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Perioperative Considerations of a Patient with Implementable Pacemaker

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PERIOPERATIVE CONSIDERATIONS OF A PATIENT WITH AN IMPLANTABLE PACEMAKER

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Chapter One

Introduction

A properly functioning cardiac conduction system is integral to a patient's physiologic well-being, as it contributes to an efficient cardiac output. There are a growing number of indications for pacemaker therapy, including atrioventricular blocks, fascicular blocks, sinus node dysfunction, prevention and treatment of tachyarrhythmias, syncope, heart failure, and dilated cardiomyopathy (Gregoratos et al., 2005). Technology in these devices has evolved from simple single-chamber, fixed-rate pacemakers to more complex multichamber, rate-responsive units that have pacing, cardioversion, and defibrillation capabilities (Gregoratos et al., 2005). Indications for cardiac pacing are set to expand even further as technology continues to advance (Salukhe, Dob & Sutton, 2004).

It is estimated that more than 325,000 pacemakers are implanted in the United States each year (Mattingly, 2005). The majority of the 1 million paced individuals in the United States are over the age of 65, currently the most rapidly growing segment of the population (Dawes, Mahabir, Hillier, Cassidy, Haas & Gillis, 2006). The aging population, improvements in implantable devices, and new indications for implantable cardiac devices will lead to an escalating number of patients in the new millennium with these devices (Miller, 2005). This will inevitably result in nurse anesthetists encountering more patients with cardiac devices in practice (Salukhe et al., 2004).

Since the invention of pacemakers, technology has made them more resistant to electromagnetic interference (EMI); however, in the surgical setting several problems still occur. Although the complications are fairly low, they are serious and often life threatening when they do occur (Madigan, Choudhri, Chen, Spotnitz, Oz & Edwards, 1999). Adverse outcomes

associated with an implantable cardiac device include damage to the device, failure of the device to pace or shock, burns to the cardiac tissue, inappropriate reprogramming, asynchronous pacing, or inappropriate antitachycardia pacing (Zaidan et al., 2005). Several adverse clinical outcomes that can be seen include tachyarrhythmia, bradyarrhythmia, hypotension, myocardial infarction, or actual damage to the myocardial tissue (Zaidan et al., 2005). Electrocautery can be a significant source of EMI in the operative setting, if proper precautions are not taken to decrease the incidence (Dawes et al., 2006).

Problem

Patients with implantable pacemakers are being encountered more frequently in hospitals and outpatient surgery centers, yet nurse anesthetist's knowledge of how to provide safe perioperative management is incomplete. Anesthesia textbooks provide only a brief overview of topic and fail to address important perioperative strategies (Mattingly, 2004). Even though the incidence of EMI has decreased due do technological advances, the consequences can be life threatening. It is imperative that anesthesia providers know how to safely provide care during the perioperative period to patients with an implantable cardiac device (Mattingly, 2004).

Purpose

The purpose of this project is to educate the reader on the function, pacing modes, and potential for electromagnetic interference with an implantable pacemaker, in addition to the management of these patients during the perioperative setting. The information will be presented at an in-service to nurse anesthetists at a small Midwestern hospital and again during the spring anesthesia meeting.

Theoretical Framework

The theoretical framework used for this paper is Malcolm Knowles adult learning theory. Malcolm Knowles developed the adult learning theory in an attempt to describe how adults learn. He used the term "andragogy" to guide his theory in adult education, which he defined as "the art and science of helping adults learn". He emphasized that adults are self-directed and expect to take responsibility for their decisions (Knowles, 1975). Knowles used five assumptions about adult learners in his theory which include:

1. Self-concept: As a person matures his self-concept moves from one of being a dependent personality toward one of being a self-directed human being.
2. Experience: As a person matures he accumulates a growing reservoir of experience that becomes an increasing resource for learning.
3. Readiness to learn: As a person matures his readiness to learn becomes orientated increasingly to the developmental tasks of his social roles.
4. Orientation to learning: As a person matures his time perspective changes from one of postponed application of knowledge to immediacy of application, and accordingly his orientation toward learning shifts from one of subject-centeredness to one of problem centeredness.
5. Motivation to learn: As a person matures the motivation to learn is internal (Smith, 1999).

Each of these assumptions attempts to explain what and how the adult learns. This theory is appropriate to my purpose, because it explains how adults go about unconsciously learning throughout their lifespan. The assumptions of the theory will be individually applied to how nurse anesthetists learn.

The assumption of experience, which is stated by Knowles (1975) "as a person matures he accumulates a growing reservoir of experience that becomes an increasing resource for learning", can be applied to nurse anesthetists who will attend the in-service. As a new graduate, the magnitude of knowledge comes primarily from text books, with little coming from clinical experience. A vast array of wisdom and knowledge develops as the CRNA continues in the profession through clinical experience and educational seminars, allowing the CRNA to accomplish his tasks with a greater sense of security as opposed to the new graduate. The sense of security gained moves the CRNA in the direction of being a more self-directed human being.

Malcolm Knowles (1975) states his assumption of readiness to learn "as a person matures his readiness to learn becomes orientated increasingly to the developmental tasks of his social roles". This assumption can be applied to the CRNA's ability to understand the relevance of education as it is needed to carry out a particular task. When the CRNA understands the importance of expanding his/her knowledge base in the area of perioperative management of a patient with a cardiac device, he/she will be able to use this information to make positive changes in the way they provide care.

Knowles (1975) assumption of orientation to learning "as a person matures his time perspective changes from one of postponed application of knowledge to immediacy of application, and accordingly his orientation toward learning shifts from one of subject-centeredness to one of problem centeredness". Since the anesthesia provider is already an adult, it is safe to assume that there is an immediacy of application of knowledge toward that of problem solving. Knowledge gained from the in-service should be seen as a direct application to practice as the CRNA strives to provide the safest care possible.

The final assumption of Knowles (1975) that will be discussed is motivation to learn, which states that "as a person matures the motivation to learn is internal". As the CRNA becomes more confident in their abilities as an anesthetist, they may begin to seek out educational opportunities, such as in-services and conferences on their own. The desire to acquire a vast knowledge base benefits both the CRNA and patient by providing better quality anesthesia care.

Definitions

The following definitions will assist the reader to elucidate some of the terminology that is discussed in this project.

1. Pacemaker Generator: An implanted device with a power source and circuitry to produce an electrical impulse in the heart to pace and support the heart rate.
2. Implantable Cardiac Device: Refers to a permanently implanted cardiac pacemaker.
3. Pacing Mode: The designation of chambers paced, chambers sensed, sensing response, programmability, rate responsiveness, and the multisite pacing function for a pacemaker.
4. Unipolar versus Bipolar Pacing: Terminology that refers to the type of pacemaker and the distance between the distal sensing electrode and the proximal electrode.
5. Electromagnetic Interference: Occurs when the electromagnetic fields from one electrical device interfere with the operation of another electrical device.
6. Perioperative Management: The preoperative, intraoperative, or postoperative period in any setting where an anesthesia provider delivers anesthesia care.

Chapter Summary

The incidence of placement of implantable cardiac devices will continue to rise as the population ages and new implications and advancements are made. The adverse outcomes of EMI are severe. Recommendations' regarding the management of patients with implanted cardiac devices becomes increasing significant both as the number of patients with devices and the number of surgical procedures increase. Through the work of this project, I hope to educate anesthesia providers on how to provide safe and effective perioperative care to a patient with cardiac device and to reduce the incidence of adverse outcomes.

Chapter Two

Review of Literature

Introduction

The increasing elderly population, improved technology, and expanding indications for implantable cardiac devices will inevitably lead to more anesthesia providers encountering patients with these devices in their practice; unfortunately, anesthesia providers lack sufficient knowledge regarding the safe perioperative management of a patient with a cardiac device. An extensive literature review of Pubmed, Cinahl, and MDConsult was conducted to gather information on the perioperative management of a patient with an implantable pacemaker. A practice advisory, case reports, and several articles published by credible sources were used in this paper that ranged from the years 1991-2007. No research studies were found in the search. The most significant areas regarding implantable pacemakers that the author discovered were articles that explained their functions and codes, electromagnetic interference with electrocautery, and perioperative management of a patient with a device.

Pacemaker Design and Function

In order to competently care for a patient with a cardiac device, the anesthetist must have an understanding of the pacemaker design, functions and codes. Pacemakers consist of 2 major components: a pulse generator and a lead system. The pulse generator contains a lithium iodine battery, electronic sensing circuitry, and a silicon semiconductor chip, the brain of the device (Mattingly, 2004). The chip and sensing circuitry provide the ability to analyze the cardiac rhythm, determine if pacing is necessary, and deliver an appropriately timed pulse (Dawes et al., 2006). The leads are insulated wires that conduct electrical signals to and from the heart (Mattingly, 2004). In single chamber pacemakers, the lead passes from the pulse generator

through the superior vena cava to the right ventricle, where the tip of the lead rests at the apex of the right ventricle. A second atrial lead is placed in the right atrium in dual-chamber pacemakers (Miller, 2005).

An important distinction in lead polarity must be made between unipolar and bipolar pacemakers. With either type of pacemaker, electrical signals are detected between the two electrodes. In the case of a unipolar pacemaker, the negatively charged electrode, cathode, is located in the heart at the electrode tissue interface, and the positively charged electrode, anode, is on the surface of the pulse generator. Sensing occurs between the distant electrodes (Mattingly, 2004). A bipolar pacemaker, in contrast, places both electrodes within the heart. The cathode is at the tip of the lead and the anode is located 1-2 cm proximal to the tip (Mattingly, 2004). The greater distance between electrodes make unipolar pacemakers more prone to sensing extracardiac signal, skeletal muscle potentials, and electromagnetic interference than bipolar pacemakers (Dawes et al., 2006).

In 1983, the North American Society of Pacing and Electrophysiology (NASPE) and British Pacing and Electrophysiology Group (BPEG) created a generic code (NBG) to standardize the classification of pacemakers. The code was last revised in 2002 (See Appendix A). Each device is assigned five letters. The first letter describes the chamber(s) being paced, the second describes which chamber(s) is being sensed, the third describes the programmed response to a sensed event, the fourth indicates whether rate modulation (rate-responsive pacing) is present or absent, and the fifth describes multisite pacing functionability (describing which chamber(s), if any, have multisite capability). The first three letters are always listed, but the last two may be omitted if the features are absent (Miller, 2005).

Due to the complexity in understanding the fourth position, rate modulation, further explanation is required. Rate-responsive pacemakers were designed for patients that are unable to increase their heart rate in response to increased oxygen demand (Miller, 2005). In addition to sensing atrial or ventricular activity, rate-responsive pacemakers contain various sensors that allow them to increase the basic pacer rate. Rate modulation sensors include: muscle activity (piezoelectric crystal on the pulse generator); motion (accelerometer); minute ventilation (transthoracic electrical impedance); QT interval; or right ventricular pressure, with motion and minute ventilation sensors most commonly used (Salukhe et al., 2004). Due to the impact of operative movement and ventilator changes, pacemakers with rate modulation are more susceptible to produce unwanted tachycardia during surgery (Bourke, 1996).

Electromagnetic Interference

Improved protective mechanisms on newer implantable pacemakers have led to fewer complications, but the consequences can be severe when they occur. In the surgical setting, electrocautery is the leading cause of EMI, requiring the nurse anesthetist to have a basic knowledge of why interference occurs and consequences it has on the pacemaker. Electrocautery uses radio frequency current usually between 300 and 500 kHz, to cut or coagulate tissues. It can be unipolar (electocutting or electrocautery) or bipolar, with the majority used being unipolar (Salukhe et al., 2004). Electrocutting uses continuous, high-frequency, high-voltage current, while electrocoagulation uses short bursts of lower voltage current. The continuous energy produced by electrocutting is more likely to produce interference than the intermittent bursts of current from electrocoagulation (Dawes et al., 2006). In both cases, unipolar current originates at the tip of the electrocautery device, impels through the body, and returns to the generator via a grounding pad (Madigan et al., 1999). Bipolar current flows only

to tissue that is in direct contact with the electrocautery device, because both electrodes are built into the tip of the instrument, making the use of a grounding pad unnecessary. Bipolar cautery produces a more local, low-intensity electromagnetic field and ultimately poses less risk to a patient with a cardiac device (Dawes et al., 2006).

EMI can produce several adverse outcomes associated with an implantable cardiac device. Such adverse outcomes include circuitry damage to the device, failure of the device pace or shock, burns to the cardiac tissue, mode reprogramming, asynchronous pacing, or inappropriate antitachycardia pacing (Zaidan et al., 2005). Interference with the cardiac device can transpire into adverse clinical outcomes that can be seen as hypotension, tachyarrhythmia or bradyarrhythmia, myocardial tissue damage, or myocardial infarction (Zaidan et al., 2005).

Pre-operative evaluation

A practice advisory developed by cardiologists and experts in the field is consistent with the current literature, regarding the necessary components when conducting a preoperative evaluation for a patient with an implantable cardiac device. Patients presenting for surgery should receive a thorough exam and be evaluated to determine whether they have an implantable cardiac device (Zaidan et al., 2005). A focused exam involves a comprehensive review of medical records, chest x-ray films, electrocardiograms (EKG), and electrolytes, along with an interview of the patient and physical exam (Madigan et al., 1999). Evidence of electrolyte imbalances (hypokalemia or hyperkalemia), arterial hypoxemia, or active myocardial ischemia should be stabilized prior to surgery, as these factors can alter stimulation thresholds of cardiac pacemakers (Bourke, 1996). Additional information regarding the history of pulse generator events, particularly the frequency of anti-tachycardia pacing, is of vast importance when performing a pre-operative evaluation (Salukhe et al., 2004). The information gathered from the

history and exam needs to be compared to assure that the device is truly a cardiac device. Pain control, thalamic, phrenic nerve, and vagus nerve stimulators are examples of other implantable devices that may be present in the pectoralis area and could be mistaken as cardiac in origin (Miller, 2005).

A case report published by Kazatsker et al. (2002) describes a situation in which a patient's x-ray and history revealed the presence of a non-cardiac implantable device. The cased report involved a 67- year old man who presented for surgery with bilateral devices implanted under the skin in the pectoralis areas. The chest x-ray confirmed the presence of bilateral pacemakers, but the leads of both devices were orientated to the neck rather than the heart. Upon further evaluation of the chart, the presence of a thalamic stimulator rather than cardiac device was confirmed. This case report is consistent with the literature suggesting the importance of a thorough pre-operative history and exam to ensure the device is truly an implantable cardiac device.

The literature is clear that the type and proper functioning of the cardiac device need to be confirmed prior to surgery. The majority of patients usually present for surgery with an identification card containing the type of cardiac device, model, and mode (Dawes et al., 2006). If necessary, this information can also be obtained by examining the patient's medical records, consulting a cardiologist or manufacturer specific programmer, or by examining the chest x-ray for the presence of pacemaker leads or model number (Zaidan et al., 2005). Literature is clear that a consult with a cardiologist or pacemaker programmer is invaluable at this phase of the pre-operative evaluation, if possible. They can perform a thorough interrogation of the device and assist in determining the programmed settings, battery status, stimulation thresholds, assessment of sensing function, and provide recommendations for perioperative programming (Dawes et al.,

2006). The EKG should be examined to determine that the pacemaker is functioning properly, by assessing for appropriate sensing, pacing, and capture (Bourke, 1996). If a comprehensive interrogation of the device is not possible due to an emergent case, then, at a minimum, pacing impulses followed by a paced beat and arterial pulse should be confirmed (Zaidan, et al., 2005).

A final recommendation in regards to the preoperative evaluation, from the practice advisory and throughout the literature, is the importance of determining the patient's underlying rhythm and if they are pacemaker dependent. This task is usually performed by the programmer or cardiologist (Stone & McPherson, 2004). Pacemaker dependency is established if one or more of the following are present: 1) symptomatic bradyarrhythmia noted in the history, requiring implantation of a cardiac device; 2) history of successful atrioventricular nodal ablation, requiring an implantable cardiac device; or 3) no spontaneous ventricular activity when the pacemaker is reset to the lowest rate in the VVI pacing mode (Zaidan, et al., 2005). Dawes et al. (2006) also suggests that pacemaker dependence may be present, if a spike is noted prior to every beat on the preoperative EKG. In this situation, a programmer or cardiologist should be consulted to investigate further by inhibiting the pacemaker as previously described.

Preoperative preparation

Several credible authorities, along with the practice advisory, agree on the components of preoperative preparation for a patient with a cardiac device. The practice advisory states that a key component involves anticipating if electromagnetic interference (EMI) will occur during the planned procedure. The most common source of EMI in the surgical setting is associated with electrocautery (Zaidan et al., 2005). Dr. Pinski and Dr. Trohman (2002), cardiologists from the Cleveland Clinic in Florida, suggest that if EMI is anticipated and pacemaker dependence is found during the pre-operative evaluation, the device should be reset to an asynchronous mode

above the intrinsic rate, while the programmed modes should not be changed if the patient is not found to be pacemaker dependent. EMI in a pacemaker-dependent patient could be life threatening, although the issue is less acute in a nondependent patient (Dawes et al., 2006).

Current American College of Cardiology/American Heart Association (ACC/AHA) guidelines advise that all anti-tachycardia pacing functions should be deactivated prior to surgery regardless of the procedure, because they are associated with a high degree of interference and could deliver inappropriate anti-tachycardia therapy. In addition, it is suggested that rate-responsive pacemakers be reprogrammed out of the rate-responsive mode prior to surgery, especially if electromagnetic interference is expected (Stone & McPherson, 2004). This is particularly important for devices that rely on minute ventilation or movement sensors for rate modulation, in order to prevent inappropriate tachycardia as a result of mechanical ventilation changes, shivering, or other operative movement (Salukhe et al., 2004).

Wong and Middleton (2001) published a case report about a 59 year old male who was scheduled for a transurethral resection of prostate surgery and experienced EMI with his rate-responsive pacemaker. Due to a history of third degree heart block, the patient was completely pacemaker dependent. He had a VVIR pacemaker, which was set at a lower ventricular rate of 60 beats per minute and an upper rate responsive limit of 130 beats per minute. Upon initiation of unipolar electrocautery, the paced ventricular rate gradually increased from 60 to 130 beats per minute. Conversely, the paced rate gradually returned to 60 beats per minute when electrocautery was discontinued. The conclusion formed in this case was that when electrocautery was used in this patient, the rate-responsive pacemaker sensed the mixture of thoracic bioimpedeance signals as a sign of elevation in minute ventilation, resulting in an

increase of ventricular rate to 130 beats per minute (Wong & Middleton, 2001). Evidence from this case report supports the literature suggesting that the rate-responsive mode should be deactivated prior to the exposure of electromagnetic interference.

With regard to magnet placement over a pacemaker, no simple rule can be safely followed. Literature is clear that simply placing a magnet over a device can cause a myriad of programming possibilities and responses to EMI depending on the pacemaker type and programming (Mattingly, 2004). Today, many surgeons and anesthesia providers enter the operating room armed with a magnet, confident that it will be able to manage complications produced by EMI. This is a dangerous practice that is not supported by literature and may result in harm to the patient or devise itself (Madigan et al., 1999). Current literature recommends consulting with a programmer prior to surgery to determine the effects of magnet placement on the particular cardiac device, as programming possibilities vary based on device type and mode (Zaidan et al., 2005).

Intraoperative management

Intraoperative management of a patient with an implantable cardiac device is focused on establishing appropriate monitoring, minimizing sources of EMI, and preventing and treating untoward events. According to the practice advisory and other credible authorities, an important component to the intraoperative management of a patient with cardiac device is diligent monitoring of the device and heart function. As well as the use of routine monitors required by ASA standards, both the electrical and mechanical heart function should be monitored. Stone and McPherson (2004) suggest the use of continuous five-lead ECG monitoring throughout the intraoperative and postoperative periods to allow electrical analysis of the rhythm during and after periods of EMI. In addition, mechanical evidence of pacing capture should be continuously

monitored by palpating for a pulse, monitoring the pulse oximetry, auscultating heart sounds, or observing the arterial line tracing (Zaidan et al., 2005). Such practices ensure continued perfusion when there is competition between the pacemaker and intrinsic activity, making the EKG difficult to interpret (Stone & McPherson, 2004).

The practice advisory and other credible sources warn that there are other potential influences on cardiac devise function that may occur during the intraoperative period. Among these influences are the effects of hyperkalemia, hypokalemia (hyperventilation), myocardial ischemia, arterial hypoxemia, severe hyperglycemia, acidosis, alkalosis, bradycardia, or type I antiarrhythmic drugs. The most common adverse outcome resulting from these factors is an increase in pacing threshold, which may cause failure of the device to pace (Stone & McPherson, 2004). The practice advisory suggests that these factors should be corrected whenever possible, because of their potential to induce unexpected cardiac device responses (Zaidan et al., 2005). Dr. Stone and Dr. McPherson (2004) suggest that succinylcholine should be used cautiously in patients with unipolar pacemakers. Skeletal muscle fasciculations produced by succinylcholine may result in pacemaker oversensing and ultimately failure to pace (Stone & McPherson, 2004). Bourke (1996) recommends the use of a defasciculating dose of non-depolarizing relaxant prior to administration of succinylcholine to prevent inhibitation of demand pacemakers.

Finfer (1990) published a case report about an 81 year old woman who had emergency surgery for a strangulated hernia. The patient had a unipolar, rate-responsive, single chamber demand pacemaker. The preoperative labs and chest x-ray were normal. The admission EKG confirmed that the pacemaker was functioning and was inhibited appropriately by intrinsic ventricular beats with no evidence of myocardial ischemia. On arrival to the operating room, a continuous EKG and arterial pressure monitoring confirmed that the pacemaker was functioning

properly. The patient was preoxygenated for five minutes and induced with thiopental 125 mg and fentanyl 0.05 mg. Following the administration of 50 mg of succinylcholine, the EKG revealed asystole with no visible pacemaker artifact or palpable carotid pulse. The conclusion formed by the author was that muscle fasciculations produced by the succinylcholine caused skeletal muscle myopotentials that inhibited the unipolar pacemaker function (Finfer, 1991). This conclusion appears accurate, because normal lab values and pacemaker function were confirmed prior to surgery; however, a defasciculating dose of rocuronium was not administered prior to succinylcholine, which may have prevented fasciculations and ultimately inhibition of pacemaker function. This case report supports recommendations by Dr. Stone and Dr. McPherson to use caution when administering succinylcholine to patients with unipolar pacemakers, especially if a defasiculating dose of rocuronium is not going to be used.

Within the surgical setting, electromagnetic interference is most commonly seen with the use of electrocautery. Although electrocautery may be avoided with some surgical procedures, other procedures would be impossible to perform without it, requiring the nurse anesthetist and surgical team to be able to recognize and manage problems produces by these devices (Madigan et al., 1999). The practice advisory and other credible sources agree on ways to reduce EMI produced during electrocautery. The literature is clear that bipolar electrocautery or an ultrasonic (harmonic) scalpel should be used in place of unipolar cautery whenever possible, because its consistent safety profile (Zaidan et al., 2005). If unipolar cautery is required, several precautions should be taken by the individual performing the surgical procedure, including the use of short, alternating bursts at the lowest possible energy level. Pauses of at least 10 seconds between bursts are recommended to allow for resumption of rhythm and normal hemodynamics (Dawes, et al., 2006). The grounding pad should be positioned so that the cardiac device is not in the

pathway of the electrocautery current. For special head, neck, or thoracic procedures, the grounding pad may need to be placed on a site other than the thigh, such as the upper, posterior aspect of the shoulder on the opposite side of the pulse generator, again avoiding positioning of the cardiac device between the grounding pad and cautery tip (Zaidan et al.). Consistent throughout the literature is the recommendation to ensure that the path between the grounding pad and the electrocautery tip are as far from the device as possible, with 15 cm being the minimum (Dawes et al.). Individuals performing the procedure should also be advised to initiate cautery only when the tip is in contact with the skin and not in the air (Mattingly, 2004).

Several case reports have been published demonstrating the safe use of an ultrasonic scalpel as an alternative to unipolar cautery in patients with pacemakers. Nandalan and Vanner (2004) submitted a case report of a 61 year-old woman who had previous atrioventricular node ablation, causing her to be 100% pacemaker dependent on a unipolar pacemaker programmed to the VVIR mode. The pacemaker sensitivity was reduced from 3.0 mV to 11.2 mV prior to surgery. Standard IV induction was initiated and an ultrasonic scalpel was used intermittently during the one hour laparoscopic cholecystectomy procedure with no EKG interference or cardiovascular disturbances. At the end of the case, the pacemaker sensitivity was reset and pacemaker checks showed no damage to the pacemaker or changes to the capture threshold, confirming the safe use of the ultrasonic scalpel in patients with pacemakers. The only disadvantage stated by the author in using the ultrasonic scalpel was the increased cost for the disposable set compared to the reusable electrocautery (Nandalan & Vanner, 2004).

Strate et al. (1999) reported similar findings of a patient with a DDD pacemaker, having a laparoscopic cholecystectomy. An ultrasonically activated scalpel was used for cutting and

coagulation during the case. No abnormal rhythms or EKG interference were detected and no change in pacing thresholds or pacemaker damage occurred (Strate et al., 1999).

Ozeren et al. (2202) published a case report about a 57 year-old male who safely underwent surgery with an ultrasonic (harmonic) scalpel without experiencing interference in his unipolar pacemaker. The patient in this case report was scheduled for an open-heart reoperation to repair a paravalvular leakage. He had a unipolar pacemaker programmed to VVIR mode for total AV block. The surgeon used an ultrasonic (harmonic) scalpel, between the levels of III and V, for cutting and coagulation during the case. Even though the rate-responsive mode was not deactivated prior to surgery, no abnormal rhythms or EKG interferences were noted during the procedure; furthermore, no changes in the pacing threshold or damage to the pulse generator were detected postoperatively. The authors reported the only disadvantage of using the ultrasonic scalpel was the slower cutting and coagulation when compared to traditional electrocautery (Ozeren, Dogan, Duzgun, & Yucel, 2002). This case report supports recommendations from the literature to use an ultrasonic scalpel whenever possible, since electrical interference with the pacemaker/ICD is completely avoided by transferring heat to the tissue without electrical current passing through the patient.

El-Gamal et al. (2001) published a survey of provisions and complications experienced by 166 cutaneous surgeons when electrocautery was used in patients with pacemakers or ICDs. The survey showed 71% of the respondents routinely used short bursts of less than five seconds, 61% used low voltage, and 57% avoided use around the pacemaker or ICD. Due to failure to consistently follow recommended guidelines for safe use with electrocautery, several types of interference occurred. The types of interference reported were "skipped beats in eight patients, reprogramming of a pacemaker in six patients, firing of an ICD in four patients, asystole in three

patients, bradycardia in two patients, depleted battery life in one patient, and an unspecified tachyarrthymia in one patient" (El-Gamal et al., 2001, p. 385). The author reports a low rate of complications (0.8 cases/100 years of combined surgical practice). The survey also reported that bipolar cautery was used by 19% of the respondents, who denied any type of cardiac device interference or damage with this type of cautery (El-Gamal et al., 2001). Results from this survey can be used to support literature recommending the safe use of bipolar cautery in patients with a cardiac device and further recommendations to consistently follow recommended guidelines when using unipolar electrocautery to prevent complications.

When electrocautery is anticipated, several steps should be taken by the anesthesia provider to prevent adverse outcomes and have adequate resources available should they arise. Zaidan et al. (2005) states it is vital to reprogram pacemakers to an asynchronous mode and suspend rate-adaptive functions prior to surgery in which electrocautery is suspected. The literature consistently suggests that temporary pacing, defibrillation equipment, and contact numbers for a cardiac device programmer should be available in the case of an emergency regardless of the surgical procedure, but especially in cases involving electrocautery, because adverse outcomes can still occur if pacemakers are reprogrammed to asynchronous mode (Dawes et al., 2006).

Smith and Hamer (1993) published a case report of an 87 year old woman who experienced interference during the use of unipolar cautery, before her VVIR pacemaker was reprogrammed out of the rate-responsive mode. This patient was scheduled for a revision of a right-hip arthroplasty and had a META rate-responsive pacemaker (VVIR) for complete heart block. Preoperative labs, chest x-ray, and EKG were all normal, with the EKG showing a paced rhythm of 70 beats per minute. An epidural catheter was placed, followed by standard IV

induction. The patient was hemodynamically stable following induction, until the initial skin incision was made using a properly positioned unipolar electrocutting device; immediately the patient's systolic blood pressure fell to 65 mmHg and the paced heart rate increased to 130 beats per minute. Electrocautery was paused and the patient's vital signs returned to normal. A second short burst of unipolar electrocautery produced the same effect. The pacemaker was then changed to a non-rate-responsive mode (VVI) by a programmer, which allowed surgery to continue uneventfully despite the use of unipolar cautery. This case report supports the literatures suggestion to program pacemakers out of the rate-responsive mode prior to electrocautery to prevent adverse outcomes.

Mangar, Atlas, and Kane (1991) published a case report of a 15 year old girl who experienced pacemaker failure despite reprogramming to asynchronous mode prior to surgery. The 15 year old girl was scheduled for correction of a value stenosis and LV-PA conduit, in which the use of unipolar cautery was anticipated; therefore, the patient's VVI pacemaker was changed to an asynchronous mode prior to surgery. After the induction of anesthesia, electrocoagulation produced transient asystole twice that reverted back to normal after cauterization was stopped. On the third use of electrocautery, sustained asystole occurred despite cessation of cautery. Cardiopulmonary resuscitation was started, followed by the insertion of a transvenous pacemaker. All proper precautions for electrocautery were taken during this case; including the use of short, intermittent burst and proper positioning of the grounding plate as far from the pacemaker as possible. The conclusion made by the author of this case was that the unipolar electrocautery caused a reduction in battery voltage, leading to eventual pacemaker and battery failure (Manger et al., 1991). This case report is the only one found in the literature in which pacemaker failure occurred despite reprogramming of the device

to asynchronous mode, making it a rare occurrence. In addition, the author did not report if the patient's electrolytes and acid-base balance were normal prior to surgery, which may have caused pacemaker interference despite being programmed to asynchronous mode. This case report, however, supports the recommendation of the literature to have emergency pacing and defibrillation equipment readily available, as adverse outcomes can still occur.

Literature is consistent that if a life threatening arrhythmia develops in a patient with a cardiac device, certain guidelines should be followed regarding emergency defibrillation or cardioversion. The primary concern when placing defibrillation or cardioversion pads is to reduce the energy flowing through the cardiac device (Zaidan et al., 2005). Eagle et al. (2002) recommends positioning the pads as distant from the pulse generator as possible and in a manner that the route of current is perpendicular to the axis of the device leads and generator, by placing them anterior and posterior. The lowest effective energy level should be selected; although damage to the device, an increase in pacing threshold, or a reversion to a backup mode may still occur (Stone & McPherson, 2004).

Finfer (1991) published a case report of a patient who experienced an increased pacing threshold following defibrillation. The 81 year-old women had a unipolar, rate-responsive, demand pacemaker. During IV induction directly following the administration of 50 mg of succinylcholine, the EKG revealed asystole with no visible pacemaker artifact or palpable carotid pulse. After external carotid massage was commenced, ventricular fibrillation was seen. The heart was defibrillated twice with 50 joules of current, followed by a slow idioventricular rhythm. Surgery was canceled in this case and the patient was admitted to the ICU, where a temporary transvenous pacing wire was inserted. Following resuscitation, the pacemaker generator was functioning normally, but with failure of both capture and inhibition. When the

system was checked, an increase in stimulation threshold to 4 V was found, leading to the failure of capture and inhibition (Finfer, 1991). This case report is consistent with the literature stating that despite the use of minimal energy levels during defibrillation, an increase in pacing threshold may still occur.

Postoperative considerations

Consistency exists in the literature regarding the postoperative management of patients with an implantable cardiac device. Literature strongly recommends the interrogation of the device by a cardiologist or programmer to determine proper functioning of the device and to assure that the device was not inadvertently reprogrammed during surgery or damaged (Mattingly, 2005). Zaidan et al. (2005) suggest the use of continuous EKG monitoring until postoperative interrogation of the cardiac device can be made. Postoperative interrogation is required any time that electrosurgical cautery was used during the case. If the device had been reprogrammed prior to or inadvertently during surgery, it should be reprogrammed to the appropriate settings (Dawes, et al., 2006).

Although no studies or case report exist in this area, the consensus of the practice advisory members with expertise in the area of implantable devices is seen as valuable. Further confidence can be established by the presence of several published articles confirming suggestions made by the practice advisory.

Chapter summary

The literature review for this project attempted to inform the reader about the function and codes of pacemakers, way to reduce EMI when electrocautery is used, and the components needed to safely manage a patient with a device during the perioperative period. Many anesthesia providers lack sufficient knowledge regarding this topic; transpiring into unsafe

practice that places the patient at risk for adverse outcomes. Therefore, it is the intended goal of the author to provide an in-service to educate nurse anesthetists on valuable information obtained from this literature review and ultimately improve patient safety.

Chapter Three

Introduction

With the number of patients with cardiac implantable devices increasing in hospitals and outpatient surgery centers, it is important that anesthesia providers know how to safely provide care during the perioperative period to patients with these devices. However, the nurse anesthetists' knowledge of how to provide safe perioperative management is often incomplete. The goal of this project was to educate anesthesia providers on the functions of pacemakers and how to safely care for a patient with an implantable cardiac device throughout the perioperative period.

Target Audience

There were two target audiences for this project. The first of which was the anesthesia providers at a rural Midwestern hospital. This 36-bed hospital serves a community of approximately 9,000 people and employs four nurse anesthetists. The anesthesia providers at this hospital provide services to three operating rooms at the main hospital and one additional operating room at a freestanding surgery center, as well as rural anesthesia in two additional smaller communities. All the practitioners at this rural hospital have many years of experience, but seldom encounter patients with implantable cardiac devices.

The second target audience of this project was anesthesia providers attending the local state association of nurse anesthetists spring meeting. Attendees were rural anesthesia providers from many different communities as well as students from the state university nurse anesthesia specialty program, encompassing CRNAs that were new to the profession as well as experienced anesthetists. Variations in knowledge and exposure to patients with an implantable pacemaker were present among this target audience.

CRNAs were chosen as the target audience because of the knowledge gap that exists when caring for patients with an implantable cardiac device during the perioperative setting. In this rural state, Certified Registered Nurse Anesthetists are the sole anesthesia providers at 64% of hospitals. After all, the CRNA is ultimately responsible for ensuring the safety of the patient during the perioperative period.

Methodology/Procedures

Information gathered about the perioperative management of a patient with an implantable pacemaker was presented during an informal in-service at the aforementioned hospital to the current anesthesia providers. The time and place was agreed upon between me and the clinical coordinator at the hospital. In addition, the information was presented again in a more formal manner at the local state association of nurse anesthetists spring meeting. Information was presented with the use of Power Point.

The in-service was based on information gathered from the literature review conducted for this paper which included the following: 1) review of functions, types, and codes of implantable pacemakers; 2) review of the preoperative, intraoperative, and postoperative management of a patient with an implantable pacemaker; and 3) types of electrocautery and the prevention of complications associated with electromagnetic interference in the operating room (See appendix B).

Prior to presenting the information at the in-service and state meeting, the presentation was evaluated and approved by my student advisor and nurse anesthesia assistant program director. A pre-test/post-test evaluation method was employed during the in-service (See appendix C). The identical ten question pre-test and post-test was administered. Comparison of pre-test with post-test results helped to determine the participants' prior knowledge base, how

much they learned from the in-service, and the effectiveness of teaching strategies. Attendees were asked to complete a five point Likert scale survey regarding the quality and usefulness of the presentation in relation to current practice.

Expected Results

The expected results of this paper and in-service were an increase in knowledge and awareness among anesthesia providers on how to safely care for a patient with an implantable pacemaker during the perioperative period. The information presented helped eliminate any questions, concerns, and anxiety that anesthesia providers have when caring for a patient with an implantable cardiac device. Increased knowledge in this area should be recognized clinically as improved patient outcomes and decreased adverse events.

Implications for Nursing

Nursing Practice

As the number of patients with implantable cardiac devices increases along with technology and the aging population, anesthesia providers will be encountered with the challenge of safely managing an increasing number of these patients during the perioperative period. It is imperative that anesthesia providers possess an abundant knowledge base regarding implantable pacemakers and the impact that electromagnetic interference can have on these devices. The information described in this paper and presented during the in-service helped to alleviate the questions and concerns of anesthesia providers, regarding the management of patients with implantable cardiac devices during the perioperative period. Information provided in this paper will help attenuate anxiety and stress levels of anesthesia providers when they encounter a patient with a cardiac device. In addition, the ultimate goal of improved patient safety and a decrease in adverse outcomes should be seen.

Nursing Research

Available research concerning the anesthetic management of patients with implantable cardiac devices consists of a practice advisory developed by the American Society of Anesthesiologists, current articles published by credible sources, and several case reports concerning adverse outcomes that have occurred in patients with implantable pacemakers during the intraoperative period. Existing research is useful in recognizing causes of adverse outcomes. Despite published research, continued case reports are needed to provide clear indications of causality and to identify the best methods to prevent electromagnetic interference. The in-service exposed the need for further publications of case reports involving positive and negative outcomes experienced in practice.

Nursing Education

The field of anesthesia is continually changing with technological advances and attempts to improve patient outcomes. Continuing education is a principle of utmost importance that anesthesia providers strive to advance in their practice. The information in this paper and provided during the in-service increased the anesthesia providers' knowledge concerning the functions, types, and codes of implantable cardiac devices. In addition, anesthesia providers expanded their knowledge on how to provide safe perioperative management of a patient with an implantable cardiac device. Information gathered from the literature review of this paper may prove beneficial to nurse anesthesia students, curriculum designers, and other anesthesia providers.

Nursing Policy

Individuals with implantable cardiac devices will continue to be a special population for anesthesia providers. Therefore, it is imperative that anesthesia providers possess the knowledge

of how to care for this type of patient. Several hospitals in the Midwestern United States have already developed pacemaker clinics and databases that contain specific information on patients with implantable devices that range from the reason for insertion to the type and mode of the device. This paper offers the basis for establishing a policy for the perioperative management of a patient with an implantable cardiac device. Information gathered from the literature review could assist anesthesia providers in predicting and preventing consequences of electromagnetic interference. Such change of existing policies at Midwestern hospitals would augment patient safety and decrease personnel stress.

Evaluation of the Project

Based on results from the survey and the pre-test/post-test evaluation, several conclusions were made regarding the prior knowledge of the participants and the effectiveness of the teaching strategies used for the in-service. The survey results showed that the information was presented in a concise, throughough manner. The survey also concluded that the anesthetists at the in-service felt that the presenter was knowledgeable about the content and well prepared for the presentation. Pre-test question results revealed some variation. One-hundred percent of the anesthetists got questions five, six, eight, nine, and ten wrong, which demonstrated areas that the participants had no prior knowledge about. Fifty percent of the anesthetists answered questions two and seven incorrectly. Seventy-five percent of the anesthetists answered questions three and four correct, demonstrating some prior knowledge in this area. Prior knowledge about the topic in question number one is confirmed by one-hundred percent of the participants getting the question correct. Examination of the pre-test/post-test confirmed that the presenter did an excellent job presenting the information and focused on important points, demonstrated by a score of a 100% on the post-test by all of the anesthetists.

Malcolm Knowles adult learning theory was utilized as the theoretical framework for this paper. The author of this paper used this theory because it deals with how adults learn. Since this project was designed to educate adult learners at different levels of experience, training, and abilities as nurse anesthetists, the concepts of assumptions of experience, readiness to learn, and motivation to learn have pertained to this paper. The author believes that Knowles theoretical framework was the right framework for this project.

Recommendations for Further Study

Existing research provides a basic guideline for the perioperative management of a patient with an implantable cardiac device. Published case reports are useful in recognizing causes of adverse outcomes. Despite published research, continued case reports are needed to provide clear indications of causality and to identify the best methods to prevent electromagnetic interference. The publication of such case reports should help improve patient safety and decrease adverse outcomes.

Chapter Summary

This paper creates an awareness of the increasing prevalence of people with an implantable cardiac device, proving it inevitable that anesthesia providers will encounter more patients with these devices in practice. Consequences from inadequate perioperative management of these patients can be fatal, especially if electromagnetic interference is a contributing factor. Anesthesia providers must be competent in providing care to patients with a device. This paper has reviewed all current literature and serves as a basic guide to providing safe, effective care to such patients.

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Appendix A

Table 1. Generic Pacemaker Code (NBG*): NASPE/BPEG Revised (2002)

Position I, Pacing Chamber(s)	Position II, Sensing Chamber(s)	Position III, Response(s) to Sensing	Position IV, Programmability	Position V, Multisite Pacing
O = none	**O** = none	**O** = none	**O** = none	**O** = none
A = atrium	**A** = atrium	**I** = inhibited	**R** = rate modulation	**A** = atrium
V = ventricle	**V** = ventricle	**T** = triggered		**V** = ventricle
D = dual (A + V)	**D** = dual (A + V)	**D** = dual (T + I)		**D** = dual (A + V)

Examples:

AAI = Atrial-only antibradycardia pacing. In the AAI mode, any failure of the atrium to produce an intrinsic event within the appropriate time window (determined by the lower rate limit) results in an atrial pacing pulse emission. There is no ventricular sensing; thus, a premature ventricular event will not likely reset the pacing timer.

AOO = Asynchronous atrial-only pacing. In this mode, the pacing device emits a pacing pulse regardless of the underlying cardiac rhythm.

DDD = Dual-chamber antibradycardia pacing function in which every atrial event, within programmed limits, is followed by a ventricular event. The DDD mode implies dual-chamber pacing with atrial tracking. In the absence of intrinsic activity in the atrium, it will be paced, and, after any sensed or paced atrial event, an intrinsic ventricular event must occur before the expiration of the atrioventricular timer or the ventricle will be paced.

DDI = Dual-chamber behavior in which the atrial activity is tracked into the ventricle only when the atrial event is created by the antibradycardia pacing function of the generator. In the DDI mode, the ventricle is paced only when no intrinsic ventricular activity is present.

DOO = Asynchronous atrioventricular sequential pacing without regard to the underlying cardiac rhythm.

VOO = Asynchronous ventricular-only pacing without regard to the underlying cardiac rhythm.

VVI = Ventricular-only antibradycardia pacing. In the VVI mode, any failure of the ventricle to produce an intrinsic event within the appropriate time window (determined by the lower rate limit) results in a ventricular pacing pulse emission. There is no atrial sensing; thus, there can be no atrioventricular synchrony in a patient with a VVI pacemaker and any intrinsic atrial activity.

* NBG: N refers to NASPE, B refers to BPEG, and G refers to generic.

Appendix B

Perioperative Considerations of a Patient with an Implantable Pacemaker

Cloris Schmidt

February 25, 2008

Problem

- Patients with implantable pacemakers are being encountered more frequently in hospitals and outpatient surgery centers
  - Over 1 million Americans currently have pacemakers
  - More than 325,000 pacemakers are implanted in the USA each year
- Nurse anesthetists often have limited knowledge of perioperative management of patients with these devices
  - Anesthesia textbooks provide a brief overview of topic and fail to address important perioperative strategies
  - Many anesthesia providers bring patients to the OR without knowing the reason for insertion, design, or mode of the implantable pacemaker
- Although complications from electromagnetic interference are rare, they are serious and often life threatening when they do occur

Purpose and Significance

- To enhance the anesthetists knowledge of how to care for a patient with an implantable cardiac device throughout the perioperative period
  - Educate participants on pacemaker function, pacing modes, effects electromagnetic interference, and perioperative management of these patients
    - Should facilitate safe, effective care and reduce the incidence of adverse events

Methods

- Extensive review of current literature
  - Practice Advisory for the Perioperative Management of Patients with Cardiac Rhythm Management Devices
    - Developed by the American Society of Anesthesiologists
  - Case reports of adverse outcomes
  - Published articles by credible sources

Implantable Cardiac Pacemakers

- Indications
  - Sick Sinus Syndrome
  - 2nd degree heart block-type 2
  - 3rd degree heart block
  - Fascicular blocks
    - Bifasicular or trifasicular
  - Atrioventricular nodal ablation
  - Tachyarrhythmias
  - Syncope
  - Heart failure
  - Dilated cardiomyopathy

Pacemaker Design and Function

- Single chamber pacemakers
  - Single lead passes from the pulse generator through the superior vena cava to the right ventricle, where the tip of the lead rests at the apex of the right ventricle
- Dual chamber pacemaker
  - A second atrial lead is placed in the right atrium

Pacemaker Design and Function

- Components of pacemaker
  - Pulse generator
    - Lithium iodine battery
    - Electronic sensing circuitry
    - Silicon semiconductor chip
      - Brain of the device
      - The chip and sensing circuitry provide the ability to analyze the cardiac rhythm, determine if pacing is necessary, and deliver an appropriately timed pulse
  - Pacing electrode leads
    - Insulated wires that conduct electrical signals to and from the heart

Pacemaker Design and Function

- Electrical sensing is detected between the two electrodes
  - Unipolar pacemakers have a greater distance between the two electrodes
    - More prone to sensing extracardiac signals, skeletal muscle potentials, and electromagnetic interference than bipolar pacemakers

Pacemaker Codes

- 5 letter code describes various pacing modalities
  - First three letters describe the types of pacemakers and the location of sensing
    - Always listed
  - Fourth and fifth letters describe generator functions
    - May be omitted if the features are absent

Pacemaker Codes

- First letter
  - Describes the cardiac chamber being paced
    - O = none
    - A = atrium
    - V = ventricle
    - D = Dual (A + V)

Pacemaker Codes

- Second letter
  - Represents the cardiac chamber in which electrical activity is being sensed
    - O = none
    - A = atrium
    - V = ventricle
    - D = Dual (A + V)

Pacemaker Codes

- Third letter
  - Represents the response of the generator to a sensed event (sensed R wave or P wave)
    - O = none
    - I = inhibited
    - T = triggered
    - D = dual (T + I)

Pacemaker Codes

- Fourth letter
  - Indicates whether rate modulation (rate-responsive pacing) is present or absent
    - O = none
    - R = rate modulation

Pacemaker Codes

- Fifth letter
  - Represents multisite pacing capability (describes which chambers can be paced in multiple sites)
    - O = none
    - A = atrium
    - V = ventricle
    - D = Dual (A + V)

Pacemaker Codes

- Rate-responsive pacemakers (represented by fourth letter)
  - Designed for patients that are unable to increase their heart rate in response to increased oxygen demand
  - In addition to sensing atrial or ventricular activity, rate-responsive pacemakers contain various sensors that allow them to increase the basic pacer rate
    - Rate modulation sensors
      - Muscle activity, motion, minute ventilation, QT interval, or right ventricular pressure
        - Motion and minute ventilation sensors are most common
  - Due to the impact of operative movement and ventilator changes, pacemakers with rate modulation are more susceptible to produce unwanted tachycardia during surgery
    - Most frequently seen with chest and shoulder surgeries, where there is significant back and forth movements of the pectoral muscles

Electromagnetic Interference

- Electrocautery
  - The leading cause of EMI in the surgical setting
    - Pacemaker senses the EMI from the cautery as a tachyarrhythmia
      - Inhibits pacing
  - Used to cut and/or coagulate tissues
    - Electrocuting
      - Uses continuous, high-voltage current
      - More likely to produce EMI
    - Electrocoagulation
      - Uses short bursts of lower voltage current

Electrocautery

- Can be unipolar or bipolar
  - Majority being used are unipolar
- Unipolar cautery
  - Current originates at the tip of the electrocautery device, impels through the body, and returns to the generator via a grounding pad
- Bipolar cautery
  - Current flows only to tissue that is in direct contact with the instrument, because both electrodes are built into the tip of the instrument
    - Makes the use of a grounding pad unnecessary
    - Produces a more local, low-intensity electromagnetic field
      - Less risk of EMI in a patient with an implantable pacemaker

Electromagnetic Interference

- Potential adverse outcomes that may occur to the implantable pacemaker
  - Circuitry damage to the device
  - Failure of the device pace or shock
  - Burns at lead-tissue interface
  - Mode reprogramming
  - Asynchronous pacing (resets to backup mode)
  - Inappropriate antitachycardia pacing

Electromagnetic Interference

- Adverse clinical outcomes that can be seen if EMI occurs in a patient with a cardiac device
  - Hypotension
  - Tachyarrhythmia or bradyarrhythmia
  - Myocardial tissue damage
  - Myocardial infarction

Pre-operative Evaluation

- Focused exam
  - Comprehensive review of medical records, combined with interview of the patient
  - Chest x-ray films
  - 12-lead EKG
  - Physical exam
  - Electrolytes

Pre-operative Evaluation

- Confirm that the device is truly a cardiac device
  - Via physical exam, patient interview, and thorough examination of the H & P
- Other devices located in the pectoralis area that can be mistaken as cardiac generators
  - Pain control generator
  - Thalamic stimulator to control Parkinson's
  - Vagus nerve stimulator to control epilepsy
  - Phrenic nerve stimulator to stimulate diaphragm in paralyzed patient

Pre-operative Evaluation

- Determine type and proper functioning of the cardiac device
  - Identification card containing the type of cardiac device, model, and mode
  - Examining the patient's medical records
  - Consulting a cardiologist or manufacturer specific programmer
  - Examining the chest x-ray for the presence of pacemaker leads or model number
- Consult with a cardiologist or pacemaker programmer highly recommended
  - Perform a thorough interrogation of the device
  - Assist in determining the programmed settings, battery status, stimulation thresholds
  - Assessment of sensing function
  - Provide recommendations for perioperative programming
- Examination of EKG to determine proper pacemaker function
  - Appropriately sensing
  - Appropriately pacing
  - Appropriately capturing
- If emergent case and a comprehensive interrogation of the device is not possible
  - At a minimum, pacing impulses followed by a paced beat and arterial pulse should be confirmed

Pre-operative Evaluation

- Determine the patient's underlying rhythm and if they are pacemaker dependent
  - Usually performed by the programmer or cardiologist
  - Pacemaker dependency is established by one or more of the following
    - History of symptomatic bradyarrhythmia, resulting in implantation of a cardiac device
    - History of successful atrioventricular nodal ablation, requiring an implantable cardiac device
    - No spontaneous ventricular activity when the pacemaker is programmed to VVI pacing mode at the lowest programmable rate
    - A spike is noted prior to every beat on the preoperative EKG
      - Pacemaker dependency may be present in this situation
      - Programmer or cardiologist should be consulted to inhibit the pacemaker

Pre-operative Preparation

- Determine whether EMI is anticipated during the planned procedure
  - Electrocautery is most common source
- If pacemaker dependence is found during the pre-operative evaluation
  - The device should be reprogrammed to an asynchronous mode above the intrinsic rate
- If the patient is not pacemaker dependent
  - Programmed modes should not be changed
  - Anesthesia provider should have a magnet available to place pacemaker in asynchronous mode if severe EMI inhibits pacing or causes hemodynamic instability

Pre-operative Preparation

- Rate-responsive pacemakers should be reprogrammed out of the rate-responsive mode prior to surgery
  - Especially if EMI is expected
  - Important for devices that rely on minute ventilation or movement sensors for rate modulation
    - Prevent inappropriate tachycardia as a result of mechanical ventilation changes, shivering, or other operative movement
  - Two ways the rate responsive mode can be shut off prior to surgery
    - Mode deactivated by a programmer
    - Placement of a magnet over the device
      - Will also place the pacemaker in asynchronous mode

Pre-operative Preparation

- Magnet placement on pacemaker
  - Will not hear a tone emitted from device
  - Places the pacemaker in asynchronous mode
    - Usually set for a rate of 85, 90, or 100 depending on the model
    - No longer senses or responds to EMI or patients own intrinsic activity
      - Paces at set rate regardless

Pre-operative Preparation

- Magnet placement
  - Current literature recommends consulting with a programmer prior to surgery to determine the effects of magnet placement on the particular cardiac device
    - Programming possibilities vary based on device type and mode

Intraoperative management

- Focused on
  - Establishing appropriate monitoring
  - Minimizing sources of EMI
  - Preventing and treating untoward events

Intraoperative management

- Intraoperative monitoring of the device and heart function
  - Routine monitors required by ASA standards
  - Continuous five-lead ECG monitoring
    - Throughout the intraoperative and postoperative periods
    - Provides electrical analysis of the rhythm during and after periods of EMI
  - Mechanical evidence of pacemaker capture via any of the following methods
    - Palpation of the pulse
    - Pulse oximetry
    - Auscultation of heart sounds
    - Arterial line tracing
    - Ultrasound peripheral pulse monitoring

Intraoperative management

- Potential influences on cardiac device function
  - Hyperkalemia
  - Hypokalemia (hyperventilation)
  - Myocardial ischemia
  - Arterial hypoxemia
  - Severe hyperglycemia
  - Acidosis
  - Alkalosis
  - Bradycardia
  - Type I antiarrhythmic drugs
- Cause an increase in pacing threshold
  - May cause failure to pace
- These factors should be avoided whenever possible

Intraoperative management

- Potential influences on cardiac device function
  - Succinylcholine
    - Should be used with caution in patients with unipolar pacemakers
    - Skeletal muscle fasciculations produced by succinylcholine may result in pacemaker oversensing and ultimately failure to pace
    - Defasciculating dose of non-depolarizing relaxant recommended prior to administration of succinylcholine

Intraoperative management

- Minimizing sources of EMI
  - Bipolar or ultrasonic (harmonic) scalpel should be used in place of unipolar cautery whenever possible
    - Bipolar cautery causes significantly less EMI with the pacemaker
    - Ultrasonic scalpel completely avoids EMI with the pacemaker
      - Transfers heat to the tissue without electrical current passing through the patient
      - Disposable set has increased cost compared to reusable electrocautery
      - Provides slower cutting and coagulation

Intraoperative management

- Minimizing EMI produced during unipolar cautery
  - Use of short, intermittent bursts at the lowest possible amplitude
  - Pauses of at least 10 seconds between bursts
  - Grounding pad should be positioned so that the cardiac device is not in the pathway of the electrocautery current
  - For special head, neck, or thoracic procedures, the grounding pad may need to be placed on a site other than the thigh
    - Such as the superior posterior aspect of the shoulder contralateral to the pulse generator
    - Careful to avoid positioning the cardiac device between the grounding pad and cautery tip
  - The path between the grounding pad and the electrocautery tip should be as far from the device as possible
    - 15 cm being the minimum
  - Initiate cautery only when the tip is in contact with the skin and not in the air

Intraoperative management

- Emergency equipment should be available, especially if patient is pacemaker dependent
  - External temporary pacemaker
  - Defibrillator
  - Atropine
  - Contact numbers for pacemaker representative

What If a Life Threatening Arrhythmia Develops?

- Asystole
  - Atropine may not work, if patient is pacemaker dependent or has underlying 2nd degree type II or complete heart block
  - Temporary external pacing may be necessary

What If a Life Threatening Arrhythmia Develops?

- Pulseless V-tach, V-fib, or unstable tachycardia
  - Emergency defibrillation or cardioversion necessary
    - Current flowing through the pulse generator and lead system should be minimized
      - Pads should be positioned as far from the pulse generator as possible and in an anterior-posterior position
        - » Allows current to flow perpendicular to the axis of the device leads and generator
    - Despite these recommendations, damage to the device, an increase in pacing threshold, or a reversion to a backup mode may still occur
      - A thorough pacemaker interrogation should occur after defibrillation or cardioversion

What if the Case is Emergent?

- Use bipolar cautery with short bursts
- Place a magnet on the device until you can find out if the patient is pacemaker dependent and if the device is a pacemaker or ICD
  - May be able to get this information from the patient, family, or medical record
  - If need more information about the device, call the pacemaker representative
- Run EKG strip to determine if there is a pacer spike prior to each P-wave or QRS complex
  - May be pacemaker dependent
    - Pacing impulses followed by a paced beat and arterial pulse should be confirmed

Post-operative Considerations

- Post-operative interrogation of the device by a cardiologist or programmer is required any time electrocautery was used during the case
  - Assures proper functioning of the device and that the device was not inadvertently damaged or reprogrammed during surgery
  - Continuous EKG monitoring is recommended until the postoperative interrogation of the device can be made