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A Retrospective Evaluation of the Cost-effectiveness of Dose Rounding Sugammadex in Pediatric Surgery Patients

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ABSTRACT

Background: To evaluate the cost-effectiveness of a standardized Sugammadex dosing quality improvement project for the pediatric population conducted at Michigan Medicine.

Methods: A retrospective chart review of children aged two and older who underwent general anesthesia with endotracheal intubation, received rocuronium or vecuronium as a neuromuscular blocking medication, and received Sugammadex as a reversal agent. The patients received pre-drawn syringes in multiples of 25 mg from the pharmacy or exact mg/kg doses drawn straight from a vial by the anesthesia provider. The primary outcome assessed was the cost of waste for pre- versus post-intervention of the dose rounding project.

Results: A total of 5856 patients aged 2 to 17 underwent general anesthesia with endotracheal intubation and received rocuronium or vecuronium as a neuromuscular blocking medication and as the reversal agent. Prior to implementation, the pre-intervention group exhibited waste equal to more than half of the total cost of the medication. Post-intervention waste was eliminated resulting in a significant cost reduction.

Conclusion: Following the implementation of the standardized dosing rounding quality improvement project greater than half of the budget spent on Sugammadex for pediatric use was reduced annually. Dose rounding can lead to a more cost-effective method of utilizing Sugammadex in the pediatric population.

Keywords: Sugammadex, Pediatric, Dose Rounding, Cost Reduction

Introduction

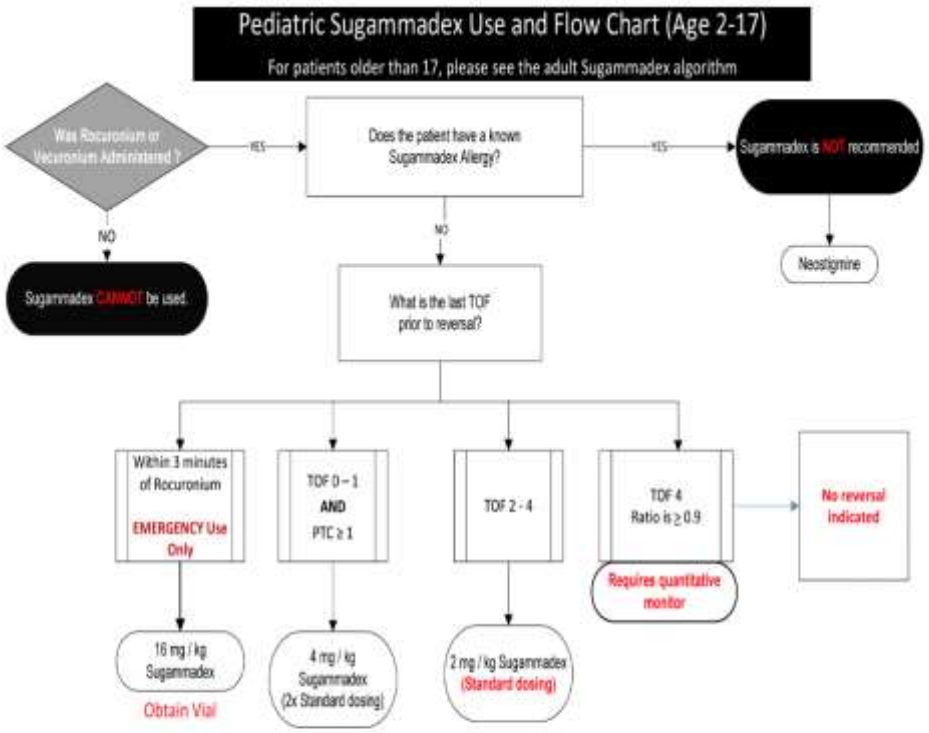
Sugammadex is a novel pharmacological agent that is indicated for neuromuscular blockade in surgical procedures. The Food and Drug Administration (FDA) approved the use of Sugammadex to reverse neuromuscular blockade induced by steroidal-based neuromuscular blockers rocuronium and vecuronium in pediatric patients aged two and older undergoing surgery on June 25th, 20211. It is a modified gamma-cyclodextrin, the first selective relaxant binding agent indicated to reverse the neuromuscular blockade in clinical anesthesia practice. Sugammadex has a different mechanism of action from the commonly used acetylcholinesterase inhibitor, neostigmine, which increases the amount of acetylcholine at the neuromuscular junction and overcoming the competitive inhibition of a non-depolarizing drug. It forms a complex with rocuronium or vecuronium in plasma to reduce the amount of neuromuscular-blocking agent available to bind to nicotinic receptors in the neuromuscular junction2. Neostigmine is used in conjunction with glycopyrrolate to reverse the effects of non-depolarizing neuromuscular blocking agents after surgery3. Compared to the combination of neostigmine and glycopyrrolate, this novel agent has fewer drug interactions, a lower potential for residual paralysis, and a lower incidence of major pulmonary complications4,5,6. Sugammadex is able to more rapidly, reliably, and safely reverse any level of neuromuscular blockade7. It can also reverse steroidal non-depolarizing blocking agents even at small doses, as indicated by one clinical study that reported a dose as low as 0.22 mg/kg8. Depending on the surgery and the depth of the block, the Sugammadex dose will vary. A moderate block will require a dose of 2mg/kg of Sugammadex, while a deep block will need a dose of 4 mg/kg to reverse the neuromuscular blockade successfully.

Given the faster onset and better clinical effects, Sugammadex is preferred over the combination of neostigmine and glycopyrrolate9. However, it is more expensive when given an exact mg/kg dosing, which has limited its widespread use across institutions. Sugammadex comes in single-use 200mg/2ml and 500mg/5ml vials that must be discarded after each patient use1. Therefore, significant medication waste presents as excess cost with the initial method of giving patients exact mg/kg dosages. To overcome the issue, Michigan Medicine has developed a standardized Sugammadex dosing quality improvement project for the pediatric population10. The logistics of this project are based on the knowledge that Sugammadex exhibits a linear pharmacokinetics in the dose range of 0.22 mg/kg-16 mg/kg, so range-based dosing with a tight dosing band would not affect the efficacy of this drug11. The project aims to lower annual budget of the hospital on Sugammadex by reducing waste and, therefore, reducing costs.

Methods

This retrospective chart review took place at Michigan Medicine using de-identified data obtained from the Department of Anesthesiology from January 1st, 2019, to March 10th, 2023, excluding April and May 2021, during the implementation of the intervention. We included all pediatric patients age two and older who underwent general anesthesia with endotracheal intubation and received rocuronium or vecuronium as a neuromuscular blocking medication and Sugammadex as the reversal agent. Furthermore, only patients who underwent surgeries needing moderate block and required a Sugammadex dose of 2 mg/kg or within 20% of 2 mg/kg (1.6-2.4 mg/kg) were included. Patients are excluded from the chart review if they underwent deep block requiring 4 mg/kg of Sugammadex. From January 1st, 2019 to March 31st, 2021, all patients received exact mg/kg doses of Sugammadex drawn straight from a vial, with the remaining amount discarded by the anesthesia provider. Following the implementation of the intervention, the pharmacy prepared pre-drawn syringes of Sugammadex in 25 mg, 50 mg, and 100 mg, and weight-based doses with a range of 1.6-2.4 mg/kg were distributed to patients From June 1st, 2021, we consider any patient who received a dose of a multiple of 25 mg to have received the pre-drawn syringes from the pharmacy. For doses that are not a multiple of 25 mg, we assume that the healthcare provider draws up the doses from a vial at the bedside. Details regarding the standardized dosing of Sugammadex are provided in Figure 1.

Figure 1. ***Pediatric Sugammadex Use and Flow Chart at Michigan Medicine***



Sugammadex Standardized Dosing		
Weight Range (Actual body weight)	Standard Dose	Pre-Drawn Syringe
10-14kg	25mg	25mg
15-28kg	50mg	50mg
29-42kg	75mg	25mg + 50mg
43-56kg	100mg	100mg
57-83kg	150mg	50mg + 100mg
84-120kg	200mg	2 x 100mg

Re-administration of Rocuronium or Vecuronium after Reversal with Sugammadex	
Minimum Waiting Time	NMBA and Dose to be Administered
5 Minutes	1.2 mg / kg Rocuronium
4 hours	0.6 mg / kg Rocuronium or 0.1 mg / kg Vecuronium
Alternatively, use Succinylcholine or Cisatracurium if indicated	

TOF = Train-of-four; PTC = Post-tetanic count

Michigan Medicine, Anesthesiology Quality Improvement Program – AQIP
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The sum of the doses given to patients, the sum of waste, and the total cost, which is the sum of the doses given and waste combined, are calculated and grouped by year. Starting in June 2021, patients in the post-intervention group received doses of a multiple of 25 mg, and the remainder of the patients were considered to have received the exact mg/kg dose drawn straight from a vial as the pre-intervention group. We also included all patients who underwent surgeries from January through March 2021 in the pre-intervention group for the year. The most recent wholesale acquisition cost of Sugammadex was in September 2024 from the pharmacy purchasing team at Michigan Medicine, which we used to calculate the costs. A 200mg/2ml and 500mg/5ml vial costs $118.41 and $216.89, respectively. Michigan Medicine's inpatient pharmacy services utilized 5ml vials to prepare pre-drawn syringes due to the lower cost per ml. Therefore, doses in the post-intervention group are assumed to be from 5ml vials. On the other hand, doses that are not a multiple of 25 mg in the pre-intervention group utilized 2ml vials in the anesthesia medication trays.

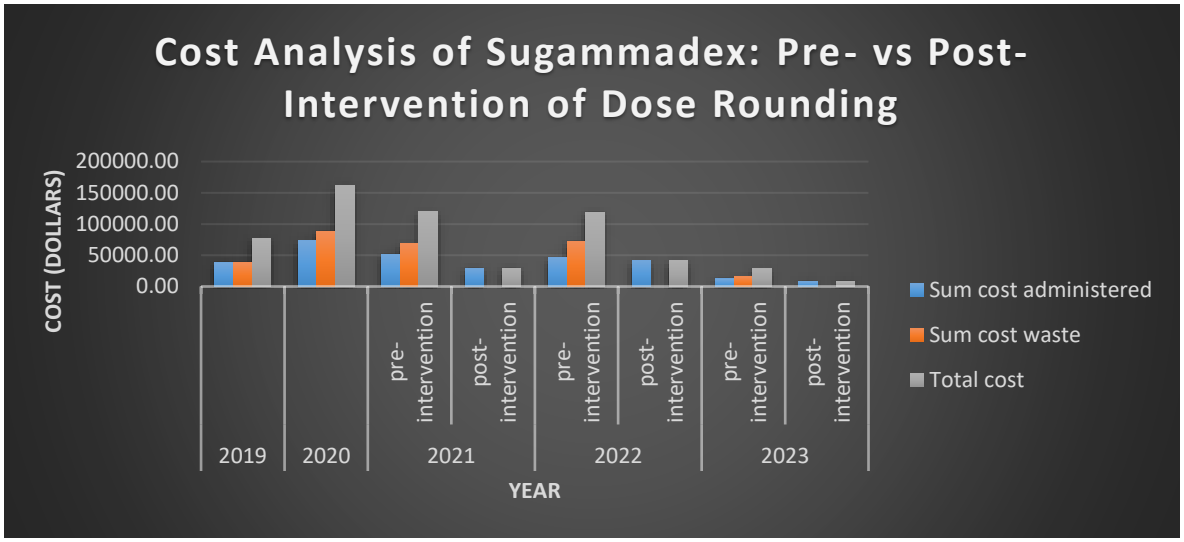

Figure 2. *Cost analysis per year as a chart.* Although dose rounding was implemented in April-May of 2021, not all patients received rounded doses from the pharmacy. Therefore, data for the years of 2021-2023 are divided into pre-intervention or post-intervention. Pre-intervention: exact mg/kg doses that are not a multiple of 25 mg. Post-intervention: rounded doses in a multiples of 25 mg.

Result

Table 1 shows the cost analysis for each group per year. From January 1st, 2019 to March 10th, 2023, a total of 5856 patients underwent general anesthesia with endotracheal intubation and received rocuronium or vecuronium as a neuromuscular blocking medication and Sugammadex as the reversal agent. In 2019 and 2020, the total cost includes the medication waste as excess cost. Waste accounts for more than half the total cost spent per year on Sugammadex, with 50.6% and 54.9% for 2019 and 2020, respectively. For 2021-2023, as excess cost, waste continues to represent more than half of the total annual spending on Sugammadex at 57%, 61%, and 56.8%, respectively. With the implementation of the standardized dosing rounding quality improvement project, waste is eliminated, and the sum of the cost of the doses given to patients equals the total cost. Figure 2 displays the cost analysis from Table 1 as a chart.

Table 1. Cost analysis per year. Although dose rounding was implemented in April-May of 2021, not all patients received rounded doses from the pharmacy. Therefore, data for the years of 2021-2023 are divided into pre-intervention or post-intervention. Pre-intervention: exact mg/kg doses that are not a multiple of 25mg. Post-intervention: rounded doses in a multiples of 25mg.

	2019	2020	2021		2022		2023 (through 3/10)	
			Pre-intervention	**Post-intervention**	**Pre-intervention**	**Post-intervention**	**Pre-intervention**	**Post-intervention**
# of patients	603	1326	987	619	978	927	225	191
Sum of cost of doses given	$37,678.57	$72,913.23	$51,643.37	$29,496.36	$46,418.70	$41,837.12	$12,164.44	$8,447.67
Sum of cost of waste	$38,574.90	$88,592.55	$68,420.32	$0.00	$72,460.92	$0.00	$16,016.19	$0.00
Total cost	$76,253.47	$161,505.78	$120,063.69	$29,496.36	$118,879.62	$41,837.12	$28,180.63	$8,447.67

Figure 3. Waste as a percentage of total cost as a chart.

Table 2 and Figure 3 show waste as a percentage of total cost based on year in different formats. Table 3 displays the cost analysis based on pre-intervention vs post-intervention groups. Table 4 shows the percentage of pre-intervention vs post-intervention, and Figure 4 displays the same information in a pie chart view.

Table 2. Waste as a percentage of total cost.

	2019	2020	2021		2022		2023	
			pre-intervention	post-intervention	pre-intervention	post-intervention	pre-intervention	post-intervention
Waste (%)	50.6%	54.9%	57.0%	0.0%	61.0%	0.0%	56.8%	0.0%

Figure 4. Pie chart view of percentage of cost

Discussion

Beginning in November 2016, Michigan Medicine started utilizing Sugammadex as a reversal agent in children aged two and older who underwent general anesthesia and received either rocuronium or vecuronium as the neuromuscular blocking agent, dosages were individualized based on weight, and patients received the exact mg/kg dose. This practice resulted in tremendous waste, which presented as excess cost for the institution. Sugammadex is available only in single-use manufactured vials. Therefore, the remaining amount in the vial must be discarded after each patient use. Chart review analysis revealed that in patients receiving exact mg/kg doses of Sugammadex, the total cost constitutes the doses given to patients and the waste, as residual amounts in the

vial were discarded. In all these scenarios, the cost of waste accounts for more than half of the total cost spent per year on Sugammadex. Following the implementation of the dose rounding project, patients received standardized dosages rounded to the nearest multiple of 25 mg with the pre-drawn syringes, eliminating waste. As demonstrated by the post-intervention data, without excess cost from the waste, Michigan Medicine reduced its spending on Sugammadex by more than 50% compared to before the implementation of the project. For instance, our institution spent $76,253.47 on Sugammadex for 603 patients in 2019. In contrast, for 619 patients who received the standardized doses in 2021, the organization spent only $29,496.36. The data shows a significant cost reduction.

Our retrospective chart review does have limitations. One limitation is that we did not evaluate dosing based on TOF or train-of-four. Another limitation is that our data shows roughly the same number of patients in pre- and post-intervention groups, even though we expected most patients to have received the standardized dosages of Sugammadex. A potential explanation is that providers might have recorded the exact mg/kg dosing in Epic even though they obtained and gave patients rounded doses from the pharmacy. However, we cannot determine with certainty the actual dose that patients received since the data does not contain the source of the dose, whether it came from manufactured vials or pre-drawn syringes. We can only assume that doses that are a multiple of 25 mg followed the project's protocol, while doses outside of the pre-drawn syringe dosing came straight from a vial.

Table 3. Cost Analysis of pre-intervention vs post-intervention

	Pre-intervention (n = 4119)	Post-intervention (n = 1737)
Cost of doses given (cost of the actual doses that patients received)	44%	100%
Cost of waste	56%	0%

Table 4. Percentage of cost of pre-intervention vs post-intervention

	Pre-intervention (n = 4119)	Post-intervention (n = 1737)
Cost of doses given (cost of the actual doses that patients received)	44%	100%
Cost of waste	56%	0%

Conclusion

Our data demonstrates that the standardized dose rounding Sugammadex quality improvement project significantly reduces annual spending on Sugammadex in Michigan Medicine's pediatric surgery population. The project provides a mechanism for the cost-effective use of Sugammadex, which could contribute to its more widespread use across many more pediatric institutions.

Author contributions

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