultrasound, and ultrasound-guided central line placement. We used a pre–post workshop survey to identify opinions and perceptions about ultrasound and a pre–post workshop test to assess knowledge about neuroanatomy, neurophysiology, and related ultrasound topics.

RESULTS: Twenty-two 22 first-year medical students consented to participate in this study. The Wilcoxon signed-rank test showed a statistically significant difference in pre- and posttest scores, suggesting that participants demonstrated higher levels of medical knowledge related to neurological physiology, anatomy, and ultrasound after participating in the workshop. The analysis of the pre–post survey showed participants attributed greater value to ultrasound as a useful tool for their future medical practice after participation in the event ($Z = -2.45$, $P = 0.014$).

CONCLUSIONS: There is value in integrating experiences with ultrasound into the neurological disorder block of medical school. Future studies, with a larger sample size, are needed to further explore the efficacy of this workshop in enhancing knowledge retention.

Keywords:

Neurology, neurosurgery, point-of-care ultrasound, undergraduate medical education

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Introduction

Ultrasound allows physicians to make quick and accurate diagnoses of a wide variety of medical problems and enhances physician performance of invasive procedures, ranging from central line placement to intraoperative ultrasound.^[1-3] As a portable imaging modality, it is a versatile tool for both inpatient and outpatient

settings. Advances in image quality and the low cost have made ultrasound a significant component of most medical practices. In addition, there is an increased emphasis on using point-of-care ultrasound for the diagnosis and management of patients.^[1,4] With the increasing growth of ultrasound in clinical practice, it is essential to integrate this modality into undergraduate medical education.^[2,3] This has the dual benefit of reinforcing anatomical knowledge and teaching skills in ultrasound image acquisition and interpretation.

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There is evidence that the use of ultrasound in teaching parts of the medical school curriculum greatly improves knowledge retention and performance.^[5] Numerous studies have shown that the use of ultrasound in undergraduate medical education is valuable in that it allows students to visualize functioning internal organs, which can provide a better understanding of anatomy and physiology.^[6-9] Ultrasound is a significant part of the undergraduate medical education curriculum at our medical school where there has been an integrated four-year ultrasound curriculum since 2005.^[5] In addition, ultrasound is a way to increase informal learning in undergraduate medical education, which builds skills for the functional learning environment in which practicing physicians work.^[10,11] The ultrasound curriculum complements many of the traditional organ system-based blocks, including hepatobiliary, cardiac, and head-and-neck blocks.^[4,12-14] There was not, however, a distinct neurologic based ultrasound component of the preclinical curriculum.

Ultrasound is widely used in assessing neurological disorders, and further advances are expanding its use in the neurological field.^[15] Transcranial Doppler (TCD), an important component for poststroke treatment, is an important use of ultrasound that is not taught at the medical school level. Some of the other uses include, but are not limited to, intraoperative visualization of intracranial tumors during surgical removal, thermal ablation in patients with Parkinson's disease, delivery of chemotherapy, and placement of external ventricular drains (EVDs).^[15-17] We developed a novel neurologic ultrasound workshop and aimed to evaluate the effectiveness of the workshop as an educational intervention for first-year medical students. This workshop included collaboration between the university's Ultrasound Interest Group and Neurosurgery Interest Group. To the best of our knowledge, this is the first described neurological disorder ultrasound workshop for medical students. We hypothesized that medical students who participated would demonstrate improved retention and application of concepts related to neurological anatomy and physiology.

Materials and Methods

We performed a prospective study evaluating student performance through a within-population pre-posttest design. We created a neurologic ultrasound workshop as an optional pilot program and offered the workshop to first-year medical students during the neurological disorder block of their curriculum. We recruited students for the study using purposive sampling. Currently enrolled first-year medical students signed up to attend the ultrasound workshop, with a capacity

of 40 participants, on a first-come, first-serve basis. We contacted students who signed up via e-mail to give them the option to participate in the study. The workshop incorporated asynchronous online learning, didactic instruction, and hands-on ultrasound practice to reinforce curriculum learning objectives. We used a pre- and postsurvey to assess participants' views and experience with ultrasound techniques and a pre- and posttest to assess gains in knowledge from the workshop. We excluded students who did not consent to the study participation. Our hospital's Institutional Review Board ruled this study exempt.

Detailed study procedures

Students who signed up to attend the ultrasound workshop received an e-mail invitation to participate in the study. The recruitment e-mail included a link to the informed consent form, followed by a preworkshop survey and test. Participants could opt out of answering any of the questions and could exit the survey at any time. Through e-mail, participants received PowerPoint slides about the basics of ultrasound, including some sonographic images of relevant neuroanatomy. The workshop duration was 120 min, divided as follows: a 20-min introductory lecture; a 90-min hands-on practice session with the ultrasound machines, proctored by medical students with special interest in neurosurgery, and expert users consisting of TCD sonographers, neurologists, and emergency medicine physicians; and a 10-min conclusion with a summative review. Immediately after the workshop, we e-mailed participants a link to complete the postworkshop survey. Four days after the workshop, we e-mailed the study participants a link to complete a posttest on material taught in the workshop that was also relevant to the neurological disorder block. The interval before sending the posttest was chosen to prevent a potential recency effect that would falsely elevate scores and to provide time to reinforce concepts with lecture material. Prior to de-identification of the data, each participant's test score was linked to data collected from the pretest and survey.

Measurements

Data were collected using a preworkshop survey, a knowledge pretest, a postworkshop survey, and a knowledge posttest [Appendix 1]. The outcomes included pre- and postworkshop test scores, preworkshop survey ratings on prior ultrasound experience and degree of comfort with neurological disorder material, and the relationship between participation in the workshop and performance on assessments on neurophysiology and neuroanatomy in the neurological disorder block.

The preworkshop survey and 12-item preworkshop test were completed before the ultrasound workshop. The preworkshop test included questions about neurological

principles and anatomy in the context of ultrasound, including identifying the function of a specific structure in a given ultrasound image. The workshop was focused on practicing ultrasound techniques, with emphasis on the relationship between anatomy and neurophysiology principles. The postworkshop survey was completed after the ultrasound workshop. On the survey, participants were asked to respond to questions about their perception of their knowledge of neuroanatomy and neurophysiology, their subjective evaluation of how the workshop changed their ultrasound knowledge and skill, and their subjective evaluation of the efficacy of this workshop in improving their understanding and application of neuroanatomy and neurophysiology. The pre-and postworkshop surveys consisted of a combination of dichotomous (yes/no) and Likert Scale items. The 12-item multiple-choice posttest was deployed 4 days after completion of the ultrasound workshop. The authors chose a 4-day delay to increase the likelihood of posttest completion since this date fell on a weekend when students had no scheduled curricular obligations while mitigating potential recency effect that could falsely inflate scores. These questions were distinct from the pretest but included items of a similar level of difficulty. The posttest similarly included questions about neurological principles and anatomy in the context of ultrasound.

Workshop stations

There were six stations at the neurologic ultrasound event [Table 1]. Students rotated through each station with 15 min per station. Scans were performed on trained simulated ultrasound patients for visualization of living anatomy whenever feasible.^[18,19] At the TCD station, students were guided through tracing the paths of the anterior and posterior cerebral circulation and identifying the Circle of Willis, *in vivo*. They were also taught about the clinical setting in which TCD is utilized. At the ocular ultrasound station, students were guided through identifying anatomical structures of

the eye. Specifically, the objectives were identifying the optic nerve, learning how to measure the optic nerve sheath diameter, and understanding clinical relevance of these techniques. In the vascular anatomy station, students were guided through tracing the path of the common carotid artery and internal jugular vein and identifying the vertebral artery from different views. This was supplemented by practice with simulated ultrasound-guided central vascular access placement, during which students learned how to place a central venous catheter into the internal jugular vein on a mannequin under ultrasound guidance. At the ultrasound-guided EVD placement station, students were taught about the anatomy of the ventricles relative to different points on the calvaria. They were taught about the clinical indications for EVD placement and the procedure of placing the EVD. At the high-intensity focused ultrasound station, students were taught about the therapeutic aspects of ultrasound in the neurological field. All six of these stations were related to topics that students were learning in the neurological disorder block of the curriculum, including anatomy, clinical presentations of diseases, and the utility of ultrasound in diagnosing and treating these diseases.

Data analysis

Data analyses were carried out with SPSS (version 25; SPSS Inc., Chicago, IL, USA). Descriptive statistics were calculated to analyze trends in pre- and postsurvey responses. Subsequent analysis of survey data was performed with a Wilcoxon signed-rank test using paired data to evaluate student perception of whether ultrasound will be a useful tool for their future practice. A Wilcoxon signed-rank test was also used to determine whether there was a significant difference in student knowledge of ultrasound and related concepts after participating in the ultrasound workshop. Missing data were excluded listwise. For both pre- and posttests, participants were excluded if answers were selected for <90% of the question items; in other cases, missing data were treated as an incorrect response.

Results

Study population and presurvey

Forty medical students signed up for the ultrasound workshop. On the day of the workshop, 26 students attended. Twenty-two of these students did the presurvey and consented for participation in the study. While 90.9% of the participating students reported prior ultrasound experience in medical school, only 50% of the participants felt comfortable or very comfortable using basic ultrasound. Among the students, 40.9% felt comfortable with their current knowledge of neuroanatomy and neurophysiology.

Table 1: Learning objectives of workshop stations

Station	Learning objectives
Transcranial Doppler	Anatomy of bone windows Relationships of cerebral vasculature
Ocular ultrasound	Obtain optic nerve sheath diameter Learn clinical application of the ocular scan
Neck scan	Learn neck anatomy Learn clinical application of this scan
Central line	Apply neck anatomy and knowledge Learn procedural aspects of ultrasound
External ventricular drain placement	Learn ventricular CSF flow Learn procedural aspects of ultrasound
High-intensity focused ultrasound	Learn how therapeutic ultrasound is utilized for treatment

CSF: Cerebrospinal fluid

Pre- and posttest knowledge

The mean pretest score ($n = 20$) was 6.75 of 12 (standard deviation = 1.68). The mean posttest score ($n = 15$) was 9.67 of 12 (standard deviation = 0.82) [Table 2]. The Wilcoxon signed-rank test was conducted for matched pairs ($n = 13$) to test whether there was a difference in medical knowledge related to neurophysiology, anatomy, and ultrasound among first-year medical students. The results showed a statistically significant difference in medical knowledge after students participated in the ultrasound workshop ($Z = -3.100$, $P = 0.002$).

Postsurvey

Eighteen students completed the postsurvey. Overall, students reported having a better understanding of ultrasound and the utility of ultrasound after the workshop. Specifically, 100% of the students reported a better understanding of neuroanatomy, neurophysiology, and ultrasound as an imaging modality. Consistent with the presurvey results, all students displayed favorable attitudes toward ultrasound as a tool to learn anatomy.

The Wilcoxon signed-rank test was conducted to test whether there was a difference in first-year medical students' responses to the item, "Ultrasound will be a useful tool in my medical practice in the future" on the pre- and postsurvey ($n = 18$). The results showed a statistically significant difference in the way participants viewed the utility of ultrasound to their future practice after participating in the ultrasound workshop ($Z = -2.45$, $P = 0.014$).

Discussion

This study assessed a population of first-year medical students who participated in a novel neurological disorder ultrasound workshop. The results demonstrate a gain in medical knowledge pertaining to neuroanatomy, neurophysiology, and applications in ultrasound due to this educational intervention, as shown by significantly higher posttest scores compared to preworkshop test scores. In addition, the results of the postsurvey suggest that students more strongly believe that ultrasound will play a significant role in their future medical practice after participating in this workshop.

Regarding the improvement in medical knowledge, there was a nearly 25% increase in test scores in the posttest compared to the pretest. The workshop may have led to this increase both by allowing students to visualize

the anatomy in an *in vivo* setting and by reinforcing the concepts with the discussion of the clinical relevance associated with each of the different stations. Students also subjectively felt that the workshop added to their medical knowledge. All 18 students who completed the postworkshop survey believed that the workshop improved their understanding of neuroanatomy and neurophysiology concepts [Figure 1]. This study suggests that participation in a neurological disorder ultrasound workshop can increase medical knowledge and deepen understanding of the material taught in the medical school curriculum.

Another important finding is the participants' belief about how useful ultrasound will be in their future medical career [Figure 1]. At our medical school, medical students are taught about the importance of point-of-care ultrasound early in the preclinical curriculum, which may be reflected in the preworkshop survey average score of 4.50, meaning most students strongly agree that ultrasound will be useful in their future medical practice. The same item on the postworkshop survey scored even higher, with an average score of 4.72, which may reflect that the students learned more about ultrasound from this workshop and therefore attributed higher importance to it as a useful imaging modality. Responses to additional items on the postworkshop survey suggested that students perceived improved knowledge of ultrasound due to this workshop. Collectively, the improved posttest scores and highly rated perceived value of this intervention suggest that integration of ultrasound into a neurological disorder block may be an efficacious way to teach and reinforce neuroscience and ultrasound concepts.

Near-peer teaching, defined as students teaching their own peers, is used in some aspect of the curriculum by nearly 50% of medical schools in the United States.^[20] Studies have shown positive learning outcomes for near-peer instructors, while showing no negative effect on student learning using this methodology. Through near-peer teaching, participants may have benefited more from the experience due to better cognitive congruence with their teachers, which helps further facilitate learning. Another aspect of education that may have had a positive effect on this workshop is the incorporation of informal learning, which provides opportunities for students to self-regulate and guide their learning.^[10,11] Informal learning is an important part of every physician's career; therefore, it is vital to create environments in which medical students may practice this kind of learning. Informal learning in ultrasound at the medical student level has been shown to increase the use of ultrasound in clinical practice and to guide exposure to further ultrasound training.^[18] This ultrasound workshop cultivates an informal learning

Table 2: Pre- and posttest descriptive statistics

	<i>n</i>	Mean	SD	Minimum	Maximum
Pretest	20	6.75	1.680	3	10
Posttest	15	9.67	0.820	8	11

SD: Standard deviation

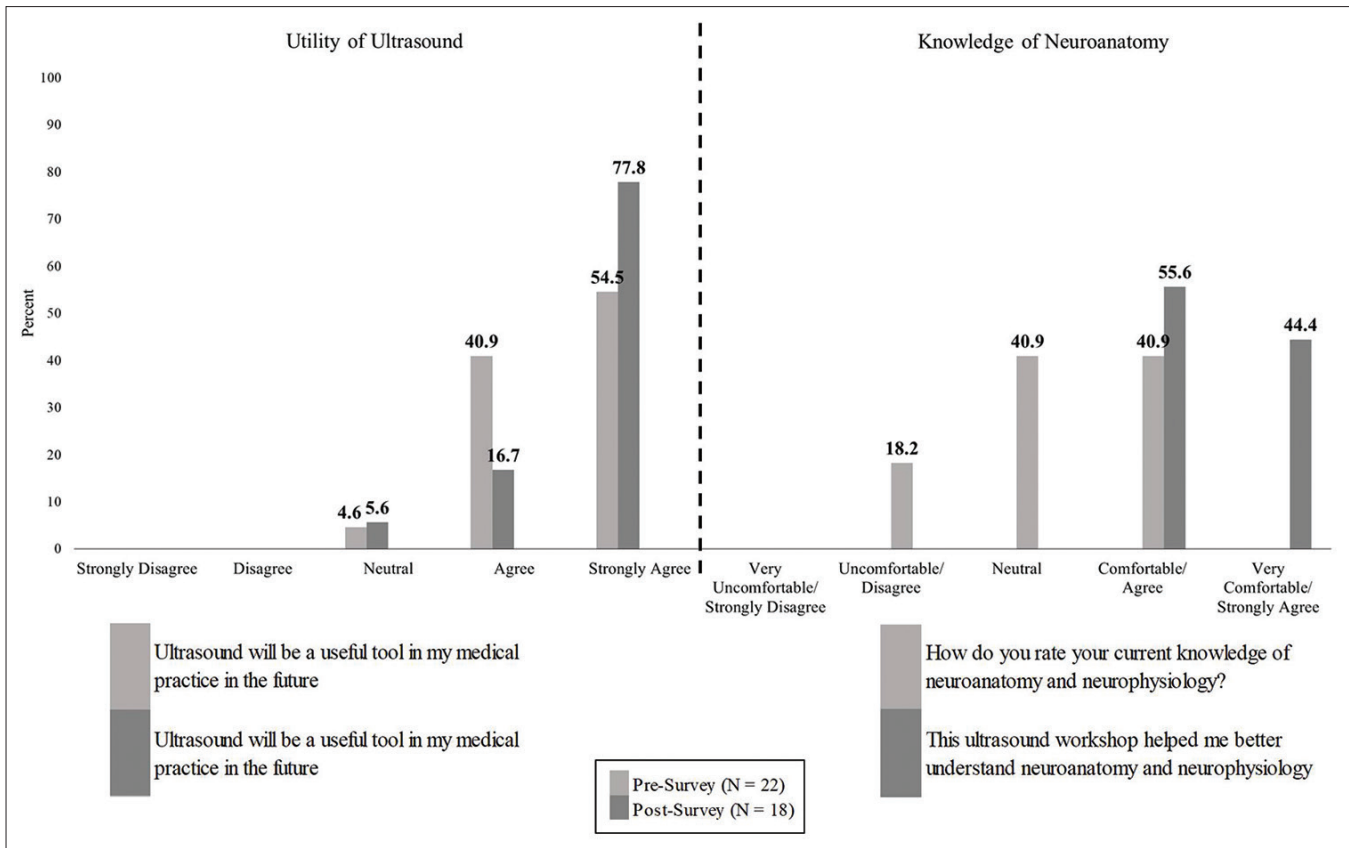


Figure 1: Efficacy of the Educational Intervention: This figure shows students' views on the utility of ultrasound and knowledge of neuroanatomy and neurophysiology before and after the workshop. The preworkshop neuroanatomy knowledge question was graded according to the first option before the backslash on the X-axis (e.g., very uncomfortable through very comfortable). The postworkshop survey neuroanatomy knowledge question was graded on a scale of strongly disagree through strongly agree

opportunity for first-year medical students. In addition, it could inspire students to pursue imaging-related specialty training. Although the goal of this study was to assess whether the addition of an ultrasound workshop to the neurological disorder curriculum could further increase medical knowledge, incorporation of these educational techniques may have also contributed to the positive findings.

This study was limited by a small sample size. All study participants completed the presurvey, but there were students who did not complete the pre and posttest. Of the 22 students who completed the presurvey, 18 completed the pretest. From these 18 students, 13 completed the posttest. A response bias is possible since students more interested in neurologic disorders or ultrasound would be more likely to participate. In addition, incomplete data were counted as incorrect answers on the posttest. It is unlikely that this affected the results significantly since this occurred with only a single question from one participant's data. This could have been due to the length of the pre- and postworkshop work. Given that 90.9% of these first-year students had already had some ultrasound experience, these results may not be applicable to populations with less baseline ultrasound experience. These factors limit the external validity of these results. Of

all the participants who completed the posttest, however, only one did not complete the postsurvey, making a response bias less likely. The smaller sample size of the postworkshop survey population compared to the preworkshop survey population may be another source of response bias since the students who perceived a greater impact from the workshop may have been more inclined to answer the postworkshop survey. Another limitation of this study is that we cannot correlate participation in the workshop or changes between pre- and posttest scores with academic performance. Ideally, we would have liked to show that this educational intervention improved scores on the neurologic disorder curricular examination, but due to the lack of a control group, this comparison was not possible. In the future, we plan to more comprehensively investigate the impact of this educational intervention by conducting a quasi-experimental approach, in which we compare performance data from the neurologic disorder curriculum between students who did participate in this workshop and students who did not. Faculty have expressed interest in broadening participation in the ultrasound workshop, which will help to achieve this goal. Finally, we will further evaluate the use of near-peer learning and informal learning environments as teaching methods for medical students.

Conclusions

In this small pilot study of a neurological disorder ultrasound workshop, the results suggest that students made a significant gain in medical knowledge related to neuroanatomy and neurophysiology. Participants perceived ultrasound as a useful part of their future medical practice after participating in the event. Although the study population was small, the results suggest that there is a value in integrating experiences with ultrasound into the neurological disorder curriculum of medical school. This workshop could be implemented at outside institutions to supplement the existing neurologic education. Future studies, with a larger sample size, are needed to further explore the efficacy of this workshop.

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Conflicts of interest

There are no conflicts of interest.

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Appendix 1

Pre-session test

1. What kind of probe is used to measure Optic Nerve Sheath Diameter?
 - A. Linear(*)
 - B. Curvilinear
 - C. Phased array
 - D. Convex
2. What is the optic nerve sheath contiguous with?
 - A. The subarachnoid space(*)
 - B. The subdural space
 - C. The epidural space
 - D. The subpial space
3. What is Optic Nerve Sheath Diameter measured to examine?
 - A. Intracranial pressure(*)
 - B. Intraocular pressure
 - C. Increased retinal blood flow
 - D. Ischemia
4. Which of the following is NOT currently a clinical indication for thermal ablation utilization of high-intensity focused ultrasound?
 - A. Essential tremor
 - B. Brain tumors-(*)
 - C. Parkinson's disease
 - D. Epilepsy
 - E. Obsessive compulsive disorder
5. What ultrasound mode is being used in this image?
 - A. Pulse Doppler
 - B. Continuous Wave
 - C. Color Doppler
 - D. B Mode (*)
6. The structure directly distal to these images is what?
 - A. External Carotid Artery
 - B. Internal Carotid Artery
 - C. Carotid Sinus
 - D. Common Carotid Artery (*)
7. What are 2 indications for an external ventricular drain?
 - A. For treating acute hydrocephalus (*)
 - B. For stroke prophylaxis
 - C. For tumor therapy
 - D. For monitoring and treating intracranial pressures (*)
 - E. For stimulation of deep brain structures
8. The asterisk in this image is called
 - A. The lateral ventricles (*)
 - B. The third ventricle
 - C. The fourth ventricle
 - D. The cerebral aqueduct

9. In the same image in question 8, the near field represents what?
 - A. The back of the skull
 - B. The cerebral cortex
 - C. Calcification of the dura
 - D. The front of the skull (*)
10. What frequency of probes do you use for TCD?
 - A. Low frequency probes: 2MHz, higher frequencies can't penetrate the skull (*)
 - B. High-frequency probes: 10MHz, lower frequencies cannot penetrate the skull
 - C. A curvilinear probe
 - D. A phased array probe
11. Which of the following is not an ideal acoustic window for TCD?
 - A. Temporal
 - B. Orbital
 - C. Suboccipital
 - D. Submandibular
 - E. Occipital (*)
12. The ultrasound mode used in this TCD is what?
 - A. Pulse Doppler
 - B. Continuous wave
 - C. Color Doppler (*)
 - D. B-mode

Postsession test

1. What is the normal Optic Nerve Sheath Diameter in adults?
 - A. >5.0 mm(*)
 - B. <5.0 mm
 - C. <3.0 mm
 - D. <1.0 mm
2. Where is Optic Nerve Sheath Diameter measured?
 - A. 3.0 mm behind the retina of the eye (*)
 - B. 5.0 mm behind the retina of the eye
 - C. 7.0 mm behind the retina of the eye
 - D. 9.0 mm behind the retina of the eye
3. Out of the 2 images, which shows a dilated optic nerve sheath?
 - A. Image A
 - B. Image B (*)
4. What is the most important feature to take into account when determining focused ultrasound treatment eligibility?
 - A. Age
 - B. Stage of disease/disorder
 - C. Skull characteristics (*)
 - D. Ethnicity
 - E. Financial burden
5. At high intensity, what is the KEY mechanism that allows for FUS to create tissue ablation?
 - A. Intensity
 - B. Probe position
 - C. Frequency (*)
 - D. Temperature

6. What would be an indication for a carotid artery Doppler?
 - A. Plaque (*)
 - B. Tumor
 - C. Inflammation
 - D. JVD

7. Identify the structure identified by the*
 - A. Common Carotid (*)
 - B. External Carotid
 - C. Carotid Bulb
 - D. Internal Carotid

8. What is a way ultrasound guided EVD placement can improve outcomes?
 - A. It is useful in patients with abnormal ventricular anatomy
 - B. Often the catheter tip ends up in the wrong spot so this will decrease complication rates
 - C. Placing the catheter correctly on the first pass will decrease complication rates
 - D. All of the above (*)

9. What are some uses of TCD?
 - A. Flow velocity in arteries
 - B. Detection of vascular stenosis
 - C. Detection of cerebral vasospasm post-SAH
 - D. Monitoring ICP
 - E. All of the above (*)

10. This ultrasound image shows what vascular structures?
 - A. The vertebral arteries
 - B. The Circle of Willis (*)
 - C. The pontine artery
 - D. The occipital artery

11. If presented with this MRI what neurological ultrasound procedure should be considered?
 - A. TCD
 - B. Carotid Doppler
 - C. HIFU
 - D. Optic Ultrasound
 - E. Ultrasound-guided EVD placement(*)

12. The following image presents what TCD acoustic windows?
 - A. Suboccipital and Temporal (*)
 - B. Temporal and occipital
 - C. Orbital and suboccipital
 - D. Temporal and mandibular