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Evidence-Based Educational Modules on the Safe Delivery of Anesthesia in MRI Suites

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Doctor of Nursing Practice Program

DNP PROJECT FORM E: ANNOUNCEMENT OF DNP PROJECT DEFENSE

This form is submitted two weeks before the DNP Project defense date.
TO:

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(List names of DNP Project Team Members)

FROM: __Mandy Cesco-Cancian________
(DNP Candidate)

FROM: _Taylor Crofoot____________________
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DATE: __5-23-2023______

Our DNP Project Defense will take place at_0900__________________
(Time)
On _May 31, 2023 online in a scheduled ZOOM meeting.
(Date)

The Chair of our DNP Project Team is_Michael Kost___

The Title of our DNP Project is: Evidence-Based Educational Modules on The Safe Delivery of Anesthesia in MRI Suites

All members of the DNP Project Team are invited to attend the defense on the approved date after the DNP Project Team Chair and DNP Project Team members agree that the DNP Project is in acceptable draft form and ready for presentation. The candidates may invite others to the defense.

Mandy Cesco-Cancian

(DNP Candidate signature)

Taylor Crofoot

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cc: All Project Team Members, DNP Program Coordinator

EVIDENCE-BASED EDUCATIONAL MODULES ON THE SAFE DELIVERY OF ANESTHESIA IN MRI SUITES

A Doctor of Nursing Practice Project

Presented to the Faculty of the

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In Fulfillment

Of the Requirements for the Degree

Doctor of Nursing Practice

By:

Mandy Cesco-Cancian and Taylor Crofoot

Doctor of Nursing Practice Program

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Title of Doctor of Nursing Practice Project:

Evidence-Based Educational Modules on the Safe Delivery of Anesthesia in MRI Suites

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DATE: **May 31, 2023**

LASALLE UNIVERSITY
SCHOOL OF NURSING AND HEALTH SCIENCES

Submitted in partial fulfillment of the requirements for the Degree of Doctor of Nursing Practice.

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Abstract

Few citations were located on the formal education on MRI patient safety for anesthesia providers administering anesthesia services in MRI suites. Consequently, patients and staff may be at risk for injury or death during MRI procedures and health care institutions can be threatened with financial loss secondary to legal exposure, equipment damage and resultant morbidity and mortality associated with MRI patient safety events. This doctoral project will create three evidence-based continuing education modules to educate anesthesia providers on the operation of the MRI unit, potential MRI associated risks and complications, and specific anesthesia considerations for providers assigned to the MRI suite for procedural care. Safety threats and injuries are confirmed in the literature and include the creation of projectiles within the MRI suite, patient burns, and death within the MRI unit itself. Integrating the three newly created evidence-based educational modules into health care quality improvement programs and required employee annual training events could improve provider preparedness and patient safety in the MRI suite.

Keywords: patient safety, MRI, anesthesia, education

Evidence-Based Educational Modules on the Delivery of Anesthesia in MRI Suites

A magnetic resonance imaging (MRI) machine is composed of one large magnet with its own magnetic field, a secondary magnet with its own magnetic field, and a radiofrequency transmitter receiver system (Tsai et. al., 2015). The main MRI magnet is made up of a large coil of wire immersed in liquid helium and housed in an insulated canister. The canister decreases power requirements by maintaining a low temperature. An electrical current is applied to the wire to create a magnetic field up to 100,000 times stronger than the earth's magnetic field. This magnitude of magnetic strength takes hours to achieve, necessitating MRI machines to remain powered on at all times (Tsai et al., 2015). The secondary magnet is composed of smaller coils that allow for images to be viewed in multiple directions and layers. The radiofrequency transmitter receiver system excites nuclear magnetism within the body and receives the return signal. To interpret the signal, the system must be sensitive to noise, meaning that external noise can interfere with accurate interpretation (Tsai et al., 2015).

The force of these magnets during scans poses a risk to patients and staff. To maintain safety, the MRI suite is separated into four zones. Zone I is an unrestricted zone where the general public are permitted (Tsai et al., 2015). Zone II requires that visitors must be supervised by trained staff. This is typically the reception area from MRI where patient information is obtained. Zone III is a locked area where patients are only permitted after being properly screened for ferromagnetic objects. This is generally where the control room and adjacent hallways are located. Finally, zone IV is the room in which the MRI machine resides. All patients in this area must be under direct supervision of trained MRI personnel (Tsai et al., 2015). Despite these safety precautions, it is still possible for ferromagnetic objects to reach zone IV in which case the magnetic field will pull the objects towards the machine, risking damage to both the machine and patients and staff in the zone.

These unique safety concerns require special education for all staff entering the MRI suite. This includes those who work consistently in MRI and those who may only provide patient care in MRI on seldom occasions. Although staff who work consistently in the MRI suite, such as MRI technicians, receive formal safety training, many other specialties who occasionally provide patient care in MRI, such as anesthesia professionals, never receive formal education on the unique risks to patients and staff. This lack of education can place anesthesia providers at risk for being unprepared to handle emergency situations and increase the risk of adverse outcomes for patients.

Anesthesia is often needed in the MRI suite to maintain patient safety and ensure quality imaging. MRIs consist of multiple image sequences, each lasting at least 10 minutes (Reddy et al., 2012). Depending on the area of the body being scanned, the entire MRI can last upwards of two hours. Any movement during the sequence can cause distortion of the images, hinder accurate diagnoses, and prolong the duration of the imaging. In addition to the duration of imaging, the MRI machine is noisy and claustrophobic, which can cause anxiety for many patients and make it difficult for them to cooperate (Reddy et al., 2012). Patient populations predisposed to requiring anesthesia during MRI include pediatrics, patients with learning disabilities or movement disorders, claustrophobic patients, or the critically ill (Swart & Rae, 2018). The goal of anesthesia within the MRI suite is to achieve patient immobility while maintaining patient safety and comfort. In some instances, this can be achieved with sedation while others require general anesthesia with airway management (Reddy et al., 2012).

Anesthesia administration during MRI scans has been reported to be more dangerous than operating room anesthesia. Metzner et al. (2009) and Herman et al. (2021) both found that morbidity and mortality significantly increased when anesthesia was provided outside of the operating room. Unique risks in the MRI suite include limited access to the patient, limited equipment, and inaccurate patient monitoring due to MRI radiofrequency interference (Reddy et al., 2012). The danger of MRI is compounded if health care providers and anesthesia clinicians are not adequately prepared or educated for managing the unique risks of MRI (Wu & Busch, 2019). Most institutions never provide anesthetists with formal education on MRI patient considerations, leaving them to learn from others and their own experiences. This lack of formal training leaves providers vulnerable to mistakes and improper preparation for anesthesia delivery and management of emergencies within the MRI suite. By developing instructional modules to increase safety within the MRI suite, nurse anesthesia providers could decrease adverse outcomes for patients in the MRI suite.

Problem Statement

Despite several safety incidents and patient deaths over the years, formalized education for providing safe anesthesia is difficult to identify. Numerous safety concerns have been associated with MRI scans for both staff and patients. Between the years 2008 and 2017, over 1,500 MRI adverse events were reported to the FDA (Delfino et al., 2019). The three most common types of adverse events were associated with thermal, mechanical, and projectile injuries (Delfino et al., 2019). According to Tokue et al.

(2019), approximately 70% of all MRI complications are related to thermal burns. Patients can develop burns on the skin by having contact with the coils or cables on monitoring equipment. Additionally, patients wearing jewelry or medicinal patches can experience thermal injury during MRI scans. Implanted devices are also a concern because many are either incompatible during MRI scans or need time to be embedded within the body before MRI scanning is considered safe. Like implanted devices, foreign objects such as shrapnel and bullets can be dislodged and are considered contraindications to MRI if near vital organs (Tsai et al., 2015).

Perhaps the most dangerous and costly are projectile injuries. Any ferromagnetic object can become a projectile. The most common projectiles include stretchers/beds, oxygen cylinders, or chairs (Tsai et al., 2015). In 2001, a six-year-old boy died after a nurse brought an MRI incompatible oxygen cylinder into zone IV of the MRI. The oxygen tank was propelled, like a missile, into the machine and struck the boy's head, fracturing his skull. He died from his injuries two days later (Hochfelder, 2019). In another report, a firearm spontaneously discharged after being pulled into the MRI machine (Beitia et al., 2002). An off-duty police officer misunderstood the technician's instructions on where to leave the weapon and brought it with him into the MRI suite. While attempting to place the gun on a shelf 3 feet away from the machine, it was pulled out of his hand and into the machine where the magnet caused the gun to spontaneously discharge. After unsuccessful attempts to remove the weapon, staff was forced to power down the machine to release the magnetic force (Beitia et al., 2002). It is estimated that projectile events such as this cost approximately $43,000 but can cost upwards of

$500,000 in the event of an emergency machine shutdown (Patient Safety Authority, 2009; Tsai et al., 2015).

Despite the impact MRI adverse events have on patients, staff, and institutions, no formal regulations have been identified on appropriate MRI safety. The Joint Commission mandates that only staff trained in MRI safety be permitted close to the MRI machine. However, no specifications on what that training must include were identified (Swart & Ducombe Rae, 2018). The American Association of Nurse Anesthesiology only provides an educational pamphlet for patients but no articles for providers about MRI safety (American Association of Nurse Anesthesiology, 2022). The American Society of Anesthesiologists (ASA) wrote a practice advisory on anesthesia care during MRI, but notes that it is not intended to be used as a guideline or standard and does not offer other documents to be used for this purpose ("Practice Advisory", 2015).

Within the practice advisory, the ASA identifies several barriers to good anesthesia care including lack of visualization and access to the patient, MRI interference with patient monitoring, and lack of equipment/resources ("Practice Advisory", 2015). The ASA stresses the importance of positioning the patient and equipment so they can be visualized from the observation room either directly or through video cameras. The lack of access to the patient can be especially troublesome when providing moderate sedation because the lighter anesthesia increases the patient's risk of laryngospasm and other airway compromise that require quick intervention to maintain patient safety. The lack of equipment and resources is often due to the MRI suite being located in an isolated area far from the operating room. For this reason, the ASA recommends anesthesia providers prepare a plan for quickly calling additional personnel in the event of an emergency.

Additionally, emergency equipment should be ready in the designated resuscitation area before anesthesia care is initiated. Emergency equipment includes resuscitation drugs, physiologic monitors, suction, oxygen, and airway devices. The ASA recommends that all anesthesia providers be educated on the health hazards and necessary precautions specific to MRI, and that they collaborate with the radiologists and other MRI staff to develop a safety protocol for the institution. Precautions specific to the MRI suite include thorough patient screening regarding comorbidities, equipment needed, and the existence of implanted devices and foreign bodies. Other precautions involve understanding the limitations to monitoring within MRI and being prepared for emergencies such as a fire, projectile event, compromised airway, and cardiovascular collapse ("Practice Advisory", 2015).

The lack of national guidelines for MRI safety makes it the responsibility of an institution to establish and to implement their own safety regulations. However, institutions can face many barriers to educating staff on safety regulations, especially in healthcare where staff members are often working inconsistent days and hours. Ward and Wood (2000) surveyed healthcare providers on the most common barriers to education and identified time, accessibility, staff motivation, financial issues, and marketing/advertising as the most frequent contributing factors to the lack of comprehensive healthcare education. Several researchers and healthcare organizations have made recommendations on how to overcome these barriers and prevent adverse events, such as yearly training, student simulations, and verbal time-outs (Tsai et al., 2015; Wilson et al., 2019). Tools such as evidence-based modules can be used in yearly training to address some of these education barriers. Case studies and statistics specific to anesthesia should be included to increase staff motivation. Designing the module to allow access through an institution's online training website improves accessibility for all staff members no matter their schedules. Although an education module does not address all barriers to education, it can make it easier for institutions to continue the education long term.

Purpose Statement

Because providers are rarely educated or evaluated on MRI patient safety practices, fast-paced patient care can result in poor decision making. Negative patient outcomes and staff injury have the potential to occur during an MRI scan. Providing evidence-based education will provide healthcare providers with the knowledge to respond safely and confidently to various patient situations and decrease patient suffering, adverse outcomes, and institutional costs associated with injury and equipment damage. Creation of an instructional intervention module may alleviate some of the education barriers institutions face and hopefully reduce adverse events and increase patient and provider safety.

Needs Assessment

After conversations with anesthesia professionals employed at various health networks in the Philadelphia and Lehigh Valley regions as well as a comprehensive literature search, it became evident that patient safety in the MRI suite is compromised and education on protecting patient safety during anesthesia in the MRI suite is lacking.

Project Question

What is the evidence based educational content required for the development of an MRI patient safety module for anesthesia providers?

Conceptual Definitions

- Magnetic resonance imaging (MRI) is a machine that uses strong magnetic fields and radiofrequency coils to produce images of the soft tissues and fluids within the body (Tsai et al., 2015)
- MRI risks are hazards to patient safety, while undergoing MRI scanning, which include projectile events, thermal injury, displacement of implanted devices, and auditory injury (Swart & Rae, 2018).
- Zone IV in an MRI suite is where the magnet is located and should only be accessed through zone III. It is designed so that the walls of the magnet room are lined with 5 Gauss lines on the fringe field of the magnet (Sammet, 2016).
- 5 Gauss line is defined as a border to which an area with a magnetic field could affect implanted devices (Sammet, 2016).
- Ferromagnetic objects will be pulled towards the center of the MRI magnet and attempt the line up with the magnetic field when within the 30 G contour (Reddy et al., 2012).
- Quench is the act of turning off an MRI machine. MRI machines are always on and to turn one off in an emergency is to quench. It is very expensive and can be dangerous, as one is releasing cryogenic gasses into a confined space, which can be deadly (Joint Commission, 2008).
- Anesthesia delivery is the act of using medications and inhaled gasses to provide immobility while maintaining patient safety and comfort (Reddy et al., 2012).
- Non- operating room anesthesia (NORA) is anesthesia delivered outside the traditional operating room and includes gastroenterology, psychiatry, pulmonary,

dental, radiology, neurosurgery, oncology, interventional radiology, cardiology (Herman et al., 2021)

- ASA physical status provides for a relative ranking system for patients based on their pathophysiologic status (Nagelhout, 2018).
- Timeout is a pause by the medical team, immediately prior to patient care, to confirm everyone knows what is expected and to review critical machine and treatment information to help prevent adverse events ("Effective Use of Timeout", 2021).
- Practice advisory provides a synthesis of expert opinions, clinical data, commentary, and consensus surveys and are intended to aid decision making in specific patient areas. ("Practice Advisory", 2015)
- Educational module is an evidence- and theoretically-based instructional intervention structured by a teaching plan, including facts, principles, and theories on MRI safety practices for certified nurse anesthetists and other anesthesia providers caring for patients during MRI scanning (Z. Wolf, personal communication, October 20, 2021).
- Teaching plan can be identified as a blueprint created to implement a set of objectives and the overall educational goal (Bastable, 2019). It includes the following components: 1) purpose, 2) statement of the goal, 3) list of objectives (cognitive, psychomotor, and affective), 4) an outline of the content to be covered in the teaching session, 5) instructional methods used for teaching the material, 6) time allocated for the teaching of each objective, 7) instructional resources, and 8) method(s) used to evaluate learning (Bastable, 2019).

Approval

Dr. Michael Kost, Director of Frank J. Tornetta School of Anesthesia, supports the development of education modules and consultation with MRI experts to standardize MRI safety. (Appendix A; Table 1).

Review of Literature

Search Strategies

A review of literature was completed using La Salle University's Library databases, including PubMed, ProQuest, and Wiley Online Library, among others. Google scholar search engine was also utilized to supplement our research inquiry. The search terms included *MRI, magnetic resonance imaging, anesthesia, patient safety, education, adverse events, projectiles, barriers, non operating room anesthesia (NORA), off site anesthesia.* Boolean connector "AND" was used to narrow the results and "OR" was used to include articles utilizing abbreviations versus full terminology. Limiters included English language and full text available. The literature search was originally limited to articles no older than 5 years but the limiter was removed after limited findings were discovered. The search yielded 1,299 results. After sorting research based on title and abstract, six articles remained. Articles were analyzed using a matrix and quality of research was assessed using the Johns Hopkins Evidence Level and Quality Guide. Refer to Table 3 for details on the search by database and Table 4 for the literature review matrix.

Empirical Literature

Patient Safety in MRI

Delfino et al. (2019) performed a retrospective study to review ten years of MRI adverse events reported to the FDA. Reports from January 2008 to December 2017 were analyzed. After excluding adverse contrast reaction reports, 1,548 reports remained. Two FDA reviewers independently analyzed the reports and placed adverse events into one of the following eight categories: thermal, acoustic, image quality, projectile, mechanical, peripheral nerve stimulation, miscellaneous, unclear.

Thermal injury was the most commonly reported adverse event (59%), followed by mechanical injury (11%), projectile events (9%), and acoustic events (6%). Thermal injury causes included unclear causes (39%), contact with a conductive object within the bore (16%), skin-to-skin contact (16%), and contact with the wall (10%). The most common projectile injuries involved patient transport equipment (26%). The major limitation was the reliance on employees to accurately and comprehensively report the event. Some information provided may be subjective or missing, making it difficult to compare to other events. Delfino et al. (2019) stress that many of these events are preventable and it is every healthcare team member's responsibility to make changes to prevent these events in the future. Providers must be educated on the specific risks involved with patient care in MRI.

In a retrospective study by Field (2018), MRI screening events reported to the Pennsylvania Patient Safety Reporting System (PA-PSRS) from 2009-2017 were reviewed to identify and analyze MRI screening events and discuss strategies for keeping ferromagnetic objects/devices from reaching the magnetic field. All reports involving errors or adverse reactions related to treatment/procedure/test were included. Reports of adverse events related to contrast, patient status change, intravenous infiltration, wrong site, or scheduling issues were excluded. 1,108 reports met the inclusion criteria. A group of analysts used narrative summary to organize the findings based on the following variables: object/device involved, whether object was on the patient, what MRI zone the event occurred, and level of harm-either incident or serious event.

65% of all adverse events involved internal patient devices, with pacemakers being the most common (33%). 44% of the external devices involved in adverse events included medical equipment (monitors, wires/leads, machines, etc). 31% of events occurred in MRI Zone IV and 4.6% of those events involved projectile objects. However, only 0.5% (5 cases) were serious enough resulting in patient injury. A major limitation of this study is that it relied on the reporting protocols and practices of healthcare systems that may have resulted in limited or no reporting of events to the PA-PSRS. Additionally, the incidents that were reported may include inaccurate subjective data. Field's (2018) research also reminds healthcare providers that MRI screening is the responsibility of all parties involved in patient care and The Joint Commission and American College of Radiology practice recommendations should be implemented for all MRI procedures to ensure patient and staff safety. (The Joint Commission 2008; American College of Radiology, 2020)

Patient Safety in NORA

Herman et al. (2021) conducted a literature review to identify weaknesses in NORA and propose methods to develop safer systems of care. They reviewed thirty studies from databases PubMed, Scopus, Proquest, and CINAHL. The search terms were *non-operating room anesthesia, anesthesia outside the operating room, remote location anesthesia.* Articles after 1994 were included; however, the earliest article reviewed was from 2004. Articles were eliminated for non-english language, focus on single anesthetic or comparison of anesthetic techniques, non-hospital anesthesia, or non-anesthesia personnel. The majority of research reviewed was conducted in the USA however other countries included South Korea, Iran, Israel, and Turkey. Articles were assessed by two reviewers and findings were organized by the SEIPS model and narrative summary. The variables measured were morbidity and mortality, adverse events, and safety risks (Herman et al., 2021).

Herman et al. (2021) estimated that NORA cases will make up at least 50% of anesthesia cases in the next ten years. The authors describe the NORA rooms as small, cramped, and dark and often requiring improvisation of equipment setup, workflow considerations, and movement within the room. They found that articles reported an overall higher morbidity and mortality for NORA compared to operating room anesthesia. There was a higher proportion of death claims and higher proportion of complications attributed to inadequate oxygenation. One study reported that all 3 of their deaths occurred in MRI. NORA events were more likely to be preventable and a result of substandard care. Most claims came from GI, radiology, cardiology suites. The main hazards of NORA were identified as older, more frail patients, restricted access to workspace that may not support anesthesia, lack of team familiarity and support, inexperienced post-op care teams, older technology, limited monitoring capabilities and time pressures. The primary limitation of this study was the possibility of missing applicable studies due to improper keyword search. There are several terms for NORA and although the researchers tried to include all of them and review the references of the articles they found to look for additional resources, it is possible that they missed significant research articles. Herman et al. (2021) recommends increased education to anesthesia providers on NORA safety considerations and education to off-site staff so they better understand what anesthesia providers may need.

Schroeck et al. (2019) performed a systematic scoping review to determine existing knowledge about anesthetic care in advanced imaging hybrid operating rooms, identify knowledge gaps, and direct future research. A literature search was performed for all articles describing challenges working in hybrid operating rooms with MRI capability written between January 1994 and August 2017. Databases used in the search were PubMed, Embase, Cochrane Library, Web of Science, and Google Scholar. The search terms included *anesthesia, intraoperative magnetic resonance imaging, tomography, and hybrid operating room.* Three authors reviewed the manuscripts for inclusion criteria which resulted in forty-seven manuscripts included in the review; ten were informal reviews, ten were institutional experiences, twelve were case series/retrospective studies, and four were prospective studies. The country of origin for the reviewed studies was not identified.

Common issues reported in the manuscripts included monitoring difficulties, availability of MRI compatible equipment, risk of airway/line dislodgement, and limited access to the patient. Many stated that they were unable to monitor the ST segment due to MRI interference and that temperature could not accurately be measured. There were also several concerns about the distance between the patient and the anesthesia team which required lengthy extension tubing on intravenous lines and breathing circuits leading to delays in IV and inhalational medications getting to the patient and increased circuit dead space. Multiple manuscripts included recommendations for specific MRI simulation training for patient events. Schroeck et al. (2019) noted an overall lack of consistency in reporting intraoperative magnetic resonance imaging (iMRI) adverse events and the outcomes of the events, making it difficult to draw many conclusions on how to improve patient safety. They recommend a more consistent reporting strategy so the events can be better analyzed and interventions can be implemented.

Metzner et al. (2009) completed a retrospective review of ASA closed claims beginning in 1990 to assess patterns of injury and liability claims from NORA compared with operating room anesthesia. Studies that were excluded involved obstetric and dental claims and those arising from acute or chronic pain management. They gathered a total of 3,374 claims with eighty-seven of those being related to NORA while the remaining 3,287 occurred within the operating room. All articles were reviewed by practicing anesthesiologists and data was evaluated using Fisher's exact test, z test, t test, and the Kolmogorov-Smirnov test. Significance was determined by a P value less than 0.05. The variables evaluated were patient characteristics, surgical procedures, sequence/location of events, critical incidents, injuries, standard of care, prevention, and payments (Metzner et al., 2009).

T- test analysis was used to show that patients undergoing NORA were significantly older; 20% of NORA patients were older than seventy years of age compared to 12% in operating room (OR) anesthesia ($P<0.001$). Fisher's exact test and z-test were used to evaluate several variables and all P values were less than 0.001. 69% of NORA patients had an ASA status of 3-5 while the same status only made up 44% of OR patients. Additionally, there were more emergent NORA cases (36%) than OR cases (15%). Mortality was almost twice as high in NORA than OR anesthesia (54% compared to 29%). The most common injury in both locations was a respiratory event however this occurred in 44% of NORA cases and only 20% of OR cases. Inadequate oxygenation/ventilation was the most common NORA claim and 7 times more likely than the OR (21% vs 3%). Other respiratory complications included difficult intubation, esophageal intubation, and aspiration. It was determined that substandard care was given in 54% of NORA cases compared to 37% in OR and 32% of complications were preventable by better monitoring in NORA compared to 8% in OR. Of the NORA cases that occurred in radiology, 70% of them were in MRI. Four of the cases occurring in MRI were due to oversedation, two were for burns, and one was for brachial plexopathy. There were no differences in cardiovascular events, equipment failure/malfunction, or medication errors. The major limitations of this study were the inability to determine cause and effect due to it being a retrospective study. Additionally, closed claim cases are often biased towards substandard care and permanent injury which may skew the results (Metzner et al., 2009). These findings support the recommendation for additional education on patient safety in NORA for all providers.

Educating Professionals

Ward & Wood (2000) performed a qualitative thematic analysis to determine the education needs of healthcare specialists and non-specialists to reach their full potential. Data gathered included focus groups and semi-structured interviews of healthcare providers in towns local to the Southwest London and Epsom Education Consortium (sponsor of the research). The interviews were conducted between April and June 1999. There were 144 participants, 39 of which were specialist staff while the other 105 were non specialist. Two researchers used qualitative thematic analysis to determine themes from the data.

Ward & Wood (2000) found that the major barriers to education were time, accessibility, financial issues, staff motivation, and marketing/advertising. They stress the importance of addressing these issues in the hopes of achieving effective education for healthcare workers. Limitations to this study include a relatively small sample size and limited area of survey. Participation was voluntary and results may be skewed due to the population most willing to volunteer for an interview.

Theoretical Literature

Barriers to Care

Anesthesia providers require periodic education to prepare for the unique barriers related to patient care in the MRI suite. Barriers in the MRI setting include monitoring devices that may be periodically inaccurate due to radio frequency interference from the MRI machine (Rose & McLarney, 2014). For example, ECG tracing interferences may result in false T wave and ST segment changes, making it difficult to detect arrhythmias and signs of ischemia (Reddy et al., 2012). Hrishi et al. (2018) describes a case where a patient's pulse oximeter reading decreased during MRI; however, when the test was paused to assess the patient's status the reading improved. The test was resumed and the pulse oximeter reading decreased until the test was paused once more. Each time the waveform maintained a normal appearance, giving no sign of an inaccurate reading. When the MRI technician commenced a different type of MRI sequencing the pulse oximeter reading remained at a normal level, suggesting that certain MRI sequences can cause false desaturations on pulse oximeters (Hrishi et al., 2018). The need for extension lines on invasive blood pressure monitoring and capnography tubing causes increased delays in readings and dampening of the blood pressure waveform (Reddy et al., 2012).

These delays translate to a delay in care if the patient decompensates and requires intervention during MRI.

In the event a patient requires intervention from the anesthesia provider during MRI, a resultant procedural delay may occur when in comparison to operating room care secondary to limited patient access. In the MRI suite, anesthesia providers are frequently in an adjacent observational area, viewing the patient through a large window and with cameras. During upper body MRI imaging, the patient is placed headfirst into the machine, making the airway virtually inaccessible and only visualized via camera monitors (Reddy et al., 2012). The darkened MRI suite also adds to the lack of visualization, making any routine assessments of the patient difficult and inefficient ("Practice Advisory", 2015; Swart & Rae, 2015). When a patient emergency occurs, the scan must first be stopped and the patient removed from the machine and 5G area before resuscitation can begin. This delay can cost the patient valuable time and compromise patient outcomes (Reddy et al., 2012). Further contributing to delay in required emergency care is the lack of equipment, resources, and trained staff. When an emergency occurs in the operating room, several anesthesia providers are available when summoned to the room, with ample available emergency resuscitative equipment. However, the MRI suite is often located offsite in a remote area of the hospital, isolated from other anesthesia staff (Rose & McLarney, 2014). Because of infrequent emergencies in MRI suite, the phenomenon of normalization of deviance may occur resulting in emergency resuscitative equipment not readily available and MRI staff who are unfamiliar with anesthesia provider needs during an emergency, making it difficult for them to provide assistance when necessary (Rose & McLarney, 2014).

Anesthesia Equipment for MRI

Anesthesia providers must understand the specific equipment required for MRI procedures. Equipment must be labeled per manufacturer safety guidelines. “MR safe” indicates that the equipment is approved for use in all MRI environments, however functionality is not necessarily guaranteed (Tsai et al., 2015). “MR compatible” means the equipment is both safe and functional within MRI environments (Swart & Rae, 2018). “MR unsafe” equipment is contraindicated and “MR conditional” indicates that compatibility depends on magnetic field strength and maximum magnetic field gradient (Tsai et al., 2015).

Prior to providing patient care, the anesthesia provider must retrieve MRI compatible anesthesia machines and designated aluminum oxygen tanks/canisters (Swart & Rae, 2018). Standard anesthesia machines are constructed of iron and steel which are ferromagnetic. MRI compatible machines utilize aluminum and plastics in their manufacturing process (Rose & McLarney, 2014). Most anesthesia machine manufacturers offer an MRI compatible model for purchase. Many intravenous medication pumps manufactured also contain ferromagnetic parts that could cause them to malfunction in MRI; thus, they must be kept in adjacent rooms and connected to the patient via long extension tubing (Swart & Rae, 2015). Anesthetists must pay close attention to the type of monitor in use as many are “MR conditional” and must be kept at a specific distance from the machine to function properly. Additionally, ECG leads and wires made of graphite and designated pulse oximetry probes must be used to minimize burns caused by radiofrequency interference with the MRI machine (Rose & McLarney, 2014).

Many airway devices used by the anesthesia care team can contain ferromagnetic material. Although the amount of ferromagnetic material is small and unlikely to harm the patient, it can impede the process of obtaining clear imaging. Endotracheal tubes and supraglottic airway devices contain pilot balloons with metal coils inside. The balloons can be taped out of the imaging path and still used, however, MRI compatible supraglottic devices are also available (Swart & Rae, 2018). Saxena (2012) found the iGel and AMBU brand supraglottic devices were best to use in MRI because they did not create any artifact with imaging.

Recommendations for Safe Anesthesia in MRI

Numerous recommendations from professional organizations for practicing safely in MRI suite are available to healthcare providers. The goal of this DNP scholarly project is the creation of evidence-based educational modules focused on the safe delivery of anesthesia in MRI suites.

There are various preventive measures that may be implemented to help keep patients and healthcare providers safe in the MRI environment. Tsai et. al. (2015) states that having ferromagnetic detectors at the entrance of zone III to alert staff to the presence of potential projectiles is essential to a safe MRI suite. In addition to ferromagnetic detectors, utilization of a policy and procedure and MRI safety checklist helps to reduce errors and keep care consistent (Tsai et. al., 2015). Annual training should be required for providers who regularly enter zones III and IV of the MRI suite. Healthcare students participating in clinical rotations within the MRI environment should also be required to complete MRI patient and provider safety training prior to observing in the patient care area. Another safety strategy that may prove beneficial is to have students simulate an induction in the MRI suite to enhance their knowledge and their level of comfort with the different equipment and policies (Tsai et. al., 2015). When in MRI zone III, it is imperative to perform a timeout. Timeout should include identification of the patient, review of the MRI screening tool, review of MRI safety with staff, and checking for MRI unsafe equipment or objects (University of California, 2017). Additional preventative measures include collaborating with MRI staff and physicians to ensure the screening process has been completed, labeling equipment as MRI safe, MRI unsafe, or MRI conditional, and performing a pre-procedure anesthesia machine check ("Practice Advisory", 2015; Kettenbach et. al., 2006).

Induction of anesthesia is one of the most important times for the patient and the anesthesia provider. It is important to consider the length of the MRI scan when determining the type of anesthesia to be used. Length of scan can help in determining whether sedation is sufficient or whether general anesthesia will be required (Wilson et. al., 2019). Induction of anesthesia must occur in an anesthesia room adjacent to the MRI suite (Reddy et. al., 2012). These rooms are designed for induction and resuscitation, if that becomes necessary. An additional metal check should be performed when transitioning from the anesthesia induction room to the MRI suite (Swart & Ducombe Rae, 2018). All emergency equipment should remain in the designated induction room for the duration of the scan (Reddy et. al., 2012). Treating each induction and procedure in the same manner regardless of MRI use will create a "force of habit", creating a safe environment and solidifying safe practices (Hemingway & Klifoyle, 2013).

Ensuring the airway is safely secured before starting the MRI scan is of utmost importance. Once the MRI scan begins, the airway will be inaccessible (Reddy et. al., 2012). When positioning a patient, choosing a position for optimal patient observation is essential. The anesthesia provider needs to be able to visualize the patient from both zones III and IV ("Practice Advisory", 2015). Along with visualization, ensuring that all tubes and wires are taped away from the patient is equally important. By securing these wires away from the patient, the risk of burns can be decreased (Swart & Ducombe Rae, 2018).

Wilson et. al. (2019) emphasizes the importance of a good working intravenous (IV) access line. Without good IV access, there is an increased risk for undetected infiltration. Infiltration can go undetected very easily in the MRI suite due to lack of visualization of the IV site itself. The long amount of IV extension tubing between pump and patient can alter the accuracy of high-pressure alarms on the IV pumps that would normally detect a nonfunctioning IV (Wilson et. al., 2019). When in the MRI suite, the high-pressure alarms may need to be adjusted to make up for this extension tubing.

Occasionally a provider must perform a procedure in an MRI suite alone. These occurrences should only be done under certain circumstances (Wilson et. al., 2019). Providing anesthesia in the MRI suite alone can safely occur if the provider has documented experience with MRI anesthesia, the provider has demonstrated knowledge of MRI hazards and safety precautions, and finally if they have demonstrated knowledge of managing emergencies within the MRI suite (Wilson et. al., 2019). By ensuring the provider is competent in the MRI suite, it will drastically decrease the risk of any adverse events from occurring.

As with any location anesthesia is administered, emergencies can and will occur. Knowing how to handle them is essential and can drastically change any outcome. A patient can decompensate at any time for any number of reasons. Knowing where the emergency cart and where all equipment is within the cart is important. All equipment should be labeled as MRI safe or conditional (Tsai et. al., 2015). The emergency cart is usually within zone III or zone IV. "Practice Advisory" (2015) states that having a plan for common airway complications including alternate airway devices and continuous suction readily available is necessary. If a complication occurs, moving the patient out of zone IV as fast as possible is most beneficial (Tsai et. al., 2015). If the patient loses a pulse, compressions should be started before moving out of zone IV and they can continue while moving into zone III (Tsai et. al., 2015). Designating a location that is magnetically safe prior to the procedure will help save time and keep all staff on the same page in case of an emergency.

An MRI magnet quench is also considered an emergency. This may occur if a projectile is in zone IV and is attracted to the magnet but may also occur spontaneously from machine failure. Quenching will immediately shut off the magnet and end the magnetic field (Tsai et. al., 2015). A superconducting coil is warmed above the threshold temperature to shut off the magnet. The warming of the coils leads to higher temperatures of the surrounding helium, which results in an explosive boiling effect. The quench pipe vents the boiling gas; however, the reaction is unstable and therefore pipe failure is a risk (Tsai et. al., 2015). If the gas leaks, it can act as an asphyxiant and create fog that makes visibility extremely low. The change in pressure from the quench can also prevent the zone IV door from opening if it is an in-swinging door (Tsai et. al., 2015). For these reasons, the patient must be removed from zone IV as soon as possible to avoid getting trapped in the MRI suite or from being exposed to caustic gasses. Immediately after evacuation from zone IV, patients should be started on supplemental oxygen to prevent complications from potential caustic gas exposure.

As with many locations within a hospital, fires are also a risk within the MRI suite. Local fire marshals should be educated on the hazards of an MRI machine (American College of Radiology, 2020). Zone III and zone IV should have MR safe fire extinguishing equipment. The MRI magnet always remains on, so oxygen tanks and other equipment used by firefighters will not be safe in these zones. A quench would have to be performed to make this equipment safe (American College of Radiology, 2020).

Educating Healthcare Professionals

Educating anesthesia providers regarding the safe delivery of anesthesia services in the MRI setting is paramount to the successful completion of this DNP scholarly project. Teaching methods should focus on active experiential learning. Experiences such as learner participation within a meaningful improvement project are best for enhancing one's knowledge on a topic (Knebel, n.d.). Providing the learner with case-based and intellectually rigorous problem solving will aid in the learning process and help the learner solidify the topic at hand (Knebel, n.d.). Learning is best accomplished by reinforcing familiar concepts and teaching concepts and skills in a setting where the learner can apply them (Knebel, n.d.). By targeting anesthesia providers for the education module, we can relate the topic to their work to help make the learning process more meaningful. This will also allow learners to reflect and relate to their own practice and improve on skills and attitudes (Knebel, n.d.).

Educating anesthesia providers in groups will promote a team feeling. People have an increased desire to participate in learning when teams are in place. This team effort will aid in better patient outcomes and improve patient care (Knebel, n.d.). Continuing education is essential to refresh the learner's memory. Continuing education also allows for the most updated research to be displayed (Olsen et. al., 2007). By creating a virtual education module, it will be easily updated to reflect the newest research and guidelines. Standard continuing medical education has proven to be ineffective at changing physician behavior. This in turn prevents interventions supported by research to be applied to practice (Olsen et. al., 2007). While typical didactic sessions unsuccessfully influence practice, interactive workshops such as role playing, case discussion, and practicing skills, have proven to provide change in performance (Olsen et. al., 2007).

Critical Summary

Research by Reddy et. al. (2012), Swart & Ducombe Rae (2018), and Tsai et. al. (2015) provides ample guidelines and practices for administering anesthesia safely within the MRI suite. Identification of the zones of the MRI suite are clearly stated in these articles. Zone I is unrestricted and the general public is permitted in this area. Zone II is the reception area where patient information is obtained. Zone III is locked and can present a danger for unscreened people and objects. Finally, zone IV is where the MRI machine resides and all personnel must be under direct supervision of MRI trained personnel while in this zone.

These three articles also clearly state the safety concerns associated with the MRI suite. Implanted devices, burns, peripheral neurostimulation, acoustic injury, and projectiles all pose great risk when in an MRI suite. Implanted devices can contain ferromagnetic material, burns can occur from contact with the coils or cables, and acoustic injury can arise from the noise caused by the gradient within the MRI machine (Reddy et. al., 2012; Swart & Ducombe Rae, 2018; Tsai et. al., 2015). Projectiles create a large risk for adverse events, accounting for approximately 9% of all events. Any ferromagnetic object can become a projectile due to the translational and torque forces from static magnetic fields (Tsai et. al., 2015).

The need for anesthesia within the MRI suite will always be present. Herman et. al. (2021) states that non-operating room anesthesia (NORA) will account for an estimated 50% of anesthesia cases in the next decade. When providing non-operating room anesthesia, there are barriers that create challenges. Inaccurate monitoring, limited access to the patient, and lack of accessibility to equipment and resources make the MRI suite a challenging place to provide anesthesia (Reddy et. al., 2012; Swart & Ducombe Rae, 2018; Tsai et. al., 2015). Using MR safe or MR compatible equipment such as ventilators, vaporizers, airway devices, and oxygen tanks will provide the best experience for patient and provider (Swart & Ducombe Rae, 2018).

Preventative measures are also of utmost importance among the research articles provided. Yearly training, the development of a policy or checklist, and collaboration among staff are ways to keep the MRI suite a safe place (Tsai et. al., 2015). Induction of anesthesia is one of the most critical steps when providing anesthesia. Having an area specific for this task is imperative. Securing the airway, maintaining a patent IV line, and positioning the patient are critical steps in caring for a patient within the MRI suite (Reddy et. al., 2012; Swart & Ducombe Rae, 2018). Understanding the process of quenching the MRI machine is one of the most valuable pieces of knowledge to have when providing anesthesia in an MRI suite. Magnet quenching is used for projectile events to deactivate the magnetic field (Tsai et. al., 2015).

Educating health professionals on the MRI suite and how to remain safe when providing anesthesia in this area is the highest priority of this paper. Research concluded that teaching methods should create an active learning environment by encouraging learner participation (Knebel, n.d.). Reinforcement and repetition is key when providing anesthesia in the MRI suite. By developing teaching modules that focus on quality and adverse events, we can provide the most up to date information in a way that will allow learners to reflect on their own practice and experiences.

While there are numerous promulgated practice guidelines and recommendations for assuring MRI patient safety, there currently is no requirement for an actual practice standard available for healthcare networks and providers to utilize. The American Society of Anesthesiologists and the American College of Radiology present multiple guidelines for safe patient care in the MRI environment. Health networks and hospitals can take these guidelines and pick and choose which ones they will use. However, this creates inconsistency across the nation. The creation of this inconsistency leaves health care providers unsure of specific equipment needs and the process for providing safe patient care in the MRI environment.

The creation of evidence-based education modules on the safe delivery of anesthesia in MRI suites may enhance the overall patient and provider experience by increasing preparedness of anesthesia professionals providing care in the MRI suite. Learning modules created as part of this DNP scholarly project will be made readily available to hospitals, clinics, and healthcare educational facilities for faculty review to assess and identify incorporation for curricular enrichment. The overall expectation of this DNP scholarly project is to educate healthcare providers regarding the MRI environment, enhance patient safety, while increasing practitioner awareness of the anesthesia requirements for delivering a safe anesthetic. Our module will discuss the basics of the MRI suite, safety considerations for any healthcare provider in the MRI suite, and anesthesia specific considerations including special equipment needed and how to prepare for and respond to emergencies.

Theoretical Framework

Malcolm Knowles (1978) discusses the fact that well into the twentieth century, there was only one theoretical framework for education, known as pedagogy. When defined, pedagogy means the art and science of teaching children (Knowles, 1978). Knowles recognized that adults learn differently and therefore, should follow a different educational framework. In Europe, Knowles discovered the theory of andragogy, which he introduced and developed in America (Knowles, 1978) Andragogy is the art and science of helping adults learn and consists of six main concepts (Chan, 2010). The first is 'Self-concept' theorizes that adults are self-directed and autonomous with their learning. 'Role of experience' explains that adults learn by relating to personal experiences. 'Readiness to learn' recognizes that adults are more willing to learn information they believe they need to know. 'Orientation to learning' focuses on adult learning centered around problem solving and task completion in immediate scenarios rather than future uses. 'Internal motivation' states that adults learn better from internal motivators rather than external. 'Need to know' recognizes that adults will learn best if they understand why they need to learn the material (Chan, 2010).

To provide learning that facilitates change, it must "occur in an atmosphere conducive to questioning in which nurses feel safe to critically think and reflect on how they have come to learn what they presently know" (Linscott et. al, 1999). To create an atmosphere conducive to adult learners, the development of education modules for delivering safe anesthesia in the MRI suite will be based on Knowles theory of adult learning. These modules will be designed for adult learners, applying the 6 concepts of andragogy. The modules will support the concepts of 'self-concept', 'role of experience' and 'internal motivation' by allowing for self-direction and providing scenarios that remind learners of their personal experiences, allowing them to reflect on past actions. 'Readiness to learn' and 'need to know' are addressed by giving examples of past safety issues that demonstrate why learners need to know the presented material. Presenting MRI safety measures that can be immediately implemented applies to the concept of 'orientation to learning'.

Methods

Design

An evidence-based teaching plan (Appendix B) was designed to convey the risks and recommendations for providing anesthesia care in MRI. Evidence-based practice has been proven to improve decision-making, especially decisions related to patient management and care (Finkelman, 2022). The teaching plan can be used in conjunction with four evidence-based educational modules to educate anesthesia staff. Bringing awareness to evidence-based practice through proper education reduces anesthesia related operative events (Finkelman, 2022). The four modules will include Non-Operating Room Anesthesia, MRI basics explaining the parts of MRI and how it works, safety concerns in MRI that apply to all healthcare providers, and specific considerations for anesthesia providers providing care in the MRI suite. The risks and recommendations included in the teaching plan and modules were determined, first, by literature review and, secondly, by content analysis from anesthesia professionals in the greater Philadelphia and Lehigh Valley areas. The content was approved and organized into an evidence-based teaching plan which will be used to guide the creation of four evidence-based education modules. The teaching plan and modules are intended to be disbursed to local anesthesia schools and health networks to provide education to anesthesia professionals so they can be better prepared for the MRI environment.

The primary data source was a comprehensive literature review across several databases including PubMed, Google Scholar, Proquest, and Wiley Online Library. Secondary data sources included consultation with anesthesia professionals and a content analysis.

Sample and Setting

The sample for this project is the empirical and theoretical literature gathered as well as relevant policies and practice advisories from professional organizations. With the exception of one article from London, England, all appraised literature is from the United States of America and relates specifically to anesthesia providers or to generalized healthcare providers. Sampling criteria for expert reviewers include CRNAs, anesthesiologists, and radiology professionals with experience providing patient care in the MRI suite. Expert reviewers were identified by convenience sampling from hospitals in the Philadelphia and Lehigh Valley regions.

The setting for this project is Frank J. Tornetta School of Anesthesia (FJTSA), affiliated with LaSalle University and Einstein Health Network in Philadelphia, Pennsylvania.

Ethical Considerations

This DNP scholarly project includes an evidence-based teaching plan regarding the safe administration of anesthesia in the MRI suite. No identifiable risks to participants of the project were noted. Any identifying information from expert reviewers will remain anonymous. Data obtained is password protected and secured via Qualtrics software. Institutional Review Board (IRB) was requested via Einstein Healthcare Network's IRB and approval was achieved October 31, 2022. An exempt status was determined due to no involvement of human subjects and no personal identifiers. Letter of IRB approval can be found in Appendix C.

Instrumentation

The program planning matrix (Table 5) provides structure to project development across a timeline. The matrix organizes our program goals, methods, evaluation methods, responsible personnel, and proposed outcomes. A content validity tool (Table 6) was used to support data collection and identify teaching plan objectives. This tool was converted to a Qualtrics survey to allow for a more streamlined survey distribution as well as organized data collection.

A total of 25 items comprised the survey: 2 demographic, 20 quantitative, and 3 qualitative. Experts used the expert content validity form to convey the relevance of each quantitative point by assigning numerical values as follows: 1=*not relevant*; 2=*somewhat relevant*; 3=*quite relevant;* 4=*highly relevant*. The results were analyzed and utilized to guide the development of the teaching plan. Both the content analysis matrix and the expert content validity form are included in the appendices.

Categories that support the evidence-based teaching plan structure were identified through direct content analysis. The approach allowed us to highlight essential concepts and formulate our educational plan. Examples of broad categories include non-operating room anesthesia, MRI basics, safety concerns in MRI, and specific considerations for anesthesia providers providing care in the MRI suite. These categories are supported by the evidence and provide an overview of how literature informs the proposed intervention. This teaching plan will support a later cohort's adoption of phase 2, the development of evidence-based education modules.

Procedures and Data Collection

Data was collected from an evidence-based literature review to determine important categories to be included in the education modules. Articles reviewed discussed adverse events in MRI, the unique challenges associated with non-operating room anesthesia, and barriers to educating health professionals. The identified categories from the literature review were compiled into a matrix and provided to expert reviewers for further analysis of relevancy. The completed expert content validity forms were analyzed to determine the importance of each category and their relevance to the teaching plan.

We developed a 25 question Qualtrics survey with provided instruction and distributed it via email to 21 professionals on January 15, 2023. A 4-week timeframe of data collection was allowed with survey closure on February 14, 2023. Collection of the quantitative and qualitative data was protected and reviewed via Qualtrics software. A statement was provided stating that the survey was completely voluntary, allowing participants to give informed consent.

Data Analysis

At the completion of our MRI safety survey, data analysis consisted of generating common statistics and themes. Quantitative data was organized by the number of reviewers that felt topics were highly relevant, quite relevant, somewhat relevant, or not relevant. Content Validity Index (CVI) was calculated and utilized for quantitative evaluation. Values range from 0 to 1 with I-CVI >0.8 suggests an item is relevant and I-CVI < 0.8 suggests an item is irrelevant or needs revision (La Salle University, n.d).

Qualitative data was collected based on common themes and differences provided by reviewer comments as they contributed to revising concepts. The DNP student team reviewed this qualitative data analysis along with the team chair and La Salle University faculty who are both experts in MRI safety. Final decisions to accept suggestions or not was made by the team. A content analysis of the narrative comments was completed. The collection of this data forms the support of anesthesia experts to develop the educational tool.

Discussion

Findings

Quantitative Findings

A total of 16 responses were obtained for quantitative analysis. Twelve respondents were CRNAs and 6 were anesthesiologists. Experience levels ranged from less than 5 years to greater than 25 years with the majority having 11-15 years of experience. 69% reported previously receiving formal MRI safety education and 39% reported experiencing at least 1 adverse event while providing anesthesia in the MRI suite. 100% of respondents felt that MRI safety education should be included in onboarding processes for new anesthesia staff.

Out of the 17 provided content areas all but three were found to be relevant without revision (Appendix D). The highest scoring content areas (I-CVI=1) were collaboration with MRI staff and physicians, general safety concerns of MRI, response to emergencies: crash cart location, and response to emergencies: airway equipment. The three content areas needing revision or elimination were MRI mechanics (I-CVI= 0.6), performing a verbal timeout prior to initiating patient care (I-CVI= 0.73), and yearly MRI training (I-CVI=0.6). After discussion with the DNP project team, the MRI mechanics content was condensed to a cursory overview to aid in the understanding of the importance of the project. The verbal timeout content will remain a brief portion of the lesson plan due to the determined importance of interdisciplinary communication and institutional timeout policies. Implementing yearly MRI training will be left up to the discretion of each institution.

Qualitative Findings

Common themes supporting the content areas were established through expert responses. Of those who experienced adverse events while providing anesthesia in MRI, contributing factors included difficulties managing the patient's airway, lack of access to the patient and subsequent delay in patient care. These reports further support the content areas identified as relevant through quantitative analysis; especially the subjects of equipment, patient accessibility, and managing patient emergencies.

In addition to the suggested content areas, respondents suggested including information regarding the assessment for implantable or wearable devices, physiological effects of the various types of contrast used in MRI, MRI procedures that require breath-holding, and the management of airway emergencies. Information on implantable devices and airway emergencies were included in the modules 3 and 4 of the teaching plan. Upon review with the DNP project team, the subjects of MRI contrast and specific MRI procedures were deemed to be outside the scope of this project.

Limitations

Limitations identified are pertinent to anesthesia specific MRI concerns. Limited literature is available regarding administering anesthesia to adults in an MRI suite as well as evidence-based guidelines for providing care safely in the MRI suite. Challenges related to effective anesthesia departmental education were identified by experts in the Qualtrics survey provided: limited time, limited exposure to MRI anesthesia cases, and limited availability of the MRI suite for training. Restricting our survey to the Philadelphia and Lehigh Valley regions is also a limitation.

Implications

The utilization of an evidence-based teaching plan for MRI safety establishes a foundation for educational intervention which equips anesthesia staff with advancing knowledge that may both improve preparedness and increase patient and staff safety. Expert content analysis supports relevant topics to be included within the educational program and highlights additional pertinent content to be addressed. The gap in literature and evidence-based guidelines in conjunction with expert analysis supports the development of evidence-based education modules on the safe delivery of anesthesia in MRI suites.

Future Projects, Plans and Dissemination

Our findings will be disseminated to La Salle University Digital Commons and to our fellow DNP cohorts at Frank J. Tornetta School of Anesthesia. Additionally, we will pursue presentations at future PANA and patient safety conferences. Creation and implementation of education modules will be completed by a later DNP cohort. The effectiveness of the modules will be assessed via pre/posttest. This multi-phase project approach allows for collaboration opportunities between DNP student cohorts. An opportunity for collaboration between CRNA staff, students, as well as healthcare administrators is also provided with this method to effect change in the practice setting. This approach provides the necessary time to review policies and procedures and to engage administrators in the approval process to implement the project, further promoting its sustainability.

Conclusion

Anesthesia is frequently required in the MRI suite to maintain patient safety and ensure quality imaging. Providing anesthesia in the MRI suite has been reported to be more dangerous than operating room anesthesia and significantly increases morbidity and mortality (Metzner et al., 2009). Despite the danger, the presence of formal education is lacking. Experts support the need for increased education and guide the inclusion of pertinent content areas. With the creation of an evidence-based teaching plan, educational modules can be created to aid the safe administration of anesthesia in the MRI suite.

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Table 1

Project Committee

Student	**DNP Project**	**FJTSA Faculty**	**LaSalle Faculty**
Mandy Cesco-Cancian Taylor Crofoot	Evidence-based Educational Modules on the Delivery of Anesthesia in the MRI Suite	Mike Kost *Content Specialist*	Mary Palovcak *Chairperson*

Table 2

Project Timeline

Tasks to Complete	*Sept. 2021*	*July 2022*	*Nov. 2022*	*Jan. 2023*	*Feb. 2023*	*March 2023*	*April 2023*	*May 2023*
Identify DNP Project Committee	*x*							
Perform literature review	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*
Prepare DNP project Proposal		*x*						
Prepare Proposal PowerPoint		*x*						
Submit Proposal to Einstein IRB			*x*					
Defend Proposal			*x*					
Perform content analysis				*x*				
Develop teaching plan					*x*			
Expert Review				*x*				
Revisions						*x*		
Finalize teaching plan						*x*	*x*	
Complete DNP Project Paper							*x*	
Defend project								*x*

X= completed P=projected DNP Project Team Chair: Dr. Mike Kost, Faculty Committee Member: Dr. Mary Palovcak

Table 3

Search Process Review of Literature

Database	Total Articles	Articles Remaining After Title Review	Articles Remaining After Abstract Review	Articles Retrieved and Examined	Articles that fit Inclusion Criteria
PubMed	384	7	4	2	2
Google Scholar	453	21	17	5	1
ProQuest Dissertations & Theses Global	218	10	2	2	1
Wiley Online Library	244	12	7	3	2

Note. Number of duplicate articles removed

Table 4

Review of Literature Matrix Systematized Review

Database # Article First Author, Year (full citation in References)	**Purpose of Study** **Major Variables (IV, DV) or Phenomenon**	**Theory or Conceptual Framework**	**Design**	**Measurement Major Variables (Instrument)**	**Data Analysis (Name of Statistics, descriptive, Inferential and Results)**	**Findings**	**Evidence Level of Research & Quality Johns Hopkins Nursing Evidence-Based Practice**
Pubmed #1 Herman, Jaruzel, Lawton, Tobin, Reves, Catchpole, Alfred (2021)	Identify weaknesses in NORA and propose methods to develop safer systems of care. Phenomenon: Patient safety in non-operating room anesthesia	None identified	Literature Review. 31 studies included. Pubmed, Scopus, Proquest, CINAHL search for articles after 1994. search terms 'non-operating room anesthesia', 'anesthesia outside the operating room',	Morbidity and mortality, adverse events, safety risks	Two reviewers organized with SEIPS model and narrative summary	Higher morbidity and mortality in NORA cases: higher proportion of death claims, higher proportion of complications attributable to inadequate oxygenation, higher likelihood that events were preventable and due to substandard care. Majority of claims came from GI,	Level III

			'remote location anesthesia'			radiology, cardiology suites. Main hazards of NORA: older more frail patients, restricted access to workspace that may not support anesthesia, lack of team familiarity and support, inexperienced postop care teams, older technology, limited monitoring capabilities, time pressures	
Pubmed #2 Metzner, Posner, Domino (2009)	Assess patterns of injury and liability claims from NORA compared with operating room anesthesia Phenomenon: Patient safety in non-operating room anesthesia	None identified	Retrospectiv e Review of ASA closed claims database for claims occurring in 1990 or later. Excluded	Patient characteri stics, surgical procedure s, sequence/l ocation of events, critical incidents,	Reviewed by practicing anesthesiologists Fisher's exact test, z test, t test, Kolmogorov-Smirnov test P<0.05	T-test: patients older in NORA (20% >70yo compared to 12% P<0.001). Fisher's exact test and z test: patients sicker in NORA (69% ASA 3-5	Level III

			obstetric and dental claims and those arising from acute or chronic pain management N=3374 (remote location claims = 87; operating room claims 3,287)	injuries, standard of care, prevention, payments		compared to 44% P<0.001) more emergent cases in NORA (36% compared to 15% P<0.001) Higher risk of death in NORA (54% compared to 29% P<0.001) Operating room more associated with temporary injuries (49% compared to 30% P<0.001) most common injury in both locations was respiratory event but NORA had a higher percentage (44% compared to 20% P<0.001) Inadequate oxygenation/ventilation most common NORA claim and 7times more likely than OR (21% vs 3% P<0.001)	

						No difference in cardiovascular events, equipment failure/malfuncti on, med errors Substandard care given in 54% of NORA cases compared to 37% in OR ($P<0.001$) Complications preventable by better monitoring in 32% of NORA compared to 8% in OR ($P<0.001$)	
Google Scholar # 1 Field (2018)	Identification and analysis of MRI screening events. Review strategies for keeping ferromagnetic objects/devices from reaching the magnetic field. Phenomenon: MRI patient safety	None identified	Analysis of MRI screening events reported to Pennsylvani a Patient Safety Reporting System from 2009-2017 1,108 met inclusion criteria	Object/de vice involved, whether object was on patient, what MRI zone the event occurred, level of harm either incident	Group of analysts used narrative summary to organize findings	65% involved internal devices with pacemakers being the most common 33%. 40% of external devices were medical equipment (monitors, wires/leads, machines, etc) 31% of events occurred in zone IV (4.6% of	Level III

				or serious event		those were projectiles) 0.5% (5 cases) were serious events causing patient injury	
Wiley #1 Delfino, Krainak, Flesher, Miller (2019)	Provide an overview of 10 year FDA adverse event reports for MRI systems Phenomenon: MRI patient safety	None identified	Retrospective study. Reports taken from January 2008-December 2017. N=1548	MRI adverse events, MRI safety, thermal, acoustic, image quality, projectile, mechanical, peripheral nerve stimulation, miscellaneous, unclear injury	Two reviewers independently reviewed adverse events to determine causes before combining into one review	Thermal injury was the most commonly reported adverse event (59%), followed by mechanical injury (11%), projectile events (9%), and acoustic events (6%). Thermal injury:unclear causes (39%), followed by contact with a conductive object within the bore (16%), skin-to-skin contact (16%), and contact with the wall (10%) Projectile injury: most common= patient transport	Level III

						and mobility equipment (26%),	
Wiley #2 Ward, Wood (2000)	Determining education needs of specialists and non-specialists in order to reach their full potential Phenomenon: Educating healthcare professionals	None identified	Qualitative thematic analysis to explore the complexities of education and training. Focus groups and semi structured interviews. April-June 1999 N=144 (39 specialist & 105 non-specialist	Education, healthcare, barriers	Two researchers discussed coding and themes while cross-checking groups of data and themes to minimize researcher bias	Barriers to education include time, accessibility, financial issues, staff motivation, and marketing/advertising. These areas must be addressed if education is to be successful.	Level III
Proquest # 1 Schroeck, Welch, Rovner, Johnson, Schroeck (2019)	Map existing knowledge about anesthetic care in advanced imaging hybrid operating rooms, identify knowledge gaps, and direct future research	None identified	Systematic scoping review to identify articles describing challenges working in hybrid operating	Anesthesia, intraoperative magnetic resonance imaging, tomography, hybrid	Three authors reviewed summarized manuscripts and data spreadsheets	Informal reviews (n=10), institutional experiences (n=10), case series/retrospective studies (n=12), prospective studies (n=4).	Level III

	Phenomenon: Patient safety in non-operating room anesthesia		rooms with MRI capability PubMed, Embase, Cochrane Library, Web of Science, Google Scholar January 1994 - August 2017	operating room		Common issues: monitoring difficulties, availability of MRI compatible equipment, risk of airway/line dislodgement, and limited access to the patient. Lack of consistency with reporting adverse events	

Table 5

Program Planning Matrix

Program Goal 1: Identify knowledge deficits related to providing anesthesia in an MRI suite. Program Goal 2: Develop comprehensive education modules to provide to staff. Program Goal 3: Distribute education modules to local organizations.					
Objectives	**Methods and Techniques**	**Timeline**	**Evaluation Methods**	**Responsible Personnel**	**Outcomes**
Short Term Objectives					
1. Identify administrative support	Administrative Organization	September 2021	Letter of support from Mike Kost	Mandy Cesco-Cancian & Taylor Crofoot Mike Kost, DNP, CRNA Mary Palovcak, DNP, CRNP	Completed: Mike Kost and Mary Palovcak identified as administrative support
2. Research evidence-based literature	Literature search utilizing research databases	Ongoing	Evaluate with team members	Mandy Cesco-Cancian & Taylor Crofoot	Completed: literature search from Pubmed, Google Scholar, ProQuest, Wiley Online Library

3. Identifying potential knowledge gaps and safety hazards in relation to anesthesia and the MRI suite	Review of literature	Fall 2021-Spring 2022	Evaluate with team members	Mandy Cesco-Cancian & Taylor Crofoot	Completed: Literature reviewed and appraised
Intermediate-term Objectives					
1. Collaborate with professionals to identify important MRI education topics.	Qualtrics Expert Validity Survey provided to staff at Einstein Medical Center, Abington Hospital, & Lehigh Valley Hospital	January 2023	Collect and analyze data from content validity form	Mandy Cesco-Cancian, Taylor Crofoot, staff at Abington Hospital & Lehigh Valley Hospital	Completed: expert-reviewed topics identified for inclusion in lesson plan.
2. Create lesson plan for comprehensive education modules for anesthesia providers.	Literature review and Qualtrics Expert Validity Survey	Spring 2023	Consult with administrative support and content experts	Mandy Cesco-Cancian & Taylor Crofoot Mike Kost, DNP, CRNA Mary Palovcak, DNP, CRNP	Completed: Expert-reviewed topics integrated into comprehensive lesson plan.

3. Present lesson plan to La Salle DNP committee	Spring DNP defense	Spring 2023	Approval of project by committee	Mandy Cesco-Cancian, Taylor Crofoot, members of La Salle DNP Committee	In Progress: Approval of final program modules by La Salle committee
Long-term Objectives					
1. Survey MRI safety knowledge of anesthesia providers before education	Pre-education survey	TBD: goal 2023-2024	Analysis of data from pre-test	Future DNP students	Future: Baseline assessment of existing knowledge on safe anesthesia in MRI.
2. Delivery of education modules regarding administering anesthesia safely in MRI	Annual education and staff meetings	TBD: goal 2023-2024	Pre and Post test	Future DNP students	Future: Staff complete annual education and attempt staff meeting to receive education.
3. Survey MRI safety knowledge of anesthesia providers after education	Post-education survey	TBD: goal 2023-2024	Analysis of data from post-test	Future DNP students	Future: Improved knowledge of safe anesthesia in MRI

Appendix A

Stakeholder Support of Project

Einstein
MEDICAL CENTER MONTGOMERY
More than Medicine

Frank J. Tornetta School of Anesthesia
LaSalle University School of Nursing

Michael Kost, DNP, CRNA
Director

Cynthia Betron, DNP, CRNA
Associate Director

October 6, 2021

Zane Robinson Wolf, PhD, RN, FAAN
Dean Emeritus & Professor of Nursing
La Salle University School of Nursing and Health Sciences
1900 W. Olney Avenue
Philadelphia, PA 19141-1199

Dear Dr. Wolf and La Salle University Nurse Anesthesia Track DNP Committee Members,

This letter is in strong support and endorsement of the Frank J. Tornetta School of Anesthesia/La Salle University School of Nursing DNP Cohort II projects outlined in the attached list of DNP project titles. The Frank J. Tornetta School of Anesthesia will adjust all currently enrolled NUR705 students' anesthesia clinical and class schedule accordingly to allow for adequate time to complete their respective DNP projects. As students progress through the La Salle University School of Nursing DNP curriculum, the Frank J. Tornetta School of Anesthesia will also submit their projects to the Einstein Institutional Review Board (IRB) for review. Since the majority of these projects are without risk to human subjects, they are expected to be given IRB approval with exempt status.

Please let me know if you have any questions or require any additional information at this time. We remain in full support of the Frank J. Tornetta School of Anesthesia/La Salle University School of Nursing DNP Cohort II currently enrolled in NUR705 and will make every effort to accommodate them so that their DNP project remains a scholarly priority while enrolled in our program.

Respectfully Submitted,

Mike Kost, DNP, CRNA, CHSE, FAAN

Mike Kost, DNP, CRNA, CHSE, FAAN
Program Director

MK/dmq

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Einstein Medical Center Philadelphia Einstein Medical Center Elkins Park Einstein Medical Center Montgomery
MossRehab Willowcrest Einstein Physicians Einstein Outpatient Care

Appendix B

Lesson Plan

Title: Evidence-Based Educational Modules on The Safe Delivery of Anesthesia in MRI Suites

Teacher: Mandy Cesco-Cancian, RN, BSN, SRNA & Taylor Crofoot, RN, BSN, SRNA

Purpose: The purpose of this teaching plan is to develop evidence-based educational modules intended to improve safety for patients undergoing anesthesia in the MRI suite.

Goal: To educate anesthesia providers (SRNAs, CRNAs, and anesthesiologists) evidence-based practices that enhance patient safety when providing anesthesia services within the MRI suite.

Behavioral Objectives At the completion of this teaching intervention, participants will be able to:	**Content Outline**	**Methods of Instruction**	**Time Allotted**	**Method of Evaluation**
Module 1: Non-Operating Room Anesthesia				
1. Delineate the subset population and procedures requiring anesthesia services in the MRI suite.	**Introduction to MRI Anesthesia** ● MRI Consists of multiple image sequences, each taking at least 10 minutes (Reddy et al., 2012) ○ Any movement causes distortion of recorded images ○ MRI scans may last up to 2 hours ● MRI scanning increases noise pollution and occurs in confined quarters ● Goals of anesthesia are to maintain immobility while keeping the patient comfortable and safe ○ Anesthesia requirements for the MRI patient range from mild sedation up to and including general anesthesia with endotracheal tube management	Lecture, Powerpoint, Discussion	10 minutes	Pre-Test, Post-Test, Q&A, Repeat demonstration

<table>
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<td>2. Identify the risks and complications associated with the administration of anesthesia in non-operating room anesthesia (NORA)</td>
<td>

General subset populations requiring anesthesia administration for include: pediatrics, patients with learning disabilities, movement disorders, claustrophobia, critically ill (Swart & Ducombe Rae, 2018).

Introduction to Non-Operating Room Anesthesia (NORA)

NORA cases expected to make up 50% of anesthesia cases in the next decade (Herman et al., 2021)
NORA rooms are described as cramped, dark, small rooms requiring improvisation of equipment setup, workflow considerations, and movement within the room (Herman et al., 2021)
Herman et al. (2021) conducted a literature review to identify weaknesses associated with NORA.
Deaths reported associated with MRI procedures.
One study reviewed had all 3 NORA deaths in MRI
Metzner et al. (2009) completed a retrospective review of ASA closed cases assessing patterns of injury from NORA compared to non-NORA administered anesthesia.
Respiratory complications are most common in NORA with inadequate ventilation/oxygenation being most common
Others include difficult intubation, esophageal intubation, aspiration
70% of radiology claims involved MRI

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	■ 4 for oversedation, 2 for burns, 1 for brachioplexopathy ○ 54% of NORA complications stemmed from substandard care			
Module 2: MRI Basics				
3. Provide detailed rationale on the basic function of MRI units 4. Differentiate the four MRI zones	**Overview of the MRI Suite** ● One large magnet with magnetic field ○ One large wire coil immersed in liquid helium inside an insulated canister ● Secondary magnet with magnetic field ○ Smaller coils - allows images to be viewed in multiple layers and directions ● Radiofrequency transmitter receiver system ○ Excites nuclear magnetism within the body ● Magnitude of magnetic strength takes hours to achieve ○ 10,000-100,000 times stronger than the earth's magnetic field ○ Magnet is never turned off ● Radiofrequency transmit receive system ○ Excites nuclear magnetization inside the body and receives return MR signal ■ Must be sensitive to noise to interpret signal ● Makes patients sensitive to the external noise as well ● 5G line: upper limit where field strength is not harmful to general public even with implantations (Tsai et al., 2015). ● Zone I: unrestricted. General public is permitted.	Lecture, Powerpoint, Visual demonstrations, Discussion	10 minutes	Pre-Test, Post-Test, Q&A, Repeat demonstration

	● Zone II: Reception area of MRI where patient information is obtained. Visitors must be supervised. ● Zone III: Danger if unscreened people/objects enter this area. Locked area. Generally, where the control room and adjacent hallways are. ● Zone IV: Room where machine resides. All persons must be under direct supervision of MRI personnel. (American College of Radiology, 2020)			
5. Delineate the four MRI equipment labels	● "MR safe": nonhazardous in all MR imaging environments, however functionality not guaranteed. ● "MR compatible": Equipment is safe, and functions as expected. (Swart & Decombe Rae, 2018) ● "MR unsafe": contraindicated in all MR imaging environments ● "MR conditional": compatibility based upon operating conditions such as magnetic field strength and maximum magnetic field gradient ● Levels of trained personnel ○ 1: minimal safety education to ensure own safety within zones ○ 2: more detailed training on MR safety ○ 3: no safety education ● Joint Commission restricts access to Zone III and IV to those trained in MR safety or those screened and supervised by MR trained personnel. (Tsai et al., 2015)			
Module 3: Safety Considerations for all Healthcare Professionals				
	MRI Safety Concerns	Lecture, Powerpoint, Visual	10 minutes	Pre-Test, Post-Test, Q&A,

6. Participants will be able to delineate the safety concerns for patients undergoing MRI procedures	● Implanted devices (Tsai et al., 2015) ○ Some require a certain amount of time to embed into tissue before MRI is safe. ○ Some may contain small enough amounts of ferromagnetic material to still be safe. ○ Foreign objects such as shrapnel and bullets may be safe if not near vital organs. ○ Pacemaker and cochlear implants make patient ineligible for MRI (Hemingway & Kilfoyle, 2013) ○ Check for removable devices such as insulin pumps and implantable continuous glucose monitors. ● Burns (Tsai et al., 2015) ○ From contact with coils/cables ■ Safety measures with protective sleeves and nonconducting pads ○ From electromagnetic induction ■ Jewelry or leads that become coiled ■ Some medicinal patches containing aluminum ■ Clothing containing silver ● Acoustic injury (Sammet, 2016) ○ Acoustic noise is caused by gradient system within MRI ○ Ear plugs or headphones are essential for patients inside the magnet ● Projectiles ○ 5G line does not safeguard against projectiles (Tsai et al., 2015) ○ Any ferromagnetic object, regardless of size, can become a projectile. (http://patientsafety.pa.gov/ADVISORIES/Pages/200906_56.aspx)	demonstrations, Graphs from research study, Discussion		Repeat demonstration

	■ Paper Clips and hairpins can travel up to 40mph into a 1.5T magnet ■ Translational and torque forces from static magnet field contributes to projecting objects ○ Usually stretchers/beds, chairs, gas cylinders (Tsai et al., 2015) ○ Death from oxygen tank crush injury ■ In 2001, in New York, a 6 year old boy was killed after an oxygen tank was pulled into the machine and crushed the boy’s skull. (ABC news article) ○ Firearm discharge (Beitia et al., 2002) ■ An off-duty police officer brought a gun into the MRI scanner after a miscommunication with MRI staff. ● He tried to place the gun on a cabinet a few feet from the magnet. The gun was pulled from his hand into the bore and spontaneously fired despite the safety being on. ○ Estimated cost of projectile event in 2004: $43,100 (http://patientsafety.pa.gov/ADVISORIES/Pages/200906_56.aspx)			

Module 4: MRI Safety Considerations for Anesthesia Professionals				
7. Identify the unique barriers to MRI patient care when providing anesthesia services.	**Barriers to Care** ● Inaccurate monitoring due to MRI interference ○ ECG leads may show T wave and ST segment changes making arrhythmia identification difficult (Reddy et al., 2012) ■ Due to radio frequency interference (Rose and Mclarney, 2014) ○ The need to add extensions to invasive BP monitoring increases dampening of the waveform displays(Reddy et al., 2012) ○ Capnography time delay is increased due to longer sample tubing (Reddy et al., 2012) ○ Pulse oximetry can demonstrate desaturations with normal waveform appearance during certain MRI sequences (Hrishi et al., 2018) ● Limited access to patient ○ In the event of a patient emergency the scan must be stopped, patient must be removed from scanner and 5G area before care can begin - delaying care by minutes (Reddy et al., 2012) ○ A patient getting upper body scans will go headfirst into the scanner making the airway practically inaccessible. (Reddy et al., 2012) ○ Many assessments cannot be completed in the MRI suite due to safety hazards. I.e. auscultation of heart and lungs (Swart & Ducombe Rae, 2018) darkened	Lecture, Powerpoint, Visual demonstrations, Discussion	30 minutes	Pre-Test, Post-Test, Q&A, Repeat demonstration

	environments leading to obstructed view of patient (Anesthesiology, 2015) ○ Need extension tubing on IV lines and breathing circuit (Schroeck et al., 2019) ■ Leads to delayed response to IV and inhalational drugs and increased dead space ● Accessibility of equipment/resources ○ Equipment is often in closets minutes away from MRI ○ MRI staff are unfamiliar with how to help us/what we need and other anesthesia providers are far away (Rose and Mclarney, 2014)			
8. Describe MRI equipment that is considered 'safe' for use in the MRI suite.	**Equipment** ● Look for MR compatible ventilators, vaporizers, anesthetic machines (Swart & Ducombe Rae, 2018) ○ Normal anesthesia machines are made with iron and steel and are incompatible (Rose and Mclarney, 2014) ■ MRI compatible machines are made of aluminum and plastics (Rose and Mclarney, 2014) ● Most major machine manufacturers have an MRI compatible machine (AANA, 2022) ● Ensure oxygen tanks are in aluminum canisters. (Swart & Ducombe Rae, 2018). ● Many anesthetic pumps contain ferromagnetic parts that would cause the pumps to malfunction in MRI (Swart & Ducombe Rae, 2018).	Lecture, Powerpoint, Visual demonstrations, Discussion	20 minutes	Pre-Test, Post-Test, Q&A, Repeat demonstration

	● LMAs may contain metal coils that cause artifact (Swart & Ducombe Rae, 2018). ○ Can be taped out of the way and still used ○ MRI compatible LMAs also exist ● Pilot balloons on ETTs have small metal springs in them. (Swart & Decombe Rae, 2018) ○ Can be taped out of the way and still used. ● Use of stainless steel instrumentation (Hemingway & Kilfoyle, 2013) ● ECG leads and pads need to be made of graphite so they don't heat up as much from the radio frequency interference (Rose and Mclarney, 2014) ● Standard pulse ox probes and cables contain ferromagnetic material that can burn patients and cause interference (Rose and Mclarney, 2014) ○ MRI may cause decrease SP02 reading without altering the waveform, making it difficult to quickly identify interference vs hypoxia (Hrishi et al., 2017) ○ MRI compatible does contains minimal ferromagnetic material and cords are fiberoptic to prevent interference (Rose and Mclarney, 2014) ● Be careful with MRI compatible monitors. Some are only compatible if kept at a certain distance (Rose and Mclarney, 2014) ● iGel and AMBU supraglottic airways do not create artifact when used in MRI (Saxena, 2012) ○ iGel doesn't have an inflatable cuff so there is no worry of ferromagnetic material			
9. Describe preventative strategies to increase	**Preventative Measures** ● Ferromagnetic metal detectors (Tsai et al., 2015) ● Development of policy and checklist (Tsai et al., 2015)	Lecture, Powerpoint, Visual demonstrations, Discussion	10 minutes	Pre-Test, Post-Test, Q&A, Repeat demonstration

patient safety within the MRI suite	● Yearly training for anyone regularly going into Zones III and IV (Tsai et al., 2015) ○ Students should be able to handle MRI specific equipment (Wilson et al., 2019) ○ Students should simulate induction in the MRI suite (Wilson et al., 2019) ● Verbal timeout in zone III (https://radiology.ucsf.edu/patient-care/patient-safety/mri/access-restriction) ○ Confirm patient ○ Review mri screening form ○ Review mri safety with staff ○ Check for MRI unsafe equipment/objects ● Collaborate with MRI staff and physicians to ensure screening has been completed prior to procedure, label anesthesia equipment as safe, unsafe, or conditional (Anesthesiology, 2015) ● Induction must be done in an anesthesia room next to the MRI scanner room. All emergency equipment must stay in designated room (Reddy et al.,2012) ● Specific room designated for induction/resuscitation (Swart & Ducombe Rae, 2018) ○ Additional metal check prior to entering MRI room ● Consider length of scan when determining whether sedation or general anesthesia is appropriate as well as which type of airway is necessary. (Wilson et al., 2019) ● Treat each procedure in an MRI suite in the same manner regardless of MRI use, “force of habit” creates safe environment (Hemingway & Kilfoyle, 2013) ● MRI ‘solo’ cases should only be done under certain circumstances (Wilson et al., 2019)			

	○ Documented experience with MRI anesthesia ○ Demonstrated knowledge of MRI hazards and safety precautions ○ Demonstrated knowledge of managing emergencies in MRI. ● Confirm good IV site (Wilson et al., 2019) ○ Increased risk for undetected infiltration due to inability to easily visualize IV site and long amounts of extension tubing altering accuracy of high pressure alarms. ■ May need to adjust high pressure alarms to make up for extension tubing. ● Ensure airway is properly secured before start-it will be mostly inaccessible during imaging (Reddy et al., 2012) ● Patient positioning ○ Choose a position for optimal patient observation whether in zone III or IV (Anesthesiology, 2015) ○ Ensure all wiring/tubes are taped away from the patient to prevent burns. (Swart & Ducombe Rae, 2018) ● Monitoring after anesthesia, in MRI, should be the same as in the OR. (Reddy et al., 2012)			
10. Identify emergency situations and how to adapt to them	**Emergencies** ● Patient decompensation ○ Know where the crash cart is. ■ All equipment on the crash cart should be labeled as MRI safe or conditional. (Tsai et al., 2015) ■ Generally in zone II or zone III. ○ Have a plan for common airway problems including alternate airway devices and	Lecture, Powerpoint, Visual demonstrations, Discussion	15 minutes	Pre-Test, Post-Test, Q&A, Repeat demonstration

	have continuous suction readily available (Anesthesiology, 2015) ○ Immediately stop imaging and move patients out of zone IV. (Tsai et al., 2015) ○ If possible appoint one person to ‘guard’ zone IV so unscreened personnel do not enter the area. (Tsai et al.,2015) ○ In the event of cardiac/respiratory arrest, immediately begin compressions while someone moves the patient out of zone IV. (manual on MR safety) ■ Designate a ‘magnetically safe’ spot for resuscitation prior to beginning anesthesia ● Magnet quench (Tsai et al., 2015) ○ Used to immediately shut off magnet field ■ I.e. Projectile ○ Triggered by button ○ Can occur spontaneously from equipment failure ○ Superconducting coil is warmed above the threshold temperature to shut off the magnetic field. ■ The warmed coils lead to higher temperatures of the surrounding helium which results in an explosive boiling effect. ■ Quench pipe safely vents the boiling gas however the reaction is unstable and there is a risk of pipe failure. ● Quench pipe failure leads to build up of helium in the room. ○ The gas acts as an asphyxiant			

	and creates a fog resulting in low visibility. ○ The change in pressure can prevent the zone IV door from opening (if it swings inward) ○ Personnel should be evacuated from zone IV immediately ○ Administer oxygen to patient immediately and remove them from zone IV ● Fire (American College of Radiology, 2020) ○ Local fire marshals should be educated of hazards of MRI machine ○ Zone III or IV should have MR safe fire extinguishing equipment ○ Magnet is always on so oxygen tanks and other equipment used by firefighters will not be safe in these zones unless a quench is performed			

Appendix C

IRB Letter of Approval

Einstein HEALTHCARE NETWORK More than Medicine

Human Subjects Research Determination

October 31, 2022

Type of Review: Initial
Project Title: Creation of Evidence-Based Education Modules on the Safe Delivery of Anesthesia in the MRI Suite
Investigator: Michael Kost
IRB ID: IRB-2023-1032

Dear Michael Kost ,

The planned activity noted above was reviewed by a member of the EHN IRB and determined not to be human subjects research. This decision only applies to the planned activity described in the materials provided to the IRB. As the person accountable for the conduct of the activity, you are responsible for ensuring that it is conducted as described in the materials provided.

Appendix D

Content Validity Summary

Topic	CVI	Topic	CVI
MRI machine mechanics	0.6	General safety concerns in MRI	1
MRI zone delineation	0.93	Identifying MRI compatible equipment	0.93
Unique challenges to patient access	0.87	Accessibility of equipment and resources	0.93
Performance of a verbal timeout prior to initiating patient care	0.73	Patient monitoring challenges due to MRI interference	0.93
Collaboration with MRI staff and physicians	1	Patient positioning considerations	0.93
Induction considerations in MRI	0.83	Response to emergencies: fire	0.87
Response to emergencies: crash cart location	1	Response to emergencies: Airway equipment	1
Response to emergencies: cardiac or respiratory arrest	0.93	Response to emergencies: MRI quench	0.87

Content areas needing revision: I-CVI <0.8
MRI mechanics
Performing a verbal timeout prior to initiating patient care
Yearly training on MRI safety