Implementation of a Cognitive Aid to Optimize Neuromuscular Blockade Reversal

Karli D. Bodine

Under Supervision of

Richard P. Conley

Second Reader

Yanka Cambell

A DNP Project Manuscript
Submitted in Partial Fulfillment of the Requirements for the
Doctor of Nursing Practice Degree

School of Nursing, University of Maryland at Baltimore
May 2024

Author Note

There is no conflict of interest to disclose.

Correspondence concerning this manuscript should be addressed to Karli Bodine.

E-mail: karli.bodine@umaryland.edu

Abstract

Problem The introduction of sugammadex at a rural hospital in Maryland led to a noticeable rise in the expense to pharmacologically reverse neuromuscular blockade. As sugammadex was used in more than half of the cases involving rocuronium administration (52%), the Anesthesia Department was urged to explore cost-saving measures. **Purpose** The purpose of this quality improvement project was to develop and implement an evidence-based cognitive aid to assist anesthesia providers in selecting reversal agents for neuromuscular blockade, while decreasing cost and improving patient outcomes. **Methods** A cognitive aid on neuromuscular blockade reversal was tailored to the needs of the institution. Using either qualitative or quantitative measures of blockade depth, reversal agent and dose were recommended. The cognitive aid was placed within each operating room (n=10). Data collection was performed using staff surveys, in addition to weekly anesthesia records and monthly pharmaceutical reports. Run chart analysis was performed. The primary outcome was compliance to the cognitive aid self-reported by anesthesia providers (n=23) and through review of anesthetic records (n=884). Secondary outcomes included the number of anesthesia providers educated (n=53) and total number of sugammadex administrations. **Results** The pre-implementation monthly average of sugammadex administrations was 330. In-person education was received by 22 anesthesia providers (42%). Baseline data from anesthesia records showed 57 of 104 cases were compliant to the cognitive aid (M=55.4%). Following implementation, preliminary reported compliance by anesthesia providers was 100%. Anesthesia records showed lower compliance, with 483 of 774 cases following recommendations (M=62.4%). While these records showed lower than reported compliance, there was overall increased compliance following implementation. The average number of sugammadex administrations increased, with a post-implementation average of 355

per month. **Conclusions** Findings suggest using a cognitive aid to guide the selection of reversal agents was associated with improved decision-making regarding the appropriate reversal agent without compromising patient safety. However, monthly sugammadex administrations were increased. The institution should continue to explore strategies for cost-effective neuromuscular blockade reversal while considering cognitive aid compliance, patient safety and financial implications.

*Keywords***:** Neuromuscular blockade reversal, sugammadex, cognitive aid

Implementation of a Cognitive Aid to Optimize Neuromuscular Blockade Reversal

Background and Significance of Problem

Every year, 15 million Americans have surgery, with safe and optimal surgical conditions frequently requiring neuromuscular blockade (NMB) (American College of Surgeons, 2023). Non-depolarizing neuromuscular blocking agents (ND-NMBA) (e.g., rocuronium and vecuronium) are the primary agents administered to facilitate endotracheal intubation and maintenance of anesthesia (Clar & Liu, 2022). ND-NMBA can be reversed by: 1) adequate metabolism, 2) administration of an acetylcholinesterase (AchE) inhibitor (e.g., neostigmine), or 3) administration of a selective relaxant binding agent (i.e., sugammadex) (Sun et al., 2021).

Neostigmine has been used to reverse the effects of ND-NMBA since the 1930s, but recently sugammadex was introduced (Lauretti, 2015). Neostigmine competitively antagonizes AchE, resulting in an increased concentration of acetylcholine at the neuromuscular junction, allowing for skeletal muscle contraction (Nagelhout & Elisha, 2018). The diffusion of sugammadex into U.S. hospitals occurred following FDA approval in 2015 (Merck & Co, Inc., 2022). Sugammadex forms a 1:1 complex with aminosteroid ND-NMBA, therefore reducing the concentration available to antagonize nicotinic acetylcholine receptors (Merck & Co, Inc., 2022). A limiting factor for sugammadex use is cost. A patent on generic formulations of sugammadex is active until 2026 (*Generic Bridion Availability*, 2022). In 2021, global sales for sugammadex were in the top 5 medication expenses, reaching $1.5 billion (Rebo & Read, 2022).

A community hospital in rural Maryland offers a broad range of surgical specialties. The hospital currently has neostigmine and sugammadex available to anesthesia providers without restrictions. An internal review of 75 cases where rocuronium was administered showed sugammadex was administered in half of the cases (52%). Favorable pharmacological properties

of sugammadex include single vial administration, rapid onset, and efficacy in reversing deep blockade with improved patient outcomes (Ledowski et al., 2021). A root cause analysis (Figure 1) identified no recommendations existed for NMB reversal at this organization.

A report from the Pharmacy Department showed reversal with sugammadex costs 10 times more than neostigmine. The maximum dose of neostigmine costs 7 dollars. One vial of sugammadex (200mg/2ml) costs 72 dollars, with some patients requiring multiple vials to adequately dose per patient weight. A complete cost comparison can be found in Table 1. Despite increased cost, anesthesia providers frequently select sugammadex for pharmacologic NMB reversal. Due to increased hospital costs, the organization hoped to reduce sugammadex use.

The purpose of this quality improvement (QI) project was to increase compliance with an evidence-based approach to reversal of NMB, leading to decreased sugammadex administrations and associated cost. Prior to reversing NMB, anesthesia providers would review the cognitive aid on NMB reversal to determine the most appropriate agent to administer based on assessed neuromuscular blockade depth. Sugammadex administration was indicated only if the patient sustained a moderate to deep blockade, indicated by a train-of four (TOF) count of two or less. If neurostimulation resulted in return of the third twitch (i.e., light blockade), neostigmine should be administered.

Specific Aims and Available Knowledge

A literature review to identify evidence-based indications for sugammadex and neostigmine was completed. Multiple randomized control trials (Level IA) were appraised, with a combination of experimental (Level I-IIA) and nonexperimental (Level IIIA-B) studies selected (*JHNEBP Appendix C: Evidence Level and Quality Guide*, n.d.). Newly published clinical practice guidelines from the American Society of Anesthesiology were included as

supportive evidence (Level IVA) (*JHNEBP*, n.d.). Evidence showed equal efficacy among sugammadex and neostigmine for reversal of light NMB (i.e., TOF 3/4) (Fiorda Diaz et al., 2022). However, for moderate (i.e., TOF 2/4) or deep blockade (i.e., 1-2 post-tetanic counts), sugammadex has superior efficacy (Fiorda Diaz et al., 2022; Ledowski et al., 2021). One study found implementation of a cognitive aid for NMB reversal to be associated with decreased sugammadex use and acquisition costs (Drzymalski et al., 2019).

Overall, there was good quality and consistent evidence supporting a practice change to optimize reversal of NMB. The completed evidence appraisal and synthesis are in Table 2 and 3, respectively. Based on this literature review, this quality improvement (QI) project to optimize reversal of NMB through utilization of a cognitive aid on appropriate reversal agents was developed.

Rationale

This QI project adapted the Conceptual Framework of Complex Innovations (CFCI) for implementation. Key constructs of the CFCI (Figure 2) include an innovation fit with user values, management support, champions, resource availability, policy and procedures, and implementation climate and effectiveness (Helfrich et al., 2007). The most important constructs for application of this framework to healthcare were champions and an innovation fit with user values (Helfrich et al., 2007). Key stakeholders from multiple departments were recruited. Anesthesia providers have an innate desire to provide safe and effective anesthesia care to all their patients. Optimization of NMB reversal to promote patient safety was in accord with these values. Adoption of the cognitive aid by individual practitioners was necessary for a successful implementation and a focus of this framework. Further project development was supported by the Revised SQUIRE 2.0 guidelines (Ogrinc et al., 2016).

Methods

Context

Selection of medication to reverse NMB was at the sole discretion of the anesthesia provider. Creating a culture for change within the anesthesia department presented challenges, as the actions of anesthesia providers have a significant and direct impact on patient safety. Residual NMB, defined as train-of-four ratio (TOFR) <0.9, occurs in nearly 40 percent of patients and was a primary concern among anesthesia providers when reversing NMB (Ledowski et al., 2021). Updated neuromuscular monitoring devices (i.e., TwitchView) were purchased by the organization and installed within each operating room (OR). These monitors allowed quantitative measurement of blockade depth, ensuring full reversal of NMB (i.e., TOFR >0.9). The new availability of TwitchView monitors helped guide selection of reversal agent and dose while fostering a culture promoting patient safety. Project team members were early adopters and led by example to inspire colleagues to accept the process change and utilizing the cognitive aid.

Intervention

The team leader used evidence from the literature review to develop a cognitive aid with appropriate reversal agent and dose based on depth of NMB. Components on the cognitive aid included indications for NMB reversal (i.e., TOFR or TOF count) with subsequent recommended NMB reversal agent dosage. A similar cognitive aid can be found in the work by Drzymalski et al. (2019). The “Reversal of NMB” cognitive aid was designed in a user-friendly format, printed, and laminated. The cognitive aid was attached to the TwitchView monitor within each OR.

Cognitive aid approval was obtained by the Chief Anesthesiologist and Nurse Anesthetist. Project go-live occurred on August 28, 2023. An infographic (Figure 3) of project details was distributed, including the Reversal of NMB cognitive aid (Figure 4). The Anesthesia Department

received in-person education on September 7th when project details were presented, and questions answered. The physical structure was changed by placement of project material (i.e., Reversal of NMB cognitive aid and NMB Cognitive Aid Utilization Survey) within each applicable OR. The desired process was for anesthesia providers to review the cognitive aid prior to reversing NMB, assisting them in selection of sugammadex only when indicated based on depth of NMB. Figures 5 and 6 contain old and current process maps.

Collaboration and communication among nurse anesthetists, anesthesiologists, and pharmacists was essential for project success. A strategy to promote accountability was obtaining formal commitment from three Nurse Anesthetists, as they were the primary providers of anesthesia. New implementation of TwitchView monitors encouraged buy-in by providing quantifiable data to support neostigmine use. Data collection required support from multiple team members. Anesthesia providers were requested to complete a survey reporting compliance to the cognitive aid for every case when a ND-NMBA was administered. The lead pharmacist and Epic analyst produced several internal reports for additional data collection. Data collection tools can be reviewed in appendices A-C.

Measures

Three process goals and one outcome goal were measured. To allow descriptive analysis of this QI project, mathematical measurements were taken pre- and post-implementation. Provider education was measured by attendance taken at the in-person education session. The number of anesthesia providers receiving education was compared to the total number of providers within the department. This allowed for the percent educated to be calculated.

Compliance to the Reversal of NMB cognitive aid was measured weekly by two methods. Anesthesia providers were given a quick response (QR) code to report compliance to

the cognitive aid. The number of anesthesia providers who reported compliance was compared to the total number of providers who completed the survey. Self-reporting compliance promoted accuracy, however, required completion by the individual. Monthly reexamination during implementation was required to confirm printed material continued to be present in each OR.

Compliance to the cognitive aid was additionally measured through an internal report generated from anesthetic records. This de-identified report allowed for appropriate administration of sugammadex to be quantified. Using the Reversal of NMB cognitive aid, appropriate sugammadex administration was defined as a TOF count of two or less (i.e., 2/4, 1/4, or 0/4). The incidence of each documented TOF count prior to sugammadex administration was collected. The sum of appropriate sugammadex administration was compared to the total number of sugammadex administrations each week.

Total sugammadex administration was measured with an outcome goal to decrease use by 25%. A monthly report on sugammadex administrations was provided by the Pharmacy Department. This data was de-identified as only the month and number of administrations were collected. The number of sugammadex administrations was compared to the previous month, in addition to the same month in the previous year. These measures have not undergone formal testing and present a limitation to this QI project.

Ethical Considerations

The web-based platform Research Electronic Data Capture (REDCap) was used to ensure confidentiality and data security. Storing data in REDCap ensured confidentiality as its secure platform used VPN with data encryption. Privacy of anesthesia providers was protected by utilization of a QR code for reporting cognitive aid compliance. Use of a QR code allowed

survey completion at a time of their choosing and in a space of their preference. Responses to QR codes were voluntary.

Non-human Subject's Research determination from the Human Research Protections Office of the UMSOM Institutional Review Board was obtained. Endorsement of this QI project was obtained by the organizations Research Review Committee (Study #P23-012). All data collected for this QI project was de-identified. The project lead was solely responsible for data collection. No actual or potential conflicts of interest were identified.

Results

Analytics

Quantitative methods were used to gauge the impact of this QI project. Numerical data stored in REDCap was used for statistical analysis. Graphical analysis with a run chart was used to illustrate this data by plotting the ratio of compliance over time. Throughout implementation, events impacting this QI project were annotated to provide insight for any observed variation. Run charts were analyzed weekly to identify any runs, shifts, trends, or astronomical data points. Based on run chart analysis, inferences were made, and any identification of special cause variation were investigated. Any negative pattern was investigated to identify a potential origin and opportunity for action.

Results

Twenty-two members of the Anesthesia Department (n=53) attended in-person education (41.5%). A visual depiction of this data is found in Figure 7. A total of 23 Cognitive Aid Utilization Surveys were submitted by anesthesia providers. All 23 reported compliance with the cognitive aid (100%). Despite reminding staff to complete surveys in week 9, no

surveys were completed in weeks 10 or 13. Too few runs (n=2) existed for this data set. No shifts or trends were identified through run chart analysis (Figure 8).

Review of anesthesia records on appropriate sugammadex administration resulted in a baseline compliance rate of 55.4%. Increased compliance was identified in week two when in-person staff education was given. Additionally, printed cognitive aids were placed within each OR at this time. Sugammadex administration was documented on 884 patients. Exclusion criteria (i.e., cardiac, thoracic, or off-site anesthesia) were met for 110 patients, leaving 774 included for review. Compliance ranged from 49% in week 7 to 70.7% in week 15. The increased compliance in week 9 was identified following additional education. Run chart analysis did not indicate any shifts or trends (Figure 9). The expected number of runs (n=10) were counted, indicating common cause variation. No astronomical data were identified.

Pre-implementation data showed sugammadex was administered, on average, 330 times per month. Averages ranged from 234 administrations in January to 394 administrations in August. A 25% decrease in monthly sugammadex use would yield a goal of 247 administrations per month. Unexpectedly, monthly sugammadex administrations increased with a post-implementation average increase to 355. Post-implementation monthly averages range from 331 in September to 378 in October. No shifts or trends were identified through run chart analysis (Figure 10). An accepted number of runs (n=7) was identified, indicating common cause variation. One astronomical data point (n=234) was identified in January. A potential explanation for this data is decreased case volume after the start of a new year.

Discussion

Current literature recommends sugammadex administration to reverse the effects NMB, however, neostigmine is a cost-effective alternative when a light blockade is present (Thilen et

al., 2023). A similar study implemented a cognitive aid for NMB reversal, resulting in decreased sugammadex use and associated cost to pharmacologically reverse NMB (Drzymalski et al., 2019). Throughout the course of this QI project, increased compliance to the NMB reversal cognitive aid was identified. Appropriate sugammadex administration was defined by having a documented TOF count of two or less (i.e., 0/4, 1/4, or 2/4) prior to administration (n=483). Inappropriate sugammadex administration was defined as having a documented TOF count of 3/4 or 4/4 (n=291). Based on this TOF count, sugammadex administration is not indicated as the depth of blockade is light and evidence shows neostigmine is equally efficacious. Despite increased compliance with appropriate sugammadex use, an overall increase in the number of sugammadex administration each month was noted.

Several key findings were observed throughout this QI project. Anesthesia providers had a self-reported compliance rate of 100%. If the cognitive aid suggested neostigmine but the provider chose to administer sugammadex, the survey offered a place for the provider to indicate the reason for sugammadex selection. Every submitted survey reported adhering to the cognitive aid, therefore no data was reported on indications for choosing sugammadex if a light NMB was assessed. Review of anesthetic records found compliance to the cognitive aid to be significantly lower than what providers were reporting. Compliance was highest at 70% during weeks 5, 9, and 15, however this is much lower than the 100% reported. One explanation for these differences was due to the small number of anesthesia providers completing the survey each week.

Evidence suggested a cognitive aid would decrease sugammadex administration, however, increased utilization was observed during this QI project. The total number of cases performed each month, specifically the number of cases requiring NMB, was not collected.

Without this data, the percentage of cases when sugammadex was administered could not be calculated. This presents a limitation to the data as case volume could directly impact the number of sugammadex administrations each month. Another limitation was the volume of patients without a documented depth of blockade prior to sugammadex administration. To maintain patient confidentiality, chart review was not completed. The number of cases with high risk patients (i.e, comorbidities and ASA class >4) were unknown, further limiting the data collected as evidence supports sugammadex regardless of blockade depth with high risk patients (Colquhoun et al., 2023).

Conclusions

Increased compliance to an evidence-based approach to reverse NMB was identified following utilization of a cognitive aid to guide NMB reversal. Cognitive aid compliance was reported at 100%, however a limitation to this data is the small number of entries. Through review of anesthetic records, the calculated median was a compliance rate increased from 55.4% to 62.4%. This data indicates sugammadex was appropriately selected as the agent to reverse NMB as the TOF count at time of reversal was 2 or less, indicating moderate to deep blockade. At this level of blockade, the only agent supported by evidence to effectively reverse the effects of NMB is sugammadex, which the anesthesia provider appropriately chose.

Despite increased compliance with the reversal of NMB, this project was associated with increased monthly sugammadex use. Further QI projects could evaluate the percentage of cases administering sugammadex each month. Additionally, they should evaluate and report data on the acuity of patients receiving sugammadex as evidence supports its use in high-risk populations (Colquhoun et al., 2023).

The sustainability of this QI project lies in the continued availability and utilization of the cognitive aid and TwitchView monitors within the Anesthesia Department. A strength of this project is no additional expense is required to continue its use, as anesthesia providers already have a copy of the cognitive aid recommendations. While a focus remains on cost-conscious pharmacologic interventions, patient safety must never be compromised.

References

American College of Surgeons. (2023). *Strong for Surgery*. ACS. https://www.facs.org/for-patients/strong-for-surgery/

Clar, D. T., & Liu, M. (2022). Non-depolarizing Neuromuscular Blockers. In *StatPearls*. StatPearls Publishing. http://www.ncbi.nlm.nih.gov/books/NBK534828/

Colquhoun, D. A., Vaughn, M. T., Bash, L. D., Janda, A., Shah, N., Ghaferi, A., Sjoding, M., Mentz, G., Kheterpal, S., Craft, R., Domino, K. B., Freundlich, R. E., Mathis, M. R., McCormick, P. J., Naik, B. I., Ruiz, J., Schonberger, R. B., Schroeder, R. A., Stewart, A. F., … Vachhani, S. (2023). Association between choice of reversal agent for neuromuscular block and postoperative pulmonary complications in patients at increased risk undergoing non-emergency surgery: STIL-STRONGER, a multicentre matched cohort study. *British Journal of Anaesthesia*, *130*(1), e148–e159. https://doi.org/10.1016/j.bja.2022.04.023

Drzymalski, D. M., Schumann, R., Massaro, F. J., Trzcinka, A., & Azocar, R. J. (2019). Effect of a Cognitive Aid on Reducing Sugammadex Use and Associated Costs: A Time Series Analysis. *Anesthesiology*, *131*(5), 1036–1045. https://doi.org/10.1097/ALN.0000000000002946

Fiorda Diaz, J., Echeverria-Villalobos, M., Esparza Gutierrez, A., Dada, O., Stoicea, N., Ackermann, W., Abdel-Rasoul, M., Heard, J., Uribe, A., & Bergese, S. D. (2022). Sugammadex versus neostigmine for neuromuscular blockade reversal in outpatient surgeries: A randomized controlled trial to evaluate efficacy and associated healthcare cost in an academic center. *Frontiers in Medicine*, *9*, 1072711. https://doi.org/10.3389/fmed.2022.1072711

Generic Bridion Availability. (2022, October 12). Drugs.Com. https://www.drugs.com/availability/generic-bridion.html

He, J., He, H., Li, X., Sun, M., Lai, Z., & Xu, B. (2022). Required dose of sugammadex or neostigmine for reversal of vecuronium-induced shallow residual neuromuscular block at a train-of-four ratio of 0.3. *Clinical and Translational Science*, *15*(1), 234–243. https://doi.org/10.1111/cts.13143

Helfrich, C. D., Weiner, B. J., McKinney, M. M., & Minasian, L. (2007). Determinants of implementation effectiveness: Adapting a framework for complex innovations. *Medical Care Research and Review*, *64*(3), 279–303.

Hurford, W. E., Eckman, M. H., & Welge, J. A. (2020). Data and meta-analysis for choosing sugammadex or neostigmine for routine reversal of rocuronium block in adult patients. *Data in Brief*, *32*, 106241. https://doi.org/10.1016/j.dib.2020.106241

Hurford, W. E., Welge, J. A., & Eckman, M. H. (2020). Sugammadex versus neostigmine for routine reversal of rocuronium block in adult patients: A cost analysis. *Journal of Clinical Anesthesia*, *67*, 110027. https://doi.org/10.1016/j.jclinane.2020.110027

JHNEBP Appendix C: Evidence level and quality guide. (n.d.). Johns Hopkin Hospital/Johns Hopkins University.

Lan, W., Tam, K.-W., Chen, J.-T., Cata, J. P., Cherng, Y.-G., Chou, Y.-Y., Chien, L.-N., Chang, C.-L., Tai, Y.-H., & Chu, L.-M. (2023). Cost-Effectiveness of Sugammadex Versus Neostigmine to Reverse Neuromuscular Blockade in a University Hospital in Taiwan: A Propensity Score-Matched Analysis. *Healthcare*, *11*(2), Article 2. https://doi.org/10.3390/healthcare11020240

Lauretti, G. R. (2015). The evolution of spinal/epidural neostigmine in clinical application: Thoughts after two decades. *Saudi Journal of Anaesthesia*, *9*(1), 71–81. https://doi.org/10.4103/1658-354X.146319

Ledowski, T., Szabó-Maák, Z., Loh, P. S., Turlach, B. A., Yang, H. S., de Boer, H. D., Asztalos, L., Shariffuddin, I. I., Chan, L., & Fülesdi, B. (2021). Reversal of residual neuromuscular block with neostigmine or sugammadex and postoperative pulmonary complications: A prospective, randomised, double-blind trial in high-risk older patients. *British Journal of Anaesthesia*, *127*(2), 316–323. https://doi.org/10.1016/j.bja.2021.04.026

Merck & Co, Inc. (2022). *Bridion (sugammadex)* [Highlights of prescribing information]. https://www.merck.com/product/usa/pi_circulars/b/bridion/bridion_pi.pdf

Nagelhout, J. N., & Elisha, S. (Eds.). (2018). *Nurse Anesthesia* (6th ed.). Elsevier.

Ogrinc, G., Davies, L., Goodman, D., Batalden, P., Davidoff, F., & Stevens, D. (2016). SQUIRE 2.0 (Standards for QUality Improvement Reporting Excellence): Revised publication guidelines from a detailed consensus process. *BMJ Quality & Safety*, *25*(12), 986–992. https://doi.org/10.1136/bmjqs-2015-004411

Personal Communication. (2023, March). *SRNA QI Project* [Personal communication].

Rebo, J., & Read, A. (2022, September 16). Sugammadex: Use criteria optimization and outcomes data evaluation [Pharmacy Times]. *Novant Health*. https://www.pharmacytimes.com/view/sugammadex-use-criteria-optimization-and-outcomes-data-evaluation

Sun, Y., Wu, Z., Wang, Q., Chen, R., Sun, S., & Lin, Y. (2021). Sugammadex, the guardian of deep muscle relaxation during conventional and robot-assisted laparoscopic surgery: A narrative review. *DovePress*, *15*, 3893–3901. https://doi.org/10.2147/DDDT.S328682

Thilen, S. R., Ng, I. C., Cain, K. C., Treggiari, M. M., & Bhananker, S. M. (2018). Management of rocuronium neuromuscular block using a protocol for qualitative monitoring and reversal with neostigmine. *British Journal of Anaesthesia*, *121*(2), 367–377. https://doi.org/10.1016/j.bja.2018.03.029

Thilen, S. R., Weigel, W. A., Todd, M. M., Dutton, R. P., Lien, C. A., Grant, S. A., Szokol, J. W., Eriksson, L. I., Yaster, M., Grant, M. D., Agarkar, M., Marbella, A. M., Blanck, J. F., & Domino, K. B. (2023). 2023 American Society of Anesthesiologists Practice Guidelines for Monitoring and Antagonism of Neuromuscular Blockade: A Report by the American Society of Anesthesiologists Task Force on Neuromuscular Blockade. *Anesthesiology*, *138*(1), 13–41. https://doi.org/10.1097/ALN.0000000000004379

Table 1

Cost Comparison of Reversal Agent

Medication	**Concentration**	**Cost ($)**
Glycopyrrolate	5mg/1ml	4.13
Neostigmine	5mg/10ml	2.93
Sugammadex	200mg/2ml	72.00

Table 2

Evidence Appraisal

Citation #1 Drzymalski, D. M., Schumann, R., Massaro, F. J., Trzcinka, A., & Azocar, R. J. (2019). Effect of a Cognitive Aid on Reducing Sugammadex Use and Associated Costs: A Time Series Analysis. Anesthesiology, 131(5), 1036–1045. https://doi.org/10.1097/ALN.0000000000002946
Level: IIIB

Purpose or Hypothesis	Type of Evidence and Research Design	Sample (population, size, setting)	Intervention Procedures	Primary Outcome/Measures	Results Conclusions
The purpose of this study was to determine if implementation of the cognitive aid resulted in a change in sugammadex use in the OR by performing an interrupted time series analysis. Their hypothesis was that the cognitive aid would decrease sugammadex use in the OR, which would be associated with decreased total acquisition costs of neuromuscular blocking drugs and reversal agents while maintaining safe and timely patient care.	- Cohort - Time series analysis	Sampling technique: Convenience Setting: Urban tertiary care, 415 bed academic medical center Inclusion: all ORs Exclusion: data 1 month after implementation Accepted: 20 months total, 12 prior to and 8 after that received a NMB under GA Control: Pre-cognitive aid period Intervention: Cognitive aid on sugammadex versus neostigmine timing and dosing based on TOF count Power analysis: Interrupted time series analysis for pre- and post-cognitive aid periods and corresponding 95% CI. A formal power analysis was not performed. Previous data showed 8 months prior and after would be sufficient	Cohort 1: Pre-cognitive aid Cohort 2: Post-cognitive aid In operating rooms with a medication dispensing cabinet, the cognitive aid was placed in the same bin as sugammadex and neostigmine. In operating rooms with standard medication sets manually dispensed by the pharmacist, the cognitive aid was included with each medication set containing sugammadex and neostigmine. Fidelity: Reliance on anesthesia providers interpretation of qualitative monitors due to lack of available quantitative monitors at the medical center.	Primary outcome: number of sugammadex administrations Secondary outcomes: total pharmaceutical acquisition costs of neuromuscular blocking drugs and reversal agents, adverse respiratory events, emergence duration, and number of neuromuscular blocking drug administrations.	Cognitive aid implementation to choose between reversal agents was associated with a decrease in sugammadex use and acquisition costs. Implementation of the cognitive aid did not significantly affect the number of adverse respiratory events, emergence duration, or number of administrations of rocuronium, vecuronium, or atracurium. An increased use of succinylcholine was noted.

Citation #2 Lan, W., Tam, K.-W., Chen, J.-T., Cata, J. P., Cherng, Y.-G., Chou, Y.-Y., Chien, L.-N., Chang, C.-L., Tai, Y.-H., & Chu, L.-M. (2023). Cost-Effectiveness of Sugammadex Versus Neostigmine to Reverse Neuromuscular Blockade in a University Hospital in Taiwan: A Propensity Score-Matched Analysis. *Healthcare*, *11*(2), Article 2. https://doi.org/10.3390/healthcare11020240
Level: IIIB

Purpose or Hypothesis	Type of Evidence and Research Design	Sample (population, size, setting)	Intervention Procedures	Primary Outcome/Measures	Results Conclusions
They hypothesized the use of sugammadex could accelerate the patient's emergence from general anesthesia, increasing operating turnover rates and, therefore, reducing total medical costs compared to neostigmine.	- Retrospective analysis of a published RCT	Sampling technique: Convenience Setting: Single medical center in Taiwan Inclusion: elective surgery requiring GA, >20yrs old, pre-anesthesia assessment completed Exclusion: inability to communicate, contraindication to either drug, incomplete medical records, or planned ICU admission needing ventilation Accepted: 2,587 patients resulting in 82 matched pairs Power Analysis: Met - 84 patients are needed in each group to detect a mean difference of 2.7 min in time to extubation between groups Homogeneity: Baseline patient characteristics were compared between groups using the absolute standardized mean difference	Patients were divided into either the sugammadex or neostigmine group. The RCT that was analyzed had two cohorts, the first being classical explanation of NMB reversal or an assisted explanation of NMB options (sugammadex or neostigmine) during the pre-anesthesia clinic for patients to select which agent they wanted. Sugammadex: 2mg/kg Neostigmine 0.05mg/kg with 0.01mg/kg glycopyrrolate Both drugs given only after TOF $\geq$ 2/4 Fidelity: Anesthesia management protocol used.	The primary outcome was time to extubation, which was defined as the interval from the administration of neuromuscular blockade reversal agents to endotracheal tube removal. The secondary outcomes were the duration of surgery and anesthesia, length of PACU stay, and adverse events in the PACU. The per-minute operating room costs were calculated using the combined labor cost when a consultant surgeon, a surgical resident, a consultant anesthetist, a scrub nurse, a circulating nurse, and a nurse anesthetist were present. Linear regression models were used to estimate the cost-effectiveness of both drugs.	Time to endotracheal extubation was significantly shorter in the sugammadex group compared with the neostigmine group. In addition, the incidence of bradycardia was significantly lower in the sugammadex group. However, the total costs were significantly lower in the neostigmine group. Despite improving postoperative recovery, the benefits of sugammadex did not outweigh its higher costs compared with neostigmine, possibly due to the low costs of labor in Taiwan's healthcare system.

Citation #3 Hurford, W. E., Eckman, M. H., & Welge, J. A. (2020). Data and meta-analysis for choosing sugammadex or neostigmine for routine reversal of rocuronium block in adult patients. *Data in Brief*, *32*, 106241. https://doi.org/10.1016/j.dib.2020.106241
Level: IIA

Purpose or Hypothesis	Type of Evidence and Research Design	Sample (population, size, setting)	Intervention Procedures	Primary Outcome/Measures	Results Conclusions
They performed a meta-analysis of 32 studies that quantitatively compared the efficacy and side effects of sugammadex with either neostigmine or placebo in adult patients requiring general anesthesia.	- Meta-analysis - Experimental and non-experimental studies	Sampling technique: Convenience Setting: PubMed, Google Scholar and Cochrane library Inclusion: 18yrs old, GA, sugammadex directly compared to neostigmine or placebo, blockade depth quantified Exclusion: pediatrics, pre/post time series studies, lack of English Accepted: 32 studies PRISMA – no studies excluded for potential bias Heterogeneity**:** Cochran's Q test and the I2 statistic	Meta-analysis was performed using random- and fixed-effects models. They calculated odds ratios (OR) and 95% confidence intervals (CI) for binary data. Mean difference (MD) and 95% CI were calculated for continuous outcome data. All *P* values were two-tailed, and a *P* value < 0.05 was considered to represent statistical significance.	Primary outcomes: time to recovery of the train-of-four ratio to > 0.9; total anesthesia time; time from admission to the post-anesthesia recovery unit (PACU) until the patient was ready for discharge from the unit; occurrence of bradycardia; occurrence of post-operative nausea and vomiting (PONV).	The mean difference in TOF recovery times between therapies was 11.7 min. The mean difference for reversing deep blockade (1 to 2 PTC) was −24.9min, for moderate block (TOF 2/4) −11.8 min, and for shallow block (4/4 TOF) was −8.0 min. Reversal with sugammadex compared with neostigmine resulted in a random-effects mean difference of −18.6min of anesthesia time. The random-effects odds ratio for incidence of bradycardia was 0.22, favoring sugammadex. The random-effects odds ratio for incidence of PONV was 0.64, favoring sugammadex.

Citation #4 Fiorda Diaz, J., Echeverria-Villalobos, M., Esparza Gutierrez, A., Dada, O., Stoicea, N., Ackermann, W., Abdel-Rasoul, M., Heard, J., Uribe, A., & Bergese, S. D. (2022). Sugammadex versus neostigmine for neuromuscular blockade reversal in outpatient surgeries: A randomized controlled trial to evaluate efficacy and associated healthcare cost in an academic center. *Frontiers in Medicine*, *9*, 1072711. https://doi.org/10.3389/fmed.2022.1072711
Level: IA

Purpose or Hypothesis	Type of Evidence and Research Design	Sample (population, size, setting)	Intervention Procedures	Primary Outcome/Measures	Results Conclusions
They hypothesized that the administration of sugammadex for the reversal of moderate neuromuscular blockade would be associated with a significant reduction in time to reach a TOF response ≥ 0.9 and OR readiness for discharge when compared to neostigmine in patients undergoing outpatient surgeries.	- RCT - Open label, double arm	Sampling technique: Convenience Setting: Single center in Ohio Inclusion: 18yrs old, ASA 1-3, outpatient, GA receiving rocuronium-based NMB Exclusion: prisoners, pregnant, significant pre-existing conditions (CKD, COPD, neurodegenerative disease) Accepted: 37 patients (S=18, N= 19) Control: Neostigmine Intervention: Sugammadex Power analysis: Not met, a total of 40 patients would provide more than 90% power to detect a difference of 360 seconds. from drug administration to extubation, assuming standard deviations of 0.8 and 6.9 in the Sugammadex and control groups, respectively, at a 5% type I error rate (22) Homogeneity: Age and sex were similar in both groups. The median body mass index (BMI) was slightly higher in Group S when compared to Group N (32.5 versus 28.2 kg/m2, respectively; p = 0.06).	Eligible subjects were randomized (1:1 ratio) into two groups to receive either sugammadex (Groups S), or neostigmine/glycopyrrolate (Group N) at the time of neuromuscular blockade reversal using Research Electronic Data Capture (REDCap) system. Fidelity: Protocol on perioperative medications and dosing included (versed, fentanyl, propofol, MAC of volatiles, NMB, etc). Q5min NMB	Primary outcome: time to reverse moderate rocuronium-induced neuromuscular blockade (TOF ratio ≥0.9) in both groups. Secondary outcomes: post-anesthesia care unit (PACU)/hospital length of stay (LOS) and perioperative costs.	Sugammadex use was associated with a significantly faster moderate neuromuscular blockade reversal. We found no evidence of increased perioperative costs associated with the use of sugammadex in patients undergoing outpatient surgeries in our academic institution.

Citation #5 Ledowski, T., Szabó-Maák, Z., Loh, P. S., Turlach, B. A., Yang, H. S., de Boer, H. D., Asztalos, L., Shariffuddin, I. I., Chan, L., & Fülesdi, B. (2021). Reversal of residual neuromuscular block with neostigmine or sugammadex and postoperative pulmonary complications: A prospective, randomised, double-blind trial in high-risk older patients. *British Journal of Anaesthesia*, *127*(2), 316–323. https://doi.org/10.1016/j.bja.2021.04.026
Level: IA

Purpose or Hypothesis	**Type of Evidence and Research Design**	**Sample (population, size, setting)**	**Intervention Procedures**	**Primary Outcome/Measures**	**Results Conclusions**
The aim of this study was to investigate the incidence of postoperative pulmonary complications after reversal with either sugammadex or neostigmine in high-risk older patients. The hypothesis was that reversal with sugammadex in high-risk patients results in a lower incidence of postoperative pulmonary complications within 7 postoperative days.	- Prospective - Blinded - Randomized control trial	Sampling technique: Convenience Setting: Multicenter near Australian and New Zealand Inclusion: ASA 3-4, >75 yrs, sugammadex or neostigmine reversal of a rocuronium induced block Exclusion: emergency surgery; incapacity to consent; pre-existing chest infection, septicemia, and severe neuromuscular disease; or patients undergoing cardiothoracic surgery. Accepted: 180 patients Control: neostigmine Intervention: sugammadex Power analysis: Met -150 subjects needed for minimum difference of 5% on a symptom scale of 0-4 with a=0.05 and power=.87. Homogeneity: No differences between treatment groups were observed for any of the recorded subject characteristics.	Induction with rocuronium (0.6mg/kg) with 5-20mg boluses as indicated during surgery. At the end of surgery, patients would receive sugammadex (2mg/kg) or neostigmine (0.05mg/kg, max dose 5mg) with atropine 0.015mg/kg. To achieve a comparable depth of neuromuscular block, quantitative monitoring of the train-of-four (TOF) at the adductor pollicis brevis muscle (via supramaximal stimulation of the ulnar nerve) was used by an (unblinded) attending research assistant (not involved in postoperative data collection) with the TOF kept at two twitches towards the end of surgery and at the point of reversal. Fidelity: Protocol used with quantitative TOF monitoring. A validated score to quantify postoperative pulmonary outcome was also used.	Measure: A 5-point (0=4; 0=best outcome; 4=worst outcome) outcome score was used to compare of postoperative pulmonary complications. Scores were obtained preoperatively and on postoperative Days 1, 3, and 7, and comprised four parameters: elevated white cell count, subjective shortness of breath, body temperature >38C, and diagnosis of pneumonia by a clinician. Primary outcome: Incidence of postoperative pulmonary complications among sugammadex versus neostigmine cohorts	Reversal of rocuronium neuromuscular block with sugammadex resulted in a small, but possibly clinically relevant improvement in pulmonary outcome in a select cohort of high-risk older patients. Sugammadex vs neostigmine resulted in a reduced probability of increased pulmonary outcome score (impaired outcome) on postoperative Day 7, but not on Days 1 and 3. More patients in the neostigmine group were diagnosed with radiographically confirmed pneumonia. The neostigmine group showed a non-significant trend towards longer hospital length of stay across all individual centers, with a significant difference in Malaysia.

Citation #6 Hurford, W. E., Welge, J. A., & Eckman, M. H. (2020). Sugammadex versus neostigmine for routine reversal of rocuronium block in adult patients: A cost analysis. *Journal of Clinical Anesthesia*, *67*, 110027. https://doi.org/10.1016/j.jclinane.2020.110027
Level: IIIB

Purpose or Hypothesis	Type of Evidence and Research Design	Sample (population, size, setting)	Intervention Procedures	Primary Outcome/Measures	Results Conclusions
The aim of the study was to better inform decisions made by health systems regarding general or restrictive use, or no use, of sugammadex as a reasonable strategy from the perspective of net hospital costs.	- Cost Analysis	They selected variables that demonstrated meaningful differences in meta-analyses of published studies and/or had significant associated costs. They used data from local hospital system information, meta-analysis of published studies, and the general literature to construct base-case scenarios and sensitivity analyses. They performed the analysis from the perspective of a single hospital system. Costs were in 2019 U.S. dollars.	A decision model evaluated the choice of reversal agent used to antagonize neuromuscular blockade by rocuronium in adult patients. Choices were to use an anticholinesterase (neostigmine) along with an anticholinergic (glycopyrrolate), sugammadex, or no reversal agent. Threshold values were calculated to estimate the point of equivalent net costs between two reversal strategies.	The outcome of the model was an estimate of net hospital costs for each strategy, which included drug costs, additional unproductive operating room time, and potential complications (unplanned postoperative mechanical ventilation and postoperative nausea and vomiting).	Routine reversal with sugammadex is preferable to choosing neostigmine or no reversal drug when accounting for potential savings in OR time. Sugammadex might also be a reasonable choice for patients at high risk of UPMV. If the cost of OR time is not considered, the analysis does not support the routine use of sugammadex in patients with perceived increased risk or solely to reduce PONV. Net costs may be lower with sugammadex in patients with a high likelihood of postoperative mechanical ventilation due to residual neuromuscular blockade.

Citation #7 Thilen, S. R., Weigel, W. A., Todd, M. M., Dutton, R. P., Lien, C. A., Grant, S. A., Szokol, J. W., Eriksson, L. I., Yaster, M., Grant, M. D., Agarkar, M., Marbella, A. M., Blanck, J. F., & Domino, K. B. (2023). 2023 American Society of Anesthesiologists Practice Guidelines for Monitoring and Antagonism of Neuromuscular Blockade: A Report by the American Society of Anesthesiologists Task Force on Neuromuscular Blockade. *Anesthesiology*, *138*(1), 13–41. https://doi.org/10.1097/ALN.0000000000004379
Level: IVA

Purpose or Hypothesis	**Type of Evidence and Research Design**	**Sample (population, size, setting)**	**Intervention Procedures**	**Primary Outcome/Measures**	**Results Conclusions**
The objective is to guide practice that will enhance patient safety by reducing residual neuromuscular blockade. These practice guidelines provide evidence-based recommendations on the management of neuromuscular monitoring and antagonism of neuromuscular blocking agents during and after general anesthesia.	- Clinical practice guidelines	The guideline task force included anesthesiologists, epidemiology-trained methodologists, and a patient representative. All patients receiving neuromuscular blocking drugs in whom antagonism and extubation is intended. Patients receiving neuromuscular blocking drugs in the intensive care unit were excluded.	It is recommended to use quantitative neuromuscular monitoring at the adductor pollicis and to confirm a recovery of train-of-four ratio greater than or equal to 0.9 before extubation. Sugammadex is recommended from deep, moderate, and shallow levels of neuromuscular blockade that is induced by rocuronium or vecuronium. Neostigmine is a reasonable alternative from minimal blockade (train-of-four ratio in the range of 0.4 to less than 0.9). Patients with adequate spontaneous recovery to train-of-four ratio greater than or equal to 0.9 can be identified with quantitative monitoring, and these patients do not require pharmacological antagonism.	The guidance focuses primarily on the type and site of monitoring and the process of antagonizing neuromuscular blockade to reduce residual neuromuscular blockade.	Less residual NMB (rNMB): - Quantitative monitors - Confirmed TOF prior to extubation - Adductor pollicis on emergence Sugammadex - Less rNMB - Faster recovery - Deep, moderate and shallow block Neostigmine - TOF ratio >0.4 - Dose not to exceed 40mcg/kg No difference - Reparalysis or reintubation rates

Citation #8 Thilen, S. R., Ng, I. C., Cain, K. C., Treggiari, M. M., & Bhananker, S. M. (2018). Management of rocuronium neuromuscular block using a protocol for qualitative monitoring and reversal with neostigmine. *British Journal of Anaesthesia*, *121*(2), 367–377. https://doi.org/10.1016/j.bja.2018.03.029
Level: IIA

Purpose or Hypothesis	**Type of Evidence and Research Design**	**Sample (population, size, setting)**	**Intervention Procedures**	**Primary Outcome/Measures**	**Results Conclusions**
They hypothesized that implementing a protocol for the management of muscle relaxation and reversal with neostigmine would be associated with a lower risk of postoperative residual neuromuscular blockade.	- Prospective - Cohort Study	Sampling technique: Convenience Setting: Two hospitals in Washington state Inclusion: ASA 1-4, elective abdominal surgery, <4hrs, NMB required Exclusion: underlying neuromuscular disease, emergent surgery Accepted: 79 patients Control: No protocol (n=38) Intervention: Protocol on neostigmine reversal (n=41) Power analysis: Met - 40 patients in each of the two study periods. Assuming a baseline incidence of PRNB (nTOF ratio <0.9 at time of extubation) of 64% as reported in the RECITE study, 4 this sample would provide 80% power for an expected incidence of 30% in the intervention group. Homogeneity: No statistical differences	Neostigmine was administered in adjusted doses after a train-of-four count of four was confirmed at the thumb. The protocol ensured a minimum of 10 min between neostigmine administration and tracheal extubation. TOF count of 4 with fade=40 mg/kg TOF count of 4 without fade: 15-25 mg/kg Dosing of neostigmine based on IBW Fidelity: Protocol with guidelines on medication management. Qualitative TOF count of 4 at adductor pollicis however confirmed by both the primary provider and the attending anesthesiologist.	Primary and secondary endpoints were incidence of postoperative residual neuromuscular block (TOFR <0.9) and severe postoperative residual neuromuscular block (TOF <0.7) at the time of tracheal extubation. Measure: TOF count using DigiStim II nerve stimulator	The incidence of postoperative residual neuromuscular block at tracheal extubation was 14/40 (35%) for patients managed according to the protocol compared with 22/38 (58%) for patients in the control group, odds ratio of 0.39, and 95% confidence interval of 0.14-1.07; P=0.068.

Citation # 9 He, J., He, H., Li, X., Sun, M., Lai, Z., & Xu, B. (2022). Required dose of sugammadex or neostigmine for reversal of vecuronium-induced shallow residual neuromuscular block at a train-of-four ratio of 0.3. *Clinical and Translational Science*, *15*(1), 234–243. https://doi.org/10.1111/cts.13143
Level: IA

Purpose or Hypothesis	Type of Evidence and Research Design	Sample (population, size, setting)	Intervention Procedures	Primary Outcome/Measures	Results Conclusions
The aim of this study was to investigate the dose-effect relationship of sugammadex and neostigmine for the reversal of vecuronium-induced shallow residual NMB (TOF ratio of 0.3) and observed related adverse reactions.	- Randomized - Double-blind	Sampling technique: Convenience Setting: Single center in China Inclusion: ASA 1-3, 18-65yrs old, BMI 18.5-25kg/m2 Exclusion: expected difficult airway, neuromuscular disease, significant hepatic or renal dysfunction, a family history of malignant hyperthermia, allergy to any of the drugs used in this trial, taking medication that might interfere with NMB or the antagonist, and glaucoma, pregnant or breastfeeding Accepted: 121 patients Control: Placebo Intervention: protocol on sugammadex or neostigmine Power analysis: Sample size calculations for a reliable regression model suggest at least 10 samples per parameter. Statistical analysis and image processing were performed using SAS software, version 9.4 Homogeneity There were no significant differences in baseline characteristics (sex, age, body mass index, and ASA physical status score) or treatment (total vecuronium dose, duration of surgery, and time from first vecuronium dose to a TOF count of 0.	During surgery:0.02 mg/kg vecuronium for TOF 2/4 End of surgery: spontaneous recovery to TOF ratio 0.3. Fidelity: Study medications, dosed according to randomization, or placebo were administered. 24hr monitoring to observe for delayed adverse effects. EMG monitors at the adductor pollicis in all groups.	Primary outcome: Dose of sugammadex or neostigmine necessary to reverse vecuronium-induced NMB from TOF ratio of 0.3 to a TOF ratio of 0.9 in 95% of patients in 5min	The median time to recovery decreased from 44.0 min (placebo) to 1.7min in the sugammadex group (2mg/kg) and 2.8min in the neostigmine (70μg/kg) group. For an upper limit recovery time of 5 min in 95% of patients, the dose was estimated to be 0.56 mg/kg (sugammadex). Neostigmine could not make 95% of patients recover within 5 min. The dose of neostigmine was calculated to be 33μg/kg for an upper limit of 10 min in 95% of patients.

Table 3

Evidence Synthesis

JHNEBP Model Level	# of Sources	Author and Quality Rating	Synthesis of Findings
Level 1 Experimental study · Randomized Controlled Trial (RCT) · Systematic review of RCTs with or without meta-analysis	3	Ledowski et al. = A He et al. = A Fiorda et al. = A	Sugammadex is shown to decrease incidence of pulmonary complication (He et al., 2022). However, when a protocol with appropriate timing and dosing was implemented, no significant differences were identified (Fiorda Diaz et al., 2022). Sugammadex and neostigmine can be used to successfully reverse NMB by steroidal NMBA (He et al., 2022).
Level II Quasi-experimental studies · Systematic review of a combination of RCTs and quasi-experimental studies, or quasi-experimental studies only, with or without meta-analysis	2	Hurford et al. = A Thilen et al. = A	Inconsistent results were found in the meta-analysis by Hurford et al. (2020) where sugammadex was shown to decrease pulmonary complications, bradycardia and PONV in some studies but have no change compared to neostigmine in other studies. Thilen et al., (2018) found a significantly reduced incidence of postoperative pulmonary complications with sugammadex.
Level III Non-experimental study · Systematic review of a combination of RCTs, quasi-experimental, and non-experimental studies, or non-experimental studies only, with or without meta-analysis · Qualitative study or systematic review of qualitative studies with or without meta-synthesis	3	Lan et al. = B Drzymalski et al. = B Hurford et al. = A	Hurford et al., (2020) found a net cost saving when using sugammadex due to a decrease in OR time and incidence of postoperative pulmonary complications. This data is inconsistent with Lan et al. (2023) finding neostigmine was cheaper, however they contributed this to affordable labor within their country. A cognitive aid on NMB reversal showed a decrease in sugammadex use without an increased documentation of pulmonary complications (Drzymalski et al., 2019)
Level IV Opinion of respected authorities and/or reports of nationally recognized expert committees/consensus panels based on scientific evidence	1	Thilen et al. = A	Sugammadex is the preferred agent to reverse neuromuscular blockade while quantitatively monitoring depth at the adductor pollicis (Thilen et al., 2023).
Overall Quality Rating w/rational and Recommendation: Good and consistent evidence with indications for practice change			
Recommendations Based on Evidence Synthesis • Strong, compelling evidence, consistent results: solid indication for a practice change. • Good and consistent evidence – practice change • Good but conflicting evidence: questionable indication for practice change; consider risk/benefit analysis • Little or no evidence: no indication for practice change			

Figure 1

Root Cause Analysis (Fishbone Diagram)

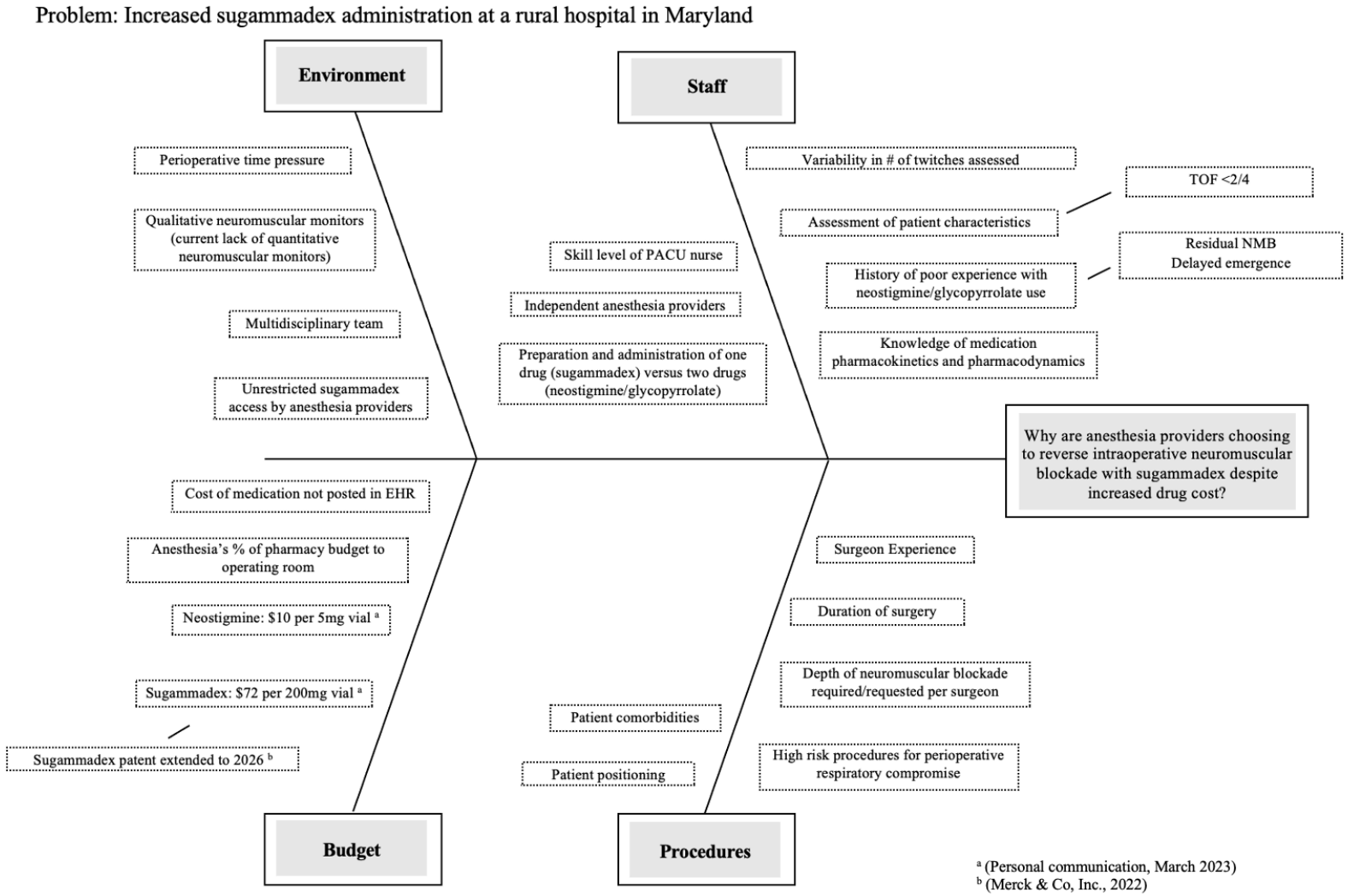
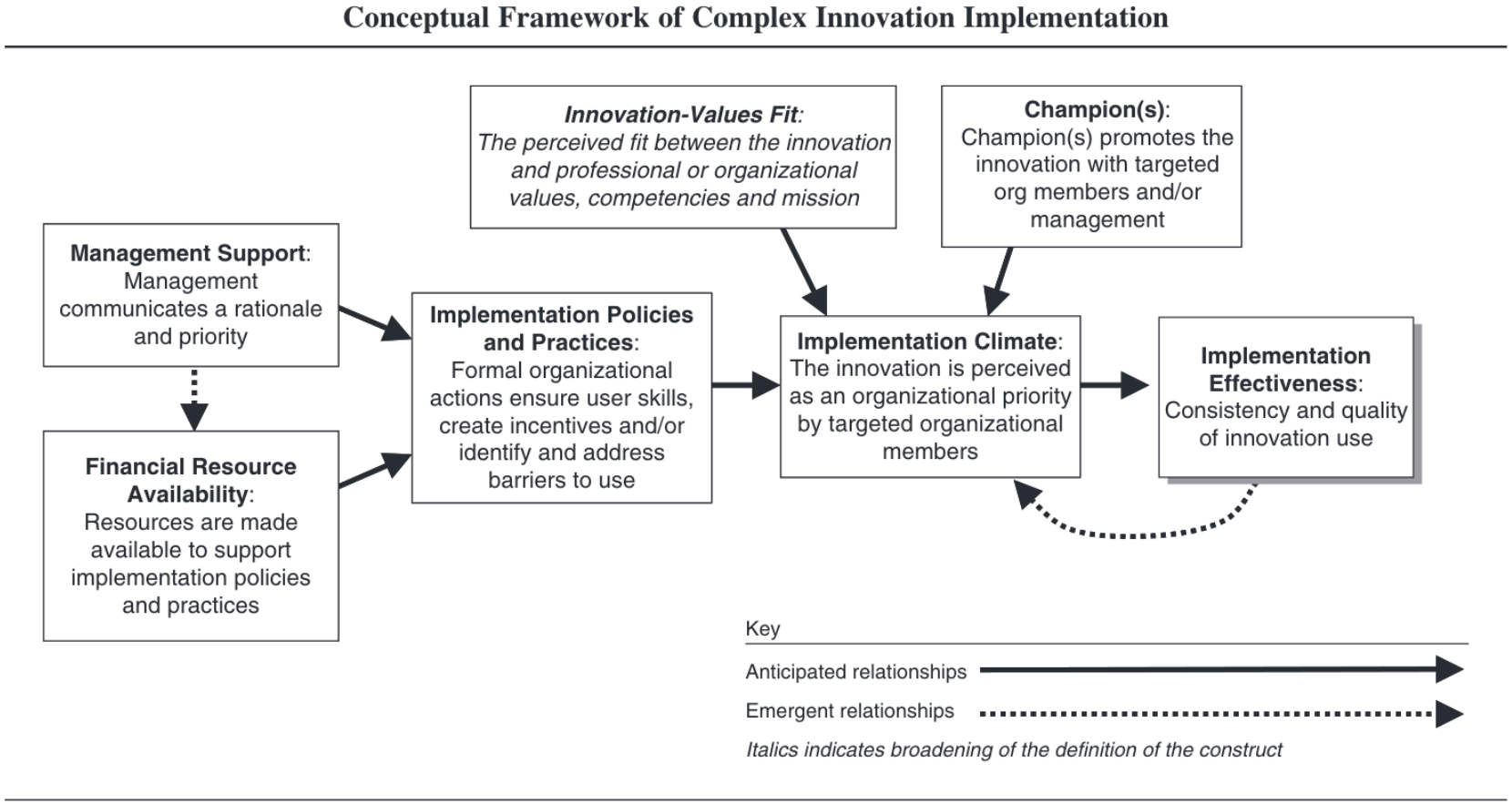


Figure 2

Outline of Conceptual Framework of Complex Innovation



Source: Adapted from Klein and Sorra (1996, 1056).

Figure 3

Infographic Distributed to Anesthesia Department

IMPLEMENTATION OF A COGNITIVE AID TO OPTIMIZE NEUROMUSCULAR BLOCKADE REVERSAL: A QUALITY IMPROVEMENT

Cognitive aid mobile download

Problem: Increased cost associated with pharmacologic reversal of neuromuscular blockade (NMB)

- Sugammadex use: 212-393 administrations per month

Process change:

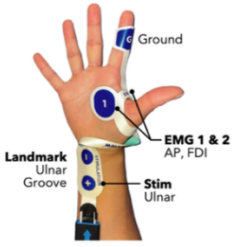
- Assess depth of neuromuscular blockade (TwitchView preferred)
- Review "Reversal of Neuromuscular Blockade" cognitive aid
  - Hard copy within the OR, near the TwitchView monitor
  - Download to mobile device (QR code)
- Select appropriate *medication and dosage* per cognitive aid
- Complete "Cognitive Aid Utilization Survey"
  - Report if recommendations were followed or if alternative reversal agent was selected

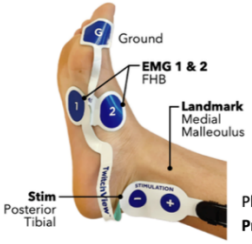
Purpose Statement: The purpose of this QI project is to increase compliance with an evidence-based approach to reversal of NMB, leading to a decreased cost and improved patient outcomes.

TwitchView
TRAIN OF FOUR MONITOR

Scan for Instructional Videos and Website

www.blinkdc.com/twitchview-user-guide





PROJECT TIMELINE

Weeks 1-2 (8/28-9/9)
- Education / Training
- In-person presentation on 9/7 at the Thursday meeting

Weeks 3-15 (9/10-12/22)
Data collection
- Cognitive Aid Utilization Survey (submit daily)
- TOF documentation
- Number of sugammadex administrations

REVERSAL OF NEUROMUSCULAR BLOCKADE	
Twitch Response	Agent + Dose
Fully reversed (TOFR >0.9)	No reversal indicated
4/4 *without fade* (TOFR >0.4)	Neostigmine 20mcg/kg
4/4 with fade (TOFR <0.4)	Neostigmine 40mcg/kg
3/4	Neostigmine 50mcg/kg
2/4	Sugammadex 2mg/kg
0/4 - 1/4	Sugammadex 4mg/kg

Notes	
Neostigmine: based on IBW	Sugammadex: based on TBW
The maximum dose of neostigmine is 5mg	
Always administer an anticholinergic (e.g., glycopyrrolate) with neostigmine	
Administer neostigmine early (peak effect at 10-15min)	
Consider sugammadex for patients at high risk for postoperative respiratory compromise	
Sugammadex can only reverse rocuronium and/or vecuronium	
Dose can be approximated (e.g., 220mg sugammadex calculated per TBW… administer one 200mg dose)	

(Przymalski et al., 2019)

Cognitive Aid Utilization Survey

Staff Education Survey

Please reach out to a project team member if you would like more details about this Quality Improvement Project.
Project Lead: Karli Bodine, SRNA (E-mail: karli.bodine@umaryland.edu)

Approved by the Research Review Committee (Study #P23-012)

Figure 4

Cognitive Aid on Reversal of Neuromuscular Blockade

REVERSAL OF NEUROMUSCULAR BLOCKADE	
Twitch Response	Agent + Dose
Fully reversed (TOFR >0.9)	No reversal indicated
4/4 *without fade* (TOFR >0.4)	Neostigmine 20mcg/kg
4/4 with fade (TOFR <0.4)	Neostigmine 40mcg/kg
3/4	Neostigmine 50mcg/kg
2/4	Sugammadex 2mg/kg
0/4 - 1/4	Sugammadex 4mg/kg

Notes	
Neostigmine: based on IBW	Sugammadex: based on TBW
The maximum dose of neostigmine is 5mg	
Always administer an anticholinergic (e.g., glycopyrrolate) with neostigmine	
Administer neostigmine early (peak effect at 10-15min)	
Consider sugammadex for patients at high risk for postoperative respiratory compromise	
Sugammadex can only reverse rocuronium and/or vecuronium	
Dose can be approximated (e.g., 220mg sugammadex calculated per TBW… administer one 200mg dose)	

(Drzymalski et al., 2019)

Figure 5

Old Process Map

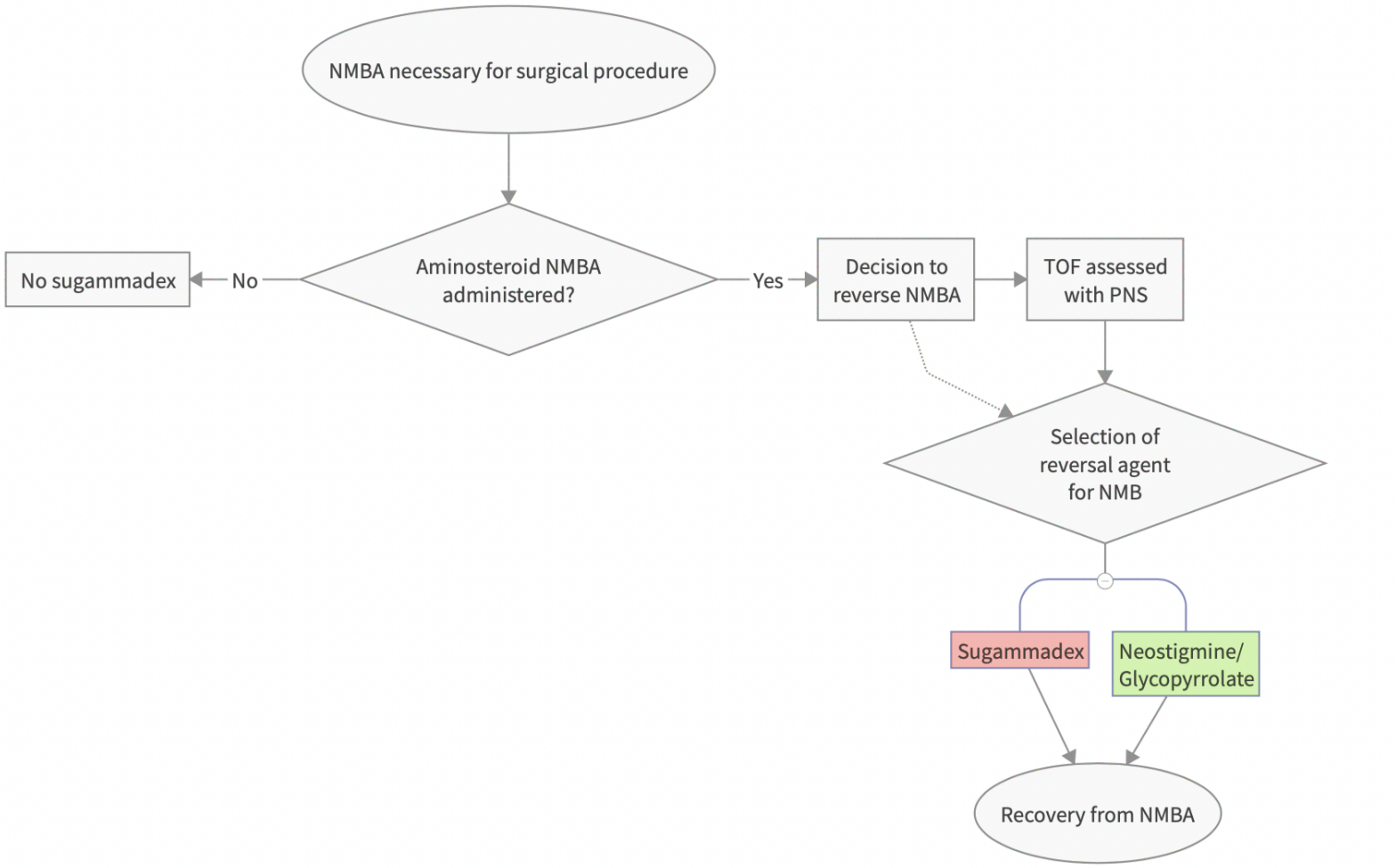


Figure 6

Current Process Map

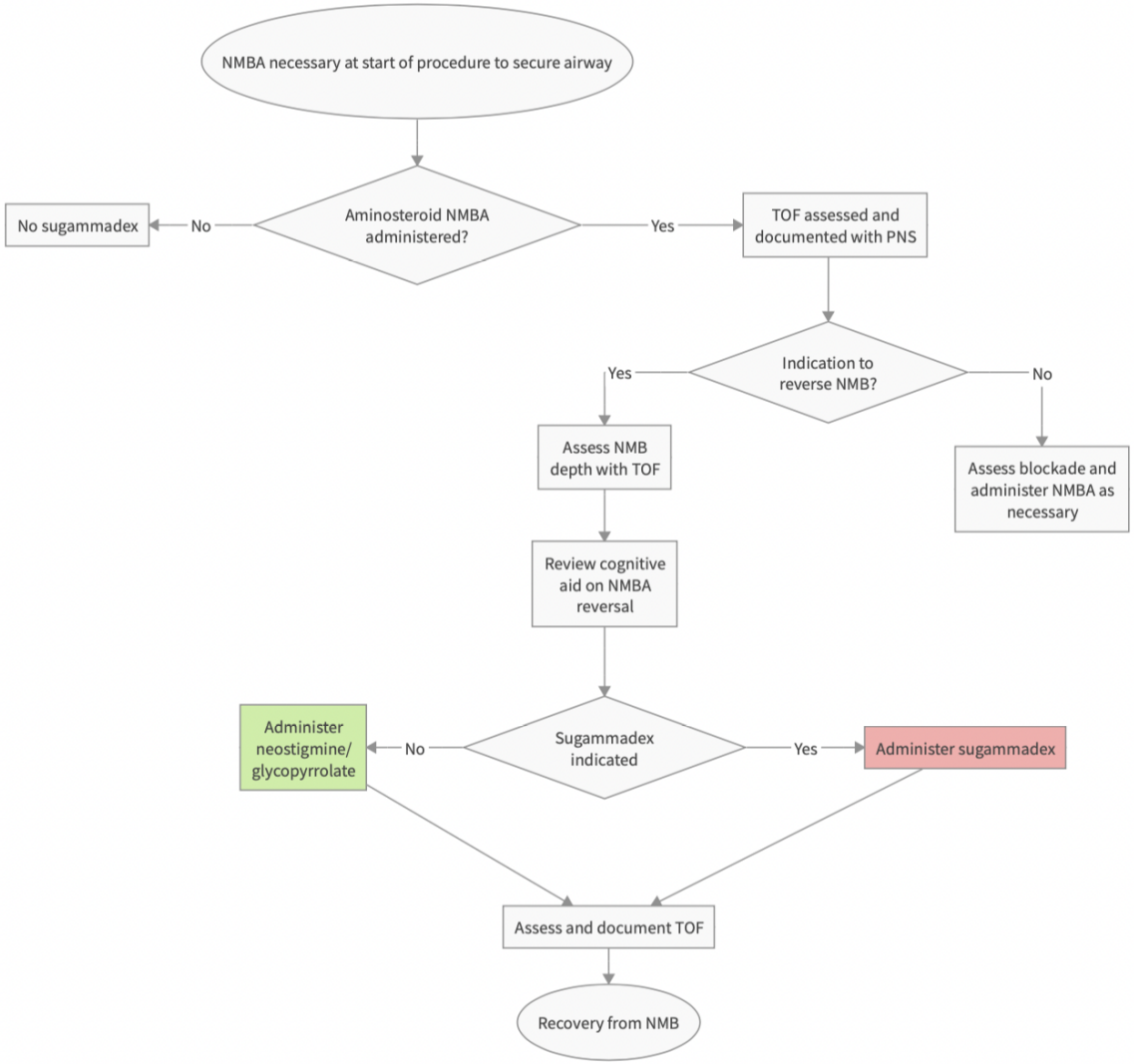


Figure 7

Pie Chart on Anesthesia Department Attendance at In-Person Education Session

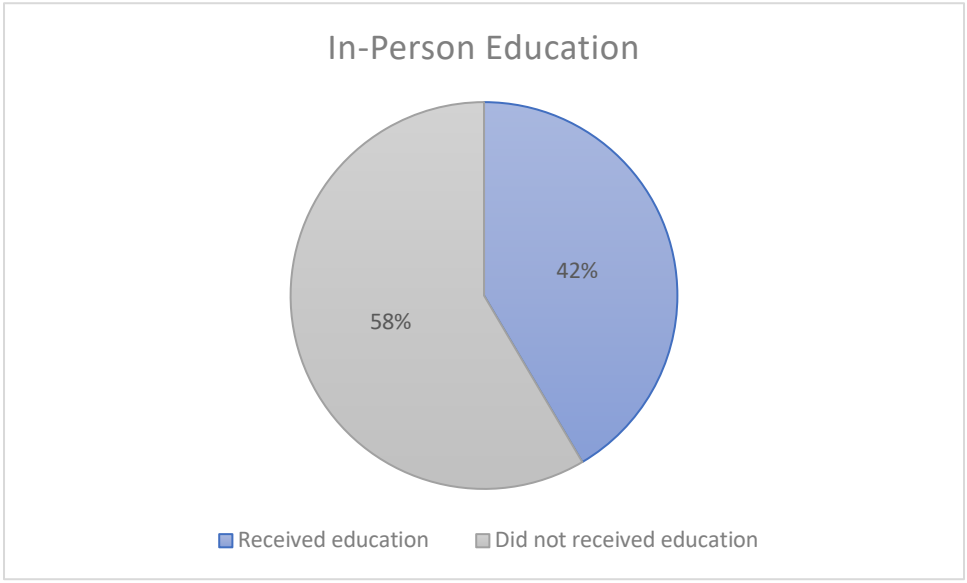


Figure 8

Cognitive Aid Utilization Survey Run Chart

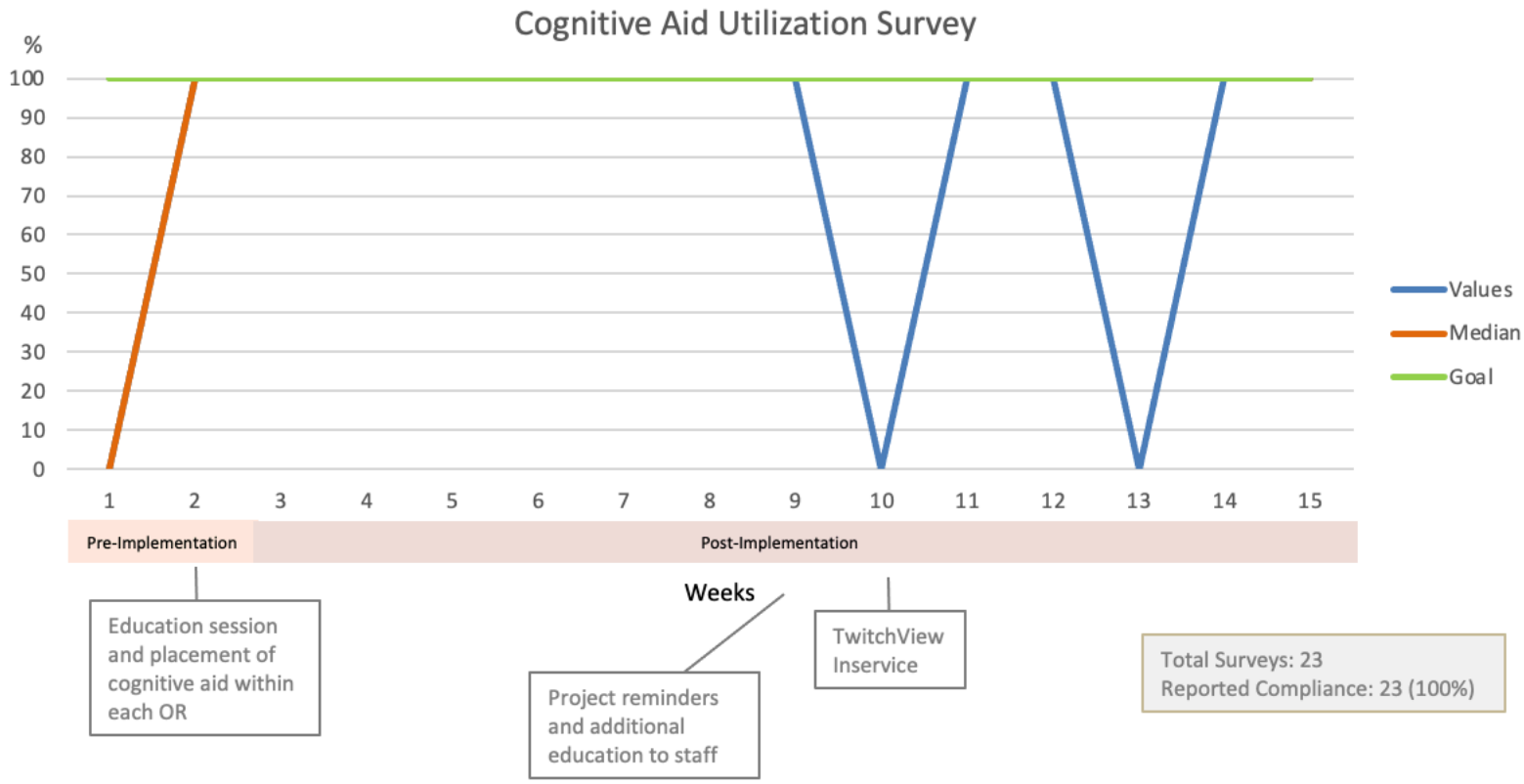


Figure 9

Epic Report on Sugammadex Administration Run Chart

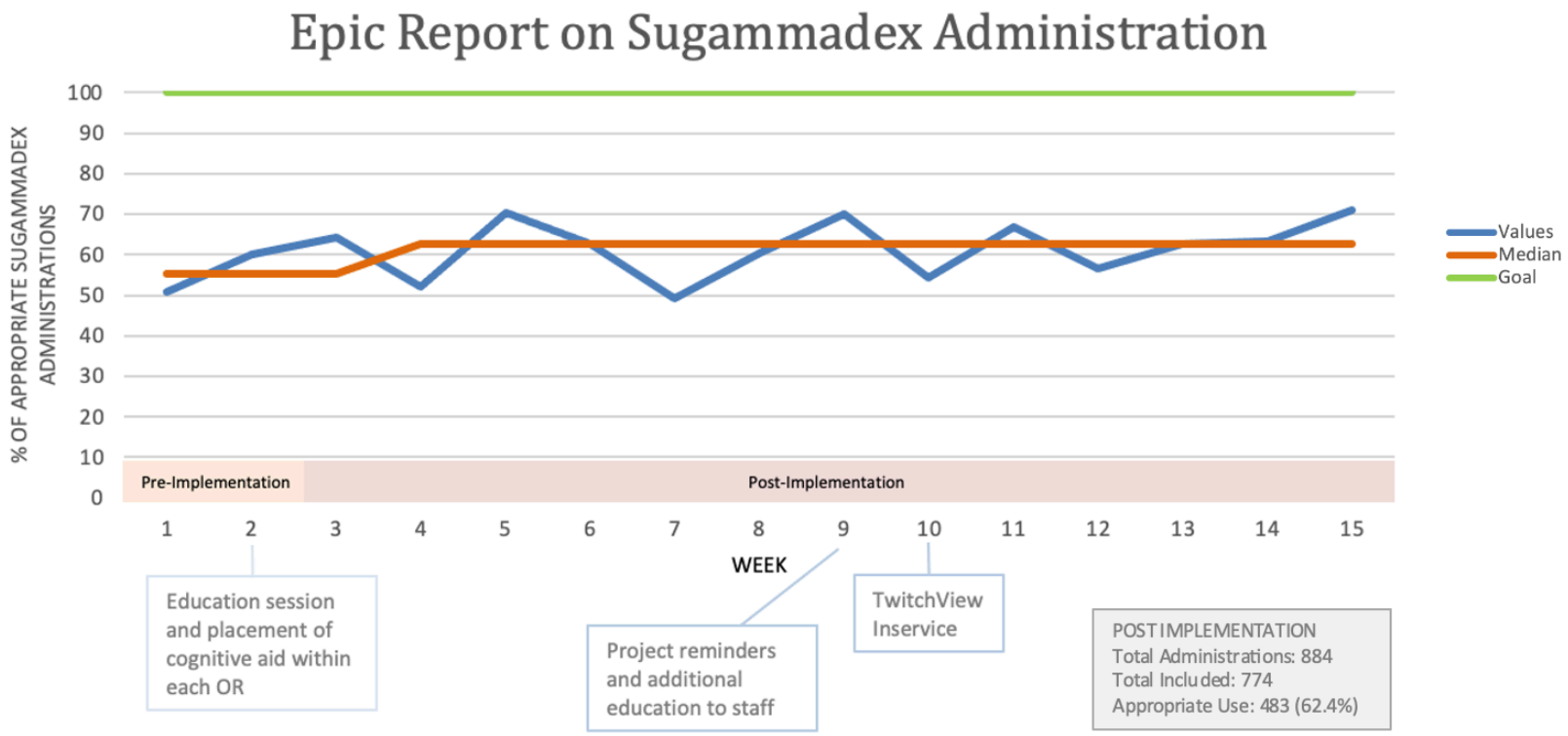
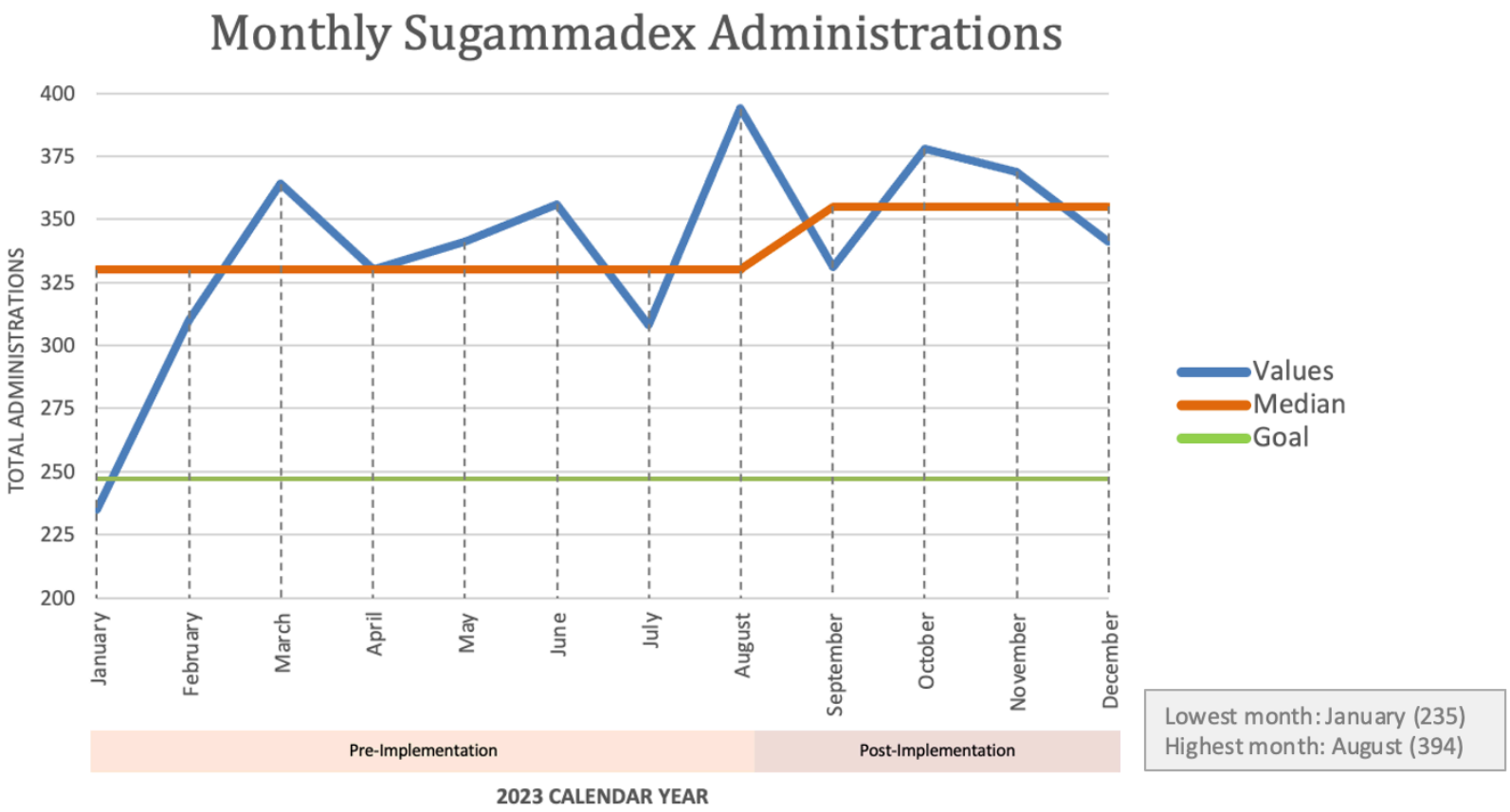


Figure 10

Sugammadex Administration Run Chart



Appendix A

Project Tool from REDCap

Cognitive Aid Utilization Survey

Please complete the survey for data on the NMB Reversal QI project.

Your response is anonymous.

Date of procedure (M/D/Y)	_____
Did you follow the recommendations on the NMB Reversal Cognitive Aid?	◯ Yes (agent and dose) ◯ Yes (agent) but not suggested dose ◯ No
Which reversal agent did you administer?	◯ Sugammadex ◯ Neostigmine ◯ Neostigmine & sugammadex
If neostigmine was recommended but sugammadex was administered, please provide rationale.	_____

Figure A. REDCap project survey for members of the anesthesia department to report NMB Reversal Cognitive Aid compliance.

Appendix B

Project Tool from REDCap

Epic Report on Sugammadex

Survey of Cognitive Aid Utilization	_____
Date of surgery	_____
TOF prior to sugammadex administration	◯ Sustained Tetany ◯ Double Burst ◯ TOFR >0.9 ◯ TOFR 0.4-0.9 ◯ TOFR < 0.4 ◯ TOF 4/4 ◯ TOF 3/4 ◯ TOF 2/4 ◯ TOF 1/4 ◯ TOF 0/4 ◯ PTC
Adherence to cognitive aid NMB reversal agent recommendations?	◯ Yes ◯ No
Indication for sugammadex identified (ex: cardiac/thoracic surgery)	_____

Figure B. REDCap project audit tool to track the depth of NMB blockade prior to administration of sugammadex.

Appendix C

Project Tool from REDCap

Sugammadex Administration

Survey of Cognitive Aid Utilization	_____
Year	◯ 2022 ◯ 2023 ◯ 2024
Month	◯ January ◯ February ◯ March ◯ April ◯ May ◯ June ◯ July ◯ August ◯ September ◯ October ◯ November ◯ December
Number of sugammadex administrations	_____

Figure C. REDCap project audit tool to track the number of sugammadex administrations.