Original Article

Sugammadex enhances recovery after abdominal surgery in cancer patients: a real-world, observational study

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Background: Sugammadex, a modified γ-cyclodextrin that selectively binds to muscle relaxants, is increasingly being used to reverse neuromuscular blockade after surgery, but the potential benefits for cancer patients in the real-world setting are obscure.

Methods: This was a real-world, retrospective study. Adult cancer patients (≥18 years) undergoing abdominal surgery at Jiangsu Cancer Hospital, a tertiary care cancer hospital in China, between 2 March 2018 and 25 November 2019, were included in the analysis. Patients received 2 mg/kg (maximally 200 mg) sugammadex based on the discretion of the attending anesthetists. Patients were extubated as soon as they were awake and able to follow commands. The endpoint measures included extubation time, bowel function recovery and length of hospital stay.

Results: A total of 1,615 patients were included in the analysis: 795 participants received sugammadex at a dosage of 2 mg/kg (maximum 200 mg) upon completion of surgery; the remaining 820 participants did not receive sugammadex or neostigmine (another antidote for neuromuscular blockade). Despite several biases that clearly favored patients not receiving sugammadex [younger, better American Society of Anesthesiologists (ASA) status, and fewer comorbidities], the extubation time was significantly shorter in patients receiving sugammadex [median: 14 (range, 0–121) *vs.* 30.5 (range, 0–183) min; P<0.001]. In multivariate linear regression analysis, sugammadex use was associated with a significantly shorter extubation time (P<0.05). Patients who received sugammadex also had accelerated bowel function recovery and shorter postoperative hospital stay.

Conclusions: Sugammadex shortens extubation time and accelerates postoperative recovery in cancer patients undergoing abdominal surgery.

Keywords: Sugammadex; aminosteroidal neuromuscular blocker; neuromuscular reversal; abdominal surgery; enhanced recovery after surgery (ERAS)

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Introduction

Acetylcholinesterase inhibitors are limited in reversing profound neuromuscular blockade in surgical patients due to their indirect reversal mechanisms, unpredictable efficacy, and undesirable autonomic responses (1-3). Clinically, residual neuromuscular block is a common complication in the post-anesthesia care unit (PACU), and approximately 40% of patients exhibit a train-of-four ratio

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(TOFR) <0.9 (4). Residual neuromuscular blockade may impair the hypoxic ventilatory drive and increase the risk of aspiration and pneumonia. Reversing neuromuscular blockade using pharmacological agents (e.g., neostigmine, and more recently, sugammadex) has been reported to reduce the incidence of residual neuromuscular blockade and the associated complications, which are conducive to early ambulation and bowel function recovery, leading to enhanced recovery from abdominal surgery (5-7). Sugammadex, a modified γ-cyclodextrin, rapidly reverses neuromuscular blockade by forming a one-to-one (1:1) stable inactive complex with aminosteroidal neuromuscular blockers, such as rocuronium or vecuronium (8,9), thereby reducing their availability to nicotinic acetylcholine receptors in the neuromuscular junction (10). Numerous studies have shown that sugammadex recovers neuromuscular function more rapidly than neostigmine after moderate and profound neuromuscular blockade (11-14). Sugammadex has been shown to be effective in fast and predictable reversal of both moderate and profound neuromuscular blockade in patients with cardiorespiratory diseases and hepatic or renal dysfunction and is also safe for elderly and pediatric patients (15,16).

The major indicators of recovery after surgery are time to food intake, time to defecation, time to ambulation, length of hospital stay and occurrences of adverse effects or complications. The enhanced recovery after surgery (ERAS) concept emphasizes a multidisciplinary approach to achieve the goal of optimizing patient outcomes without increasing postoperative complications or readmissions (15,16). Increasing evidence suggests that sugammadex could be a positive contributor to ERAS. A randomized controlled trial of 154 adult patients undergoing abdominal surgery demonstrated that, compared to neostigmine/glycopyrrolate, sugammadex eliminated residual neuromuscular blockade by rocuronium in the post-anesthesia care unit (PACU) and shortened the interval between reversal agent administration and operating room (OR) discharge readiness (17). A meta-analysis of 6 studies (518 patients) suggested that sugammadex markedly reduced the mean time from OR to PACU and from PACU to the ward *vs.* neostigmine, with a more rapid discharge from hospital after general anesthesia (18). In another meta-analysis of 1,384 patients, it was reported that sugammadex reversed neuromuscular blockade more rapidly than neostigmine; however, it did not significantly reduce postoperative nausea and vomiting (PONV) or pain (19). Currently, the effect of sugammadex on recovery after abdominal surgery remains inadequately elucidated. A recent study of sugammadex *vs.* neostigmine for 50 patients undergoing elective laparoscopic cholecystectomy or abdominal wall hernia repair showed reduced PACU stay (20). A single-center, retrospective, observational study of patients after major abdominal surgery showed that sugammadex significantly reduced the 30-day readmission rate, curtailed the length of hospital stay by 20%, and decreased hospital costs by 24% (21). Meanwhile, a randomized trial of 130 adults undergoing major abdominal surgery demonstrated no statistical difference in pulmonary function and the incidence of postoperative atelectasis between patients receiving sugammadex and neostigmine (22).

Despite accumulating evidence supporting a role of sugammadex in ERAS, there is no evidence available in the literature regarding the effects of sugammadex on enhanced recovery after abdominal surgery and postoperative complications in cancer patients. Therefore, we conducted a real-world, retrospective study to examine the potential effects of sugammadex on postoperative recovery characteristics after abdominal surgery in cancer patients. We present the following article in accordance with the STROBE reporting checklist (available at https://dx.doi.org/10.21037/apm-21-3398).

Methods

This real-world, retrospective study was approved by the Ethics Committee of Jiangsu Cancer Hospital (No. 2020Ke-039), and due to its retrospective nature, informed consent was waived by the Ethics Committee. All procedures performed in this study involving human participants were in accordance with the Declaration of Helsinki (as revised in 2013).

We screened adult cancer patients (≥18 years) undergoing abdominal surgery between 2 March 2018 and 25 November 2019 at Jiangsu Cancer Hospital, Nanjing, China. Patients with unknown time to extubation or previous surgery were not included in the final analysis. Patients who received neostigmine were also excluded from the analysis.

The choice of using or not using sugammadex was based on the discretion of the attending anesthetists. Sugammadex was given at 2 mg/kg, with a maximum of 200 mg per patient (23). Patients were extubated as soon as they were awake and able to follow commands. Patients with PONV were routinely managed with intravenous ondansetron 4 mg (maximum 12 mg/day) or metoclopramide 10 mg (maximum 30 mg/day). Postoperative pain was managed with

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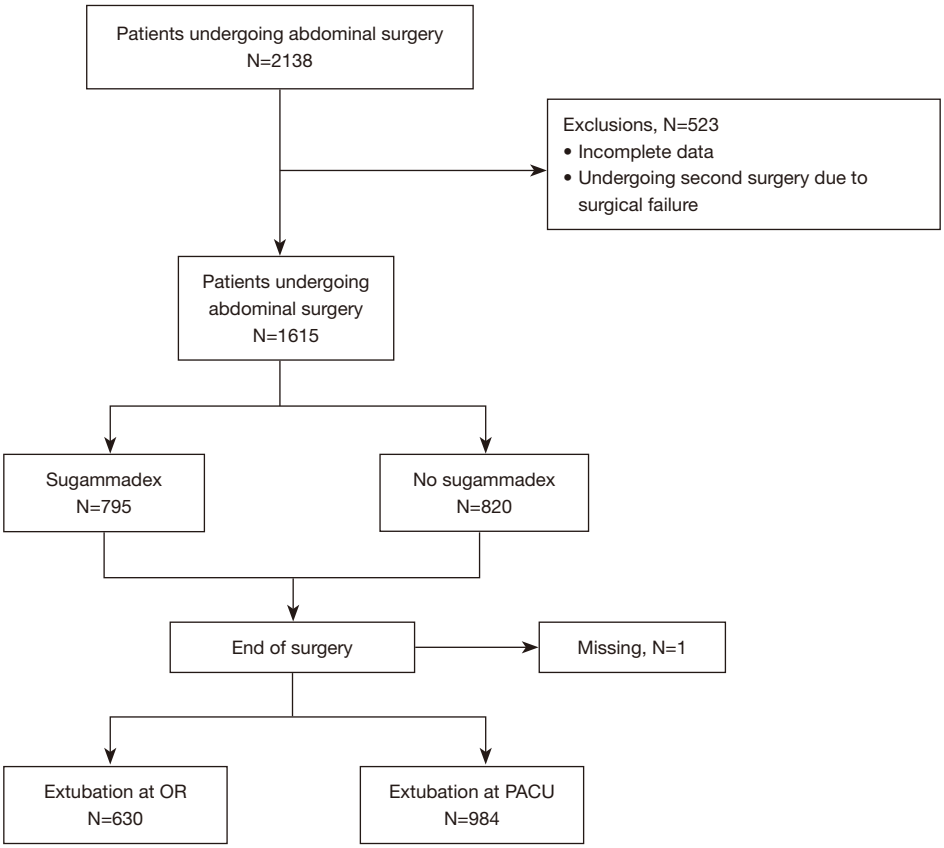

Figure 1 The study flowchart. OR, operating room; PACU, post-anesthesia care unit.

intravenous flurbiprofen (50 mg twice daily) and patient-controlled intravenous analgesia with dezocine or tramadol.

All time measures, including extubation time (min), were calculated from the end of surgery to the index events.

The primary outcome was extubation time (min) and secondary outcomes included time to return to the ward, time to passage of flatus, food intake, and time to ambulation and postoperative hospital stay.

Statistical analysis

All statistical analyses were conducted using the software SPSS 20.0 (SPSS, Inc., Chicago, Illinois, the United Stated of America). Descriptive statistics were used to summarize demographic and baseline characteristics. Normally distributed continuous variables were expressed as mean and standard deviations (SD) and analyzed using Student's *t*-test. Continuous variables not conforming to normal distribution were expressed as median (range) and analyzed using the Mann-Whitney U test. Categorical variables were expressed as numbers (%) and analyzed using the chi-square test. Multivariate regression was used to identify factors associated with extubation time, using site of surgery as a dummy variable. All statistical tests were two-tailed, and a P value of less than 0.05 was considered significant.

Results

Patient demographic and baseline characteristics

The study flowchart is shown in *Figure 1*. A total of 2,138 patients underwent abdominal surgery during the study period. The final analysis included 1,615 patients (62.8±11.0 years of age; 66.3% men); 795 received sugammadex and the remaining 820 did not. Most patients had American Society of Anesthesiologists (ASA) II (73.3%) or III (24.1%) status (*Table 1*). The most common comorbidity was hypertension (37.7%), followed by diabetes (12.1%) and heart disease (10.8%).

The follow-up ended upon discharge from hospital. Patients receiving sugammadex were significantly older

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Table 1 Patient demographic and baseline characteristics

Variables	All (n=1,615)	Sugammadex (n=795)	No sugammadex (n=820)	P value
Age, years				<0.001
Mean (SD)	62.8 (11.0)	64.2 (11.3)	61.4 (10.4)	
Range	18–91	25–91	18–86	
Male gender, n (%)	1,071 (66.3)	526 (66.2)	545 (66.5)	0.899
Body mass index, kg/m^2				0.935
Mean (SD)	23.70 (3.14)	23.72 (3.19)	23.69 (3.09)	
Range	14.88–38.05	14.88–38.06	15.06–33.01	
ASA, n (%)				<0.001
I	12 (0.7)	4 (0.5)	8 (1.0)	
II	1,183 (73.3)	523 (65.8)	660 (80.5)	
III	389 (24.1)	251 (31.6)	138 (16.8)	
IV	27 (1.7)	17 (2.1)	10 (1.2)	
Missing	4 (0.2)	0(0)	4 (0.5)	
Post chemotherapy, n (%)	178 (11.0)	89 (11.2)	89 (10.9)	0.827
Comorbidities, n (%)				
Hypertension	609 (37.7)	316 (39.8)	293 (35.7)	0.096
Diabetes	196 (12.1)	111 (14.0)	86 (10.5)	0.027
Heart disease	175 (10.8)	126 (15.9)	49 (6.0)	<0.001
Cerebral infarction	86 (5.3)	50 (6.3)	36 (4.4)	0.089
Asthma	10 (0.6)	8 (1.0)	2 (0.2)	0.051
Chronic obstructive pulmonary disease	28 (1.7)	22 (2.8)	6 (0.7)	0.002
Anemia	66 (4.1)	29 (3.7)	37 (4.5)	0.380

ASA, American Society of Anesthesiologists; kg, kilogram; m, meter; n, number; SD, standard deviation.

than patients not receiving sugammadex (P<0.001; *Table 1*). In comparison to patients not receiving sugammadex, a significantly higher proportion of patients receiving sugammadex had ASA III or IV status (33.7% *vs.* 18.0%; P<0.001), heart disease (15.9% *vs.* 6.0%; P<0.001), diabetes (14.0% *vs.* 10.5%; P=0.027), and chronic obstructive pulmonary disease (COPD) (2.8% *vs.* 0.7%; P=0.002).

Operative characteristics

Patient operative characteristics are shown in *Table 2*. The majority of participants received intestinal (36.8%) or gastric (36.4%) surgery. Furthermore, 60.9% of participants were extubated in the PACU and 39.0% in the operating room. The mean anesthesia time was 215.4±78.3 min. The mean duration of surgery was 178.6±72.9 min. The mean total amount of rocuronium used was 144.05±47.92 mg/kg.

A markedly lower proportion of patients receiving sugammadex had intestinal surgery than patients not receiving sugammadex (34.3% *vs.* 39.1%; P=0.003). A higher percentage of patients receiving sugammadex were extubated in the operating room than patients not receiving sugammadex (57.9% *vs.* 20.7%). Participants receiving sugammadex also consumed a smaller amount of rocuronium than those not receiving sugammadex (140.29±51.07 *vs.* 147.74±44.42 mg/kg; P<0.001). The 2 groups were comparable in other operative variables, including anesthesia time and operative time.

Extubation time

The median extubation time was 22.6 min (range, 0–

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Table 2 Patient operative characteristics

Variables	All (n=1,615)	Sugammadex (n=795)	No sugammadex (n=820)	P value
Sites of surgery, n (%)				0.003
Intestine	594 (36.8)	273 (34.3)	321 (39.1)	
Stomach	588 (36.4)	286 (36.0)	302 (36.8)	
Liver	113 (7.0)	55 (6.9)	58 (7.1)	
Others	320 (19.8)	181 (22.8)	139 (17.0)	
Anesthesia time, min				0.507
Mean (SD)	215.4 (78.3)	216.48 (78.9)	214.51 (77.9)	
Range	40–718	40–534	70–718	
Operative time (min)				0.604
Mean (SD)	178.6 (72.9)	178.9 (73.1)	180.4 (72.8)	
Range	31–644	31–478	39–644	
Rocuronium usage, mg/kg				<0.001
Mean (SD)	144.05 (47.92)	140.29 (51.07)	147.74 (44.42)	
Range	30–475	30–475	61.88–412.5	

183 min) for the entire study population and was significantly shorter in participants receiving sugammadex than in those not receiving sugammadex [median:14 (range, 0–121) *vs.* 30.5 (range, 0–183) min; P<0.001]. Multivariate linear regression analysis showed that sugammadex use was associated with a significantly shorter time to extubation than no sugammadex use (standardized β: −0.109; P<0.001). Higher body mass index (BMI) was associated with a significantly shorter extubation time than lower BMI (standardized β: −0.051; P=0.011), whereas cerebral infarction was associated with a markedly longer extubation time than no infarction (standardized β: 0.060; P=0.003). Additionally, intestinal, urinary, gastric or prostate surgery was associated with a significantly shorter extubation time than hepatic surgery (P<0.05 for all).

Other outcomes

Participants receiving sugammadex had a markedly shorter return to the ward time than patients not receiving sugammadex (P<0.001 for all) (*Table 3*). Multivariate linear regression showed an association between the use of sugammadex and a shorter time to return to the ward (standardized β: −10.126; P<0.001) (Table S1). Furthermore, patients receiving sugammadex had a significantly shorter time to passage of flatus, food intake, and time to ambulation (P<0.001 for all). Multivariate linear regression showed an association between the use of sugammadex and shorter time to passage of flatus (standardized β: −0.134; P<0.001), food intake (standardized β: −0.312; P<0.001), defecation (standardized β: −0.083; P<0.001), and ambulation (standardized β: −0.367; P<0.001) (Table S1). Postoperative hospital stay was significantly shorter in patients receiving sugammadex than those not receiving sugammadex (P=0.019). Sugammadex use was not associated with the length of hospital stay.

Except for a significantly lower static visual analogue scale (VAS) score on postoperative day 1 (POD1) in patients receiving sugammadex *vs.* those not receiving sugammadex (P=0.041), no statistical difference was observed in static VAS score on POD2 and the dynamic VAS scores on POD1 and POD2 between the 2 groups (*Table 4*). Multivariate linear regression revealed an association between the use of sugammadex with a lower static VAS score on POD1 (standardized β: −0.055; P<0.001). The rate of PONV did not differ between the 2 groups. A significantly lower proportion of participants receiving sugammadex experienced cough (1.6% *vs.* 6.2%; P<0.001), elevated transaminases (11.6% *vs.* 24.0%; P<0.001), hypoproteinemia (16.4% *vs.* 23.1%; P<0.001), bilirubinemia (16.1% *vs.* 24.9%; P<0.001), and renal dysfunction (2.5% *vs.* 5.5%; P=0.002) than those not receiving sugammadex. No

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Table 3 Rapid recovery characteristics

Variables	All (n=1,615)	Sugammadex (n=795)	No sugammadex (n=820)	P value
Time to extubation, min, median [range]	22.6 [0–183]	14 [0–121]	30.5 [0–183]	<0.001
Time to return to ward, min, median [range]	45 [5–201]	34 [5–152]	55 [9–201]	<0.001
Time to ambulation, d, median [range]	2 [1–16]	2 [1–16]	2 [1–15]	<0.001
Time to passage of flatus, d, mean ± SD [range]	3.84±1.38 [1–16]	3.68±1.36 [1–10]	3.99±1.38 [1–3]	<0.001
Time to food intake, d, median [range]	4 [1–30]	3 [1–16]	5 [1–30]	<0.001
Time to defecation, d, mean ± SD [range]	4.5±1.7 [1–16]	4.41±1.70 [1–16]	4.65±1.63 [1–13]	<0.001
Length of hospital stay, d, mean ± SD [range]	21.1±8.0 [5–86]	20.9±8.2 [5–86]	21.3±7.9 [7–69]	0.081
Length of postoperative hospital stay, d, mean ± SD [range]	12.6±6.9 [1–78]	12.4±7.0 [1–78]	12.9±8.7 [2–58]	0.019

d, day; min, minute; n, number; SD, standard deviation.

Table 4 Postoperative pain and the rates of postoperative complications

Variables	All (n=1,615)	Sugammadex (n=795)	No sugammadex (n=820)	P value
Static VAS score, median [range]				
POD1	0 [0–9]	0 [0–3]	0 [0–9]	0.041
POD2	0 [0–2]	0 [0–3]	0 [0–2]	0.390
Dynamic VAS score, median [range]				
POD1	2 [2–6]	2 [0–5]	2 [0–6]	0.202
POD2	2 [0–4]	2 [0–4]	2 [1–4]	0.781
PONV, n (%)				
POD1	127 (7.9)	53 (6.7)	54 (6.6)	0.948
POD2	76 (4.7)	37 (4.7)	39 (4.8)	0.923
Cough, n (%)	64 (4.0)	13 (1.6)	51 (6.2)	<0.001
Pneumonia, n (%)	65 (4.0)	28 (3.5)	37 (4.5)	0.311
Atelectasis, n (%)	86 (5.3)	40 (5.0)	46 (5.6)	0.605
Gastrointestinal paralysis, n (%)	14 (0.9)	10 (1.0)	4 (0.5)	0.095
Postoperative drainage volume, mL, median [range]	853.5 [0–37,757]	842.50 [0–37,757]	870 [0–17,160]	0.177
Transaminase elevations, n (%)	289 (17.9)	92 (11.6)	197 (24.0)	<0.001
Hypoproteinemia, n (%)	319 (19.8)	130 (16.4)	189 (23.1)	0.001
Bilirubinemia, n (%)	332 (20.6)	128 (16.1)	204 (24.9)	<0.001
Renal dysfunction, n (%)	65 (4.0)	20 (2.5)	45 (5.5)	0.002
Requiring transfusion, n (%)	167 (10.3)	74 (9.3)	93 (11.3)	0.180

n, number; POD, postoperative day; PONV, postoperative nausea and vomiting; VAS, visual analogue scale.

statistical difference was observed in the rates of pneumonia, atelectasis, gastrointestinal paralysis, and blood transfusions. Regression analysis showed an association between the use of sugammadex with lower rates of postoperative cough, pneumonia, transaminase elevation, hypoproteinemia, hyperbilirubinemia, and renal dysfunction (Table S2).

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Discussion

Neostigmine is an acetylcholinesterase inhibitor and has long been used for reversal of neuromuscular blockade during the administration of anesthesia to patients undergoing surgery that require muscle relaxation (23). Its use has been hampered by an indirect mechanism of neuromuscular blockade reversal, limited and unpredictable efficacy, and undesirable muscarinic responses including bradycardia, diplopia, nausea, and vomiting, which are dose dependent (24). Compared to neostigmine, which could not rapidly reverse profound neuromuscular blockade, sugammadex has a distinct mechanism of action, with a very fast onset, and, most importantly, it causes fewer side effects (23). Such benefits are particularly relevant in cancer patients receiving surgical treatment due to high rate of co-morbidities. The current study showed that patients receiving sugammadex were older, had more complications, and poorer ASA status. Notwithstanding the biases for patients not receiving sugammadex (younger, better ASA status, and fewer comorbidities), sugammadex use was associated with shorter extubation time as well as relevant measures that reflected faster postoperative recovery. Rocuronium dosage was statistically smaller in participants who received sugammadex, but probably not clinically relevant. Contrary to previous studies, we found shorter extubation time in patients with higher BMI. Such a discrepancy may reflect the fact that majority of the patients had normal BMI; higher BMI in this specific population reflects better overall physical condition. To our knowledge, this is the first real-world, observational study to examine the potential benefits of sugammadex for postoperative recovery and treating complications in cancer patients undergoing abdominal surgery.

The shorter extubation time in patients receiving sugammadex in the current study is consistent with previous findings in other surgical settings (25). In the multivariate regression analysis, the use of sugammadex was a significant determinant of extubation time, even after adjustment for confounding variables (e.g., site of surgery, BMI, and cerebral infarction). In addition to the benefits for individual patients, shorter extubation time is an important factor for improving OR efficiency (26).

Early extubation is associated with improved postoperative recovery in abdominal aortic surgery, esophagectomy, and cardiac surgery (27-29). Extubation in the OR significantly reduced intensive care unit (ICU) stay and postoperative length of postoperative hospital stay (29). In our study, more patients receiving sugammadex were extubated in the OR than patients not using sugammadex (57.9% and 20.7%, respectively). In the multivariate regression analysis, sugammadex use was associated with a more rapid return to the ward. Additionally, our study revealed that sugammadex markedly accelerated gastrointestinal function recovery, with significantly reduced time to passage of flatus, oral food intake, and defecation. Sugammadex also reduced time to ambulation.

Postoperative length of hospital stay has been used as a surrogate endpoint of surgical and anesthetic success and a part of the evaluation framework of quality outcomes. In line with earlier findings (22), our study showed that patients undergoing abdominal surgery with neuromuscular blockade reversal by sugammadex had a significantly shorter postoperative length of hospital stay than those not receiving sugammadex. In the multivariate regression analysis, however, we failed to show a statistically significant association between sugammadex use and postoperative length of hospital stay, possibly because not all relevant confounding factors (e.g., Eastern Cooperative Oncology Group (ECOG) performance status and tumor stage) were included in the regression model.

The current study showed that patients undergoing abdominal surgery with neuromuscular blockade reversal by sugammadex had a significantly lower static VAS score on POD1, but there was no marked difference in the static VAS score on POD2 and the dynamic VAS scores on POD1 and POD2. This is largely consistent with the findings of a meta-analysis of 1,384 patients showing that sugammadex does not significantly reduce the likelihood of pain and PONV (19). We also found that the incidence of PONV on POD1 and POD2 was not statistically different between patients receiving sugammadex and those who did not receive sugammadex. Yağan *et al.* showed that, compared to neostigmine, sugammadex reduced PONV at 1 h postoperatively, but not on POD1 (30). In addition, we found no statistical difference in the rate of pneumonia and atelectasis between patients receiving sugammadex and those not receiving sugammadex. Meanwhile, Kheterpal *et al.* showed that compared to neostigmine, sugammadex caused a 47% reduction in the risk of postoperative pneumonia in adult patients undergoing inpatient surgery (31). Although sugammadex has been proven safe for use in patients with hepatic and renal dysfunction, there has been no evidence that sugammadex reduces the incidence of postoperative hepatic and renal dysfunction. The study suggested lower rates of postoperative transaminase elevation, hypoproteinemia, hyperbilirubinemia, and renal

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dysfunction in patients receiving sugammadex; however, the findings must be considered preliminary and should be examined more rigorously in future studies.

This study has several limitations. This is an observational study and cannot avoid selection bias and the study findings need to be confirmed by randomized controlled trials. Furthermore, it was a real-world investigation and a causal relationship could not be established among the variables; hence, the data should be interpreted with caution. Another limitation is the single-center design in a tertiary care setting and, therefore, the findings may not be generalizable to other healthcare settings. Furthermore, the ERAS concept is well established in daily clinical work at our institution and the results may not be applicable to hospitals that do not implement an ERAS protocol in daily clinical work. Additionally, patients receiving neostigmine were not included (due to the very small number of such patients at our institute).

Conclusions

In conclusion, our study showed that in the real-world setting, attending anesthetists are more likely to administer sugammadex to older patients, those with poorer ASA status, and those with significant comorbidities. Despite these biases, patients receiving sugammadex had shorter extubation times, and cancer patients undergoing abdominal surgery who received sugammadex had shorter postoperative hospital stay. The findings support the use of sugammadex, particularly in elderly patients with poor ASA status and significant comorbidities.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://dx.doi.org/10.21037/apm-21-3398

Data Sharing Statement: Available at https://dx.doi.org/10.21037/apm-21-3398

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://dx.doi.org/10.21037/apm-21-3398). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This real-world, retrospective study was approved by the Ethics Committee of Jiangsu Cancer Hospital (No. 2020Ke-039), and due to its retrospective nature, informed consent was waived by the Ethics Committee. All procedures performed in this study involving human participants were in accordance with the Declaration of Helsinki (as revised in 2013).

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Supplementary

Table S1 Multivariate linear regression analysis of the effect of sugammadex use on patient recovery characteristics

Variables	β	Standard error	Standardized β	P value
Time to extubation				
Sugammadex (*vs.*no sugammadex)	−4.869	0.993	−0.109	<0.001
Constant	−1.556	4.820		<0.001
Time to return to the ward				
Sugammadex (*vs.* no sugammadex)	−7.212	1.232	−10.126	<0.001
Constant	−14.742	4.219		<0.001
Time to passage of flatus				
Sugammadex (*vs.* no sugammadex)	−0.370	0.067	−0.134	<0.001
Constant	3.380	0.225		<0.001
Time to food intake				
Sugammadex (*vs.* no sugammadex)	−1.535	0.112	−0.312	<0.001
Constant	3.531	0.383		<0.001
Time to defecation				
Sugammadex (*vs.* no sugammadex)	−0.275	0.082	−0.083	0.001
Constant	3.198	0.271		<0.001
Time to ambulation				
Sugammadex (*vs.* no sugammadex)	−0.367	0.082	0.072	<0.001
Constant	2.543	0.426	0.093	<0.001
Postoperative static VAS score at POD1				
Sugammadex (*vs.* no sugammadex)	−0.044	0.020	−0.055	<0.001
Constant	0.080	0.016		<0.001

POD, postoperative day; VAS, visual analogue scale.

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Table S2 Conditional forward regression analysis of the effects of sugammadex on postoperative complications

Variables	Wald	Df	P value	EXP (β)	95% CI
Cough					
Sugammadex (*vs.* no sugammadex)	21.682	1	<0.001	0.218	0.115–0.414
Constant	216.611	1	<0.001	0.034	
Pneumonia					
Sugammadex (*vs.* no sugammadex)	4.456	1	0.035	0.550	0.316–0.958
Constant	45.210	1	<0.001	0.001	
Transaminase elevations					
Sugammadex (*vs.* no sugammadex)	44.728	1	<0.001	0.367	0.274–0.493
Constant	5.570	1	0.018	0.257	
Hypoproteinemia					
Sugammadex (*vs.* no sugammadex)	11.660	1	0.001	0.647	0.503–0.830
Constant	207.869	1	<0.001	0.300	
Hyperbilirubinemia					
Sugammadex (*vs.* no sugammadex)	19.298	1	<0.001	0.568	0.441–0.731
Constant	61.394	1	<0.001	0.196	
Renal dysfunction					
Sugammadex (*vs.* no sugammadex)	11.003	1	0.001	0.394	0.227–0.683
Constant	38.088	1	<0.001	0.005	

CI, confidence interval; Df, difference; EXP, expected.

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