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Decreasing Post-Operative Ventilator Time in the Cardiovascular Surgical Patient: A Nursing Education Quality Initiative

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Abstract

Extended mechanical ventilation times after open heart surgery can contribute to complications prolonging recovery and length of stay, as well as increasing mortality. Standardized staff education of immediate post-open-heart recovery and ventilator weaning protocols, combined with the use of ABCDE and VAP bundles can reduce these complications. At Hospital X during summer of 2022, the average length of time patients remained mechanically ventilated after open heart surgery increased. After an initial needs survey was distributed to nursing staff, a set of novel QR codes was created to simplify and centralize training for staff in the ICU to facilitate early extubation and mobility, as well as increase adherence to standards of care. As a result, average post operative ventilator times showed a downward trend and staff reported increased confidence in their skills. In addition, QR codes have led to an electronic resource of protocols that could be updated as needed. Use of QR codes can be extended to other areas of education and patient care.

Key words: mechanical ventilation, QR codes, care bundles, standards of care

Introduction

Cardiovascular, or open heart, surgeries are performed throughout the world to correct a variety of heart conditions. These surgeries can include valve repairs and replacements, aortic repairs, and revascularization of the arteries supplying the heart muscle through coronary artery bypass grafting. There are many integral parts to cardiovascular surgery before, during, and after. Hospitals who perform these surgeries must employ a team approach to the care of patients to have the best outcomes. Cardiovascular or open-heart surgery can be a planned elective procedure or done under more urgent scenarios of acute illness. In all cases of open-heart surgery, regardless of urgency, the multidisciplinary team works to optimize the condition of the patient prior to surgery to ensure fewer complications. This can include consultation from physical therapy, respiratory therapy, and anesthesia before surgery, and a continued team approach perioperatively and postoperatively. However, this does not eliminate all risk of complications from the process.

The risk of complications after cardiovascular surgery falls in to two categories, preventable and non-preventable. Pulmonary complications are among the most difficult and can include atelectasis, pneumonia, pulmonary embolus, and acute respiratory distress system (Mali and Haghaninejad, 2019). Some of these can be minimized or prevented using a multidisciplinary approach to mechanical ventilation and early weaning protocols. In addition, nurses who care for these patients require consistent, standardized training to continuously improve the quality of care. This paper will aim to improve adherence to the standard of care for this patient population with the novel use of quick response (QR) codes in the clinical setting.

Statement of the problem:

Each year over two million patients undergo open heart surgery all over the world, according to the National Institutes of Health (2022). In the United States more than 500, 000 open heart surgeries are performed each year. Not all hospitals are large enough or have the need to be classified as a comprehensive cardiac facility. In the state where Hospital X is located there are twenty-six hospitals, only four of which perform open heart surgery. Hospital X performs an average of 300 cardiovascular surgeries yearly. A priority goal in the immediate post-operative period is to extubate the patient safely in a timely manner. Ideally, a patient should be extubated within 24 hours of surgery, however, the Society of Thoracic Surgeons have set a benchmark of six hours in patients without underlying conditions that may impede that goal (Goeddel et al, 2018). While there is no current guideline for the actual timeframe in which a patient should be extubated, the Society of Thoracic Surgeons guideline of six hours is the industry standard. On average, the length of time a patient remains mechanically ventilated after surgery is between six and eight hours, usually closer to six hours.

However, in quarters 2 and 3 the average ventilation times for patients who meet the 24 hour benchmark at Hospital X have been slowly trending upwards overall, from an average of six hours to just over seven hours. In May 2022 the average time was 8.58 hours, in June 6.87 hours, in July 8.76 hours, and in August 7.29 hours. Patients undergoing cardiothoracic surgery who remain mechanically ventilated for extended periods of time postoperatively are at higher risk of developing complications, experience an increased length of stay in both the Intensive Care Unit and overall hospital stay, and have increased associated costs. Kotfis et al, (2018) found that patients who were extubated in under twelve hours had fewer complications and shorter lengths of stay than those that remained intubated more than twelve hours after surgery.

Removing a patient from mechanical ventilation after surgery is a multidisciplinary, multifactorial process. It begins pre-operatively with patient optimization, continues through surgery, and ends in the post-operative phase in ICU. Postoperatively, the time to extubation starts with "end anesthesia" time and the clock starts ticking. "End anesthesia" is the time that the anesthesia provider considers the peri-operative anesthesia care complete, and the patient is transferred to the intensive care unit. If a patient requires reintubation, their total amount of time spent on mechanical ventilation is counted. This can add minutes, hours, and days to their time. Based on recommendations by the Society of Thoracic Surgeons, past efforts, both nationally and at Hospital X, to decrease ventilator times have included changes to anesthesia medications, such as using dexmedetomidine in place of propofol, and utilizing lower doses of sedatives just prior to transfer to intensive care. Other efforts at Hospital X have included using more standardized ventilator settings and coordinating care between nursing staff and respiratory staff to remove patients from the ventilator earlier.

Staff turnover has contributed to the increased need for a more standardized approach to training nurses to care for these patients. In recent years, nurses have left the bedside for various reasons including job and career changes, as well as life events. Not all intensive care unit nurses care for patients in the immediate post operative period, so the training is highly specialized, and a lack of knowledge persists as training continues to fill the vacancies at the bedside.

Current knowledge:

The risk of complications for patients who require mechanical ventilation is not only significant but increases the longer a patient remains on mechanical ventilation. For decades clinicians have known about the possible adverse effects of prolonged mechanical ventilation, which can include decreased cardiac output, respiratory alkalosis, renal and hepatic complications, intracranial pressure changes, and infectious processes, including ventilator associated pneumonia (Pierson, 1990). While this is an older reference, it shows the medical field has long known that early extubation is crucial to the care of patients and the prevention of complications.

A meta-analysis in 2014 by He, et al, showed the incidence of ventilator associated pneumonia among open heart patients ranged from 6.4-35.2% of patients. This higher number correlated with longer lengths of mechanical ventilation, including those over 48 hours. The overall rate was occurrences of 21.27 episodes/1000 days of mechanical ventilation (2014). Ventilator associated pneumonia rates can be reduced with the use of care bundles, which include consistent mouth care, raising the bed to 30 degrees, spontaneous awake trials or sedation vacation and assessing the readiness to wean by means of spontaneous breathing trials.

Spontaneous awake trials and spontaneous breathing trials should occur within a short timeframe of each other to promote early extubation. These guidelines were introduced in 2016 (Hellyer, Ewan, Wilson, and Simpson) by the Intensive Care Society to give guidance to providers and staff. They are considered standard practice in intensive care unit settings. However, with short staffing and newer nurses learning how to care for critically ill patients and post-open-heart patients, keeping up with these standards becomes more difficult. Nurses who are new to caring for this patient population have critical care knowledge but caring for a patient immediately after open heart surgery requires another level of knowledge.

In a small comparative study by Reis, et al (2002) patients who were extubated within 30 minutes of ICU arrival versus within eight hours of arrival showed no increase in rate of complications. In addition, the mortality and morbidity of the two groups were relatively the same. The two groups were very similar in demographics, history, and surgical scenario, as well as preoperative medications. In both groups the criteria for extubation were achieved including normothermia, hemostasis, hemodynamic stability, and adequate respiratory function. One difference that was noted was the use of isoflurane as an anesthetic during the procedure, where all other factors were similar (2002). Romancito et al (2016) reiterated this conclusion with patients undergoing elective surgery of the aorta. In addition, they showed that patients who are extubated earlier, especially those extubated in the operating room, have a shorter length of stay and fewer complications than those with longer extubation times.

There are multiple modalities that can improve outcomes for patients in this population, all of which require a team approach from nursing and ancillary staff. Open heart patients present unique scenarios and complications but are in some ways similar to general surgery patients. Some aspects of the plan of care for general surgical patients also apply to open heart patients including early mobility, enhanced recovery after surgery, ABCDEF bundles, and over all staff training.

Early mobility after surgery is a concept of getting patients up and moving sooner rather than later in the post operative period. Gone are the days where patients unnecessarily remain in bed following general surgery. Early mobility can reduce length of stay in both the ICU and the hospital. It is a component of the ABCDEF bundle utilized in critical care settings to "optimize intensive care unit patient recovery and outcomes" (Marra et al, 2017). In Marra's article, the components of the bundle are described and the author details how intensive care units can use the bundle to create a multidisciplinary approach to managing the care and progression of critically ill patients. Bundle elements include addressing pain, spontaneous awake and breathing trials (a key component of this quality project), analgesia and sedation, delirium, early mobility, and family involvement. Analgesia and sedation are factors associated with length of mechanical ventilation and will be included in an aspect of intervention.

Enhanced recovery after surgery is a collection of patient-centered pathways to reduce complications after any surgery. The American Association of Nurse Anesthesiology standardized some of the same concepts into their model, Enhanced Recovery After Surgery (ERAS). The pathways of ERAS start in the preoperative period and continue through the post discharge phase. In the post operative phase recommendations include early mobility, management of pain with multimodal analgesia, and family and patient involvement (Coleman et al, 2019). As part of their approach, a multidisciplinary concept is used; composed of patient, staff, and facility. Ongoing staff education and support is a key factor in the success of both ERAS and ABCDEF protocols.

A systematic review conducted by Santos et al (2017) analyzed nine randomized control trials (RCTs) and came to multiple conclusions. The first was that early mobilization, regardless of method, was beneficial over no mobilization at all. They also concluded that there is no set definition of what early mobilization entails or what specific protocol to follow. Due to the inconsistency in mobilization definition, studies in the analysis compared a wide range of interventions including pulmonary therapy techniques and time frames, frequency of mobilization and onset of therapy after surgery, and amount of pre-operative education. The outcomes analyzed included length of hospital stay, length of stay in the wards after ICU discharge, distance during a six-minute walking test, quality of life, and post operative functional level, among others (2017).

In general, cardiovascular surgical patients are also similar to general surgical patients in regard to optimization of respiratory status and are screened by respiratory prior to surgery, except in very emergent cases. Patients who have elective open-heart surgery often have little indication they will require prolonged intubation times. Patients who do start physical therapy early tend to be patients who may continue to be ventilated more than the benchmark of less than 24 hours set forth by the Society of Thoracic Surgeons (2022). By reducing sedation and extubating open-heart patients earlier, they can be mobilized earlier.

Barriers to these interventions and processes often are related to staff education, turnover, and short staffing. While general surgical and cardiovascular surgical patients do have similarities, these interventions can be adapted and specialized to the cardiovascular population. This can create a knowledge gap for the newer nurses and ancillary staff in the absence of consistent and standardized training. Gallo (2012) states:

> "With patient safety and evidence-based practice at the core of continuing education, new knowledge will continue to require staff development. In today's clinical setting, traditional classroom instruction will need to continue alongside innovative technological approaches to accommodate the learning needs of the multigenerational nurse workforce."

Rationale:

With multiple factors involved in removing patients from mechanical ventilation, this project focused on nursing care and education. The Adult Learning Theory was used as the basis for initiating this project. According to Donna Wright (2005) adult learning principles 1) articulate why the learner needs to know the skill, 2) build on the learner's previous experience, 3) provide a variety of learning methods and 4) use self-directed learning option when possible. The clinical coordinator and the nursing educator in the ICU at Hospital X have been focusing on principles one and two in their overall streamlining of the nursing process used by the staff in the ICU. Nurses are only trained to care for this population of patients if they have already completed competencies as an ICU nurse.

Nurses spend a significant amount of time at the bedside and are often considered the coordinators of care with ancillary services. In recent years the number of nurses at Hospital X who are trained to care for immediate post op heart patients has decreased due to staff turnover, management turnover, retirement, and vacated positions. In addition, new graduate nurses are often not trained until they have had a few years of ICU nursing experience. Of the current nurses at Hospital X who are trained to care for patients in the immediate post operative period half have been trained in that role for less than one year.

A survey of these nurses was distributed through a team email by the ICU manager, clinical coordinator, and educator. The results of that survey noted that quick references for key aspects of patient care would be beneficial and not interfere with either workflow or patient care (Appendix A). Most of the nurses who are trained to care for the post open heart patients at Hospital X belong to generations where technology has been at the forefront of their patient care. By utilizing a simple form of technology, known as a quick response (or QR) code, nurses weree able to access information quickly with up-to-date information, without having to flip through a manual or packet.

Quick response codes were originally created in 1994 as a way for the Toyota company to track parts during manufacturing and production (Karia, 2019). However, these codes can be used to hold and distribute information in any industry. Karia analyzed how the use of QR codes could be used in nursing education. Nurses will have less time taken away from patient care if resources are readily available. A recent study by Kahn, Rosenthal, Ternes, Sing, and Sachdev

(2022) found that intensive care nurses spend an average of 17.5% of their shift documenting in the electronic health record.

In order to not take focus away from patient care and required documentation, selecting an intervention that does not add to the time on the computer is crucial. Other industries have used QR codes to increase the efficiency of workers. This can translate to nursing at the bedside, as well. QR codes can be either static, where information is linked, but cannot be changed once linked, or dynamic. Dynamic QR codes allow the designer to change the information linked to the code without changing the graphic. Dynamic QR codes were chosen for this project due to the constant change and improvement in healthcare. These QR codes can be posted once and remain in convenient locations, but the information linked to them can be updated at any time, as policies and procedures change.

Specific aims:

The specific aim of this project was to implement a quick reference educational QR code tool for nursing staff and ancillary staff who care for post open-heart patients. This tool is intended to assist new and experienced nurses with evidence-based care to help reduce the length of time patients are mechanically ventilated after surgery and reduce reintubation after extubation. It will also help newer nurses become more competent and confident in the care they provide patients in this population. Over the course of three months, from December 1, 2022 to February 28, 2023, the aim was for the average time patients remain on mechanical ventilation following open heart surgery to be reduced to less than six hours and to improve the adherence to standards of care by both nursing and ancillary staff.

Methods

Context:

This study was conducted in a nineteen-bed intensive care unit in a medium-sized community hospital in southern New Hampshire. The intensive care unit staff consists of 40 nurses, six of whom are trained to care for open heart patients in the immediate post operative period. There are three cardiovascular surgeons, four cardiovascular anesthesiologists, three perfusionists, and three intensivists, as well as six intensivist advanced practice professionals (APPs). In the ICU the intensivists and APPs manage the ventilators with respiratory therapists.

Patients range in age from early forties to eighties and have various preoperative comorbidities. Limitations of this study include these co-morbidities, patient reactions to medications given in the operating room, individual practices of the anesthesia providers administering medications in the OR and staffing issues. In addition, other limiting factors include a short time frame of data collection due to project timeline, current knowledge of staff, and involvement of staff. There are a few staff members who are training the newer staff that are experts at caring for this patient population. They may not feel the need to access the QR codes. Many of these variables and limitations are individual to each patient and case.

Interventions:

Interventions for this quality project included the implementation of a QR based information system. Utilizing QR codes that can be accessed from personal smart phones and hospital issued VoiP iMobiles, nurses and ancillary staff were able to access quick reference information, independent of the hospital's electronic health record. Information available included 1) the American Association of Critical-Care Nurses hemodynamics management quick reference card, (Appendix B) 2) medication and hemodynamics information specific to open heart patients, 3) standardized plan for patient care in the post operative period, and 4) links to hospital specific educational materials for care of open-heart patients. QR codes were laminated and placed in convenient locations in all intensive care unit rooms, paper copies placed in the orientation packet for nurses training to care for open heart patients, and in common areas for other staff to access. In addition, copies were made available to ancillary staff, including respiratory therapy, via their manager.

Staff were provided education on the information contained in the QR code links, how to access the information, and when it would be available through multiple modalities, including in person meetings, group staff meetings and the staff's group text message. QR codes were intended to be easily accessible and not interfere with the workflow of staff but enhance it. The intent is that the QR codes will be mainly used in the first twenty-four hours after surgery, more so in the first six, when staff are most active in trying to extubate the patients.

Study of the interventions:

After three months of use of the intervention, nursing staff who care for open heart patients were surveyed again using a voluntary survey, regarding the impact of the intervention and how it affected the length of time patients remain on mechanical ventilation (Appendix C). This survey was online with a link sent through a group email from the manager. In addition, data collected by the hospital based on Society of Thoracic Surgeons benchmarks for mechanical ventilation times was analyzed and correlated with survey results. Data collected included length of time on mechanical ventilation for two groups of patients: average length of time for all patients and those extubated within 24 hours, and nurses' perception of the intervention. Utilizing a Plan-Do-Study-Act method, this author continually reassessed the needs of the staff regarding how they were doing with the intervention throughout the three months of data collection.

Measures:

Pre- intervention mechanical ventilation times were recorded from May 2022 to November 2022 and compared with post-intervention times recorded during phase 3 from December 2022 through February 2023. This information was collected from a database used to voluntarily report times to the Society of Thoracic Surgeons. The database information is collected from chart review in the electronic health record and in person tracking by the Cardiovascular Services Coordinator.

A needs assessment was conducted during phase one via an electronic survey sent to nursing staff (Appendix A). Management and education process needs were also assessed through meetings with the project leader and in person observation in the ICU by the project leader. Staff requested specific information they felt would be helpful. A second post -intervention online survey was sent to nursing staff regarding the usefulness and ease of access of the QR codes, and how the QR codes affected their workflow, confidence in caring for this patient population, and adherence to the standards of care.

QR code data was collected by the project leader from the platform used to create the QR codes, QRcodechimp.com. Data points included how many times each QR was accessed and at what time of day for each of the three months of data collection. All data points were used to determine if there was increased adherence to the standard of care for patients of this population.

Analysis:

Statistical analysis was used to analyze quantitative data for this initiative. Inferential statistics were used to analyze data on an ongoing basis until the completion of data collection. Descriptive narratives from nursing surveys were analyzed for common themes and summarized. Average ventilation times at time of intervention implementation was compared to average ventilation times three months post-implementation.

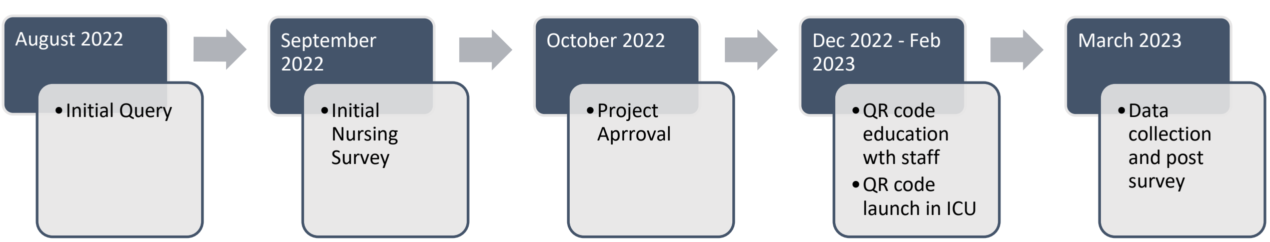
Ethical considerations:

Because the focus of this project is the educational activities of nursing staff, patients were only indirectly involved. As a result, an initial IRB application was filled out with the facility and IRB review was deemed unnecessary. However, patient specific data was collected and analyzed, therefore confidentiality was always maintained. All patients in the population were included in the study, though informed consent was not required. The patient population was at no risk for harm in this study.

Results

The process for this project can be broken down into multiple phases. The initial query was started in August 2022 and the final stage started in March 2023. The timeline can be found in diagram 1.

Diagram 1



Phase One

Baseline data was collected from the cardiovascular coordinator, including average ventilation times for all patients, and for those who met the 24-hour benchmark for the months of May 2022 through November 2022. During the initial survey (Appendix A) nurses were asked about their background in nursing, how long they had been caring for open heart patients, and what skills they felt were their strengths and weaknesses. In addition, management and educators for the ICU and respiratory therapy were asked about how their staff obtain and maintain competency to care for open heart patients. The project leader spent time in the ICU observing and speaking with ICU staff as patients arrived from the OR to determine the flow of care and areas for improvement. This information was used to create QR codes, which contained specific information needed to care for open heart patients, including policies and procedures to wean patients from mechanical ventilation, as well as reference materials. Reference material included cheat sheets on hemodynamics and phases one and two of immediate postoperative recovery.

Phase Two

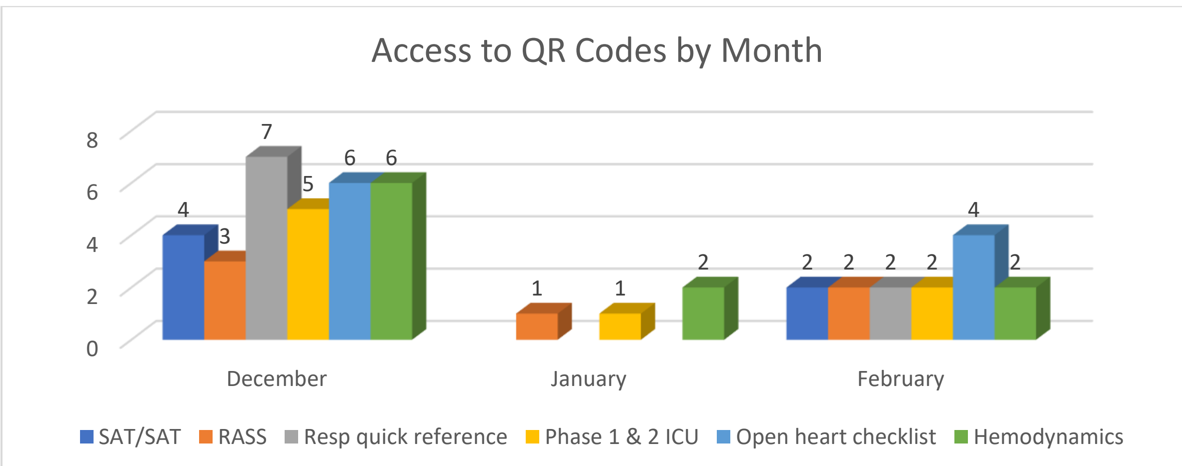
Once the QR codes were created and the information was approved by the managers and educators, the QR codes were placed in ICU rooms with open heart patients, common areas around the ICU, and included in the ICU open heart orientation packet for new open-heart nurses. The project leader rounded in the ICU during times when open heart patients would be transferring from the OR and talked to nurses who were caring for these patients or training with a preceptor.

Phase Three

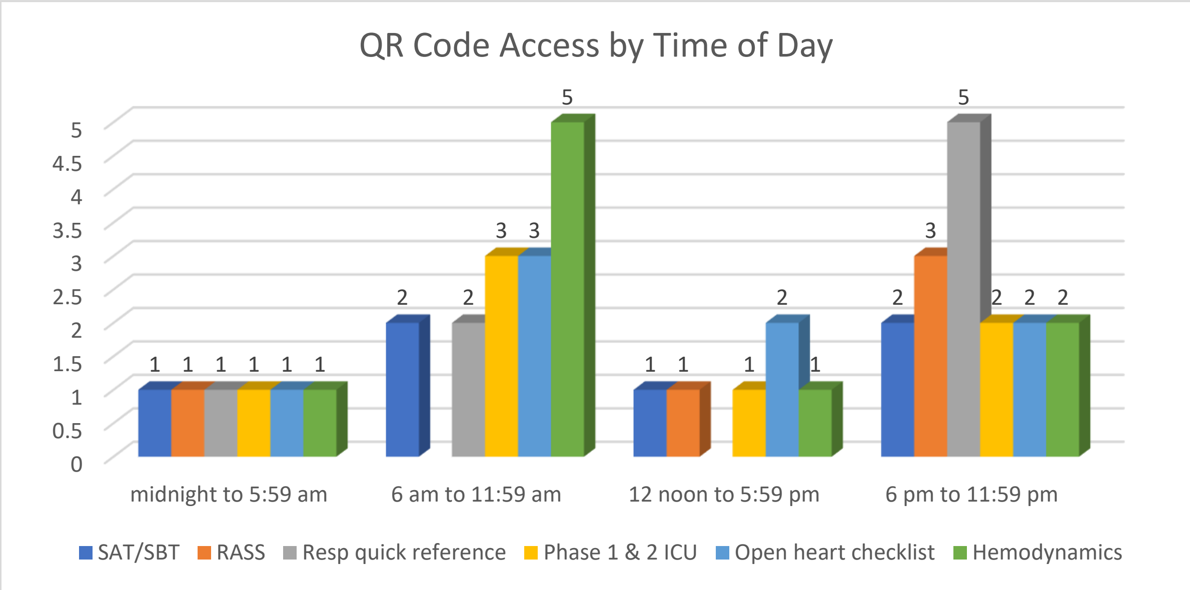
Three sets of data were collected over a three-month period from December 1, 20022 to February 28, 2023: QR code access, average length of time to extubation, and post-intervention survey for nursing staff.

QR codes were accessed a total of 49 times; in December there were 31 accesses (63%), January there were four (8%), and 14 in February (29%), graph 1. In addition, QR codes were tracked by the time of day they were accessed, graph 2.

Graph 1



Graph 2



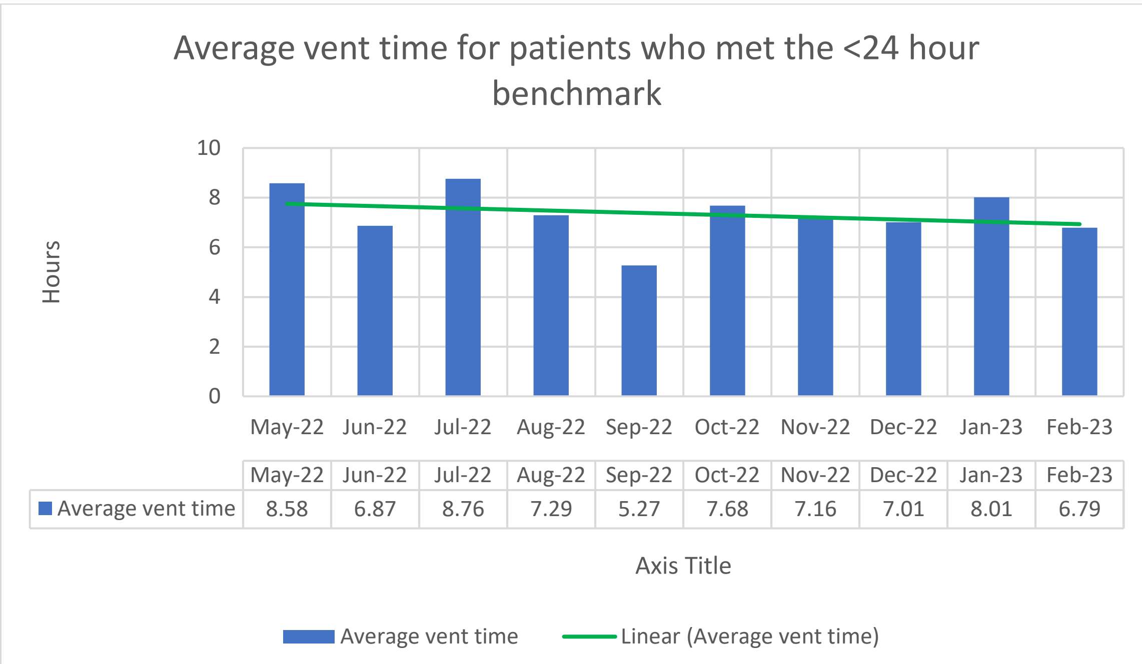
Each QR code was accessed a different total number of times as shown in table 1. The QR codes that were accessed most often were the Open-Heart Checklist and Hemodynamics. The information linked to these two codes is also the most complex information of the six.

Table 1

	Number	(%)
ABCDE-SAT-SBT	6	12.24
RASS	6	12.24
Respiratory quick reference	9	18.36
Phase 1 & 2 ICU	8	16.32
Open Heart Checklist	10	20.42
Hemodynamics	10	20.42

During the three months of data collection there were a total of 66 open heart surgeries performed: 20 in December 2022, 22 in January 2023, and 24 in February 2023. Hospital X tracks the average ventilation time for two categories, those extubated in <24 hours, and the average for all patients (Graph 3). The blue line denotes the actual average, whereas the green line shows a downward trend in the average time. These results are voluntarily reported to the Society of Thoracic Surgeons in monthly increments. During the months of January and February there were multiple patients who remained intubated outside of the 24 hours benchmark, which greatly increased the average for total patients.

Graph 3



Finally, a post-intervention survey was distributed to the nursing staff through their clinical coordinator and manager. The survey was an eight-question survey consisting of multiple choice and ranked answers regarding their use of the QR codes, the content of the QR codes, and the ease of use. This survey was created using Qualtrics, an online platform for survey creation and analysis, for ease of use and distribution. Nurses could access the survey from their computer or smartphone and was intended to take only a few minutes to complete. Unfortunately, only one nurse responded to the survey. Results are as follows:

How long have you been an RN?	2-5 years

How long have you been caring for open heart patients?	1-5 years
How easy were the QR codes to use?	Very easy
How useful was the content of the QR codes?	Very useful
How often did you utilize or access the QR codes?	Once per shift
Did using the QR codes add too many steps to your workflow?	No
Did using the QR codes give you more confidence in caring for open heart patients?	Yes
How relevant was the content to caring for open heart patients?	Very relevant

Contextual Elements:

During multiple phases of this project organizational changes occurred which altered the project team and access to information needed to collect data. The clinical analyst who collected and organized data for STS left the organization and the position remained unfilled until the later parts of phase three. General staffing in the ICU and APPs for the cardiovascular surgical team changed. While this did not alter the general nursing care of the patients, changes in providers and adding a teaching element for new providers can change the dynamic of the process for patient care.

In addition, the organization launched an updated version of the electronic health record in January. The roll-out occurred while the EHR was continuously being built and adjusted, adding a new learning curve for staff and increasing the time it took for general care of patients. Staff were focused on learning the new system versus utilizing a new form of staff education.

Staffing during this time also continued to be a factor. During times and shifts where there were fewer nurses available, nurses with the most experience were caring for patients undergoing open heart surgery. These nurses are not likely to use the QR codes, as the information contained on them is well known to them. In addition, QR codes were placed in common areas and patient rooms, where access was available to anyone with a smartphone. This may have skewed the number of times the codes were accessed, as their availability was not regulated.

Discussion

This project had two main goals 1) to increase the adherence to standards of care by the nursing and ancillary staff and 2) reduce the length of time patients remained on mechanical ventilation after open heart surgery. Despite a few patients remaining on mechanical ventilation for longer than 24 hours, there is a slight downward trend in the total average after the QR codes were launched in December. December had a decrease in total average ventilation time from November. During this time QR codes were accessed a total of 31 times, which was the highest access amount in the three months data was recorded. During January there was an increase in ventilation times again, which may be correlated to a decrease in the number of times the QR codes were accessed, a total of four times. This represents the month with the least amount of QR codes accesses. The increase in ventilator times during the month of January could also be attributed to the roll out of the new EHR at Hospital X. While the new EHR was a newer version of the previously used EHR, its setup and functionality were different. Learning how to navigate the new system, document, verify orders, and look up results slowed workflow for a period as staff adjusted to the change. February had the shortest average ventilator times since the introduction of the QR codes, and had one of the lowest averages since July of 2022. In addition, there was an increase in the number of times the QR codes were accessed in February, a total of 14, which is more than three times the number of accesses in January. In general, the number of QR code accesses is inversely proportional to the average length of time of post-operative ventilation.

Although only one nurse responded to the post-intervention survey, they did feel more confident in their care of this patient population. They reported that the QR codes were easy to use and had relevant information. In the months where the QR codes were accessed the most the average time patients remained ventilated was lower. This could correlate to an increase in the adherence to the standard of care. The timing of access to the QR codes and which QR codes were accessed most often may have contributed to the increase in confidence and adherence to standards. Codes were accessed more often during times nursing and ancillary staff would be researching the patient coming from the OR and preparing to initiate the early extubation procedures. Patients who were operated on early in the morning typically arrived in the ICU in the early afternoon and staff would be preparing before noon. A case that followed an early morning case would be arriving in the ICU in the evening, after 1900 shift change. Orientation of new staff to care for this population is usually conducted during the day shift, which correlated with the times that the QR codes were accessed.

The three most popular QR codes contained the more complex information of the six QR codes. Increased access of these codes likely contributed to the increased adherence to the standards. Both the hemodynamics QR code (which is pertinent to other patients not undergoing open heart surgery) and the open-heart checklist were the most often accessed. These are two key elements that newer staff would benefit the most from.

One of the key strengths of this project is the novel use of the QR codes and the ability to alter and update the information attached to the codes in the future. It served as an effective way to standardize information in a quick format that can be used in different areas of healthcare. This concept can be used on other floors outside of the ICU to help orient new staff to the standard of care, in addition to other forms of education. QR codes can also be used outside of education to simply disseminate key information to staff. During the timeframe of the project management and educators in the ICU were looking for a way to standardize the education model and training for nurses caring for patients in the immediate post operative period. This project has served as a framework for them and helped determine where the strengths and weaknesses of their staff lie.

The unintended difficulties of this project included more of a soft rollout than a definitive start date. Posting material in patient rooms proved to be a challenge as most rooms in the ICU are not designated for open heart patients and were occupied at the start date by patients who were not cardiovascular surgical patients. Materials were posted in a more staggered fashion, so as to not interfere with patient care for non-open-heart patients. Anecdotally, staff who do not care for open heart patients expressed curiosity and excitement that additional QR codes could be added with information useful to all ICU staff, not just the select group.

Interpretation:

Data collected during phases two and three did show some correlation between the use of the QR codes and both the length of intubation time and staff confidence. However, the length of time a patient remains ventilated can be multifactorial, and sometime caused by non-preventable factors. Staff education continues to be a factor in reducing the length of ventilation time. In a similar study by Parisi, et al (2016) staff were given pamphlets and continuing education on VAP protocols to reduce the length of time of ventilation and the rate of infection. As a result of consistent education, VAP occurrences were reduced from 21.6 to 11.6 events per 1000 days of ventilation and length of ventilation was reduced from 26 to 21 days. In addition, the length of ICU stay was reduced from 36 to 27 days (2016). While these studies were not identical, both showed a reduction in ventilation times when a consistent, standard education component was used as an intervention. Impact on the system was minimal, though this may have had more to do with the timing of the project and timeframe. The nurse who responded to the post intervention survey reported positively on its usefulness, which may lead to future extension and continued use of the intervention.

Limitations:

Staffing was a limiting factor in this study, as was the short timeframe of the intervention period. Utilizing this technology in a larger ICU as part of a formal training program could contribute to a more successful outcome. Only a small percentage of the staff in the ICU are trained to care for this population of patients. Those who have been trained for several years would have a limited need for information in the QR codes. In a larger ICU where there is a larger pool of staff being oriented, this project might be more beneficial. A large teaching hospital with a dedicated cardiovascular ICU, versus the mixed ICU where this project was located, would be an ideal location for a project of this nature. Over time, the use of these QR codes may become habit versus novel, if it were to be initiated during the orientation process.

The location of the QR codes in the ICU and the ability to access them by anyone potentially skewed the results. The website used to create the QR codes allows the creator to track type of device, geographical location, and time, but is limited to this data. Only staff who care for this population of patients were given specific information regarding the purpose of the codes to mitigate potentially unintended use, however, some of the QR codes contained information that was useful to all nurses in the ICU. By having the QR codes posted in a public location, the staff can easily access them for real time information, but it does allow for others to do the same, as well.

During phase two Hospital X integrated an updated version of their EHR system. As a result, QR codes were accessed less often as the priority for staff was to familiarize themselves with the new system. Both this new EHR integration and the timeframe of this project did limit the ability to perform any additional formal PDSA. Continuous check-ins with staff, educators, and management did occur, though on a more informal basis. This was also due to a change in role of the project leader within the hospital.

Conclusion

Use of a novel QR code system to standardize information and training for staff caring for open heart patients in the immediate post-operative period may have contributed to a reduction in mechanical ventilation time and increased adherence to standard of care in the ICU. During the three months of phase two data collection there was a direct correlation to the length of post-operative intubation times and the number of times the QR codes were accessed. Continued use may further both aspects and be utilized for other training systems throughout the hospital. Hospital staff who used the QR codes reported an increase in confidence in caring for this patient population. This system of QR codes can be modified or adapted to other specialties in nursing and other nursing floors. The use of dynamic codes allows for the education and management staff to individualize the information to each floor’s specific needs, as well as allow for updated as changes in practice occur. Standards of care for orthopedic patients differ from that of oncology patients, but each floor could determine what information to link to codes for their staff. Staff would be able to access the codes when needed and not rely on handouts that risk being lost or quickly out of date.

Little research has been conducted on how QR codes can be utilized in bedside nursing. In the future, this project could serve as a springboard for use in other areas and continue to be used in the orientation program for this ICU. However, there is room for expansion in the research of this topic.

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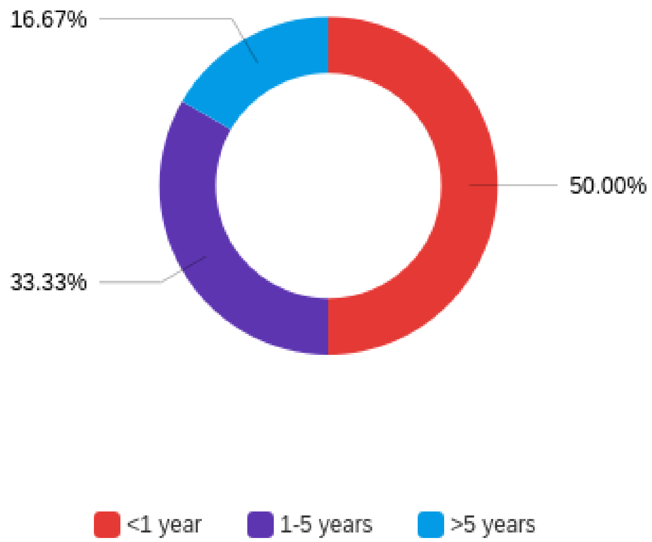
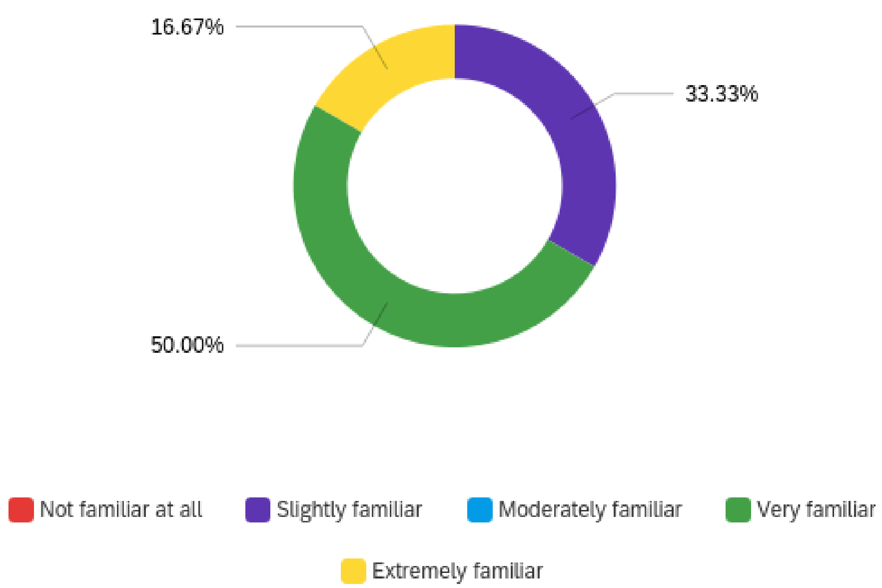
Appendix A:

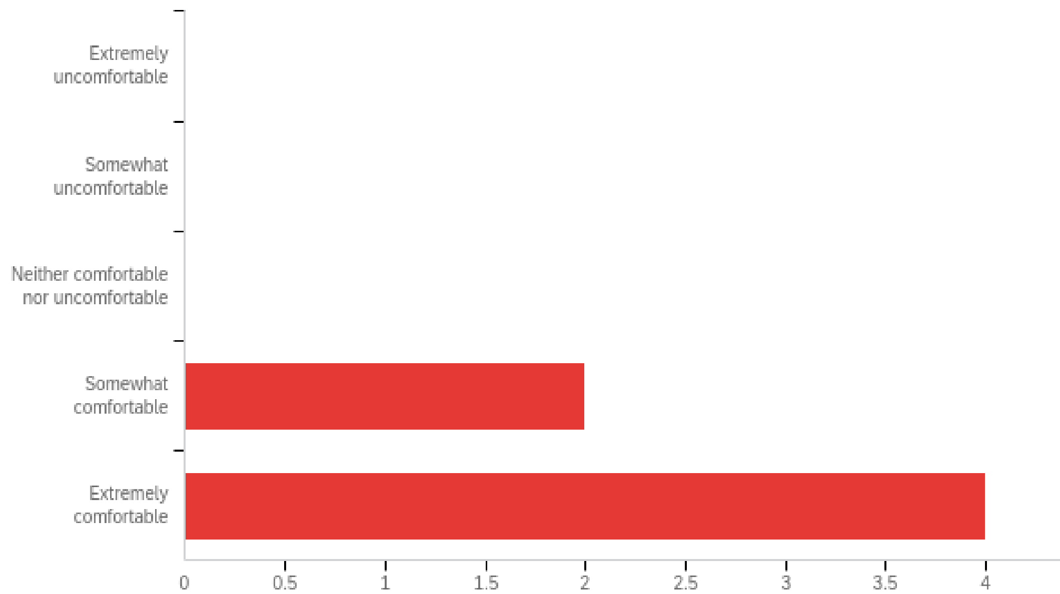
Q1 - How long have you been caring for open heart patients?



Q2 - How familiar are you with the current guidelines/goals for post-op vent times?



Q3 - How comfortable are you at assessing RASS for your patients.



Q4 - What do you feel we are doing well at for post-open heart care?

What do you feel we are doing well at for post-open heart care?
Early mobilization
Fast track times for extubation
Critical care communication
1:1 nursing care, identifying changes early
We have consistent post op flow
vent weaning protocol

Q5 - What do you feel we could improve on?

What do you feel we could improve on?
Prescreen for ETOH
Pharmacy verifying orders for meds we don't even have available. Example: knowing that we don't have albumin 250ml bottles in Pyxis, but still verifying the order so we're forced to override smaller bottles and take time to get the order changed.
Following industry standard vent/respiratory procedures. Having care/meds be less provider dependent

Ambulating care (need thoracic walkers and tele boxes to walk patients in hallways PO Day 0-1
Pre-op education on what to expect. I have had multiple patients wake up and not know that their leg was going to be operated on.
inotrope weaning protocol

Q6 - What do you feel we are doing well at in terms of prompt extubation?

What do you feel we are doing well at in terms of prompt extubation?
Communication with RT
Communication with respiratory therapy
Constructive involvement of critical care
Early sedation shut off
Nursing rarely gives narcotics or heavy sedatives post op
precedex instead of prop for a faster wake up

Q7 - What do you feel are some of the barriers to extubation?

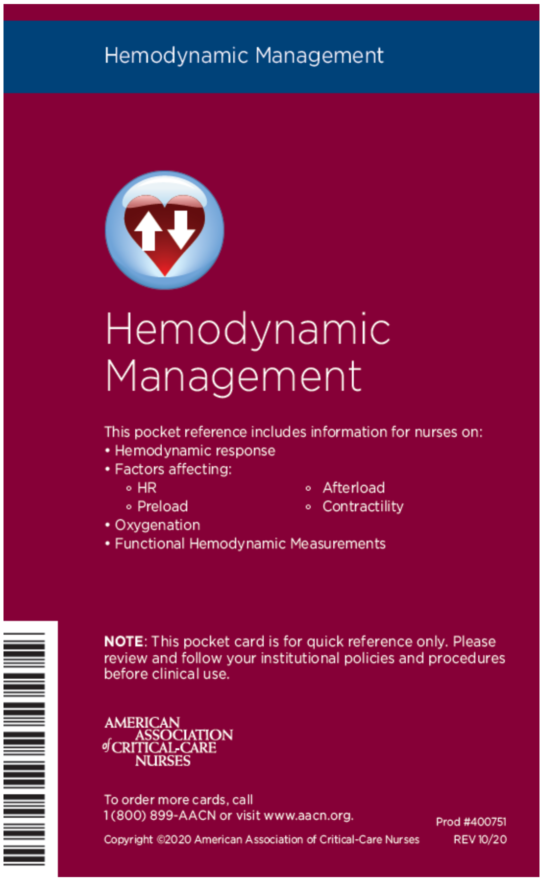
What do you feel are some of the barriers to extubation?
Pt own comorbidities
Hemodynamic instability related to extremely dry patients post op. Requiring heavy fluid resuscitation.
Patients preexisting medical problems.
Sedation out of OR inhibiting fast track extubation, no clear anesthesia report at bedside after case regarding recent sedation/paralytics
Patients come out heavily under such heavy anesthesia from the CVOR
RT delays at getting ABGs

Q8 - What would you like to see for education/quick reference for open heart care?

What would you like to see for education/quick reference for open heart care?
One of the other nurses gave me a very helpful two pager when I started
Quick med & hemodynamics reference

Standardized goals that are not provider dependent
The AACN cardiac surgery/hemodynamic reference card helpful to have on hand for other nurses
Info on new surgical procedures/approaches

Appendix B:


Hemodynamic Management
Hemodynamic Management
This pocket reference includes information for nurses on:
• Hemodynamic response
• Factors affecting:
◦ HR
◦ Preload
◦ Afterload
◦ Contractility
• Oxygenation
• Functional Hemodynamic Measurements
NOTE: This pocket card is for quick reference only. Please review and follow your institutional policies and procedures before clinical use.
AMERICAN ASSOCIATION of CRITICAL-CARE NURSES
To order more cards, call 1 (800) 899-AACN or visit www.aacn.org.
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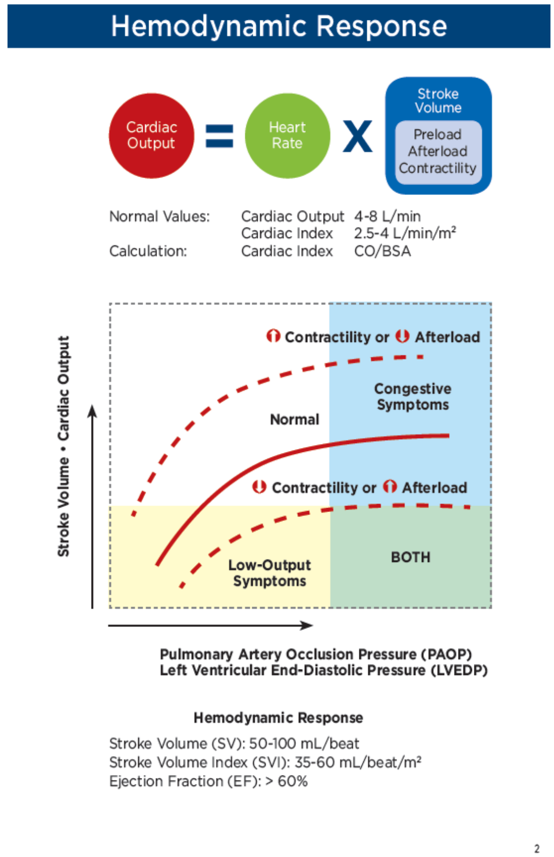
REV 10/20


Hemodynamic Response
Cardiac Output = Heart Rate X Stroke Volume
Preload
Afterload
Contractility
Normal Values: Cardiac Output 4-8 L/min
Cardiac Index 2.5-4 L/min/m²
Calculation: Cardiac Index CO/BSA
Stroke Volume • Cardiac Output
Contractility or Afterload
Congestive Symptoms
Normal
Contractility or Afterload
Low-Output Symptoms
BOTH
Pulmonary Artery Occlusion Pressure (PAOP)
Left Ventricular End-Diastolic Pressure (LVEDP)
Hemodynamic Response
Stroke Volume (SV): 50-100 mL/beat
Stroke Volume Index (SVI): 35-60 mL/beat/m²
Ejection Fraction (EF): > 60%
2

Heart Rate

Normal Values:

• Adult/Adolescent	60-100 beats/min	• Toddler (1-2 y)	98-140 beats/min
• School Age (6-12 y)	70-118 beats/min	• Infant (1-12 mo)	100-180 beats/min
• Preschool (3-5 y)	80-120 beats/min	• Neonate (0-1 mo)	100-205 beats/min

	Increased	Decreased
Mechanism/Effect	• Sympathetic nervous system stimulation in response to stressful stimuli • Compensatory mechanism for decreased CO and/or decreased SV • Cardiac rhythm disorder from increased excitability of cardiac pacemaker cells	• Parasympathetic nervous system stimulation (vagal stimulation) • Compensatory mechanism for increased blood pressure • Cardiac rhythm disorder from decreased excitability of cardiac pacemaker cells
Causes	• Sympathetic stimulation (fear, pain, anxiety, stress, agitation) • Exercise (physical activity) • Decreased blood volume (preload) • Increased vascular tone (afterload) • Hypermetabolic states (fever, hyperthyroidism) • Hypoxia and hypercarbia • Conditions causing myocardial excitability, increased conduction (medications, cardiac cellular damage/edema) • Medications and stimulants (caffeine, nicotine, cocaine, etc.) • Accessory cardiac conduction pathways (re-entry phenomenon)	• Cardiac conduction defect • Vagal stimulation (intubation, suctioning, nasogastric tube placement, vomiting, Valsalva maneuver, diver's reflex, carotid pressure) • Relaxed state (sleep, sedation) • Severe hypoxia • Conditions that cause decreased myocardial excitability • Neurogenic (Cushing's triad, increased intracranial pressure, anoxic injury) • Myocardial tissue damage • Normal variation (physical fitness) • Medications that cause bradycardia (tricyclic antidepressant overdose, digoxin, beta and select calcium channel blockers)
Treatment	• Correct sympathetic stimulus (control pain/anxiety, decrease physiologic stressors) • Optimize preload, afterload, and contractility • Optimize oxygenation/ventilation • Decrease metabolic/oxygen demands (sedation, paralysis, fever management) • Medications that slow conduction, decrease irritability (digoxin, calcium-channel blockers, beta-blockers, amiodarone, lidocaine, procainamide, adenosine, magnesium sulfate)	• Remove vagal stimulus • Administer positive chronotropic medications (epinephrine, dopamine, atropine) • Pacemaker (transcutaneous, transvenous, permanent) • Optimize oxygenation and ventilation

3

Preload

Normal Values (Adult):

• CVP	2-8 mm Hg
• PAOP	8-12 mm Hg

	Increased	Decreased
Mechanism/Effect	• Increased myocardial muscle fiber stretch leads to increased ventricular blood volume, increased SV, increased CO, increased ventricular work • Overstretched myocardial muscle fibers lead to decreased force of contraction, decreased SV, heart failure (Frank-Starling phenomenon)	• Decreased myocardial muscle fiber stretch from decreased circulating blood volume, decreased SV, decreased CO, vascular volume depletion, hypotension, cardiovascular collapse • Increased volume corresponds with increased CO to a point of optimal stretch of myocardial muscle fibers
Causes	• Decreased fluid excretion (kidney failure) • Excess fluid administration (fluid overload) • Ineffective cardiac pumping (right and left heart failure) • Aortic insufficiency • Vasoconstriction (alpha stimulation) • Inotropic medication • Pregnancy	• Vascular volume loss (hemorrhage, diarrhea, vomiting, burns, edema, decreased intake, diuretics, third spacing) • Vasodilation (medications, septic shock) • Pathological conditions (diastolic ventricular failure, mitral or tricuspid stenosis) • Loss of atrial kick
Treatment	• Correct condition causing fluid volume retention/overload) • Vasodilation (see increased afterload) • **Diuretics** ∘ Furosemide ∘ Bumetanide ∘ Mannitol ∘ Spironolactone ∘ Chlorothiazide ∘ Hydrochlorothiazide ∘ Metolazone • Hemodialysis • Continuous renal replacement therapy for fluid overload with kidney failure	• Correct condition causing fluid volume loss • Volume expansion ∘ **Crystalloid** - Saline - Lactated Ringer's ∘ **Colloid** - Albumin - Plasma - RBCs • **Vasoconstrictors** (norepinephrine, dopamine, phenylephrine, epinephrine) may be used to correct severe hypotension when given in conjunction with fluid resuscitation

4

Afterload

Normal Values (Adult):
- SVR 800-1,200 dynes sec/cm^{-5}
- PVR 150-250 dynes sec/cm^{-5}

Calculations:
- SVR = [(MAP- CVP) / CO] x 80
- PVR = [(MPAP - PAOP) / CO] x 80

Increased	Decreased
Mechanism/Effect • Increased resistance to forward flow is related to increased arterial resistance, increased PVR and SVR, increased end-diastolic pressure, increased aortic or pulmonic impedance, increased blood viscosity, and increased aortic blood volume • Increased resistance to forward flow leads to increased left ventricular stroke work, which leads to increased myocardial oxygen demands, which lead to increased left ventricular failure	**Mechanism/Effect** • Decreased resistance to forward flow is related to decreased arterial resistance, decreased PVR and SVR, decreased end-diastolic pressure, decreased aortic or pulmonic impedance, decreased blood viscosity, and decreased aortic blood volume
Causes • Hypertension • Sympathetic stimulation • Peripheral vasoconstriction • Vasopressors • Aortic stenosis, pulmonic stenosis • Polycythemia • Medications/substances causing hypertensive effects (cocaine, amphetamines) • Hypothermia • High positive end-expiratory pressure • Increased ventricular-wall tension (dilation)	**Causes** • Vasogenic shock (vasodilatory shock) • Septic shock (early), endotoxin release • Anaphylactic shock • Neurogenic shock • Vasodilators • Medications causing hypotension (narcotics, antidepressants) • Hyperthermia
Treatment ∘ Reduce sympathetic stimulation ∘ Normalize body temperature ∘ **Vasodilators** - Nitroglycerin - Nitroprusside - Labetalol - Milrinone - Hydralazine - Enalapril, captopril, lisinopril - Isosorbide • **IABP increases pumping ratio** (1:1) • **Diuretics** (see increased preload)	**Treatment** • **Vasopressors** ∘ Epinephrine ∘ Dopamine ∘ Norepinephrine ∘ Phenylephrine ∘ Vasopressin ∘ Angiotensin II • **Volume expansion** (see decreased preload) ∘ Crystalloids ∘ Colloids

5

Contractility

Normal Values (Adult):
- SVI = 35-60 mL/beat/m^2
- RVSWI = 7-12 g/m^2/beat
- LVSWI = 35-85 g/m^2/beat

Calculations:
- SVI = CI/HR x 1000
- RVSWI = (MPAP - CVP) x SVI x 0.0136
- LVSWI = (MAP - PAOP) x SVI x 0.0136

Increased	Decreased
Mechanism/Effect • Increased contractile state of myocardium leads to increased force of contraction, which leads to increased SV, which leads to increased CO and myocardial oxygen demand	**Mechanism/Effect** • Decreased contractile state of myocardium leads to decreased force of contraction, which leads to decreased SV, which leads to decreased CO and myocardial oxygen demand
Causes • Positive inotropic medications • Increased HR • Sympathetic stimulation (beta$_1$ receptor) • Electrolyte imbalance (hypercalcemia) • Toxic ingestion (digoxin) • Systemic inflammation	**Causes** • Negative inotropic medications • Parasympathetic stimulation (vagus nerve) • Hypoxia • Hypercapnia • Metabolic acidosis • Electrolyte imbalance • Cardiotoxic medications/substances (chemotherapy, salicylate overdose) • Toxin release (septic shock)
Treatment When positive inotropic effects are undesirable because of increased myocardial oxygen demand • **Correct positive inotropic effects** (correct calcium level, decrease sympathetic stimuli, decrease HR) • **Negative inotropic medications** ∘ Beta-blockers ∘ Calcium-channel blockers ∘ Barbiturates • **Correct toxic effect**	**Treatment** • **Correct negative inotropic effects** (oxygen, ventilation, acid/base balance, electrolyte balance, remove vagal stimulus) • **Positive inotropic medications** ∘ Dobutamine ∘ Dopamine ∘ Digoxin ∘ Milrinone ∘ Calcium infusion ∘ Epinephrine • **Optimize preload** ∘ Correct volume deficit ∘ Correct volume excess

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6

Oxygenation

Normal Ranges:

- SvO_2 60%-80%
- $ScvO_2$ > 70%

SvO_2 and $ScvO_2$ are measurements of the relationship between oxygen consumption and oxygen delivery in the body. They reflect the oxygen saturation returning from the body through the venous system. The 3 influencers of SvO_2 and $ScvO_2$ measurements are:

- Hemoglobin
- CO
- Metabolic demand/oxygen consumption

In general:

- An increase in SvO_2/$ScvO_2$ = decreased cellular oxygen extraction
- A decrease in SvO_2/$ScvO_2$ = increased cellular oxygen extraction

Conditions that decrease SvO_2 (increase oxygen demand)	Medications that increase or decrease SvO_2* (increase oxygen demand)	Procedures that decrease SvO_2 (increase oxygen demand)	Factors that increase SvO_2 (decrease oxygen demand or increase oxygen delivery)
• Seizures • Fever • Bone fracture • Agitation • Increased work of breathing • Chest trauma • Multiple organ failure • Shivering • Burns • Sepsis • Head injury	• Norepinephrine • Dopamine • Dobutamine • Epinephrine *Although these medications all increase oxygen demand, SvO_2 may increase as CO improves.	• Dressing change • Nursing assessment • 12-lead ECG • Visitors • Bath • Chest x-ray • Endotracheal suctioning • Turning • Getting out of bed • Nasal intubation	• Hypothermia • Sedation/ analgesia • Anesthesia • Assist/control ventilation • Oxygen administration • Propranolol in head injury • Neuromuscular blockade

Hemodynamic Alterations in Shock

Parameter	Hypovolemic	Cardiogenic	Distributive
BP	↓	↓	↓
CI	↓	↓	↑↔
CVP	↓	↑↔	↓
PAOP	↓↓	↑↑	↓
SVR	↑	↑	↓↓
SvO_2	↓	↓	↓

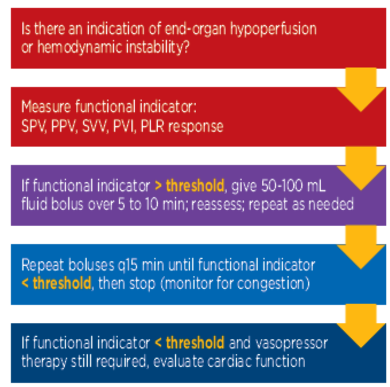
Functional Hemodynamic Measurements

For patients receiving ventilatory support with a Vt > 6 mL/kg, using arterial pressure data from a bedside monitor during respiratory cycle, systolic pressure variation (SPV), pulse pressure variation (PPV), and stroke volume variation (SVV) can be calculated using the following equations:

Formulas

Variable	Equation	Threshold for Responders
SPV	SBPmax - SBPmin	> 10 mm Hg
SPV %	[(SBPmax - SBPmin)/(SBPmax + SBPmin/2)] x 100	> 10%
PPV %	[(PPmax - PPmin)/(PPmax + PPmin/2)] x 100	> 13-15%
SVV %	[(SVmax - SVmin)/(SVmax + SVmin/2)] x 100	> 10-15%
Pleth Variability Index (PVI)	Derived from oximeter perfusion index	12%-16%
Δ SV (Delta SV)	% change in stroke volume compared before and after fluid challenge or PLR	> 10-15%

Simplified treatment algorithm based on functional hemodynamic parameters



Legend: **BP**, blood pressure; **BSA**, body surface area; **CI**, cardiac index; **CO**, cardiac output; **CR**, classic reference; **CVP**, central venous pressure; **HR**, heart rate; **IABP**, intra-aortic balloon pump; **LVSWI**, left ventricular stroke work index; **MAP**, mean arterial pressure; **MPAP**, mean pulmonary artery pressure; **PAOP**, pulmonary artery occlusion pressure; **PLR**, passive leg raising; **PVR**, pulmonary vascular resistance; **RVSWI**, right ventricular stroke work index; **SBP**, systolic blood pressure; **SV**, stroke volume; **$ScvO_2$**, central venous oxygen saturation; **SVI**, stroke volume index; **SvO_2**, mixed venous oxygen saturation **SVR**, systemic vascular resistance; **Vt**, tidal volume

Appendix C:

Post intervention Survey

Please answer the following questions:

1. How long have you been a nurse?

2. How long have you been trained to care for open heart patients?

3. Please rate the ease of use of the QR codes
   Very easy (5), somewhat easy (4), neutral (3), Somewhat difficult (2), very difficult (1)

4. Please rate the content of the QR codes
   Very useful (5, Somewhat useful (4), neutral (3), not very useful (2), not useful at all (1)

5. How often did you utilize any of the QR codes?
   a. More than once per shift
   b. Once per shift
   c. Less than once per shift
   d. Not at all

6. Did using or accessing the QR codes add too many steps to your workflow?

7. Did using the QR codes give you more confidence in the care you are providing to your patients?

8. Did you find the information on the QR codes relevant in caring for post open heart patients?