ECG Lead Placement in the Perioperative Period: A Quality Improvement Project

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Abstract

Continuous monitoring of heart rate and rhythm via ECG is a staple of perioperative care. It allows timely response to changes that require intervention and allows the anesthesia provider to make proper decisions about care. Accuracy of the ECG is dependent on correct placement of the leads, however researchers have shown that ECG leads are frequently misplaced. Improper ECG lead placement may not reveal true cardiac changes and may emulate untrue changes simply due to lead malposition. The aim of this Doctor of Nursing Practice Quality Improvement (QI) project was to assess anesthesia providers' perceived confidence in placing ECG electrodes in the three most common surgical positions (supine, lateral, and prone), before and after using an ECG lead placement education tool in their practice for a two-week period. This project was conducted at a large, level 1 trauma center located in the southeastern United States. A single plan, do, study, act cycle was completed using a pre- and post-survey design incorporating Qualtrics and Excel for data collection and analysis. The project involved 10 CRNAs who participated voluntarily. Results demonstrated an increase in perceived confidence in placing ECG electrodes after using the educational tools, and revealed additional considerations that may be beneficial to include in future iterations.

Keywords: ECG, leads, placement, CRNA, accuracy

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Section I. Introduction

Background

Surgical interventions are some of the most diverse tools of modern healthcare. Surgery can restore form and function following injury, remove life-threatening pathology, and create beauty. Despite its many applications, however, a commonality is risk. Irrespective of the procedure, surgery has many serious risks, including death. To mitigate these risks, the anesthesia provider is responsible for monitoring vital signs and maintaining the patient's stability in the perioperative setting. In an effort to deliver consistent and safe practice, several professional organizations have published unanimous monitoring standards that form the basis of acceptable care in the operating room. The Anesthesia Patient Safety Foundation (APSF; 1987) Circulation Objective, Method 1; American Association of Nurse Anesthesia (AANA; 2019) Standard 9, Section C; and American Society of Anesthesiologists (ASA; 2020) Standard 2.3.2, all recommend a constellation of non-invasive monitoring which has been the standard of care for almost 40 years. Included in this bundle is continuous monitoring of the patient's heart rate and rhythm through electrocardiography (ECG).

Despite substantial technological advances since these standards were initiated, even the most sophisticated monitors are still subject to human error. For ECG monitoring, the most common error is poor placement of the ECG leads. Rajaganeshan et al. (2008) found that ECG lead placement varied between different disciplines and between clinicians within the same discipline. While one may assume an inverse correlation between ECG lead placement error and higher education, paradoxically, more highly trained providers were found to have the highest rates of inconsistencies, with cardiologists being the most inconsistent. Kania et al. (2014) conclusively demonstrated that inappropriate positioning of ECG leads, especially precordial leads, can depict inaccurate morphology. Most notably the V1 and V2 leads, when placed incorrectly, can change the QRS complex time interval, leading to misinterpretation or failure to recognize serious cardiac events. Rajaganeshan et al. (2008) found V1 and V2 to be amongst the most inconsistently placed leads, especially with respect to their vertical positions.

The implications of imprecision during surgery can be life-altering. Perhaps even life-ending. Surgery has the power to radically transform one's health, but the surgical process includes many factors that can be problematic if there is inconsistent management. This is a time when monitoring needs to be exact, diagnosis confident, and intervention quick and calculated. Seizing the opportunity to ensure consonant ECG lead placement is an important step toward improving patient care and outcomes across the spectrum of surgical intervention.

Organizational Needs Statement

As a level 1 trauma center and tertiary care hospital serving residents of much of eastern North Carolina, the partnering institution performs thousands of surgeries each year. Patient demographics across this region often include several comorbidities that make cardiac monitoring a vital component of perioperative care (T. Chabo, personal communication, November 8, 2022). When Oh et al. (2022) reviewed data regarding perioperative adverse cardiac events (PACEs) during surgery they found these events not only affect perioperative morbidity but are also correlated with increased mortality at the one year mark. Of all adverse events studied, abnormal heart rhythm was the most common complication. Proactive mitigation strategies must first include the ability to accurately diagnose a cardiac problem. At the heart of diagnosis is monitoring.

Expectations for healthcare services are constantly being raised. Global healthcare leader, the Institute for Healthcare Improvement (IHI, 2022b), has proposed a Triple Aim campaign designed to improve three major facets of health care. These three metrics include creating a better patient experience, reducing health care costs, and improving population health. An education program to encourage proper anatomical lead placement that is consistent across all disciplines aligns the partnering hospital with these aims and upholds ideal compliance with patient safety and monitoring standards set forth by the APSF (1987). Additionally, reducing complications of surgery should have positive downstream effects, including shorter average duration of hospital stay, reduced healthcare burdens, unnecessary treatment, and the ability to treat more patients in a given time period. Though it is difficult to quantify the costs of delayed or missed cardiac diagnoses, it is indisputable that fewer inconsistencies would result in cost reduction and an improvement in patient satisfaction.

Problem Statement

Inaccurate and/or inconsistent ECG lead placement in the perioperative setting has the potential to result in incorrect, missed, or delayed patient diagnoses. This may lead to unnecessary interventions, increased cost of care, and poor patient outcomes.

Purpose Statement

This Doctor of Nursing Practice (DNP) quality improvement (QI) project assessed the perceived efficacy of a standardized educational aid designed to streamline ECG lead placement and increase consistency among certified registered nurse anesthetists (CRNAs) in the perioperative setting. ECG lead placement education included standard 6-lead placement and alternative placement required for varying surgical procedures and positioning.

Section II. Evidence

Description of Search Strategies

To better understand the breadth and scope of this project, the initial literature searches began with an exploration of ECG lead misplacement. Searches were guided by the PICOT question: For ECG leads, how does a pictographic education bulletin affect the consistency of lead placement for surgical patients in the operating room (OR)? Further searches were conducted to examine data for incidence of specific lead misplacement and practice variance across disciplines, as well as the clinical effects of lead misplacement on patient care, diagnoses, and outcomes. Finally, a search was conducted to uncover any previous QI initiatives aimed at proper ECG lead placement. Literature was reviewed in PubMed and Cumulative Index to Nursing and Allied Health Literature (CINAHL) databases, as well as Google Scholar search engine. MeSH terms in PubMed, subject headings in CINAHL, and the Boolean operators AND and OR were utilized to narrow the results and ensure specificity of searches. Most literature was restricted to the most recent five-year period, with a few exceptions for high quality and landmark studies within the past eight years. Only articles in the English language were included. Keywords included *ECG, lead placement, and error*. For further information on MeSH terms, subject headings and keywords see Appendix A.

Upon full-text review of search reports, multiple pertinent articles were identified that included ECG lead misplacement and its clinical effects. This provided a total of 15 articles for a full literature review (see Appendix B). Published practice guidelines and standards of care for ECG and patient monitoring from the APSF, ASA and AANA were also included. Duplicate articles resulting from multiple searches were eliminated and articles retained were reviewed for relevance and utility. References from articles were appraised for academic quality and the final inclusion criteria included incidence for ECG lead misplacement and its specific effects on clinical outcomes. Finally, Melnyk & Fineout-Overholt's (2019) hierarchy of evidence was used to stratify articles. The retained literature was grouped as follows: seven Level VI (observational study), two Level IV (quality improvement (QI)), three Level II (randomized trial) and one Level I (systematic review). See Appendix C literature matrix for further information.

Selected Literature Synthesis

Current practice for ECG lead placement suffers from an alarming rate of lead misplacement. The incidence of lead misplacement varies widely but has been measured as high as 94.2% in some cases (Paget et al., 2019). One might conclude that errors in such a standard task might be relegated to disciplines with relatively less education, but in fact, in some studies, cardiologists possessed the least accuracy in identifying bony landmarks and placing precordial ECG leads properly (Rajaganeshan et al., 2008).

Continuous ECG monitoring is considered a core component of patient monitoring. Its widespread use makes misplacement a sweeping and insidious problem. Surgical patients in the OR, patients with life-threatening illness in the intensive care unit (ICU), and healthy patients in ambulatory service centers all have continuous ECG monitoring as part of their standard of care. This creates the opportunity for inaccuracy to result in everything from missed early diagnosis of a new cardiac disease to failure to address an acute, life-threatening arrhythmia during surgery. Clinicians frequently depend on ECG analysis during each procedure; therefore time needs to be invested in ensuring precision in ECG lead placement. Increased sensitivity has been pursued by adding precordial Wilson leads, using K point deviation instead of the traditional J point method, investigating in accuracy of placement by practitioners and students, and analysis of hypothetical patients with ECG leads placed in over 600 positions mapped with body surface potential mapping to detect even the slightest deviations (Giannetta et al., 2020; Loewe et al., 2015)

The clinical impact of lead misplacement also varies greatly. Precordial leads are the most important for precision, with as little as one intercostal space or 2 cm in any direction affecting the accuracy of diagnosis (DiLibero et al., 2016; Kania et al., 2014; Wirt, 2014). Gross oversight, such as reversing the limb leads, or swapping an upper limb lead for a lower limb lead, are typically evident to the provider interpreting the ECG. Smaller disparities, however, such as a vertical or horizontal shift of a precordial lead, may go unrecognized and mimic pathology, leading to unnecessary intervention and cost. ECG lead specificity has a direct correlation with proximity to the heart. This means the closer the lead, the more important accurate placement becomes. Analysis suggests that the most important leads to place, V1 and V2, are also the leads most frequently misplaced (DiLibero et al., 2016; Kania et al., 2014; Medani et al., 2017; Rajaganeshan et al., 2008; Rehman & Rehman, 2020; Rjoob et al., 2020; Walsh, 2018).

Imprecise placement of ECG leads may result in patients being misdiagnosed with Brugada syndrome, poor r-wave progression, pulmonary embolus (PE), bundle branch block (BBB), and even ST-elevation myocardial ischemia (STEMI; Kania et al., 2014; Rehman & Rehman, 2020; Walsh, 2018). These diagnoses are serious and require additional interventions to further explore cardiovascular instability. Rehman & Rehman (2020) extrapolated an estimated national financial burden due to ECG lead misplacement of $3.2 billion annually by using local costs and commonly accepted incidence rates. Walsh (2018) presented five real patient case studies that illustrate unnecessary testing done at the request of a provider reading an ECG with improperly applied leads. They concluded that V1 and V2 are frequently misplaced and mimic morphology that warrants investigation. These inaccurate ECG tracings cause expense and anxiety and negatively affect patient management.

Deleterious effects extend beyond unnecessary testing, however. Oh et al. (2022) found that perioperative adverse cardiac events (PACEs) correlated with more than three-fold higher mortality; 2.2% in the control group and 7.7% in the PACE group, at the 1-year post-op mark, and 9.0% in the control group and 24.3% in the PACE group at the 3-year post-op mark. These findings underscore the importance of properly monitoring, diagnosing, and treating cardiac events, especially in the perioperative setting.

Owing to the substantial impact of ECG lead misplacement, several strategies have been developed to help improve accuracy and mitigate misdiagnosis. Education programs and in-service training have been implemented with improvements in accuracy among staff as high as 80-85% (DiLibero et al., 2016; Medani et al., 2017). Prearranged ECG lead templates have also been developed to ensure proper relative positions which allow clinicians to simply apply the template while considering a few anatomical landmarks (Roy et al., 2020). The most dramatic improvements are related to hands-on demonstration with unit champions and a culture that holds colleagues accountable (DiLibero et al., 2016; Medani et al., 2017). This type of educational endeavor produced improvements that were sustained at a 3-month follow up analysis at a rate greater than 85% (DiLibero et al., 2016). Medani and colleagues (2017) found that ability to correctly place all ECG leads rose from 34% to 83% six months post intervention.

Although there is no consensus on the ideal solution, it is evident that ECG lead misplacement is a common problem from which extraneous expense originates and inappropriate testing ties up resources not germane to the patient’s actual need. These problems present myriad downstream effects. Many groups of researchers have assessed multiple approaches to remedy this problem, but a standardized solution remains to be accepted on a broad scale.

Project Framework

The plan-do-study-act (PDSA) method was used to implement the IHI (2022a) model for improvement in the execution of this QI project. PDSA is a process conducive to implementing a QI change. There is no endpoint, as the process is circular. An initial goal or clinical question aims the project. Once the aim(s) have been established and objective methods of measurement assigned, the intervention can be developed (*plan*). That intervention is then deployed (*do*) and assessed for efficacy (*study*). Any observed shortcoming can be readdressed, and another iteration can be formulated (*act*). This model guides any initiative formed under its principles to be analyzed in perpetuity allowing the PDSA cycle to simultaneously be an endpoint, and any results can then be applied to a new cycle for further improvement and refinement (IHI, 2022a).

In the planning stage of this project, the educational material for ECG lead placement was created and two surveys were formulated; one to assess the existing perception of ECG lead placement practice, and a post-intervention survey to collect feedback on the perceived efficacy of the intervention. The *do* stage consisted of a two-week implementation of the educational material. A PDF and PowerPoint presentation were made available via links sent through email and tangible copies were placed in the anesthesia work room and break room for the CRNAs. Pre- and post-intervention surveys were utilized to analyze staff perception of the educational material and its effect on care in the context of ECG lead placement. The *study* phase assessed the data pool to draw conclusions about the efficacy of the intervention. Further, it provided a time to assess which aspects of the QI process were successful and which components of the QI process would need revision in a future cycle. The *act* stage was comprised of a presentation disseminating the results of the project and offering recommendations for future researchers to expand on or revise the intervention idea.

Ethical Considerations and Protection of Human Subjects

This project qualified as exempt from full Institutional Review Board (IRB) status as a QI project through a joint process between the [redacted]) and the University and Medical Center Institutional Review Board (UMCIRB). A more specific review was also completed through the organization's center for research and grants in coordination with the [redacted] UMCIRB. See Appendix D. All elements of the educational intervention aligned with currently accepted practice in the organization. Participants were CRNAs working in the designated project area and who placed ECG leads as part of their usual work responsibilities. Each volunteered to be part of the initiative without coercion. No potential risks to participants were identified other than for slight time stress from the additional educational element applied to their work. No personal data was gathered from participants and survey responses were kept confidential. No patients were included in this study and no patient data was gathered.

Potential benefits include more accurate and consistent ECG lead placement facilitating improved ECG diagnosis, more timely intervention for cardiac irregularities, and improved patient outcomes. Absence of exclusion criteria means any benefit would be equally applied to all roles and settings. Ethically, an additional step in an otherwise routine process can potentially cost time without providing any measurable benefit. In preparation for this project all researchers completed the Collaborative Institutional Training Initiative (CITI) modules available from https://about.citiprogram.org.

Section III. Project Design

Project Setting

This DNP project took place in a tertiary care hospital in eastern North Carolina with which this academic institution has a long-standing, mutually beneficial relationship. This relationship provided a familiarity with the annual DNP project requirements of the nurse anesthesia program, and thus facilitated participation by the institutional staff. During the course of normal patient care, the participants generally applied ECG leads to several patients each day, which allowed opportunities to utilize educational material for proper ECG placement.

Barriers to project completion were two-fold. First, ECG lead placement is often limited by the surgical procedure being performed, requiring alternative lead selection or variations in lead location. Patient individuality and body habitus may limit this further, making ideal placement difficult to achieve. Additionally, there existed a time component to initially view, and later revisit, the educational materials that may have been burdensome to participants in light of the production pressure inherent to the job of anesthesia.

Project Population

The nurse anesthetists who participated in this project are predominantly permanent employees, only a few are contracted workers. This QI project requested participants modify their daily routine to include utilization of our educational materials while applying ECG leads before surgery. It is conceivable that this additional step added time to their daily routine, thus creating a barrier to participation. The potential participants work in an educational environment where learner projects and research are commonplace. Additionally, several alumni of this nurse anesthesia program are employed in the project setting.

Project Team

This project was developed using a team approach involving collaboration by the author as lead for this QI project and three other SRNAs as well as the project chair. After the project was developed, the author individually led project implementation, data collection, and analysis of the data, though with support of the project chair who provided guidance and oversight for the planning, implementation, and assessment of the project. A representative serving as the main contact for the participating facility signed a letter of acknowledgement of data collection plans and assisted in coordinating participation. All collaboration between the academic institution and participating healthcare facility was made possible by the clinical contact liaison. Finally, the nurse anesthesia program director and course director also assisted in facilitating instruction and implementation of this project.

Methods and Measurement

The overall goal of this QI project was to assess perceptions about current standards of care for ECG lead placement among CRNAs in selected department of the participating healthcare institution and whether an educational reference tool for proper placement was perceived as helpful for increasing accuracy and consistency in their practice. The project first ascertained CRNA perceptions of the prevalence of misplacement for ECG leads as well as potential causes through a pre-intervention survey distributed to participants via email. This email contained a link to a Qualtrics survey as well as educational materials which served as the project intervention, specifically a PowerPoint presentation and PDF tool. In addition to these digital education materials, printed copies of the PDF tool were provided in a central place easily accessible to all participants. The PowerPoint presentation was sent through email to CRNAs who initially volunteered to participate. Both were also provided as printed copies left in the anesthesia work room and break room.. This educational material can be viewed in Appendix E and Appendix F, and email correspondence is available in Appendix G. At the conclusion of the intervention, a post-intervention survey was conducted, also via email, with a Qualtrics link sent to potential participants. The pre- and post-intervention surveys were constructed with Qualtrics software (www.qualtrics.com) and can be found in Appendix H and Appendix I, respectively. The primary measured outcome was the perception of participating anesthesia providers regarding the educational materials' impact on their ECG lead placement practices.

The PDSA cycle for improvement guided each step of this QI project. In the planning phase, a comprehensive literature search was completed to identify the currently documented prevalence and major contributors for ECG lead misplacement. Articles were also included that contained various interventions designed to ameliorate this problem. This body of evidence was synthesized to produce the educational presentation using Microsoft PowerPoint and a reference guide in PDF format to be available for download to any smartphone. Qualtrics software was used to form pre- and post-intervention surveys. The main operating room practice setting was chosen by the collective input of the project clinical contact person, lead researcher, and institutional contact person.

During the *do* phase, the clinical contact person identified potential CRNA participants and subsequently provided access for the project conductor to disperse emails with the pre-interventions survey links, the educational PowerPoint presentation and the PDF quick-reference guide. These materials were to be integrated into the routine placement of ECG leads for each patient over a two-week practice period. At the conclusion of these two weeks, a post-intervention survey link was then emailed to participants with the goal of assessing staff perceptions of the education intervention.

In the *study* and *act* phases, data were compiled and analyzed. Results were integrated into this DNP paper. Earnest attempts to maintain confidentiality were made, though true anonymity is difficult to ensure with such a limited sample size. No private health information data was collected, only email addresses of participants were gathered, as these were required for sending surveys and educational materials. A final poster presentation was offered both in person and online and included members of the ECU nurse anesthesia program as well as project participants. The project paper and the poster, in their entirety, may be viewed in *The Scholarship* which serves as ECU's digital repository.

Section IV. Results and Findings

Results

Results from this project were intended to provide insight into the perceived accuracy of ECG lead placement and how an educational tool impacted that aspect of practice. Initial data was collected on a pre-intervention survey distributed via Qualtrics. Links were sent via email and participants were given two weeks to complete the questionnaire. A total of ten CRNAs were contacted for this project. Two of those ten responded via email that they were on vacation during that time, so an extra two weeks was allowed for them to complete the surveys and use the information and PDF tool. This resulted in all ten participants registering a response in the pre-intervention survey.

The email containing the pre-intervention survey link also contained the educational materials. An attached Microsoft PowerPoint presentation included fundamental aspects of ECG monitoring and proper lead placement in the supine position with a standard 6-lead and standard 12-lead configuration, right lateral position, and prone position. Along with the PowerPoint was a PDF with pictures of proper lead placement for these positions and descriptions of anatomical landmarks for finding them. The PowerPoint served as an educational refresher on cardiac electrophysiology, and the PDF was to be used as a real-time reference while applying monitors to patients in the operating room. The participants were instructed to integrate these educational guides into practice for two weeks, after which the post-intervention survey link would be distributed. During the two-week implementation, one reminder email was sent about the pre-intervention survey, and to encourage participation.

At the conclusion of two weeks, an email containing a link to the post-intervention Qualtrics survey was distributed. One week after this a reminder email was sent to encourage participation in the post-survey, for which the deadline was also extended two extra weeks to allow participation of the two CRNAs who were on vacation. All ten participants completed the post-intervention survey. Emails can be found in Appendix G.

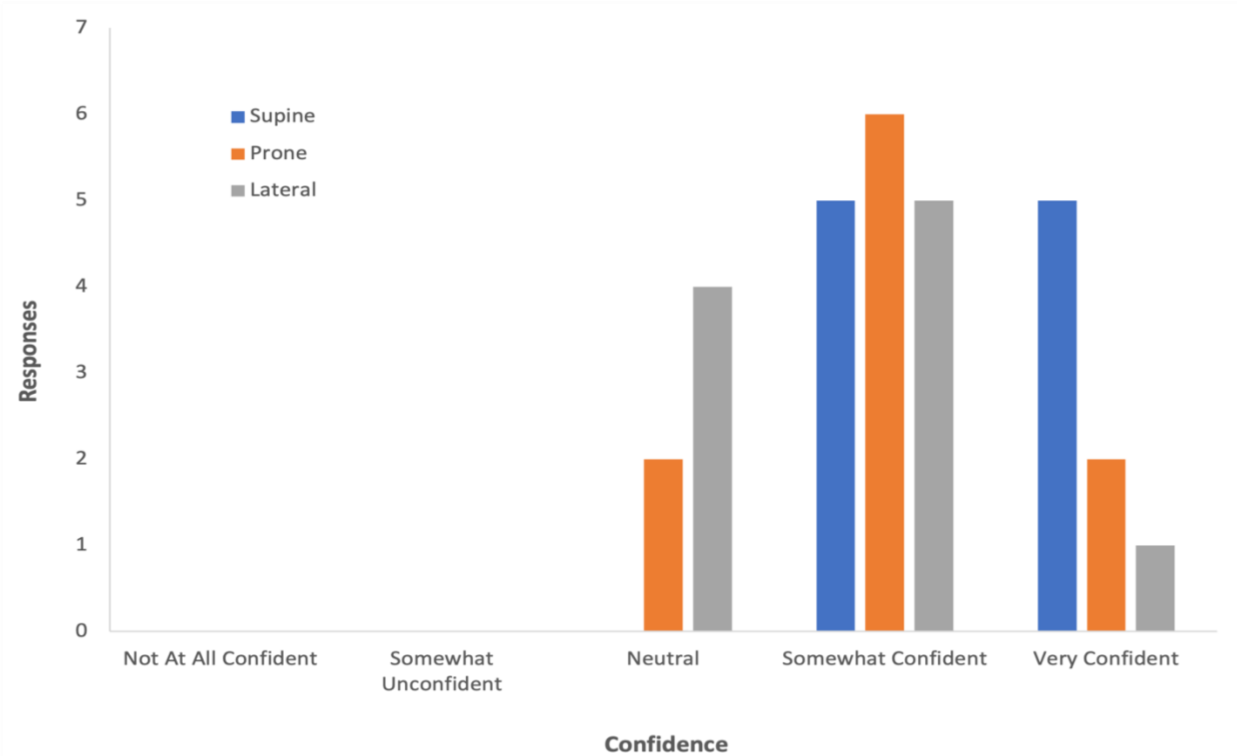
Project data was imported into Microsoft Excel for analysis. The following charts depict the change in perception of ECG lead placement accuracy before and after the educational intervention. The pre-intervention and post-intervention survey questionnaires can be found in Appendix H and Appendix I, respectively. Some survey questions involved more specific aspects of practice and were used to make correlations or draw conclusions about the implications of the educational tool for real-world practice.

For the pre-survey, a total of ten responses were recorded for all questions. CRNAs were asked if they had any formal training in ECG lead placement as part of their onboarding process when beginning work in their discipline. Seven CRNAs answered “yes” and three answered “maybe.” The survey also asked how often ECG leads were placed with the assistance of a standardized tool. Recorded responses included two “always,” four “most of the time,” three “sometimes,” and one “never.” Additionally, CRNAs were asked about their perceived confidence placing ECG leads in supine, lateral, and prone positions. The results of the pre-intervention survey are depicted in Figure 1.

The survey asked how often the CRNAs experienced poor morphology or artifact in their ECG tracings. Responses included two “most of the time,” two “about half the time,” and six “sometimes.” Next, the survey addressed the frequency with which ECG leads were repositioned to achieve an acceptable tracing. Responses included four “most of the time,” three “about half the time,” two “sometimes,” and one “never.” CRNAs were asked how often they received a patient who already had ECG leads placed that were not in the correct location. Responses included two “always,” five “most of the time,” two “about half the time,” and one “sometimes.”

Figure 1

Confidence Placing ECG Leads in Listed Positions, Pre-Intervention (n=10)



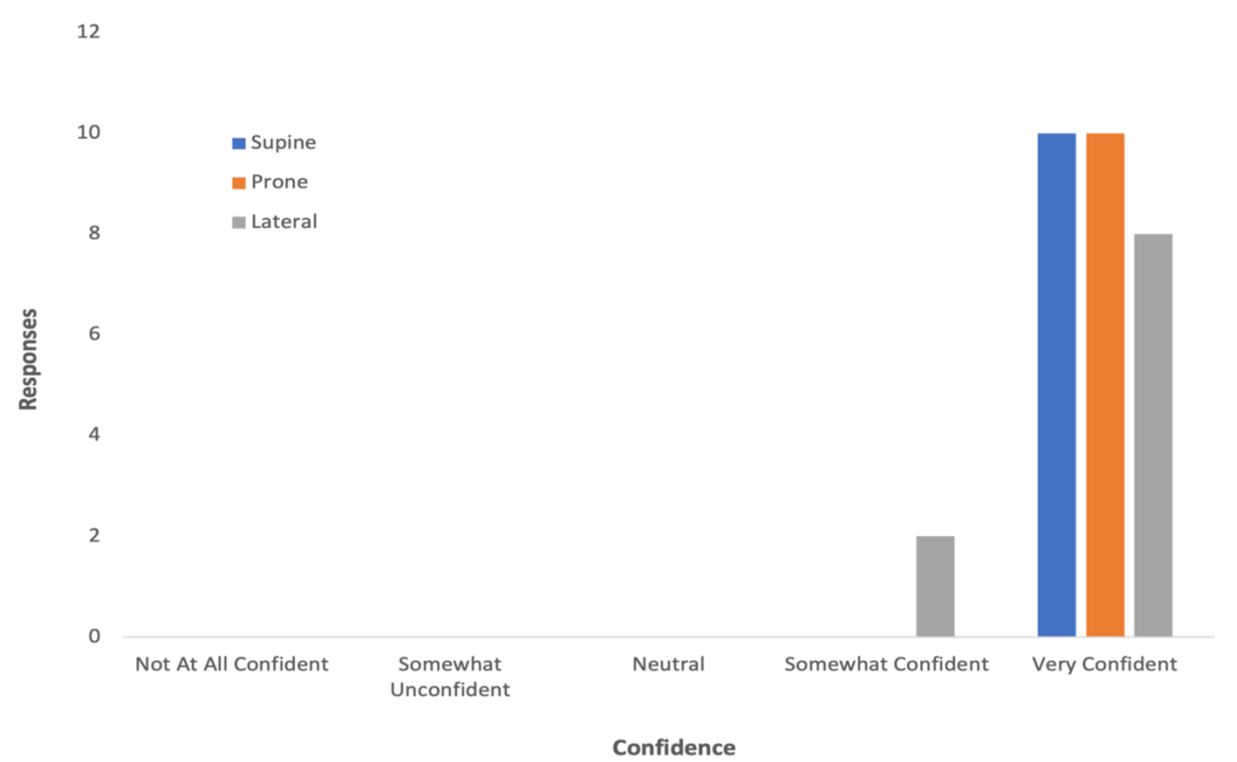
Regarding CRNAs’ perceptions as to whether patient care could be improved with more accurate ECG lead placement, responses included five “definitely yes,” three “probably yes,” and two “might or might not.” Finally, a free response field was provided for the CRNAs to submit their own perceived obstacles to placing ECG leads in the correct location. Six provided answers related to surgery, including “position,” “placing correctly due to surgical prep area,” “limited body surface that is not part of surgical field,” “body habitual and surgical prep,” “props lead placements are in surgical field a lot of the times," and "restrictions presented by surgical conditions." One CRNA reported a modifiable patient factor, "hair." One CRNA reported "60 cycle interference" from other electronic equipment, one CRNA responded "None.", and one CRNA did not provide a response to this question.

In the post-survey, a total of ten responses were collected for all questions. The CRNAs were asked to report perceived confidence placing ECG leads in the supine, lateral, and prone positions after using the educational tools. The results are depicted in Figure 2. This survey asked, after using the ECG placement tool, how often was incorrect morphology or artifact experienced. Responses included, one "most of the time," two "about half the time," and seven "sometimes." CRNAs reported how frequently ECG leads required adjusting placement for body habitus, dressings or other reasons after using the intervention tool. Responses included three "most of the time," one "about half the time," and six "sometimes." With respect to how likely the CRNA was to use the ECG lead placement tool in the future, responses included two "extremely likely," three "somewhat likely," and five "neither likely nor unlikely."

Next, accessibility to the ECG reference guide was assessed. When described as easily accessible, responses included eight "strongly agree," and two "somewhat agree." The survey asked how often the CRNA used the ECG lead placement tool in practice. Responses included two "always," five "most of the time," two "about half the time," and one "sometimes." Data was gathered about how much additional time it took to reference the ECG lead placement guide, with responses including eight "less than 1 minute," and two "1-2 minutes." When asked if they perceived that the ECG lead placement tool improved the quality of care he or she delivered, responses included two "strongly agree," six "somewhat agree," one "neither agree nor disagree," and one answer left blank.

Figure 2

Confidence Placing ECG Leads in Listed Positions, Post-Intervention (n=10)



In the post-intervention survey CRNAs were asked if, after using the ECG lead placement tool, they felt an annual continuing education (CE) module to refresh them on proper ECG lead placement would be beneficial. Responses included seven “yes,” and three “maybe.” Finally, a free-response item was provided for any suggestions or feedback the CRNAs wished to provide. Only three participants left responses; each indicated adjustments required for surgery would have been more useful than standard alternative positions. Responses included: “What about adjusting leads as required for different surgeries. Would have been an extremely relevant issue to address”; “Alternate locations for surgical procedures would have been more helpful”: and “What about limitations for various surgeries?”

The question represented in Figures 1 and 2 encapsulates the core of the project and broadly represents the perceived accuracy of ECG leads placed by CRNAs prior to and two weeks after using the educational tool.

Analysis

Through data analysis of survey results, inconsistencies in ECG lead placement and a lower level of confidence in placing ECG leads were identified. This findings were unexpected from well-trained anesthesia providers, especially when considering that almost all CRNAs confirm receiving formal training in ECG lead placement. Survey respondents are having to adjust ECG lead placement to avoid artifact and poor morphology regularly, and all indicated receiving patients from other disciplines with inappropriately placed ECG leads. All CRNAs responded that they felt their quality of care could be improved to some degree with more accurate ECG lead placement.

After the intervention, confidence levels regarding ECG lead placement were higher in each position, though CRNAs still indicated having to move ECG leads for various reasons with some regularity. All respondents agreed that the intervention tool was easily accessible and added minimal time to their daily routine. Most CRNAs agreed that the ECG education tool improved the quality of care they delivered their patients and believed that an annual ECG refresher module would be beneficial to them and their patients.

From the results of the pre-intervention survey, it was suggested that CRNAs at this institution believed that inaccurate ECG lead placement is a problem within their own discipline as well as with other professionals from whom they receive patients. It appears that even with formal training, their perceived confidence in placing ECG leads correctly is lower than expected. This could perhaps be attributed to a lack of continuing education to maintain the accuracy and level of education once attained. Results from the post-intervention survey results support this hypothesis.

Both surveys had similar results for the frequency with which CRNAs must adjust lead placement to avoid artifact or a poor tracing. There was a reduction, however, in how often CRNAs moved ECG leads to eliminate poor morphology from body habitus, dressings, etc. when comparing the pre-intervention and post-intervention surverys. One explanation for this could be that the biggest barrier to placing ECG leads correctly was limitations produced by the surgical conditions necessary for certain procedures. This may explain why CRNAs were still moving ECG leads for proper monitoring just as frequently, even though the reasons provided in the survey for having to move leads saw a reduction. The free responses in the pre- and post-intervention surveys support this presumption with nearly all indicating that addressing limitations for surgery would have been helpful.

Based on the frequency with which CRNAs used the intervention tool and the time added to use it, it is safe to conclude that an educational module that is easy to access and quick to reference would be welcomed if it improved patient care. Most CRNAs agreed that this ECG education tool improved patient care, and that an annual CE module would be beneficial. The intervention tool appeared to be highly efficacious in improving perceived accuracy of placing ECG leads in the three given positions when comparing pre-intervention to post-intervention results. It is reasonable to conclude this educational tool was successful in improving perceived accuracy of ECG lead placement.

Section V. Implications

Financial and Nonfinancial Analysis

Using data from Rehman and Rehman (2020), the approximate annual cost of inaccurately placed ECG leads in the United States is roughly $3.2 billion. According to the American Hospital Association (2022) there are 6,129 hospitals in the United States. This means that on average each hospital represents an unnecessary cost of $522,108 in healthcare expenses. That cost breaks down to about $10,000 per week. Considering the size and demographics of the partnering institution, it is reasonable to assert that this cost is even higher at this center.

As the focus of this project was CRNAs' utilization of the ECG tool and proper ECG placement, the financial information used to develop a cost/benefit analysis was exclusively based on financial data for CRNAs. While there are a range of salaries, on average a CRNA at this facility makes about $100 per hour worked (Salary.com, 2023). Approximately 80 CRNAs are employed at any one time throughout the year (T. Chabo, personal communication, June 29, 2023). The educational PowerPoint created for this project was seven minutes long. If a similar annual training module were required and employees were compensated for completing it, even if its length were doubled to include additional information to make the module universal for all disciplines, the cost to require CRNAs to complete this would total approximately $2,000 (80 employees paid for 0.25 hours @ $100 per hour).

Additional costs must be considered for the added time to reference the tool and properly apply the ECG leads while in the operating room. While operating room costs can vary widely depending on the complexity of the procedure being performed, an editorial from Macario (2010) found that the average cost per minute in the United States was $62. With all survey participants reporting fewer than two minutes to access the education tool, an approximate cost of $124 can be added for each patient. However, since this is billable time, it is not a true cost to the institution, and is likely trivial in the context of the total cost of a surgical operation. Conservatively, assuming the cost for improper ECG lead placement is only the additional costs of unnecessary diagnostics, the money spent on annual ECG training for CRNAs would pay for itself in less than two days.

Additional benefit can be realized from resources that only require an upfront cost to create. Digital versions of the ECG lead placement and quick reference guides can be produced for a single cost of production, and digitally reproduced indefinitely. As evidence for best practice evolves, digital copies are easy to modify with minimal cost. Digital copies are easily accessible and easily integrated into practice, as evidenced by the survey responses. Digital versions can also be built into the electronic health record charting system or hosted on the organization’s employee intranet. These duties would be performed by existing personnel, so the cost is more difficult to estimate.

The American Hospital Association (2022) reports that the average cost of a single day in the hospital for a North Carolinian in 2020 was $2,528. The cost of a single patient being admitted to the hospital for observation and/or additional testing due to misplaced leads is already greater than the estimated annual cost of the proposed intervention. This is without even considering the incalculable costs of preventing a sentinel event by identifying rhythm changes or myocardial ischemia intraoperatively, both of which rely on properly placed ECG leads.

Finally, litigious costs must be considered. An adverse perioperative cardiac event that went unnoticed due to improper ECG lead placement could be devastating. Although lawsuits are rare, they do occur. Intangible costs can be challenging to estimate. Forfeiting future business from a patient due to an unfavorable visit or complication that should have been avoided is costly. Missing potential revenue from patients who go elsewhere due to reputation is also costly. Additionally, these kinds of errors often come with fines and higher levels of scrutiny from governing organizations.

A major obstacle for implementing and sustaining a change is the pace and production pressure of the operating room. An efficient operating room may account for up to 60% of the revenue for the entire hospital (Chernov et al., 2020). As such, there is production pressure for things to move quickly. Despite this, most CRNAs reported the time spent referencing the tool was less than 1 minute. All reported less than 2 minutes. Presumably, if the tool was more streamlined with workflow and better integrated into the routine of applying monitors this time may be reduced further. Additionally, after a period of consistent use the habit of properly applying monitors should become routine and the annual continuing education module would be sufficient to sustain this practice change. Otherwise, the barriers to accurate application of ECG monitors and tool utilization are minimal. The materials and time to produce the reference guide and continuing education modules would be minimal as the infrastructure and personnel are already in place.

The resources needed to bring this to fruition currently exist in this organization. There are computers in every operating room and throughout each of the pre-operative and post-anesthesia care unit (PACU) patient care areas. An employee intranet contains links to policies and company information. Electronic health record charting is used. A free-to-the-employee company email account is furnished. With these, documents can be hosted digitally and easily disseminated to every employee. The Information Technology department can create a PDF for these purposes. The PDF is also easily viewable on any of the current smartphone offerings.

Printed and laminated copies could be posted in each operating room by the computer and monitoring equipment, as well as pre-operative and PACU holding areas. If copies were laminated for durability, 50 copies would supply all areas mentioned with some extras. A rough estimate of $0.68 per copy totals $34 (FedEx, 2023).

The cost of producing materials needed and implementing this intervention are minute when compared to the potential costs of errors causing unneeded diagnostics, or missing a true change in cardiac functionality. Survey responses indicate the participants agree that the ECG reference tool improved the quality of patient care and that a continuing education module would be beneficial, increasing quality assurance, decreasing absorbable costs, and increasing efficiency from treating patients appropriately. This would represent a marked return on investment.

Implications of Project

Minimum acceptable monitoring in the perioperative period includes continuous ECG monitoring while in the operating room (AANA, 2019; APSF, 1987; ASA, 2020). This expectation cannot properly be met unless the ECG leads are accurately placed to provide accurate monitoring. The literature describes an astounding incidence of inappropriate ECG lead placement, as high as 94.2% (Paget et al., 2019). Survey results from this project confirm those findings, with all participants reporting that they found ECG leads required repositioning at least some of the time.

The current literature suggests accuracy improvements as high as 85% with in-service training and interventions similar to this QI initiative (Medani et al., 2017). Survey results support a drastic increase in perceived accuracy placing ECG leads and a reduction in repositioning leads to ensure accurate monitoring. In a similar QI project, DiLibero et al. (2016)

found that improvement carried forward three months beyond the intervention period. Survey results from this project suggest support that annual continuing education modules for ECG lead placement would increase quality of care delivered to patients. It appears reasonable to conclude that a short educational refresher provides results that last at least three months. Potential improvement in accuracy longer than three months may be realized, and reoccurring annual training may solidify these practices further.

Rehman and Rehman (2020) estimated that extraneous costs due to inaccurate ECG lead placement in the United States tally roughly $10,000 per week per hospital. This was only accounting for direct and measurable expenses, meaning mostly diagnostics performed when not needed. How much more could be saved by identifying a cardiovascular problem that may have otherwise gone unnoticed? The tangible cost for such a catch could be thousands. Early diagnosis and intervention could mean tens, if not hundreds of hours saved on medical visits and treatments. It could mean countless patients realizing a more robust status of health and wellness and a more vibrant and vivacious community. It could mean more revenue and better profit margins for healthcare institutions, which may translate to better salaries and provider to patient ratios for the employees at those facilities.

For the partnering institution on this project, which serves over 20 counties in eastern rural North Carolina, it could mean catching a problem during surgery for a patient that otherwise never visits a healthcare provider. Such a change would shift toward more proactive and preventative care. These may seem like grandiose propositions, but if even one life was impacted by this change the costs, both measurable and immeasurable, would be worth it.

Sustainability

Existing data and materials could be scaled to a facility-wide level for use throughout the partnering institution. As mentioned previously, actual time and investment for the ECG education module and materials could be as little as $2,034 for the CRNA department. Viewed another way, roughly $25.43 per employee. With most employees having lower hourly rates, the cost to extend this training would be substantially lower for other healthcare providers to participate. The responsibility of creating and maintaining digital materials could be absorbed by existing personnel, and uploaded for use on existing digital platforms, representing no real additional cost.

The cost is insignificant, no matter how it is viewed, when compared to the potential and real benefits of having ECG monitoring acutely measured and recorded. Financial barriers should not represent the biggest obstacle to implementation of the materials and training. As noted by Chernov et al., (2018), the operating room is a high-pressure, fast-paced environment. Immaculate performance is not only expected but demanded. What may prove more difficult for system-wide project implementation is the culture shift required to allow accuracy, and ultimately patient safety, to consistently take priority over efficiency and/or productivity. Regarding ECG lead placement, it may be that providers believe accurate monitoring is possible with leads in the general vicinity of proper placement. However, as little as a 2 cm misplaced lead can mimic pathology and display inaccurate results (DiLibero et al., 2016; Kania et al., 2014; Wirt, 2014).

Sustainability would require reframing the perception of ECG monitoring, its importance, its implications for health, and the process needed for obtaining accurate results. Understanding the importance behind change is critical to supporting it. An announcement from leadership could describe the initiative and its implications for the patients, institution, and the institution's mission statement. Healthcare providers commonly enter practice to impact patients' lives for the better. Once the benefits of this intervention were obvious, support should soon be behind it full force.

Dissemination Plan

The data from this QI project was analyzed and a poster depicting a summary of the data was created. Results were shared during a poster presentation to the nurse anesthesia department members and students, with project participants also invited to attend. The final versions of this project paper and the project poster are now hosted by and freely accessible through The Scholarship, ECU's digital repository.

Section VI. Conclusion

Limitations

Limitations for this project included a limited sample size restrained to a single discipline. In the unit where this project was conducted, ECG lead placement is the responsibility of many different providers with widely varied levels of education. To provide a better system-wide picture of need and efficacy, the participant group should be extended. Additionally, a limitation for the project participants, based on free responses in the surveys, is a lack of guidance provided for ECG lead placement related to the specific procedures being performed. Other discipline-specific limitations likely exist that would not be discovered until the sample size included other healthcare providers and patient care settings.

Another potential barrier could be the limited number of survey questions and responses. Perhaps stratifying responses with greater than five Likert scale selections would have provided more insightful information. It is also possible that more helpful information may be discovered if different questions were asked.

Recommendations for Future Implementation and/or Additional Study

Future PDSA cycles of this QI initiative could increase in generalizability by extending the sample size and patient locations to include other specialties within the healthcare umbrella. In many ways, word of mouth can be the best advertising tool. As such, project champions assigned to explain the goals, answer questions, and encourage participation in organic interactions throughout the workday may increase staff involvement and adherence to improving care and following updated guidelines. With perpetual feedback and refinement, granular adjustments could be made to address some of the free response concerns about barriers identified in this iteration.

Despite full participation the sample size for this project was small and should be increased in future implementations. Additionally, a longer period of implementation would allow more opportunity for participants to participate and respond and perhaps provide better insight into efficacy. Although the two-week implementation period provided some insights, a longer timeframe would better demonstrate the likelihood of CRNAs to consistently incorporate these tools in practice. Additionally, crossing interdisciplinary lines with the intervention would allow educational guidance for all regarding proper placement and cause less disruption in patient handoffs due to inappropriately placed ECG leads. Continuity of proper ECG placement for patients across disciplines and throughout the perioperative period would yield better data for efficacy of the educational tools, and presumably increase the quality of care patients receive perioperatively.

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Appendix A

Concept Table

	Concept 1: EKG Lead Placement	Concept 2: Error	Concept 3: Education
Keywords (these are the “normal” words you would use anywhere)	EKG placement	Error	Education
PubMed MeSH (subject heading specific to PubMed)	“Electrocardiography lead“ [MeSH]	None given, N/A	“Education”, “educational status”, “teaching” [MeSH]
CINAHL Subject Terms (Subject headings specific to CINAHL)	Electrodes, Catheter Placement Determination, Electrocardiography	Diagnostic Errors, Treatment Errors	Education; Education, Nurse Anesthesia
Google Scholar	EKG OR ECG AND lead placement	Placement AND error	Education AND EKG OR ECG

Appendix B

Literature Search Log

Search date	Database or search engine	Search strategy	Limits applied	Number of citations found/kept	Rationale for inclusion/exclusion of items
23 Sept, 2022	PubMed	(EKG lead placement) AND (error) (((("electrocardiography"[MeSH Terms] OR "electrocardiography"[All Fields] OR "ekg"[All Fields]) AND ("lead"[MeSH Terms] OR "lead"[All Fields]) AND ("placement"[All Fields] OR "placements"[All Fields])) OR (("electrocardiography"[MeSH Terms] OR "electrocardiography"[All Fields] OR "ecg"[All Fields]) AND ("lead"[MeSH Terms] OR "lead"[All Fields]) AND ("placement"[All Fields] OR "placements"[All Fields]))) AND ("error"[All Fields] OR "error s"[All Fields] OR "errorful"[All Fields] OR "errors"[All Fields])) AND (2010:2022[pdat])	2010-2022	27 results/9 kept	Articles discuss frequency of EKG lead placement, Clinical consequences of lead misplacement, morphology changes with varying placement of specific leads, and comparison of different disciplines with respect to accuracy and consistency of lead placement
23 Sept, 2022	CINAHL	((MH "Electrodes") OR (MH "Catheter Placement Determination") OR (MH "Electrocardiography")) AND ((MH "Human Error") OR (MH "Diagnostic Errors") OR (MH "Measurement Error") OR (MH "Health Care Errors") OR (MH "Treatment Errors"))	2017-2022	107 results/4 kept	Articles discuss a peer-led education process for EKG lead placement, clinical consequences of lead misplacement, and causes of error and artifact
23 Sept, 2022	Google Scholar	(EKG lead placement) AND (error)	2017-2022	About 3,560 results/ reviewed 10 pages of results, 6 kept	Articles discuss incidence of EKG lead misplacement, correct technique and variations, implications and cost of lead misplacement on clinical outcomes

Appendix C

Literature Matrix

Year	Author, Title, Journal	Purpose & Conceptual Framework or Model	Design and Level of Evidence	Setting	Sample	Tool/s and/or Intervention/s	Results
2022	Oh, A., Park, J., Lee, J., Kim, H., Yang, K., Choi, J., Ahn, J., Sung, J., & Lee, S. (2022). Association between perioperative adverse cardiac events and mortality during one-year follow-up after noncardiac surgery. *Journal of the American Heart Association,* 2022;11;e024325.	To assess the long-term implications of adverse cardiac events following noncardiac surgery as new endpoints for research and influencing factors on mortality. No conceptual framework.	Observational Study (Level VI)	Samsung Medical Center, Seoul, Korea.	202,584 surgical patients	Retrospective analysis with chi-square, Fisher's exact test, Mann-Whitney test and Cox regression analysis to assess mortality at 1-year and 3-year intervals after surgery.	Adverse cardiac events in noncardiac surgery are correlated with higher mortality rates at both 1-year and 3-year postoperative intervals. Arrhythmias were the most common adverse cardiac event underscoring the importance of accurate ECG monitoring.
2020	Giannetta, N., Campagna, G., Di Muzio, F., Di Simone, E., Dionisi, S., & Di Muzio, M. (2020). Accuracy and knowledge in 12-lead ECG placement among nursing students and nurses: a web-based Italian study. *Acta bio-medica, 91*(12-S), e2020004.	Survey to evaluate degree of accuracy and knowledge on positioning ECG electrodes for nurses and nursing students. No conceptual framework.	Quantitative pilot with survey (Level VI)	Nurses and nursing students in Italy	484 RNs and nursing students (149 male, 335 female), (337 RN, 97 students)	Multiple choice web-based questionnaire with analysis using multivariate regression and Cronbach's alpha	Existing education for ECG lead placement and clinical significance is lacking. Post-intervention survey demonstrate improvements in both placement and significance
2020	Rehman, M., & Rehman, N. (2020). Precordial ECG lead mispositioning: It's incidence and estimated cost to healthcare. *Cureus, 12*(7), e9040.	To estimate the cost of unnecessary diagnostic tests performed due to misplaced ECG leads and the resulting false ECG. No conceptual framework.	Observational Study (Level VI)	Guthrie Clinic, Robert Packer Hospital, Sayre, USA	9,424 ECGs from 6.417 adult patients	Retrospective analysis of ECG with possibility to be falsely labeled as myocardial infarction and cost estimated with data from other studies on ECG lead misplacement incidence and Medicare reimbursement rates	Using the gross estimated incidence rate of 10.8% for lead misplacement the cost of inaccurate ECG lead placement for the USA would be approximately $3.2 billion

2020	Rjoob, K., Bond, R., Finlay, D., McGilligan, V., Leslie, S. J., Rababah, A., Guldenring, D., Iftikhar, A., Knoery, C., McShane, A., & Peace, A. (2020). Machine learning techniques for detecting electrode misplacement and interchanges when recording ECGs: A systematic review and meta-analysis. *Journal of Electrocardiology, 62*, 116-123.	Perform meta-analysis of the impact of ECG lead misplacement on signals and interpretation and how machine learning can compensate, if possible. No conceptual framework.	Systematic Review (Level I)	Variety of health care venues in systematic review	14 articles met all inclusion criteria and were used for final systematic review and synthesis	Systematic review and meta-analysis of 228 articles from online database search of IEEE, PubMed, and Science Direct. 3 articles were included from additional sources	Machine learning may be able to adapt to a degree of lead misplacement, but algorithms lack ability to provide accurate ECG morphology in every context. This study underscores accurate ECG lead placement as an essential skill
2020	Roy, S., Shah, S., Villa-Lopez, E., Murillo, M., Arenas, N., Oshima, K., Chang, R., Lauzon, M., Guo, X., & Pillutla, P. (2020). Comparison of electrocardiography quality and clinical interpretations using prepositioned ECG electrodes and conventional individual electrodes. *Journal of Electrocardiography, 59*, 126-133.	To determine the accuracy of pre-positioned electrodes compared with individual electrodes to eliminate misplacement error and inconsistency. No conceptual framework.	Comparative analysis (Level IV)	UCLA Medical Center, Division of Cardiology	234 patients in the Emergency Department and cardiac testing lab	Used QT ECG pre-positioned ECG strip to perform side-by-side ECG with individually placed electrodes and had each ECG analyzed by a group of cardiologists to determine accuracy of pre-positioned ECG electrodes	The single-piece, pre-positioned ECG electrodes are clinically equivalent to conventional, individual electrodes and may eliminate user positioning error
2019	Paget, S., & Kilner, T. (2019). 01 Accuracy of ECG chest lead placements by paramedics. *Emergency Medicine Journal, 36(*10), e2-e2.	ECG lead placement on mannequin compared to correct placement with 19mm tolerance for correctness. No conceptual framework.	Observational Study (Level VI)	Emergency Services Show, Birmingham, AL	52 participants	Mannequin-based ECG lead placement measured against Cardiological Science & Technology's Clinical Guidelines to assess accuracy.	Within the emergency services discipline there was high variability with lead placement and low incidence of correct lead placement (5.8%)
2018	Medani, S. A., Hensey, M., Caples, N., & Owens, P. (2018). Accuracy in precordial ECG lead placement: Improving performance through a peer-led educational intervention. *Journal of Electrocardiology, 51*(1), 50-54.	Before and after assessment to evaluate efficacy of an education pilot on ECG lead placement accuracy. No conceptual framework.	Randomized pre/post education comparison for ECG lead placement (Level II)	University Hospital Waterford (Waterford, Ireland) Cardiology Department	100 randomly selected staff members (pre: 56 RNs, 34 MDs, 10 cardiac techs) (post" 75 RNs, 20 MDs, 5 cardiac techs)	Actual ECG lead placement on a mannequin before and after education seminar, followed by accuracy analysis with z-test, Chi test and Bonferroni post hoc correct.	Education effectively raised the rate of accurate ECG lead placement from 10% pre-intervention to 60% post-intervention. Brief education is effective in improving accuracy of ECG lead placement

2018	Walsh, B. (2018). Misplacing V1 and V2 can have clinical consequences. *American Journal of Emergency Medicine, 36,* 865-870.	To present evidence supporting the morphology changes and subsequent erroneous care from misplacement of V1 and V2 ECG leads, especially placement too superiorly. No conceptual framework.	Case presentations demonstrating clinical consequences of misplacing lead V1 and V2 (Level VI)	Bridgeport Hospital, Bridgeport, CT	5 real-life patient scenarios as case studies	ECG tracings are provided from 5 patient encounters in which misplacement caused inappropriate treatment. Each case is discussed and resolution provided with the patient outcomes after proper ECG lead placement	Misplacing V1 and V2 can incorrectly indicate PE, bundle branch blocks, Brugada syndrome, and STEMI. Accurate lead placement is crucial for proper ECG diagnosis and detection of cardiac ischemia
2016	DiLibero, J., DeSanto-Madyea, & O'Dongohue, S. (2016). Improving accuracy of cardiac electrode placement. *Clinical Nurse Specialist, 30*(1), 45-50.	Facilitate sustainable improvement in accuracy of cardiac electrode placement in ICU patients. No conceptual framework.	QI (Level IV)	MICU in Boston tertiary care hospital	62 RNs 12 PCTs 659 ECG placement observations	Excel spreadsheet with data tracking for pre/intra/post intervention of 20-min in-service with hands on education delivered by CNS. Data collection by direct observation and audits. Fisher exact test and XLSTAT to analyze.	At 3 months post intervention, sustained accuracy increased 85% over baseline
2015	Loewe, A., Schulze, W., Jiang, Y., Wilhelms, M., Luik, A., Dössel, O., & Seeman, G. (2015). ECG-Based detection of early myocardial ischemia in a computational model: Impact of additional electrodes, optimal placement, and a new feature for ST deviation. *BioMed Research International, 2015*, Article 530352.	Simulated cross correlation to determine how lead placement can facilitate early detection of ischemia even without ST changes. No conceptual framework.	Quantitative comparison of lead placement and ability to detect a ranging severity of LV ischemia (Level II)	Karlsruhe Institute of Technolog y (Germany)	3 virtual models, 765 different lead locations,	Comparative analysis of detection rates for ischemia of various severity for different thresholds values and ECG lead placement configurations	K point deviation (KPD) alone reduces detection in all scenarios. Additional electrodes can compensate but only when appropriately placed. KPD may be superior to ST segment deviation for ischemia detection
2014	Kania, M., Rix, H., Fereniec, M., Zavala-Fernandez, H., Janusek, D., Mroczka, T., Stix, G., & Maniewski, R. (2014). The effect of precordial lead displacement on ECG morphology. *Medical & Biological Engineering & Computing, 52*(2), 109-119.	Cross correlation to analyze degree of effect on amplitude and frequency of ECG components resulting from inaccurate lead placement. No conceptual framework.	Quantitative comparison of ECG morphology with various led placement (Level II)	General Hospital of Medical University of Vienna (Austria)	60 patients with diagnosed cardiac disease age 38-83	Morphology analysis in 5cm range of correct placement with shape differences analyzed by root-mean-square error and relative variability	V2 > V3 > V1 > V4 for sensitivity to misplacement. V5 and V6 only change amplitude. All misplaced precordial electrodes cause ECG tracing distortions

2014	Wirt, E., Milbrath, C., & Farnsworth, M. (2014). Precordial electrode placement accuracy by nurses in a large midwestern tertiary care hospital. *The Journal of Continuing Education in Nursing, 45*(7), 327-332.	To improve precordial lead placement accuracy in the ICU and progressive care units. No conceptual framework.	QI (Level VI)	ICU and Progressive Care Unit, Mayo Clinic Hospital, Rochester, MN	69 pre-intervention patient audit; 75 post-intervention RNs; 75 patients	Pretest/posttest educational intervention to assess efficacy of a tip card, poster and video presented to increase accuracy/consistency of ECG lead placement. Analysis done via spreadsheets and chi-square	The multimodal educational initiative effectively increased accuracy of ECG lead placement by nurses.
2008	Rajaganeshan, R., Ludlam, C. L., Francis, D. P., Parasramka, S. V., & Sutton, R. (2008). Accuracy in ECG lead placement among technicians, nurses, general physicians and cardiologists: Accuracy in ECG lead placement. *International Journal of Clinical Practice, 62*(1), 65-70.	To determine the reliability of precordial ECG lead placement by health care providers. No conceptual framework.	Observational Study (Level VI)	Six UK hospitals	119 participants (72 MDs, 37 RNs, 10 cardiac techs)	Questionnaire with diagram of a human torso skeleton upon which each participant indicated ECG lead placement location. Results were digitized and analyzed for degree of spread from ideal and location variation	There is substantial variability in ECG lead placement across disciplines and within the same discipline. Leads are frequently misplaced in the same incorrect manner, and some leads are placed incorrectly 84% of the time.

Note: Key to Levels of Evidence: I: Systematic review/meta-analysis of randomized controlled trials (RCTs); II: RCTs; III: Nonrandomized controlled trials; IV: Controlled cohort studies; V: Uncontrolled cohort studies; VI: Descriptive or qualitative study, case studies, EBP implementation and QI; VII: Expert opinion from individuals or groups. Adapted from *Evidence-based practice in nursing and healthcare: A guide to best practice* (4th ed.), by B. M. Melnyk and E. Fineout-Overholt, 2019, p. 131. Copyright 2019 by Wolters Kluwer.

Appendix D

Approval Process Documents

Click "download PDF" to save a copy of this page for your records.
Note: The IRB Office does not maintain copies of your responses.

Below is a summary of your responses

Download PDF

Quality Improvement/Program Evaluation Self-Certification Tool

Purpose:
Projects that do not meet the federal definition of human research pursuant to 45 CFR 46 do not require IRB review. This tool was developed to assist in the determination of when a project falls outside of the IRB's purview.

Instructions:
Please complete the requested project information, as this document may be used for documentation that IRB review is not required. Select the appropriate answers to each question in the order they appear below. Additional questions may appear based on your answers. If you do not receive a STOP HERE message, the form may be printed as certification that the project is "not research", and does not require IRB review. The IRB will not review your responses as part of the self-certification process. For projects being done at [redacted], site support will be required. Please email [redacted] to obtain site support from [redacted]

Name of Project Leader:

Travis Chabo

Project Title:

Quality Improvement DNP Project: Perioperative ECG Lead Placement

Brief description of Project/Goals:

The purpose of this quality improvement project is to assess anesthesia providers' and/or Intensive care nurses' perceived adequacy of a newly developed reference tool for proper ECG lead placement. Process: A quick-reference perioperative guide to proper ECG lead placement, based upon accepted national guidelines, will be developed. Certified Registered Nurse Anesthetists [redacted] [redacted]r will be asked several questions (through Qualtrics) about their perceptions of the adequacy of their current ECG lead placement resources and practice. An educational video about the use of a newly developed reference tool for proper ECG lead placement will be made available to them, and they will be asked to use the reference tool for two weeks. Upon completion of the two-week utilization period, they will be asked to complete a questionnaire about their perceptions of the adequacy of the proper lead placement reference and their current practice. Qualtrics survey software will be used to deliver the intervention link and gather participant perceptions prior to and post implementation of the project. No patient information will be recorded or maintained during this project.

Will the project involve testing an experimental drug, device (including medical software or assays), or biologic?

- ○ Yes
- ● No

Has the project received funding (e.g. federal, industry) to be conducted as a human subject research study?

- ○ Yes
- ● No

Is this a multi-site project (e.g. there is a coordinating or lead center, more than one site participating, and/or a study-wide protocol)?

- ○ Yes
- ● No

Is this a systematic investigation designed with the intent to contribute to generalizable knowledge (e.g. testing a hypothesis; randomization of subjects; comparison of case vs. control; observational research; comparative effectiveness research; or comparable criteria in alternative research paradigms)?

- ○ Yes
- ● No

Will the results of the project be published, presented or disseminated outside of the institution or program conducting it?

- ● Yes
- ○ No

Would the project occur regardless of whether individuals conducting it may benefit professionally from it?

- ● Yes
- ○ No

Does the project involve "no more than minimal risk" procedures (meaning the probability and magnitude of harm or discomfort anticipated are not greater in and of themselves than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests)?

- ● Yes
- ○ No

Is the project intended to improve or evaluate the practice or process within a particular institution or a specific program, and falls under well-accepted care practices/guidelines?

- ● Yes
- ○ No

Based on your responses, the project appears to constitute QI and/or Program Evaluation and IRB review is not required because, in accordance with federal regulations, your project does not constitute research as defined under 45 CFR 46.102(d). If the project results are disseminated, they should be characterized as QI and/or Program Evaluation findings. Finally, if the project changes in any way that might affect the intent or design, please complete this self-certification again to ensure that IRB review is still not required. Click the button below to view a printable version of this form to save with your files, as it serves as documentation that IRB review is not required for this project. 11/17/2022

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Center for Research and Grants [redacted]

Quality Improvement Project vs. Human Research Study Determination Form

This worksheet is a guide to help the submitter to determine if a project or study is a quality improvement (QI) project or research study, is involving human subjects or their individually identifiable information, and if IRB approval as defined by the Health and Human Services (HHS) or Food and Drug Administration (FDA) is required. (For more guidance about whether the activity meets the definition of Human Subjects Research see the IRB FAQs or the Human Subject Research Decision Chart)

Please use Microsoft Word to complete this form providing answers below. For signatures, please hand sign or convert into a PDF file and electronically sign. Once completed and signed please email the form to the [redacted] Center for Research and Grants [redacted] at [redacted] A CRG team member will contact you with the results of their review and may request additional information to assist with their determination. The determination will be made in conjunction with the UMCIRB office.

Project Title: ECG Lead Placement in the Perioperative Period: A Quality Improvement Project		
Funding Source: None		
Project Leader Name: Chad Greene, BSN, SRNA/ Travis Chabo, PhD, CRNA ☐ **Ed.D.** ☐ **J.D.** ☐ **M.D.** ☐ **Ph.D.** ☐ **Pharm.D.** ☒ **R.N.** ☐ **Other(specify):**		
Job Title: ECU SRNA/ECU CRNA Faculty	**Phone:** [redacted]	**Email:** [redacted]
	Primary Contact (If different from Project Leader):	
	Phone: [redacted]	**Email:** [redacted]

Key Personnel/ Project Team members:

Name and Degree:	**Department:** (Affiliation if other than ECU Health)	**Email:**
Chad Greene	ECU Nurse Anesthesia Program	greenec21@students.ecu.edu
Travis Chabo	ECU Nurse Anesthesia Program	chabot14@ecu.edu

Rev 2.2023 Page **1** of **6**

QI/QA Assessment Checklist:

Consideration	Question	Yes	No
PURPOSE	Is the PRIMARY purpose of the project/study to: • IMPROVE care right now for the next patient? OR • IMPROVE operations outcomes, efficiency, cost, patient/staff satisfaction, etc.?	☒	☐
RATIONALE 1	The project/study falls under well-accepted care practices/guidelines or is there sufficient evidence for this mode or approach to support implementing this activity or to create practice change, based on: • literature • consensus statements, or consensus among clinician team	☒	☐
RATIONALE 2	The project/study would be carried out even if there was no possibility of publication in a journal or presentation at an academic meeting. (**Please note that answering "Yes" to this statement does not preclude publication of a quality activity.) **Of note, quality must not be published as if it is research!**	☒	☐
METHODS 1	Are the proposed methods flexible and customizable, and do they incorporate rapid evaluation, feedback and incremental changes?	☒	☐
METHODS 2	Are patients/subjects randomized into different intervention groups in order to enhance confidence in differences that might be obscured by nonrandom selection? (Control group, Randomization, Fixed protocol Methods)	☐	☒
METHODS 3	Will there be delayed or ineffective feedback of data from monitoring the implementation of changes? (For example to avoid biasing the interpretation of data)	☐	☒
METHODS 4	Is the Protocol fixed with fixed goal, methodology, population, and time period?	☐	☒
RISK	The project/study involves no more than minimal risk procedures meaning the probability and magnitude of harm or discomfort anticipated are not greater in and of themselves than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests.	☒	☐
PARTICIPANTS	Will the project/study only involve patients/subjects who are ordinarily seen, cared for, or work in the setting where the activity will take place?	☒	☐

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FUNDING	Is the project/study funded by any of the following? • An outside organization with an interest in the results • A manufacturer with an interest in the outcome of the project relevant to its products • A non-profit foundation that typically funds research, or by internal research accounts	☐	☒

If all of the check marks are inside the shaded gray boxes, then the project/study is very likely QI and not human subject research. Projects that are not human subject research do not need review by the IRB.

In order to assess whether your project meets the definition of human subject research requiring IRB review or may qualify as a quality improvement/assurance activity, please provide the following information:

1. Project or Study Summary:

The purpose of this quality improvement project is to assess anesthesia providers' perceptions of adequacy of a newly developed ECG lead placement guide. A quick-reference (PDF and PowerPoint) guide, based upon accepted national guidelines, will be developed. Anesthesia providers at [redacted] will be asked several questions (through Qualtrics) about their perceptions of the adequacy of their currently used ECG lead placement practice and preparedness for a quality improvement educational process. An educational video about the use of the newly developed ECG lead placement tool will be made available to them, and they will be asked to use the guide for two weeks. Upon completion of the two-week utilization period, they will be asked to complete a questionnaire about their perceptions of the adequacy of the guide. Qualtrics survey software will be used to gather these participant perceptions of acceptability and adequacy of the intervention prior to and post implementation of the project. The only identifying information connected to responses will be the IP address of the computer used for completing each Qualtrics survey. No individually identifiable information will be collected or connected to responses.

a) **The project's primary purpose:** The project will assess the perceived efficacy of an educational PowerPoint presentation and visual ECG lead placement guide as it pertains to the consistent practice of accurate ECG lead placement.

b) **The project design:** The project will consist of a single Plan, Do, Study, Act cycle using a pre- and post-intervention survey design.

c) **Any interaction or intervention with humans:** CRNA participants will be contacted via email and asked to complete a pre-survey and then utilize an informational tool based on current evidence that aligns with practices currently accepted within the facility to support their practice regarding ECG lead placement. After two weeks they will then be asked to complete a post-survey addressing their perceptions of the intervention and their own practice. The primary

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researcher will be available electronically, by phone, or in person to consult with participants as needed.

d) **A description of the methods that will be used and if they are standard or untested.** The intervention for this project will be a newly created informational tool focused on accurate ECG lead placement which is based on current evidence and falls within current accepted practice standards within the facility.

e) **Specify where the data will come from and your methods for obtaining this data -please specify who/where**
(i.e. CRG will provide you with the data, or someone from a specific department will provide you with the data, or you will pull it yourself). Data will be gathered directly from participants through completion of Qualtrics pre- and post-surveys delivered and completed electronically.

f) **Specify what data will be used and any dates associated with when that data was originally collected (i.e Patient Name, Diagnosis, Age, Sex),** ***If applicable, please attach your data collection sheet.*** Aside from participant email and IP addresses, no identifiable data will be gathered. Data of interest is participant opinions and perceptions of practice and the newly developed informational tool.

g) **Where will the data (paper and electronic) for your project be stored? Please specify how it will be secured to protect privacy and maintain confidentiality. For paper data, please provide physical location such as building name and room number and that it will be kept behind double lock and key. For electronic data, please provide the file path and folder name network drive where data will be stored and specify that it is secure/encrypted/password protected. If using other storage location, please provide specific details.** All data will be gathered using Qualtrics survey software then transferred to Excel for analysis. The only identifying information connected to responses will be the IP address of the computer used for completing each Qualtrics survey. No individually identifiable information will be collected or connected to responses. Qualtrics survey software is accessed through ECU and involves multifactorial password protection. Data in Excel will be on a password protected personal laptop. IP addresses will be deleted from Excel files after both surveys are completed

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and analysis of results begins.

h) **Please specify how long data will be stored after the study is complete? (Keep in mind that data collected/generated during the course of the project that includes protected health information (PHI) should have identifiers removed at the earliest opportunity.)** No PHI will be collected for this project. Data will be stored in Qualtrics and in Excel files (de-identified) until student graduation, anticipated to be spring of 2024.

i) **Please specify how the collected data will be used (internal/external reports, publishing, posters, etc.) and list name(s) of person responsible for de-identification of data before dissemination.** The deidentified data will be analyzed with results shared via a poster presentation to the ECU Nurse Anesthesia Program students and faculty, with participants invited to view the presentation remotely. If requested, a presentation of results to the participating department will be provided. Additionally, analysis of results will be addressed in a DNP Project Paper, completion of which is required for program graduation. This paper will be posted in the ECU digital repository, The Scholarship. Chad Greene will be responsible for de-identification of all data prior to dissemination.

Please use this space above or **attach a** separate **summary and/or any other additional documentation describing your project**.

2. If the Primary purpose of your project is for QI, have you obtained approval from the [redacted] operational leader within your department or health system:

☐ **No [STOP. Please contact the appropriate operational leader for approval before proceeding.]**

☒ **Yes** [Please specify here whom and obtain their signature in the signature section below]

DeWayne Byrd

[redacted] Operational Mgr/Leader Name: _________________________

DocuSigned by:

[redacted] __________________________ ____________________

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[redacted] Operational Mgr/Leader Signature Date
(Part 11 Compliant Electronic Signatures Acceptable-i.e. AdobeSign or DocuSign)

Please note:

- By submitting your proposed project/study for QI determination you are certifying that if the project/study is established to qualify as QI project, you and your Department would be comfortable with the following statement in any publications regarding this project: "This project was reviewed and determined to qualify as quality improvement by the [redacted] Center for Research and Grants."
- If you are submitting a Poster to Media Services, you will also need to submit this Quality Determination Form or IRB Approval to Media Services for printing.
- If the [redacted] determines the activity is <u>not</u> human subject research, then any presentation, publication, etc.
  should <u>not</u> refer to the activity as "human subject research," "exempt research," or "expedited research."

Attestation of Understanding

My signature below indicates that I fully understand that HIPAA Privacy standards as they apply to Quality Projects involving Protected Health Information and patient medical records as outlined below.

Under HIPAA's minimum necessary provisions, [redacted] must make reasonable efforts to limit PHI to the minimum necessary to accomplish the purpose of the use, disclosure or request.

Under HIPAA, a Covered Entity (i.e. [redacted]) can disclose PHI to another CE (i.e. BSOM) for the following subset of health care operations activities of the recipient CE without needing patient consent:

- Conducting quality assessment and improvement activities
- Developing clinical guidelines
- Conducting patient safety activities as defined in applicable regulations
- Conducting population-based activities relating to improving health or reducing health care cost

Identified [redacted] healthcare data utilized in this project should not be shared outside of the CE without a fully executed data use/sharing agreement. [redacted] leadership reserves the opportunity to review all articles for

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dissemination/ publication for which [redacted] data has been utilized and that the content is being disseminated in the appropriate manner as a quality initiative, not resembling research in any context.

Feb 12, 2023

Project Leader Signature **Date**

(Part 11 Compliant Electronic Signatures Acceptable-i.e. AdobeSign or DocuSign)

-------------------------------------for [redacted] Use Only-----------------------------

NHSR vs. HSR Determination:

☑ **Not Human Subject Research:** The [redacted] has determined that based on the description of the project/study, approval by the IRB is not necessary. Any changes or modifications to this project may be discussed with the [redacted] at that time to ensure those changes do not elevate the project to human research that would need IRB approval.

☐ **Human Subject Research:** This project/study requires review by the IRB prior to initiation. An application in the electronic IRB submission system should be submitted.

Approval Signatures:

[redacted] **CRG Reviewer:** [redacted] **Date:** 3/6/2023

UMCIRB Office Staff Reviewer: [redacted] **Date:** 3/8/23

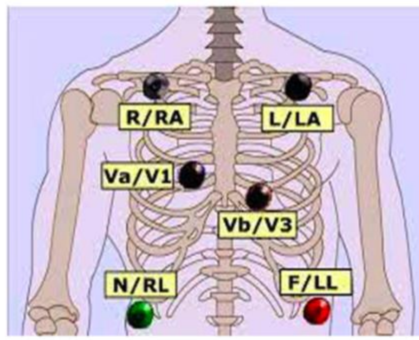
Appendix E

ECG Lead Placement Intervention PDF

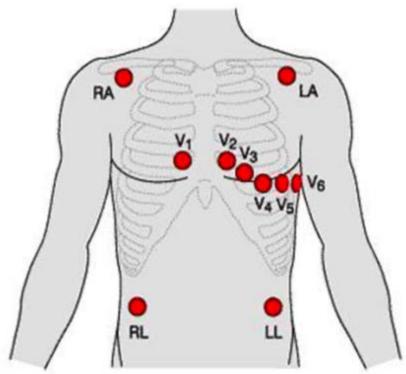
ECU ECG Lead Placement

Stephen Whedbee
Chad Greene
Haley Cutler
Lindsay Wright
College of Nursing,
East Carolina University

Electrode	Color	Position
RA	White	Right Arm
LA	Black	Left Arm
RL	Green	Right Leg
LL	Red	Left Leg
Va/V1	Red	Sternal Edge Right 4th ICS
Vb/V3	Green	Midway between sternal edge Left 4th ICS and MCL Left 5th ICS

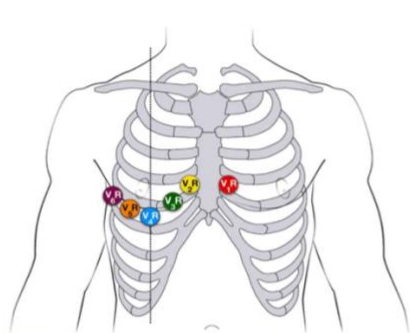


Electrode	Color	Position
RA	White	Right Arm
LA	Black	Left Arm
RL	Green	Right Leg
LL	Red	Left Leg
V1	Red	Sternal Edge Right 4th ICS
V2	Yellow	Sternal Edge Left 4th ICS
V3	Green	Midway between V2 and V4
V4	Blue	Mid-Clavicular Line Left 5th ICS
V5	Orange	Between V4 and V6 Left 5th ICS
V6	Purple	Mid-Axillary Line Left 5th ICS



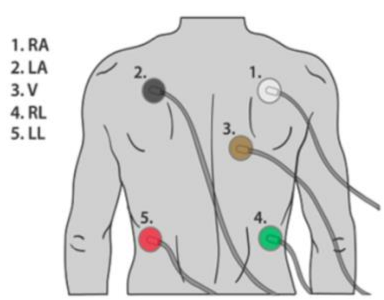
Right-Sided Electrode Placement

- When right sided ischemia is suspected a right sided ECG can be performed for further diagnosis
- A complete set of right sided leads is obtained by placing leads V1-6 in a mirror image position on the right side of the chest
- It can be simpler to leave V1 and V2 in their usual positions and just transfer leads V3-6 to the right side of the chest (i.e. V3R to V6R



Right sided 12 lead ECG lead placement

Prone ECG Lead Placement



Appendix F

ECG Lead Placement PowerPoint Education

ECU

ECG Lead Placement

Stephen Whedbee, BSN, SRNA
Chad Greene, BSN, SRNA
Haley Cutler, BSN , SRNA
Lindsay Wright, BSN, SRNA
College of Nursing,
East Carolina University

Standard and Alternative ECG Lead Placement

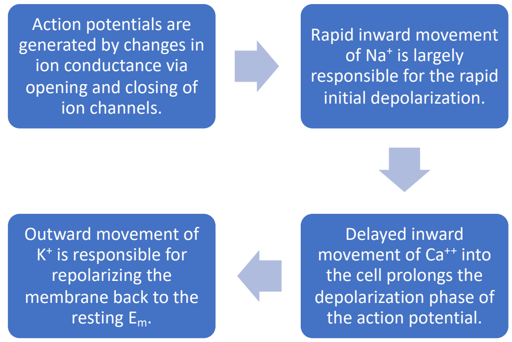
ECU

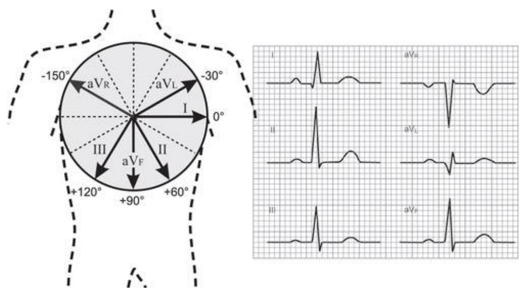
ECG Lead Placement

Stephen Whedbee, BSN, SRNA
Chad Greene, BSN, SRNA
Haley Cutler, BSN , SRNA
Lindsay Wright, BSN, SRNA
College of Nursing,
East Carolina University

Electrophysiology Basics of ECG

- A wave of depolarization traveling toward a positive recording electrode displays a positive voltage on the ECG tracing.
- A wave of repolarization moving away from a positive recording electrode displays a positive ECG voltage.
- The voltage is negative if the depolarization wave is moving away from the positive recording electrodes or a repolarization wave is moving toward the electrode.
- Depolarization or repolarization waves traveling perpendicular to the lead axis of a positive recording electrode display no net voltage.
- The magnitude of the recorded voltage is related to the mass of the muscle undergoing depolarization or repolarization.





ECU

ECG Lead Placement

Stephen Whedbee, BSN, SRNA
Chad Greene, BSN, SRNA
Haley Cutler, BSN , SRNA
Lindsay Wright, BSN, SRNA
College of Nursing,
East Carolina University

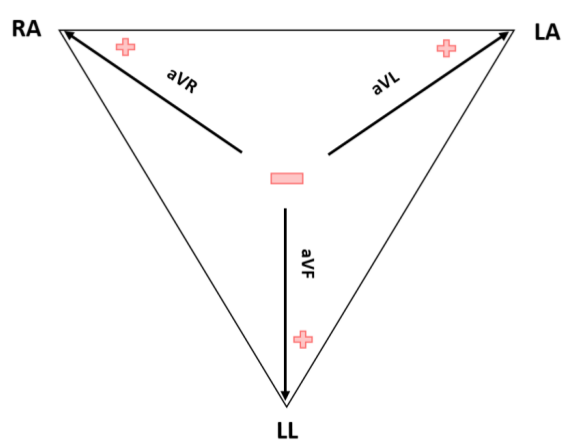
Basics of ECG Monitoring

There are 3 type of leads in typical ECG waveforms:

- Unipolar /Augmented leads
  - aVR, aVL, aVF
- Bipolar leads
  - Lead I, Lead II, Lead III
- Precordial / Chest Leads
  - V1,V2,V3,V4,V5,V6

Lead groupings are based on areas of the heart they examine:

- Inferior: leads II, III, and aVF
- Antero-septal: leads VI and V2
- Anterior: leads V3 and V4
- Lateral: leads I, aVL, V5, and V6



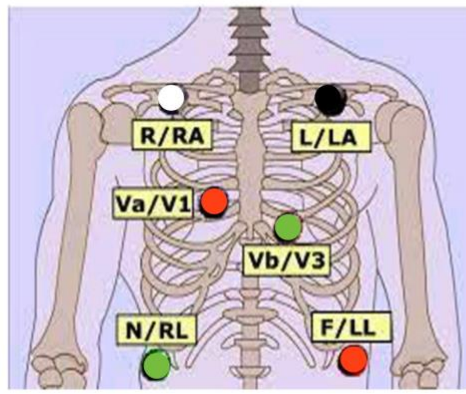
ECU

ECG Lead Placement

Haley Cutler, BSN , SRNA
Chad Greene, BSN, SRNA
Stephen Whedbee, BSN, SRNA
Lindsay Wright, BSN, SRNA
College of Nursing,
East Carolina University

Standard 6-Lead ECG Placement

Electrode	Color	Position
RA	White	Right Arm
LA	Black	Left Arm
RL	Green	Right Leg
LL	Red	Left Leg
Va/V1	Red	Sternal Edge Right 4th ICS
Vb/V3	Green	Midway between sternal edge Left 4th ICS and MCL Left 5th ICS



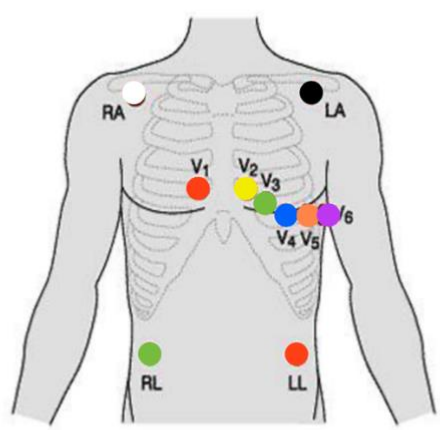
ECU

ECG Lead Placement

Stephen Whedbee, BSN, SRNA
Chad Greene, BSN, SRNA
Haley Cutler, BSN , SRNA
Lindsay Wright, BSN, SRNA
College of Nursing,
East Carolina University

Standard 12-Lead ECG Placement

Electrode	Color	Position
RA	White	Right Arm
LA	Black	Left Arm
RL	Green	Right Leg
LL	Red	Left Leg
V1	Red	Sternal Edge Right 4th ICS
V2	Yellow	Sternal Edge Left 4th ICS
V3	Green	Midway between V2 and V4
V4	Blue	Mid-Clavicular Line Left 5th ICS
V5	Orange	Between V4 and V6 Left 5th ICS
V6	Purple	Mid-Axillary Line Left 5th ICS

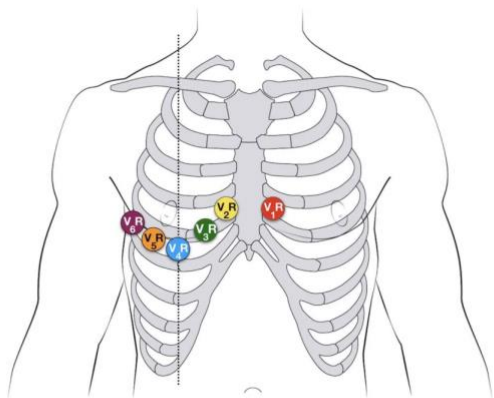


ECG Lead Placement

Stephen Whedbee, BSN, SRNA
Chad Greene, BSN, SRNA
Haley Cutler, BSN , SRNA
Lindsay Wright, BSN, SRNA
College of Nursing,
East Carolina University

Right-Sided Electrode Placement

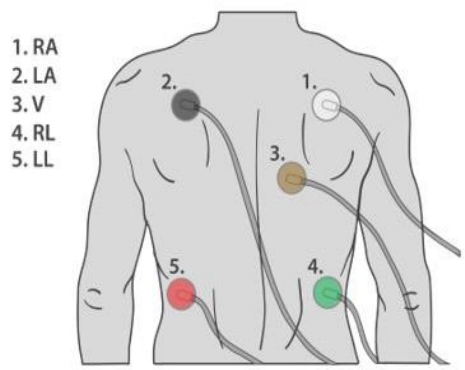
- When right sided ischemia is suspected a right sided ECG can be performed for further diagnosis
- A complete set of right sided leads is obtained by placing leads V1-6 in a mirror image position on the right side of the chest
- It can be simpler to leave V1 and V2 in their usual positions and just transfer leads V3-6 to the right side of the chest (i.e. V3R to V6R



Right sided 12 lead ECG lead placement

Prone ECG Lead Placement

- A prone ECG lead waveform is obtained by placing leads in a mirror image position on the back
- While this is a five-lead tracing, the additional V3 lead may also be utilized in the mirror image position for a 6-lead tracing



ECG Lead Placement Reference Tool

Stephen Whedbee, BSN, SRNA
Chad Greene, BSN, SRNA
Haley Cutler, BSN , SRNA
Lindsay Wright, BSN, SRNA
College of Nursing,
East Carolina University

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Klabunde, R. E. (2017). Cardiac electrophysiology: normal and ischemic ionic currents and the ECG. *Advances in physiology education, 41*(1), 29-37.

Open Critical Care (2022). *ECG lead placement.* https://opencriticalcare.org/wp-content/uploads/2022/04/ECG-Electrode-Placement-rlsyjx.png

The Student Physiologist (2022). *The ECG leads, polarity, and Einthoven's Triangle.* https://thephysiologist.org/study-materials/the-ecg-leads-polarity-and-einthovens-triangle/

Appendix G

Emails to Participants

Dear [redacted]

Thank you for considering participating in a quality improvement project titled "ECG Lead Placement." The purpose of this project is to assess perception of ECG lead placement accuracy and impact of an educational PowerPoint and a visual education tool at [redacted]

Participation is voluntary and will involve completing a short pre-intervention survey, viewing a brief video, utilizing a visual ECG placement guide PDF in your CRNA practice for two weeks (at your discretion), and completing a short post-intervention survey when the two-week implementation period is over.

Each survey and the video should take less than 2-4 minutes to complete. The surveys were created and are completed using Qualtrics® survey software. The use of this visual ECG placement guide PDF falls within currently accepted practice in your work area. Your participation is voluntary and confidential. We will share the results of this QI study with you upon completion.

First, complete the pre-intervention survey:
https://ecu.az1.qualtrics.com/jfe/form/SV_3K4NWv8wASNfqB0

Following completion of the survey, please view the short education powerpoint and visual ECG placement guide PDF which will be distributed by email. A printed copy of this placement guide is also available in the anesthesia workroom.

Again, thank you for your participation in our quality improvement project. I will be at [redacted] if you have any questions. You may also reach out to me or [redacted] by email at any time.

Sincerely,

[redacted]

Hello [redacted],

I just wanted to send a quick reminder about the ongoing DNP Project on ECG Lead Placement (original email below). If you've already filled out the pre-survey and viewed the video, thank you! If you haven't had a chance to do so yet, it's not too late and would be very helpful and much appreciated. There are still printed ECG placement guides in the anesthesia workroom if you haven't already received one. You may use these at your discretion. After the end of next week, I will begin sending out the post-surveys.

Link:
https://ecu.az1.qualtrics.com/jfe/form/SV_3K4NWv8wASNfqB0

Please let me know if you have any questions and thank you again for your participation.

Sincerely,
[redacted]
ECU Nurse Anesthesia Program
Class of 2024

Dear [redacted]

Thank you to everyone who has already completed my pre-survey and viewed the video. It's now time to complete the brief post-survey.

If you have not filled out a pre-survey, I would really and truly appreciate your participation (it's just surveys and a video!). The link to the pre-survey is here, and you can follow it up by watching the introductory PPT. A printed ECG placement guide is available for your use if you would like them, but their use is not mandatory for participation in this project.

If you've already completed the first survey, please complete the post-survey here. It should take less than 2 minutes.

If anyone has questions or issues with any of these links please let me know. Again, thank you to everyone for your help and for being excellent providers. I look forward to working with you again soon.

Sincerely,
[redacted]
ECU Nurse Anesthesia Program
Class of 2024

Appendix H

Pre-Intervention Survey

Q1. Did you receive any formal training in ECG lead placement as part of the onboarding process for your discipline?

- No
- Maybe
- Yes

Q2. How often do you follow a standardized method for applying ECG leads?

- Never
- Sometimes
- About half the time
- Most of the time
- Always

Q3. How confident do you feel placing ECG leads accurately in the following in standard and alternative positions?

	Not at all confident	Somewhat unconfident	Neutral	Somewhat confident	Very confident
Supine	O	O	O	O	O
Prone	O	O	O	O	O
Lateral	O	O	O	O	O

Q4. How often do you experience artifact or incorrect morphology with your current ECG lead placement practice?

- Never
- Sometimes
- About half the time
- Most of the time
- Always

Q5. How often do you adjust ECG lead placement for body habitus, position, dressings, etc. to achieve an acceptable ECG tracing?

- Never
- Sometimes
- About half the time
- Most of the time
- Always

Q6. How often do you receive patients with inaccurate ECG lead placement?

- Never
- Sometimes
- About half the time
- Most of the time
- Always

Q7. Do you believe the quality of patient care could be improved with more accurate ECG lead placement?

- Definitely not
- Probably not
- Might or might not
- Probably yes

○ Definitely yes

Q8. What are any other obstacles to accurate ECG lead placement that you have observed?

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Appendix I

Post-Intervention Survey

Default Question Block

Q1. After using the ECG placement tool, how confident do you now feel placing ECG leads accurately in standard and alternative positions?

	Not at all confident	Somewhat unconfident	Neutral	Somewhat confident	Very confident
Supine	○	○	○	○	○
Prone	○	○	○	○	○
Lateral	○	○	○	○	○

Q2. After using the ECG placement tool, how often do you experience artifact or inaccurate morphology?

- ○ Never
- ○ Sometimes
- ○ About half the time
- ○ Most of the time
- ○ Always

Q3. After using the ECG placement tool, how often do you adjust ECG lead placement for body habitus, position, dressings, etc to achieve an acceptable ECG tracing?

- ○ Never
- ○ Sometimes
- ○ About half the time
- ○ Most of the time
- ○ Always

Q4. How likely are you to continue using the ECG placement tool when applying ECG leads in the future?

- Extremely unlikely
- Somewhat unlikely
- Neither likely nor unlikely
- Somewhat likely
- Extremely likely

Q5. The ECG placement tool was easily accessible.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

Q6. How often did you use the ECG placement tool in your practice since receiving it?

- Never
- Sometimes
- About half the time
- Most of the time
- Always

Q7. About how much additional time did it take to reference this tool in your daily practice?

- Less than 1 minute
- 1-2 minutes
- 3-5 minutes
- More than 5 minutes

- I never used it

Q8. The ECG placement tool improved the quality of care I delivered my patients.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

Q9. After using this reference tool and participating in this QI project, do you feel an annual continuing education module on ECG lead placement would improve patient care?

- No
- Maybe
- Yes

Q10. Please provide any additional feedback or suggestions that haven't been addressed.

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