Anesthetic Implications for Implanted Cardiac Devices in Patients Undergoing Non-Cardiac Surgery

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Abstract

A scholarly project presentation for *Anesthetic Implications for Implanted Cardiac Devices in Patients Undergoing Non-Cardiac Surgery* was executed to the Adventist University of Health Sciences Nurse Anesthesia Program Student Registered Nurse Anesthetist (SRNA) cohorts of 2018 and 2019. This particular project and topic was of interest because there was a noticeable deficit in understanding regarding anesthetic management of implantable cardiac device education in the Nurse Anesthesia Program. The objective of this project was to enhance the knowledge base for future clinical encounters. After obtaining informed consent, a completely anonymous pre-test was administered to the research subjects. The researchers then provided a research-based PowerPoint presentation. After the presentation, an anonymous post-test was given. The researchers aimed to see evidence of enhanced baseline knowledge by observing an increase in mean scores from the pre-test to the post-test. The presentation, was, in fact, effective, as there was in increase in mean scores of 34.18% on the pre-test, to an average of 76.83% on the post-test. The conclusion can be drawn that the researchers were successful in their aim to increase knowledge base in this population, and the method of a PowerPoint presentation was effective at achieving the goal.

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Introduction

Implanted cardiac devices are common and are known to prolong and save lives. The population of patients that have these devices is growing throughout the United States. It is no longer true that only cardiac-specialized anesthesia providers should have the basic knowledge required to provide anesthesia for these patients, as they frequently require anesthesia in non-cardiac arenas such as endoscopy or general surgery. These devices are frequently seen in all types of perioperative settings, including academic centers, office-based, and rural hospitals. However, with more and more devices being introduced to the market, it may be difficult for anesthesia providers to stay up-to-date.

Anesthesia providers that are not specialized in cardiac anesthesia may be uncomfortable when receiving a patient with one of these devices in a non-cardiac setting. Uncertainties include basic troubleshooting, monitoring concerns, and possible perioperative events to prevent or prepare for. Should the device be disabled during the perioperative time period? If so, what possible events and interventions are important for the anesthesia provider to consider? Probably the most important consideration is how to manage these devices in the event of a perioperative cardiac arrest.

Project Questions

In patients with implanted cardiac devices undergoing non-cardiac surgery, what is the preferred anesthetic management? Would the presentation of a formal PowerPoint to the ADU SRNA cohorts of 2018 and 2019 regarding the anesthetic management of patients with implanted cardiac devices undergoing non-cardiac surgery improve their current knowledge base on the topic?

Literature Review and Synthesis

The current student nurse anesthesia curriculum at Adventist University of Health Sciences mildly touches on ventricular assist devices (VADs) and permanent pacemakers/automatic implantable cardioverter-defibrillators (AICDs) and their purpose, but little is discussed about the anesthetic implications, perioperative care, and complications when encountering a patient with these devices in a non-cardiac surgical setting. As the goal of these SRNAs is to become certified registered nurse anesthetists, learning the ideal perioperative anesthesia management is essential when working with these patients in a collaborative medical practice. Correct knowledge of the devices and their function, as well as the most appropriate induction techniques, anesthetic maintenance, and perioperative monitoring will help to provide the safest anesthetic in this population.

Research related to the use and management of ventricular assist devices (VADs), permanent pacemakers and/or automatic implantable cardioverter-defibrillators (AICD) in the perioperative period is steadily increasing. Heart failure is an unfortunate disease with an elevated risk of morbidity and mortality, claiming about half the lives of those diagnosed within five years of their diagnosis (Peacher, 2016). Heart failure remains the dominant cause of death in the United States, regardless of time spent on aggressive medical management, making it statistically responsible for 193.6 deaths out of 100,000 citizens (Abernathy et al., 2015). Ideally, a heart transplant is the only absolute cure for heart failure. Due to limited donors for transplantation, the necessity of other treatment modalities led to the advent of ventricular assist devices (Peacher, 2016).

As a result of more than 5 million total people in the United States suffering from heart failure, the use of VADs (with or without AICDs) is rapidly climbing (Abernathy et al.,2017, Haddadin, Mangi and Slinunger, 2013). A staggering 13,000 LVADs were utilized between 2006

and 2014 in this patient population. The success of LVADs in improving quality of life as well as decreasing mortality has led to a substantial increase in patients with these devices presenting for non-cardiac procedures (Preacher, 2016). Therefore, with the rapid increase in the use of LVADs, it is imperative the anesthesia provider is not only acquainted with these devices, but is also well-versed in potential perioperative complications related to them, and ideal anesthetic management of the patient with them.

Patients with heart failure also tend to have automatic implantable cardioverter-defibrillators to aid in converting sudden lethal arrhythmias because of their low ejection fractions, especially if it is below 35%. The placement of an AICD in these instances is part of the long-standing recommendations and guidelines for treatment of heart failure by the American Heart Association. In other instances, even with the implantation of the AICD, heart failure can progress to worsening heart failure, leading to the need for placement of an LVAD. Therefore, oftentimes, patients with LVADs have AICDs additionally (Peacher, 2016).

In clinical practice at Florida Hospital sites in Orlando, it has been noted that many providers experience confusion regarding pacemakers and AICDs. Evaluation of the device is crucial and failure to do so has led to adverse outcomes (Rozner and Schulman, 2013). Preoperatively, it is the responsibility of the anesthesia provider to ensure information is available about the type of pacemaker, interrogations, and if the patient is totally dependent on the pacemaker. It is known that AICDs can erroneously initiate anti-tachycadia therapy in the presence of electrocautery. Therefore, ideally, the AICD should be converted to an asynchronous mode and converted back to its original mode after surgery (Peacher, 2016). It is a commonly upheld belief that AICDs will convert themselves to an asynchronous mode with the placement of a magnet over the device. Confusion related to when, and if, to place this magnet exists within

the anesthesia profession in general. The literature review has revealed magnet placement can be undependable and does not always reliably achieve the desired effect. In some newer devices, the ability of a magnet to cause this switch has been totally disabled, in fact (Rozner and Schulman 2013).

Surgeries for this group of patients can occur in a formal operating room, or in an out of operating room setting such as, but not limited to, endoscopy, ambulatory surgery, radiology or in office procedures. The timing of surgical procedures for these patients can be broken up into "early post-implantation (i.e. <30 days) period and the late post-implantation period (i.e. >30 days)" (Haddadin et al., 2013). Surgical considerations in the early period are typically owed to airway problems, thoracic surgical needs, or infections. Later surgical considerations include more common non-cardiac surgeries like cholecystectomies and endoscopies, ranging to open neurological procedures (Haddadin et al., 2013).

In general, up to half of patients with continuous flow LVADs can experience some sort of abnormal bleeding (Abernathy et al., 2016) Not surprisingly, then, these patients frequently present in endoscopy suites for evaluation of gastrointestinal bleeding (Abernathy et al., 2016; Haddadin et al., 2013; Peacher, 2016). Continuous flow LVADs can cause an acquired von Willebrand disorder. Structural change of von Willebrand factor occurs from the continuous blood flow through the LVAD pump (Abernathy et al., 2016; Haddadin et al., 2013). Also, a contributing factor is that these patients are anticoagulated with Coumadin to achieve a maintenance INR of 2-2.5 (Abernathy et al., 2015).

Inducing anesthesia is a risky time as LVADs are heavily reliant on preload. Abruptly adjusting systemic vascular resistance, such as during laryngoscopy, can have a detrimental effect in a patient with an LVAD by altering their cardiac output. Keeping heart rate and rhythm

steady is crucial while maintaining inotropy of the right ventricle. Caution with positive pressure ventilation should be exercised as this can also alter preload. Monitoring considerations should be geared toward the non-pulsatile nature of the device. Therefore, traditional non-invasive blood pressure monitoring may not be adequate and pulse oximeters may not accurately register oxygen saturation. In more precarious surgical procedures, the use of CVP, arterial lines, or other invasive monitoring lines may be desired. If the patient also has an AICD, it should preoperatively be inactivated to reduce any interference with electric cautery (Haddadin et al., 2013). Studies have shown that it is possible to safely administer an anesthetic of all sorts to these patients without mortality (Abernathy et al., 2015).

Within a collaborative medical practice that incorporates CRNAs and anesthesiologists, it is critical the anesthetist in any operative venue has a thorough understanding of what would be required when providing safe care to this patient population. Patents with implanted cardiac devices pose multiple challenges to an anesthesia provider in a myriad of surgical contexts, as preoperative planning involving monitoring and drug selection is different than the average non-cardiac surgical patient (Peacher, 2016). Slight changes in hemodynamics can have a more profound effect on these patients, therefore, the need to increase the knowledge base on the appropriate perioperative care for patients with implanted cardiac devices in any operative setting is crucial.

Contribution and Dissemination/Justification

Formal education on the basic anesthetic implications of VADs and AICDs/pacemakers in the non-cardiac patient is briefly discussed in the Adventist University Nurse Anesthesia Program, but a majority of the knowledge is learned in clinical. The procedures that involve the placement of these devices are more commonly discussed than how to manage a patient with this

device as a pre-existing condition undergoing a surgery that is unrelated to the device itself. After speaking with students, the researchers saw an overlying theme of confusion as to how to manage these devices in a perioperative setting.

In order to contribute to the awareness of the function and the anesthetic implications of cardiac devices in a non-cardiac setting, this project will provide a succinct summary including the function of each device, along with specific perioperative events that should be anticipated. Discussion of each device will be organized into five parts: The function of the device, preoperative considerations, perioperative considerations, postoperative considerations, and considerations in the event of a cardiac arrest.

The target population for this educational project is the SRNAs at ADU from the classes of 2018 and 2019. As critical care nurses, they are familiar with these devices already, and may only need a quick review of their functionality with more of an emphasis on the perioperative anesthetic implications. The project has a presentation timeframe of fall of 2017. At this time, both cohorts should have a basic understanding of congestive heart failure, coronary artery disease, and arrhythmias.

Project Aims

The aim of this project is to enhance the knowledge base regarding the perioperative management of patients with VADs and pacemakers/AICDs undergoing non-cardiac surgery as evidenced by an increase in mean post-test scores compared to mean pre-test scores. The project will be presented to the currently enrolled SRNAs at ADU in the fall of 2017 via PowerPoint. The independent variable in this study is the PowerPoint presentation, and the dependent variable is the difference between pre-test and post-test scores.

Project Methods

Following IRB/SRC approval or exemption, the researchers will proceed with the study. The researchers will present a comprehensive PowerPoint presentation to the SRNA cohorts of 2019 and 2018 at ADU (sample size of 50). The sample that will be the target of the intervention is the SRNAs in the cohorts of 2018 and 2019. Inclusion criteria include acceptance to the ADU SRNA program, being in the class of 2018 or 2019, completion of the first and second trimester didactic material, and a signed informed consent. Exclusion criteria are not being present for the presentation and refusal.

Prior to the presentation, the students will be given an informed consent to sign. The informed consent describes that participation in this study is voluntary and that the results of the project will be published, but names and identities will not be disclosed. There will also be clear instructions as to how to contact the researchers if further questions arise regarding how the data will be used and stored.

After collection of the signed consent forms, the students will be given a pre-test. The pre-test will be written by the project presenters in order to assess the students' baseline knowledge of VADs and AICDs/pacemakers and the perioperative anesthetic implications. After the PowerPoint presentation, the students will then be given the exact same test to take again as a post-test. Students will not be asked to write their names on the tests. Scores and tests will be kept anonymous through the use of envelopes and a numbering system.

The measurable outcome of this project is an enhanced knowledge base of the perioperative management of implantable cardiac devices, as evidenced by an average increase in mean post-test scores compared to mean pre-test scores. The pre-tests and post-tests will be

graded with the results recorded into a Microsoft Excel Spreadsheet. The results will then be analyzed using a simple paired t-test to look for a relationship between the pre and post-test scores.

All data collected in this project will be de-identified. Through the use of a number system, no names will be required in the collection of the data. After the final project paper has been written, thoroughly reviewed, and submitted, the specific scores and data will be fully deleted.

Timeline

The estimated date for the presentation of this project is the fall of 2017 during the class period for MSNA 501 and 504. The exact due date and presentation date remains to be determined by the Nurse Anesthesia Program faculty. Data collection will be initiated on that day, starting with a pre-test prior to the presentation. Post-implementation data will be collected immediately after the presentation.

Data Collection Plan

After the consent forms are signed, the researchers will provide each student with an envelope. Inside the envelope will be a pre-test and a post-test with a single, randomly given number written on the front of both tests. Although the two sheets of paper in the envelope will be clearly labeled as “pre-test” and “post-test”, the questions will be identical. The purpose of the number is to be able to compare the mean overall scores between the pretest and the posttest.

The students will be instructed to fill out the pre-test first and turn it in. Once all pre-tests are collected, the PowerPoint presentation will commence. Any students that arrive to class after the pre-test has already been given will not be permitted to participate in the study. However, they will still be able to listen to the presentation and ask questions as desired. Once the

presentation is complete and any questions have been answered, the students will be instructed to take out the labeled post-test and answer the same questions again. The questions will be in a multiple-choice format so as to avoid any identification of students based on handwriting characteristics.

Once the students have finished taking the post-tests, they will be asked to turn them in. The researchers will then collect the post-tests and pair them with the pre-tests according to the pre-written numbers. In further effort to avoid identification of individual student tests, the numbers will be completely random and not in any particular order so as to ensure no correlation to seat location in the classroom. The researchers will not take note of each student's individual number, and will not require the students to write their names on the tests as the test scores will be kept de-identified. The tests will then be graded, with the scores transcribed into a Microsoft Excel spreadsheet for examination.

Evaluation Plan

Once all of the tests have been graded, the scores will be transcribed into a Microsoft Excel spreadsheet and the researchers will pursue statistical analysis assistance through the aid of Dr. Roy Lukman, statistician at Adventist University. The data spreadsheet will be sent to Dr. Lukman within three weeks of the data collection date. The data will then be analyzed through the computer program SPSS. Using a simple paired t-test analysis, the data will be examined for a relationship between the pre and post-test scores.

After receiving feedback from Dr. Lukman, the data will be further analyzed. The researchers will then be able to determine if SRNAs who receive a formal PowerPoint presentation on anesthetic implications for patients with implanted cardiac devices undergoing non-cardiac surgery have an increased knowledge base on the topic as evidenced by

improvement in posttest scores. The researchers will then provide project findings in the form of a research paper and poster presentation.

Results and Findings

The pre-test mean score was 34.18%, with a standard deviation of 18% and a standard error mean of 2.55%. The post-test resulted in a mean score of 76.83%, with a standard deviation of 20.9%, and a standard error mean of 2.95%. Therefore, the average mean percentage scores increased by 42.6%. The paired samples t test revealed a mean of -42.65, with a standard deviation of 24.81, and a standard error mean of 3.5. The t value was -12.15 and is associated with a p value of <0.001 (See Appendix D).

Conclusion and Limitations

The pre-test clearly demonstrated that the student's initial understanding of anesthetic implications of implanted cardiac devices was limited, with an average score of 34.18%. However, comparison of pre and post-test scores showed that the knowledge base of the topic significantly increased after the presentation, as evidenced by an average percentage increase in pre-test to post-test scores of 42.6%. With a p value of <0.001, it is clear that this finding is of statistical significance. The aim of this project was to enhance SRNA knowledge base regarding the perioperative management of patients with implantable cardiac devices undergoing non-cardiac surgery, as evidenced by an increase in mean post-test scores compared to mean pre-test scores. The statistical evidence showed that the aim of the project was met. The statistical analysis also verified that the Power Point presentation was effective in increasing this knowledge base.

There were some known limitations to this study. One limitation was the short amount of time elapsed between the pre and post-test. Ideally, in order to truly prove retention of the

information provided, the post-test would be given several days to a week after the administration of the pre-test. As the pre and post-tests were identical, taking the post-test several days after the presentation would make it more difficult for students to simply recall the questions that they saw on the pre-test, therefore only answering from wrought memory rather than true understanding. Another limitation of this study was the use of only SRNAs that were attending Adventist University, providing a smaller, more homogenous sample. Adding SRNAs from other schools would have provided a stronger study by allowing for a larger, more heterogeneous sample.

References

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Appendix A

ADU NAP CAPSTONE PROJECT – INFORMED CONSENT

Our names are Brittni Saladino and Valerie Tulenko, 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 *Anesthetic Implications for Implanted Cardiac Devices in Patients Undergoing Non-Cardiac Surgery.* This project is being supervised by Steven Fowler, DNP CRNA. 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 the SRNA cohorts of 2018 and 2019 on the appropriate perioperative care of a patient with a pacemaker/AICDs and/or ventricular assist devices (VADs) in patients undergoing non-cardiac surgery. This includes monitoring methods, induction of anesthesia, maintenance of anesthesia and general information about the devices.

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 current knowledge level of anesthetic implications for patients with implanted cardiac devices presenting for non-cardiac surgery. Your participation by attendance at the presentation and completion of the survey is anticipated to take approximately one hour.

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 anesthetic management of the patient with an implanted cardiac device undergoing non-cardiac surgery.

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. Identifying data, such as participant's names, will not be included on the assessments. The assessments will only be numbered. Thus, the investigators will not have access to any participants' identities. After data collection is complete, all assessments and data will be deleted off the researcher's computers.

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

Your participation will cost approximately one hour 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 Brittni Saladino at brittnisaladino@gmail.com or Valerie Tulenko at jensenvc@gmail.com . If you have concerns about the project process or the investigators, please contact the Nurse Anesthesia Program at (407) 303-9331.

_____ **Date** _____

Participant Signature/ Participant Name

_____ **Participant Name (PRINTED LEGIBLY)**

Appendix B

Pretest

1. Which is true related to AICDs and magnets?
    a. A magnet disables all functions of the AICD
    b. A magnet disables antitachycardia functions of the AICD
    c. A magnet disables antibradycardia pacing
    d. Placing a magnet over the AICD guarantees protection from an inappropriate shock
2. For a pacemaker, which mode is the safest mode to use in the OR during surgery?
    a. DDD
    b. VOO
    c. VVI
    d. DDI
3. Dual chamber pacemakers can have a mode-switching ability. This is triggered by:
    a. Atrial tachyarrhythmia events
    b. Ventricular tachyarrhythmia events
    c. Heart rate below the set pacing trigger
    d. Interference by electrocautery
4. Interrogation by inductive transmission provides what information about the pacemaker?
    a. Battery life
    b. Integrity of the leads
    c. Sensing and pacing threshold
    d. Stored arrhythmia events
    e. All of the above
5. Transtelephonic monitoring and remote interrogation must be conducted every _____, whereas remote monitoring is conducted every _____.
    a. Month; day
    b. Two months; week
    c. Three months; day
    d. Week; month
6. Which of the following monitors would not be useful in monitoring a patient with a VAD?
    a. ECG
    b. Cerebral oximeter
    c. Pulse oximeter
    d. Intraarterial catheter

7. What is not a usual cause of hypotension in patients with continuous-flow LVADS?
    a. Decreased preload
    b. Right ventricular failure
    c. Increased afterload
    d. Increased preload
8. What is true regarding the use of cautery in patients with VADS?
    a. bipolar cautery should be used, or the grounding electrode of the monopolar cautery should be placed in a way that directs the current away from the VAD generator
    b. monopolar cautery should be used, or the grounding electrode of the bipolar cautery should be placed in a way that directs the current away from the VAD generator
    c. Any type of cautery is okay as long as it is below the waist.
    d. Cautery should be completely avoided in patients with VADs.

9. Your patient has a non-pulsatile VAD and is presenting for an endoscopy and colonoscopy as part of the heart transplant work up. You go to do your pre-op and find them nonresponsive. You call for help and one of your colleagues secures the airway. What should you do next?
    a. Start compressions
    b. Check on the battery status of the VAD
    c. Give epinephrine 1mg
    d. Give Vasopressin

Appendix C

Anesthetic Implications for Patients with Implanted Cardiac Devices Undergoing Non-Cardiac Surgery

Brittni Saladino, SRNA, RN and Valerie Tulenko, SRNA, RN
Project Mentor: Robert Wade, MSNA,
CRNA Project Chair: Steve Fowler, DNP,
CRNA

Objective

The aim of this project is to enhance the knowledge regarding the anesthetic management of patients with Ventricular Assist Devices (VADs), pacemakers, and Automatic Implantable Cardioverter Defibrilators (AICDs) undergoing non-cardiac surgery.

Why is this important to be familiar with?

- ~~89 year old~~ male with AICD/pacemaker presents for lithotripsy under general anesthesia.
  - To magnet or not to magnet? What could be the consequences?
- ~~67 year old~~ male with LVAD in endoscopy pre-op for a heart transplant work up
  - Alarms are going off on the VAD monitor and the nurses ask you for help!

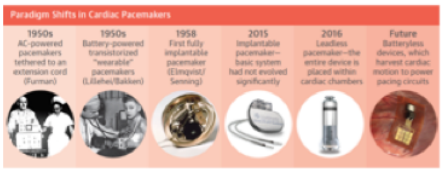
These situations are becoming more and more common!

Heart Failure

- Heart failure remains the dominant cause of death in the United States, regardless of time spent on aggressive medical management, making it responsible for 193.6 deaths out of 100,000 citizens
- A heart transplant is the only *true* treatment for heart failure
- Limited supply of donors, necessitating other modalities
  - Patients with heart failure tend to have automatic implantable cardioverter-defibrillators to aid in converting sudden lethal arrhythmias because of their low ejection fractions, especially if it is below 35%.
    - This is not a definitive treatment, and heart failure can still progress to the need of a VAD.
  - As a result of more than 5 million total people in the United States suffering from heart failure, the use of VADs (with or without AICDs) is rapidly climbing
    - 13,000 LVADs were utilized between 2006 and 2014

Pacemakers

Pacemakers Throughout History



Indications for Cardiac Pacing

- Generally, cardiac pacing can be indicated for:
  - Diseases of the SA node, AV node, of Purkinje system secondary to aging, inflammation, fibrosis, etc.
    - Symptomatic bradycardias that are non-reversible
  - Sinus node dysfunction
  - Neurocardiogenic syncope
    - Carotid sinus hypersensitivity
  - Neuromuscular diseases
    - Many have an unpredictable course and a predisposition for cardiac muscle fibrosis
  - CHF

Nomenclature

- First developed by the AHA and American College of Cardiology
- The code has letters that can be in 5 positions to describe the settings and function of the PPM
  - The letter "A" denotes atrium
  - The letter "V" denotes ventricle
  - The letter "D" denotes "dual," or both atrium and ventricle
  - The letter "I" denotes inhibition of output during an event and starts a new timing cycle
  - The letter "O" typically denotes absence of the function of the position it's in

Nomenclature, continued

- The letter in position 1 describes which chamber(s) are being paced
- The letter in position 2 describes with chamber(s) are being sensed
- The letter in position 3 describes the mode of sensing (how the device will respond to an event that was sensed)
  - This will either be inhibited ("I"), triggered ("T"), dual ("D"), or absent ("O")
    - "T" is essentially never used- refers to device's ability to trigger an impulse in either, or both, chambers while incorporating an appropriate AV delay
- The letter in position 4 describes if the rate response is turned on
  - Presence of an "R" or not
- The letter in position 5 describes if multisite pacing is present
  - Multisite pacing refers to stimulating the myocardium from multiple locations to create a more synchronous systole (resynchronization therapy)
  - "O" for not present

Single Chamber Modes	Dual Chamber Modes
VOO	DDD
VVI	VDD
AOO	DDI
AAI	DOO

Common Modes Explained

- VVI
  - Ventricle paced, ventricle sensed, response inhibited
  - In this mode, the PPM can sense intrinsic activity and either inhibit pacing or initiate pacing
  - "Demand pacing" to fire at preset rate when intrinsic rate drops below it
  - Indicated for atrial fibrillation with slow ventricular response, symptomatic bradycardia

Common Modes Explained

- DDD
  - Both chambers paced, both chambers sensed, both chambers inhibited *or* paced
  - Intrinsic p-wave *and* QRS complex (within set AV delay timer) can inhibit pacing
  - Has "AV delay" timer: if intrinsic p-wave, QRS must follow within set time frame, or a V pace will initiate
  - Has "atrial activity timer" or "ventricular activity timer" depending on settings: within set time frame, if PPM does not sense a subsequent p-wave or complex, it will initiate one
  - Indicated for patients with SA node dysfunction, AV node dysfunction, AV conduction abnormalities

Dual chamber PPMs are unique in that they have mode switching ability- it can identify an atrial tachyarrhythmia, which can lead to rapid ventricular pacing, and switch to a mode that inhibits in the third position (VVI, DDI, OVI)

Asynchronous Pacing

- Asynchronous pacing is critical during surgeries, especially when electrocautery is being used
  - Asynchronous pacing (VOO, AOO, DOO) allows pacing at a set rate without regard to any intrinsic or extrinsic activity, therefore preventing any inhibition
  - This is crucial as electrocautery can interfere with the EKG and the pacemaker can potentially erroneously recognize activity and inhibit pacing, leading to prolonged bradycardia and even asystole

It is important to note that these modes are only used temporarily, and a patient's PPM will never be normally programmed in this mode. While safest in the OR, this mode still carries the risk that an erroneous pacing impulse can occur on the T wave, leading to a lethal tachyarrhytmia

Automatic Implantable Cardioverter-Defibrillators (AICDs)

- The first AICD was implanted at Johns Hopkins in 1980
- Commercially available in 1986 after FDA approval
- Early AICDs (first and second generation) implanted were through median sternotomy, eventually converting to anterior thoracotomies and subxiphoid approaches after surgical technique developments
- The current transvenous method was adopted in 1986 (for third generation AICDs)
  - Leads advanced to the epicardium transvenously, and the AICD is placed in the sub-pectoral space
- The first generations of AICDs were very bulky with a short battery life
  - First and second generation AICDs battery life could be depleted in 18 months
  - Third generation AICDs battery life is around 7-8 years

- Indications for placement of an AICD:
  - Spontaneous VT/VF episodes with unpredictable response to other therapies
  - Recurrent spontaneous VT/VF episodes while on antiarrhythmics
  - Spontaneous VT/VF in the presence of suboptimal drug therapy or noncompliance
  - Persistent inducibility of VT/VF refractory to drugs, or surgical measures (ablation)
  - Prevention of sudden cardiac death secondary to arrhythmia in the presence of severe heart failure or cardiomyopathy

- A current AICD has these components:
  - Sensor lead
  - Logic circuit/pulse generator for analysis of signals
  - Power supply
  - Capacitor for storing and delivering shock
    - low energy cardioversion at 0.5-2J, or defibrillation at 15-20J
  - Tachycardia detection system with the capability to discern VT from SVT/ST



Monitoring/Interrogation

- Transtelephonic monitoring/Remote interrogation
  - In use since 1970s, requires patient to make contact with skin electrodes that record an EKG that is transmitted through analog telephone to the office or clinic, or inductive wand held over device for full interrogation equivalent to one done in the office
  - Less convenient and requires coordination between doctor's office/clinic and patient
  - Connected via landline or cellphone server to deliver a report that includes: diagnostic information, battery status, lead integrity, sensing threshold, and arrhythmia events
  - Usually routinely conducted every 3 months

Monitoring, continued

- Remote Monitoring
  - Requires no effort from patient and automatically transmits device information
  - Pulse generator receives and sends information via radiofrequency signals from a wandless transmitter as long as the device is in range
    - Can place transmitter on table/nightstand/etc. - allows daily communication in the event of alerts (i.e. arrhythmias)
    - Periodic full diagnostic transmissions are sent, and patients can press transmission button to manually send report
  - Major benefits to remote monitoring:
    - Reports sent on a daily basis, as compared to TTM and RI which are done every three months
    - Can detect abnormalities via alerts sooner than TTM or RI

Anesthetic Implications

Pacemakers/AICDs

Cautions:

- MRI, CT
  - Generally contraindicated if PPM/AICD
  - Some companies have made MRI conditional devices
    - No totally "safe" devices, just devices that are safe under certain MRI conditions
  - Studies of MRIs with PPM/ICD- Greatest risk is reset of device- changing mode
- Electromagnetic Interference (EMI)
  - Highest risk with surgery of the chest and up
  - Risk reduction: bipolar cautery, 5s bursts with 5s between bursts, grounding pads to direct current away from the pacemaker
  - Surgery above umbilicus: interrogation done and device reprogrammed to asynchronous mode (this is a MUST if pacemaker dependent)
    - Magnet as analternative
    - Restore settings aftersurgery

Preoperative Assessment

- In patients with AICDs or PPMs:
  - Why was the device implanted?
  - What is the brand, model, and magnet mode?
    - Magnet mode in modern devices is programmable and cannot be assumed as safe
      - Application of a magnet will only disable antitachycardia functions of the AICD and cannot 100% guarantee that no inappropriate shock will be delivered
    - Many PPM's magnet mode is asynchronous at 99bpm, but in the presence of low battery life can set to 50bpm
  - Was there cardiac clearance, if needed?
  - Has the device been interrogated?
    - Has the device fired recently? When? Why? How often?
    - Have there been any "events" recorded?
    - Did interrogation reveal good, working order?
  - Is the patient having any abnormal symptoms with the device?
    - Syncope, vertigo
  - Is the patient device dependent?
    - Have external pacing equipment prepared

Ventricular Assist Devices

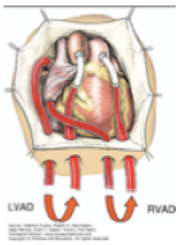
(VADs)

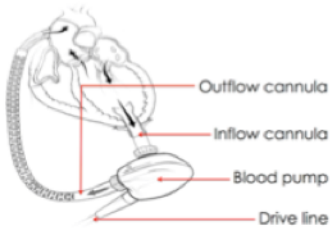
VADs: Indications

- Heart Failure
  - Short term support to allow myocardium to recover
  - Bridge to Transplant
  - "Destination Therapy"
- LVADs are most common

Function

- LVADs: Left Atrium → Aorta
- RVADs: deoxygenated blood comes from right atrium and is pumped into pulmonary circulation. Inflow cannula is attached to either the right ventricle or right atrium and the outflow cannula is attached to the pulmonary artery (usually seen with an LVAD as well)
- Continuous or pulsatile, majority seen today are continuous





VADs: Complications

- Pump thrombus
- Pump malfunction/loss of power
- Hypovolemia leading to left ventricular "suck-down"
- Trauma to percutaneous driveline
- Infection to percutaneous driveline
- LVAD associated Aortic Valve insufficiency

Suction Event

- Hypotension, hypovolemia, arrhythmias, decrease in pump speed, increase in Pulsatile Index
- Possible causes: RV failure, hypovolemia, obstruction

Treatment:

Evaluate using TEE

Give volume

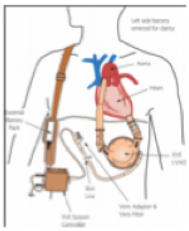
If there is an obstruction, surgically remove it!

Clinical Pearls: LVADs

- Causes of hypotension: decreased preload, RV failure, increased afterload
  - Preload dependent
    - Non-pulsatile devices: Continuous drainage of an underfilled left side will lead to LV suck-down and collapse.
    - Pulsatile devices: hypovolemia leads to slowed pump filing and pumping, leading to decreased CO and hypotension
  - RV function dependent:
    - Avoid increases in PVR (acidosis, hypercarbia, hypoxia)
      - Vasopressin, Milrinone, Nitric oxide
    - Want a NSR, imperative to maintain filling from right side of heart
  - Avoid large increases in SVR: This impedes pump outflow.

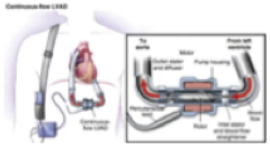
Pulsating

- First generation LVADs
  - Example: Heartmatel, Abiomed BVS500, Thoratec
- Collects the entire cardiac output and ejects into the ascending aorta.
- Complicated device with valves to prevent retrograde blood flow.
- Large and noisy, prone to mechanical pump failure and thrombus.
- Not very common today
- These patients will have a pulse.
- Considered to be a full stomach-RSI

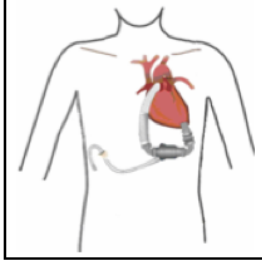


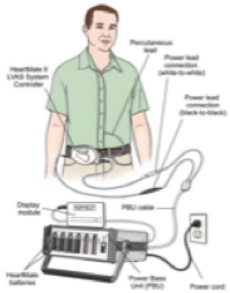
Continuous Flow LVADs

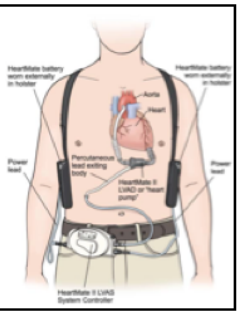
- Example: Heartmate II, Jarvik2000
- Rotary pump, no valves
- Autoregulates flow to match the volume delivered by the right heart
- Most common, smaller and more durable, fewer incidence of complications such as pump thrombus and stroke.
- Continuous, Nonpulsatile-no palpable pulse!
- Assess perfusion: capillary refill, auscultation of machine with stethoscope, assess BP with doppler and manual BP cuff (A regular NIBP cuff will not work!)



Percutaneous Lead







Explanation of LVAD Parameters

- **Pump Speed:** Normal 8,500 to 9,800 rpm
  - How fast the pump spins in revolutions per minute
  - Determined by prescribing physician
  - Large changes in speed may indicate a left ventricular suction event. The VAD will autoregulate and drop the low speed limit until the suction event had ended.
- **Pump Power:** Normal 4-7 W
  - Direct measurement of motor voltage and current, affected by pump speed, flow, and physiological demand (how well/tage the device needs to maintain flow)
  - Power increases, gradual or abrupt, may indicate a thrombus.
- **Pump Flow:** Normal 4-6L/min
  - Estimated CO value based on the pump power and speed.
  - A thrombus will increase pump power and will erroneously cause a high flow.
  - Hypovolemia or postural hypotension may result in reduced pump flows

Explanation of LVAD Parameters

- **Pulsatility Index:** measures intravascular volume and RV performance. Normal = 4-7
  - Measures the flow through the pump, determined by pump speed and native heart function.
  - Higher values mean more native heart function
  - Lower values indicate that the pump is providing greater support.
  - CVP 10-12
    - Low CVP with low PI suggests hypovolemia
    - Low CVP with high PI suggests systemic hypertension
    - High CVP with low PI indicates RV dysfunction

Coagulopathies

- Acquired VWB disease (get a hematology consult)
  - Treat with Desmopressin, Factor VIII concentrate or cryoprecipitate
  - GI bleeds
  - AVMs, especially in the GI tract, due to low pulse pressures and oxidative stress

Anesthesia Plan

- Regional/local encouraged.
  - However, anticoagulation status may be a contraindication to regional.
- General Anesthesia

Preoperative Considerations

- What's the INR?
  - Therapeutic is 2-3, but we usually do not want to have surgery if it is more than 1.5
- Have they been bridged to heparin therapy for surgery?
- Hematology consult
- If on PDE3 inhibitors, should be allowed to continue throughout the perioperative period.
- Is the patient receiving any inotropic support (for the right ventricle, especially)?
  - If so, continue it.
- Antibiotics are extremely important for this patient population! Frequently, 2-3 different ones are used.
- Insert an arterial line!
- Consider CVP/FloTrac to guide volume status
- ALWAYS apply defibrillator pads.

Preoperative Considerations

- Pulsatile VADs must be switched to a fixed rate mode to limit electromagnetic interference.
- Ensure the grounding pad is placed so that the electrical current does not go through the VAD.
- Check the back up battery.
- Pulsatile Index (PI): measures intravascular volume and ventricular performance. Normal = 4-7

Perioperative Considerations

- Even though there is a back up battery, the VAD should be plugged in. Loss of power will cause the LVAD to stop pumping!
- Induction of general anesthesia:
  - Avoid abrupt changes in SVR. Caution with propofol. Consider etomidate, ketamine, and higher doses of benzodiazepines.
  - First generation VADs should be considered a full stomach with RSI.
  - Ensure adequate anesthesia prior to laryngoscopy to avoid abrupt increases in SVR and drops in CO
  - Maintain preload! Consider giving fluids in pre op to avoid the drop in preload seen frequently with induction. These patients are preload dependent!

Perioperative Considerations

- Intraoperative:
  - Positioning: Think about venous return!
  - Expect and prepare for more blood loss than usual due to coagulopathies.
  - Maintain preload, avoid abrupt changes in SVR, maintain RV contractility and rate
  - Avoid excessive PEEP (preload!)
  - Maintain spontaneous respirations if possible
  - Avoid increases in pulmonary vascular resistance (PVR). Protect the RV!
    - Avoid acidosis, hypercarbia, hypoxia

Perioperative Considerations

- Monitoring:
  - Almost all VAD patients should have an arterial line.
    - Remember, if the patient's VAD is non-pulsatile, the arterial line will be difficult to obtain without a palpable pulse! Use ultrasound.
  - Pulse oximetry may not be very useful
  - Assess and maintain RV function and consider a CVP or PAC to monitor preload and RV function.
  - Consider using a BIS monitor as depth of anesthesia cannot be as easily monitored with vital signs in this patient population.

Perioperative Considerations

- Emergence:
  - Must be smooth!
  - Avoid hypertension and tachycardia

Postoperative Considerations

- These patients frequently require a stay in the ICU.
- Goal is usually to extubate in the OR. Avoid hypoventilation en route to ICU.
- Safe transport, check the batteries
- Plug VAD in once you arrive!

LVADs: Cardiac Arrest

- Two most common causes of pump failure: failure of driveline and disconnection of power. Check these first!
- If the VAD is a continuous pump, like the Heartmate II, the patient will not have a palpable pulse.
  - Assess responsiveness, ECG, pump parameters,ETCO2.
  - Assess perfusion: capillary refill, auscultation of machine with stethoscope, assess BP with doppler and manual BP cuff
- According to major manufacturers, chest compressions should be avoided.
  - American Heart Association, June 2017 "...withholding chest compression in a patient with a VAD who is truly in circulatory failure that is not attributable to a device failure would cause more harm to the patient than the potential to dislodge the device."
- Heartmate II manual: "Performing external chest compression may result in damage to the outflow graft conduit or the dislodgement of the Left Ventricular Assist Device inflow cannula."
- Follow standard ACLS drug guidelines
- Remember, the VAD does not affect your EKG. Pacing and defibrillating per regular guidelines, just keep the pads away from the VAD.

Chest Compressions in Patients with LVADs?

- Chest compressions may be safe in arresting patients with left ventricular assist devices (LVADs) by Z. Shinar et al., 2013
- Retrospective case study, reviewing the cases of eight LVAD patients who received chest compressions at a Level II trauma center
  - None of the eight patients had cannula dislodgement as evidenced by autopsy or intact inflow/outflow cannulas after resuscitation.
  - Limitations: small sample size, slight disruptions of cannulae may not show up clinically

Chest Compressions in Patients with LVADs?

- Conclusion: Chest compressions may be safe in LVAD patients, but more research needs to be done.
- A cannula is more likely to dislodge if the VAD was recently put in. In this study, the shortest time from implantation was 50 days.
  - Need more research to determine if chest compressions are effective in LVAD patients.
  - If the arrest is caused by a nonfunctioning LVAD, there would be no perfusion without chest compressions and retrograde flow through the outflow cannula may be possible.
  - Arrests with a functioning LVAD: no cardiac activity, adequate perfusion. Compressions would help deliver blood to the outflow cannula and restore circulation.

Figure 6. Algorithm showing response to a patient with a left ventricular assist device (LVAD) with unresponsiveness or other altered mental status.

Figure 5. HeartMate II troubleshooting chart.

Questions?

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Appendix D

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-Test	34.1880	50	18.05766	2.55374
	Post-Test	76.8340	50	20.92043	2.95860

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pre-Test - Post-Test	-42.64600	24.81877	3.50990	-49.69942	-35.59258	-12.150	49	.000

Correct	Incorrect	Grade (%)	Correct	Incorrect	Grade (%)
2	8	11.1	6	3	66.6
4	5	44.4	9	0	100
3	6	33.3	4	5	44.4
3	6	33.3	7	2	77.8
3	6	33.3	6	3	66.6
4	5	44.4	7	2	77.7
4	5	44.4	7	2	77.7
7	2	77.7	7	2	77.7
5	4	55.5	8	1	88.8
2	8	11.1	1	8	11.1
7	2	77.7	1	8	11.1
2	7	22.2	6	2	66.6
2	7	22.2	8	1	88.8
3	6	33.3	8	1	88.8
4	5	44.4	9	0	100
3	6	33.3	9	0	100
5	4	55.5	8	1	88.8
2	7	22.2	7	2	77.7
2	7	22.2	7	2	77.7
4	5	44.4	7	2	77.7
2	7	22.2	4	5	44.4
2	7	22.2	8	1	88.8
5	4	55.5	7	2	77.7
5	4	55.5	7	2	77.7
3	6	33.3	8	1	88.8
2	7	22.2	8	1	88.8
4	5	44.4	7	2	77.7
3	6	33.3	7	2	77.7
2	7	22.2	7	2	77.7
1	8	11.1	7	2	77.7
2	7	22.2	8	1	88.8
6	3	66.6	7	2	77.7
4	5	44.4	8	1	88.8
1	8	11.1	4	5	44.4
5	4	55.5	9	0	100
2	7	22.2	9	0	100
0	9	0	6	3	66.6
2	7	22.2	9	0	100
2	7	22.2	5	4	55.5
2	7	22.2	5	4	55.5
3	6	33.3	8	1	88.8
1	8	11.1	5	4	55.5
3	6	33.3	5	4	55.5
3	6	33.3	9	0	100
2	7	22.2	5	4	55.5
5	4	55.5	9	0	100
4	5	44.4	9	0	100
6	3	66.6	9	0	100
2	7	22.2	8	1	88.8
1	8	11.1	7	2	77.7
Average % correct		34.188	Average % correct		76.834