Evaluating Outcomes of Sugammadex Administration: Robotic Surgery Recovery Implications

Howard Brown

The University of Alabama

Capstone College of Nursing

Todd Smith PhD, MSHA, MBA, NEA-BC, RN

Sean Moore DNP, CRNA

September 26, 2021

Table of Contents

Abstract

Introduction: Enhanced recovery after surgery (ERAS) protocols are frequently combined with robotic surgery in order to provide safe, efficient, high quality patient care. Previous research has shown that the use of sugammadex for reversal of neuromuscular blockade (NMB) after general anesthesia for minimally invasive robotic surgery prevents many complications. This study will compare the efficacy of neostigmine reversal, sugammadex reversal, no pharmacological reversal or both reversal agents for patients following minimally invasive robotic surgery.

Methodology: 562 patients at the Promedica Toledo Hospital (PTH) undergoing robotic surgery were selected randomly based on inclusion criteria to see if sugammadex provided an enhanced recovery. Patients having robotic surgery from May 2020 to May 2021 were divided into four groups by type of reversal drug: sugammadex, neostigmine, no reversal or both reversals. Using a chi-square goodness of fit test, we determined if there were significant differences between the patients in each of the four groups during the post-anesthesia recovery period as related to post-operative nausea and vomiting, time in PACU, pulmonary complications and unplanned admission for pulmonary complications.

Results: A total of 562 cases were included in our analyses. No statistical significance was found across the four independent variables. However, we found clinical significance in a 15.78-minute mean reduction in PACU time for the sugammadex group when compared to the neostigmine group. Clinical significance was also indicated in the neostigmine group as 58.5% of those patients required a rescue dose of sugammadex to prevent complications of residual NMB.

Discussion: For the reversal of NMB, the cost of sugammadex is higher than neostigmine. However, this additional costs of sugammadex could be offset by improved outcomes and potentially lead to financial healthcare savings. Also, quality outcome indicators could be more effectively met through an ERAS protocol combining minimally invasive surgery and sugammadex.

Keywords**:** Sugammadex; Neostigmine; Neuromuscular blockade; Nausea and vomiting; Robotic surgery; Pulmonary complications; Enhanced recovery after surgery

Evaluating Outcomes after Sugammadex Administration: Robotic Surgery Recovery Implications

Background

Minimally invasive robotic surgery poses challenges to the anesthesia provider. This type of surgery has increased in popularity over the past decade. Benefits such as decreased hospital stay and blood loss have been demonstrated (Maerz et al., 2017). The uniqueness of the surgery has made the vigilance for patient positioning and fluid administration of an even higher concern (Maerz et al. 2017). The implications for providers include alterations in the anesthetic plan to account for the requirements of robotic surgery. The attractiveness of robotic surgery is the shortened recovery period for the patient with increased patient satisfaction (Swenson et al. 2016). The anesthetic plan should include alterations to coincide with a decrease in recovery time and complications of surgery. Zhao et al. (2018) found the rate of complications and decreased hospital stay have been demonstrated when a protocol for enhanced recovery for robotic surgery patients is followed and the anesthesia plan directly impacts the enhanced recovery efforts for these patients.

The increase in surgery time results in an increased exposure to anesthetic agents. Moderate neuromuscular blockade (NMB) has been shown to be necessary and beneficial to robotic surgery (Kim et al. 2018). Deep or moderate NMB typically requires a reversal agent to be administered. Acetylcholinesterase inhibitors, such as neostigmine, have traditionally been used for reversal of non-depolarizing neuromuscular blocking agents. However, these drugs have significant limitations, such as indirect mechanisms of reversal, limited and unpredictable efficacy, and undesirable autonomic responses (Hristovska et al. 2017). The limitations to this method of reversal may decrease the progress to early recovery and discharge from the post anesthesia care unit (PACU).

Nationwide, five percent of adult patients undergoing a non-cardiac surgery experience a pulmonary complication (Kheterpal et al. 2020). These pulmonary complications can range from oxygen desaturation to respiratory failure and unexpected ICU admission. Results from retrospective studies (Kirmeier et al. 2020) suggest that use of neuromuscular blocking agents during general anesthesia might be linked to postoperative pulmonary complications. Post-operative respiratory impairment may be due to various causes, such as age, surgery type, comorbidity, smoking, preoperative anemia, and general anesthesia. However, increasing evidence from Cammu, 2020, suggests that residual neuromuscular block is an important risk factor for postoperative pulmonary complications and may affect the outcome. Thus, the need for appropriate management of neuromuscular block in the prevention of postoperative pulmonary complications is important, but the causes are multifactorial (Cammu, 2020).

Enhanced Recovery After Surgery (ERAS) pathways have been shown to improve outcomes, including reduced opioid consumption, length of stay, and post-operative nausea and vomiting (Chui et al. 2018). Post-operative nausea and vomiting (PONV) is a common adverse effect of anesthesia and surgery. Up to 80% of patients may be affected. PONV is a major cause of patient dissatisfaction and may lead to prolonged hospital stay and higher costs of care along with more severe complications (Weibel et al. 2020). Laparoscopic and robotic surgery is associated with a high incidence of PONV. The use of carbon dioxide pneumoperitoneum has been proposed as a potential cause of high PONV incidence. This may be related to enhanced perfusion to the main effector sites for PONV, including the brain and gastrointestinal tract (Son et al. 2017). Neostigmine has also been shown to increase the incidence of PONV in the first hour of post-operative recovery (Yagan et al. 2017).

Problem Statement

Robotic surgery patients present unique challenges to the anesthesia provider. Combining an ERAS protocol with robotic surgery can decrease recovery time and post-operative complications. The use of older NMB reversal agents may contribute to post-operative complications hindering the goals of ERAS. Resistance to the more effective reversal agent, sugammadex, is based on cost.

Organizational Gap

The Promedica Toledo Hospital (PTH) provides access to sugammadex, but generally discourages its use. It is primarily encouraged to be used as a rescue agent for the resultant failure of neostigmine, or for profound NMB circumstances. Cost considerations for equal efficacy dosage is the primary concern. Robotic surgeries have increased over the past ten years at PTH. Attempts have been made at an ERAS protocol, but have been unofficial and un-sustained. Many of the common complications of improper pharmacologic NMB reversal may not be appropriately linked to a failure in a PACU discharge metrics. The addition of sugammadex to an ERAS protocol may decrease the incidence of common costly complications. The replacement of neostigmine with sugammadex while initially more costly per dose, may result in institutional savings along with increased reimbursement. Sugammadex has been demonstrated to be superior to neostigmine in the reversal of NMB (Unal et al., 2015).

Review of the Literature

Patient safety, comfort and satisfaction are part of the recovery process. The purpose of an ERAS protocol is to improve outcomes including length of stay (Chui et al. 2018). According to the American Association of Nurse Anesthetists (AANA), in 2019 reimbursement through CMS for procedures has become largely dependent on meeting benchmarks. Prolonged hospital stays and associated complications are often not covered under reimbursement guidelines. The application of ERAS protocols can improve recovery time, patient satisfaction scores and save money (Chui et al. 2018). The anesthesia plan is an important part of an ERAS protocol. Techniques and drug choices directly impact the effectiveness of the protocol. Patients undergoing robotic surgery can benefit from a quick and complete recovery from anesthesia, including reversal from NMB. Sugammadex has been associated with a clinically and statistically significant lower incidence of major pulmonary complications (Kheterpal et al. 2020). Unal et al. (2015) confirmed the efficacy of sugammadex over neostigmine for the reversal of rocuronium-induced neuromuscular block; specifically, sugammadex decreased the incidence of post-operative respiratory complications and related costs. In older adults undergoing prolonged surgery, sugammadex was associated with a 40% reduction in residual NMB, and a 10% reduction in 30-day hospital readmission rate (Togioka et al. 2020). According to the American Association of Nurse Anesthetists (AANA) (2019), despite the routine use of anticholinesterase reversal agents, between 20 to 40 percent of patients arrive in the PACU with objective evidence of residual neuromuscular blocking agents. Yagan (2016) found the incidence of PONV decreased in the first post-operative hour of recovery when compared to neostigmine.

After abdominal surgery, sugammadex reversal eliminated residual neuromuscular blockade in the PACU, and shortened the time from start of medication administration to the time the patient was ready for discharge from the operating room (Brueckmann et al. 2015).

According to Laporta et al. (2020), the anesthesia recovery is a complex physiologic process as systems recover from the effects of surgery and anesthesia. Inadequate recovery of respiratory physiology can lead to severe hypoxemia-induced end-organ damage and even death. Emerging evidence suggests that signs of respiratory depression during early anesthesia recovery may portend increased risk for future severe adverse events. Laporta et al. (2020) report that studies showed even a single episode of respiratory depression in the PACU was strongly associated with subsequent respiratory complications. According to Bartels et al. (2020) a hypoxemic event was defined as peripheral saturation of oxygen (SpO2) <90% by continuous pulse oximetry for ≥3 minutes. Hypoxemia was classified as mild (lowest SpO2 86%-89%) or moderate/severe (lowest SpO2 ≤85%). Bartels et al. (2020) adds that secondary outcomes included postoperative respiratory interventions, intensive care unit admission, and hospital length of stay. In addition, Salas et al. (2020) showed significant differences in unplanned overnight admission in relation to the type of anesthesia and duration, which resulted in admission most commonly due to inadequate postoperative pain management, nausea or wound complications. Finally, Rao et al. (2018) discovered that postoperative respiratory impairment occurs as a result of a combination of patient, surgical, and management factors and contributes to both surgical and anesthetic risk, resulting in an increase in mortality and hospital length of stay. Rao et al. (2018) also says there is mounting evidence to suggest that patients remain vulnerable to respiratory impairment well into the postoperative period, with the vast majority of adverse events occurring during the first 24 hours following discharge from anesthesia care.

Evidence Based Practice

A thorough literature review provided evidence-based guidelines to form a recommendation for the addition of sugammadex to an ERAS protocol for robotic surgery patients. Will robotic surgery patients with the addition of sugammadex as an ERAS protocol versus patients receiving neostigmine, have a decreased incidence of PONV and pulmonary complications while shortening the time in the PACU?

Practice Model/ Framework

The implementation strategy for this proposal is through a visual conceptual framework (see appendix C). This framework was referred to in order to guide the direction of the study. The systemic approach to the assessment of the factors contributing to PONV, pulmonary complications and their impact on PACU discharge delay were superimposed over the choice of NMB reversal agent.

Exclusion Criteria

Exclusion criteria for the study included patients with a preexisting diagnosis of chronic obstructive pulmonary disease (COPD) or a current smoking history. Patients over the age of 100 were excluded. Robotic surgery patients who did not receive carbon dioxide insufflation of their abdomen, or were converted to an open procedure were excluded. Patients who received total intravenous anesthetic due to a history of severe PONV were excluded. In an attempt to account for confounding factors to prevent a spurious association, medications or techniques that may have altered the recovery course were discarded from the data. Pharmacologic agents used in the intra-operative period may have influenced the PACU data, as well as anesthetic techniques like the addition of regional anesthesia.

Expected Outcomes

The goal of this study was to make a recommendation for the addition of sugammadex to an ERAS protocol though standard of care data collection and rigorous literate review. The use of sugammadex versus neostigmine may demonstrate a decrease in the incidence of PONV, respiratory complications and PACU time. Over a one-year period an expected decrease in the PACU nurse recording of variables indicating PONV or respiratory complications was expected. A decrease in PACU time was also expected. The administration of the NMB reversal agent was decided by the anesthesia provider, and recorded on the EMR. The PACU nurse recorded patient data indicating the incidence or PONV and respiratory complications, as well as total PACU time in minutes (see appendix A).

Methods

Case data was collected retrospectively from robotic surgery patients from May 2020 to May 2021 at Promedica Toledo Hospital. The data collected was recorded on an Excel spreadsheet. Data categories were divided into four groups (see appendix A): neostigmine reversal, sugammadex reversal, no pharmacological reversal or both reversal agents. Data was collected in categories recording evidence of pulmonary complications, PONV and time in the PACU (see appendix A). IRB approval was obtained through Promedica Toledo Hospital with a letter of deferment from the University of Alabama.

The recording of pulmonary complications will be determined by an O2 saturation less than or equal to 90% for 3 or more minutes. Bartels et al. (2020) classifies postoperative hypoxemia (POH) based on the presence of POH or not No-POH during a documented peripheral saturation of oxyhemoglobin (SpO2) less than or equal to 90% for 3 minutes or longer. PONV will be assessed on the Epic EMR from the PACU nurse's recording of an emetic event or administration of ondansetron. The 5-HT3 receptor antagonists like ondansetron are popular drugs for PONV prophylaxis because of their better efficacy to older drugs and favorable side effect profile and can be used as rescue anti-emetics (Bhalla et al. 2015).

Once the non-randomized data groups were divided into one of the four independent variable groups, neostigmine, sugammadex, no intervention, or both reversal agents, dependent data was recorded. Subjects who received neostigmine initially with a rescue dose of sugammadex were recorded as receiving both interventions. Evidence of pulmonary complications including an oxygen saturation of 90% or less for greater than 3 minutes, need for assistive positive pressure ventilation or extended PACU stay or unplanned ICU admission were placed in the Excel format (see appendix A). Evidence of PONV was assessed as use of antiemetic agents in the PACU (Bhalla et al. 2015), extended stay in the PACU or unplanned admission for PONV. EMR charting of PONV or emetic events from the PACU nurse were recorded. Differences in PACU time were analyzed. PACU admission time to discharge time was assessed as a dependent variable. PACU time was considered to be expired once an order was received for discharge from the PACU. Time spent waiting for bed availability or transport was not included. Decreased recovery time is a major aim of the study. The goal of an ERAS protocol is to increase comfort and decrease recovery time (Chui et al. 2018).

Project Design

This practice intervention design took place at PTH using quantitative data. The data was expected to show favorable results in both patient outcomes and increased economy. The cost savings from the avoidance of complications should offset the immediate increase in pharmacy charges. An improvement in metrics effected by an ERAS protocol was expected.

Project Site and Population

The study took place in Toledo, Ohio at the Promedica Toledo Hospital. Promedica Toledo Hospital is a 794 bed, nonprofit, level 1 trauma, tertiary care center that provides a wide range of surgical services. The population included patients undergoing minimally invasive laparoscopic robotic surgery. Access to the Epic EMR was required. No additional pharmacy or treatment resources were needed for the retrospective collection of standard of care data. A sample size of 100 (n=100) was required to ensure sufficient power ($p<0.05$). The PTH pharmacy department maintains the data regarding the cost and usage of NMB agents. The PTH pharmacy had concerns about the budgetary impact of an increase in sugammadex usage. However, the use of sugammadex was not impacted by this study due to the retrospective method of data collection. The four groups- neostigmine, sugammadex, no intervention or both- were planned to have a sample size of approximately 100 (n=100). Time in the PACU was collected in minutes. PACU discharge time was recorded when discharge criteria were met and an order for discharge was given. Time spent waiting for transport or bed availability was not included in the PACU minutes data. Evidence of reversal-based complications were recorded (see appendix A). All was collected from the EMR Epic system at PTH.

Measurement instruments

Data was collected from the PTH Epic EMR from May 2020 until May 2021. Data collected from the EMR included dependent and independent variables (see Appendix A). Data collection was from the Epic EMR and was recorded on an Excel spreadsheet. Excel spreadsheet data underwent statistical analysis with SPSS software. Data was entered into a Microsoft Excel Spreadsheet and imported to Statistical Package for the Social Sciences (SPSS) Version 27 (Armonk, NY) for statistical analysis. See data analysis section for complete statistical test battery.

Data Collection Procedures

A search for all robotic cases for the one-year period was performed through a systematic approach to find and collect the desired data. With assistance from the PTH information technology department (IT), reports were created with the desired data brought to the top. Exclusion criteria was considered and data points were added as needed. Raw data from PTH (IT) was presented in Excel format. The data was de identified, and encoded for statistical analysis. All variables were coded with numeric values for analysis. IRB deferment from the University of Alabama was obtained with IRB approval from PTH.

Data Analysis

Demographic and anthropometric characteristics of the patients (e.g., age, BMI) were collected for the four groups. To compare individual symptoms among the three groups, chi-square goodness of fit testing was conducted to determine if there were statistical differences. The chi-square test can identify if the observed proportion of symptoms is statistically different or similar to the expected proportion of symptoms. The expected proportion of symptoms among each group was determined by the research committee.

Chi-square testing was used to compare the proportion of patients who experience postoperative nausea and vomiting (PONV), pulmonary complications, and unplanned intensive care unit (ICU) admission. The observed results were not the expected results, a Chi- square test was used to assess any relationship that may have occurred between the variables themselves.

As the variables were continuous, we compared the means of each group using the analysis of variance testing (ANOVA) with post-hoc tests to explore differences between multiple group means. The Tukey test was used to determine where statistical significance occurred from the ANOVA testing. The Tukey test was used as essentially a post-hoc t-test that compared PACU times between two of the three groups at a time. The lack of statistical significance from the ANOVA testing was therefore confirmed by the Tukey test. T tests were performed between each of the paired variables to assess for significance in PACU time.

Cost Benefit Analysis

Cost for the study came from staff interview and assistance. Communication with the departments of information technology and pharmacy was necessary. The overall cost benefit analysis will come from the initial increase cost of sugammadex usage. The benefit and savings will come from a decrease in complications and their associated un-reimbursed charges (see appendix D).

Timeline

The expected dates for the project (see appendix B)

Ethical Considerations/Protection of Human Subjects

The Promedica Toledo Hospital Institutional Review Board (IRB) and The University of Alabama (UA) Institutional Review Board (IRB) deferral was obtained prior to initiating the project. The retrospective collection of standard of care data did not require consent. HIPPA standards were observed. All data collected was saved anonymously with password secured devices and encrypted data types. Hard copy data was not saved, nor was any identifiable data markers.

Results

There were no significant differences between the demographic data across the four groups. There were measurable differences that did not show statistical significance or impact the analyses. Demographics for the 562 subject study are presented in Table 1. The study contained 222 (39.5%) male and 338 (60.1%) females and gender was not recorded for two (0.4%). Race and ethnic background are also included in Table 1. Subject ages ranged from 17 to 100 years, with a mean age of 54.3. The neostigmine group is, on average, 7.21 years younger than the no drug (none) group and neostigmine group is, on average, 10.295 years younger than sugammadex group. Distribution between intervention groups was sugammadex 44% (n=247), neostigmine 10% (n=56), no reversal 32% (n=180) and both drugs 14% (n=79). Patients receiving both drugs (n=79) were initially treated with neostigmine and then were given a "rescue" dose of sugammadex related to complications of incomplete NMB reversal. The "Both" group was also included in the neostigmine group numbers in a separate statistical analysis, but this analysis did not find any significant change in the statistical significance in any of the dependent variables.

Across all four groups surgery time ranged from 54 to 584 minutes with a mean value of 190.6 minutes. Post anesthesia care unit (PACU) time ranged from 23 to 1081 minutes with a mean value of 129.9 minutes. Antiemetic "rescue" doses in the PACU ranged from 0 to 3 doses with a mean value of 0.31 doses. Mean age for sugammadex group was 56.96 years, neostigmine group was 46.66 years, no reversal 53.87 years and both was 52.4 years. Surgery time (OR time) in minutes across the 4 groups; sugammadex 198.9, neostigmine 180.48, no reversal 174.01 and both 209.63. The increased time in the (both) group was due to incomplete reversal of NMBA's with neostigmine. The treatment of adverse effects potentially compounded OR time. Time in the PACU in minutes across the 4 groups; sugammadex 133.74, neostigmine 145.54, no reversal 122.98 and both 121.86. Mean rescue antiemetic doses across the 3 groups receiving intervention were sugammadex 0.33, neostigmine 0.27, and both 0.27. Descriptive statistics for the intervention groups are in table 2.

Data collection results for pulmonary complications were not included in statistical analysis. The data collected yielded no recorded episodes of hypoxemia or unplanned admission for pulmonary complications. There were no recorded accounts of oxygen saturation below 92% in the PACU. Unplanned ICU admissions were recorded for surgical complications or unknown reasons. No unplanned ICU admissions for pulmonary complications or mechanical ventilation were found in the data.

There was no statistical significance in PACU time between the sugammadex group and the neostigmine group ($p=0.48$). Even with the exclusion of a 1081-minute outlier, no significance was assessed. There was a mean difference between the two groups though.

Sugammadex patients spent a mean time of 15.78 minutes less in the PACU than the neostigmine group. There was no significant difference found across the no reversal (none) or both intervention groups. Comparing just sugammadex and neostigmine through an independent samples t-test determined there was no difference in PACU time ($p = 0.48$). The T-test was used to determine if there was a statistically significant difference between just those 2 groups. A 1:1 ratio of sugammadex to neostigmine could have potentially achieved a significant level ($p>0.05$).

Rescue antiemetic measurements yielded no significant statistical differences across the four groups.

Discussion

While no statistically significant differences were found with PACU time, PONV or pulmonary complications, we found clinical significance between certain groups. Specifically, we found that sugammadex administration resulted in a mean time decrease in the PACU of 15.78 minutes (i.e., a decrease in PACU recovery time) which is a prime goal of an ERAS protocol. Variations in PACU time is multifactorial, and we note that some of the potential variables impacting PACU time are reflected in the data included in this analysis, others are not. For example, variables such as pain and type of robotic surgery were not included in our analyses. Additionally, the impact of the included variables may have been strengthened with an increased sample size, and as such we may not have reached significance due to the smaller sample size included in our analysis. Also, we note that our results do not follow the major results of existing literature regarding pulmonary complications and PONV. Specifically, Hristovska et al. (2018) found that sugammadex more safely and reliably reversed NMB agents with decreases in cardiopulmonary complications and PONV. The use of sugammadex has been shown to decrease many common anesthesia complications. Additionally, regarding costs, the avoidance of these events has been shown to result in cost savings of 10.9% in a modeled case type (Jiang et al. 2021).

Independent of statistical analysis, some clinical factors may have led to our results not mirroring previous literature on pulmonary complications regarding low O2 saturation. According to Kheterpal et al. 2020, about 5% of adults undergoing surgical procedures will have a pulmonary complication including oxygen desaturation. Our data demonstrated 0% of 562 patients had an episode of desaturation. The data also shows a 0% incidence of unplanned ICU admission for pulmonary complications. Inaccuracies in point of care EMR data recording could be the cause of this disparity with established literature. Although, Togioka et al. 2020 found no difference in pulmonary complications in elderly adults undergoing prolonged surgery between sugammadex and neostigmine.

The decision to study the “both” group separately from the neostigmine group was made because of the potential skewing of data for the side effects of neostigmine- only. Specifically, if a rescue dose of sugammadex was administered for incomplete NMB reversal, the adverse effects of neostigmine could be eliminated from the data. The both group (n=79) combined with the neostigmine group (n=56) resulted in 135 patients receiving a dose of neostigmine, while 79 received a rescue dose of sugammadex. Considering those numbers, 58.5% of study participants required a rescue dose of sugammadex. However, the reason why the rescue dose was administered was not available. The clinical significance mirrors the existing literature in terms of more effective and reliable reversal of NMBA’s. Sugammadex as a rescue agent was found to intercept incomplete adverse effects of incomplete reversal of NMBA’s and avoid poor respiratory outcomes (Krause et al. 2020).

Promedica Toledo Hospital pharmacy financial impact data was not available. The percentage of patients receiving both neostigmine and sugammadex resulted in a cost that is higher than patients receiving just sugammadex. Over half of the patients included in the neostigmine group required this second charge. The additional costs of sugammadex for the reversal of rocuronium or vecuronium induced NMB could be offset by improved outcomes and potentially lead to overall healthcare budgetary savings versus reversal with neostigmine or spontaneous recovery (Jiang et al. 2021). In Jiang's study in 2021, a 12% reduction in pulmonary complications alone was achieved using sugammadex. This resulted in a $3,079,703 budgetary savings at one institution.

Combining an ERAS protocol with robotic surgery is designed to save money and improve patient outcomes and decrease post-operative complications. The use of sugammadex has been shown to do both. A decrease in PACU time of over 15 minutes has a financial impact. Without factoring in the cost of treating complications, a 15.78-minute time savings is impactful. PTH charges for PACU time per 15-minute block. Each block is charged at $370. As soon as a new 15-minute block is started, another $370 charge is incurred. Thus, a 15.78-minute time reduction equates to a $740 savings per case.

Conclusion

ERAS protocols and minimally invasive robotic surgery represent the safest and most economic methods of patient care. Patient safety and achievement of quality outcome indicators result in cost savings. This economy results from avoidance of costly complications. Many of the common complications from anesthesia can be avoided with the switch to safer medications. While the safer medications may be more costly initially per dose, the resultant clinical pathways are much cheaper. The literature supports this decrease in complications when using sugammadex over neostigmine. When examining the study population, the decreased time in PACU corresponds with the use of sugammadex. A decrease in PACU time results from faster recovery. Achieving discharge criteria is made easier and faster with the use of sugammadex. Institutional cost to PTH will be lower with the addition of sugammadex into a minimally invasive robotic surgery ERAS protocol.

Acknowledgements

The authors would like to thank Dr. Brian Fink Ph.D., MPH, CHES, Professor of Epidemiology and Statistics at the University of Toledo for his help with the statistical analysis for this quality improvement project.

References

Bartels, K., Kaizer, A., Jameson, L., Bullard, K., Dingmann, C., & Fernandez-Bustamante, A. (2020). Hypoxemia within the first 3 postoperative days is associated with increased 1-year postoperative mortality after adjusting for perioperative opioids and other confounders. Anesthesia and Analgesia, 131(2), 555-563. doi:10.1213/ANE.0000000000004553

Bhalla, J., Baduni, N., & Bansal, P. (2015). Comparison of palanosetron with ondansetron for postoperative nausea and vomiting in patients undergoing laparoscopic cholecystectomy under general anesthesia. Journal of Minimal Access Surgery, 11(3), 193-197. doi:10.4103/0972-9941.140219

Brueckmann, B., Sasaki, N., Grobara, P., Li, M. K., Woo, T., de Bie, J., . . . Eikermann, M. (2015). Effects of sugammadex on incidence of postoperative residual neuromuscular blockade: A randomized, controlled study. British Journal of Anesthesia, 115(5), 743-751. doi:10.1093/bja/aev104

Cammu, G. (2020). Residual neuromuscular blockade and postoperative pulmonary complications: What does the recent evidence demonstrate? Current Anesthesiology Reports, , 1-6. doi:10.1007/s40140-020-00388-4

Chiu, C., Aleshi, P., Esserman, L. J., Inglis-Arkell, C., Yap, E., Whitlock, E. L., & Harbell, M. W. (2018a). Improved analgesia and reduced post-operative nausea and vomiting after implementation of an enhanced recovery after surgery (ERAS) pathway for total mastectomy. BMC Anesthesiology, 18(1), 41. doi:10.1186/s12871-018-0505-9

Chiu, C., Aleshi, P., Esserman, L. J., Inglis-Arkell, C., Yap, E., Whitlock, E. L., & Harbell, M. W. (2018b). Improved analgesia and reduced post-operative nausea and vomiting after implementation of an enhanced recovery after surgery (ERAS) pathway for total mastectomy. BMC Anesthesiology, 18(1), 41. doi:10.1186/s12871-018-0505-9

Hristovska, A., Duch, P., Allingstrup, M., & Afshari, A. (2017). Efficacy and safety of sugammadex versus neostigmine in reversing neuromuscular blockade in adults. The Cochrane Database of Systematic Reviews, 8, CD012763. doi:10.1002/14651858.CD012763

Jiménez Salas, B., Ruiz Frontera, M., Seral García, B., García-Álvarez García, F., Jiménez Bernadó, A., & Albareda Albareda, J. (2020). Causes of unplanned admission after orthopedic procedures in ambulatory surgery. Revista Espanola De Cirugia Ortopedica Y Traumatologia, 64(1), 50-56. doi:10.1016/j.recot.2019.09.001

Kheterpal, S., Vaughn, M. T., Dubovoy, T. Z., Shah, N. J., Bash, L. D., Colquhoun, D. A., Saager, L. (2020a). Sugammadex versus neostigmine for reversal of neuromuscular blockade and postoperative pulmonary complications (STRONGER): A multicenter matched cohort analysis. Anesthesiology, 132(6), 1371-1381. doi:10.1097/ALN.0000000000003256

Kim, H. J., Lee, K., Kim, M. H., Kim, H., & Bai, S. J. (2019). Effects of deep vs moderate neuromuscular block on the quality of recovery after robotic gastrectomy. Acta Anaesthesiologica Scandinavica, 63(3), 306-313. doi:10.1111/aas.13271

Laporta, M. L., Sprung, J., & Weingarten, T. N. (2020). Respiratory depression in the post-anesthesia care unit: Mayo clinic experience. Bosnian Journal of Basic Medical Sciences, doi:10.17305/bjbms.2020.4816

Maerz, D. A., Beck, L. N., Sim, A. J., & Gainsburg, D. M. (2017). Complications of robotic-assisted laparoscopic surgery distant from the surgical site. British Journal of Anesthesia, 118(4), 492-503. doi:10.1093/bja/aex003

Rao, V. K., & Khanna, A. K. (2018). Postoperative respiratory impairment is a real risk for our patients: The intensivist's perspective. Anesthesiology Research and Practice, 2018, 3215923. doi:10.1155/2018/3215923

Son, J., Oh, J., & Ko, S. (2017a). Effects of hypercapnia on postoperative nausea and vomiting after laparoscopic surgery: A double-blind randomized controlled study. Surgical Endoscopy, 31(11), 4576-4582. doi:10.1007/s00464-017-5519-8

Son, J., Oh, J., & Ko, S. (2017b). Effects of hypercapnia on postoperative nausea and vomiting after laparoscopic surgery: A double-blind randomized controlled study. Surgical Endoscopy, 31(11), 4576-4582. doi:10.1007/s00464-017-5519-8

Swenson, C. W., Kamdar, N. S., Harris, J. A., Uppal, S., Campbell, D. A., & Morgan, D. M. (2016). Comparison of robotic and other minimally invasive routes of hysterectomy for benign indications. American Journal of Obstetrics and Gynecology, 215(5), 650.e1-650.e8. doi:10.1016/j.ajog.2016.06.027

Togioka, B. M., Yanez, D., Aziz, M. F., Higgins, J. R., Tekkali, P., & Treggiari, M. M. (2020a). Randomized controlled trial of sugammadex or neostigmine for reversal of neuromuscular block on the incidence of pulmonary complications in older adults undergoing prolonged surgery. British Journal of Anesthesia, 124(5), 553-561. doi:10.1016/j.bja.2020.01.016

Ünal, D. Y., Baran, İ, Mutlu, M., Ural, G., Akkaya, T., & Özlü, O. (2015). Comparison of sugammadex versus neostigmine costs and respiratory complications in patients with obstructive sleep apnea. Turkish Journal of Anesthesiology and Reanimation, 43(6), 387-395. doi:10.5152/TJAR.2015.35682

Weibel, S., Rücker, G., Eberhart, L. H., Pace, N. L., Hartl, H. M., Jordan, O. L., Kranke, P. (2020a). Drugs for preventing postoperative nausea and vomiting in adults after general anesthesia: A network meta-analysis. The Cochrane Database of Systematic Reviews, 10, CD012859. doi:10.1002/14651858.CD012859.pub2

Yağan, Ö, Taş, N., Mutlu, T., & Hancı, V. (2017a). Comparison of the effects of sugammadex and neostigmine on postoperative nausea and vomiting. Brazilian Journal of Anesthesiology (Elsevier), 67(2), 147-152. doi:10.1016/j.bjane.2015.08.003

Zhao, J., Hu, J., Jiang, Z., Wang, G., Liu, J., Wang, H., Li, J. (2018). Outcome of discharge within 72 hours of robotic gastrectomy using enhanced recovery after surgery programs. Journal of Laparo-endoscopic & Advanced Surgical Techniques. Part A, 28(11), 1279-1286. doi:10.1089/lap.2018.0051

Hristovska, A., Duch, P., Allingstrup, M., & Afshari, A. (2017). Efficacy and safety of sugammadex versus neostigmine in reversing neuromuscular blockade in adults. The Cochrane Database of Systematic Reviews, 2017(8) doi:10.1002/14651858.CD012763

Jiang, Y., Bash, L. D., & Saager, L. (2021). A clinical and budgetary impact analysis of introducing sugammadex for routine reversal of neuromuscular blockade in a hypothetical cohort in the US. Advances in Therapy, 38(5), 2689-2708. doi:10.1007/s12325-021-01701-1

Krause, M., McWilliams, S. K., Bullard, K. J., Mayes, L. M., Jameson, L. C., Mikulich-Gilbertson, S. K., . . . Bartels, K. (2020). Neostigmine versus sugammadex for reversal of neuromuscular blockade and effects on reintubation for respiratory failure or newly initiated noninvasive ventilation: An interrupted time series design. Anesthesia and Analgesia, 131(1), 141-151. doi:10.1213/ANE.0000000000004505

Appendix

Appendix A Measured Variables

	PACU Min	Add. Sugammadex	Pulm Admit	SaO2<90%	Add. Zofran	PONV Admit
Sug						
Neo						
None						
Both						

A- Time in PACU t=minutes

B- Need for rescue sugammadex

C- Unplanned admission/ ICU admission for pulmonary issues

D- O2 saturation < or = to 90% POH (post-operative hypoxemia)

E- Additional anti emetics in PACU

F- EMR recording PONV as an anesthesia complication

Appendix B Timeline

March 2021	Accepted proposal
April 2021	IRB approval
May 2020 to May 2021	Data collection
July 2021	Statistical analysis
September 2021	Dissemination of findings and clinical recommendations

Table 1. Demographics

Gender	N	%
Male	222	39.5
Female	338	60.1
Missing	2	0.4
Total	562	100.0
Race	N	%
White	464	82.6
Black	66	11.7
Hispanic	16	2.9
Middle Eastern	4	0.7
Multiracial	5	0.9
Unknown	3	0.5
Missing	4	0.7
Total	562	100.0
Drug Group	N	%
Sugammadex	247	44.0
Neostigmine	56	10.0
Both	79	14.0
None	180	32.0
Total	562	100.0

Table 2. Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Patient Age	None	178	53.87	17.374	1.302	51.30	56.44	18	89
	Suggamadex	247	56.96	18.606	1.184	54.62	59.29	20	100
	Neostigmine	56	46.66	16.007	2.139	42.37	50.95	18	77
	Both	79	52.41	15.392	1.732	48.96	55.85	17	84
	Total	560	54.30	17.768	.751	52.83	55.78	17	100
Minutes in OR	None	180	174.01	78.358	5.840	162.49	185.54	67	531
	Suggamadex	247	198.96	102.250	6.506	186.14	211.77	54	584
	Neostigmine	56	180.48	85.671	11.448	157.54	203.42	83	446
	Both	79	209.63	105.830	11.907	185.93	233.34	81	517
	Total	562	190.63	94.872	4.002	182.77	198.49	54	584
Length of Stay	None	180	5.27	8.038	.599	4.08	6.45	0	53
	Suggamadex	247	4.28	6.086	.387	3.52	5.05	0	44
	Neostigmine	56	2.13	2.175	.291	1.54	2.71	0	8
	Both	79	4.13	5.004	.563	3.01	5.25	0	24
	Total	562	4.36	6.448	.272	3.83	4.90	0	53
PACU Time Spent (in minutes)	None	168	122.98	97.157	7.496	108.18	137.77	23	589
	Suggamadex	239	133.74	113.077	7.314	119.33	148.15	38	1081
	Neostigmine	56	145.54	109.137	14.584	116.31	174.76	50	546
	Both	78	121.86	90.945	10.298	101.35	142.36	32	539
	Total	541	129.90	104.897	4.510	121.04	138.76	23	1081
Number of PACU Anti-Emetic Doses	None	167	.29	.584	.045	.20	.38	0	2
	Suggamadex	239	.33	.626	.040	.25	.41	0	3
	Neostigmine	56	.27	.556	.074	.12	.42	0	2
	Both	78	.27	.551	.062	.15	.39	0	2
	Total	540	.31	.595	.026	.26	.36	0	3

Appendix C Conceptual Framework