

NOISE REDUCTION IN THE OPERATING ROOM

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A Project Report Submitted to
the Faculty of The School of Nursing at
The University of North Carolina at Greensboro
in Partial Fulfillment
of the Requirements for the Doctorate in Nursing Practice

Greensboro

2022

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Abstract

The operating room is often seen as the noisiest clinical environment, with noise directly affecting the cognitive efficiency and communication of anesthesia providers. Studies show that noise levels are higher during emergence from anesthesia, a critical time for patient safety. The sterile cockpit, a concept developed by the aviation industry, may be effective to reduce noise in healthcare. The purpose of this project is to reduce noise levels in the operating room during emergence from anesthesia by creating a sterile cockpit. Pre-intervention noise levels were collected during emergence from general anesthesia cases using the NIOSH iPhone application. Staff were educated about the sterile cockpit concept, and a sterile cockpit was implemented in the operating room during emergence from general anesthesia cases. Post-intervention noise levels were collected. The results showed a reduction in average sound levels with the intervention, with no change in peak sound levels. The results of this quality improvement project suggest that the use of a sterile cockpit may be an effective tool to decrease noise levels in the operating room. Future studies may consider choosing perception of noise as an additional outcome measure as noise levels perceived by the anesthetist during emergence may reflect how a decrease in noise from the intervention impacts the practitioner.

Key Words: “noise reduction in the operating room,” “noise reduction during anesthesia emergence,” “noise reduction,” “noise reduction in anesthesia,” “distraction-free operating room,” “distraction-free anesthesia,” “operating room,” “sterile cockpit,” “sterile cockpit in healthcare,” “no-interruption zones in healthcare”

Background and Significance

Noise in Healthcare

Elevated noise levels are routinely present in healthcare settings, specifically the operating room (OR) environment, which is often seen as the noisiest clinical environment (Cheriyana et al., 2016). Various agencies within the United States and internationally have set forth recommendations for maximum noise levels that should be present in a hospital (Association of Perioperative Registered Nurses, 2020). The Environmental Protection Agency recommends that noise in hospitals not surpass 45 decibels (dB) at a given time, while the World Health Organization recommends 30 dB (United States Environmental Protection Agency, 2016; Berglund et al., 1999). Studies routinely show that noise levels in the operating room exceed these limits (Cheriyana et al., 2016; Engelmann et al., 2014; Giv et al., 2016). Noise levels can range from 53.49 dB to 81.78 dB, with varying levels dependent on noise producers in the operating room like equipment or music (Cheriyana et al., 2016; Engelmann et al., 2014; Giv et al., 2016). This can be compared to the noise of a freight train which has a noise level of 82.2 dB (Cheriyana et al., 2016). Noise levels vary for types of surgeries, with highest levels in orthopedic surgeries and lower levels in heart surgeries (Giv et al., 2016).

Noise, an auditory distraction, comes from various sources in the operating room. These include alarms, monitors, medical equipment, suction, conversations, staff entering and exiting the room, mechanical equipment, phones, and music (Association of Perioperative Registered Nurses, 2020). Some sources, like alarms and monitors, are designed to purposely make noise to alert staff to a patient's condition. Other noise, like medical equipment, is often expected and necessary to adequately care for a patient. Unnecessary noises in the operating room, however, are prevalent. Research shows that the most prevalent distractors producing noise are external staff entering the OR, conversation not pertinent to the case, slamming doors/bins, case cart movement, music, singing, autoclave systems, and dropped supplies (Broom et al., 2011; Giv et

al., 2016; van Harten et al., 2020; Wheelock et al., 2015). Case-irrelevant conversation is most often reported as the main noise distractor (Broom et al., 2011; van Harten et al., 2020; Wheelock et al., 2015).

Noise and Anesthesia

All staff can be affected, but studies show anesthesia providers are particularly vulnerable to adverse effects of a noisy operating room (Wheelock et al., 2015). This can lead to consequences such as miscommunications, ineffective task completion, lack of concentration, and increased stress (Association of Perioperative Registered Nurses, 2020). When auditory distractions are present, anesthesia providers are noted to have higher workloads than other medical specialties (McNeer et al., 2016; Tsiou et al., 2008; Wheelock et al., 2015). Excess noise also has negative work effects and causes higher stress levels according to reports from anesthesia providers (McNeer et al., 2016; Tsiou et al., 2008; Wheelock et al., 2015). Furthermore, a decrease in short-term memory and cognitive efficiency occurs with anesthesia residents in a noisy operating room (Murthy et al., 1995). Effective verbal communication requires a sound level of 10 dB above the ambient noise level in the room (Pereira et al., 2011). Pronounced effort in voice typically reaches around 64 dB and thus an ambient noise level in the operating room around 54 dB would still require a poignant increase in voice level to be heard (Pereira et al., 2011); sound levels in the OR are often higher than this, rendering communication difficult (Cheriyen et al., 2016; Engelmann et al., 2014; Giv et al., 2016). This could lead to difficulty when communicating patient concerns between providers. These noise related consequences could cause a range of anesthesia related complications, varying in severity.

Noise effects on anesthesia are often considered in relation to the three phases of anesthesia. The phases are induction, maintenance, and emergence. Induction is the phase when

a rapid onset of anesthesia occurs, often utilizing intravenous medications and techniques to secure an airway for ventilation (Miller & Pardo, 2018). Maintenance phase is the state after induction and before emergence when the focus is maintenance of amnesia, analgesia, and control of the sympathetic nervous system during the procedure (Miller & Pardo, 2018). Emergence occurs once the procedure is complete, bringing the patient back into the awake state by discontinuing amnestic medications, reversing skeletal muscle relaxation if necessary, and removing airway devices like endotracheal tubes (Miller & Pardo, 2018). Induction and emergence are consistently considered by anesthesia professionals to be critical times of anesthesia (Miller & Pardo, 2018). Multiple studies show that noise levels are higher during emergence from anesthesia and that distractors, often noise related, occur most frequently during emergence (Broom et al., 2011; Campbell et al., 2012). During emergence, serious complications can occur such as hypertension, oxygenation issues, laryngospasm, tachycardia, and other cardiovascular and respiratory issues (Casella et al., 2018). Other complications such as emergence delirium are possible as well (Miller & Pardo, 2018). A noisy environment can impede the patient from a calm emergence from anesthesia (Broom et al., 2011). Any distraction producing noise could result in the anesthesia provider struggling to respond to potential complications.

Noise Recommendations

Both the Association of Perioperative Registered Nurses (AORN) and The Joint Commission have issued position statements on noise levels in the operating room (Association of Perioperative Registered Nurses, 2020; The Joint Commission, 2017). The AORN emphasizes that critical times in the operating room, such as that of emergence from anesthesia, require the full focus of staff (Association of Perioperative Registered Nurses, 2020). Noise can threaten

patient safety and must be “minimized the greatest extent possible” (Association of Perioperative Registered Nurses, 2020, p. 3). Congruently, The Joint Commission (2017) highlights the complexity of the operating room and the necessity of staff to maintain vigilance as noise increases the risk for error and could pose unsafe conditions for patients. Recommendations emphasize the importance of reducing noise levels by a systems approach (The Joint Commission, 2017).

Elevated noise levels are present in the operating room and can threaten patient safety, especially during critical anesthesia events such as emergence. At this time, procedures to minimize intra-operative noise are not in place at the project site. An intervention is needed to address this problem. Multiple interventions have been suggested, the sterile cockpit being one prominent option (Association of Perioperative Registered Nurses, 2020).

The Sterile Cockpit

The idea of the sterile cockpit was developed by the Federal Aviation Administration during the 1980’s (Sumwalt, 1993). The development was in response to an increasing number of aviation accidents, often related to inattention by crew members (Sumwalt, 1993). The sterile cockpit rule dictates that only essential activities be performed during taxi, takeoff, landing, or while the plane is below 10,000 feet during flight (Sumwalt, 1993). This allows for non-essential discussions to occur, but outside of critical flight windows (Sumwalt, 1993). Companies establish a given method of notifying staff of a sterile cockpit when critical times are occurring (Sumwalt, 1993). Since the induction of the sterile cockpit, accidents have reduced, despite the near doubling of flight hours (Boeing, 2019). Furthermore, fatalities nationwide and globally continue to decrease with the industry’s major focus on safety (Boeing, 2019).

Reports of 200,000 preventable healthcare related deaths are estimated in the United

States alone each year (Kapur et al., 2015). This would be the comparison of three fatal aircraft crashes a day (Kapur et al., 2015). Such a statistic necessitates that healthcare errors be addressed. Aviation's feats in safety have led to comparisons to healthcare, with a focus on how healthcare can catch up to the strides of air travel (Kapur et al., 2015). The sterile cockpit, or "no-interruption zone," concept in aviation has been suggested for use in healthcare because critical times in air travel have been compared to complex or critical procedures in medicine (Kapur et al., 2015). The concept implies that reduced distraction may aid in safer outcomes for patients just as it does for aviation (Kapur et al., 2015). Consequently, the sterile cockpit has been used in healthcare to attempt to reduce noise and distraction during critical times (Behazin et al., 2014; Crockett et al., 2019; Federwisch et al., 2014; Flynn et al., 2016; Fore et al., 2012; Hay et al., 2016; Saxton & Cabill, 2017; Wright, 2016; West et al., 2012). More specifically, aviation has been compared to anesthesia (Broom et al., 2011). The concept of a plane taking off and landing is often compared to induction and emergence of anesthesia (Broom et al., 2011). Given the similar nature of anesthesia and aviation, along with prior use of the sterile cockpit concept in healthcare, a sterile cockpit could be effective to reduce noise in the operating room.

Purpose

The purpose of this project is to reduce noise levels in the operating room during emergence from anesthesia by creating a sterile cockpit.

Review of Current Evidence

Search Strategy and Introduction

Evidence for the literature review was obtained by searching PubMed, CINAHL, and Google Scholar. The search was conducted for sources published from 2010 to 2021 due to limited recent research. Sterile cockpit research was from years prior to 2010 as this concept was introduced in the 1980's. Search terms included, "noise reduction in the operating room," "noise

reduction during anesthesia emergence,” “distraction-free operating room,” “distraction-free anesthesia,” “noise reduction and operating room,” “sterile cockpit,” “sterile cockpit in healthcare,” and “no-interruption zones in healthcare.” The “similar articles” tab from PubMed, which suggests articles related to a selected article, was utilized. Additionally, reference lists from relevant articles were also investigated. Inclusion criterion was full text, peer-reviewed sources related to the application of the sterile cockpit during anesthesia. Exclusion criteria were articles outside of healthcare.

Nineteen articles were found related to noise reduction in healthcare and nine articles were used for the synthesis and appraisal of this literature review. The other 10 articles were considered for relevant material but were not used in the review given they did not use the sterile cockpit as an intervention. This literature review considered the current state of knowledge on the topic. Four themes were identified from the literature: settings in healthcare where the sterile cockpit was implemented, target outcome of sterile cockpit, indicators used to signal sterile cockpit, and impact of sterile cockpit implementation. Gaps in the literature were identified as well as support for the planned intervention is discussed.

Current State of Knowledge

The sterile cockpit has been implemented as a technique to reduce both noise and distraction in various areas of healthcare, not solely operating room settings (Behazin et al., 2014; Crockett et al., 2019; Federwisch et al., 2014; Flynn et al., 2016; Fore et al., 2012; Hay et al., 2016; Saxton & Cabill, 2017; Wright, 2016; West et al., 2012). A literature review revealed nine journal articles that trialed the sterile cockpit method in a healthcare setting.

Use of Sterile Cockpit in Health Care Settings

The sterile cockpit has been translated to many areas of healthcare, with implementation

occurring in various settings. A significant portion of research on its execution has been done on nursing units (Federwisch et al., 2014; Flynn et al., 2016; Fore et al., 2012; Saxton & Cabill, 2017; West et al., 2012). The sterile cockpit has primarily been used during nurse medication administration (Federwisch et al., 2014; Flynn et al., 2016; Fore et al., 2012; Saxton & Cabill, 2017). However, it has also been implemented in procedural areas. It has been used as an intervention in gastrointestinal endoscopy suites in multiple studies (Behazin et al., 2014; Hay et al., 2016). The sterile cockpit concept has been implemented in the operating room in both an academic teaching hospital and outpatient setting (Crockett et al., 2019; Wright, 2016). Crockett et al. (2019) only used the sterile cockpit during induction of anesthesia. Conversely, Wright (2016) used it during induction, time-out, specimen collection, final count, and emergence from anesthesia.

Target Outcome of Implementing Sterile Cockpit

Research that used the sterile cockpit as an intervention targets similar, but slightly different outcomes. Some articles sought to reduce noise in particular while others simply used umbrella terms, distraction or interruptions as its target reduction. Noise is considered an auditory distraction, deriving from many sources (Association of Perioperative Registered Nurses, 2020). However, distraction can encompass more than noise. Some literature uses the terms interchangeably, but others differentiate. Wright (2016) sought to decrease noise specifically and used a digital sound meter as an instrument. Other studies mentioned noise as the problem but used the overarching term “distractions” when it considered its outcome measure (Behazin et al., 2014; Crockett et al., 2019). Both studies used a form of self-report as its instrument measure (Behazin et al., 2014; Crockett et al., 2019). Other research sought to reduce interruptions, which could include excess noise like alarms and unnecessary conversation

(Federwisch et al., 2014; Flynn et al., 2016; Fore et al., 2012; Hay et al., 2016; Saxton & Cabill, 2017; West et al., 2012). Some of these studies used surveys and other self-report tools to determine reductions (Federwisch et al., 2014; Fore et al., 2012; Hay et al., 2016; West et al., 2012). Others used data collectors with developed tools (Flynn et al., 2016; Saxton & Cabill, 2017). One used data reflecting the time it took to complete the tasks specified in the sterile cockpit zone (West et al., 2012).

Indicators Used to Signal Sterile Cockpit is in Effect

The majority of research that implemented the sterile cockpit used an indicator to signify to everyone in the surrounding that a sterile cockpit was occurring (Behazin et al., 2014; Crockett et al., 2019; Federwisch et al., 2014; Flynn et al., 2016; Fore et al., 2012; Hay et al., 2016; Saxton & Cabill, 2017). Various types of indicators were used to notify staff, patients, and visitors during the selected sterile cockpit time, but no clear consensus was evident to support one specific type. Signs were often used in the area or on medication carts to notify individuals that only essential activity or conversation were to occur (Behazin et al., 2014; Crockett et al., 2019; Federwisch et al., 2014; Fore et al., 2012; Hay et al., 2016; Saxton & Cabill, 2017). A verbal cue was given in one study (Crockett et al., 2019). Certain research studies did not use indicators, just simply educated staff on when a sterile cockpit should be implemented during a certain procedure or task (West et al., 2012; Wright, 2016). Vests were used for some nurses during medication administration to indicate they were not to be disturbed (Flynn et al., 2016; Fore et al., 2012). One study used red tape around the pyxis to indicate this was a sterile cockpit zone (Saxton & Cabill, 2017).

Impact of Sterile Cockpit Intervention

All of the studies reviewed had some decrease in noise or distractions after

implementation of the sterile cockpit (Behazin et al., 2014; Crockett et al., 2019; Federwisch et al., 2014; Flynn et al., 2016; Fore et al., 2012; Hay et al., 2016; Saxton & Cabill, 2017; Wright, 2016; West et al., 2012). The only study that measured noise reduction via a digital sound meter had a decrease in noise levels between 1.99 dB and 8.68 dB, depending on the phase of the operating room time (Wright, 2016). Behazin et al. (2014) and Crockett et al. (2019) measured distraction levels caused by noise. The authors found that distractions decreased from 13.1 to 5.12% and from 61 to 10% percent respectively (Behazin et al., 2014; Crockett et al., 2019). Similar to Behazin et al. (2014), Hay et al. (2016) studied distractions in the gastrointestinal suite, finding that there was a significant reduction in distractions and awareness of interruptions. West et al. (2012) measured the time it took for nursing assistants to complete vital sign checks after a sterile cockpit intervention to find that times decreased from 2.5 to 0.5 hours. Less reduction occurred with some studies (Federwisch et al., 2014; Flynn et al., 2016). Researchers from Federwisch et al. (2014) found that 31% of respondents did report a decrease in interruptions but 66% reported no change. Flynn et al. (2016) authors found that while one nursing unit had a reduction of distractions from 23 to 4%, 2 other units had no change or an increase in interruptions after the intervention.

Gaps

Gaps in the literature exist when analyzing the sterile cockpit concept and its use in healthcare. The majority of its implementation has occurred with medication administration, and only a few studies have been done using it in procedural areas. More so, only two studies have been done in recent years looking at its use in the operating room (Crockett et al., 2019; Wright, 2016). There is limited evidence for how it can be used with the phases of anesthesia. Additionally, there has been only a limited amount of research done on its use in recent years.

Support for Intervention

Literature analyzing elevated noise levels in the operating room recommends the sterile cockpit concept for a noise reduction strategy (Broom et al., 2011; Cheriyan et al., 2016; Van Harten et al., 2020; Wheelock et al., 2015). OR staff will be encouraged to turn music off, have non-essential staff exit, and no extra conversation occurs during critical times in the operation (Broom et al., 2011; Cheriyan et al., 2016). Both The Joint Commission and the Association of Perioperative Registered Nurses recommends the use of the sterile cockpit as a technique to reduce noise in the operating room (Association of Perioperative Registered Nurses, 2020; The Joint Commission, 2017). Studies that have implemented the sterile cockpit have been successful in reducing noise and/or distraction (Behazin et al., 2014; Crockett et al., 2019; Federwisch et al., 2014; Flynn et al., 2016; Fore et al., 2012; Hay et al., 2016; Saxton & Cabill, 2017; Wright, 2016; West et al., 2012). While there was no one indicator that was shown to be most effective, the fact that most of the studies used an indicator supports the idea that an indicator should be used with sterile cockpit implementation. The evidence supports a sterile cockpit may be effective in reducing noise at the current research site.

Theoretical Model

The Distraction-Conflict Theory provides a framework for understanding the concepts and solutions to the problem considered in this project. The Distraction-Conflict Theory was developed in 1974 by Robert Baron in the field of psychology (Baron, 1986). It was developed to explain certain elements of social facilitation research. The researcher himself has refined and analyzed this theory even years after its original conception. There are three main components to his theory. One is that individuals themselves are distracting to others. Another is that distraction can lead to the inability to properly complete tasks but can also elevate drive. The final concept is that multiple distractors can elevate both stress and drive. This theory states that distraction

can improve an individual's drive to complete simple tasks but that such distraction can hinder complex tasks.

This theory relates to the project as it provides a basis for understanding the problem. Staff members contribute to the elevated noise levels present in operating rooms and can be a distraction (Wheelock et al., 2015). This is directly in line with part one of Baron's theory that says individuals are distracting. Furthermore, Baron also asserts that such distractions can hinder complex tasks (Baron, 1986). Anesthesia emergence is considered a complex task and thus susceptible to hinderance from distractors (Casella et al., 2018). Furthermore, there are multiple distractors in the OR, a factor that Baron says can increase stress (Baron, 1986). The Distraction-Conflict Theory supports the notion that distractors such as noise from staff can be a problem and that an intervention addressing individuals in the operating room could help minimize issues during emergence from anesthesia.

Methods

Design

The design of this study was quasi-experimental with the implementation of a sterile cockpit during emergence from general anesthesia. Noise levels in the operating room prior to the sterile cockpit implementation were measured. After implementation of the sterile cockpit intervention, noise levels were measured again to determine if a change occurred.

Translational Framework

This project is a quality improvement project, specifically designed according to the Plan-Do-Study-Act Model. The Plan-Do-Study-Act Model has been utilized many times in healthcare settings for quality improvement purposes (Institute for Healthcare Improvement, n.d.). This model is based on four steps; planning how to test a change within an organization,

implementing the change, analyzing data from the change, and modifying the change based on the results (Institute for Healthcare Improvement, n.d.). The components of this model are cyclical in nature and can be utilized repetitiously as the intervention changes. For instance, if one Plan-Do-Study-Act intervention proves to be somewhat effective but can be improved upon, researchers can identify an improved intervention in the act phase and continue back into the plan phase, determining how to test the new intervention. This cycle can continue until the problem is adequately addressed.

This translational framework was useful in addressing the high noise levels in the operating room. The *Plan* portion of this method was done when planning how to test the change in noise levels in the operating after introducing an intervention. The planning portion included determining who would test noise levels, choosing what types of surgeries, identifying timing pre- and post-intervention, defining emergence, and deciding what specific noise detector to use along with its location in the operating room. The *Do* portion occurred when pre-intervention noise levels were tested, intervention implemented, and post-intervention noise levels were tested. The *Study* step occurred during the statistical analysis phase where noise levels were analyzed to determine if a noise reduction occurred. The *Act* phase was when the findings were considered, and recommendations were made on if and how the intervention needs adjustment. Specific implications and recommendations could then be used to start a new Plan-Do-Study-Act cycle by other researchers or interested parties.

Setting

The project took place in a community-based hospital with 175 beds and 11 operating rooms. Operating services typically involve adults only with various types of operating services including general surgery, urology, gynecology, or orthopedics. This facility was chosen because

anesthesia providers at the site reported complaints regarding the elevated noise levels during anesthesia emergence.

Sample

The sample consisted of 30 general anesthesia cases. General anesthesia, for the purpose of this project, was defined as the use of an endotracheal tube or laryngeal mask airway. Fifteen cases were used to gather pre-intervention noise data, and another 15 were used to gather post-intervention noise levels. Case types included general surgery, urology, gynecology, and orthopedics. At least one of each case type was included in both pre- and post-intervention measurements. The sample was a convenience sample based on the operating room schedule. Surgery duration was not considered in the sampling. Given that no patient information was considered or collected, consent from patients was not needed. Pediatric cases were excluded given that these are not typically done in the setting selected. Non-general anesthesia cases were also excluded because there is not a defined emergence period for these types of anesthetics. The data collector was able to identify which cases on the schedule used general anesthesia by conferring with staff CRNAs prior to the start of the case.

Intervention

The intervention was the implementation of a sterile cockpit. The sterile cockpit dictated that no non-essential work or conversation occur during emergence from general anesthesia. Staff were alerted to the presence of the sterile cockpit by the CRNA verbalizing “emergence.” This signified to the staff in the room that only essential work and discussion should occur during this time. The CRNA used a voice level to ensure all those present could be heard. The CRNA verbalized emergence when it was their opinion that emergence was beginning.

Staff were notified of the sterile cockpit intervention after the pre-intervention data had been collected. The primary investigator discussed the intervention in an anesthesia staff meeting and with a virtual presentation to operating room staff. To ensure all anesthesia staff were aware of the proposed intervention, including those not present at the staff meeting, an email was sent by the anesthesia assistant director to staff about the intervention. The email included a write-up done by the primary investigator (Appendix A). This email write-up was used by the primary investigator in the anesthesia staff meeting to aid in the explanation of the intervention. Anesthesia staff were receptive to the intervention, as excess noise had been an ongoing issue that needed addressing. The virtual presentation to the OR staff included a 30-minute PowerPoint presentation discussing noise, its effects in the OR, and the sterile cockpit intervention. Furthermore, flyers with a brief synopsis of the project were also posted in various offices and breakrooms around the operating room (Appendix B).

Data Collection

Procedures

All data collection was done by the primary investigator. Noise levels in the operating room were collected both before and after the implementation of the sterile cockpit. Average and peak sound levels (dB) were recorded during emergence by a sound level meter. Case type, maximum number of people present during emergence, and length of measurement time were noted by the data collector. Pre- and post-intervention data collection occurred over two separate 2-week periods until target sample was achieved.

For sound levels, the investigator's personal iPhone used the National Institute for Occupational Safety and Health Sound Level Meter application with the latest version at the time of study (EA LAB, 2021). Along with the application, an external microphone was used as

recommended by the application manufacturers. The external microphone was a MicW i437L Omnidirectional Measurement Microphone. The phone was placed within 4-feet of the head of the bed in every case, sitting in the same location on top of the Pyxis machine during every reading. The location was chosen with the expectation that it was close enough to capture noise levels that the anesthesia provider may experience, while not interfering with OR staff functioning. This location allowed the data collector an out of the way place to stand yet accessible to the sound meter.

The primary investigator monitored the surgical board at the OR front desk for final case closing time, signaling emergence was nearing. The PI then entered the operating room and positioned herself and the iPhone in an inconspicuous location without drawing attention. CRNAs at the project site were aware of the project purpose during the pre-intervention data collection phase given that they had reported excess noise and knew a solution was being considered. OR staff were not aware of the project at this phase. If staff questioned the investigator's role, the investigator reported that they were there to monitor patient safety and to proceed as if the investigator was not present.

In pre-intervention data collection, emergence was defined as when oxygen flows were turned up above maintenance levels. The investigator started the noise recorder at this time during the pre-intervention phase. For post-intervention data collection, the investigator turned on the noise level meter when the primary CRNA verbalized "emergence." Anesthesia staff members were told to vocalize "emergence" at the time in which they felt emergence from anesthesia was starting. By allowing the individual CRNA the ability to determine when emergence occurs in their opinion, this is reflective of when they personally may be at most risk

for distraction from excess noise. In both pre- and post-intervention, data collection ended once the patient exited the room.

Informed consent was not needed for data collection. There was no accessing of the electronic medical record, nor were any patient specific characteristics noted during data collection. Data did not reflect date of procedure nor specific staff present. There was no risk for patient harm or privacy concerns as collection notes did not reflect any patient or staff data. Data for analysis was transposed to the computer from paper used during operating room collection. Such data included: case type, case number, and maximum number of staff. Measurement time, and sound levels were collected via the app and were then stored in the app with their case number. This data did not have any identifying information of staff or patient. UNCG IRB determined this QI project was not research.

Instruments

The National Institute for Occupational Safety and Health Sound Level Meter application was used to collect sound levels (EA LABS, 2021). This application is tested and validated by the NIOSH (National Institute for Occupational Safety and Health, 2019). The application, developed by the NIOSH, complies with type 2 requirements of IEC 61672/ANSI S1.4 standard when used with an external microphone (Center for Disease Control and Prevention, January 2019). The app was tested in the NIOSH acoustics lab, which is considered the standard with which to measure such noise levels (Celestina et al., 2018). The application, in conjunction with an external microphone, was found to not only meet type 2 requirements but also has a narrow gap between it and professional sound meters (Celestina et al., 2018; Kardous & Shaw, 2016). Few other applications available are compliant with such standards (Center for Disease Control

and Prevention, January 2019). The application is open access and available for use by anyone without permission. The application measures sound in A, C, or Z-weighted decibels depending on user-selection (National Institute for Occupational Safety and Health, 2019).

Along with the application, an external microphone was used as recommended by the application manufacturers. The external microphone used was a MicW i437L Omnidirectional Measurement Microphone. Multiple studies used a MicW type i436 external microphone when verifying the validity and reliability of this application in conjunction with an external microphone (Celestina et al., 2018; Kardous & Shaw, 2016). Kardous & Shaw (2016) proved this microphone to be adequate in enhancing the sound monitoring of the NIOSH application. For this data collection, the MicW type i437L was chosen because it is an upgraded version to the i436L. Furthermore, the i436L was no longer compatible with later model iPhone’s, like the iPhone 11 used for these measurements. The i436L was purchased by the primary investigator for a cost of \$159.00.

Prior to data collection, noise levels of common occurrences were measured using the application along with the external microphone to determine a baseline for comparison. Common measurements included various points both inside and outside the OR (Table 1). These were compared to reported sound levels (Table 1) from the Center of Disease Control (Center for Disease Control, October 2019).

Table 1
Common Noise Measurements

Source	Sound Level (dB)	
	Project Instrument	Literature Reported
Empty OR Front Desk	43	N/A
Empty Anesthesia Office	43	N/A
Empty OR	54	N/A
Conversation	59	60

Soft whisper	38	30
Washing machine	78	70
Lawnmower	91	85
Shouting	99	110

Note. dB = decibel scale

Data Analysis

The program IBM SPSS Statistics was used for data analysis (IBM Corp., 2019). An independent-samples Mann-Whitney U test was used to compare noise levels during emergence from pre-intervention and interventions groups. A p-value <0.05 was considered statistically significant. Excel (Version 2201) was used to determine correlations between sound levels and maximum number of staff present or measurement length. A two-sample t-test assuming equal variances was done to compare case types and sound levels. A p-value <0.05 was considered statistically significant.

Results

The purpose of the project was to determine if noise was reduced by implementing a sterile cockpit as an intervention. Total sample size was $N=30$. Specific types of cases were comparable both pre- and post-intervention (Table 2). Average emergence times pre-intervention were 11 minutes 15 seconds and were 10 minutes 25 seconds post-intervention. The average maximum number of staff in the room was 6.6 individuals in the pre-intervention phase and 6.7 in the post-intervention phase. The mean of the average sound level in the pre-intervention phase was 63.74 dB and 61.74 dB in the post-intervention phase. The average peak sound level for the pre-intervention phase was 85.12 dB and 83.27 dB in the post-intervention phase.

Average sound levels of the measurement periods were compared prior to and after implementing the sterile cockpit. Average sound levels were significantly lower after implementation of the sterile cockpit (Table 3). Peak sound levels of the measurement periods were compared prior to and after implementing the sterile cockpit. There was no statistically

significant difference in peak sound levels with the implementation of the sterile cockpit (Table 3). There was a weak correlation between noise levels and maximum number of staff present for pre-intervention average sound levels (Table 4). There was no correlation among noise levels and measurement length (Table 4). There was no significant difference in peak or average sound levels after the implementation of the intervention for most case types (Table 5). For general surgery cases, there did seem to be a significant difference in average sound levels after the implementation of the sterile cockpit (Table 5).

Table 2
Case Type Numbers

Case Type	Number of cases	
	Pre-intervention	Post-intervention
Orthopedics	4	3
General Surgery	7	7
Urology	3	4
Gynecology	1	1

Table 3
Summary of Project Findings (N=30)

	Pre-intervention	Post-intervention	Mean Difference (dB)	<i>P</i>
	<i>n</i> = 15	<i>n</i> = 15		
Mean of Average (dB)	63.74	61.74	2	.0065
Mean of Peak (dB)	85.13	83.27	1.86	.1085

Note. dB = decibel scale

Table 4
Correlations

	Correlations			
	Average Sound Level		Peak Sound Level	
	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention
Maximum number of staff	-.423	-.099	.216	.136
Measurement Length	.124	-.228	.231	.019

Table 5*Case type t-test*

Case Type	P-value	
	Average Sound Level	Peak Sound Level
Orthopedics	.10	.09
General	<.01	.22
Urology	.60	.41
Gynecology	N/A*	N/A*

*Sample size of this group too small to perform t-test

Discussion

The purpose of this project was to use a sterile cockpit to reduce noise levels in the operating room during emergence from general anesthesia. Research frequently shows noise levels are high in the operating room and the project site was no exception to this. A sterile cockpit was implemented to determine if recorded noise levels could be reduced with this intervention.

Average dB Outcome

Statistical analysis showed that there was a reduction of 2 dB in average noise levels between pre- and post-intervention, a statistically significant difference. While a roughly 2 dB decrease in noise may not be considered clinically significant when compared to general noise levels, there was also a perceived significant decrease in noise by staff. This was noted by both the PI and from OR and anesthesia staff report. The PI observed that noise was often reduced in the post-intervention phase. Many CRNAs reported to the PI that emergence was much quieter and less distracting with the sterile cockpit in place. Additional OR staff also thought the overall sound was decreased. A prior study of a noise reduction intervention also determined a roughly 2 dB decrease in average noise was statistically significant (Hogan & Harvey, 2015). Considering that this project as well as published works are reporting similar results, the small degree of

quantitative change plus anecdotal staff reports of decreased noise should be considered a positive result.

Another possibility for the discordance between absolute average noise reduction and staff perception of noise reduction may be a limitation in the noise measurement instrument used. The noise measurements in Table 1 compare noise levels measured by the project instrument to published noise levels for common sounds. The project instrument under-recorded some sounds and over-recorded others. This indicates that the instrument may not measure sounds as accurately as other devices. However, given that there is no gold-standard sound level meter, it is hard to know. Furthermore, there could be user error when using the instrument. The distance between the noise recorder to the noise source may also have contributed to the discrepancies between published sound levels for common noises and the levels measured by the project device. If the sound level meter was not positioned to capture all the sound sources in the operating room, this could impact the sound level measures.

The factors discussed bolster the idea that measures of OR staff perception of noise must be considered in addition to absolute sound levels. This is supported by literature reporting the use of the sterile cockpit in healthcare. Many studies measured staff-reported sound decreases as a way to determine sterile cockpit effectiveness (Behazin et al., 2014; Crockett et al., 2019; Federwisch et al., 2014; Flynn et al., 2016; Fore et al., 2012; Hay et al., 2016; Saxton & Cabill, 2017). Measuring both staff perception and sound levels may more accurately capture the effectiveness and impact of the sterile cockpit.

Peak dB Outcome

Statistical analysis showed that peak noise levels were not reduced with the sterile cockpit for this project. Peak dB may not be the outcome measure most appropriate for capturing

the effect of noise on the cognitive efficiency of anesthesia providers. A more appropriate measure may be the number of peaks rather than the highest peak. By counting the number of peaks, this would eliminate the possibility of having a single loud event that skews the sound recording. This measurement approach is supported by the literature; one study measuring noise levels chose to measure average and peak but also added a record of the number events greater than 70 dB (Hogan & Harvey, 2015). Number of peaks may be more beneficial to measure rather than the peak alone.

Staff Numbers and Measurement Lengths

Statistical analysis showed no correlation between maximum number of staff in the OR and noise levels. This suggests that limiting the number of people in the room may not reduce the noise. Engelmann et al. (2013) also found that the number of individuals present did not significantly affect noise levels. This indicates that limiting needed staff in the OR will not be helpful in reducing noise. However, all staff who may be present in the OR should be educated on the sterile cockpit and its importance. The lengths of emergence times also had no correlation with noise levels. This means that lengthier emergences are not necessarily noisier. There is no documented research on emergence lengths and staff numbers to support this finding. Further study needs to be done.

Case Type

Statistical analysis showed that there was no significant difference between case types in sound levels pre- and post-intervention. The exception to this was average sound levels for general surgery cases. This means that overall, no one case type has higher noise levels than another. This is not an unexpected finding as the surgeon is generally not present in the OR during emergence, and thus not affecting noise during this time. There is limited prior research on this, with most studies implementing an intervention in only one specialty.

Limitations

A significant limitation to this project is the small sample size. Extending the period of the pre- and post-intervention data collection would allow for a larger sample size, adding to the significance of the results. Another limitation is that CRNAs were aware of the project and its goals during the pre-intervention phase when noise data was collected. This could have caused CRNAs to consciously or subconsciously be louder or quieter during pre-intervention data collection, thus skewing numbers. Additionally, they may have subconsciously perceived a decrease in noise even if there wasn't one during the post-intervention phase. Furthermore, measuring peak and average sound levels are just two potential outcome measures to determine the effectiveness of the intervention. These measures may not accurately reflect the perception of noise by staff in the OR nor the persistence of loud noise.

Recommendations for Future Study

To consider using this quality improvement initiative at another institution, a few changes may be useful. It may be helpful to more specifically define the emergence time period. This project considered emergence to be from when oxygen flow levels were increased until the patient exited the room. In future projects, it may be helpful to narrow this time period since noise reduction may not be necessary while the patient is exiting the room if the patient is stable and not requiring uninterrupted focus from the CRNA. A more critical phase may be prior to and immediately after extubation. Furthermore, there may need to be a calibration with the instrument used. Investigating more advanced noise level meters with calibration abilities may be beneficial in ensuring noise level measured is calibrated accurately to the environment. In addition, choosing an outcome measure that records perception of noise in addition to a concrete noise level may be more effective in reflecting a decrease in noise from the intervention. A

survey or more descriptive means of measuring perceived noise may provide valuable information.

Relevance and Recommendations for Clinical Practice

The results of this quality improvement suggest that the use of a sterile cockpit may be an effective tool to decrease noise levels in the operating room. This intervention may decrease complications of anesthesia, specifically during emergence at the project site. It may also be effective in operating rooms at other facilities, from hospital-based ORs to freestanding outpatient surgical centers. The promising results reinforce support the continued use of the sterile cockpit in the OR. With its continued use, there could be a correlation with reduced number of patient safety issues and the potential to improve the outcome of patients. These outcomes should be investigated.

Conclusion

The purpose of this project was to reduce noise in the operating room during emergence from general anesthesia. Elevated noise levels can result in distraction for anesthesia providers and have the potential to lead to negative patient consequences. The sterile cockpit was implemented to curb this issue and resulted in a decrease in noise at the project site. This successful intervention could lead to safer care and aid in improving patient outcomes. To ensure the success of this intervention at other institutions, challenges and limitations could be overcome by learning valuable lessons from this project.

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Appendix A

Email Attachment/ In-person script to inform staff of quality improvement project:

Hello all,

As some of you may be aware, there is a need to address the high levels of noise that are occurring during the emergence phase of anesthesia or in other words, the time after the procedure is over and before the patient has left the operating room. Not only have there been staff complaints, research supports the need for a quiet environment when a patient is emerging from anesthesia. The operating room environment is often seen as the noisiest clinical environment. Elevated noise levels can cause distractions for anesthesia providers and other adverse effects. These consequences include miscommunications, ineffective task completion, lack of concentration, and increased stress. These noise related consequences could cause a range of anesthesia related complications, ranging in severity. During emergence, serious complications can occur such as hypertension, oxygenation issues, laryngospasm, tachycardia, and other cardiovascular and respiratory issues. Any distraction producing noise could result in the anesthesia provider struggling to respond to potential complications during this critical time. Multiple interventions have been suggested, the sterile cockpit being one prominent option. The sterile cockpit is an intervention designed by the Federal Aviation Administration in 1981 to curb air carrier accidents, prohibiting crew members from performing non-essential tasks or having conversations during critical times. The sterile cockpit has been used in healthcare to attempt to reduce noise and distraction during critical times. As such, I am proposing a plan to implement a sterile cockpit during emergence from anesthesia. The sterile cockpit dictates that no non-essential work or conversation is to be done during this time. Staff in the OR will be alerted to the presence of the sterile cockpit by the CRNA verbalizing “emergence.” This signifies that only essential work and discussion should occur during this time. The CRNA will use a voice level to ensure all those present can be heard. The CRNA will verbalize emergence when it is their opinion that emergence is occurring. Please refrain from moving equipment or instruments at this time unless necessary to care for that patient. No conversations should be occurring unless essential to care for that patient. Entering and exiting the room should only occur if necessary. The sterile cockpit phase will last until the patient has exited the room. I will be evaluating this new quality improvement initiative over the next two weeks to see if it is effective. Please let me know if you have any questions.

Thank you!

Beth Pulliam CRNA

Appendix B

HEY OR STAFF!

What's the problem?

There is a lot of noise in the OR during emergence from anesthesia. Research says the operating room is often seen as the **noisiest** clinical environment (Cheriyana et al., 2016). Multiple studies show that noise levels are higher during emergence from anesthesia compared to the rest of the case (Broom et al., 2011; Campbell et al., 2012). Here at Wesley Long, sound level measurements were done during emergence from general anesthesia cases. Sound levels were well above the recommended range. Research shows that the most prevalent distractors producing noise are external staff entering the OR, conversation not related to the case, slamming doors/bins, case cart movement, music, and dropped supplies (van Harten et al., 2020).

Why do we care?

High levels of noise can make it difficult for staff to concentrate on the patient and necessary tasks. The most notable adverse effect of excess noise is difficulty with communication amongst staff (Giv et al., 2017). Communication problems are a common cause of adverse events (Keller et al., 2016). Serious complications can occur during emergence such as oxygenation issues, laryngospasm, tachycardia, and other cardiovascular and respiratory issues (Casella et al., 2018). If there is a delay in recognizing or communicating about these issues, this can cause patient harm.

What can we do about it?

The sterile cockpit concept was introduced by the aviation industry to help curb air carrier accidents and is still used today. The sterile cockpit occurs anytime the plane is flying below 10,000 feet and requires crew members to only perform essential activities with no non-essential conversation to occur during the specified time. The sterile cockpit has been implemented as a technique to reduce both noise and distraction in various areas of healthcare, including the OR. Because of this, we are going to implement a sterile cockpit during emergence!

So, what do I do?

When emergence starts, the primary CRNA will verbalize “EMERGENCE” aloud for everyone to hear. The timing of this may vary from case to case because there is no set emergence time. When this is said, this is a signal to everyone in the OR that the sterile cockpit is starting. The sterile cockpit dictates that no non-essential work or conversation is to be done during this time. Only essential work and discussion should occur. At this time, everyone in the OR, should only perform tasks that are necessary for that patient at that time. Only conversations that are pertinent to the patient should occur. The goal is to minimize noise that could be a distraction for OR staff to safely care for the patient! The sterile cockpit will be in effect until the patient exits the room. For staff entering the OR after emergence has started, ie. OCTs, just assume “EMERGENCE” has already been said and the sterile cockpit is in effect.

When do we start this?

FRIDAY OCTOBER 1ST! It will continue for a few weeks.

Any Questions? Contact Beth Pulliam