Clinical Uses and Limitations of the FloTrac Monitoring System

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Abstract

Background: The Edwards Lifesciences FloTrac Monitoring System can be utilized in the operating room to improve patient outcomes with the use of continuous measurement of hemodynamics. Those measurements can be used to help determine a patient's fluid status or cardiac function. Student registered nurse anesthetists often have a lack of understanding and familiarity with FloTrac. The aim of this study was to educate those SRNAs with a PowerPoint presentation and increase their ability to utilize FloTrac.

Methods: After informed consent was obtained, a convenience sample of 23 SRNAs at Adventist University of Health Sciences were given a 10-question test. A PowerPoint was then presented to the participants. At the conclusion of the PowerPoint, the SRNAs were given the same 10-question test. The tests were graded, and those numbers were then analyzed.

Results: The mean score of the pretest was 3.8696, while the posttest was 8.4348. The standard deviation of the pretest was 1.86607 and the posttest was 1.07982. The obtained t value was -9.991, which is associated with a $p < 0.05$. This is considered statistically significant.

Conclusions: The statistics show that the SRNAs demonstrated a significant increase in their knowledge and understanding of FloTrac. The participants may now have the understanding and confidence needed to appropriately utilize FloTrac in the clinical setting. Hopefully, this will lead to an increase is patient safety.

Table of Contents

ABSTRACT **2**
PROBLEM **4**
REVIEW OF LITERATURE **6**
PROJECT DESCRIPTION **12**
EVALUATION **13**
RESULTS AND CONCLUSIONS **14**
REFERENCES **15**
APPENDIX A (CONSENT FORM) **17**
APPENDIX B (PRE & POST TEST) **19**
APPENDIX C (POWERPOINT) **22**

Problem

The Edwards Lifesciences FloTrac Monitoring System (FloTrac) is a minimally invasive monitor that can be utilized in the operating. It can be attached to an existing arterial line (A-line) and displays continuous hemodynamic measurements. It is a valuable tool that can be utilized by Student Registered Nurse Anesthetists (SRNAs) in a variety of different cases; unfortunately not every SRNA is comfortable with this system. Many SRNAs may have used the system during their critical care experience as registered nurses (RN), however many have never worked with this technology prior to their experience in the operating room (OR).

There appears to be both a lack of understanding and a lack of experience using Flotrac. There also seems to be a lack of knowledge concerning when you should use Flotrac, how to set the machine up, and in which situations your values are going to be reliable or unreliable. This project is important because it will fill a knowledge gap for SRNAs and enable them to become better practitioners and provide better care for their patients going forward. It is important to understand the types of procedures that Flotrac will be of significant benefit and to which procedures it may not provide substantial benefit, but using up valuable resources. Factors such as blood pressure, heart rate/rhythm, patient positioning, previous medical and surgical histories, etc. may all be important in determining the benefits of using FloTrac.

Problem Statement: Student registered nurse anesthetists have a lack of clinical familiarity and understanding concerning Edwards Lifesciences FloTrac Monitoring System, which has lead to a knowledge deficit about its setup, implications, contraindications, and use. These deficiencies may lead to underutilization of FloTrac and may lead to incorrect and possibly harmful interventions based on inaccurate values and/or interpretations of those values.

A PowerPoint presentation may help to alleviate these issues and provide the knowledge necessary for SRNAs to provide better, safer care to their patients in the future.

Review of Literature

Accurate fluid resuscitation is an important part of providing safe anesthesia. Through maintaining optimal tissue perfusion and stable hemodynamics during surgery, it has been shown to result in faster recovery times and shorter hospital stays, as well as improved patient stability during a given procedure. (www.edwards.com)

The FloTrac sensor and Vigileo monitor are important tools used to help provide the anesthetist with valuable information to aid in the treatment of patients undergoing surgery. The monitor provides valuable information regarding fluid volume status and cardiac output (CO), all the while being much less invasive than the traditional methods of obtaining these same values. These methods include the use of a pulmonary artery catheter and echocardiography, which cannot always be performed or readily interpreted.

In a study by Vasdev et al. (2012) it was concluded that barring patients meeting exclusion criteria for the monitor, such as aortic regurgitation, the arterial pressure waveform derived cardiac output (CO) from the FloTrac system, software version 3, showed good correlation with pulmonary artery catheter (PAC) derived cardiac output in both the radial and femoral sites.

A 2011 study in Australia found CO measurements from the FloTrac to be clinically comparable to transthoracic Doppler echocardiography in critically ill patients (McLean, Huang, Kot, Rajamani, & Hoyling, 2011). FloTrac is a useful tool to the anesthetist, as it is one of only a few pieces of equipment capable of providing continuous CO values. There are a few noted limitations with the FloTrac system, primarily, inaccuracy with severe aortic stenosis and arrhythmias such as atrial fibrillation and frequent ectopy (McLean et al., 2011).

Edwards Lifesciences is continuously looking to improve its own devices. The algorithm that is used to derive values has been updated as more information becomes available and a larger patient database is collected. Each generation of software has improved the accuracy of FloTrac. The newest 4th generation algorithm has claimed the ability to account for some of the known limitations, mainly its ability to now filter out most arrhythmias. At the current time, Florida Hospital (the facility where the SRNAs do their training) is using the 3rd generation algorithm.

The FloTrac system analyzes the arterial pressure waveform by using an algorithm where stroke volume is relational to arterial pulsatility. The system calculates arterial pulsatility multiplied by vascular tone factor that translates flow as stroke volume. The vascular tone factor is calculated using several variables; age, sex, weight and height, according to the model described by Langewouters, Wesseling, and Goedhard (1985).

Early in its development, there was uncertainty of the validity of the values derived by the FloTrac system (Hamm et al., 2010). As stated previously, the system software has progressed through several versions improving accuracy and frequency of derived values. The third generation software added variables to the calculation of vascular tone making the device more accurate and able to adjust for hyperdynamic and vasodilated patients. It should be known that Edwards Lifesciences has not been willing to disclose their exact algorithms.

A number of studies have challenged the accuracy of the FloTrac system in various patients. According to Tejedor et al. (2015) the FloTrac system CO values were inconsistent with the thermodilution technique through a pulmonary artery catheter (PAC) in morbidly obese patients. These inconsistencies are thought to derive from changes in vasomotor tone, especially in the morbidly obese patients with co-morbidities.

Maeda et al. (2014) describes inaccuracy of FloTrac in patients with low cardiac index (CI) values, which was described as a CI less than 2.2L/min/m^2. Transesophageal echocardiography was the tool used to compare the CI numbers in this study. Finally, Monnet et al. (2012) described FloTrac's ability to accurately track changes in CI in critically ill patients induced by volume expansion, however, changes in CI induced by norepinephrine were found to be inaccurate. The authors of that paper theorize the cause of this inaccuracy to be partly due to changes in vasomotor tone. In response to reduced CO, the endocrine system will activate a sympathetic response to cause vasoconstriction to maintain CO.

A 2011 study by Meng et al looked at the impact of phenylephrine, ephedrine, and increased preload on the 3rd generation Flotrac versus esophageal Doppler CO measurements. Most studies tend to compare Flotrac to thermodilution via pulmonary artery catheter, however the authors of this studied decided to use the Doppler because it can be utilized for beat-to-beat measurements whereas thermodilution takes considerable time to obtain values. This is important because thermodilution may not be able to accurately track rapid and transient changes in CO induced by vasopressors. All of the patients were under general endotracheal tube anesthesia with mechanical ventilation and were treated only if indicated by a decrease in MAP of >20% from baseline.

The study found that while both ephedrine and increased preload CO measurements correlated well with esophageal Doppler, phenylephrine CO measurements consistently trended in the opposite direction of Doppler measurements. The results revealed that CO was decreased after phenylephrine administration according to the Doppler, but it was increased with Flotrac. Since phenylephrine is a pure alpha-1 agonist, causing vasoconstriction, the authors attribute the findings to an inability of Flotrac to adequately account for changes in vasomotor tone. In the 4th

generation algorithm for FloTrac, Edwards Lifesciences claims greater ability to account for vasomotor tone due to a larger patient database. (www.edwards.com)

As a result of the new software and the claims made by Edwards, Suehiro et al (2015) conducted a study that compared the ability of 4th generation FloTrac and thermodilution to track changes in CO induced by increases in peripheral vascular resistance. They noted the aforementioned study by Meng et al (2011), as well as several others, concerning the 3rd generation software's inability to accurately track CO after administration of phenylephrine.

For this study, 23 patients who were undergoing elective cardiac surgery were observed. CO measurements were taken when MAP fell below 70 mmHg. One measurement was taken before phenylephrine administration while the other was taken 2 minutes after administration. All measurements were obtained before cardiopulmonary bypass was initiated. (Suehiro et al., 2015)

The results found that the 4th generation FloTrac software has greatly improved its ability to trach CO changes in response to changes in vasomotor tone. A couple of limitations were noted. One was that only 2 minutes after phenylephrine administration were allowed to pass before obtaining the second set of numbers. This amount of time may not have been adequate for the medication to take effect in all patients. Secondly, systemic vascular resistance index (SVRI) was noted in all of the patients prior to phenylephrine administration. They were to be categorized into low SVRI, normal SVRI, or high SVRI. The study did not yield any low SVRI results. Previous studies have shown that CO changes after giving phenylephrine differ between low and high SVRI states. Lastly, as described earlier, the inability of the thermodilution technique to obtain beat-to-beat measurements make it less ideal to track the rapid and transient changes in CO after vasopressor administration.

There are other devices on the market that work similarly to FloTrac. A study by Romagnoli et al (2013) compared the accuracy of cardiac output measurements by FloTrac and MostCare devices to traditional transthoracic echocardiographic cardiac output estimation in a prospective observational study. The study included 26 patients undergoing elective vascular surgery, carotid endarterectomy, both endovascular and open abdominal aortic aneurysm repair, and both open and endovascular peripheral arterial reperfusion.

The authors noted that the devices use different methods for deriving the calculated values, reflecting that the FloTrac method uses a 100Hz sample rate over 20 seconds, which yields 2000 data points, and a database of demographic and anthropometric data compared to the MostCare method of a continuous 1000Hz sample rate analyzing the entire cardiac cycle. The limitation of the MostCare method is the necessity of the device to be able to determine the dicrotic notch for correct interpretation. The authors noted that they had to incorporate the use of an adjustable damping device inline prior to the pressure transducer on eight of the subjects in order to get the MostCare to function, without accounting for the potential detriment this could have inflicted on the FloTrac devices ability to function properly. The study was forced to excluded one subject due to an extremely under dampened waveform.

Even though the authors did not account for the adjustable damping device and its effect on the FloTrac function, they concluded that the FloTrac system did not demonstrate to be reliable for CO monitoring when compared with TTE derived CO.

Most of the studies that have been conducted on the FloTrac system have used software versions 1, 2, or 3. As discussed earlier, Edwards Lifesciences has released a 4th version of the software for which there have been relatively few studies conducted. Further studies should be conducted to test the claims of the 4th generation algorithm to rapidly adjust to changes in

vascular tone, filter out arrhythmias, and the ability to be used on higher risk surgical patients (Edwards, n.d.).

Overall, the FloTrac system seems to be of value in a variety of intraoperative settings, but it can be challenging for the novice anesthesia provider to determine when to utilize this tool. This literature review, in combination with the manufacturer's recommendations, has allowed the authors to create a PowerPoint presentation that may lead safer patient care through increased knowledge.

Project Description

Prior to implementation, approval was granted from both the Scientific Review Committee and Institutional Review Board of Adventist University of Health Sciences (ADU). It was proposed to address the lack of understanding and clinical familiarity with FloTrac in SRNAs through the use of a PowerPoint Presentation. A convenience sample of 23 SRNAs from ADU was selected. After informed consent was obtained from all participants, an initial test of 10 questions (Appendix A) was administered to evaluate the level of comprehension and working knowledge prior to the PowerPoint Presentation.

The PowerPoint was presented, and through the use of verbal instruction and visual aid, aimed to educate SRNAs on the appropriate use of FloTrac. The PowerPoint covered mechanical/physical operation of the device – including setup and operation. It also addressed the critical thinking aspect of the operation of FloTrac, including appropriate patient selection, interpretation of data, and interventions/modifications to the plan of care. At the conclusion of the presentation, the same 10-question test was administered. Both the pretests and posttests were number coded to maintain anonymity.

Evaluation

The effectiveness of the presentation was evaluated through the graded responses of the participants on the tests. The end goal was an increase in the mean test scores of the SRNAs. Those increased scores will hopefully lead to an increase in the appropriate use of FloTrac in future practice, and a subsequent increase in patient safety.

The measurable outcome of this project was the test scores. To ensure the accuracy of the interpretation of those scores, they were sent to Roy Lukman, PhD to be analyzed. To be considered successful, the analysis of the results had to demonstrate a statistically significant increase in the mean scores between the pre- and post-tests.

Results and Conclusions

The mean score of the pretest was 3.8696, while the posttest was 8.4348. The standard deviation of the pretest was 1.86607 and the posttest was 1.07982. The standard error mean of the pretest was 0.38910, the posttests was 0.22516. The obtained t value was -9.991, which is associated with a $p < 0.05$. This is considered statistically significant.

It can be concluded that the average values between pre-test and post-test increased significantly and that the project was successful. The numbers indicate that the participants increased their working knowledge of FloTrac. The authors recognize that due to the increase in knowledge and understanding that there would be an increase in use and appropriate intervention by SRNAs, which has the potential to improve patient safety.

References

Hamm, J., Nguyen, B., Kiss, G., Wargnier, J., Jauffroy, A., Helaine, L., ... Gueret, G. (2010, March). Assessment of cardiac output device using arterial pulse waveform analysis, vigileo, in cardiac surgery compared to pulmonary arterial thermodilution. *Anaesthesia and Intensive Care*, *38*(2), 295-301. Retrieved from http://resource.adu.edu/login?url=http://search.proquest.com/docview/224827254?accountid=35793

Maeda, T., Yoshitani, K., Inatomi, Y., & Ohnishi, Y. (2014). Inaccuracy of the flotrac/vigileo system in patients with low cardiac index. *Journal of Cardiothoracic and Vascular Anesthesia, 28*(6), 1521-1526. http://dx.doi.org/10.1053/j.jvca.2014.04.013

Meng, L., Phuong, N., Alexander, B., Laning, K., Chen, G., Kain, Z., & Cannesson, M. (2011, October). The impact of phenylephrine, ephedrine, and increased preload on third-generation vigileo-flotrac and esophageal doppler cardiac output measurements. *Anesthesia and Analgesia*, *113*(4), 751-757. http://dx.doi.org/10.1213/ANE.0b013e31822649fb

Monnet, X., Anguel, N., Jozwiak, M., Richard, C., & Teboul, J. (2012). Third-generation flotrac/vigileo does not reliably track changes in cardiac output induced by norepinephrine in critically ill patients. *British Journal of Anaesthesia*, *108*(4), 615-622. http://dx.doi.org/10.1093/bja/aer491

Romagnoli, S., Ricci, Z., Romano, S., Dimizio, F., Bonicolini, E., Quattrone, D., & De Gaudio, R. (2013, December). Flotrac/vigileo (third generation) and mostcare/pram versus echocardiography for cardiac output estimation in vascular surgery. *Journal of Cardiothoracic and Vascular Anesthesia*, *27*(6), 1114-1121. http://dx.doi.org/10.1053/j.jvca.2013.04.017

Slagt, C., Malagon, I., & Groeneveld, A. (2014, January 14). Systematic review of uncalibrated arterial pressure waveform analysis to determine cardiac output and stroke volume variation. *British Journal of Anaesthesia*, *112*, 626-637. http://dx.doi.org/10.1093/bja/aet429

Suehiro, K., Tanaka, K., Mikawa, M., Uchihara, Y., Matsuyama, T., Matsuura, T., ... Nishikawa, K. (2015, June). Improved performance of the fourth-generation flotrac/vigileo system for tracking cardiac output changes. *Journal of Cardiothoracic and Vascular Anesthesia, 29*(3), 656-662. http://dx.doi.org/10.1053/j.jvca.2014.07.022

Tejedor, A., Rivas, E., Rios, J., Arismendi, E., Martiznez-Palli, G., Delgado, S., & Balust, J. (2015). Accuracy of vigileo/flotrac monitoring system in morbidly obese patients. *Journal of Critical Care*, *30*(3), 562-566. http://dx.doi.org/10.1016/j.jcrc.2015.01.015

Vasdev, S., Chauhan, S., Choudhury, M., Hote, M. P., Malik, M., & Kiran, U. (2012, February 17). Arterial pressure waveform derived cardiac output flotrac/vigileo system (third generation software): comparison of two monitoring sites with the thermodilution cardiac output. *Springer Science+Business Media*, *26,* 115-120. http://dx.doi.org/10.1007/s10877-012-9341-5

Appendix A

ADU NAP CAPSTONE PROJECT – INFORMED CONSENT

Our names are Adam Simpson and Jonathan Morris, and we are MSNA students in the Nurse Anesthesia Program (NAP) at Adventist University of Health Sciences (ADU). We are doing a Capstone Project called *Clinical Uses of the Vigileo™/Flotrac™ Monitoring System: A Teaching Module for Student Registered Nurse Anesthetists*. This project is being supervised by Dr. Steve Fowler. We would like to invite you to participate in this project. The main purpose of this form is to provide information about the project so you can make a decision about whether you want to participate.

WHAT IS THE PROJECT ABOUT?

The purpose of this project is to educate student registered nurse anesthetists about the Flotrac™/Vigileo™ Monitoring System. The teaching module will consist of general information about the system and also include some of its limitations.

WHAT DOES PARTICIPATION IN THIS PROJECT INVOLVE?

If you decide to participate in this project, you will be asked to complete an anonymous pre-assessment, attend a classroom presentation, and then complete an anonymous post-assessment. The assessment will address the information found in the teaching module. Your participation by attendance at the presentation and completion of the survey is anticipated to take approximately 30 – 45 minutes.

WHY ARE YOU BEING ASKED TO PARTICIPATE?

You have been invited to participate as part of a convenience sample of students currently enrolled in the ADU NAP. Participation in this project is voluntary. If you choose not to participate or to withdraw from the project, you may do so at any time.

WHAT ARE THE RISKS INVOLVED IN THIS PROJECT?

Although no project is completely risk-free, we don't anticipate that you will be harmed or distressed by participating in this project.

ARE THERE ANY BENEFITS TO PARTICIPATION?

We don't expect any direct benefits to you from participation in this project. The possible indirect benefit of participation in the project is the opportunity to gain additional knowledge about the Vigileo™/Flotrac™ Monitoring System.

HOW WILL THE INVESTIGATORS PROTECT PARTICIPANTS' CONFIDENTIALITY?

The results of the project will be published, but your name or identity will not be revealed. To maintain confidentiality of assessments, the investigators will conduct this project in such a way to ensure that information is submitted without participants' identification. The assessments will not contain any personal information, including your name. Instead, we will number code the assessments to match the pre and post assessments. Thus, the investigators will not have access to any participants' identities.

WILL IT COST ANYTHING OR WILL I GET PAID TO PARTICIPATE IN THE PROJECT?

Your participation will cost approximately 30 – 45 minutes of your time, but will require no monetary cost on your part. You will not be paid to participate.

VOLUNTARY CONSENT

By signing this form, you are saying that you have read this form, you understand the risks and benefits of this project, and you know what you are being asked to do. The investigators will be happy to answer any questions you have about the project. If you have any questions, please feel free to contact Adam Simpson (adam.simpson@my.adu.edu) or Jonathan Morris (jonathan.morris@my.adu.edu). If you have

concerns about the project process or the investigators, please contact the Nurse Anesthesia Program at (407) 303-9331.

Participant Signature **Date**

Participant Name (PRINTED LEGIBLY)

Appendix B

Questions used for the pre and post-tests.

1. Current implications for the use of FloTrac in the pediatric population include…?
    a. The values obtained will be the same as in an adult.
    b. The values obtained will be 10 – 15% lower than in an adult.
    c. The values obtained will be 10 – 15% higher than in an adult
    d. The use of Flotrac is currently not approved for pediatric use.
2. Stroke Volume Variation (SVV) is best used to assess what parameter?
    a. Afterload
    b. Preload Responsiveness
    c. Contractility
    d. Both A and B
3. You are utilizing FloTrac while caring for a 55-year-old male undergoing low anterior resection. Current hemodynamic readings include BP 85/42, HR 93, CI 1.8, and SV 55. You suspect your patient is dry and decide to give a 250 mL bolus of crystalloid. After your bolus is complete you notice the following readings; BP 94/47, HR 85, CI 1.9, and SV 65. What should you do next?
    a. Start a phenylephrine drip
    b. Start a milrinone drip
    c. Give an additional 250 mL bolus of crystalloid.
    d. Nothing, all of the parameters are within normal limits.

4. Which of the following is FALSE regarding traditional vital signs, heart rate, blood pressure, and central venous pressure?
    a. May be affected by compensatory mechanisms cloaking signs of hypoperfusion.
    b. May lose up to 18 % of blood volume before changes in blood pressure are seen.
    c. Blood pressure, central venous pressure and heart rate show considerable lack of sensitivity and specificity as predictors of fluid responsiveness
    d. Blood pressure and central venous pressure are an accurate reflection of adequacy of perfusion.
5. (T/F) When using FloTrac, a patient must be on positive pressure ventilation in order for your numbers to be accurate?
    a. True
    b. False
6. (T/F) Third generation software of the FloTrac system can filter out arrhythmias such as atrial fibrillation.
    a. True
    b. False
7. FloTrac displays numbers that have been obtained and calculated over a period of…?
    a. 5 seconds
    b. 20 seconds
    c. 1 minute
    d. 5 minutes

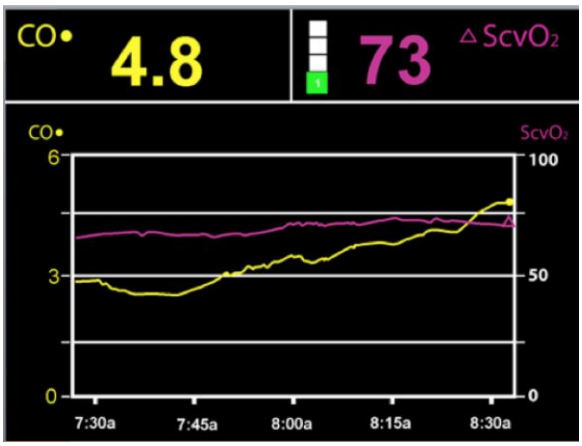
8. During mechanical ventilation, optimal tidal volume for accurate measurement of FloTrac parameters.
    a. ≥ 6 ml/kg
    b. ≥ 7 ml/kg
    c. ≥ 8 ml/kg
    d. ≥ 9 ml/kg
9. (T/F) FloTrac is a reliable indicator of CO after administration of vasopressors such as phenylephrine, ephedrine, and norepinephrine?
    a. True
    b. False
10. (T/F) The FloTrac system requires manual calibration?
    a. True
    b. False

Appendix C

Power Point Presentation

FloTrac monitoring system

Adam Simpson, RN, BSN
Jonathan Morris, RN, BSN
Project Chair: Steve Fowler, CRNA, DNP
Project Mentor: Frederick Norris IV, MD

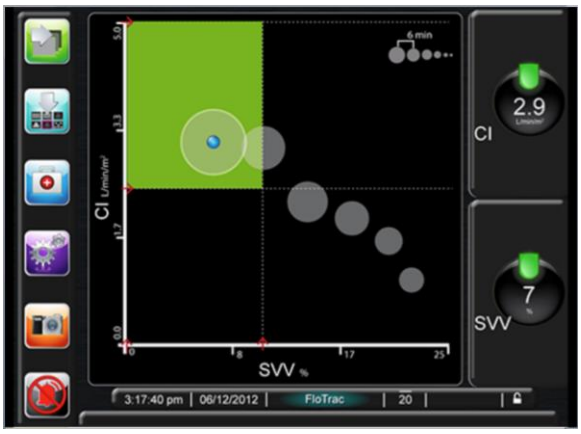


Why this project?

- Limited exposure prior to anesthesia school
- Increased utility as a monitor in certain procedures
- Increased use of FloTrac due to Perioperative Goal-Directed Therapy (PGDT)/ Enhanced Recovery After Surgery (ERAS)
- Need to have a working knowledge of tools we are expected to use
- Improved confidence

Goals

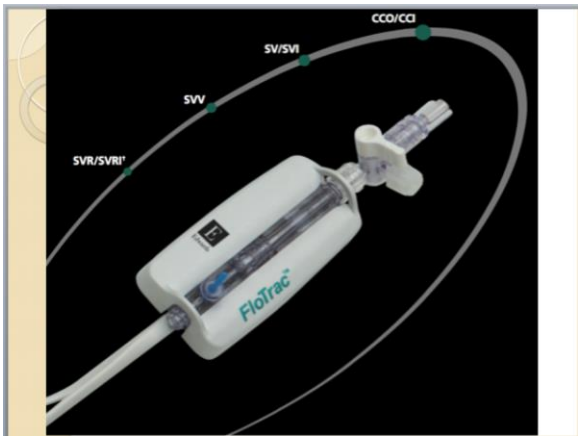
- Improve SRNA knowledge of FloTrac/ Vigileo/EV1000 equipment and its utility and use.
- Familiarize SRNA's with PGDT protocols and how to implement those with the use of FloTrac



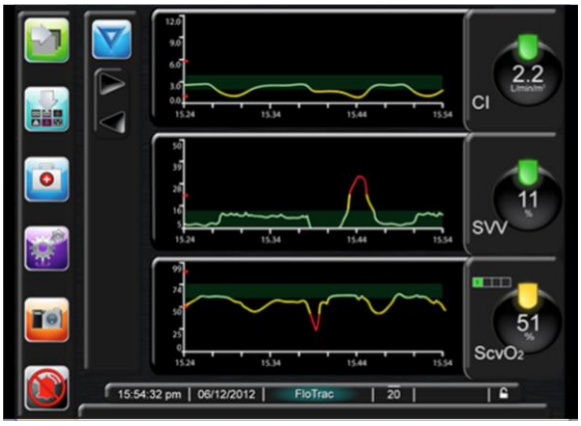
Introduction to FloTrac

Minimally invasive hemodynamic monitoring

Advantage of FloTrac is the ability to provide key flow parameters (CCO/CCI, SV/SVI, SVV, SVR/SVRI) through an existing peripheral arterial line.



FloTrac/Vigileo setup



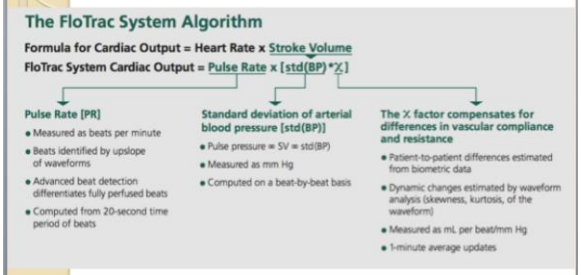
Initial Monitor Setup

- Power button (%) – machine will initiate POST (power on self test)
- Once POST is complete, must enter patient info: gender, age, height, weight before cardiac output monitoring can occur
- Plug sensor to monitor with green tipped pressure monitor cable
- Rotate knob and select "CO menu", select 'zero arterial pressure' – perform just as you would with normal transducer and cap with non vented cap
- CO will display within 40 seconds (2 cycles)

Sensor Setup

- How to de-air and prime IV bag and FloTrac system: Invert IVF bag and spike with fluid set, keeping drip chamber upright. With bag still inverted, squeeze air out of bag with one hand while pulling flush tab on the transducer until bag is free of air and chamber is half full.
- Insert IV bag into Pressure Bag and hang on IV pole (do not inflate yet)
- Using gravity only, flush FloTrac sensor holding pressure tubing in upright position as the column of fluid raises (pushing air out of the tubing until the fluid reaches the end)
- Pressurize the bag until it reaches 300 mmHg
- Connect the bedside monitors arterial pressure cable to red connector on FloTrac sensor.
- Level the FloTrac sensor to phlebostatic axis *keep FloTrac sensor level at phelbostatic axis at all times to ensure accuracy of CO.

How does it work?



Setup tips

- Dependent on good monitoring practices
- Avoid kinked catheters, non level transducers, or dampened lines
- Only use with Vigileo or EV1000 monitor
- Do not modify the sensor kit or tubing
- Ensure accurate demographic data
- Monitoring site selection

Clinical Application

Provides calculated CCO, CI, SV, SVV

What causes SVV? (what is SVV)

How do I use SVV?

What good is it?

Patient Selection

- Appropriate patient selection
- Who not to use it on
- Who can't it be used on
  - VAD
  - IABP
  - Severe, persistent arrhythmias
  - Severe, persistent peripheral vasoconstriction or arterial spasm – femoral access
  - Pediatric

Basic Principles

- FloTrac samples at 100 Hz every 20 seconds – 2,000 measurements along the pressure curve to produce a mean BP
- FloTrac uses baseline vascular resistance data , and analyzes the shape of the waveform for change
- These data are used to calculate SV, which is then divided by BSA to calculate SVI
- Pulse x SVI = CI
- Accuracy of data

Value of values

SV – treating SV to responsiveness demonstrated by a plateau on the frank starling curve will optimize the 'tank' (prevent hypovolemia or excessive fluid administration)

SVV – for controlled ventilated patients, SVV is a highly sensitive indicator of preload responsiveness Oxygen delivery optimization

CCO – used in combination with SaO2 and Hgb can be used to monitor and optimize DO2 with fluid (including RBC's), and inotropes

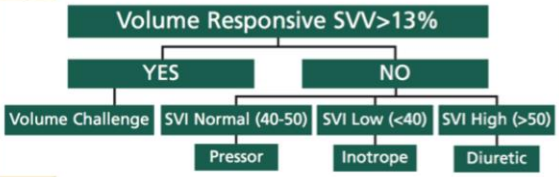
Using SVV

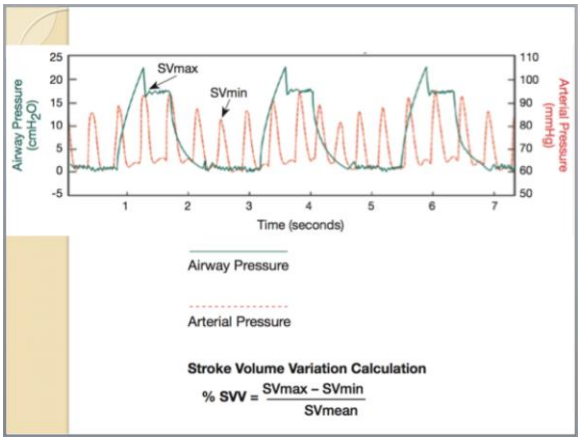
- SVV is not an indicator of actual preload but instead it is an indicator of relative preload responsiveness.
- SVV has been shown to have a very high sensitivity and specificity when compared to traditional indicators of volume status (HR, MAP, CVP, PAD, PAOP), and their ability to determine fluid responsiveness.
- Normal SVV values are less than 10-15% on controlled mechanical ventilation.
- Use SVV as a guide for volume resuscitation with a goal SVV of <13%.

Stroke Volume Variation (SVV)

- What causes SVV?
- Stroke volume variation is a naturally occurring phenomenon in which the arterial pulse pressure falls during inspiration and rises during expiration.
- Reverse pulsus paradoxus is the same phenomenon with controlled mechanical ventilation, however, in reverse. Arterial pressure rises during inspiration and falls during expiration due to changes in intra-thoracic pressure secondary to positive pressure ventilation.
- SVV = (SVmax – SVmin)/SVmean

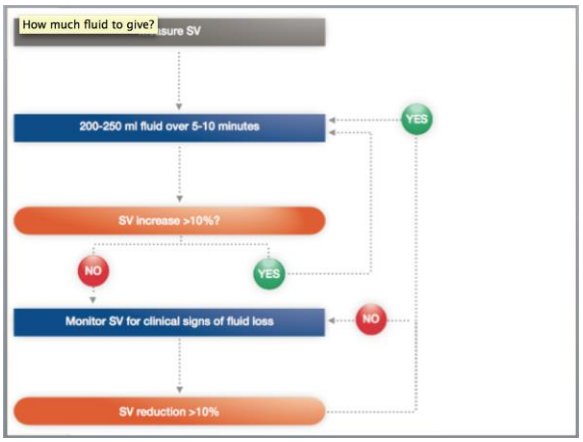
Volume Response Algorithm

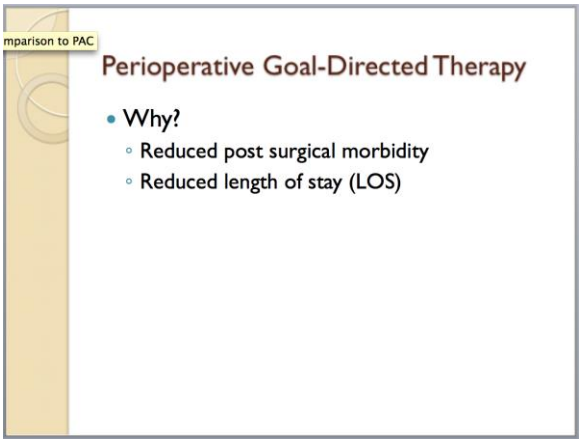


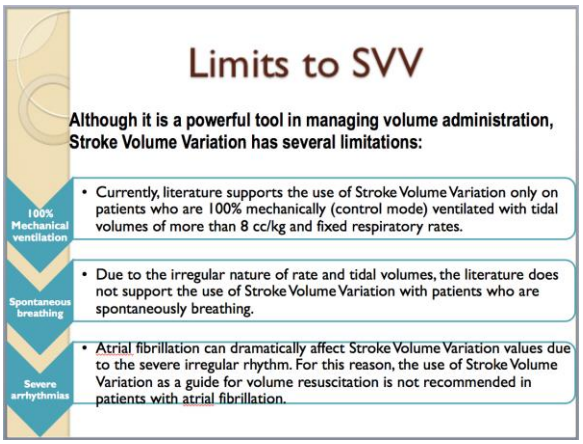


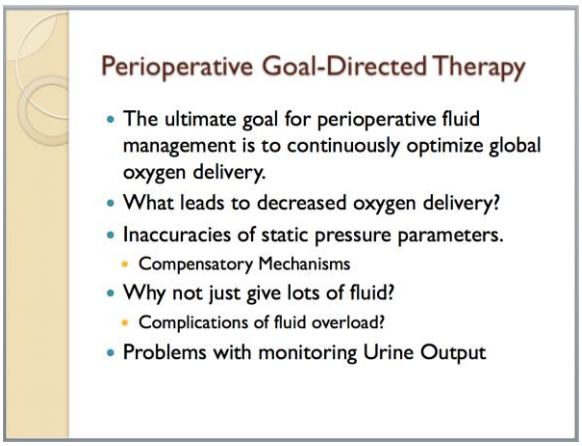
How much fluid to give?

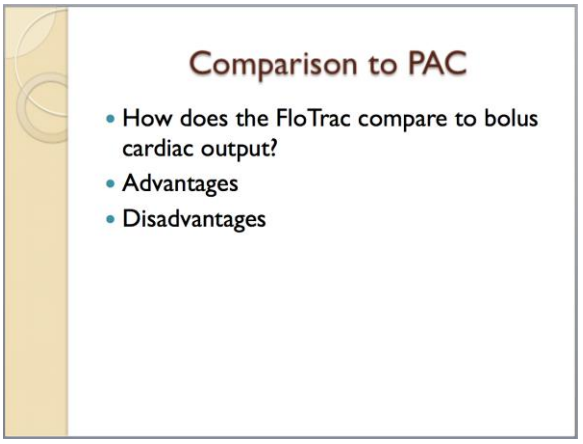
- **NHS-NICE/Kuper Protocol**
- **Study Design:** Quality improvement program (before-after comparison)
- **Patient Population:** Undergoing emergency and elective abdominal, orthopedic, gynecologic, urologic, and vascular surgery
- **Inclusion Criteria:** Three cohorts of patients aged ≤60, 61-71, and ≥71 years with ASA >1
- **Target Parameters:** Stroke Volume
- **Intervention:** Fluid
- **Primary Outcomes:** 3.7-day decrease in hospital length of stay(25%)


How much fluid to give?
sure SV
200-250 ml fluid over 5-10 minutes
YES
SV increase >10%?
NO
YES
Monitor SV for clinical signs of fluid loss
NO
SV reduction >10%

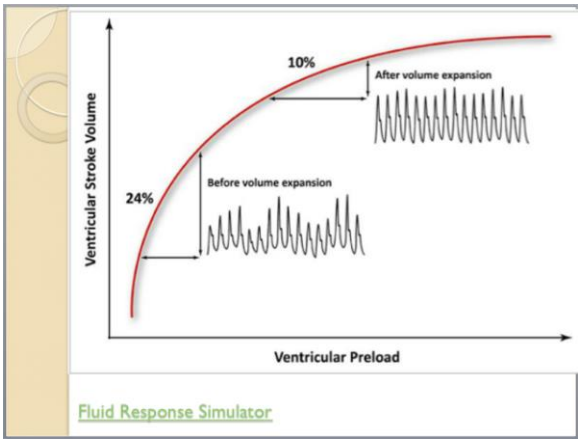

mparison to PAC
Perioperative Goal-Directed Therapy
Why?
Reduced post surgical morbidity
Reduced length of stay (LOS)


Limits to SVV
Although it is a powerful tool in managing volume administration, Stroke Volume Variation has several limitations:
100% Mechanical ventilation
Currently, literature supports the use of Stroke Volume Variation only on patients who are 100% mechanically (control mode) ventilated with tidal volumes of more than 8 cc/kg and fixed respiratory rates.
Spontaneous breathing
Due to the irregular nature of rate and tidal volumes, the literature does not support the use of Stroke Volume Variation with patients who are spontaneously breathing.
Severe arrhythmias
Atrial fibrillation can dramatically affect Stroke Volume Variation values due to the severe irregular rhythm. For this reason, the use of Stroke Volume Variation as a guide for volume resuscitation is not recommended in patients with atrial fibrillation.


Perioperative Goal-Directed Therapy
The ultimate goal for perioperative fluid management is to continuously optimize global oxygen delivery.
What leads to decreased oxygen delivery?
Inaccuracies of static pressure parameters.
Compensatory Mechanisms
Why not just give lots of fluid?
Complications of fluid overload?
Problems with monitoring Urine Output

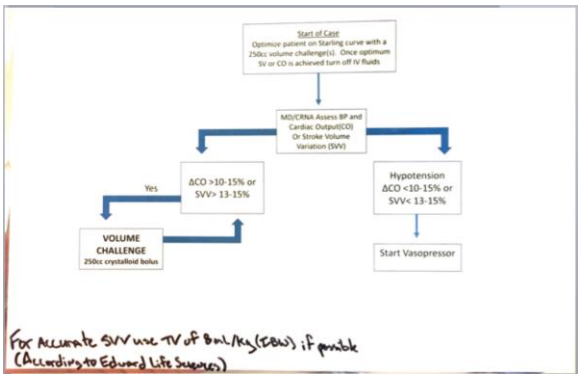

Comparison to PAC
How does the FloTrac compare to bolus cardiac output?
Advantages
Disadvantages


Perioperative Goal-Directed Therapy
4 Approaches to perioperative fluid management
Eh, don't worry about
Make assumptions and give a lot
Make assumptions and restrict
Goal-directed therapy.



Literature Review Article 2

- Systematic review of uncalibrated arterial pressure waveform analysis to determine cardiac output and stroke volume variation
  - 2234 patients
  - 3 patient groups based on hemodynamic variability
  - 3rd generation software adequate for normodynamic and hypodynamic condition patients
  - 3rd generation software compared with intermittent thermodilution CO in treatment of septic shock showed good tracking ability during the course of treatment



Summary

- FloTrac can be a useful tool in a variety of different cases, although its use is currently not validated for use in patients with persistent arrhythmias, artificial hearts, ventricular assist devices, intaaortic balloon pumps, during shock states, and pediatric patients.
- The newest version of the Flotrac system can be used with some arrhythmias and has increased its ability to account for changes in vasomotor tone.
- SVV can be used to monitor fluid responsiveness in patients who are mechanically ventilated with Vt of 8 - 10mL/kg. A generally accepted rule is that patients with a SVV > 13% – 15% will be fluid responsive.
- SV can also be used to assess fluid responsiveness. When CI is < 2.0, a fluid bolus can be used to assess changes in SV.
- FloTrac should be used to monitor for trends in values as opposed to absolute values.
- PGDT is a great way to monitor our patients fluid status/needs and is especially helpful in a number of cases. Each institution will use its own algorithm to determine interpretation of values and appropriate interventions.

Literature Review Article 1

- The Impact of Phenylephrine, Ephedrine, and Increased Preload on Third-Generation Vigileo-FloTrac and Esophageal Doppler Cardiac Output Measurements
  - 33 anesthetized patients undergoing elective surgery
  - Radial A-line placed in all patients prior to induction. Ventilated with 8-10 mL/kg TV with RR titrated to keep ETCO2 35-40 mmHg.
  - Patients were treated with either Phenylephrine, Ephedrine, or full body tilting if MAP fell >20 % after induction of anesthesia.
  - CO was recorded immediately before and 2 minutes after treatment. One CO was obtained using FloTrac, while the other was obtained using esophageal Doppler.
  - The Study concluded that FloTrac was significantly affected by changes in vasomotor tone induced by the administration of phenylephrine. It also found that its ability to accurately track changes induced by ephedrine was acceptable and tracking changes induced by increased preload was good.

References

- Hamm, J., Nguyen, B., Kiss, G., Warxnier, J., Jauffroy, A., Helaine, L., ... Gueret, G. (2010, March). Assessment of cardiac output device using arterial pulse waveform analysis, vigileo, in cardiac surgery compared to pulmonary arterial thermodilution. *Anaesthesia and Intensive Care, 38*(2), 295-301. Retrieved from http://search.proquest.com/docview/224827254?accountid=35793
- Maeda, T., Yoshitani, K., Inatomi, Y., & Ohnishi, Y. (2014). Inaccuracy of the flotrac/vigileo system in patients with low cardiac index. *Journal of Cardiothoracic and Vascular Anesthesia, 28*(6), 1521-1526. http://dx.doi.org/10.1053/j.jvca.2014.04.013
- Meng, L., Phuong, N., Alexander, B., Laning, K., Chen, G., Kain, Z., & Cannesson, M. (2011, October). The impact of phenylephrine, ephedrine, and increased preload on third-generation vigileo-flotrac and esophageal doppler cardiac output measurements. *Anesthesia and Analgesia, 113*(4), 751-757. http://dx.doi.org/10.1213/ANE.0b013e3182264f9b
- Monnet, X., Anguel, N., Jozwiak, M., Richard, C., & Teboul, J. (2012). Third-generation flotrac/vigileo does not reliably track changes in cardiac output induced by norepinephrine in critically ill patients. *British Journal of Anaesthesia, 108*(4), 615-622. http://dx.doi.org/10.1093/bja/aer491
- Romagnoli, S., Ricci, Z., Romano, S., Dimizio, F., Bonicolini, E., Quattrone, D., & De Gaudio, R. (2013, December). Flotrac/vigileo (third generation) and mostcare/pram versus echocardiography for cardiac output estimation in vascular surgery. *Journal of Cardiothoracic and Vascular Anesthesia, 27*(6), 1114-1121. http://dx.doi.org/10.1053/j.jvca.2013.04.017
- Slagt, C., Malagon, I., & Groeneveld, A. (2014, January 14). Systematic review of uncalibrated arterial pressure waveform analysis to determine cardiac output and stroke volume variation. *British Journal of Anaesthesia, 112*, 626-637. http://dx.doi.org/10.1093/bja/aet429
- Suehiro, K., Tanaka, K., Mikawa, M., Uchihara, Y., Matsuyama, T., Matsuura, T., ... Nishikawa, K. (2015, June). Improved performance of the fourth-generation flotrac/vigileo system for tracking cardiac output changes. *Journal of Cardiothoracic and Vascular Anesthesia, 29*(3), 656-662. http://dx.doi.org/10.1053/j.jvca.2014.07.022
- Teiedor, A., Rivas, E., Rios, J., Arismendi, E., Martiznez-Palli, G., Delgado, S., & Balust, J. (2015). Accuracy of vigileo/flotrac monitoring system in morbidly obese patients. *Journal of Critical Care, 30*(3), 562-566. http://dx.doi.org/10.1016/j.jcrc.2015.01.015