Utility of Viscoelastic Hemostatic Analysis During Postpartum Hemorrhage

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Abstract:

Postpartum hemorrhage (PPH) remains a leading cause of maternal morbidity and mortality worldwide. Traditional coagulation tests (TCT) have limitations in diagnosing and managing PPH effectively, prompting interest in viscoelastic testing (VET) for its potential to improve patient outcomes. This study aimed to assess anesthesia providers' knowledge, attitudes, and acceptance of perioperative VET during PPH and develop a practice guideline for its implementation. A mixed-methods research design was employed, including pre/post-intervention surveys to measure the effectiveness of an educational intervention. The study found a significant improvement in participants' knowledge and attitudes towards VET post-intervention, despite lingering concerns about cost and the need for further research. While the proposed VET protocol was not immediately adopted, the study underscores the importance of continued education and advocacy for VET in maternal healthcare. Further research is warranted to address barriers and enhance VET utilization in clinical practice.

Background and Significance:

The leading cause of maternal morbidity and mortality worldwide is postpartum hemorrhage (PPH) (Liew-spilger et al, 2021). During an obstetrical hemorrhage, the provider should suspect one of four common etiologies: retained placental tissues, uterine atony, trauma of the birth canal, and coagulopathy (Afshari et al., 2015). In addition to surgical interventions and uterotonics, PPH's two main management strategies to achieve hemostasis are massive transfusion protocol (MTP) and viscoelastic testing (VET). The traditional method is empiric treatment with MTP and augmentation with standard coagulation tests (PT/INR and aPTT). However, MTP may result in the transfusion of unnecessary blood products and lead to further complications such as fluid volume overload, anaphylaxis, and transfusion-related acute lung injury (Waters, 2020), (Barclay et al., 2019), (Baumgartner et al., 2019). In addition, when standard coagulation tests are used during MTP to characterize coagulopathy with improved granularity, they provide little value during acute hemorrhage as they have a long turnaround time and often result after hemostasis has occurred (Rigouzzo et al., 2020) (Ahmadzia, 2020).

Furthermore, standard coagulation tests frequently fail to adequately describe the cause of bleeding diathesis (Butwick & Goodnough, 2015). For these reasons, there has been increased interest in using viscoelastic testing to diagnose coagulopathy and provide targeted blood product administration to achieve hemostasis. Studies have shown that VET can promptly detect changes in hemostasis, reduce the number of blood products transfused, and reduce the risk of mortality during PPH (Ahmadzia, 2020), (Barclay et al., 2019), (Baumgartner et al., 2019). These advantages result in reduced resources required to achieve improved patient outcomes, suggesting a trend to superiority compared to standard clotting tests.

Purpose:

This project aims initially to determine anesthesia providers' knowledge, attitudes, and acceptance towards perioperative viscoelastic testing during postpartum hemorrhage before and after an educational presentation in an urban hospital. An additional objective will be to develop a practice guideline for using viscoelastic testing to manage postpartum hemorrhage and evaluate any perceived barriers to the guideline implementation and future development. The effectiveness of the educational exposition will be measured using a 10-point pre/post-intervention questionnaire.

Review of Current Evidence:

In most facilities, traditional coagulation tests (TCT) are currently the primary modality for defining and characterizing coagulopathy in parturients. These tests measure aspects of the intrinsic and extrinsic coagulation cascade and include D-dimer, Partial Thromboplastin Time (APTT), Prothrombin Time (PT), and International Normalized Ratio (INR) values. The main advantages of using traditional coagulation assessment methodology are its wide availability and demonstrated track record for quality control and reproducibility (Liew-Spigler et al, 2021). Unfortunately, these tests have low sensitivity for the differentiation and diagnosis of coagulopathy because their initial intended use was to evaluate the therapeutic effects of heparin and vitamin K antagonists (Butwick & Goodnough, 2015). Standard coagulation tests are inferior in diagnosing bleeding diathesis because PT and INR parameters do not predict whether patients will bleed excessively, nor does a normal INR rule out coagulopathy (Collins et al., 2018). The lack of predictive value of TCT limits the efficacy and pre-emptive treatment options available to the patient. This inherent weakness of TCT indicates the need to improve existing models to increase their sensitivity and predictive value. However, given the convenience and familiarity many providers have with existing protocols, the transition to a more accurate and descriptive system will require a clear strategy for implementation.

While most healthcare facilities already possess the lab equipment necessary to process TCT and do not require additional staff training, the turnaround times for these tests are long. In most clinical settings, a result may not be available for 45 to 60 minutes or more (McLintock, 2020). In rapidly evolving life-threatening hemorrhages, such as those seen with cardiac surgery, trauma, and postpartum hemorrhage (PPH), TCT may not provide actionable information until after hemostasis has occurred and may be of little use. As a result, many clinicians rely on massive transfusion protocols (MTP) and clinical judgment to guide transfusion therapy. Furthermore, as confirmed by Amis et al. (2015), there is no high-level evidence from randomized controlled trials to indicate the usefulness of TCT in diagnosing coagulopathy or guiding blood transfusion therapy.

Improved turnaround times:

In PPH, expeditious lab results allow providers to make evidence-based decisions, leading to better patient outcomes. Point-of-care testing through viscoelastic hemostatic assay analysis exhibits profound benefits in this situation. Viscoelastic testing allows for rapidly detecting hypofibrinogenemia and thrombocytopenia compared to TCT, facilitating prompt treatment (Rigouzzo et al., 2020), (Ahmadzia, 2020). Similarly, McLintock (2020) noted that TEG® can be used to assess global hemostasis with lab values available to the clinician within 10-20 minutes. Viscoelastic assays can allow providers to make near-real-time decisions based on objective information. These tests also display data graphically, allowing a trained provider to quickly evaluate multiple aspects of the clotting cascade, such as the activity of clotting factors, the amount of fibrin available for clotting, and the clot's resistance to fibrinolysis.

Improved Outcomes:

TEG®and Rotational Thromboelastography (ROTEM®) provide therapeutic advantages when treating postpartum hemorrhage. By measuring the viscoelastic properties of whole blood in near-real-time, clinicians can deviate from the formulaic algorithms recommended through the MTP and provide goal-directed blood transfusion therapy. In targeted blood administration practices, clinicians can limit the number and kinds of unnecessary blood products transfused

(Baumgartner et al., 2019). Waters (2020) demonstrated a 98% reduction in plasma transfusion for 605 women experiencing moderate to severe hemorrhage. Snegovskikh et al. (2018) compared the postoperative outcomes of patients experiencing postpartum hemorrhage. One group received TEG® guided blood transfusion, and the control group received MTP with TCT. There was a significant reduction in the total number of blood products transfused for the group receiving viscoelastic assay-guided blood product administration, as well as a reduction in the volume of transfused blood products, episodes of pulmonary edema, and ICU admissions (Snegovskikh, 2018), (Afshari, 2015). As blood products are often in short supply, clinicians should employ conservation methods. Goal-directed blood product administration through viscoelastic analysis can decrease patient complications and conserve vital resources.

Transfusion triggers:

Viscoelastic assays have the advantage of accurately predicting the incidence of postpartum hemorrhage. Collins et al. (2018), Grottke et al. (2020), and Butwick et al. (2015) all confirmed that a decrease in fibrinogen levels (<2g/L) as measured by viscoelastic testing (TEG® MA <12mm or FIBTEM A5<12mm), was associated with progression to severe postpartum hemorrhage. Cunningham et al. (2022) verified these results and coincided with a study performed by Barclay et al. (2019), demonstrating an association between MA levels <12mm and postpartum hemorrhage. Barclay et al. (2019) and Grottke et al. (2020), using individualized goal-directed transfusion therapy, demonstrated that treatment with fibrinogen concentrate resulted in a statistically significant reduction in morbidity and mortality.

Preventative applications:

Investigators have been evaluating the value of preemptive treatment with tranexamic acid [TXA] following viscoelastic analysis. Liew-Spilger (2021) and Cunningham (2022) noted that viscoelastic analysis can help identify patients at risk of postpartum hemorrhage, treat them prophylactically with TXA, and limit blood loss in the peripartum period. Ahmadzia et al. (2020) and Afshari et al. (2015) verified that viscoelastic testing could be valuable in the risk categorization of patients preoperatively and in identifying the need for prophylactic treatment; however, in their studies, there was no increase in mean clot firmness (MCF) or clotting time (CT) for healthy nonpregnant, healthy pregnant, or obese pregnant women. The preeclamptic population was the only group that saw a significant increase in MCF after TXA administration. These findings highlight the importance of developing patient-specific protocols to aid clinicians and provide the most appropriate care for each patient.

Limitations and Barriers:

A significant limitation to implementing this technology in obstetrics is the lack of a universal definition for postpartum hemorrhage. Various endpoints for the classification of postpartum hemorrhage exist and include hemoglobin and blood loss thresholds, which vary depending on the source of information (Liew-Spilger et al., 2021), (Baumgartner et al., 2019). Further confounding the issue is a lack of internationally accepted transfusion triggers for both TEG® and ROTEM® (Liew-Spilger et al, 2021) (Baumgartner et al., 2019). The absence of large randomized controlled trials, poor understanding, and incorrect data interpretation stemming from a lack of training in viscoelastic testing are barriers to widespread acceptance of the technology (Ahmadzia et al., 2020), (Collins et al., 2018).

Theoretical model:

The Johns Hopkins Nursing Evidence-Based Practice (JHNEBP) model is the most appropriate framework for this initiative. The project started with an inquiry regarding current practice guidelines surrounding PPH at an urban hospital. It will also require forming a multidisciplinary team that includes key stakeholders such as the medical directors from the anesthesia and obstetrics departments. Furthermore, to progress this project into the implementation stage, a thorough and robust discovery phase is needed to compile evidence to support a practice change. As supported by evidence, the change will need to be evaluated by measures defined by the PICO question. Future development and large-scale implementation should lead to best practices and practice improvements. Utilizing this framework to develop a VET protocol will ensure the reliability of the project and adherence to best practices by supporting evidence-based medicine. Gaining assistance from key stakeholders is a crucial step in the project's progression and will determine the project's scope. The research project question that will guide discovery is" Will an educational intervention and development of a practice guideline (I) increase the use of VET (C) vs. standard assessment of coagulation by anesthesia providers (P) to improve knowledge and performance on a post-intervention questionnaire (O)? This year (T)?"

Materials and Methods:

The first step in the evidence-based practice process is to generate the P (population), I (intervention), C (comparison), and O (outcome) questions leading to the best relevant information in the current literature. The PICO question for this project was "Will an educational intervention and development of a practice guideline (I) increase the use of VET (C) vs. standard assessment of coagulation by anesthesia providers (P) to improve knowledge and performance on a post-intervention questionnaire (O)? This year (T)."

Project Design:

This project will utilize a mixed methods research design encompassing qualitative and quantitative data analysis components. The effectiveness of the intervention will be measured using a pre-post-intervention survey. The initiative will utilize convenience sampling of anesthesia providers for data retrieval. Participants will be recruited in person at the commencement of the educational offering.

Translational Framework:

Change theory will be used as the theoretical basis for the investigation. Change theory has three guiding principles. The first is identifying the key stakeholders and developing a collaborative approach to reflect understanding. The second principle is that the investigation should be guided by, tested, and revised based on current evidence. The final principle is that the project should support continuous learning at all stages to encourage improvement. This approach correlates with the aims of this investigation, as the first stage will require collaboration with key stakeholders. Individuals initiating a practice change include the Chief Certified Registered Nurse Anesthetist (CRNA), Anesthesiologist Department chief, and CRNAs and Anesthesia Assistants. A thorough and robust literature review will be performed to compile all current evidence to support the goals and objectives of the project. Continuous learning for all project stages will be maintained through constant inquiry.

Search Strategy:

A literature review was performed using a free text search with restrictions of randomized control trial and meta-analysis performed on pregnant women. The search was restricted to articles in English and included articles from PubMed, CINAHL, and Scopus. The search was conducted with dates of publication between 2015 and 2023. Articles were selected based on the evaluation of viscoelastic hemostatic analysis during postpartum hemorrhage and at-risk patients. Only full-text peer-reviewed studies were incorporated. Search terms included "viscoelastic," "obstetrics," "postpartum hemorrhage," "TEG," "thromboelastography," "ROTEM," "FIBTEM," and "rotational elastography."

Exclusion Criteria were editorials, expert opinions, and articles that did not have free full text.

By searching the three databases and utilizing other methods, such as reviewing reference lists, 54 articles were found. From the total, 24 were eliminated as duplicates, and the remaining 30 were screened for title and abstract. Based on the inclusion and exclusion criteria, an additional ten were removed. The remaining 20 articles were assessed for eligibility, and four were excluded because they evaluated cardiac and trauma patients.

Sample and Setting:

The sample participants will be the anesthesia staff at an urban hospital in North Carolina that take part in the educational offering and survey. The population under investigation is the anesthesia staff at an urban trauma center in the southeastern U.S. that participates in caring for obstetrics patients. Recruitment will be carried out before the initiation of the presentation. Additional or repeat presentations may be necessary to ensure a larger enough sample for thorough data analysis. However, there are no similar projects at comparable facilities to conclude effect size or anticipated variance. Therefore, the minimum number of participants required to power the project to at least 80% is unknown.

The process for the selection of the investigation site was guided by identifying a facility with the resources and staff to operate VET. A large level-one trauma center with high-risk obstetric patients was also required to facilitate the need for VET analysis.

Data Collection:

This author developed the survey by drawing from existing literature and with the guidance of faculty at the University of North Carolina in Greensboro. Implementation of the project began with a pre-intervention survey to reveal the understanding and knowledge base of the anesthesia staff at the facility regarding (VET). Following the pre-intervention evaluation, the primary investigator presented a summary of evidence supporting the utilization of the VET in PowerPoint form over approximately 15 minutes. Details concerning when to initiate VET and the appropriate interventions as guided by VET parameters was described. The presentation culminated in delineating the evidence-based VET protocol for postpartum hemorrhage. After the presentation was completed, a post-survey evaluation was administered that contained identical knowledge-based questions regarding the use of thromboelastography and the adoption of the clinical guideline.

IRB Approval:

This project was submitted to the Internal Review Board (IRB) at the project site and through the University of North Carolina Greensboro IRB to ensure the integrity and protection of the project participants. Exempt status for both IRB entities was granted as the initiative was considered a quality assurance and quality improvement project (QA/QI). Anonymity for respondents for the pre-and post-intervention survey was maintained by requesting the participant enter the first name of both parents and the two-digit number associated with their birth month.

Measurement Methods:

The survey used to evaluate the anesthesia staff at an urban hospital in North Carolina was developed explicitly for this purpose. Content validity was maintained by ensuring the survey was representative of all aspects of the initiative as guided by the PICO question. Specific reliability was preserved by administering identical pre- and post-survey questions to the participants. Validity was maintained by writing questions appropriate to assess a knowledge gap based on the educational offering.

The pre-and post-questionnaires will be paired but will maintain the anonymity of the participants. consisted of three sections. Section A captured the respondents' demographic information, such as years of experience and degree type (i.e., Anesthesia Assistant (AA), Master of Nursing (MSN), Doctor of Nursing (DNP), and Medical Anesthesiologist (MDA). Section B was developed to explore the participants' knowledge about perioperative VET use and interventions based on results. Section B consisted of four multiple-choice questions. Each correct answer was worth one point. The maximum points a participant could score was four, while the minimum was zero. Section C explored the attitudes and potential barriers to implementing a VET-guided transfusion protocol during PPH. It consisted of four statements regarding TCT, along with VET use in the perioperative setting, which respondents could select to agree or disagree on a four-point Likert scale (1- strongly agree, 2- agree, 3- disagree, 4- strongly disagree). These questions focused on evaluating the attitudes of providers regarding the cost and clinical benefits of VET as well as provider comfort with the interpretation of VET results.

Data Analysis:

The number of respondents who participated in the survey was 15. The primary outcomes were analyzed as knowledge base improvement and increased likelihood of adoption of VET in future practice. Secondary outcomes were measured as the influence of the number of years and degree type on current understanding and barriers to future implementation.

Data for the responses was collected from the paper surveys and entered electronically into Excel spreadsheets for statistical analysis. Descriptive statistics were utilized to develop frequencies and proportions for categorical data, such as attitude towards VET, sociodemographic, and professional experience information. The most appropriate statistical method for evaluating the effectiveness of the educational presentation on improving the functional knowledge regarding VET would be a non-parametric assessment like Mcnemar's test. However, due to the previously described grading system for the knowledge section of the survey, most answers would cancel out, leading to a very small sample size. Therefore, in collaborating with a statistician at the University of North Carolina Greensboro, it was determined that a paired sample t-test would provide the most relevant statistical analysis.

Results:

Evaluate Outcomes:

There were 20 anesthesia clinicians present at the time of the didactic presentation. Of the 20 responses collected 15 were complete (i.e., each question in sections A through C was answered) and thus were used for analysis (response rate of 75%). At the same time, the five incomplete surveys were discarded and not incorporated into the data set.

Section A – Demographics

The number of years of professional experience of respondents along with the degree type for the practitioner are displayed in Table 1.

Table 1: Sociodemographic and professional characteristics of survey participants, n = 15

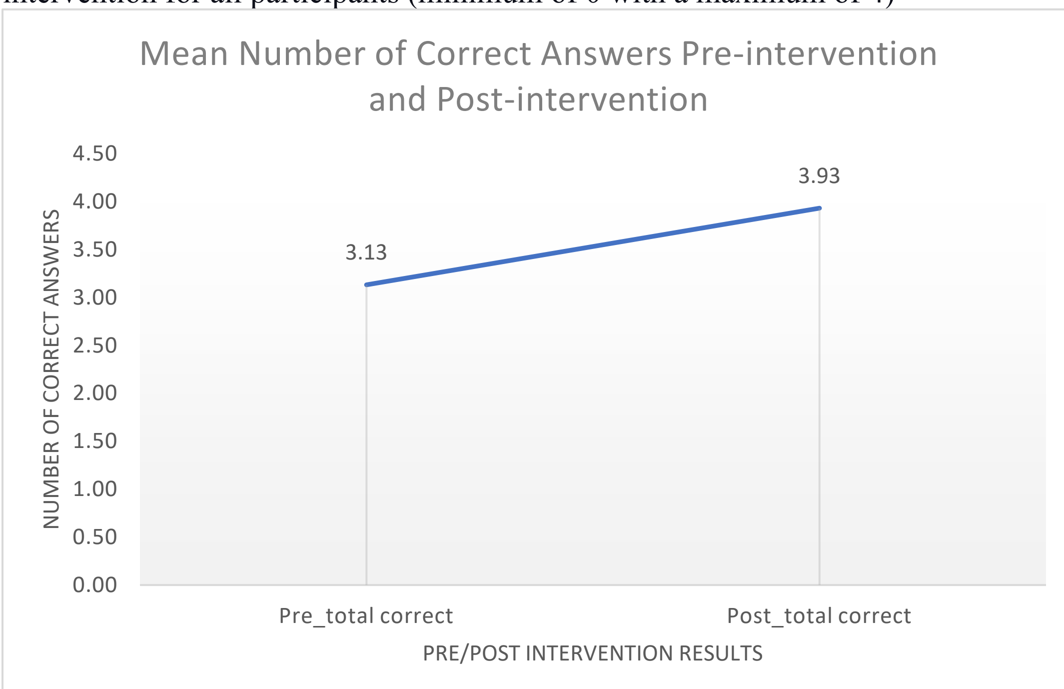
Characteristic	Frequency (%)
Years of Experience	
< 3 Years	3 (20)
3 – 10 Years	8 (53.3)
> 10 Years	4 (26.7)
Degree Type	
MDA	1 (0.67)
DNP	4 (26.7)
MSN	6 (40)
AA	4 (26.7)

Legend: (MDA: Medical Anesthesiologist; DNP: Doctor of Nursing Practice; MSN: Master of Nursing; AA: Anesthesia Assistant)

Section B – VET knowledge

Statistical analysis revealed the average score for the 15 participants on knowledge-based questions regarding VET was 78.3% before the commencement of the educational presentation. Following the intervention participants selected the correct answer choice 98.3% of the time. The p-value of 0.017 indicates a statistically significant increase in the basic knowledge of VET along with appropriate interventions.

Figure 1: Mean number of correct answer choices before and after educational intervention for all participants (minimum of 0 with a maximum of 4)



Section C – Attitude and Perceived Barriers Regarding VET

Figure 3 and Figure 4 summarize the spectrum of responses (labeled Q1-Q3) to questions presented to participants in section C of the questionnaire. Question 1 explored whether respondents believed TCT provided sufficient information about the patient's perioperative coagulation status. Before the educational intervention, 11 participants, or 73% of those surveyed, believed that TCT was sufficient. This contrasts with the post-survey group where the majority (53%) disagreed with the statement. The majority (66.7%) of pre-intervention survey respondents in question 2 indicated that they did not believe VET was too expensive to implement as part of a standardized perioperative management protocol. Interestingly, in the post-survey responses, there was an increase in the number of participants who believed VET was too costly for ubiquitous use within the facility. Unsurprisingly, all participants believed that VET could reduce morbidity and mortality both pre and post-intervention. However, the number of participants who strongly believed in this potential reduction in morbidity and mortality doubled from 20% to 40%.

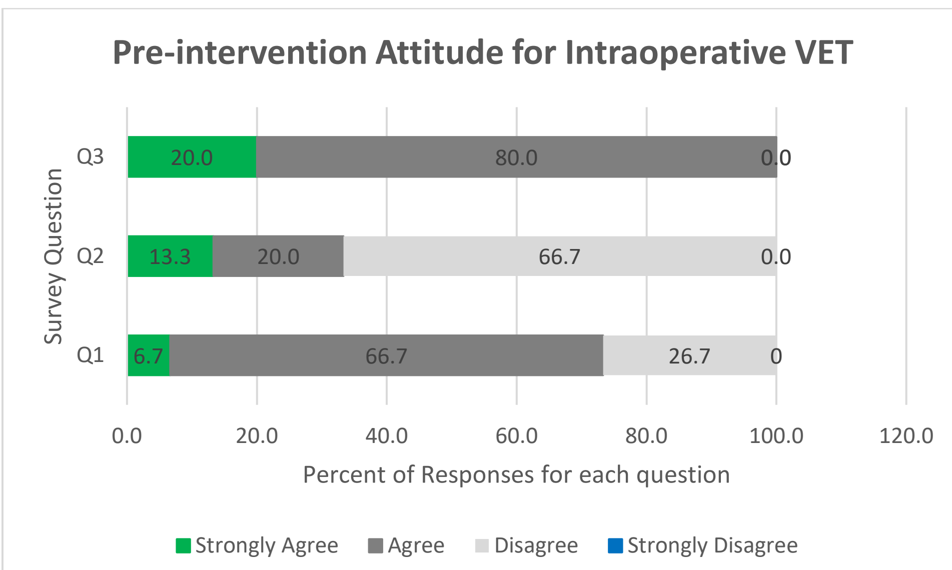


Figure 3: Divergent stacked bar graph summarizing the breakdown of responses for each respective statement in Section C of the Survey before intervention.

Q1 - common coagulation tests provide me with sufficient information about a patient's perioperative coagulation profile

Q2 - TEG is too costly to have as part of a standardized perioperative patient management protocol

Q3 - TEG can lead to decreases in morbidity and mortality for obstetric patients at my hospital if implemented properly

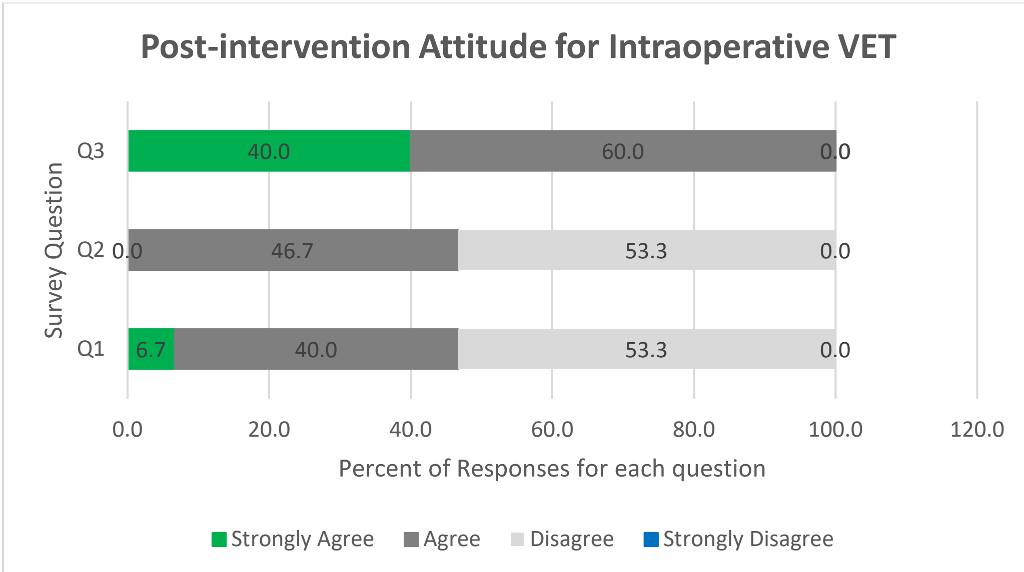


Figure 4: Divergent stacked bar graph summarizing the breakdown of responses for each respective statement in Section C of the Survey after intervention.

Q1 - common coagulation tests provide me with sufficient information about a patient's perioperative coagulation profile

Q2 - TEG is too costly to have as part of a standardized perioperative patient management protocol

Q3 - TEG can lead to decreases in morbidity and mortality for obstetric patients at my hospital if implemented properly

Several perceived obstacles to implementing a practice guideline for VET in PPH exist. In the pre-intervention survey participants, a third indicated that they were uncertain of a clinical benefit, another third indicated that the cost was too high for protocolization, and the final third specified that the major barrier to further implementation was a lack of confidence in their ability to interpret the results of VET appropriately. As depicted in Figure 5, there was a shift in perception regarding VET following the educational intervention, and 5 of the 15 (33.3%) participants no longer had any perceived barriers to implementation. Again, data from Figure 5 demonstrates an increase in concerns regarding the cost of VET in the perioperative area, and 2 out of the 15 (13.3%) still demonstrated uncertainty regarding the clinical benefits. No responses suggested a lack of confidence in their ability to interpret VET.

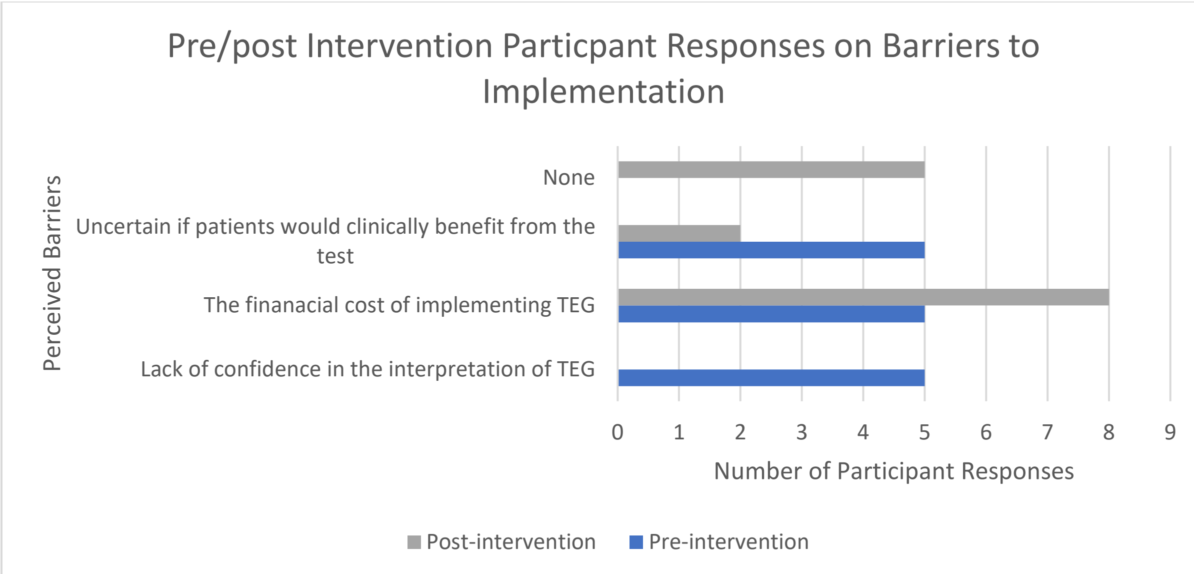


Figure 5: Cluster bar graph summarizing the participants' perceived barriers to VET implementation before and after educational intervention.

Identify Barriers to Success

During the implementation of this project, several barriers were encountered. Some of the major expected barriers were concerns about the costs of VET, the knowledge gap for provider interpretation of results, and fostering a paradigm shift away from TCT. Based on the survey results, a leading barrier that must be addressed before the protocol can be adopted is ensuring that staff and primary stakeholders know that TEG is economical. As this issue was addressed during the educational presentation, there is a clear disconnect. A potential method to ameliorate this barrier could be using case studies highlighting TEG's financial advantage over TCT and making the topic more tangible. By creating a direct correlation between the patient experience and the interventions used, providers may be more receptive to the change.

Furthermore, following the educational intervention, participants indicated a continued hesitation regarding clinical benefits for patients treated with TEG compared to TCT. Additional educational materials, such as an information note card depicting the head-to-head comparison between TEG and TCT, may improve some misgivings surrounding the hospital-wide adoption of the practice guideline.

An additional barrier that may need to be dismantled to increase the potential for acceptance of a VET guideline for PPH is to improve integration into current clinical pathways. Incorporating viscoelastic testing into existing clinical pathways and guidelines for PPH management can help promote its routine use and facilitate its integration into clinical practice.

Multidisciplinary collaboration between obstetricians, hematologists, anesthesiologists, and other relevant healthcare professionals could help promote interdisciplinary approaches. Ensuring a multidisciplinary team that includes healthcare providers outside of the anesthesia specialty could aid in fostering a practice change guided by the most recent evidence.

While all the evidence supports using VET in PPH, large multicenter randomized controlled trials still need to be conducted. This culminates in a lack of definitive transfusion triggers, which could result in wide variations in treatment recommendations. Therefore, it is essential to support further research and clinical studies to generate robust evidence demonstrating the clinical utility and cost-effectiveness of viscoelastic testing in PPH management. This can help establish clear guidelines and best practices for its use in clinical practice.

Identify strengths to overcome the barriers

A significant strength of the project was the open lines of communication between the project advisor and the chief CRNA at the hospital which allowed for expedited processing of the IRB application and subsequent scheduling for the initiative. For future projects that focus on progressing a similar goal, it would be prudent to lean on these relationships and ensure the participation of all stakeholders. This may improve the success of any forthcoming projects.

Another strong element of the project was the educational style, which garnered robust participant engagement and resultant retention of information, as evidenced by the improvement of post-presentation knowledge-based questions. Building on that foundation, future projects may be beneficial to direct more time toward dispelling the concerns regarding the cost of using VET.

Discussion

The main finding of this project was that an educational intervention improved participants' knowledge and performance on a post-intervention questionnaire. Additional findings included increased provider confidence regarding interpreting and consequent clinical implications of VET analysis. Furthermore, most respondents had a positive attitude towards perioperative VET following the intervention. Participants acknowledged its ability to reduce morbidity and mortality and provide enhanced granularity on the coagulation profile of surgical patients. Before the intervention, the identified barriers to the application of VET were wide-ranging and included issues with cost, uncertainty with clinical benefits, and lack of confidence in interpretation. Following the intervention, many of these concerns were addressed, but there was a sharp increase in concern among participants that the test was too expensive to be incorporated into a hospital-wide protocol during PPH. The cost associated with VET was a focus of the presentation, and references to contemporary literature with results supporting a reduction in overall patient cost were cited. However, to date, only one study has evaluated the cost-effectiveness of VET compared to TCT. More research in this area is warranted to support its use during PPH.

Reflecting on the theoretical model employed to develop this initiative a fundamental failure can be identified. Participation by senior stakeholders, a core component of the JHNEBP model, needed to be bolstered during the project's implementation phase. Therefore, despite providing evidence to support the use of VET during PPH, which resulted in increased knowledge and acceptance of the improved patient outcomes, the facility did not adopt the protocol. As such, the project did not impact maternal morbidity and mortality.

Conclusion:

Based on the results of this project, an educational presentation regarding VET is directly beneficial for practicing anesthesia clinicians. There were increases in both provider knowledge and confidence with result interpretation. The participants acknowledged there was a conferred mortality benefit to those who received VET-guided transfusion protocols. Even though the proposed VET protocol was not adopted. The anesthesia providers appear willing to increase their utilization of VET in this patient population. However, it would be pragmatic to reinforce the concept that VET testing can reduce admission for hospitalized patients who receive blood transfusions. Given the paucity of evidence in this area, more research may be warranted to improve support among anesthesia providers.

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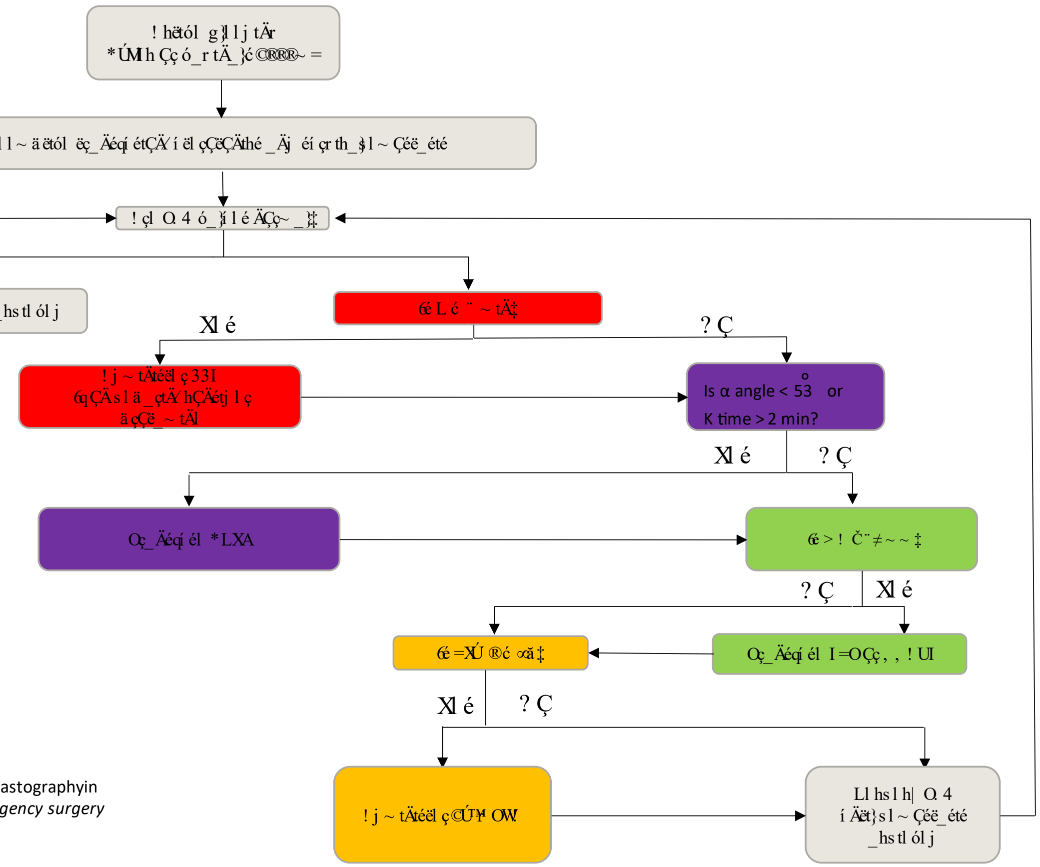
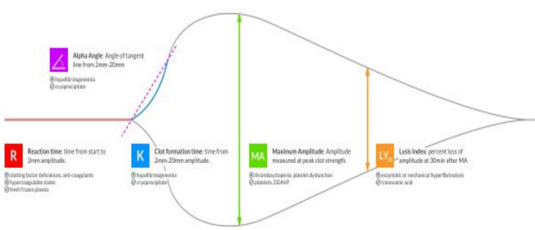
Appendix A

Proposed VET Protocol for PPH





Modified from Li,et al (2014). Goal-directed transfusion protocol via thrombelastography in patients with abdominal trauma: a retrospective study. *World journal of emergency surgery WJES*, *9*, 28. https://doi.org/10.1186/1749-7922-9-28

This practice guideline is intended to be used as a reference during the management of PPH. This flow chart begins with active bleeding originating from either a vaginal delivery or following cesarean section that is estimated to be equal to or greater than 1000 mL with associated signs and symptoms of hemodynamic compromise. These include but may not be limited to tachycardia, hypotension, tachypnea, change in mental status, and diaphoresis. If the hemorrhage is uncontrolled and ongoing, initial interventions should include attaining the patient's coagulation status. Fluid volume resuscitation and preemptive transfusion should not be delayed while awaiting VET values. In addition, surgical hemostasis and appropriate uterotonics must be administered. As soon as VET values are available, the provider should first evaluate the reaction time (R), as noted by the red box. If this value is abnormal (greater than 4 mins), the provider will follow the arm to the left and begin correcting this abnormal value by administering fresh frozen plasma (FFP). After administering FFP or if the R time was normal (< 4 mins) the provider will evaluate the purple box. This box addresses the alpha angle (α) and Kinetic time (K). If the α and K are less than 53° or greater than 2 mins, respectively, the most appropriate action is transfusing cryoprecipitate. After administering cryoprecipitate or if the α and K are normal, the provider should next evaluate the green box, which addresses the maximal amplitude (MA). If the maximal amplitude is less than 45mm of displacement, the provider should transfuse platelets or desmopressin (DDAVP). Following the transfusion of platelets or DDAVP, or if this value is normal (>45mm), the provider must next evaluate the lysis 30 index (LY-30), highlighted in yellow. If the LY-30 is greater than 8%, the provider should consider administering a procoagulant therapy such as tranexamic acid (TXA). This process of sending serial TEGs and transfusing appropriate blood products should continue until hemostasis or futility has been concluded.