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Original Research

Improving Compliance With Institutional Performance on Train of Four Monitoring

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Introduction

Train of four (TOF) monitoring plays an important role in assessing the depth of neuromuscular blockade (NMB), in guiding appropriate dosing of neuromuscular blocking agents and their antagonists, and in assessing the adequacy of NMB reversal prior to extubation.[1,2] Appropriate use of TOF monitoring helps prevent the occurrence of residual neuromuscular blockade (RNMB) which can lead to significant respiratory complications, including hypoxemia, airway obstruction, and need for reintubation, as well as increased risk for increased postanesthesia care unit length of stay and critical care admission.[3-5] Neuromuscular monitoring (NMM) by TOF ratio, a quantitative measure of NMB, along with appropriate dosing of neuromuscular reversal, has been shown to reduce the incidence of RNMB and its associated complications when compared to clinical tests and qualitative measures.[1,6-8]

However, even with a large number of publications on this topic, including numerous consensus guidelines recommending qualitative TOF monitoring as a minimum requirement to guide and assess adequacy of reversal,[9-11] the routine application of evidence-concordant NMM remains low, which represents a significant practice gap in the dissemination and implementation of published research. There is also concern that the introduction of sugammadex may be associated with less application of evidence-based NMM. However, after the administration of sugammadex, the rate of RNMB can be as high as 9.4%.[12] As such, based on current evidence, the optimal approach to reducing RNMB is either a graduated dosing of reversal agent when qualitative monitoring is used (ie, peripheral nerve stimulator) or quantitative NMM with goal of TOF ratio of at least 0.9 in all cases in which a NMB agent is used, regardless of what reversal agent is given to the patient.[10]

In light of this evidence, and with a concern that our own practices were not in line with current recommendations, we undertook a multistep quality improvement (QI) project to evaluate and address our current performance in relation to NMM in our department. We designed and tested the use of a novel framework that included the Anesthesiology Performance Improvement and Reporting Exchange (ASPIRE) QI program, a targeted learning module, and a series of surveys to identify facilitators and barriers to department-wide implementation. The aim of this study was to improve our understanding of the facilitators and barriers to increasing the evidence-based use of TOF monitoring in routine clinical practice at our institution.

Materials and Methods

Study Setup

This quasi-experimental QI study was conducted at the Vanderbilt University Medical Center and approved by the Vanderbilt University Institutional Review Board (IRB 210530; Nashville, Tennessee, USA). Requirement for informed consent was waived. Research was conducted in a manner that adheres to the applicable Standards for Quality Improvement Reporting Excellence (SQUIRE) 2.0 reporting guidelines.[13] See Supplemental Online Material, Supplemental Figure 1, for a completed SQUIRE 2.0 checklist. Prior to initiation of this study, we conducted a review from the institutional electronic health record that indicated that our current practices for NMM as a department was concordant with published guidelines only 42% of the time. As a next step of our study, we had defined a structured, multistep process for QI initiatives in our department that follows best practices of a learning health care system.[14] For this study, we chose the topic of monitoring of NMB and the Multi-institutional Perioperative Outcomes Group (MPOG) ASPIRE program metric associated with this (NMB-01). Our institutional performance on NMB reversal and its MPOG ASPIRE program associated metric (NMB-02) was adequate and thus our study did not focus on identifying facilitators and barriers to improving this specific metric. The departmental anesthesia providers included in the QI program are attending physicians, residents, and certified registered nurse anesthetists (CRNAs).[15]

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MPOG ASPIRE QI Program

Participating in the MPOG ASPIRE program provides departmental and provider-level quality performance reports (QPRs) that allow providers to review and improve their performance on quality measures relevant to anesthesia practice.

The MPOG ASPIRE QI initiative created more than 30 measures to track both the processes and outcomes associated with procedures requiring anesthesia. Information on neuromuscular blockade with TOF monitoring (NMB-01), a process measure, is extracted from the anesthesia electronic health record and uploaded on a regular basis to the MPOG ASPIRE QI Coordinating Center Database. NMB-01 is defined as assessing the percentage of operative cases using a nondepolarizing neuromuscular blocker that have a TOF documented after the last dose of neuromuscular blocker and prior to earliest extubation.[16] Cases are classified according to the definition of this process measure as *passed*, *flagged* (measure failed), or *excluded*, and subsequently the performance rates for this process measure are made available through departmental-level and provider-level QPR applications and tools. Based on the definition of NMB-01 and the information received from the MPOG coordinating center, any compliance or noncompliance with the measure will reflect on all providers involved in the care of the patient. The performance target for this measure that has been set by MPOG is ≥90% of included cases passing the metric.

QuizTime: Webapp Educational Platform

QuizTime is a web-based quizzing application (webapp) developed in 2016 at Vanderbilt University Medical Center (Nashville, Tennessee).[17] Online Supplemental Material, Supplemental Figure 2 illustrates QuizTime's learning experience design. QuizTime employs the evidence-based educational concepts of spaced learning, retrieval with feedback, and microlearning.[17,18] The educational content for the MPOG ASPIRE NMB-01 QuizTime module was developed with the help of 8 anesthesia providers (residents, nurse anesthetists, and attending anesthesiologists) who were content experts in NMB agent use, NMM, and NMB agent reversal. We configured the QuizTime application for use with 3 quizzes and 3 populations: (1) a condensed pilot quiz of 20 questions, delivered twice a weekday for 2 weeks for 25 targeted learners for test and feedback; (2) the study quiz of the same 20 questions delivered once per weekday over 4 weeks to a 400-learner population of providers; and (3) a subsequent refresher quiz of 5 questions delivered once a day for 1 week to the combined populations of the pilot and study quizzes. We configured the 3 quizzes in the instructor-led mode, meaning all enrollees were placed into a quiz simultaneously so all learners would begin and end within a specified period.

For each of the 3 quizzes, participants were given 24 hours to answer a question after delivery. The question display showed participants a question stem and 4 possible answers. Participants could select an answer by choosing 1 of the unnumbered and unlettered radio buttons (see Online Supplemental Material, Supplemental Figure 2). A correct or incorrect answer provided participants with either a green or red background, which included the question's key point, rationale, and references. Learners who answered correctly on first attempt were required to read and acknowledge this information in order to receive continuing medical education (CME) credit. Learners who answered incorrectly were provided an immediate second attempt after acknowledging that they had read the rationale and learner material accompanying the question. They had 24 hours to reattempt the question. Upon second attempt, learners were required to reread and acknowledge the question's key point, rationale, and references (see Online Supplemental Material, Supplemental Figure 2).

For the pilot quiz and the study quiz, each question that was submitted, regardless of correctness, counted toward the possibility of continuing education credit. If learners attempted at least 80% of the questions (16 of 20), they could claim 4 credits of either American Medical Association Physician's Recognition Award (AMA PRA) Category 1 Credits (physicians) or Non-Physician Attendance credits (CRNAs) within Vanderbilt University Medical Center's Cloud CME system. The subsequent refresher quiz did not offer the possibility of continuing education credit. Of note, no other educational intervention on NMB use/reversal and TOF monitoring was implemented during the study period and no other incentives or remediations took place regarding this metric over the course of the study period.

Interventions

For the design of this QI study, we adapted the plan-do-study-act (PDSA) framework and implemented 2 PDSA cycles.[19-21] The project timeline is depicted in Figure 1. In this study, several combined pedagogical approaches as described below were taken to test their impact on improving TOF monitoring.

Prior to Phase I (January 29, 2021), we presented a departmental Grand Rounds on the importance and value of TOF monitoring and the relevant MPOG ASPIRE quality metrics. This was followed by Phase I, in which we enrolled 25 anesthesia providers with a variety of clinical experience to participate in a PDSA cycle. The primary interventions used in Phase I were conducted between January 29, 2021 and April 23, 2021 and included: (1) a process by which these participants were familiarized with the MPOG ASPIRE system by receiving MPOG personalized QPRs displaying their performance on NMB-01 compared to their respective peers, (2) access to the ASPIRE dashboard to help them complete a case-by-case review of flagged and excluded cases, and (3) a targeted educational module through QuizTime. The MPOG QPRs were sent via email in the fourth week of the month for January and March 2021 to Phase I providers who treated patients the prior month. These anesthesia provider participants were also given access to the MPOG ASPIRE dashboard, which allowed them the opportunity to perform a review of each case with an indication as to whether the case had been coded as *passed*, *flagged* (measure failed), or *excluded* for the NMB-01 measure. The targeted educational module in Phase I consisted of use of QuizTime, as outlined above.[22] In this phase, 2 multiple-choice questions (MCQs) were sent to participants each weekday over a 2-week period (April 12 – April 23, 2021).

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In Phase II, a second PDSA cycle was undertaken in which we enrolled 400 anesthesia providers from the department that were recipients of the monthly QPR. These providers were given the opportunity to opt out of participating in QuizTime. Phase II began with a preintervention survey being delivered via email on February 19, 2021. The goal of sending out the preintervention survey so early in Phase II was to capture as many responses as possible from a large number of our participating providers. This was followed by the first MPOG QPR being sent out on April 28, 2021. Subsequently, from May 10 through June 4, 2021, a single MCQ was sent each weekday to each anesthesia provider in a similar manner (Figure 1). As Phase II was followed by the start of a new academic year with a new set of anesthesia learners (residents and fellow) and providers, a shorter version of our original QuizTime module with 5 MCQs (termed *Refresher QT*) was administered from Aug 30, 2021, through September 3, 2021, to all anesthesia providers (Figure 1).

Outcomes

Our primary outcome included identifying the facilitators and barriers to implementation of our intervention aimed at increasing TOF monitoring. Data for the primary outcome was gathered via REDCap survey (Vanderbilt University),[23] similar to the approach several other publications have used in identifying facilitators and barriers.[24-26] The survey was distributed both prior to and following the initial set of interventions. The survey included both a set of Likert scale questions on a 4-point scale about perceptions of the ASPIRE QI system as well as open-ended questions designed to gain an understanding of providers' perceived barriers as well as what they believed were the intended results and outcomes of the study (Online Supplemental Material, Supplemental Figure 3). Our secondary outcome was the proportion of patient cases that passed the NMB-01 measure, a documented TOF after the last dose of neuromuscular blocker and prior to earliest extubation, before and after implementation of Phase I and Phase II of PDSA cycle framework.

Qualitative Analysis

Data from REDCap surveys from Phase I and Phase II were analyzed using inductive thematic analysis using the steps outlined by Braun and Clarke.[27] Briefly, these steps include becoming familiar with the data, systematically generating initial codes based off the most salient features of the data, identifying themes among the code, reviewing the themes, defining and naming the themes, and finally, reporting your findings.[27] Survey responses were systematically coded for features relevant to the question being asked. These codes were then collated into overarching themes, which were more clearly and concisely named.

Statistical Analysis

The proportion of patient cases that passed the NMB-01 measure before and after implementation of Phase I and Phase II interventions was determined and compared using a 2-sample proportion test. All statistical tests were 2-tailed, and statistical signficance was set at $P \leq .05$. All analyses were performed using SPSS statistical software version 28.0 (IBM SPSS for Macintosh, version 28.0, IBM Corp., Armonk, New York).

Results

Phase 1 (PDSA Cycle 1)

This phase began with an anonymous REDCap preintervention survey, followed by the QuizTime learning module and MPOG QPR, and ended with the REDCap postintervention survey (Figure 1). All 25 providers in Phase I completed the preintervention survey. The level of training and years of practice of these 25 anesthesia providers are shown in Table 1.

Thematic analysis of preintervention survey data from Phase I of anesthesia provider attitudes regarding the intended results, barriers to implementation, and important outcomes of implementation of this QI project (Table 2) indicated that intended results were centered on quality of patient care, barriers to implementation largely encompassed issues with technology/equipment and the increased burden placed on providers, and important outcomes were focused on patient outcomes and improving provider knowledge.

All 25 anesthesia providers participated in the process of testing the learning activity provided through the QuizTime application. The delivery method (ie, text, email), quality, and functionality in addition to the content itself were tested. All participants were able to provide immediate feedback to the QuizTime office on how to improve the quality and content of the questions in the learning module. Additionally, attending anesthesiologists were eligible to claim 4 AMA PRA Category 1 Credits, and CRNAs were eligible to claim 4 Non-Physician Attendance credits within the Cloud CME system for attempting 16 or more questions.

In Phase I, the pilot quiz had a 96% active learning population, meaning all but 1 of the 25 enrollees submitted an answer to at least 1 question. At the QuizTime activity-level, on average learners answered the question within 3 hours of receiving it (specifically, 2 hours and 53 minutes). Of the 500 first-attempt question instances delivered, 234 were answered correctly, 99 were answered incorrectly, and 166 were never answered. Of the 99 second-attempt questions sent, 58 were answered correctly, 7 were answered incorrectly, and 34 were never answered. Of the 24 active learners, 45.8% answered 16 or more quiz questions, which gave 11 learners eligibility to claim continuing education credit.

All 25 providers completed the postintervention survey. Thematic analyses of preintervention and postintervention survey data from Phase I resulted in similar themes, as depicted in Table 2.

Phase 2 (PDSA Cycle 2)

As in Phase I, Phase II began with an anonymous REDCap preintervention survey followed by the QuizTime module and MPOG QPR, and then a REDCap postintervention survey. Results from the additional 5-question QuizTime module are also reported in this section. Of the 400 anesthesia providers enrolled in Phase II, we were only able to determine level of training and years in practice for the providers that completed the preintervention survey (n = 222) and postintervention survey (n = 201), shown in Table 1.

Thematic analysis of preintervention survey data from Phase II (n = 222) concerning this

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QI project are shown in Table 2. There were differences observed in the themes resulting from Phase II preintervention survey data compared to Phase I preintervention survey data. Those differences were specifically for the questions focused on intended results of the project and barriers to implementation. Improved knowledge was emphasized as an intended result across the department. Additional areas that were reported as potential barriers to fully implementing best practice for NMM included a fear of loss of individualization due to standardization of patient care plan, differences between the attending overseeing the case and the in-room provider who is making decisions/completing documentation, and the frequency of intraoperative handovers.

During Phase II, 400 anesthesia providers were enrolled in the QuizTime learning module. Similar to Phase I, in Phase II attending anesthesiologist and CRNA participants were eligible to receive CME or Non-Physician Attendance credits, respectively, for opening and answering 16 or more of the 20 questions. The Phase II quiz, 73% (n = 292) of the enrollees attempted at least 1 question and 27% (n = 108) never attempted a question. On average, learners answered questions within about 4.5 hours of them being sent (specifically, 4 hours and 34 minutes). Of the 8000 first-attempt question items delivered in Phase II, 2489 (31%) were answered correctly, 1189 (15%) were answered incorrectly, and 4322 (54%) were never answered. Of the 1189 second-attempt questions sent, 740 (62%) were answered correctly, 106 (9%) were answered incorrectly, and 343 (29%) were never answered. Of the active learners, 45.21% answered 16 or more quiz questions, which gave 132 learners eligibility to claim continuing education credit.

Thematic analysis of postintervention survey data from Phase II (n = 201) of anesthesia provider attitudes are shown in Table 2. The differences observed in the themes resulting from postintervention survey department data compared to postintervention survey pilot data were again seen for the questions on intended results and barriers to implementation. Similar to the preintervention survey department data, there was an increased emphasis placed on improved knowledge as an intended result. However, different from both the postintervention survey pilot data and the preintervention survey department data, there was also an emphasis placed on increased awareness and identification of areas for improvement as being intended results of these interventions. Similar to the preintervention survey department data, barriers to implementation that were noted included differences between the attending overseeing the case and the in-room provider who is actually making decisions/completing documentation. However, different from both the postintervention survey pilot data and the preintervention survey department data, additional barriers to implementation that were noted after department-wide completion of the interventions included increasing expectations placed on providers and lack of applicability of the measures to the case.

The 5-question QuizTime question series implemented at the end of Phase II was used to reinforce the education previously introduced to providers. Of the 191 providers in Phase II that answered any Refresher QT questions, 16.75% answered 1 question, 13.09% answered 2 questions, 16.75% answered 3 questions, 19.90% answered 4 questions, and 33.51% answered 5 questions (Table 3).

Frequency of TOF Monitoring

As seen in Figure 2 and based on the information presented in MPOG ASPIRE dashboard, use of the ASPIRE QI Program framework in combination with a targeted learning module demonstrated an improvement in the TOF monitoring with the performance rate improving from 42% (984/2335) to 56% (1457/2618) of eligible patient cases following the completion of Phase I (an absolute 14% difference; $P < .001$). The performance rate continued to improve over the course of Phase II from 56% (1457/2618) to 65% (1663/2550) prior to the implementation of the 5-question Refresher QuizTime series (9% difference; $P < .001$). By December 2021, we observed an additional improvement in TOF with the performance rate increasing from 65% (1663/2550) to 70% (1853/2666), a 5% absolute difference $P < .001$ (Figure 2). Thus, evidence-concordant TOF monitoring increased from 42% to 70% throughout the overall program (28% absolute difference; $P < .001$).

Discussion

Lack of evidence-based TOF monitoring can increase the risk for RNMB and postoperative respiratory complications even in patients reversed with sugammadex.[12] A gap analysis and needs assessment performed at our institution found that TOF monitoring was evidence-concordant only 42% of the time. Therefore, we sought to identify methods for improving TOF monitoring through a structured QI process. Our major finding is that this structured QI program was associated with a significant increase in the delivery of guideline-concordant patient care across a large anesthesia practice at a quaternary medical center.

To place our findings within prior research in this domain, several studies particularly from Todd et al and Weigel et al must be discussed. Similar to our study, Todd et al found that iterative departmental PDSA cycles that included feedback to the faculty led to an improvement in evidence-based care and patient safety.[28] They concluded that their educational and QI initiatives that spanned a 2-year period resulted in a significant increase in TOF monitoring and a reduction in the incidence of RNMB in the postanesthesia care unit. Our study builds upon theirs in 2 ways. First, it shows that 10 years after their publication, routine care regarding NMM and reversal still needs to be improved. Second, their study included observations from roughly 400 patients over a 2-year period. Our study included information on clinician behaviors from over 10 000 patients in a shorter period. We describe QI processes that can be used at scale to improve NMM through the steps of a learning health care system across a large academic practice.[14] These included leveraging the MPOG ASPIRE system and the QuizTime webapp, which are approaches that could be employed in practice regardless of the practice size because of their automated nature. Weigel et al more recently implemented a single institutional professional practice change initiative that used many interventions

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including monitoring equipment trials, educational videos, placement of quantitative monitors in all anesthetizing locations, electronic clinical decision support with real-time alerts, and also initiated an ongoing professional practice metric all with the goal of attaining TOF documentation ratios greater than or equal to 0.9.[29] The combined effects of implementing each of these interventions was a decrease in postanesthesia care unit length of stay, postoperative pulmonary complications, and hospital length of stay. Similarly, our study used multiple interventions in a combined approach, with our study's primary aim focusing more on gathering feedback from our providers on these interventions opposed to directly assessing short-term and long-term outcomes.

It should be noted that an additional publication from Todd et al of 2 cases with severe postoperative pulmonary complications found that failures in NMM likely led to the untoward outcomes.[30] This is in line with the report from Fuchs-Buder et al related to the POPULAR study that having recommendations in place is not enough, but rather that evidence-based guidelines for NMM and reversal must actually be followed to improve patient safety and reduce harm.[2] These observations clearly highlight the potential risks for a continued failure by some providers to use the available technology and change long-held and dangerous beliefs that such monitoring is unnecessary. This is in line with our findings showing that even after significant improvement in care delivered that was in line with the ASPIRE NMB-01 guideline, we still only reached approximately 70% compliance. These studies and our own finding highlight the fact that there are ongoing challenges for overcoming barriers and creating true organizational learning, and these QI and educational efforts will need to continue until all patients receive evidence-based care. There are several limitations to our study. First, we were not able to determine which of the interventions was most effective in the observed increase in TOF monitoring. That is, we did not test multiple pedagogical approaches against one another and therefore cannot know at this time if traditional approaches (ie, grand rounds presentations), the QuizTime modules, or the combination thereof are needed to realize these changes. As a single-institution study, we did not have a continuous control group.

Second, there is a potential for the Hawthorne Effect.[31] Our providers were notified in advance of the QI program implementation, its purpose, and ensuing interventions. Third, it is possible that some of the observed improvement in TOF monitoring could be accounted for by improved documentation of the process measure without a change in actual clinical performance. Providers may have understood the importance of monitoring TOF without grasping the importance of documentation. Finally, while we observed significant performance improvement over time, we do not know the exact educational dose (ie, number of MCQs), frequency of feedback, or frequency and dose of refresher training that is needed to optimize uptake and change practice.

Future studies will include investigation of factors associated with sustained adherence to MPOG ASPIRE process metrics regarding NMM after implementation of department-wide QI programs, determining the optimal delivery methods of workplace education using QuizTime, and identifying best practices for soliciting engagement and promoting buy-in from a majority of our providers. Follow-up studies will also need to investigate the impact of these interventions on the rate of postoperative respiratory complications.

In conclusion, our study showed an association between the implementation of a structured QI program using a novel educational intervention and improvements in process metrics regarding NMM. However, despite our interventions, perceived barriers to implementation remained and provide guidance for the primary areas on which to focus future QI efforts.

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Abstract

Background: We performed a multistep quality improvement project related to neuromuscular blockade and monitoring to evaluate the effectiveness of a comprehensive quality improvement program based upon the Multi-institutional Perioperative Outcomes Group (MPOG) Anesthesiology Performance Improvement and Reporting Exchange (ASPIRE) metrics targeted specifically at improving train of four (TOF) monitoring rates.

Methods: We adapted the plan-do-study-act (PDSA) framework and implemented 2 PDSA cycles between January 2021 and December 2021. PDSA Cycle 1 (Phase I) and PDSA Cycle 2 (Phase II) included a multipart program consisting of (1) a departmental survey assessing attitudes toward intended results, outcomes, and barriers for TOF monitoring, (2) personalized MPOG ASPIRE quality performance reports displaying provider performance, (3) a dashboard access to help providers complete a case-by-case review, and (4) a web-based app spaced education module concerning TOF monitoring and residual neuromuscular blockade. Our primary outcome was to identify the facilitators and barriers to implementation of our intervention aimed at increasing TOF monitoring.

Results: In Phase I, 25 anesthesia providers participated in the preintervention and postintervention needs assessment survey and received personalized quality metric reports. In Phase II, 222 providers participated in the preintervention needs assessment survey and 201 participated in the postintervention survey. Thematic analysis of Phase I survey data aimed at identifying the facilitators and barriers to implementation of a program aimed at increasing TOF monitoring revealed the following: intended results were centered on quality of patient care, barriers to implementation largely encompassed issues with technology/equipment and the increased burden placed on providers, and important outcomes were focused on patient outcomes and improving provider knowledge. Results of Phase II survey data was similar to that of Phase I. Notably in Phase II a few additional barriers to implementation were mentioned including a fear of loss of individualization due to standardization of patient care plan, differences between the attending overseeing the case and the in-room provider who is making decisions/completing documentation, and the frequency of intraoperative handovers. Compared to preintervention, postintervention compliance with TOF monitoring increased from 42% to 70% (28% absolute difference across N = 10 169 cases; $P < .001$).

Conclusions: Implementation of a structured quality improvement program using a novel educational intervention showed improvements in process metrics regarding neuromuscular monitoring, while giving us a better understanding of how best to implement improvements in this metric at this magnitude.

Keywords: Neuromuscular monitoring, plan-do-study-act, quality improvement

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Figures

Figure 1. *Project timeline. This project timeline outlines plan-do-study-act (PDSA) Cycle I (Phase I) and PDSA Cycle II (Phase II) over the course of January 2021 to June 2021. Over the course of each cycle, 2 Multi-institutional Perioperative Outcomes Group (MPOG) personalized quality performance reports were sent out to participants. A REDCap preintervention survey and a REDCap postintervention survey was sent to participants to complete during both Phase I and Phase II. Lastly, the month-long QuizTime Learning Intervention was implemented for participants in Phase I and Phase II with an additional QuizTime Refresher 5-question set sent out to Phase II participants in September 2021.*

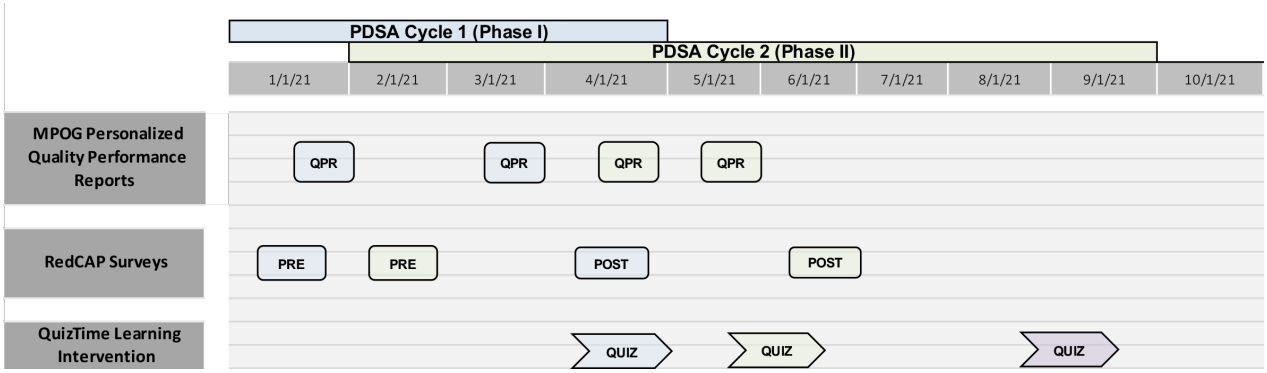
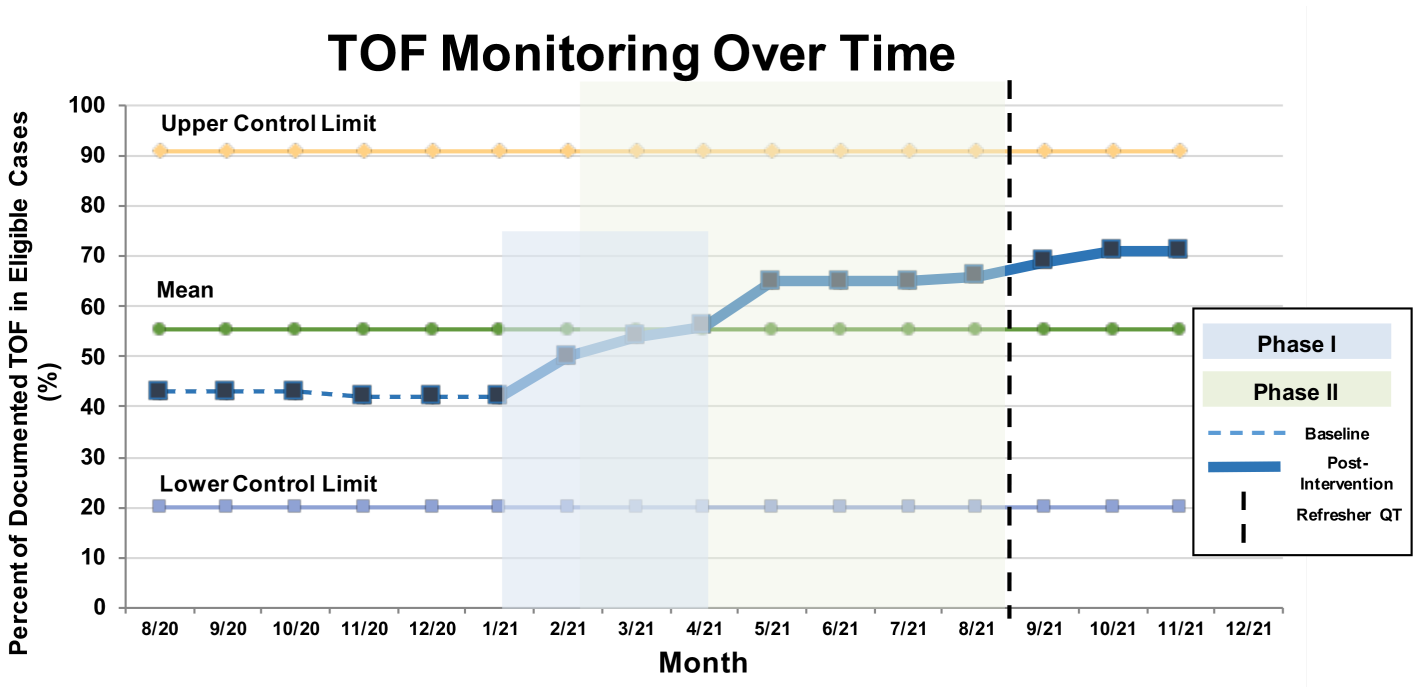


Figure 2. *Train of Four (TOF) monitoring rate over time. TOF monitoring rate increased from baseline (shown as the horizontal dashed line) over the course of Phase I (blue box) and Phase II (green box). The vertical dashed line depicts the time at which the Refresher QuizTime was implemented. The solid line depicts postintervention improvement in TOF, with continued increase after the Phase II was completed.*



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Tables

Table 1. *Phase I and Phase II Demographics*

	Level of Training (%)	Years in Practice/PGY
Phase I (n = 25)		
Attending Anesthesiologist	17 (68.0)	0-5 years: 4
Certified Registered Nurse Anesthetist	4 (16.0)	6-10 years: 6 11-15 years: 3 16-20 years: 4 20+ years: 4
Resident/Fellow Anesthesiologist	4 (16.0)	PGY4: 4
Phase II – Presurvey (n = 222)		
Attending Anesthesiologist	87 (39.2)	0-5 years: 54
Certified Registered Nurse Anesthetist	81 (36.5)	6-10 years: 32 11-15 years: 38 16-20 years: 8 20+ years: 36
Resident/Fellow Anesthesiologist	50 (22.5)	PGY6: 1 PGY5: 9 PGY4: 11 PGY3: 17 PGY2: 11 PGY1: 1
Nonclinical Faculty	4 (1.8)	
Phase II – Postsurvey (n = 201)		
Attending Anesthesiologist	73 (36.3)	0-5 years: 51
Certified Registered Nurse Anesthetist	82 (40.8)	6-10 years: 29 11-15 years: 35 16-20 years: 11 20+ years: 29
Resident/Fellow Anesthesiologist	43 (21.4)	PGY6: 0 PGY5: 12 PGY4: 14 PGY3: 11 PGY2: 6 PGY1: 0
Nonclinical Faculty	3 (1.5)	

Abbreviation: PGY, postgraduate year.

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Tables *continued*

Table 2. *Survey Data Results*[a]

Intended Results	Barriers to Implementation	Intended Outcomes
Phase I: Preintervention Survey and Postintervention Survey Responses Based on Feedback Given by 25 Providers		
• Patient Outcomes • Quality of Patient Care • Patient Safety • Measure of Individual and Departmental Performance • Standardization of Care	• Provider Engagement/Buy-In • Knowledge Gaps • Unavailable or Difficult Using Equipment/Technology • Fear of Punitive Action • Reduced Efficiency • Inaccuracy of Measurement • Email/Feedback Fatigue	• Patient Outcomes • Quality of Patient Care • Patient Safety • Measure of Individual Performance • Standardization of Care • Improved Provider Knowledge
Phase II: Preintervention Survey Responses Based on Feedback Given by 222 Providers		
• Patient Outcomes • Quality of Patient Care • Patient Safety • Measure of Individual and Departmental Performance • Standardization of Care • Improved Knowledge	• Provider Engagement/Buy-In • Knowledge Gaps • Unavailable or Difficult Using Equipment/Technology • Fear of Punitive Action • Reduced Efficiency • Inaccuracy of Measurement • Email/Feedback Fatigue • Loss of Individualization due to Standardization of Patient Care Plans • Decision/Documentation Completed by In-Room Provider • Frequent Intraoperative Handovers	• Patient Outcomes • Quality of Patient Care • Patient Safety • Measure of Individual and Departmental Performance • Standardization of Care • Improved Provider Knowledge
Phase II: Postintervention Survey Responses Based on Feedback Given by 201 Providers		
• Patient Outcomes • Quality of Patient Care • Patient Safety • Measure of Individual and Departmental Performance • Standardization of Care • Improved Knowledge • Identifying Areas for Improvement • Increased Awareness	• Provider Engagement/Buy-In • Knowledge Gaps • Unavailable or Difficult Using Equipment/Technology • Fear of Punitive Action • Reduced Efficiency • Inaccuracy of Measurement • Email/Feedback Fatigue • Decision/Documentation Completed by In-Room Provider • Lack of Applicability • Increasing Expectations Placed on Providers	• Patient Outcomes • Quality of Patient Care • Patient Safety • Measure of Individual and Departmental Performance • Standardization of Care/ Evidence-Based Practice • Improved Provider Knowledge • Identifying Areas for Improvement

[a] Since our approach was inductive (no existing framework was presented to the respondent), themes emerged based on similar responses to open-ended questions, which resulted in multiple themes per respondent. Therefore, the number of respondents was not equal to the number themes produced.

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Tables *continued*

Table 3. *QuizTime Participation Across Phase I and Phase II, including the Refresher QuizTime*

	15 or Fewer Questions (< to 80%)			16 or More Questions (80% to >)	
QuizTime Phase I (n = 25)	54.166			45.833	
QuizTime Phase II (n = 400)	54.79			45.21	
	1 Question	2 Questions	3 Questions	4 Questions	5 Questions
Refresher QuizTime (n = 409)	16.75%	13.09%	16.75	19.90%	33.51%

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Supplemental Online Material

Supplemental Figure 1. *SQUIRE checklist.*

Revised Standards for Quality Improvement Reporting Excellence (SQUIRE 2.0)
September 15, 2015

Text Section and Item Name	Section or Item Description	
Notes to authors	• The SQUIRE guidelines provide a framework for reporting new knowledge about how to improve healthcare • The SQUIRE guidelines are intended for reports that describe system level work to improve the quality, safety, and value of healthcare, and used methods to establish that observed outcomes were due to the intervention(s). • A range of approaches exists for improving healthcare. SQUIRE may be adapted for reporting any of these. • Authors should consider every SQUIRE item, but it may be inappropriate or unnecessary to include every SQUIRE element in a particular manuscript. • The SQUIRE Glossary contains definitions of many of the key words in SQUIRE. • The Explanation and Elaboration document provides specific examples of well-written SQUIRE items, and an in-depth explanation of each item. • Please cite SQUIRE when it is used to write a manuscript.	**As you review the manuscript, place a checkmark in this column for each SQUIRE item that is appropriately addressed in the manuscript. Remember that not every item is necessary in every manuscript.**
Title and Abstract		
1. Title	Indicate that the manuscript concerns an initiative to improve healthcare (broadly defined to include the quality, safety, effectiveness, patient-centeredness, timeliness, cost, efficiency, and equity of healthcare)	✓
2. Abstract	a. Provide adequate information to aid in searching and indexing b. Summarize all key information from various sections of the text using the abstract format of the intended publication or a structured summary such as: background, local problem, methods, interventions, results, conclusions	✓

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Supplemental Online Material *continued*

Supplemental Figure 1. *continued*

Introduction	*Why did you start?*	
3. Problem Description	Nature and significance of the local problem	✓
4. Available knowledge	Summary of what is currently known about the problem, including relevant previous studies	✓
5. Rationale	Informal or formal frameworks, models, concepts, and/or theories used to explain the problem, any reasons or assumptions that were used to develop the intervention(s), and reasons why the intervention(s) was expected to work	✓
6. Specific aims	Purpose of the project and of this report	✓
Methods	*What did you do?*	
7. Context	Contextual elements considered important at the outset of introducing the intervention(s)	✓
8. Intervention(s)	a. Description of the intervention(s) in sufficient detail that others could reproduce it b. Specifics of the team involved in the work	✓
9. Study of the Intervention(s)	a. Approach chosen for assessing the impact of the intervention(s) b. Approach used to establish whether the observed outcomes were due to the intervention(s)	✓
10. Measures	a. Measures chosen for studying processes and outcomes of the intervention(s), including rationale for choosing them, their operational definitions, and their validity and reliability b. Description of the approach to the ongoing assessment of contextual elements that contributed to the success, failure, efficiency, and cost c. Methods employed for assessing completeness and accuracy of data	✓
11. Analysis	a. Qualitative and quantitative methods used to draw inferences from the data b. Methods for understanding variation within the data, including the effects of time as a variable	✓
12. Ethical Considerations	Ethical aspects of implementing and studying the intervention(s) and how they were addressed, including, but not limited to, formal ethics review and potential conflict(s) of interest	✓

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Supplemental Online Material *continued*

Supplemental Figure 1. *continued*

Results	*What did you find?*	
13. Results	a. Initial steps of the intervention(s) and their evolution over time (*e.g.*, time-line diagram, flow chart, or table), including modifications made to the intervention during the project b. Details of the process measures and outcome c. Contextual elements that interacted with the intervention(s) d. Observed associations between outcomes, interventions, and relevant contextual elements e. Unintended consequences such as unexpected benefits, problems, failures, or costs associated with the intervention(s). f. Details about missing data	✓
Discussion	*What does it mean?*	
14. Summary	a. Key findings, including relevance to the rationale and specific aims b. Particular strengths of the project	✓
15. Interpretation	a. Nature of the association between the intervention(s) and the outcomes b. Comparison of results with findings from other publications c. Impact of the project on people and systems d. Reasons for any differences between observed and anticipated outcomes, including the influence of context e. Costs and strategic trade-offs, including opportunity costs	✓
16. Limitations	a. Limits to the generalizability of the work b. Factors that might have limited internal validity such as confounding, bias, or imprecision in the design, methods, measurement, or analysis c. Efforts made to minimize and adjust for limitations	✓
17. Conclusions	a. Usefulness of the work b. Sustainability c. Potential for spread to other contexts d. Implications for practice and for further study in the field e. Suggested next steps	✓
Other information		
18. Funding	Sources of funding that supported this work. Role, if any, of the funding organization in the design, implementation, interpretation, and reporting	✓

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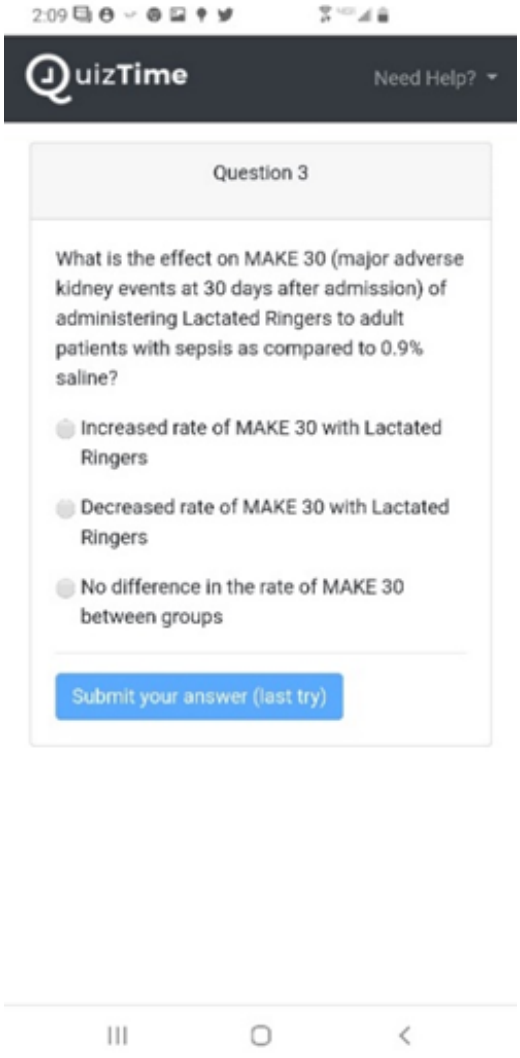
Supplemental Online Material *continued*

Supplemental Figure 2. *Learning experience design (LDX).*

Learner received a question



If answered correctly, learner receives an abbreviated rationale with references

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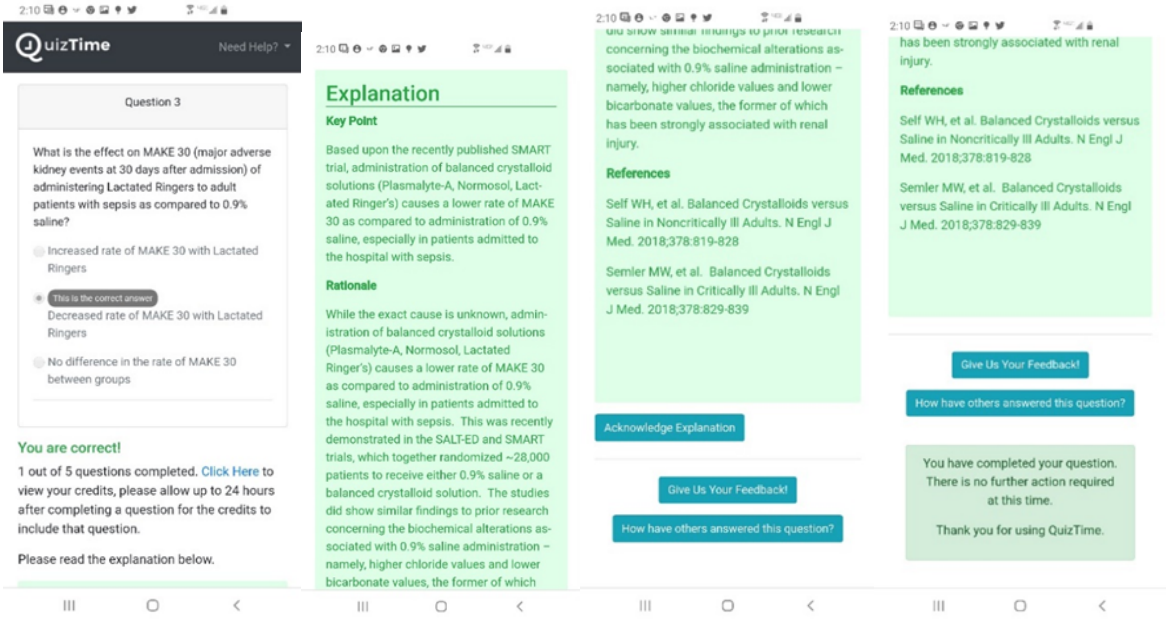
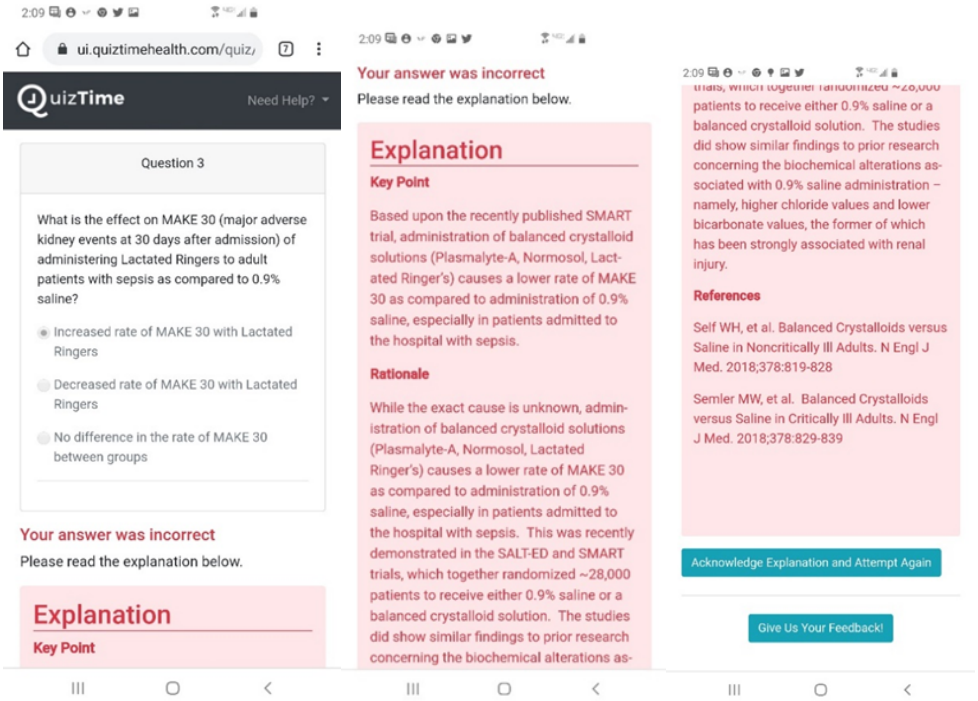
Supplemental Online Material *continued*

Supplemental Figure 2. *continued*



If answered incorrectly, learner receives an abbreviated rationale with references and is provided a second attempt to answer correctly.



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Supplemental Online Material *continued*

Supplemental Figure 3. *REDCap Preintervention Survey and Postintervention Survey.*

ASPIRE Quality Improvement Program_Department

Please answer the following questions regarding your expectations surrounding the Anesthesiology Performance Improvement and Reporting Exchange (ASPIRE) Quality Improvement Program. (The topic for the 1/29/2021 Grand Rounds presentation "DO LET METRICS IMPROVE AND REINFORCE YOUR PRACTICE: the Multicenter Perioperative Outcomes Group (MPOG) & The Anesthesiology Performance Improvement and Reporting Exchange (ASPIRE) Measures")

	Strongly Agree	Agree	Disagree	Strongly Disagree
Monthly emails summarizing my patient outcomes should be a key component of reflecting on my clinical decisions.	○	○	○	○
Personalized provider feedback is essential to helping me improve my clinical decision making.	○	○	○	○
A personalized quality measure dashboard of patient outcomes and process measures is a key component in improving patient safety.	○	○	○	○
A quality measure dashboard of departmental performance is a useful tool for improving patient outcomes and process measures.	○	○	○	○

The most effective method for teaching/reinforcing best practices for anesthesia providers is:
(You may choose more than one)

- ☐ formal didactic lectures such as Grand Rounds
- ☐ online videos/modules in Learning Management System
- ☐ small group instruction
- ☐ case based learning exercises/Journal Club
- ☐ simulation
- ☐ multiple choice questions/QuizTime
- ☐ other
(method)

You chose "other" in the question above, please explain.

_____
(other)

In your own words, please describe what you understand is the intended result of the implementation of the ASPIRE Quality Improvement Program.

_____

Please review the example of the MPOG ASPIRE provider feedback report, in order to complete the questions that follow.

[Attachment: "MPOG_Provider_Feedback_Email_Example.pdf"]

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Supplemental Online Material *continued*

Supplemental Figure 3. *continued*

Based on your review of the personalized MPOG ASPIRE provider feedback report, please answer the questions below.

	Strongly Agree	Agree	Disagree	Strongly Disagree
The general purpose of the email is clear.	○	○	○	○
The instructions to login to the reporting website are clear.	○	○	○	○
It is clear where to navigate to in order to locate FAQs.	○	○	○	○
It is clear to me where I should navigate in order to submit a question.	○	○	○	○

Please chose your role.

- ○ Attending physician
- ○ Certified Registered Nurse Anesthetist
- ○ Resident/Fellow
- ○ Student Registered Nurse Anesthetist
- ○ Other

You chose other, please describe your role.

_____

Please choose the number of years you have been in practice.

- ○ 0-5
- ○ 6-10
- ○ 11-15
- ○ 16-20
- ○ 20+

Please choose your year of training.

- ○ PGY1
- ○ PGY2
- ○ PGY3
- ○ PGY4
- ○ PGY5
- ○ PGY6

Please choose your year of training.

- ○ Junior
- ○ Senior

Please select the service area(s) where you typically provide patient care.
(Choose all that apply)

- ☐ Adult Cardiac
- ☐ Ambulatory
- ☐ Critical Care
- ☐ Obstetrics
- ☐ Pain
- ☐ Pediatric Anesthesia
- ☐ Pediatric Cardiac
- ☐ Multi-Specialty Anesthesia
- ☐ Neuroanesthesia

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Supplemental Online Material *continued*

Supplemental Figure 3. *continued*

The measures below have been chosen for our department ASPIRE Quality Improvement Program. After reviewing the list, please asnswer the questions below.

Adult:
Neuromuscular monitoring (Train of Four, Reversal Administered)
Temperature (Temperature Vigilance-Active Warming; Thermoregulation Monitoring-Core Temperature)
Pain Management (Opioid Equivalency)
Glucose Management (High Glucose Treated Intraop; Low Glucose Treated Intraop)
Blood pressure (Low MAP Prevention < 55 mmHg; Low MAP Prevention < 65 mmHg)
Transfusion (Overtransfusion)
Acute Kidney Injury

Pediatric:
Neuromuscular monitoring (Reversal Administered)
Temperature (Perioperative Hypothermia)
Pain Management (Peds: Multimodal Analgesia)

Please list what you believe to be the top 3 barriers/challenges to successful implementation of the ASPIRE Quality Improvement Program at VUMC/VCH. _____

Please list what you believe would be the top 3 most important outcomes that would be gained from successful implementation of the ASPIRE Quality Improvement Program at VUMC/VCH. _____