Transcranial Doppler for Vasospasm Monitoring: A Quality Improvement Project to Understand Provider Utilization in an Urban Neurointensive Care Unit

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Abstract

Subarachnoid hemorrhage (SAH) is a type of hemorrhagic stroke that occurs in the space between the arachnoid mater and pia mater (Yeager & Green-Chandos, 2013). Common causes include aneurysms, trauma, vasculitides, and arteriovenous malformations (Yeager & Green-Chandos, 2013). SAH is a condition associated with high morbidity and mortality and lends itself to a multitude of pathophysiologic complications such as delayed cerebral ischemia (Ferreira Da Silva, Gomes, Wachsman, Rodriguez de Freitas, & Provencio, 2017). In order to reduce the morbidity or mortality associated with this particular complication, early identification and treatment is vital (Francoeur & Mayer, 2016). Transcranial doppler ultrasound, one of many imaging modalities, has been developed to monitor for the development of vasospasm, a significant contributor to delayed cerebral ischemia (Ryu, Ko, Hu, & Shadden, 2017). This relatively non-specific approach is lauded because of its relative low cost and non-invasive nature (Saqqur, Zygun, Demchuk, & Manosalva, 2014).

The specific aim of this quality improvement project was to elucidate provider preferences and practices through a survey, compare/contrast to the available data, and propose interventions for quality improvement if the current practice did not align with the evidence basis. Six of 11 recipients responded to the survey. Based on responses, it was determined that providers at Legacy Health generally practice in line with the evidence-based recommendations. However, some practice gaps exist that would benefit from an education update or policy development.

Keywords: Transcranial doppler ultrasound, subarachnoid hemorrhage, delayed cerebral ischemia

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Introduction

Problem Description

Delayed cerebral ischemia (DCI) is a common complication associated with subarachnoid hemorrhage (SAH) and is strongly correlated with significant morbidity and mortality (Ferreira Da Silva et al., 2017). In order to prevent the deleterious effects of this pathology, a strategy of early detection and intervention is vital (Francoeur & Mayer, 2016). There are a variety of imaging options that are employed to achieve these objectives. These include computed tomographic (CT) angiography (CTA), CT perfusion (CTP), transcranial doppler ultrasound (TCD), and digital subtraction angiography (DSA). According to the consensus opinion, each imaging method has strengths and weaknesses. For example, CTA and CTP are minimally invasive but require radiation exposure and contrast dosing. TCD is lower in cost and invasiveness but lacks specificity and DSA—although the most invasive--is considered the gold standard for both detection and treatment (Mahajan & Gupta, 2016). At the setting in question, there did not appear to be a consistent utilization of these imaging modalities for vasospasm monitoring.

Available Knowledge

SAH is a type of hemorrhagic stroke that occurs between the arachnoid mater and pia mater (Yeager & Green-Chandos, 2013). Trauma is the most common causative insult but it can also occur spontaneously secondary to intracranial aneurysms, arteriovenous malformations, vasculitides, arterial dissections, and venous thromboses (Yeager & Green-Chandos, 2013). Among these nontraumatic causes, aneurysmal SAH is the most common and accounts for 2-5%

of all strokes (Yeager & Green-Chandos, 2013). This devastating neurologic injury affects approximately 30,000 individuals yearly in the United States and is responsible for 27% of all stroke-related potential years of life lost before the age of 65 (Lantigua et al., 2015). Those at highest risk for aneurysmal SAH are African American women between the ages of 40-60 (Yeager & Green-Chandos, 2013).

Despite clinical advances in detection and management, SAH remains a condition associated with high morbidity and mortality—among the reviewed studies, death estimates ranged from 10% to 43% (Ferreira Da Silva et al, 2017; Lantigua et al, 2015). Risk factors for mortality in SAH included poor clinical grade on presentation, advanced age, rebleeding of the aneurysm, vasospasm-induced cerebral infarction, and high aneurysm size burden. High aneurysm size burden was defined as diameter greater than or equal to 7 mm, with the risk of rupture increasing proportionally with size (Lantigua et al, 2015; Singer, Ogilvy, & Rordorf, 2013). A "poor" clinical grade was assigned if the patient was stuporous with moderate or severe hemiparesis (grade IV) or if there was coma and decerebrate posturing (grade V) (Singer, Ogilvy, & Rordorf, 2018). Of the patients who survived the initial bleeding event, 20-30% were left with an array of motor and cognitive dysfunctions as a result of the most common complication of SAH—delayed cerebral ischemia (Francoeur & Mayer, 2016).

Delayed cerebral ischemia (DCI) is defined as a type of neurologic deterioration involving a new infarction on imaging or a new, irreversible neurologic deficit unrelated to the initial injury that develops within six weeks after the occurrence of an aneurysmal SAH. To qualify as DCI, the infarct must not have been present on initial SAH imaging and other possible causes such as sequelae of surgical or endovascular management must have been ruled out. Prior to the completion of a neurologic exam to diagnose the condition, the patient's hemodynamic,

metabolic, and respiratory status must be optimized (Sanelli et al., 2014). If these conditions are met, the new neurologic deficit is present for longer than one hour, and the change results in a reduction of the Glasgow Coma Score (GCS) by at least two points, it is considered DCI. The complication most typically occurs four to nine days following an initial SAH, but it has been known to occur as late as two weeks post-bleed (Durrant & Hinson, 2015).

For many years, DCI was thought to be the direct effect of cerebral vasospasm, however, novel research has hypothesized the origin to be multifactorial (Durrant & Hinson, 2015). Other contributing factors recently elucidated include microcirculatory dysfunction and subsequent loss of autoregulatory function; intimal inflammation leading to endothelial dysfunction and cell death; immune-mediated responses instigated by the initial bleed that cause inflammatory cascades; microthrombosis formation; cortical spreading depression; and oxidative stress (Durrant & Hinson, 2015; Francoeur & Mayer, 2016). These unique physiologic responses, combined with vasospasm, create a high-risk profile for the brain. The resultant ischemia and infarction strongly correlate with severe morbidity and/or mortality in patients that are already remarkably fragile (Francoeur & Mayer, 2016). It necessitates early detection via frequent clinical exams and/or imaging tools and subsequent expeditious intervention, where and when possible (Ryu et al., 2017).

Serial clinical examination is the most reliable way to identify and diagnose early changes in neurologic status that might indicate DCI. Unfortunately, this is limited because of the inability of many patients afflicted with SAH to reliably follow commands--either because of a poor grade SAH or because of necessary pharmacologic sedation (Francoeur & Mayer, 2016). As a result, many imaging modalities have become available for the purpose of screening and/or diagnosing the condition. These include transcranial doppler (TCD), computed tomography

perfusion (CTP), computed tomography angiography (CTA), and digital subtraction angiography (DSA) with the last being the gold standard for both diagnosis and treatment (Ryu et al., 2017). DSA is beneficial because it allows for prompt endovascular treatment after diagnosis, but the tool is costly and invasive (Ryu et al., 2017). Both CTA and CTP are easily accessible and can be added to the portfolio of images obtained during a non-contrast head CT (NCCT) series but they both carry the risks associated with radiation and contrast exposure. This leaves TCD ultrasonography as the least expensive, least invasive validated tool for monitoring of DCI development (Ryu et al., 2017).

TCD ultrasonography is available at the bedside and functions by creating a surrogate measure of vasospasm via quantification of the mean blood flow velocity (FVm). If this value is below 120cm/s, the negative predictive value is high and if it is above 180 cm/s, the positive predictive value is likewise high (Francoeur & Mayer, 2016). TCD is reliably sensitive for detecting intracranial vasospasm. Interpretation of this data in the clinical setting typically involves the use of a "velocity ratio" between certain intracerebral and extracerebral arteries in an attempt to allay the effects of systemic hemodynamic variability (Ryu et al., 2017). Limitations of this tool include a high level of examiner dependency, low specificity, anatomical limitations in patients who lack adequate bone windows, and poor correlation with the presence of DCI (Francoeur & Mayer, 2016). Despite these limiting factors, TCD is still considered a helpful tool for monitoring along with the clinical exam because of its sensitivity and non-invasive nature. The results should be considered with respect to the patient's clinical exam and injury timeline (Durrant & Hinson, 2015).

Rationale

The query was guided by the Plan, Do, Study, Act (PDSA) framework because the intention was to improve the process surrounding TCD utilization in the intensive care unit (ICU) setting (Minnesota Department of Health, n.d.).

Specific Aims

Patients afflicted with SAH are remarkably susceptible to severe morbidity or mortality even with optimal management (Mahajan & Gupta, 2016). Current data supports the utilization of TCD as an adjunct to the clinical exam, but it was evident that there was not a clear and consistent implementation among providers at the setting in question. The primary aim of this quality improvement project (QIP) was to investigate provider preferences and standard practices as they related to the utilization of TCDs. The secondary aim was to identify gaps in practice when provider preferences were compared to available evidence and, through synthesis of the literature and the information obtained, determine plausible areas for improvement.

Methods

Context

The project began in September 2019 as a result of discussions with the program coordinator for Legacy Health's Comprehensive Stroke Center. Initially, the inquiry was set to be about the system's recent implementation of the "Code Stroke" process. However, data about the process utilization had already been collected and analyzed. The stroke coordinator subsequently identified the gap in care that existed for the utilization of transcranial doppler ultrasound in patients afflicted with subarachnoid hemorrhage among providers in the intensive care unit. It was determined that a survey about its utilization and a literature search would be beneficial for the stroke program. A project proposal was written and submitted to the Doctor of Nursing Practice (DNP) chair, edited for clarity, and then submitted to Legacy's IRB with

approval being granted in early February 2020. The survey was then submitted for review and approval by OHSU's IRB and granted exemption status in mid-March 2020. Answers were collected from late March to mid-April 2020 and submitted for DNP review on May 1, 2020. See Appendix A for a flow chart representation of this timeline. The following data is a verbal report of the information collected in SurveyMonkey's embedded "analysis and review" function.

The setting for this QIP was the Neurotrauma Intensive Care Unit (NTICU) at Legacy Emanuel Medical Center (LEMC) in Portland, OR. There are 24 beds and four dedicated neurointensive care providers. Additional critical care attendings provide coverage when the neurointensive care specialists are off-service. Between 40-50 patients with SAH, on average, are cared for annually in the NTICU. The intended participants were the licensed independent providers (LIPs) who comprise the neurointensive care attending team and those neurology consulting providers who co-manage patients in the NTICU, all of whom order TCDs in their care of patients with SAH.

Interventions

A survey about the practices and preferences related to TCD utilization in the NTICU was created using SurveyMonkey, Legacy Health's preferred platform. SurveyMonkey is a web-based survey program capable of securely collecting and transmitting protected data (SurveyMonkey, 2020). Security within SurveyMonkey is maintained through multiple avenues including utilization of Security Assertion Markup Language (SAML) 2.0 single sign-on; storage of data in accredited data centers; and transmission of information over secure connections (SurveyMonkey, 2020). The survey was distributed to providers via e-mail or web link. Surveys were collected between mid-March 2020 and mid-April 2020. There was an introduction

message with the survey link, a reminder at seven days, and a reminder 10 days after the first. Data about provider preferences and practices were collected and quantified using a Likert-based scale. The first four questions collected basic demographic data. Questions five and six were based on an "Always" to "Never" scale. Questions 7-10 were based on a "Strongly Agree" to "Strongly Disagree" scale. Questions 11, 12, and 13 were free-text-enabled and assessed for thematic trends. Estimated time required to complete the survey was approximately ten minutes, but the average completion rate was four minutes and 36 seconds. Survey content has been attached to this document in Appendix B.

Measures

Assessment of the free-text data was accomplished through analysis and tagging of the responses and was oriented toward summarization of the information (Sandelowski, 2000). The Likert-scale data was analyzed using the analysis and review function integrated into the SurveyMonkey platform and verified using Microsoft Excel.

Analysis

The survey was created, distributed, analyzed, and securely stored in the SurveyMonkey database. For the open-entry questions at the end of the survey, thematic production and inference occurred via open, axial, and selective coding (Robert Wood Johnson Foundation, 2008). This was augmented with the tagging capabilities integrated into the SurveyMonkey platform. The purpose of this QIP survey was to collect provider responses and perceptions as they pertained to transcranial doppler ultrasound in the setting of subarachnoid hemorrhage. Survey results were compared to the available evidence and recommendations to encourage practice improvement were made if appropriate.

Ethical Considerations

There was no direct patient data collected. Institutional Review Board (IRB) approval was sought and acquired prior to initiation of the QIP. The project was determined to be an exempt quality improvement effort by the IRBs at Legacy Health and Oregon Health & Science University (OHSU). Data was and is securely stored in the SurveyMonkey database and identifying information was redacted in order to respect the privacy of the participants. No funding was utilized in the implementation of this QIP.

Results

The following data is a verbal report of the information collected in SurveyMonkey's embedded "analysis and review" function. The survey was sent to a total of 11 recipients with six responses for a 54% response rate. Three of the responses were from three of the four neurointensive care providers, and three were from neurology consultants. No medicine intensive care providers who provide cross-coverage for critically ill neurologic patients provided responses.

Control Question, Demographic Information

The first question in the survey queried whether the providers ordered TCDs as a part of their practice in managing patients with subarachnoid hemorrhage. This was included as a control. One hundred percent of the respondents ordered TCDs as part of their practice. In this group, 16.67% of the respondents had been in practice for 2-4 years, 50% had been in practice for 5-10 years, and 33.33% of the respondents had been in practice for 10+ years. With regards to case load, 33.33% of participants managed an average of 0-2 SAH cases per month; 33.33% 3-4 cases per month; and 33.33% five or more cases per month. A graphical representation of this data is attached in Appendix C.

Questions Five and Six: Frequency of Use and Practicality of TCDs

These questions collected information about the frequency of TCD utilization and whether providers felt that the information influenced their care decisions. One third (33.33%) of respondents selected ‘always’ when asked if they order TCDs for patient suffering from aneurysmal subarachnoid hemorrhage; 16.67% of respondents stated that they ‘usually’ order TCDs for patients suffering from SAH; and 50% of respondents indicated that they “sometimes” ordered TCDs for patients suffering from SAH. When asked whether TCD data influences management decisions, 66.67% of respondents felt that TCD data “sometimes” affected management. Other answers indicated that 16.67% of respondents felt that TCD data “usually” or “rarely” influenced their treatment decisions.

Questions 7-10: Data Interpretation Skill, Confidence in Evidence Basis

These questions collected information about respondents’ confidence in interpreting TCD data and the evidence behind the imaging modality. When asked whether respondents felt confident in their ability to interpret TCD data as it is reported at Legacy Health, 50% responded with “strongly agree;” 16.67% responded with “agree;” and 33.33% reported that they “neither agree nor disagree.” Two thirds (66.67%) of respondents selected “agree” when asked if TCDs are clinically useful for detecting vasospasm in the setting of subarachnoid hemorrhage. One third (33.33%) “neither agreed nor disagreed.”

When asked if the data supporting the negative predictive value of TCDs is sufficient when the velocity reading is less than 120 cm/s, 33.33% of respondents chose “agree,” “neither agree nor disagree,” and “disagree,” respectively. Lastly, when assessing whether respondents felt that the data supported the positive predictive value of TCDs when the velocity is > 180 cm/s, 16.67% “strongly agreed,” 33.33% “agreed,” 33.33% “neither agreed nor disagreed,” and 16.67% “disagreed.”

Questions 11, 12, and 13: Free-Text Responses

These questions were free-text enabled and respondents were asked to comment on a variety of items.

Individual rationale behind selection of TCDs. Question 11 asked about the rationale for TCDs. Respondents indicated that they might order TCDs if a patient lacked a reliable clinical exam and/or if they were deemed high risk for vasospasm development and required closer monitoring. Providers also indicated that a reason for choosing this test may be because of its minimal invasiveness and accessibility when compared to alternatives. Overall, the theme for this question was established as the "presence/absence of a quality clinical exam."

Cases in which respondents felt that TCDs were inappropriate or unwarranted. When asked about situations in which a TCD might be inappropriate or unwarranted, provider responses indicated that this may be the case if a "clinical exam is entirely intact," if the test was being done "per protocol/without consideration of a patient's clinical status," or if the test was unable to be completed secondary to "difficult bone windows." Another disqualifier for providers was the "availability of alternative testing means" such as DSA.

On whether the respondents routinely select a TCD alternative and if so, their rationale. The final question asked about whether respondents utilized a tool other than TCDs and, if so, what their rationale was. Five of the 12 recipients responded. The most common tags applied for these answers were "clinical exam," "CTA/CTP," and "DSA." These responses had very strong themes of "angiographic imaging (DSA or CTA)" and "clinical exam." If the patient had a clinical exam that was easy to follow or if the patient had already had/needed to receive a DSA or CTA/CTP study, TCD was felt to be unnecessary.

Associations, Consequences, and Benefits Observed in the Data

The responses from the neurocritical care attendings were similar in that all responded with “strongly agree” when asked if they felt confident in their ability to interpret the TCD data as it is reported at Legacy. This could be related to the more frequent utilization of TCDs in the intensive care setting. Another observation is that there was good representation across all groups for different experience levels (each category had 33.33% of respondents). Lastly, there were common themes in the free-text responses among all recipients. Unintended consequences/benefits include the establishment that providers at Legacy Health appear to have a common understanding of when they use TCD, when they are inappropriate or unwarranted, and a common utilization of testing alternatives such as CTP, CTA, or DSA. Graphical representations of this data produced using SurveyMonkey’s embedded “analysis and review” function is available in Appendix B. The Excel tables used to verify the data are attached in Appendix D.

Discussion

Summary

This process was guided by the Plan, Do, Study, Act framework because of the intention to analyze and improve the process utilization of TCDs (Minnesota Department of Health, n.d.). Although the data set is limited, some conclusions can be drawn and the results may serve as a starting point for development of further staff surveys, educational materials for staff onboarding and/or evidence updates. Strengths of the project are the equal representation of two important staff groups (neurointensive care providers, consulting neurology providers), representation of multiple groups with regards to years of clinical experience, and establishment of the current knowledge/utilization basis of TCD at Legacy Health.

Interpretation

This quality improvement project established an understanding of the present practices and helped to identify potential areas for improvement with regards to the understanding and utilization of TCDs in patients afflicted with subarachnoid hemorrhage at Legacy Health's NTICU. This was accomplished by analyzing provider responses and comparing/contrasting them with the available literature.

According to Ryu et al (2017), TCDs are an inexpensive, non-invasive and validated tool for the purpose of detecting vasospasm (Ryu, Ko, Hu, & Shadden, 2017). For these reasons, the imaging modality should be utilized as a tool to follow both the pathology itself and the interventions that are implemented to prevent further damage (Saqqur, Zygun, Demchuk, & Manosalva, 2014). Because none of the submissions indicate that recipients "rarely" or "never" order TCDs, the survey supports the conclusion that the providers who responded are ordering the tool appropriately as an adjunct to the clinical exam (Durrant & Hinson, 2015).

Furthermore, the data demonstrates that Legacy's providers are using appropriate clinical suspicion when incorporating the information into the care plan. This is notable because, although TCD is validated clinically and has been established as a helpful adjunct, it does have a number of limitations and must be performed consistently, interpreted correctly, and considered in the context of the individual patient and their anatomic and/or physiologic limitations (Francoeur & Mayer, 2016).

In contrast to the favorable data above, the survey questions relating to the evidence basis for TCDs demonstrated a gap between practice and recommendations. Francoeur & Mayer (2016) state that if the FVm value is below 120 cm/s, the negative predictive value is sufficient to direct clinical management and, likewise, if the value is above 180 cm/s, the positive predictive value is reliable enough to direct management (Francoeur & Mayer, 2016). According

to the survey data, only 33.33% of participants agreed that the negative predictive value was reliable enough to direct data. One third (33.33%) neither agreed nor disagreed, and 33.33% disagreed that the strength of the negative predictive value was sufficient to determine clinical management. Moreover, only 16.67% of respondents “strongly agreed” that the positive predictive value evidence was sufficient; 33.33% “agreed;” 33.33% “neither agreed nor disagreed;” and 16.67% “disagreed.” These responses indicate that further education may be beneficial to the clinical staff at Legacy about the value of the FVm produced by a TCD ultrasound exam. According to available evidence, the velocity of blood flow through the middle cerebral artery is directly proportional to the severity of vasospasm and the data acquired is sufficient to safely influence the clinical course (Djelilovic-Vranic, Basic-Kes, Tiric-Campara, Djozic, & Kulenovic, 2017; Francoeur & Mayer, 2016).

Discussion of Free Text Responses

The pertinent findings from the free-text data were identified through a process of tagging and coding according to perceptible thematic trends (Robert Wood Johnson Foundation, 2008). This method allowed the author to account for variations in phrasing, nomenclature, and question interpretation and revealed a number of trends among providers ("SAGE encyclopedia of communication research methods," 2017).

Individual rationale behind selection of TCDs. These responses indicated that the most frequent reason that providers utilized TCDs was for the inability to obtain a reliable, followable clinical exam. This is considered consistent with the evidence basis because it has been established that TCD ultrasonography is a dependable adjunct to the clinical exam (Durrant & Hinson, 2015). Additionally, the answers indicated that the survey recipients use this modality as a non-invasive, easily accessible tool at the bedside. This approach is well-supported in the

literature and may help to prevent secondary injury to ICU patients that can occur as a result of risky transfers for more invasive imaging techniques (Ali & Liebeskind, 2014; Saqqur et al., 2014).

Cases in which respondents felt that TCDs were inappropriate or unwarranted. When asked about scenarios in which the provider believed TCD to be inappropriate or unwarranted, the most commonly applied tag was "clinically unnecessary." This was applied to answers that discussed patients who had no deficits or exams that were easy to follow; patients who were scheduled to undergo a DSA within 24 hours or were at high risk for requiring urgent intervention; and patients who experienced traumatic SAH (Kramer, Winer, Pease, Amar, & Mack, 2013). Given that the clinical exam is the most reliable tool by which DCI is identified, this indicates that the Legacy Health providers who responded to the survey are acting in accordance with the evidence basis (Francoeur & Mayer, 2016).

On whether the respondents routinely select a TCD alternative and if so, their rationale. Question 13 queried alternative methods for DCI detection. The answers indicate that when TCDs are not utilized, providers are using somewhat more invasive tests in conjunction with the clinical exam. Given that DSA is still considered the gold standard for evaluation and treatment of vasospasm that contributes to DCI, this, too, supports that Legacy's providers are acting in accordance with the evidence basis (Mahajan & Gupta, 2016). However, the tests are more invasive and carry the risks of both radiation and contrast dose exposure so should be considered in the context of the patient's clinical deterioration and/or need for definitive intervention (Ali & Liebeskind, 2014). Further research is needed to directly compare the benefits and risks of CT perfusion studies with TCD ultrasonography in the context of vasospasm and DCI.

The anticipated outcome of this quality improvement project was that there would be a greater gap between the evidence basis and the standard practice at Legacy Health. This assumption was founded on conversations with the stroke program coordinator and providers at the institution leading up to the project conception. The observed outcomes are encouraging, however tempered by the absence of response from the medicine critical care attendings and additional consulting neurologists. It could be that the medicine attending physicians who provide cross-coverage have alternative practices and/or more significant practice gaps that would benefit from intervention.

Limitations

Limitations that affect the generalizability of this work include the lower-than-desired, (although better than average) response rate and the focus of the QIP on a limited adult population in an urban intensive care unit (Keller, 2014; Lindemann, 2019). Additionally, the survey was designed, distributed, and interpreted by a single author in an unvalidated form. Lastly, it is possible that some institutions may not have access to TCD-capable ultrasounds, trained technicians, or radiologists who can expediently interpret the data for clinical use.

Factors that may have limited the internal validity of this QIP include potential sampling bias and imprecision of the design given the short course of time and limited resources available to support project completion (Lindemann, 2019). Efforts made to minimize these limits to internal validity include use of a third-party survey platform and review of the survey questions by multiple parties prior to publication.

Notable contextual elements that interacted with the intervention include the more global effect of a healthcare pandemic that occurred simultaneously during the data collection period. The survey was distributed to the group of neurologists, neurointensive care providers, and

medicine intensive care providers who regularly consult on or manage cases of subarachnoid hemorrhage in the NTICU. However, responses were not received from the medicine intensive care providers nor one of the neurologists to whom the survey was sent. This could be because of the need to prioritize the critical care of patients afflicted with the novel coronavirus disease that was recognized in Oregon starting in March 2020 or, alternatively, a downstream effect of the clinical rotation limits enacted in order to preserve vital resources. These unexpected challenges may have affected the response rate (6/11 recipients responded) and could account for the limited data set that was produced.

Conclusions

This QIP yielded important information about the current practices surrounding TCD ultrasonography at Legacy Health. It was established that the neurocritical care providers and consulting neurologists have a fairly consistent practice with a small practice gap that may be easily remedied with a point-of-care evidence update. The impact of the project is its contribution to the development of a consistent policy or procedure at Legacy Health. This is helpful because it makes the information more accessible to the providers and support staff at the institution and allows for widespread, trustworthy dissemination of information to other locations that manage neurocritical care patients.

This project has the potential to catalyze the development of a system-wide, evidence-based policy and/or procedure that could impact the system's ICUs in a measurable way. This may be especially useful for the system's ICUs who provide a wide array of care that includes, but is not limited to, neurologically injured patients. In addition to dissemination within the system's own ICUs, the project could also be adapted for smaller, regional ICUs or similar urban ICUs in the same or other cities.

Further research in this area could involve repetition of the survey at a time when the cross-coverage attendings are more capable of providing answers. Additionally, it could involve inquiry into or the development and validation of a clinical decision algorithm or system policy for TCD utilization. Suggestions for next steps after the conclusion of this quality improvement project would be to repeat the survey when the contextual features limiting response rates are less significant.

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compliance/?ut_source=mp&ut_source2=data-security-and-compliance&ut_source3=inline&ut_ctatext=HIPAA%2520Compliance

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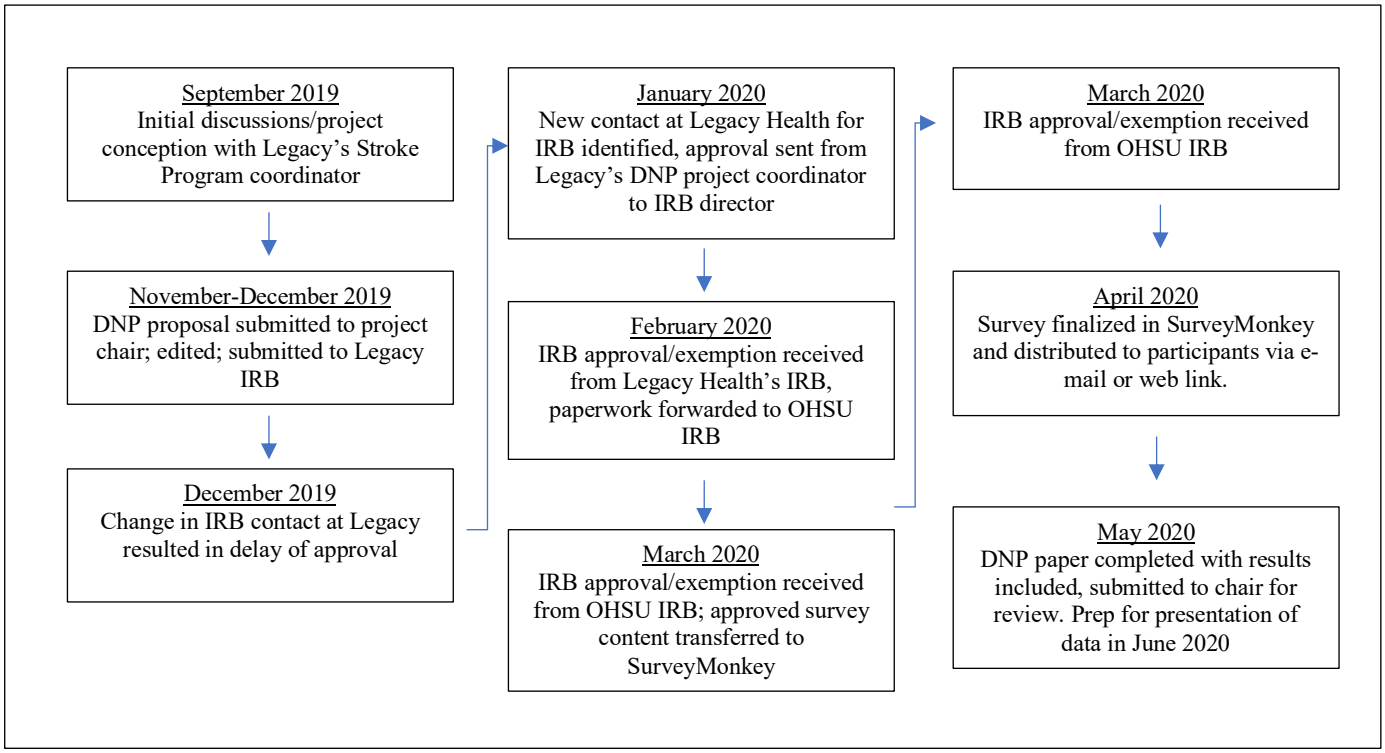
Appendix A

Graphical representation of project timeline



Appendix B

Survey Introduction, Disclaimer, and Survey Content

This survey is part of a quality improvement project (QIP) being completed to fulfill requirements for a Doctor of Nursing Practice (DNP) degree at Oregon Health & Science University.

The purpose of this survey is to examine provider preferences and practices surrounding the utilization of transcranial doppler (TCD) for the purpose of identifying post-injury vasospasm in adult (18+) patients suffering from subarachnoid hemorrhage in the NTICU.

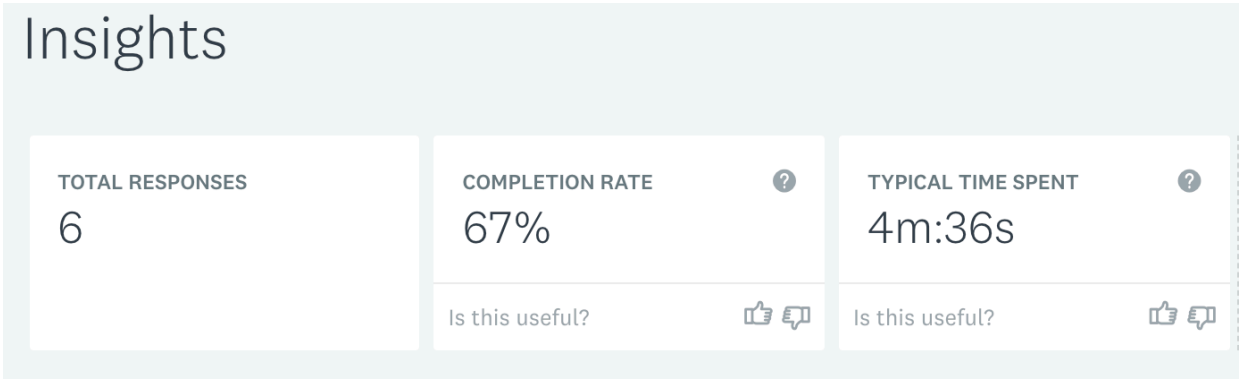
Participation is entirely voluntary. Measures will be taken to minimize the small potential identification risk associated with any sort of data collection. Efforts to maintain confidentiality of responses include password protection of survey data, computer-derived anonymity of responses, and limited user access to data. Only general demographic information will be collected and analyzed. Responses will have no bearing on employment status or performance evaluations. Expected time required for survey completion is approximately ten minutes.

Contact information for the survey author is below—please do not hesitate to reach out for any questions, concerns, or troubleshooting assistance. Thank you.

Margaret Persing | MSN, AGACNP-BC, DNP Student

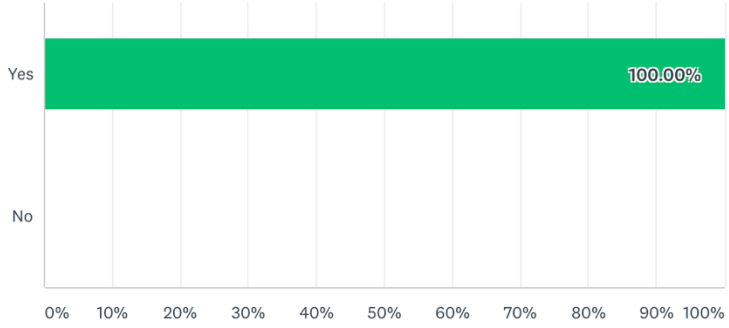
(408) 843-7101

persingm@ohsu.edu



Do you order or utilize TCD? If NO, do not proceed through the rest of the survey

Answered: 6 Skipped: 0



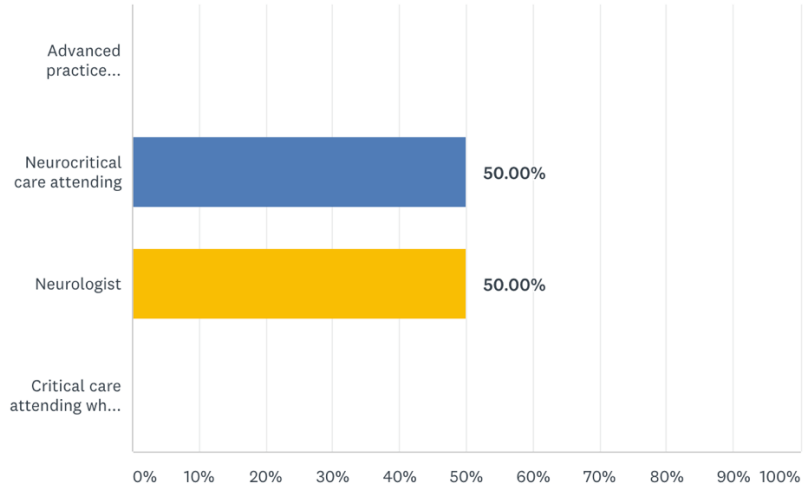
ANSWER CHOICES	RESPONSES	
Yes (1)	100.00%	6
No (2)	0.00%	0
TOTAL		6

BASIC STATISTICS				
Minimum	Maximum	Median	Mean	Standard Deviation
1.00	1.00	1.00	1.00	0.00

Question 1: Control

What is your primary role in the care of patients with subarachnoid hemorrhage?

Answered: 6 Skipped: 0



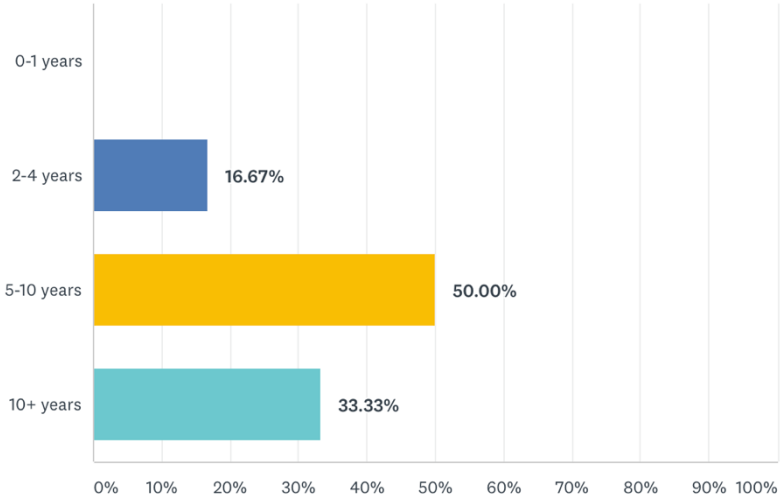
ANSWER CHOICES	RESPONSES	
Advanced practice provider (NP, PA) (1)	0.00%	0
Neurocritical care attending (2)	50.00%	3
Neurologist (3)	50.00%	3
Critical care attending who provides coverage for the neurointensive care service (4)	0.00%	0
TOTAL		6

BASIC STATISTICS				
Minimum	Maximum	Median	Mean	Standard Deviation
2.00	3.00	2.50	2.50	0.50

Question 2

How many years have you been in practice?

Answered: 6 Skipped: 0



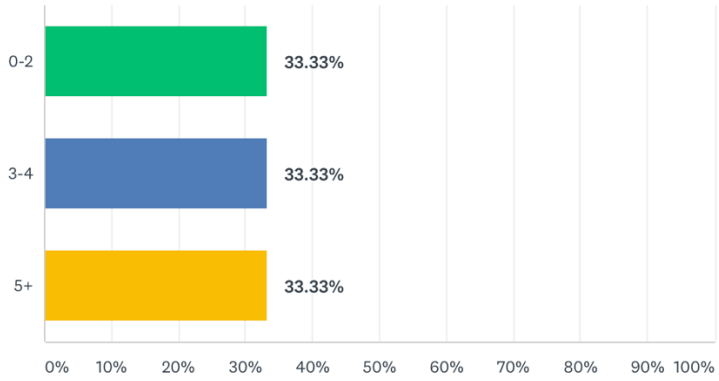
ANSWER CHOICES	RESPONSES	
0-1 years (1)	0.00%	0
2-4 years (2)	16.67%	1
5-10 years (3)	50.00%	3
10+ years (4)	33.33%	2
TOTAL		6

BASIC STATISTICS				
Minimum	Maximum	Median	Mean	Standard Deviation
2.00	4.00	3.00	3.17	0.69

Question 3

On average, how many cases of subarachnoid hemorrhage do you manage in a given month?

Answered: 6 Skipped: 0



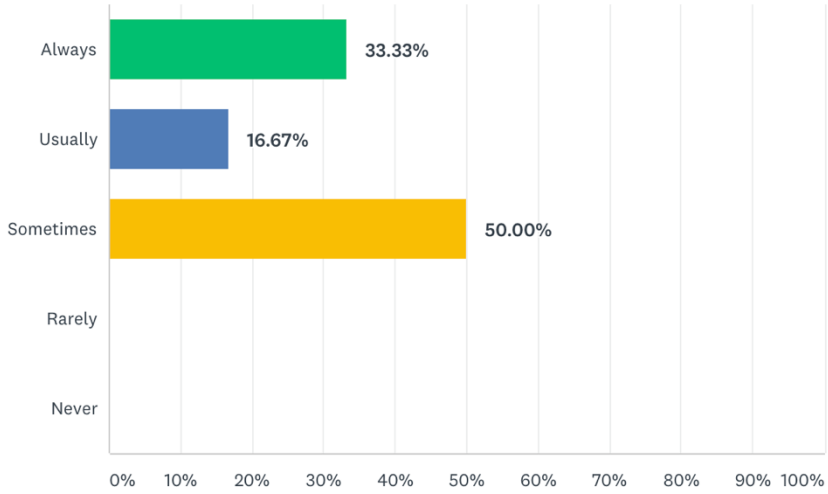
ANSWER CHOICES	RESPONSES	
0-2 (1)	33.33%	2
3-4 (2)	33.33%	2
5+ (3)	33.33%	2
TOTAL		6

BASIC STATISTICS				
Minimum	Maximum	Median	Mean	Standard Deviation
1.00	3.00	2.00	2.00	0.82

Question 4

I order TCDs for patients suffering from aneurysmal subarachnoid hemorrhage (excluding those with anticipated progression to comfort measures only)

Answered: 6 Skipped: 0



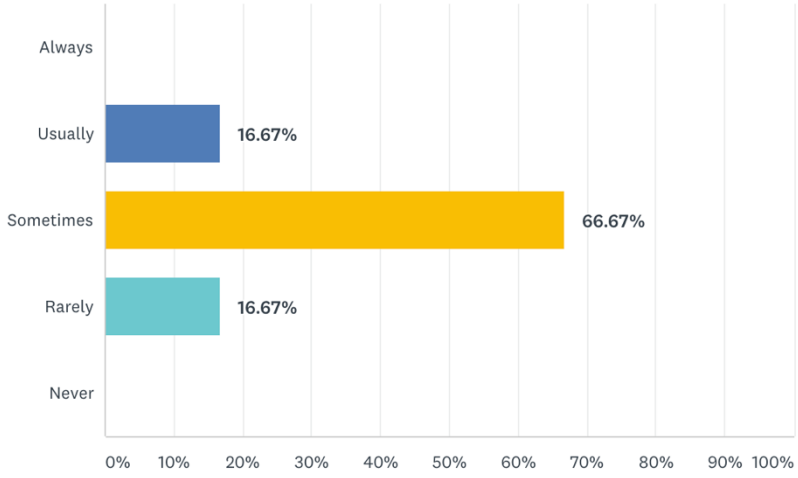
ANSWER CHOICES	RESPONSES	
Always (1)	33.33%	2
Usually (2)	16.67%	1
Sometimes (3)	50.00%	3
Rarely (4)	0.00%	0
Never (5)	0.00%	0
TOTAL		6

BASIC STATISTICS				
Minimum	Maximum	Median	Mean	Standard Deviation
1.00	3.00	2.50	2.17	0.90

Question 5

TCD data influences my management decisions for patients with aneurysmal subarachnoid hemorrhage:

Answered: 6 Skipped: 0



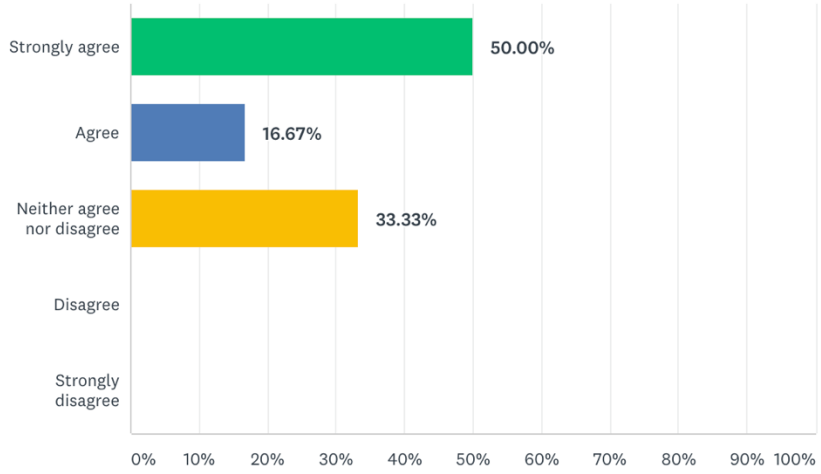
ANSWER CHOICES	RESPONSES	
Always (1)	0.00%	0
Usually (2)	16.67%	1
Sometimes (3)	66.67%	4
Rarely (4)	16.67%	1
Never (5)	0.00%	0
TOTAL		6

BASIC STATISTICS				
Minimum	Maximum	Median	Mean	Standard Deviation
2.00	4.00	3.00	3.00	0.58

Question 6

I feel confident in my ability to appropriately read and interpret the TCD data as it is reported at Legacy

Answered: 6 Skipped: 0



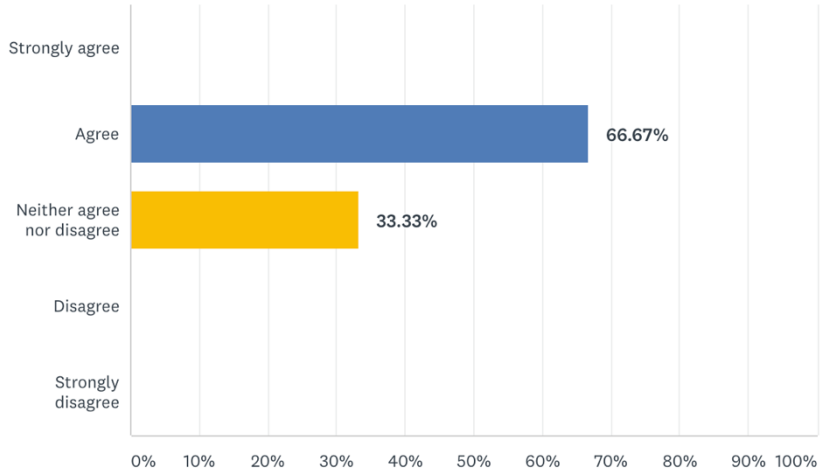
ANSWER CHOICES	RESPONSES	
Strongly agree (1)	50.00%	3
Agree (2)	16.67%	1
Neither agree nor disagree (3)	33.33%	2
Disagree (4)	0.00%	0
Strongly disagree (5)	0.00%	0
TOTAL		6

BASIC STATISTICS				
Minimum	Maximum	Median	Mean	Standard Deviation
1.00	3.00	1.50	1.83	0.90

Question 7

I believe TCDs are clinically useful for detecting vasospasm in the setting of subarachnoid hemorrhage

Answered: 6 Skipped: 0



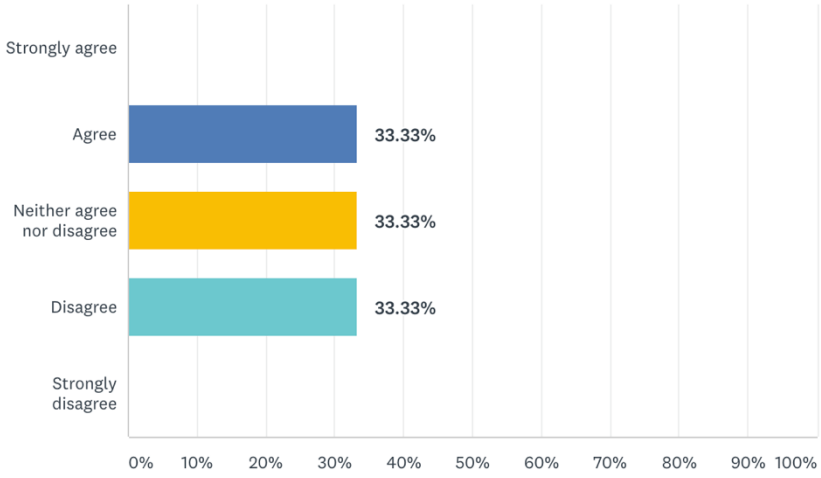
ANSWER CHOICES	RESPONSES	
Strongly agree (1)	0.00%	0
Agree (2)	66.67%	4
Neither agree nor disagree (3)	33.33%	2
Disagree (4)	0.00%	0
Strongly disagree (5)	0.00%	0
TOTAL		6

BASIC STATISTICS				
Minimum	Maximum	Median	Mean	Standard Deviation
2.00	3.00	2.00	2.33	0.47

Question 8

The data supporting the negative predictive value of TCDs when the velocity is < 120 cm/s is sufficient to direct clinical management

Answered: 6 Skipped: 0



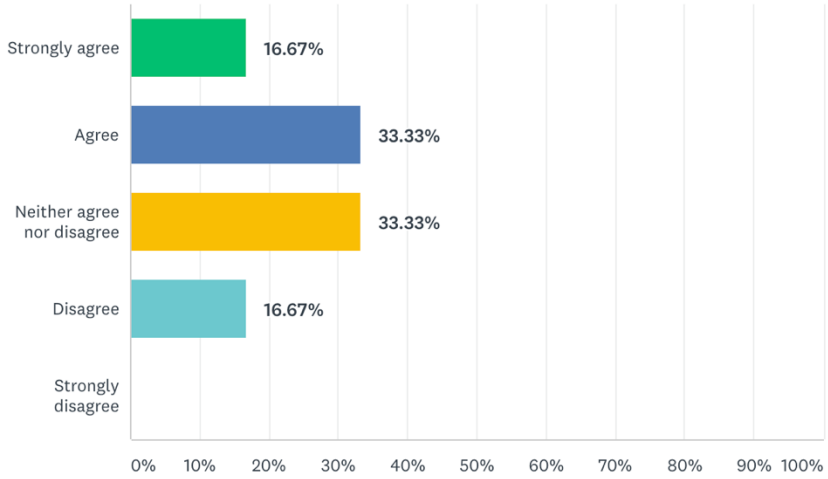
ANSWER CHOICES	RESPONSES	
Strongly agree (1)	0.00%	0
Agree (2)	33.33%	2
Neither agree nor disagree (3)	33.33%	2
Disagree (4)	33.33%	2
Strongly disagree (5)	0.00%	0
TOTAL		6

BASIC STATISTICS				
Minimum	Maximum	Median	Mean	Standard Deviation
2.00	4.00	3.00	3.00	0.82

Question 9

The data supporting the positive predictive value of TCDs when the velocity is > 180 cm/s is sufficient to direct clinical management

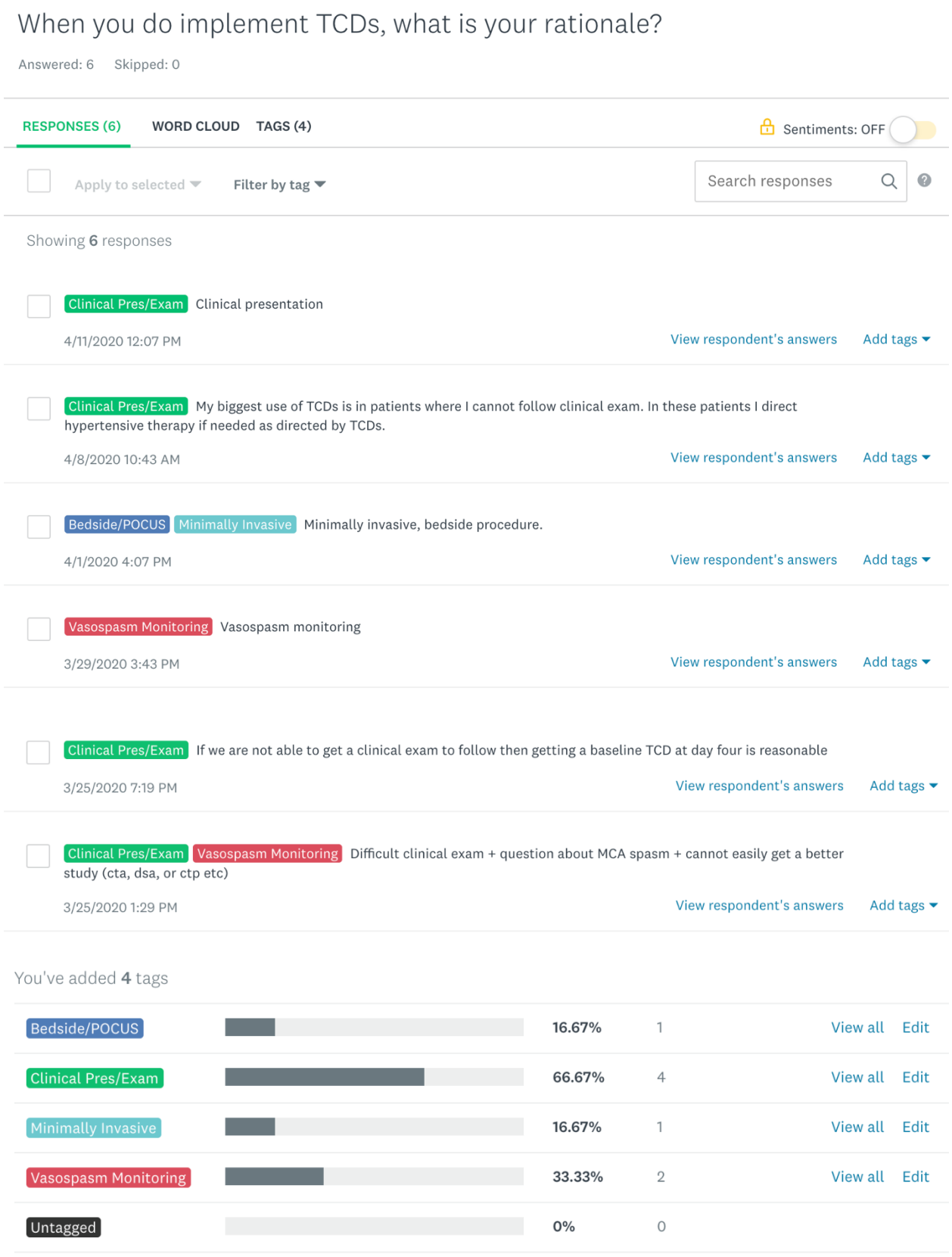
Answered: 6 Skipped: 0



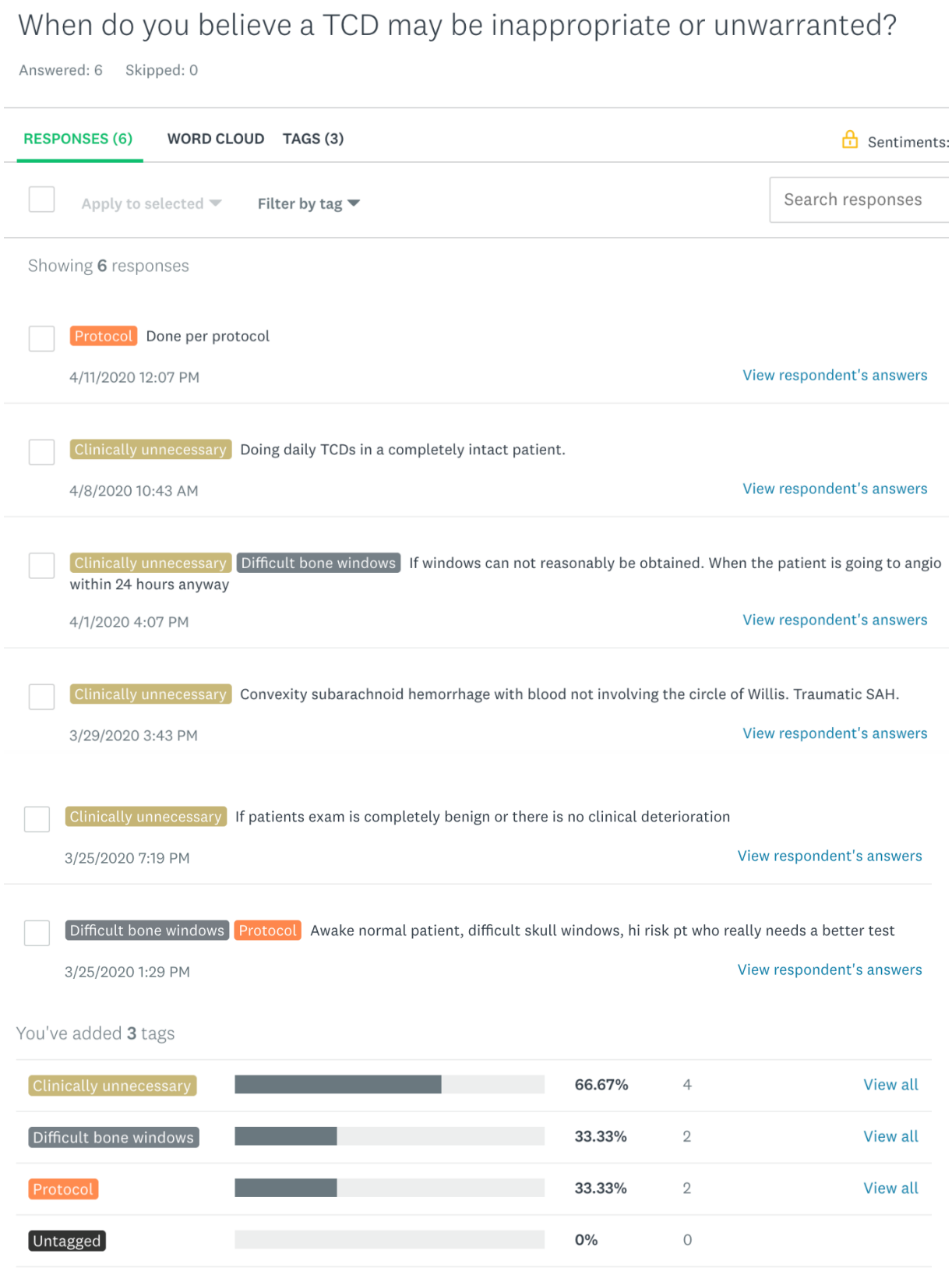
ANSWER CHOICES	RESPONSES	
Strongly agree (1)	16.67%	1
Agree (2)	33.33%	2
Neither agree nor disagree (3)	33.33%	2
Disagree (4)	16.67%	1
Strongly disagree (5)	0.00%	0
TOTAL		6

BASIC STATISTICS				
Minimum	Maximum	Median	Mean	Standard Deviation
1.00	4.00	2.50	2.50	0.96

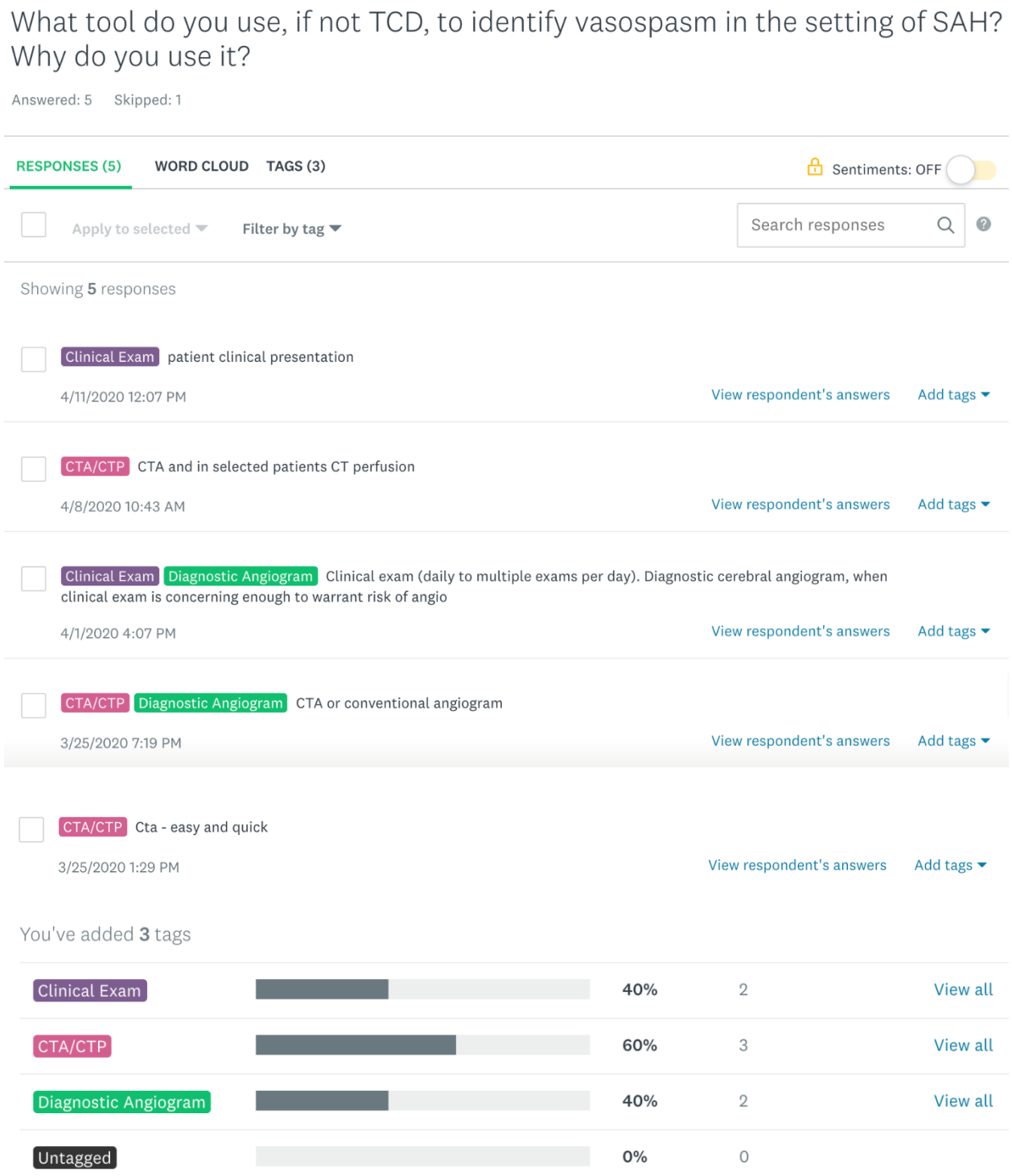
Question 10


When you do implement TCDs, what is your rationale?
Answered: 6 Skipped: 0
RESPONSES (6)
WORD CLOUD
TAGS (4)
Sentiments: OFF
Apply to selected
Filter by tag
Search responses
Showing 6 responses
Clinical Pres/Exam Clinical presentation
4/11/2020 12:07 PM
View respondent's answers
Add tags
Clinical Pres/Exam My biggest use of TCDs is in patients where I cannot follow clinical exam. In these patients I direct hypertensive therapy if needed as directed by TCDs.
4/8/2020 10:43 AM
View respondent's answers
Add tags
Bedside/POCUS Minimally Invasive Minimally invasive, bedside procedure.
4/1/2020 4:07 PM
View respondent's answers
Add tags
Vasospasm Monitoring Vasospasm monitoring
3/29/2020 3:43 PM
View respondent's answers
Add tags
Clinical Pres/Exam If we are not able to get a clinical exam to follow then getting a baseline TCD at day four is reasonable
3/25/2020 7:19 PM
View respondent's answers
Add tags
Clinical Pres/Exam Vasospasm Monitoring Difficult clinical exam + question about MCA spasm + cannot easily get a better study (cta, dsa, or ctp etc)
3/25/2020 1:29 PM
View respondent's answers
Add tags
You've added 4 tags
Bedside/POCUS 16.67% 1 View all Edit
Clinical Pres/Exam 66.67% 4 View all Edit
Minimally Invasive 16.67% 1 View all Edit
Vasospasm Monitoring 33.33% 2 View all Edit
Untagged 0% 0

Question 11


When do you believe a TCD may be inappropriate or unwarranted?
Answered: 6 Skipped: 0
RESPONSES (6)
WORD CLOUD
TAGS (3)
Sentiments:
Apply to selected
Filter by tag
Search responses
Showing 6 responses
Protocol Done per protocol
4/11/2020 12:07 PM
View respondent's answers
Clinically unnecessary Doing daily TCDs in a completely intact patient.
4/8/2020 10:43 AM
View respondent's answers
Clinically unnecessary Difficult bone windows If windows can not reasonably be obtained. When the patient is going to angio within 24 hours anyway
4/1/2020 4:07 PM
View respondent's answers
Clinically unnecessary Convexity subarachnoid hemorrhage with blood not involving the circle of Willis. Traumatic SAH.
3/29/2020 3:43 PM
View respondent's answers
Clinically unnecessary If patients exam is completely benign or there is no clinical deterioration
3/25/2020 7:19 PM
View respondent's answers
Difficult bone windows Protocol Awake normal patient, difficult skull windows, hi risk pt who really needs a better test
3/25/2020 1:29 PM
View respondent's answers
You've added 3 tags
Clinically unnecessary 66.67% 4 View all
Difficult bone windows 33.33% 2 View all
Protocol 33.33% 2 View all
Untagged 0% 0

Question 12


What tool do you use, if not TCD, to identify vasospasm in the setting of SAH? Why do you use it?
Answered: 5 Skipped: 1
RESPONSES (5)
WORD CLOUD
TAGS (3)
Sentiments: OFF
Apply to selected
Filter by tag
Search responses
Showing 5 responses
Clinical Exam patient clinical presentation
4/11/2020 12:07 PM
View respondent's answers
Add tags
CTA/CTP CTA and in selected patients CT perfusion
4/8/2020 10:43 AM
View respondent's answers
Add tags
Clinical Exam Diagnostic Angiogram Clinical exam (daily to multiple exams per day). Diagnostic cerebral angiogram, when clinical exam is concerning enough to warrant risk of angio
4/1/2020 4:07 PM
View respondent's answers
Add tags
CTA/CTP Diagnostic Angiogram CTA or conventional angiogram
3/25/2020 7:19 PM
View respondent's answers
Add tags
CTA/CTP Cta - easy and quick
3/25/2020 1:29 PM
View respondent's answers
Add tags
You've added 3 tags
Clinical Exam 40% 2 View all
CTA/CTP 60% 3 View all
Diagnostic Angiogram 40% 2 View all
Untagged 0% 0

Question 13

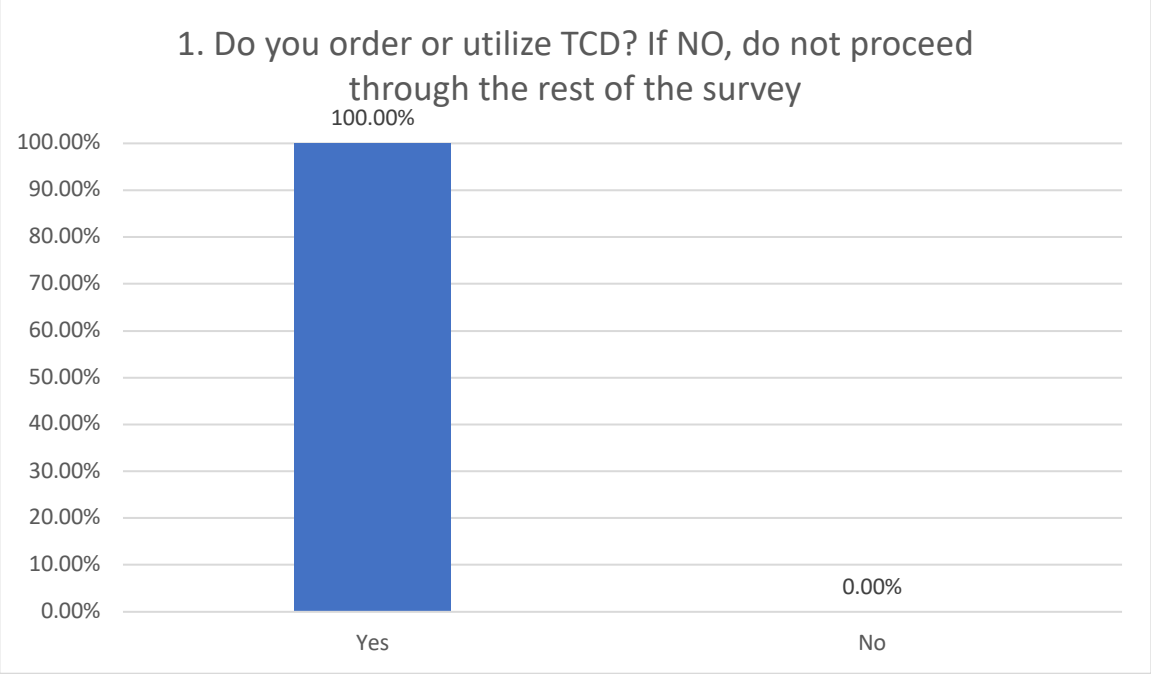
Appendix C

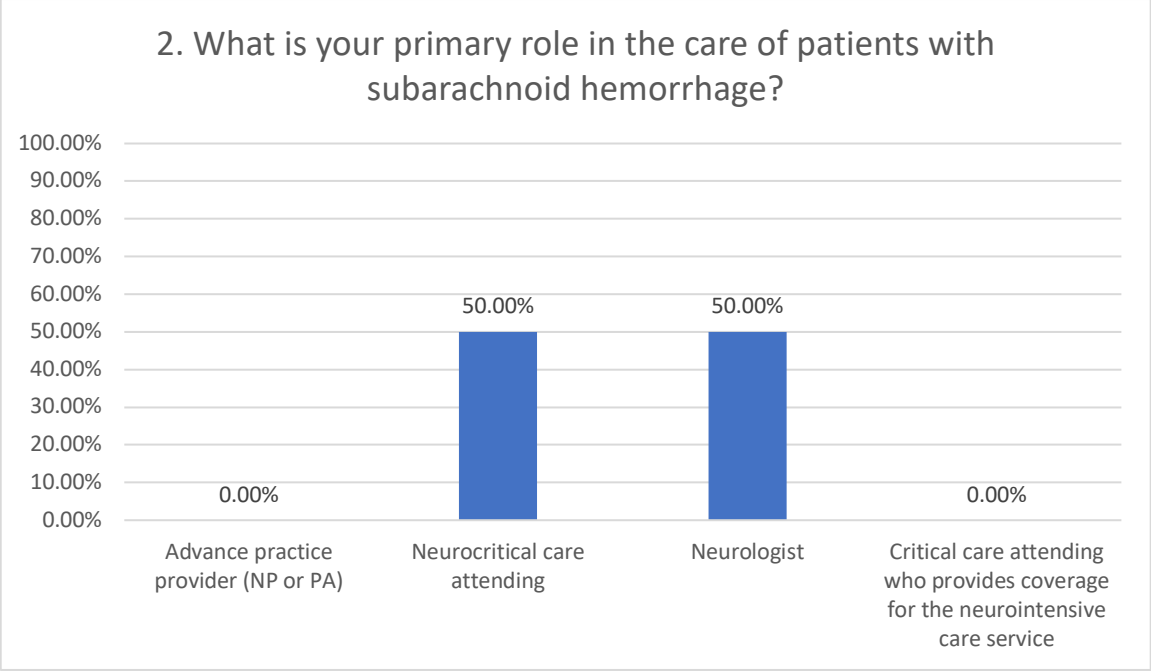
Graphical representation of demographic data

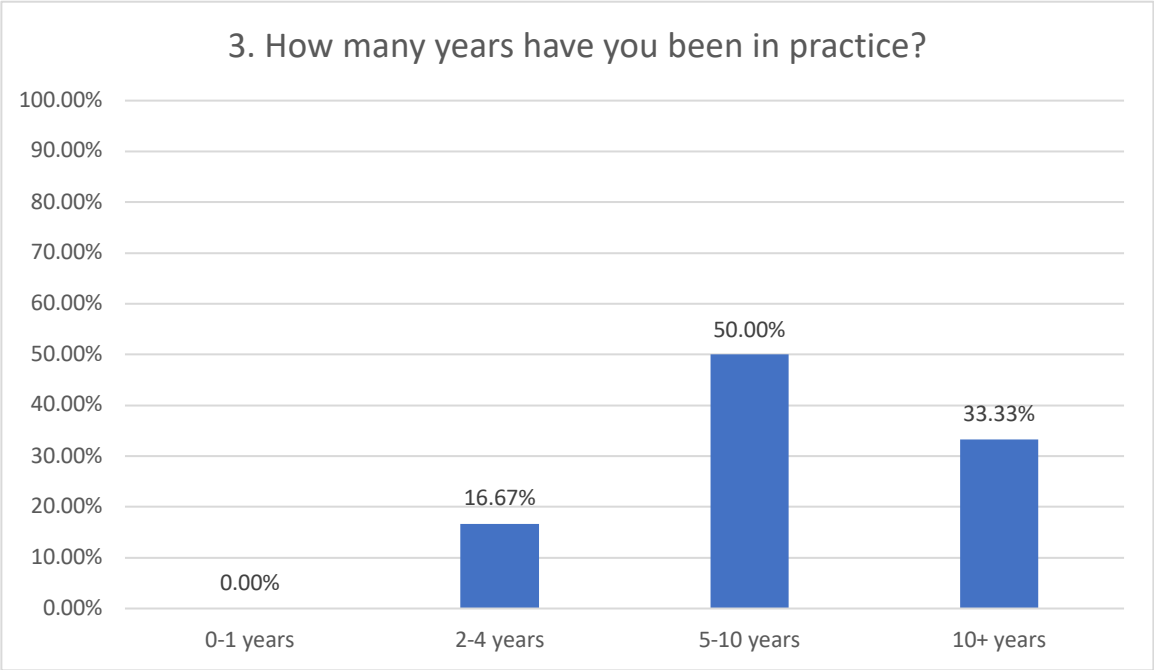
% of providers who order TCDs for SAH patients	100%
% of providers with 2-4 years of experience	16.67%
% of providers with 5-10 years of experience	50%
% of providers with 10+ years of experience	33.33%
% of providers who manage 0-2 cases SAH/month	33.33%
% of providers who manage 3-4 cases SAH/month	33.33%
% of providers who manage 5+ cases SAH/month	33.33%

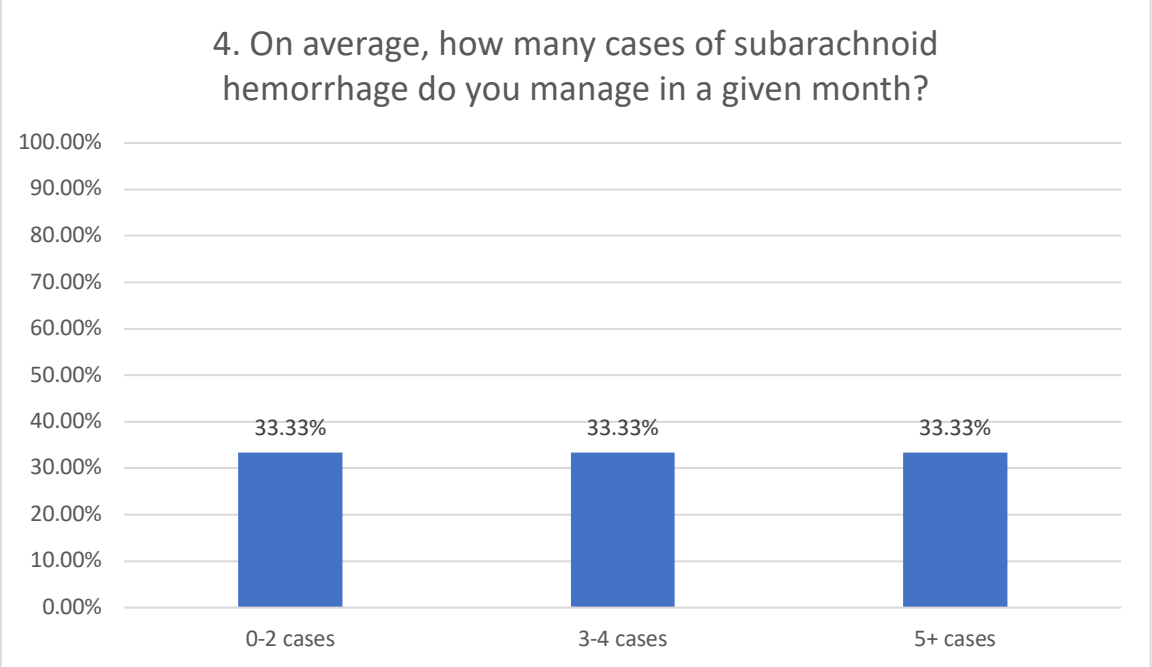
Appendix D

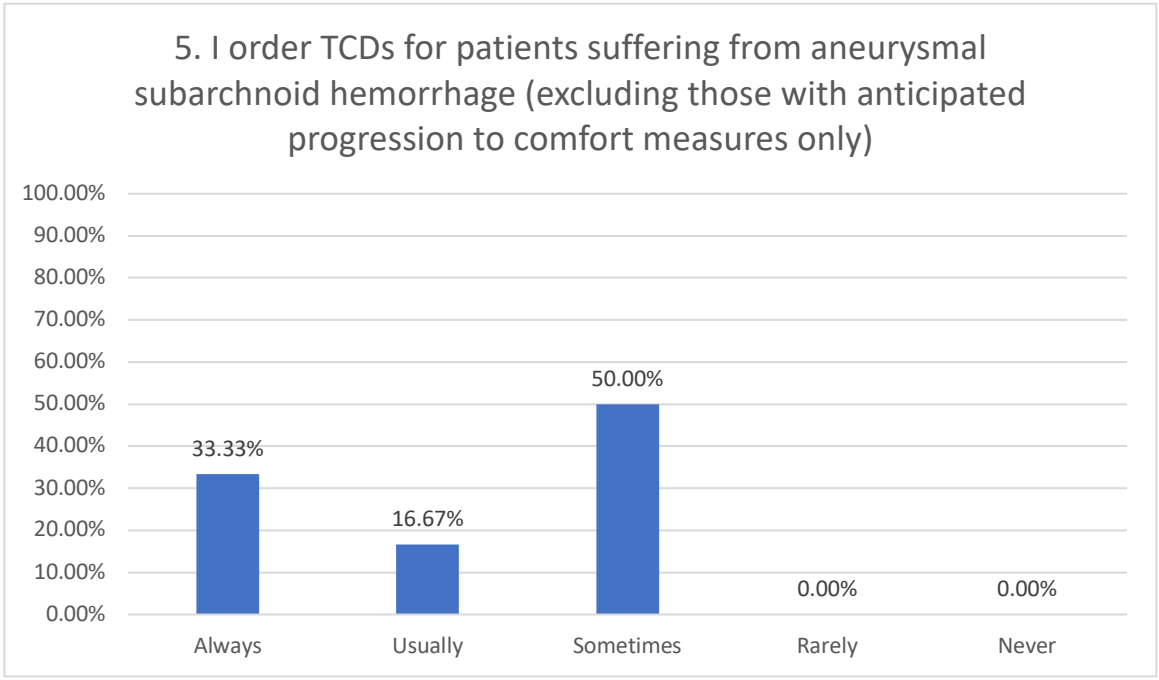
Excel Tables

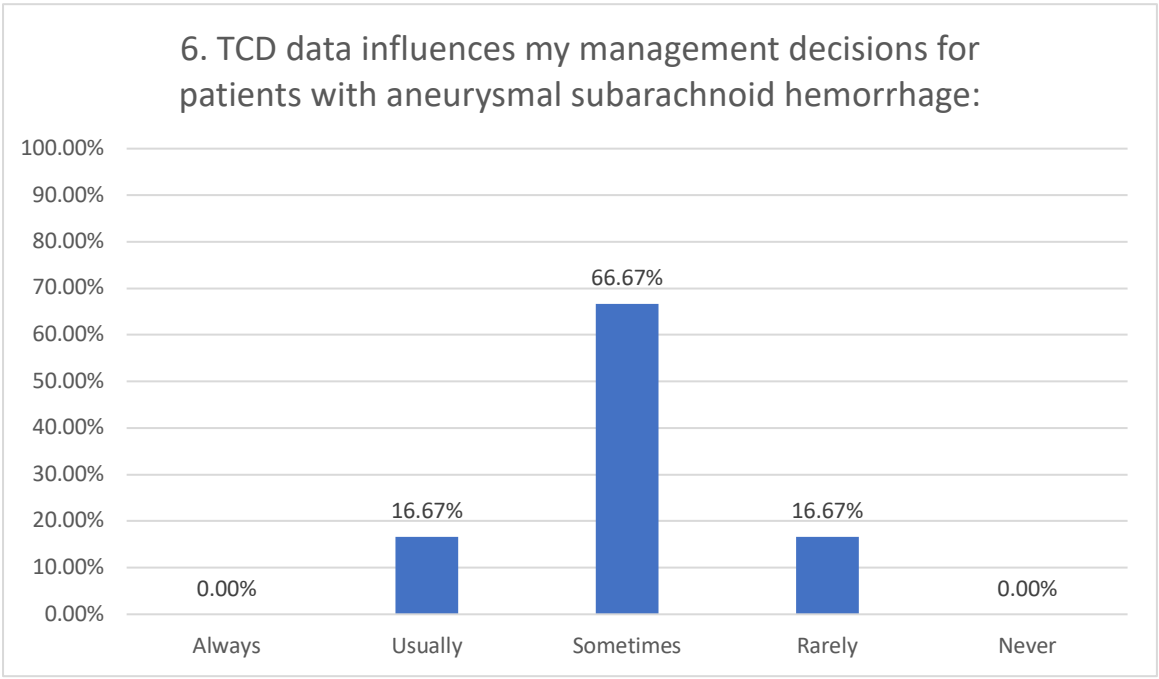


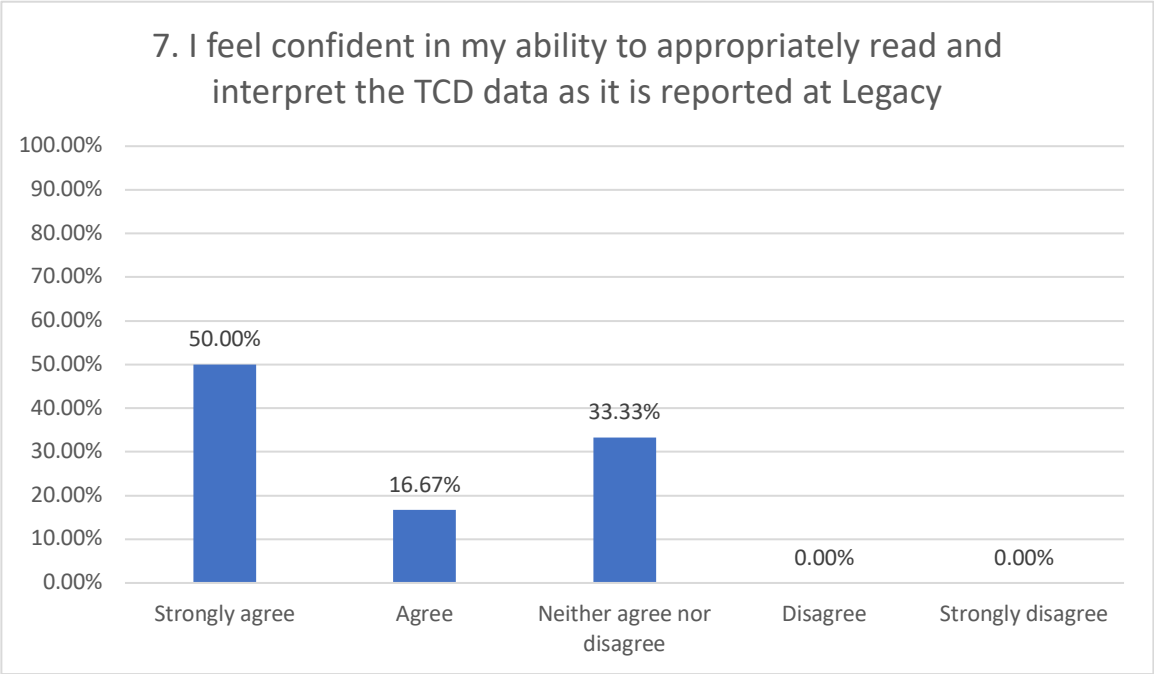


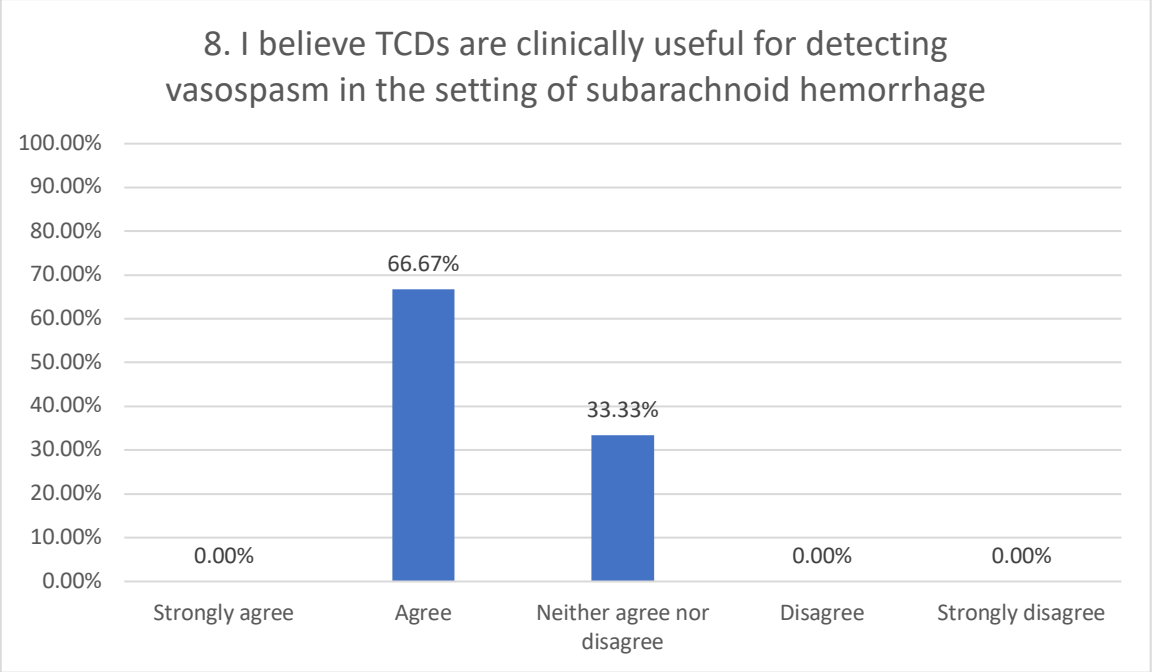

3. How many years have you been in practice?
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
0.00%
16.67%
50.00%
33.33%
0-1 years
2-4 years
5-10 years
10+ years

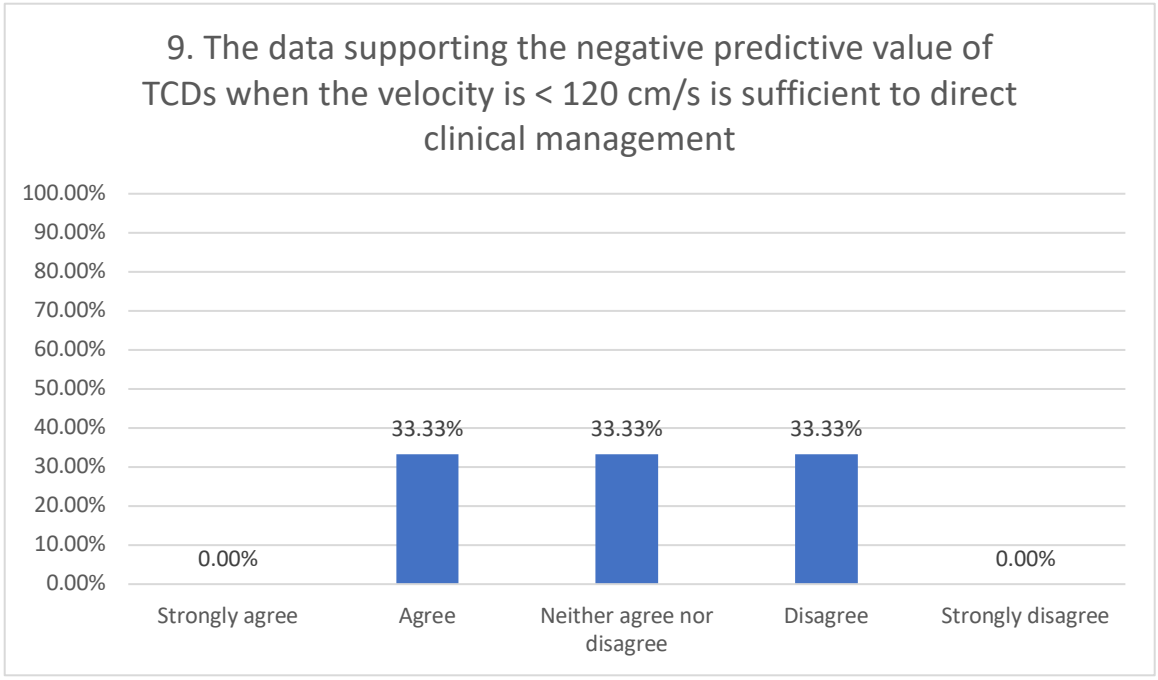

4. On average, how many cases of subarachnoid hemorrhage do you manage in a given month?
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
33.33%
33.33%
33.33%
0-2 cases
3-4 cases
5+ cases

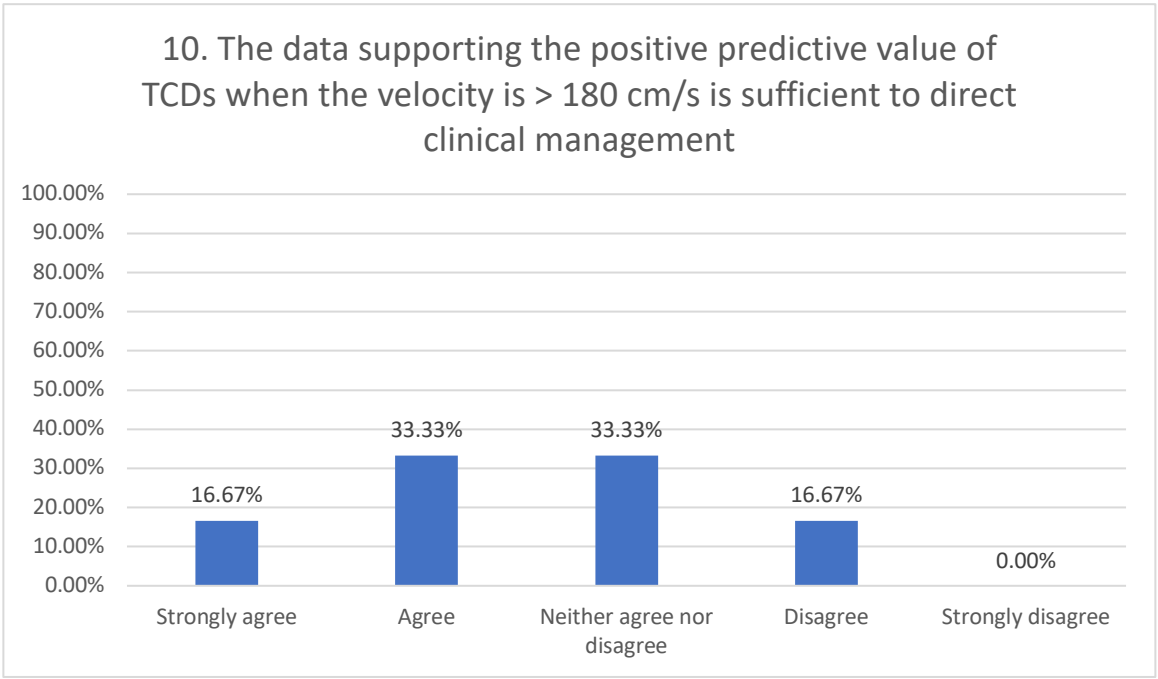

5. I order TCDs for patients suffering from aneurysmal subarchnoid hemorrhage (excluding those with anticipated progression to comfort measures only)
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
33.33%
16.67%
50.00%
0.00%
0.00%
Always
Usually
Sometimes
Rarely
Never


6. TCD data influences my management decisions for patients with aneurysmal subarachnoid hemorrhage:
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
0.00%
16.67%
66.67%
16.67%
0.00%
Always
Usually
Sometimes
Rarely
Never


7. I feel confident in my ability to appropriately read and interpret the TCD data as it is reported at Legacy
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
50.00%
16.67%
33.33%
0.00%
0.00%
Strongly agree
Agree
Neither agree nor disagree
Disagree
Strongly disagree


8. I believe TCDs are clinically useful for detecting vasospasm in the setting of subarachnoid hemorrhage
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
0.00%
66.67%
33.33%
0.00%
0.00%
Strongly agree
Agree
Neither agree nor disagree
Disagree
Strongly disagree


9. The data supporting the negative predictive value of TCDs when the velocity is < 120 cm/s is sufficient to direct clinical management
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
0.00%
33.33%
33.33%
33.33%
0.00%
Strongly agree
Agree
Neither agree nor disagree
Disagree
Strongly disagree


10. The data supporting the positive predictive value of TCDs when the velocity is > 180 cm/s is sufficient to direct clinical management
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
16.67%
33.33%
33.33%
16.67%
0.00%
Strongly agree
Agree
Neither agree nor disagree
Disagree
Strongly disagree