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Clinical Application: A Cost-Benefit Analysis of Sugammadex Versus Neostigmine for a North Mississippi Delta Hospital

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CLINICAL APPLICATION: A COST-BENEFIT ANALYSIS OF SUGAMMADEX VERSUS NEOSTIGMINE FOR A NORTH MISSISSIPPI DELTA HOSPITAL

by

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A Doctoral Project
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Approved by:

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ABSTRACT

As the cost of health care continues to rise and insurance reimbursements have decreased, organizations have to find avenues to cut costs and increase profits. A goal of this project is to help prepare anesthesia providers with the best evidence-based knowledge about sugammadex and neostigmine and allow providers to make a sound, cost-efficient decision when choosing a reversal method. A needs assessment was conducted with the chief certified registered nurse anesthetist (CRNA) at a north delta Mississippi facility. The needs assessment demonstrated that cost was the main concern and reason for choosing neostigmine over sugammadex. Further, providers at the chosen hospital also wanted to know whether the benefits of sugammadex outweighed the cost of the medication.

A thorough literature review and detailed cost analysis indicated that sugammadex is a superior reversal agent for reversing the paralytic effects of rocuronium and could create a cost-effective surgical care model if implemented fully into clinical practice. The cost-benefit analysis of neostigmine versus sugammadex demonstrated that the purchasing price of sugammadex was more expensive than the cost of neostigmine, but a thorough literature review and detailed cost analysis indicated that sugammadex could potentially have a cost savings of $345,640 to $997,064 over a 6-month period by increasing the rate of discharge from the operating room. Sugammadex has a purchasing cost of $70.72, and if this reversal technique was used for each of the 800 abdominal surgical cases over the 6-month period, the overall purchasing cost would be $48,360.

Implementing sugammadex into clinical practice could have a potential cost savings of $345,640 at minimum over a 6-month period after the purchasing cost of

sugammadex is considered and will drastically improve patient outcomes by preventing residual muscle paralysis from incomplete reversal of paralysis. An evidence-based literature review and a detailed cost analysis demonstrated that sugammadex is far superior in reversing the effects of rocuronium and can allow operating rooms to save a tremendous amount of money by improving operating room discharge times, which would offset the purchasing cost of sugammadex and create an efficient surgical care model.

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Several notable figures need to be acknowledged for their roles involved in this investigation, all persons were key, and we could not have accomplished this task without them. First, we would like to sincerely thank our Committee Chair, Dr. Nina McLain for her knowledge, continuous support, and countless phone calls and emails. Secondly, we would like to thank Dr. Stephanie Parks and Dr. Lachel Story for their doctoral guidance, clinical experience, and leadership that helped solidify this investigation. We could not have accomplished this achievement without all of their unwavering patients and drive to push us to finish this investigation. We would also like to extend gratitude to Dr. Mary Jane Collins for helping this investigation in the early stages of development and further would not be at this destination without her.

Several clinical experts were pivotal in the development of this investigation and further gave invaluable clinical expertise that helped us correlate our investigation to anesthesia providers. John Moyer, CRNA, was crucial with the development of this project and was readily available for expert advice, support and helped sculpt us into the providers we are today. The anesthesia group at Greenwood Leflore Hospital which included Marty Self, Sandy Weathers, Jody Simcox, and Dave Franklin were all pivotal in developing us anesthesia providers and supported us throughout this entire process. Many more people also were so vital in this process and we are extremely grateful for their support.

DEDICATION

Our dedication is also for our families who have loved, supported, and pushed us to be excellent while shouldering the tremendous tasks that we left to them. First, we would like to give thanks to God who gave us peace in a time of struggle and joy in times of sorrow. Next, we would like to dedicate this project to both of our moms, we would not be here today without their love and support. While we were away at clinical sites our mothers took our vacancy in our families and became the spouse and father in our absence. Secondly, our wives, who have encouraged us and allowed us to chase our dreams even when it meant extreme sacrifices, never once complaining to us, but telling us to press onward. We love you both so much and this accomplishment is as much yours as it is ours. Lastly to our children, the reason we are chasing our dreams in life is because of you, you were the reason for the late nights of studying, the long hours in the operating room, and the long weeks away from your laughs, hugs, and kisses. We pray and hope that we are setting the right example and that you will always have the courage to chase your dreams, no matter what obstacles stand in your way. Finally, we would like to extend thanks to our families who have supported, prayed, and loved us during this chapter in our lives; we are eternally grateful.

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LIST OF ABBREVIATIONS

AACN	American Association of Critical Care Nurses
ASA	American Society of Anesthesiologist
CBA	Cost Benefit Analysis
CMS	Centers for Medicare and Medicaid Services
CRNA	Certified Registered Nurse Anesthetist
DNP	Doctor of Nursing Practice
IRB	Institutional Review Board
IT	Information Technology
Mg/kg	Milligrams per kilogram
NAP	Nurse Anesthesia Program
NMB	Neuromuscular Blockade
OR	Operating Room
PACU	Post Anesthesia Care Unit
SRBA	Selective Relaxant Binding Agent
SRNA	Student Registered Nurse Anesthetist
TOF	Train of Four
USM	University of Southern Mississippi
CONHP	College of Nursing and Health Professions

CHAPTER I - INTRODUCTION

With the rising cost of health care and limited reimbursement from insurance companies, organizations are continually trying to find new avenues to decrease costs and improve profits. The healthcare reform has forced anesthesia providers to critique their anesthetic plan to ensure cost savings and make providers aware of anesthetic costs, such as medicines (Zhou, 2016). In anesthesia, multiple drug options are available to cause the same effect, such as reversals for neuromuscular blocking agents.

In anesthesia, several options exist for neuromuscular blockade reversal. The two most commonly used are neostigmine and sugammadex. Neostigmine, an anticholinesterase, is currently the most widely used drug for neuromuscular blockade reversal. While sugammadex is a newer option that is being implemented into practice to reverse the effects of steroidal neuromuscular blockers such as rocuronium. The cost and benefits of each medication were the focus of this investigation to determine the most evidence-based proven reversal method and its associated cost. Providers' knowledge and preference were also investigated to further evaluate each medication and why a provider chooses one reversal over another.

Problem Description

Are the benefits of sugammadex worth the expense when reversing steroidal neuromuscular blockers when compared to neostigmine? The purpose of this project was to investigate the cost and benefit comparison of sugammadex versus neostigmine. A cost-benefit analysis was performed to compare the medications.

Purpose and Context

The cost and benefits of each medication were the focus of this investigation to determine the most evidence-based proven reversal method and its associated cost between neostigmine and sugammadex. Provider preference were investigated by administering a survey to an expert group of providers to help answer whether sugammadex was worth the associated expense. Finally, sugammadex and neostigmine were compared to each other to discover which reversal technique provides improved patient outcomes.

Purpose of the Project

The purpose of this project was to investigate the current standard of practice and to determine the most beneficial and cost-effective method for reversing rocuronium, a non-steroidal neuromuscular blocker. The reversal medications that were the focus of this investigation were neostigmine and sugammadex. Neostigmine has been used in clinical practice for many years to reverse the effects of rocuronium. Sugammadex is new to clinical practice and specifically designed to reverse steroidal neuromuscular blockers such as rocuronium. Analyzing the cost, patient benefits, and providers' preferences were the focus of this project.

Summary

In summary, the purpose of this project was to investigate whether sugammadex's benefits were worth the increased expense over neostigmine. Sugammadex and neostigmine both reverse the effects of rocuronium, a neuromuscular blocker that causes paralysis. A cost-benefit analysis was performed to determine which reversal technique was superior and provided the most cost-effective care. A cost-analysis without the

considerations of benefits of each medication was considered but the investigation revealed that more factors were involved in determining whether sugammadex or neostigmine was the superior reversal technique.

CHAPTER II – METHODOLOGY

Intervention

Once the project received approval from The University of Southern Mississippi (USM), Institutional Review Board (IRB), and a north Mississippi delta hospital the cost of each medication, surgical time, post-anesthesia care unit (PACU) time, and hospital stay were documented for comparison. Using the obtained literature from the investigation's data search, a literature review was conducted to determine which medication has the highest incidence of residual neuromuscular blockade and how this affects discharge times from the PACU. The investigation calculated and compared each medication to create a cost-benefit analysis to be presented to a north Mississippi delta hospital. After completion, the detailed cost-benefit analysis was given to the chief CRNA and anesthesiologist at the rural Mississippi hospital for review to increase awareness and knowledge about the differences between the two reversal methods and which option has better patient outcomes and is more cost-efficient.

DNP Essentials

The requirements for the doctoral nursing project (DNP) for the Commission on Collegiate Nursing Education included meeting the American Association for Colleges of Nursing (AACN) DNP Essentials (AACN, 2006). The cost-benefit analysis of sugammadex versus neostigmine specifically meets all essentials as demonstrated in the following:

- Essential I, Scientific Underpinnings for Practice, was met by conducting a cost-benefit analysis literature review of Neostigmine and Glycopyrrolate versus Sugammadex, along with the costs, benefits, and risks of each. By integrating

nursing science using analytics, the project was able to directly improve the outcome of patient care.

- Essential II, Organizational and Systems Leadership for Quality Improvement and Systems Thinking, was met by determining which rocuronium reversal technique is the most cost-effective in decreasing the costs for both patients and hospital organizations.
- Essential III, Clinical Scholarship and Analytical Methods for Evidence-based practice were met by reviewing and utilizing a current literature review and completing an itemized cost analysis for both neostigmine and glycopyrrolate versus sugammadex.
- Essential IV, Information Systems/Technology and Patient Care Technology for the Improvement and Transformation of Health Care were met by utilizing the organization's Information Technology department in securing the necessary data to allow for a thorough cost-benefit analysis to be completed.
- Essential V, Health Care Policy for Advocacy in Health Care, was met because the results of this project can help guide the organization in determining the most cost-efficient and best practice standard when reversing the effects of rocuronium.
- Essential VI, Inter-professional Collaboration for Improving Patient and Population Health Outcomes were met by collaborating with a panel of anesthesia professionals to help determine the cost savings and benefits of reversal techniques for their patients and the organization.
- Essential VII, Clinical Prevention and Population Health for Improving the Nation's Health was met because neuromuscular blocker reversals are essential in

anesthesia practice for reversing the effects of rocuronium, which is also essential for recovery from anesthesia. By utilizing evidence to choose the most cost-efficient and safest technique of reversing rocuronium, patients will receive more efficient and safer anesthetic care.

- Essential VIII, Advanced Nursing Practice, was met by educating CRNAs and anesthesiologists on the cost-benefit analysis results, then they will be encouraged to utilize the provided evidence to implement the most cost-efficient and best practice technique for reversing rocuronium.

Stakeholders

Stakeholders for this project included the Coordinator of the Nurse Anesthesia Program, the chief CRNA of a small rural hospital in north Mississippi, and the anesthesia staff, surgeons, PACU, and surgical patients at this small rural hospital. Additional stakeholders included the nursing staff and the DNP project committee of this project. One goal of this project was to provide stakeholders with the most evidence-based and cost-effective reversal technique when reversing rocuronium.

Data Collection and Analysis

The chief CRNA was approached at a rural hospital in north Mississippi about the need for a cost-benefit analysis on neuromuscular blockade reversal. The lack of use of the recently approved sugammadex, the first selective relaxant binding agent (SRBA) to be introduced as a reversal for the clinical neuromuscular blockade was discussed in great detail and how its high cost has deterred its use at the facility. One of the goals of this project was to evaluate current care in small financially burdened hospitals and present cost-effective alternatives that may help quality and reduce costs. The chief CRNA at this

facility provided a detailed pharmacy report that included the cost of sugammadex, neostigmine, and glycopyrrolate per vial as well as the operating room (OR) costs and PACU costs. This information was used to develop a cost-benefit analysis for each reversal technique.

The investigation utilized a thorough literature review to determine which neuromuscular blockade reversal agent had less incidence of postoperative residual paralysis. A cost-benefit analysis was then developed for the facility that included the initial cost, cost over the intraoperative period, and the efficacy of each reversal method. A voluntary questionnaire was offered to each CRNA working at the facility to determine if there is a provider preference for which medication they use for neuromuscular blockade. The data from the survey was then compiled, analyzed, and the results summarized. The summarized survey results demonstrated the relevance of this investigation and the potential impact it could have on anesthesia practice.

Measures

The desired goals of this project included determining the best practice for reversing neuromuscular blockade and which medication was more cost-effective for the provider. The investigation discovered which reversal method was more cost-effective and provided improved patient outcomes by utilizing the information obtained from the chief CRNA at a north Mississippi delta hospital and a thorough literature review for neostigmine and sugammadex. The purpose of this investigation was to make a clear determination for which medication was the best choice when considering medication costs and benefits of neostigmine and sugammadex.

Further, another vital role of this investigation was to help educate CRNAs and other anesthesia providers about each reversal technique and provide evidence-based literature as to whether sugammadex or neostigmine was superior. A panel of experts was utilized to provide the investigation with their first- hand knowledge of their clinical experience when administering neostigmine and sugammadex. Finally, the investigation was able to make this determination after data was collected, with a completed literature review, and detailed cost analysis.

Population and Setting

For this project, the population was surgical patients 18 years of age or older, classified by the American Society of Anesthesiologist (ASA). The investigation chose ASA I and II classifications who have received general anesthesia with a rocuronium-induced neuromuscular blockade and were given either neostigmine and glycopyrrolate or sugammadex for its reversal. Exclusion criteria included neuromuscular disorders, diagnosed or suspected renal disease defined as an estimated creatinine clearance of <30 ml/min, hepatic dysfunction, allergies to sugammadex, neostigmine, glycopyrrolate, or rocuronium, and planned admission to the hospital. The setting was a small, 220-bed rural hospital in north Mississippi delta. The hospital performs approximately 6,000 surgeries a year.

Barriers

Barriers for this project included anesthesia providers' preferences for certain medications used for neuromuscular blockade reversal. Inadequate train of four (TOF) documentation by the anesthesia provider to determine the level of neuromuscular blockade at the time of reversal could lead to the improper dosage of neuromuscular

reversal agents, altering the results of the overall research. The anesthesia provider utilizes TOF monitoring to determine how paralyzed a patient is before selecting a neuromuscular blockade reversal dose, this is vital because if an inadequate dose is chosen then the patient is at risk for pulmonary aspiration and respiratory failure. Another barrier is a lack of documentation of TOF in the PACU setting to determine if residual neuromuscular blockade has occurred. Finally, the sample size of the population surveyed was small due to facility size, a larger sample may have yielded different results.

Ethical Considerations

The ethical considerations included two standards of care being delivered in the intraoperative period for which cost-benefit analysis was conducted to find evidence supporting the best neuromuscular blockade reversal. Further, CRNAs are responsible for providing cost-effective anesthesia care at this rural facility The cost-benefit analysis has been completed using evidence-based research, the CRNAs at this north Mississippi delta hospital were given access to evidence-based knowledge needed to provide the best standard of care by providing the safest and most cost-effective way to reverse neuromuscular- blockade.

Discussion

Are the benefits of sugammadex worth the expense when reversing steroidal neuromuscular blockers when compared to neostigmine and glycopyrrolate? Further, has inexperience or possibly expense associated with sugammadex created a barrier to a possible superior method when reversing steroidal neuromuscular blockers that would greatly improve patient outcomes? Anesthesia providers have a great deal of

independence, but with this independence comes increased responsibility that the providers must be aware of, such as patient benefits and costs of certain anesthetic techniques.

Utilizing paralytics is a common anesthetic practice that serves the purpose of inducing neuromuscular blockade or paralysis during general anesthesia to paralyze the vocal cords and jaw muscles to facilitate endotracheal intubation (Babu et al., 2018). Neuromuscular blockade is a common practice in anesthesia, but neuromuscular blockers have several risk factors that can lead to costly complications if not successfully reversed postoperatively, for example, delayed discharge and post-operative ventilation requiring critical care.

These complications can have a large impact on patient outcomes that ultimately affect the financial reimbursement for quality care that is received. As the cost of health care continues to rise and limited reimbursements from insurance companies, organizations are continually trying to find ways to cut costs and increase profits. The healthcare reform has forced anesthesia providers to critique their anesthetic plan to ensure cost savings and make providers aware of anesthetic costs, such as medicines (Zhou, 2016).

Complete neuromuscular strength is imperative in the recovery phase of anesthesia to allow for appropriate ventilation and sensitivity to hypoxia to prevent respiratory failure in the recovery room (Babu et al., 2018). The purpose of this project was to investigate the costs and benefits of sugammadex versus neostigmine when used for steroidal neuromuscular blockade reversal and whether or not it was preventing improve patient outcomes. Neostigmine is the most commonly used anticholinesterase

drug worldwide for neuromuscular blockade reversal (Zaouter et al., 2017). Neostigmine is cost-effective but is usually co-administered with glycopyrrolate to counteract the occurrence of its muscarinic side effects, such as nausea, vomiting, and bradycardia (Insinga et al., 2016).

Sugammadex is a selective relaxant agent used as a reversal for clinical neuromuscular blockade. “It is a modified gamma-cyclodextrin that works by encapsulating and forming a very tight water-soluble complexes at a 1:1 ratio with steroidal neuromuscular blocking drugs” (Nagelhout & Elisha, 2018, p.163). Sugammadex was recently approved in the United States and has been shown to provide a more consistent and faster reversal of rocuronium without the muscarinic side effects of neostigmine (Insinga et al., 2016). The cost and benefits of each medication were the focus of this investigation to determine the most evidence-based proven reversal method and its associated cost.

Future implications of this study should closely follow the associated cost of delayed discharge from the PACU and further investigate outpatient surgeries that had to be admitted to the hospital due to post-operative residual paralysis due to inadequate reversal with neostigmine. A thorough cost analysis needs to be conducted after this event occurs to demonstrate the amount of funds that could be possibly lost due to not meeting appropriate Centers for Medicare and Medicaid Services (CMS) guidelines. The investigator could open the eyes of providers to look at more than just front-end purchase cost of sugammadex and investigate the long-term cost and benefits of implementing sugammadex into clinical practice.

Summary

The expected outcome of this project was to determine which neuromuscular blockade reversal agent would enhance OR efficiency and reduce complications related to inadequate neuromuscular blockade reversal. The cost-benefit analysis was completed by comparing the cost of each medication using the information obtained from the chief CRNA. A literature review was then used to determine which reversal method had the least amount of complications; the benefit analysis and the cost analysis were then combined to create a cost-benefit analysis of neostigmine vs sugammadex.

The cost-benefit analysis was presented to a panel of experts, which included the Nurse Anesthesia Program Coordinator, one USM College of Nursing and Health Professions Associate Dean, and the current CRNA employed at the rural hospital. The CRNAs at the small rural hospital were given a short questionnaire regarding their current practice for neuromuscular blockade reversal. These results were carefully analyzed and discussed as part of the investigation.

CHAPTER III - Results

Analysis

Neostigmine is the most widely used reversal method for a neuromuscular blockade; however, several life-threatening side effects are associated with its use such as arrhythmias and bronchospasms. Neostigmine works on the parasympathetic system and can cause severe bradycardia and must be administered with an anticholinergic to prevent bradycardia. Neostigmine is also known for its slow onset of action and its inability to reverse deep neuromuscular blockade. Sugammadex mechanism of action creates a faster and safer reversal when compared to neostigmine. The most significant factor when comparing neostigmine to sugammadex is its overwhelming ability to reverse deep neuromuscular blockade reliably and quickly (Zaouter et al., 2017). Residual paralysis occurs less frequently with sugammadex than neostigmine. “Residual paralysis may increase morbidity by impairing coughing, swallowing, and the patient’s ability to breathe deeply” (Ezri et al., 2016, p. 16).

In a 2015 study comparing sugammadex and neostigmine for reversing neuromuscular blockade, sugammadex reduced all signs of residual postoperative paralysis such as hypoxia, upper airway obstruction, and decreased oxygen saturation in 1553 participants (Abad-Gurumeta et al., 2015). Studies have consistently shown that sugammadex reduces the clinical signs of postoperative residual paralysis caused by rocuronium when compared to neostigmine. A study aimed to investigate residual blockade and operating room discharge times, 154 adult patients undergoing abdominal surgery were given rocuronium for neuromuscular blockade. None of 74 patients who were given sugammadex for reversal showed signs of a residual blockade at PACU

admission, and 33 out of 76 patients who received neostigmine and glycopyrrolate had symptoms of residual paralysis. Sugammadex also increased discharge times by 3.9 minutes respectively (Brueckmann et al., 2015).

A study involving 140 patients with a post-tetanic count of 1-2 received a dose of 4 milligrams per kilogram (mg/kg) dose of sugammadex, spontaneous recovery from deep rocuronium-induced blockade occurred in 1.8-2.8 minutes compared to 50.4 minutes when using neostigmine. Deep neuromuscular blockade maintained until the end of surgery shows to increase the quality of certain operational conditions, especially in obese patients. Sugammadex is also associated with a shorter length of stay in PACU because of faster recovery time and less pain (Zaouter et al., 2017).

Report of Findings

For this DNP project, data was obtained to develop a cost-benefit analysis of neostigmine and glycopyrrolate vs sugammadex and implement a best practice recommendation for the reversal of neuromuscular blockade in the intraoperative setting by anesthesia providers. The student nurse anesthetists used evidence-based research that was collected for comparison of each medication's benefits. These benefits were determined by two factors while performing the cost-benefit analysis. The first factor was that multiple studies have shown that sugammadex provides faster recovery times when compared to neostigmine, and the second factor was that the time saved can be converted into shorter workdays or allow for more time to perform a greater number of surgeries during the current work schedule. The cost of each medication was obtained from the purchasing agent for the anesthesia department and then compared by adding the amount used to reverse neuromuscular blockade (NMB) for a 100 kilogram patient as shown in

Table 1. The cost of OR and PACU time was also obtained from the purchasing agent for the anesthesia department and documented in Table 2.

Table 1

Cost of Each Medication

Medication	Cost per vial	Est. cost per surgical case for a 100kg patient
Sugammadex	$70.72	$70.72
Neostigmine	$6.57	$6.57
Glycopyrrolate	$1.84	$3.70

Table 2

Cost of Operating Room and PACU Time

Surgical Area	First 30 minutes	Every minute after 30 minutes
Operating Room	$1533	$29
PACU	$1109	$29

According to studies documented by Zaouter et al. (2017), sugammadex provides favorable cost-effectiveness based on its ability to reduce the amount of time to reach a TOF ratio of .9 in the OR after neuromuscular blockade reversal when compared to neostigmine. Sugammadex has demonstrated its cost-effectiveness and when combined with less post-operative complications when using sugammadex could provide the facility cost savings and time to perform more surgeries. That time was then multiplied by the cost of an OR time per minute to determine a per case cost saving. Time saved when reversing NMB with sugammadex compared to neostigmine was documented in Table 3.

Table 3

Time Saved When Reversing NMB with Sugammadex Compared to Neostigmine

Depth of blockade	Medication dose	Time reduced to reach a TOF of 0.9	Amount saved per surgical case	Amount Saved Over 800 Cases
Superficial NMB	2 mg/kg	17 minutes	$432.05	$345,640
Moderate NMB	2-4 mg/kg	18.6 minutes	$478.95 - $408.23	$326,584 - $383,160
Deep NMB	4 mg/kg	47.5 minutes	$1,246.33	$997,064

Descriptive statistics were used from adult abdominal cases over a six-month period at a hospital in the north delta of Mississippi to determine a cost-benefit analysis (CBA) by comparing the cost per case of each reversal technique performed and then using the obtained research to demonstrate the costs and benefits of sugammadex based on the time saved from a faster recovery.

Clinical Scenario 1 for Superficial NMB

Over a 6-month time period, 800 abdominal surgeries (estimated number of surgeries performed during this time period) are performed and NMB is reversed with sugammadex, 17 minutes of operating room time could be saved for each case when compared to using neostigmine. Implementation of sugammadex would create a cost savings of $345,640 over this time period. These savings only increase with the depth of NMB that is needed to be reversed. This cost savings could be as high as $997,064 over a 6-month period if the best practice guideline for the facility for NMB reversal was sugammadex.

Clinical Scenario 2 for Superficial NMB

The average time for an abdominal case is approximately 90 minutes, which allows 5 abdominal surgeries to be performed in one room or by one surgeon in an 8-hour day. If 17 minutes could be saved with a reversal of NMB with sugammadex, the time saved with sugammadex would allow for an extra 85 minutes per day. An extra 85 minutes per day would allow time for an extra 109 cases over a 6-month period if sugammadex is implemented into clinical practice at the north Mississippi delta hospital.

Implementation into Clinical Practice

Implementation of sugammadex use in reversing rocuronium in a north Mississippi delta hospital could be accomplished easily and further increase cost savings and improve patient outcomes for this hospital. Provider training will not have any associated costs but may encounter some pushback from providers due to change in technique in reversing rocuronium. Further, the providers already have access to sugammadex and have used this medication in practice but do not utilize it consistently due to cost. As mentioned earlier, the largest barrier to implementation of sugammadex into clinical practice are providers becoming convinced that sugammadex over time will increase savings and improve patient outcomes. Implementation of sugammadex into clinical practice could simply be accomplished by replacing neostigmine and robinal with sugammadex when reversing the paralytic effects of rocuronium.

Summary

In summary, the cost-benefit analysis of neostigmine versus sugammadex demonstrated that the purchasing price of sugammadex was more expensive than the cost of neostigmine, but after a thorough literature review and detailed cost analysis, the

investigation found that sugammadex could potentially have a cost savings of $345,640 to $997,064 over a 6-month period, by increasing the rate of discharge from the operating room. The potential cost savings would arise from the ability of sugammadex to rapidly reverse the effects of rocuronium, unlike neostigmine, as well as protect the patient from postoperative neuromuscular residual paralysis. Implementation of sugammadex into clinical practice could be accomplished by providing the anesthesia department with the cost-benefit analysis of sugammadex versus neostigmine demonstrating the benefits of sugammadex outweigh its cost.

CHAPTER IV – DISCUSSION

Correlation to Clinical Practice by Survey

The participants were chosen because they have significant clinical experience with neostigmine and sugammadex and a combined 50 years of anesthesia experience. Further, this panel of experts was practicing at the facility when the descriptive statistics were obtained for cost comparison and have a particular interest in whether the North Mississippi delta hospital should implement sugammadex to improve outcomes of their patients and find potential cost savings. The survey consisted of seven questions that can be viewed in Appendix c. This survey helped correlate real clinical practice to the investigation.

Survey in Use of Sugammadex and Neostigmine

The panel of experts took a voluntary and unanimous survey to describe how their facility utilizes sugammadex and neostigmine. The purpose of this survey was to discover how relevant this investigation was to clinical anesthesia practice. This survey can be found in Appendix C under the table of contents. The results of the survey found that 1 out of 7 providers preferred sugammadex over neostigmine, which the survey further revealed that the other 6 providers preferred neostigmine due to the cost of sugammadex. Further, all 7 providers answered that if sugammadex had the same cost as neostigmine that they would implement the reversal method more in their clinical practice.

In regard to the clinical benefits of sugammadex versus its cost, 1 out of 7 providers answered that the benefits of sugammadex does not overcome its cost. All 7 participants have sugammadex and neostigmine readily available at their facility and have the independence to decide which reversal method to choose. The results of this

survey demonstrated the importance of this investigation and the results of the investigation could have a direct impact on the anesthesia practice at this facility.

Limitations

The cost-benefit analysis of sugammadex versus neostigmine could possibly have several limitations that could alter the results of this project. The first factor that could impact this study is the size of the facility selected for this project, the north Mississippi delta hospital is a 220-bed facility and findings may not adequately represent larger facilities. Further, the investigation was based solely on abdominal procedures and did not investigate other types of procedures where deep paralysis was warranted for surgery. Approximately 800 abdominal surgical cases were performed where rocuronium was used to induce muscle paralysis. This amount may not accurately reflect the possible cost savings for facilities that perform more or less abdominal surgeries over a six-month period. Further, the sample size of the population surveyed was small due to facility size, a larger sample may have yielded different results. Finally, only 7 anesthesia providers participated in the survey, which may not accurately reflect the opinion of all anesthesia providers.

Future Implications

Future implications of this study should closely follow the associated cost of delayed discharge from the PACU and further investigate outpatient surgeries that had to be admitted to the hospital due to post-operative residual paralysis due to inadequate reversal with neostigmine. A thorough cost analysis needs to be conducted after this event occurs to demonstrate the amount of funds that could be possibly loss due to not meeting appropriate Centers for Medicare and Medicaid Services or CMS guidelines. The

investigator could open the eyes of providers to look at more than just front-end purchase cost of sugammadex and investigate the long-term cost and benefits of implementing sugammadex into clinical practice.

Discussion

The needs assessment conducted with the chief CRNA at this facility indicated that cost was the main concern and reason for choosing neostigmine over sugammadex. Further, providers at the chosen hospital also wanted to know whether the benefits of sugammadex outweighed the cost of the medication. The investigation revealed that sugammadex is a superior reversal agent for reversing the paralytic effects of rocuronium and if implemented fully into clinical practice could create a cost-effective surgical care model. Finally, the investigation only took into account the cost savings during the intra-operative period and did not investigate the potential cost-savings that may occur in the post-operative period as well.

Summary

In summary, the cost-benefit analysis of neostigmine versus sugammadex demonstrated that the purchasing price of sugammadex was more expensive than the cost of neostigmine, but after a thorough literature review and detailed cost analysis, the investigation found that sugammadex could potentially have a cost savings of $345,640 to $997,064 over a 6-month period, by increasing the rate of discharge from the operating room. Sugammadex has a purchasing cost of $70.72. If this reversal technique was used for each of the 800 abdominal surgical cases over the 6-month period, the overall purchasing cost would be $48,640. Implementing sugammadex into clinical practice could have a potential cost savings of $345,640 at the minimum over a 6-month period

after the purchasing cost of sugammadex is considered and more importantly will drastically improve patient outcomes by preventing residual muscle paralysis from incomplete reversal of paralysis.

Further consideration needs to be taken to remember the investigation only considered abdominal cases and did not include the many other procedures that utilize paralytics at the facility, further cost savings could be found by including all procedures that utilize neuromuscular blockade. An evidence-based literature review and a detailed cost analysis indicated sugammadex is far superior in reversing the effects of rocuronium and can allow operating rooms to save a tremendous amount of money by improving operating room discharge times, which would offset the purchasing cost of sugammadex and create an efficient surgical care model.

APPENDIX A – DNP Essentials

Essential I	Scientific Underpinnings for Practice	Conducting a cost-benefit analysis literature review of neostigmine and glycopyrrolate versus sugammadex, along with the costs, benefits, and risks of each. By integrating nursing science using analytics, we will be able to directly improve the outcome of patient care.
Essential II	Organizational and Systems Leadership for Quality Improvement and Systems Thinking	Determining which rocuronium reversal technique is more cost-effective in decreasing the costs for both patients and the hospital.
Essential III	Clinical Scholarship and Analytical Methods for Evidence-Based Practice	Reviewing and utilizing a current literature review and completing an itemized cost-benefit analysis of both neostigmine and glycopyrrolate versus sugammadex.
Essential IV	Information Systems/Technology and Patient Care Technology for the Improvement of Transformation of Health Care	Utilizing the organization's Information Technology (IT) department in securing the necessary data to allow for a thorough cost-benefit analysis to be completed.
Essential V	Health Care Policy for Advocacy in Health Care	The results of this project can help guide the organization in determining the most cost-efficient and best practice standard when reversing the effects of rocuronium.
Essential VI	Inter-professional Collaboration for Improving Patient and Population Health Outcomes	Collaborating with a panel of anesthesia professionals to help determine the cost savings and benefits of paralytic reversal

		techniques for their patients and the organization.
Essential VII	Clinical Prevention and Population Health for Improving the Nation's Health	Neuromuscular blocker reversals are essential in anesthesia practice for reversing the effects of rocuronium, which is also essential for recovery from anesthesia. By utilizing evidence to choose the most cost-efficient and safest technique of reversing rocuronium, patients will receive more efficient and safer anesthetic care.
Essential VIII	Advanced Nursing Practice	Educating CRNAs and anesthesiologists on the cost-benefit analysis results, then they will be encouraged to utilize the provided evidence to implement the most cost-efficient and best practice technique for reversing rocuronium.

APPENDIX B – IRB Approval Letter

Office *of*
Research Integrity

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

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NOTICE OF INSTITUTIONAL REVIEW BOARD ACTION

The project below has been reviewed by The University of Southern Mississippi Institutional Review Board in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services regulations (45 CFR Part 46), and University Policy to ensure:

- The risks to subjects are minimized and reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered involving risks to subjects must be reported immediately. Problems should be reported to ORI via the Incident template on Cayuse IRB.
- The period of approval is twelve months. An application for renewal must be submitted for projects exceeding twelve months.

PROTOCOL NUMBER: IRB-19-454
PROJECT TITLE: Clinical Application: A cost-benefit analysis of sugammadex versus neostigmine for a north mississippi delta hospital.
SCHOOL/PROGRAM: School of LANP, Leadership & Advanced Nursing
RESEARCHER(S): Andrew Bundt, Nina Mclain, Donald Carver

IRB COMMITTEE ACTION: Approved
CATEGORY: Expedited

7. Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

PERIOD OF APPROVAL: November 4, 2019

Donald Sacco Jr.

Donald Sacco, Ph.D.
Institutional Review Board Chairperson

APPENDIX C – Facility Approval Letter

[redacted]

So Far Advanced So Close To Home

[redacted]

To whom it may concern,

· Andrew Bundt and Donald Carver have permission to perform a cost benefit analysis on sugammadex versus neostigmine and glycopyrrolate at [redacted] Hospital with support from our department and hospital.

Sincerely,

[redacted]

[redacted]

APPENDIX D – Project Summary

Purpose of Project

The purpose of this project was to investigate the current standard of practice and to determine the most beneficial and cost-effective method for reversing rocuronium, a non-steroidal neuromuscular blocker. The reversal medications that were the focus of this investigation were neostigmine and sugammadex. Neostigmine has been used in clinical practice for many years to reverse the effects of rocuronium. Sugammadex is new to clinical practice and was specifically designed to reverse steroidal neuromuscular blockers such as rocuronium. Analyzing the cost, patient benefits, and providers' preferences were the focus of this investigation.

Report of Survey

The results of the survey found that 1 out of 7 providers preferred sugammadex over neostigmine, which the survey further revealed that the other 6 providers preferred neostigmine due to the cost of sugammadex. Further, all 7 providers answered that if sugammadex had the same cost as neostigmine that they would implement the reversal method more in their clinical practice. In regard to the clinical benefits of sugammadex versus its cost, 1 out of 7 providers answered that the benefits of sugammadex does not overcome its cost. All 7 participants have sugammadex and neostigmine readily available at their facility and have the independence to decide which reversal method to choose. The results of this survey demonstrated the importance of this investigation and the results of the investigation could have a direct impact on the anesthesia practice at this facility.

Report of Main Findings of Each Medication

Neostigmine is the most widely used reversal method for a neuromuscular blockade, however, there are several life-threatening side effects associated with its use such as, arrhythmias and bronchospasms when the anticholinesterase outlast the vagolytic action of the anticholinergic agents that is co-administered. Neostigmine is also known for its slow onset of action and its inability to reverse deep neuromuscular blockade. Sugammadex mechanism of action creates a faster and safer reversal when compared to neostigmine. The most significant factor when comparing neostigmine to sugammadex is its overwhelming ability to reverse deep neuromuscular blockade reliably and quickly (Zaouter et al., 2017). Residual paralysis occurs less frequently with sugammadex than neostigmine. "Residual paralysis may increase morbidity by impairing coughing, swallowing, and the patient's ability to breathe deeply" (Ezri et al., 2016, p.16).

Best Practice Recommendation

Through an evidence-based literature review and a detailed cost analysis, sugammadex demonstrated it is far superior in reversing the effects of rocuronium and can allow operating rooms to save a tremendous amount of money by improving operating room discharge times, which would offset the purchasing cost of sugammadex and create an efficient surgical care model.

Primary Literature Review

Abad-Gurumeta, A., Ripolles-Melchor, J., Casans-Frances, R., Espinosa, A., Martinez-Hurtdo, E., Lopez-Timoneda, F., & Fernandez-Perez, C. (2015). A systematic review of sugammadex vs neostigmine for reversal of neuromuscular blockade. *The Association of Anaesthetists of Great Britain and Ireland, 70,* 1441-1452. https://doi.org/10.1111/anae.13277

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APPENDIX E – Survey of Sugammadex and Neostigmine Use

This is an anonymous survey in the use of Sugammadex and Neostigmine. Completion and participation of this survey is voluntary.

Questionnaire:

1. Which medication do you prefer when reversing neuromuscular blockade induced by Rocuronium?
   A. Sugammadex
   B. Neostigmine and Glycopyrrolate
2. Does cost affect your decision when choosing a medication to reverse neuromuscular blockade induced by Rocuronium?
   A. Yes
   B. No
3. Does your facility have a preference when reversing neuromuscular blockade induced by Rocuronium?
   A. No
   B. Yes. If yes, list the medication.
4. Would you use Sugammadex more if the cost was the same as Neostigmine and Glycopyrrolate?
   A. Yes
   B. No
5. Do you believe the benefits of Sugammadex can out way the cost?
   A. Yes
   B. No

6. Is sugammadex available at your facility?
   A. Yes
   B. No
7. Comments:

APPENDIX F – Cost-Benefit Analysis of Sugammadex and Neostigmine

Cost-benefit analysis of sugammadex and neostigmine utilized an evidence-based literature review and a detailed cost analysis, sugammadex demonstrated it is far superior in reversing the effects of rocuronium and can allow operating rooms to save a tremendous amount of money by improving operating room discharge times, which would offset the purchasing cost of sugammadex and create an efficient surgical care model. A cost analysis is listed below to demonstrate the cost differences of each reversal technique.

Table A1.

Cost-Comparison of Sugammadex and Neostigmine and their Associated Cost

Medications	Sugammadex	Neostigmine
Actual Medication Cost	$70.72	$6.57
5 ml syringe	$0.05	$0.05
20-gauge needle	$0.02	$0.02
Co-Administered Drugs	$0	$3.70
Total:	$70.79	$10.34

Sugammadex had an administration cost of $70.79, while neostigmine had an administration cost of $10.34. At first glance, an anesthesia provider would assume that neostigmine was the less expensive option for reversing the effects of rocuronium, but the provider must also take into account the long-term cost effects of each reversal method, for example, the operating room time saved when using sugammadex instead of neostigmine. The most significant factor when comparing neostigmine to sugammadex is its overwhelming ability to reverse deep neuromuscular blockade reliably and quickly (Zaouter et al., 2017).

Sugammadex has a purchasing cost of $70.72 if this reversal technique was used over Neostigmine for each of the 800 abdominal surgical cases over the 6-month period the overall purchasing cost of sugammadex would be $48,360 at the minimum. Further, over a 6-month period after the purchasing cost of sugammadex is considered the minimum cost savings would be $345,640 based on time saved during NMB reversal over 800 abdominal surgical cases.

Table A2.

Time Saved when Reversing NMB with Sugammadex Compared to Neostigmine

Depth of blockade	Medication dose	Time reduced to reach a TOF of 0.9	Amount saved per surgical case	Amount Saved Over 800 Cases
Superficial NMB	2 mg/kg	17 minutes	$432.05	$345,640
Moderate NMB	2-4 mg/kg	18.6 minutes	$478.95 - $408.23	$326,584 - $383,160
Deep NMB	4 mg/kg	47.5 minutes	$1,246.33	$997,064

Benefits of sugammadex were demonstrated from the literature review, several benefits were found including time saved during NMD reversal and decrease the incidence of residual paralysis. If the average time for each abdominal case is 90 minutes, this allows for 5 abdominal surgeries to be performed in one room or by one surgeon in an 8-hour day. If 17 minutes could be saved with a reversal of NMB with sugammadex, this could allow for an extra 85 minutes per day. That would allow time for an extra 109 cases over a 6-month period if Sugammadex is implemented into clinical practice at the North Mississippi delta hospital. Residual paralysis occurs less frequently with sugammadex than neostigmine. “Residual paralysis may increase morbidity by impairing

coughing, swallowing, and the patient's ability to breathe deeply" (Ezri et al., pg. 16, 2016).

In summary, the cost-benefit analysis of neostigmine versus sugammadex demonstrated that the purchasing price of sugammadex was more expensive than the cost of neostigmine, but after a thorough literature review and detailed cost analysis, the investigation found that sugammadex could potentially have a cost savings of $345,640 to $997,064 over a 6-month period, by increasing the rate of discharge from the operating room.

APPENDIX G - Literature Matrix

Author	Research type	Outcome measures	Population /Sample size	Pertinent data from results	Suggested Conclusions
Abad-Gurumeta et al., 2015.	A systematic review of sugammadex vs neostigmine for reversal of neuromuscular blockade	Signs of muscular weakness and drug-related adverse events.	1533 participants from 17 randomized studies.	Sugammadex reduced all signs of residual postoperative paralysis and minor respiratory events. There was no difference in critical respiratory events. Sugammadex reduced drug-related side effects and there was no difference in the rate of postoperative nausea and vomiting.	This source was useful in the research because it provides data about postoperative paralysis and side effects related to each medication.
Babu et al., 2018.	Randomized control study	This study was to find out whether calcium administration after reversal with neostigmine and glycopyrrolate could enhance the recovery from neuromuscular blockade.	60 patients aged between 18-60 belonging to ASA 1 and 2.	Patients were divided into two groups and reversed with neostigmine .05mg/kg and glycopyrrolate .01mg/kg followed by 10 ml of 10 % calcium gluconate in the first group and 10 ml of normal saline in the second group. The time of attainment of full muscle power was assessed by a tongue depressor test.	Calcium decreased the response time from an average of 7.1 seconds to 3.7 seconds after the administration of neostigmine and glycopyrrolate for NMB.

Brueckmann et al., 2015.	Randomized control studying the effects of Sugammadex on the postoperative residual neuromuscular blockade.	The study was aimed to investigate whether reversal of rocuronium-induced NMB with Sugammadex reduced the incidence of the residual blockade and facilitated OR discharge readiness.	154 randomized patients.	After abdominal surgery, Sugammadex reversal eliminated residual neuromuscular blockade in the PACU and shortened the time from the start of the study medication administration to the time the patient was ready for discharge from the operating room.	Sugammadex decreased operating room time by 3.9 minutes when compared to neostigmine.
Ezri et al., 2016.	Randomized study	Sugammadex was compared to neostigmine in terms of residual paralysis incidence in the PACU.	150 patients undergoing abdominal surgery.	No patient had residual paralysis after reversal with sugammadex (0 out of 74) compared to 43% after neostigmine (33 out of 76) usual care patients. However, it should be emphasized that residual paralysis may still occur after reversal with sugammadex if a lower than recommended dose is administered.	This source will be useful when comparing each method of reversal for residual paralysis.
Insinga et al., 2016.	Exploratory analysis	Discrete event simulation model was developed to compare ORs using neostigmine compared to	93 procedures with sugammadex and 91 with neostigmine	When using sugammadex compared to neostigmine, 30 minutes of OR time was saved per procedure.	Sugammadex can enhance operating room efficiency and potentially reduce the

		sugammadex for NMB reversal and how this affected OR procedure time (Admission to discharge).		Paid overtime hours dropped from 84.1 to 32.0, with a 93% reduction of a postoperative residual blockade. Residual NMB was reduced from 60% to 4% when using sugammadex compared to neostigmine when full neuromuscular blockade recovery was not verified before extubating.	reduce complications of RNMB in clinical practice when compared to neostigmine.
Nagelhout & Elisha, 2018.	Textbook	Properties of medications and their mechanisms of action.	N/A	N/A	N/A
Zaouter et al., 2017.	Cost-effective analysis of literature from January 2013-October 2016	Superficial, moderate, and deep NMB reversal meantime was compared when using sugammadex versus neostigmine and glycopyrrolate.	PubMed database literature over a four-year period.	Sugammadex decreased OR time during superficial NMB by 17 minutes, moderate NMB by 18.6 minutes and deep NMB by 47.5 minutes when compared to neostigmine.	Economic impact relies on faster recovery times and this can be converted to positive revenue for the hospital.

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