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Retrospective analysis of 30-day unplanned readmission after major abdominal surgery with reversal by sugammadex or neostigmine

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Abstract

Background: Sugammadex is associated with fewer postoperative complications, but its impact on 30-day unplanned readmission is unclear.

Methods: This was a single-centre retrospective observational study of patients after major abdominal surgery between 2010 and 2017, where rocuronium was the only neuromuscular blocker used. The primary endpoint was the difference in incidence of 30-day unplanned readmission between reversal with sugammadex or neostigmine. The secondary endpoints were the length of hospital stay after surgery and related hospital charges (total charges excluding those related to surgery and anaesthesia). Analysis included propensity score matching and generalised mixed-effects modelling.

Results: Mixed-effects logistic regression analysis of 1479 patients (sugammadex: 355; neostigmine: 1124) showed that the incidence of 30-day unplanned readmission was 34% lower (odds ratio [OR]: 0.66, 95% confidence interval [CI]: 0.46–0.96, $P=0.031$), the length of hospital stay was 20% shorter (exponential regression coefficient: 0.80, 95% CI: 0.77–0.83, $P<0.001$), and related hospital charges were 24% lower (exponential regression coefficient: 0.76, 95% CI: 0.67–0.87, $P<0.001$) in the sugammadex group than in the neostigmine group. For patients living ≥50 km from the hospital, the incidence of 30-day unplanned readmission was 68% lower in the sugammadex group than in the neostigmine group (OR: 0.32, 95% CI: 0.13–0.79, $P=0.014$), while it was not significant for patients living <50 km from the hospital ($P=0.319$).

Conclusions: Compared with neostigmine, reversal of rocuronium with sugammadex after major abdominal surgery was associated with a lower incidence of 30-day unplanned readmission, a shorter hospital stay, and lower related hospital charges.

Keywords: anticholinesterase; hospital readmission; neuromuscular blocking agents; postoperative complications; reversal agents; length of stay; rocuronium

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Editor's key points

- Sugammadex use is associated with reduced postoperative pulmonary complications, but its impact on unplanned hospital readmission is unknown.
- In a single-centre retrospective analysis, use of sugammadex *vs* neostigmine for reversal of neuromuscular block was associated with a reduction in unplanned readmission at 30 days after major abdominal surgery.
- Propensity score matching and generalised mixed-effects modelling also showed that use of sugammadex was associated with a shorter hospital stay and lower hospital-related charges.

Sugammadex is a selective binding agent for steroidal non-depolarising neuromuscular blockers that does not affect cholinergic transmission or exhibit intrinsic biologic effects. It is capable of reversing neuromuscular block (NMB) rapidly and reliably.[1–3] This contrasts with neostigmine, an anticholinesterase that produces a limited reversal of NMB, and cholinergic side-effects and wide inter-individual variability.[4,5] When using sugammadex, deep intraoperative NMB is possible with improved surgical conditions,[6,7] and postoperative residual NMB can also be reduced.[8] However, the comparative expense of sugammadex and limited data regarding patient outcomes cause hesitation among some anaesthesiologists considering routine use of sugammadex.

A reduction of readmissions is important for improving patient care and lowering costs[9]; readmissions after surgery are closely associated with postoperative complications.[10] Postoperative residual NMB increases the risk of major postoperative pulmonary complications.[11,12] In this regard, NMB reversal by sugammadex may be associated with a lower incidence of the 30-day readmission rate; however, information regarding this claim is lacking. We investigated whether use of sugammadex for reversal of NMB was associated with a lower incidence of 30-day unplanned readmission rate after major abdominal surgery compared with use of neostigmine. The secondary aims were to evaluate the effect of sugammadex on the length of hospital stay after surgery and related hospital charges.

Methods

This was a retrospective observational study conducted under the approval of the Seoul National University Bundang Hospital Institutional Review Board (approval number: B-1806/474-103). Informed consent was waived, considering the retrospective design.

Patients

Data were collected by reviewing the medical records of adult patients >19 yr of age who underwent elective major abdominal surgery in a single tertiary teaching hospital between January 2010 and December 2017. Major abdominal surgery was defined as any abdominal surgical procedure with surgery time >2 h and estimated blood loss >500 ml. Patients with incomplete medical records and those who received cisatracurium for NMB were excluded.

Sugammadex

Rocuronium was the most commonly used agent for NMB during major abdominal surgery. Sugammadex ($\geq$2 mg kg^{-1}) or neostigmine (0.03–0.05 mg kg^{-1}) was generally used as the neuromuscular reversal agent. In all patients in whom neostigmine was used, glycopyrrolate was co-administered to prevent cholinergic complications of neostigmine.

Thirty-day unplanned readmission, length of hospital stay, and related hospital charges

Unplanned readmission to the hospital within 30 days of discharge after major abdominal surgery was defined as 30-day readmission. Patients who had planned readmissions for routine evaluation, chemotherapy, or radiotherapy according to existing protocols in the surgical department were excluded.

Length of hospital stay was calculated from the day of surgery to the day of discharge. Because NMB reversal by sugammadex was performed at the end of anaesthesia, related hospital charges were calculated as: total hospital charges at the time of discharge—charges for surgery and anaesthesia. In South Korea, all patients are covered by the National Health Insurance Service, which provides coverage for approximately two-thirds of hospital charges.[13] The calculated charges were converted using a Korean Currency 1060 won=1 US dollar conversion rate.

Patient characteristics

Physical characteristics (age, BMI [kg m^{-2}], sex), calculated distance from home to hospital based on ZIP code (km), preoperative comorbidities (ASA classification, hypertension, diabetes mellitus, ischaemic heart disease [from stable angina to myocardial infarction], cerebrovascular disease, liver disease [hepatitis, liver cirrhosis, hepatocellular carcinoma], and cancer), and operative data (surgical time [min], estimated blood loss [ml], emergency surgery, type of surgery [general surgery/urologic or gynaecologic surgery], total intraoperative rocuronium [mg kg^{-1}] and remifentanil doses [mg], and information regarding staff anaesthesiologists for each surgery) were also collected. Additionally, total relative value unit scores, which reflect surgical complexity,[14] were collected (detailed information is in Supplementary material Appendix 1).

Endpoints

The primary endpoint was the difference in 30-day readmission rates after major abdominal surgery between the sugammadex and neostigmine groups. Secondary endpoints were the length of hospital stay after surgery and related hospital charges.

Statistical analysis

In order to correct for selection bias and confounding factors, we used the propensity score matching method without replacement,[15] which could balance the covariates between the two groups. The following covariates—patient characteristics, preoperative comorbidities, and operative characteristics—were matched at a 1:5 ratio with a 0.25 calliper by the nearest neighbour method. To determine balance between the two groups before and after propensity score matching, absolute standardised difference (ASD) was used; an ASD <0.1 for the covariates indicated that the two groups were sufficiently balanced.

After confirming balance in the matched cohort, a generalised linear mixed-effects model was used for three dependent variables to control provider effects by the anaesthesiologist. Additionally, propensity score matching identification was included in each mixed-effect model as a random intercept to incorporate matched sets into the final mixed modelling analysis. For these mixed-effects models, three confounding factors (intraoperative rocuronium dose, intraoperative remifentanil dose, and total relative value unit score), which were excluded in the initial propensity score matching were included for adjustment. These three confounders were excluded from initial propensity score matching for the following reasons: 1) intraoperative rocuronium and remifentanil doses could be affected by differences in the protocols used by individual anaesthesiologists,[16] so they could be clustered by anaesthesiologists in a mixed-effects model; and 2) associations between the total relative value unit score of major abdominal surgery and the three dependent variables could give useful information.

First, we performed mixed-effects logistic regression analysis for 30-day unplanned readmission, with clustering by anaesthesiologist and matching identification. Second, we performed mixed-effects Poisson log-linear regression analysis for length of hospital stay, with clustering by anaesthesiologist and matching identification. In this model, a Poisson distribution was assumed for the dependent variable (length of hospital stay). Third, we performed mixed-effects log-linear regression analysis for related hospital charges, with clustering by anaesthesiologist and matching identification. In this model, a gamma distribution was assumed for the dependent variable (related hospital charges). Considering that 30-day unplanned readmission could be affected by distance from home to hospital, sensitivity analyses according to distance from home to hospital (<50 or ≥50 km) were performed using the same method in matched cohorts. Finally, we performed multivariable generalised linear mixed-effects analysis for 30-day unplanned readmission, length of hospital stay after surgery, and related hospital charges with all covariates in the combined cohort, in order to demonstrate that the results in the matched cohort would be generalisable to all patients in our hospital.

The package matchit of the R program (version 3.4.4; www.r-project.org) was used as a propensity score matching tool; the analysis was performed with SAS software version 9.4 (SAS Institute Inc., Cary, NC, USA). A *P*-value <0.05 was considered statistically significant in general; *P*<0.025 was considered statistically significant for two secondary endpoints (length of hospital stay and related hospital charges) after Bonferroni correction, which is known to reduce type I error in multiple comparisons.[17]

Results

Among 4217 patients who underwent major abdominal surgery between January 2010 and December 2017, we excluded 164 patients who were under the age of 19 yrs, 301 patients who had incomplete medical records, and 288 patients who were administered cisatracurium, with 3464 patients included in the analyses (Fig 1). Unplanned readmission at 30 days occurred in 461 patients (13.3%) (Table 1). The most common chief complaints at the time of 30-day unplanned readmission (Table 2) were: pain (156/461, 33.8%), gastrointestinal symptoms (74/461, 16.1%), and fever (70/461, 15.2%).

Table 3 shows the pre-propensity score matching (sugammadex group: 370; neostigmine group: 3,094) and post-

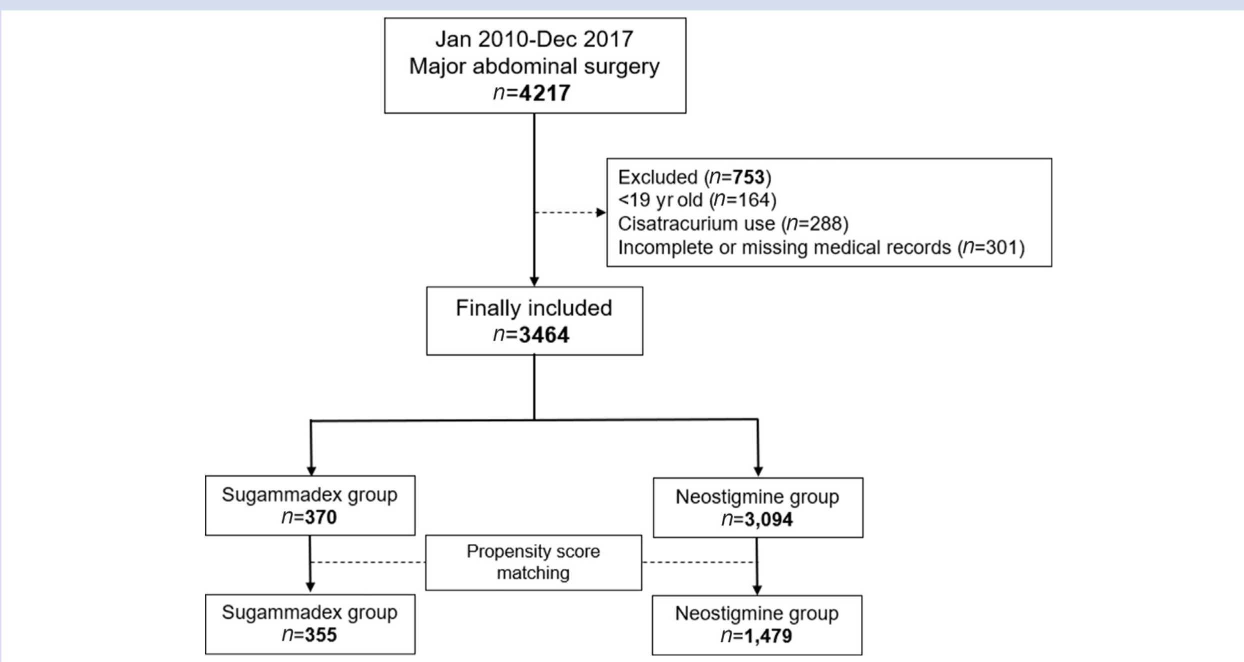

Fig 1. Flow chart of patient selection.

Table 1 Characteristics of patients who received major abdominal surgery 2010–17. Presented as *n* (%) or mean (SD). *Total RVUs for each surgery represents the total of three component RVUs (detailed information is in Supplementary material Appendix 1). HCC, hepatocellular carcinoma; LC, liver cirrhosis; NMB, neuromuscular blocker; RVUs; relative value unit score; SD, standard deviation.

Variables	Total (3464)	Mean (SD)	Range
Age (yr)		58.9 (14.1)	19–93
BMI (kg m^{-2})		23.9 (3.6)	14–43
Sex: male	1851 (53.4)		
Distance between hospital and home (km)		62.9 (90.7)	5.0–443.0
Preoperative comorbidities			
ASA physical status			
1	1509 (43.6)		
2	1914 (55.3)		
≥3	41 (1.2)		
Hypertension	961 (27.7)		
Diabetes mellitus	181 (5.2)		
Ischaemic heart disease	59 (1.7)		
Cerebrovascular disease	69 (2.0)		
Liver disease (hepatitis, LC, HCC)	317 (9.2)		
Cancer	279 (8.1)		
Information regarding surgery			
Surgery time (min)		322 (146)	120–995
Estimated blood loss (ml)		1223 (1705)	500–47 000
Emergency surgery	207 (6.0)		
Type of surgery			
General surgery	2045 (59.0)		
Urologic or gynaecologic surgery	1419 (41.0)		
Year of surgery			
2010–12	1088 (31.4)		
2013–15	1371 (39.6)		
2016–17	1005 (29.0)		
Staff anaesthesiologist			
A	959 (27.7)		
B	409 (11.8)		
C	433 (12.5)		
D	674 (19.5)		
E	329 (9.5)		
F	141 (4.1)		
Others	519 (15.0)		
Total dose of rocuronium (mg kg^{-1})		1.3 (0.9)	0.1–7.3
NMB reversal by sugammadex	370 (10.7)		
Intraoperative remifentanil dose (mg)		1.0 (1.8)	0–24
Total RVUs for surgery*		29 486 (33 927)	243–410 383
Unplanned readmission within 30-day	461 (13.3)		
Length of hospital stay after surgery (days)		14.2 (15.1)	1–212
Related hospital charge (US dollars)		14 040 (17 864)	1400–31,162

propensity score matching (sugammadex group: 355; neostigmine group: 1124) covariate comparisons. There is a difference between the intended matching ratio (1:5) and the actual matching ratio (approximately 1:3.2) because the matching algorithm was set to the nearest neighbour method with a 0.25 calliper. After propensity score matching, all covariates were well-balanced with an ASD <0.1. Supplementary material Appendix 2 shows the distribution of propensity scores before (A) and after (B) propensity score matching; notably, the distribution of propensity scores between the two groups became similar after propensity score matching.

Mixed-effects logistic regression analysis after propensity score matching showed that the incidence of 30-day unplanned readmission was 34% lower in the sugammadex group than in the neostigmine group (odds ratio [OR]: 0.66, 95% confidence interval [CI]: 0.46–0.96, P=0.031; Table 4). Mixed-effects Poisson log-linear regression analysis after propensity score matching showed that the length of hospital stay after surgery in the sugammadex group was 20% shorter in the sugammadex group compared with the neostigmine group (exponential regression coefficient: 0.80, 95% CI: 0.77–0.83, P<0.001; Table 4). Mixed-effects log-linear regression analysis after propensity score matching showed that the related hospital charges were 24% lower in the sugammadex group compared with the neostigmine group (exponential regression coefficient: 0.76, 95% CI: 0.67–0.87, P<0.001; Table 4). Figure 2 shows forest plots representing the OR for 30-day unplanned readmission (Fig 2a), exponentiated coefficient for length of hospital stay after surgery (Fig 2b), and related hospital charge (Fig 2c) after propensity score matching.

In the sensitivity test stratified by distance between home and hospital, the incidence of 30-day unplanned readmission for patients living ≥50 km from the hospital was 68% lower in the sugammadex group compared with the neostigmine group (OR: 0.32, 95% CI: 0.13–0.79, P=0.014; Supplementary material Appendix 3), while the incidence of 30-day unplanned readmission for patients living <50 km from the hospital was not

Table 2 Chief complaints for 30-day readmission after major abdominal surgery 2010–17. Presented as *n* (%). Total 30-day readmission after major abdominal surgery was 681 patients, and among these, 461 patients were classified as unplanned 30-day readmission. *Included cardiac arrest, psychological symptom, hospice care, ear-nose-throat symptom, trauma, and endocrinological symptom.

Chief complaint for 30-day unplanned readmission	Total (461)
Pain	156 (33.8)
General weakness or poor oral intake	15 (3.3)
Fever	70 (15.2)
Gastrointestinal symptom	74 (16.1)
Gastrointestinal bleeding	9 (2.0)
Oedema or ascites	6 (1.3)
Wound complication	36 (7.8)
Urinary symptom	10 (2.2)
Respiratory symptom	24 (5.2)
Neurologic symptom	12 (2.6)
Cardiovascular symptom	9 (2.0)
Others*	40 (8.7)

significantly different between groups (P=0.319). In the combined cohort (*n*=3464), multivariable generalised linear mixed-effect analysis showed similar trends with the overall results of the matched cohort (Supplementary material Appendix 4).

Discussion

This single-centre retrospective observational study showed that the incidence of 30-day unplanned readmission was 34% lower in patients receiving sugammadex for reversal of NMB compared with those receiving neostigmine, independent of intraoperative rocuronium dose, remifentanil dose, or total relative value unit score after major abdominal surgery. Length of hospital stay was 20% shorter and related hospital charges were 24% lower in the sugammadex group than in the neostigmine group.

There have been a few previous retrospective reports regarding 30-day readmission rate in relation to anaesthesia.[18,19] Thevathasan and colleagues[18] reported a positive association between intraoperative non-depolarising neuromuscular blocking agent dose and 30-day readmission after abdominal surgery. The likely reason for this difference from our results is that sugammadex administration was the main variable used in our mixed-effects logistic regression model, which might have nullified the effect of the rocuronium dose on 30-day unplanned readmission rate. Thevathasan and colleagues[18] would not have considered sugammadex as a covariate or main independent variable in their study because they analysed data from a tertiary care hospital in Boston, MA, USA during the period of 2007–14 and sugammadex was not approved by the US Food and Drug Administration until December 2015.[20] In contrast, sugammadex has been used in South Korea since 2011, and our retrospective study analysed

Table 3 Comparison between sugammadex and neostigmine groups before and after propensity score matching. Presented as *n* (%) or mean (SD). *Liver disease (hepatocellular carcinoma, liver cirrhosis, hepatitis). ASD, absolute value of standardised mean difference; GYN, gynaecologic; PS, propensity score; URO, urologic.

Variables	Before propensity score matching (*n*=3464)		ASD	After propensity score matching (*n*=1479)		ASD
	Sugammadex	Neostigmine		Sugammadex	Neostigmine	
	n=370	*n*=3094		*n*=355	*n*=1124	
Age (yr)	61.4 (14.2)	58.6 (14.1)	0.19	61.3 (14.4)	60.2 (13.4)	0.00
Sex: Male	258 (69.7)	1593 (51.5)	0.40	248 (69.9)	711 (63.3)	0.04
Body mass index (kg m^{-2})	24.4 (3.6)	23.8 (3.6)	0.14	24.4 (3.6)	24.2 (3.6)	0.00
Preoperative comorbidities						
ASA physical status			0.44			0.01
1	94 (25.4)	1415 (45.7)		89 (25.1)	352 (31.3)	
2	269 (72.7)	1645 (53.2)		259 (73.0)	755 (67.2)	
≥3	7 (1.9)	34 (1.1)		7 (2.0)	17 (1.5)	
Hypertension	128 (34.6)	833 (26.9)	0.16	124 (34.9)	367 (32.7)	0.02
Diabetes mellitus	42 (11.4)	139 (4.5)	0.19	37 (10.4)	88 (7.8)	0.01
Ischaemic heart disease	6 (1.6)	53 (1.7)	0.00	6 (1.7)	21 (1.9)	0.05
Cerebrovascular disease	10 (2.7)	59 (1.9)	0.05	10 (2.8)	35 (3.1)	0.02
Chronic kidney disease	2 (0.5)	10 (0.3)	0.03	2 (0.6)	5 (0.4)	0.02
Liver disease*	50 (13.5)	267 (8.6)	0.14	48 (13.5)	134 (11.9)	0.02
Cancer	53 (14.3)	226 (7.3)	0.20	49 (13.8)	134 (11.9)	0.02
Operative characteristics						
Surgery time (min)	341 (139)	320 (147)	0.15	340 (139)	332 (148)	0.01
Emergency surgery	8 (2.2)	199 (6.4)	0.27	8 (2.3)	37 (3.3)	0.02
Estimated blood loss (ml)	885 (552)	1264 (1,790)		880 (543)	938 (758)	0.03
Type of surgery			0.45			0.04
General surgery	282 (76.2)	1763 (57.0)		270 (76.1)	795 (70.7)	
URO or GYN surgery	88 (23.8)	1331 (43.0)		85 (23.9)	329 (29.3)	
Year at surgery			0.90			0.07
2010–12	0 (0.0)	1088 (35.2)		0 (0.0)	14 (1.3)	
2013–15	124 (33.5)	1247 (40.3)		118 (33.2)	561 (49.9)	
2016–17	246 (66.5)	759 (24.5)		237 (66.8)	549 (48.8)	

Table 4 Mixed-effects regression analysis with clustering by staff anaesthesiologists for 30-day unplanned readmission, related hospital charge, and length of hospital stay after propensity score matching. In each mixed-effect model, propensity score matching identification was also included with anaesthesiologists as a random intercept to incorporate matched sets into final mixed modelling analysis. CI, confidence interval; Coef, coefficient; Exp, exponentiated; ID, identification; Intraop, intraoperative; LOS, length of hospital stay; rmFTN, remifentanil; ROC, rocuronium; RVUs, relative value unit score.

Variables	30-day unplanned readmission		LOS after surgery		Related hospital charge*	
	Odds ratio (95% CI)	P†	Exp Coef (95% CI)	P‡	Exp Coef (95% CI)	P¶
Sugammadex (*vs* neostigmine)	0.66 (0.46, 0.96)	0.031	0.80 (0.77, 0.83)	<0.001	0.76 (0.67, 0.87)	<0.001
Confounders						
Intraop rmFTN dosage (10 mg)	1.05 (0.32, 3.47)	0.931	1.19 (1.06, 1.33)	0.002	1.27 (0.79, 2.04)	0.316
Total RVUs§ (10 000 point)	1.06 (1.02, 1.09)	0.001	1.01 (1.01, 1.02)	<0.001	1.08 (1.06, 1.09)	<0.001
Intraop ROC dosage (10 mg kg^{-1})	1.33 (0.29, 6.14)	0.713	1.79 (1.53, 2.08)	<0.001	3.01 (1.71, 5.32)	<0.001

* Related hospital charge: total hospital charges—charges for surgery and anaesthesia, and 2/3 of related charges were paid by National Health Insurance Service in South Korea.

† 30-Day unplanned readmission: generalised linear mixed-effects model assuming binomial distribution and logistic link function was used considering anaesthesiologists and matching ID as random intercept with three confounding factors.

¶ Related hospital charge: generalised linear mixed-effects model assuming Poisson distribution and log link function was used considering anaesthesiologists and matching ID as random intercept with three confounding factors, and Bonferroni correction was used to adjust type I error for multiple comparisons. $P<0.025$ was considered as statistically significant.

‡ Length of hospital stay after surgery: generalised linear mixed-effects model assuming gamma distribution and log link function was used considering anaesthesiologists and matching ID as random intercept with three confounding factors, and Bonferroni correction was used to adjust type I error for multiple comparisons. $P<0.025$ was considered as statistically significant.

§ Total RVUs for each surgery represents the total of three component RVUs: one for physician work (36.1%), one for practice expense (62.1%), and one for malpractice expense (1.8%), and can be downloaded in the homepage of Health Insurance Review & Assessment Service in South Korea: http://www.hira.or.kr/eng/main.do. We used the total RVU, which was updated in July 2018. Total RVU of surgery is often used for adjustment of surgical complexity (detailed information is in Supplementary material Appendix 1).

data from 2010 to 2017. Thevathasan and colleagues[18] proposed that residual NMB represented a rationale for the increased 30-day readmission rate.

However, residual NMB is known to be reduced by sugammadex administration, and by the use of proper neuromuscular monitoring, regardless of the quantity of rocuronium used.[12,21–24]

Another study by Boon and colleagues[19] showed a relationship between residual NMB and NMB reversal by sugammadex. They hypothesised that the intraoperative advantage created by high-dose rocuronium would decrease 30-day unplanned readmission, and reported lower 30-day unplanned readmission rates in a high-dose rocuronium cohort compared with a low-dose cohort. The high-dose cohort was consistently monitored for neuromuscular activity, which was completely antagonised with sugammadex; the low-dose rocuronium cohort was unreliably monitored and just 33% of matched patients were antagonised with sugammadex. Our patients were managed similarly, that is patients antagonised with sugammadex tended to have intraoperative deep NMB under neuromuscular monitoring and the dose of sugammadex was determined by the neuromuscular monitoring. The advantage of our study is that we conducted propensity score matching on a larger study sample size, placed greater focus on sugammadex use, and performed mixed-effects logistic regression analysis after propensity score matching with clustering by anaesthesiologist. Through this mixed-effects regression model, we found that sugammadex reversal, rather than rocuronium dose, was the main factor related to 30-day unplanned readmission rates.

In this study, the most common chief complaint at readmission was pain (33.8%). Because pain is known as an important associated factor for unplanned readmission after surgery,[25,26] it might have affected the 30-day unplanned readmission rate as a confounding factor. A previous study reported that poorly controlled postoperative pain is associated with increased morbidity, development of persistent pain, and prolonged opioid use.[27] Considering that severe postoperative pain is closely related to overall 30-day complications after surgery,[28] severe postoperative pain associated with inadequate analgesia could have affected the increase in 30-day unplanned readmission rate in this study as a confounder. However, in the matched cohorts, there was no significant difference between the proportion of pain as a chief complaint in 30-day unplanned readmissions in the neostigmine group (3.6%, 40/1124) and that in the sugammadex group (3.4%, 12/355) ($P=0.271$). Therefore, we believe that severe postoperative pain did not affect the results of this study.

Previous studies reported that NMB reversal using sugammadex is cost-effective.[29,30] There are a few differences between this study and others on the economics of sugammadex use. First, because NMB reversal was performed at the end of anaesthesia, we excluded charges for surgery and anaesthesia from related hospital charges. Second, we analysed charges, not costs; notably, charges differ from costs in that human resources of medical staff are not included in charges.[31] Third, patients included in this study received financial coverage (approximately two-thirds of total hospital charges) through the National Health Insurance system in Korea.[12] Therefore, results regarding related hospital charges in the context of sugammadex use should be interpreted with consideration for these issues.

In previous retrospective studies, there were no reports of a significant association between the length of hospital stay after surgery and NMB reversal by sugammadex based on simple regression analysis.[32,33] To lower prediction errors for length of hospital stay in the statistical analysis, a generalised linear regression model should be considered[34]; however,

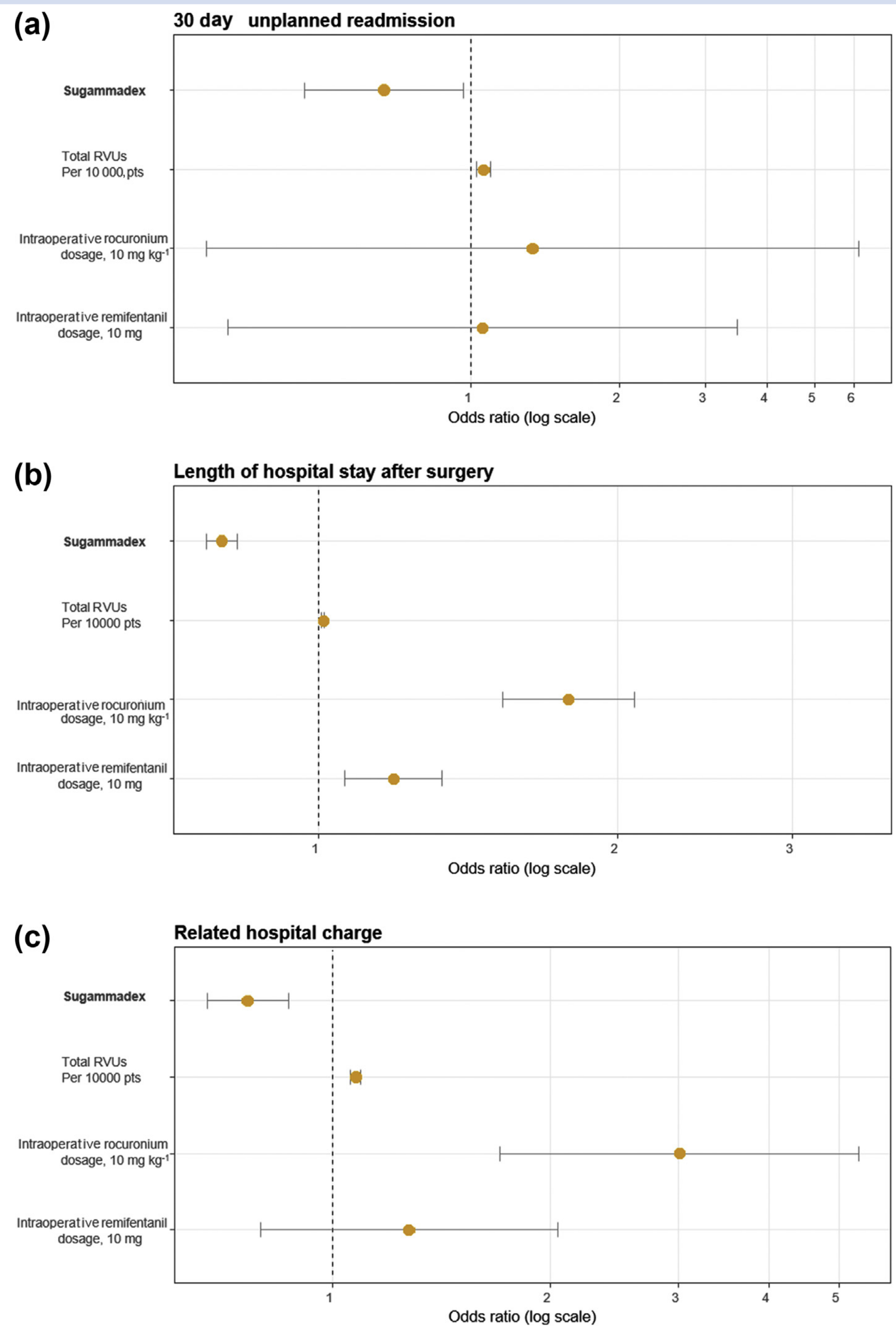

Fig 2. Odds ratio for 30-day unplanned readmission (a), exponentiated coefficient for length of hospital stay after surgery (b), and related hospital charge (c) after propensity score matching. RVUs, relative value unit score.

previous studies did not perform generalised linear regression analyses with Poisson, negative binomial, or gamma distributions. Because we used mixed-effects log-linear regression analysis with Poisson distribution and clustering by anaesthesiologist after propensity score matching, the 17% shorter length of hospital stay after surgery is a valuable and valid finding.

In our sensitivity analysis, we found that results regarding 30-day unplanned readmission differ based on patient distance from home to hospital, and that the effect of sugammadex use to reduce 30-day unplanned readmission rate was significant in the group with a $\geq$50 km distance from home to hospital. Because we counted all 30-day unplanned readmissions after discharge, many patients could have been admitted to our institution for other medical illnesses, rather than postoperative complications. It is possible that patients who lived far from our institution, who experienced illnesses other than surgical complications, might be hospitalised in other hospitals for convenience. However, patients with surgical complications returned to our institution for treatment regardless of the distance. Considering that the main effect of sugammadex use is to reduce postoperative complications by reducing residual NMB,[7] the effect of sugammadex use might be more evident among patients who lived far from the hospital, but more studies are needed to clarify the impact of sugammadex use on 30-day unplanned readmission rate with respect to distance from home to the hospital.

This study has a few limitations. First, the retrospective observational study design may have resulted in selection bias, and data quality or accuracy may be compromised compared with a prospective study. Second, this was a single-centre study, which may have compromised the generalisability of the findings. Third, the proportion of patients who underwent NMB reversal with sugammadex was relatively low at 10.7%, and a large sample was discarded through propensity score matching. Lastly, although we performed sensitivity analysis according to the distance from home to the hospital by using ZIP codes, we did not count cases of unplanned readmission in another hospital, which could have biased our results.

In conclusion, 30-day unplanned readmission rate after major abdominal surgery was lower in patients whose NMB was antagonised by sugammadex compared with neostigmine. Additionally, the length of hospital stay after surgery was shorter and related hospital charges were lower in the sugammadex group than in the neostigmine group.

Authors' contributions

Designed study, drafted paper: TKO.
Data acquisition: JHR, BWK, IAS, SWN.
Data analysis: HJJ.
Data interpretation, critical revisions of paper: AYO.
Approval of paper: all authors.

Declarations of interest

The authors declare that they have no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bja.2018.11.028.

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Corrigendum

Corrigendum to 'Retrospective analysis of 30-day unplanned readmission after major abdominal surgery with reversal by sugammadex or neostigmine' (Br J Anaesth 2019; 122: 370–378)

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The authors regret that an error was present in Figure 1. The correct version of the figure appears below:

The authors would like to apologise for any inconvenience caused.

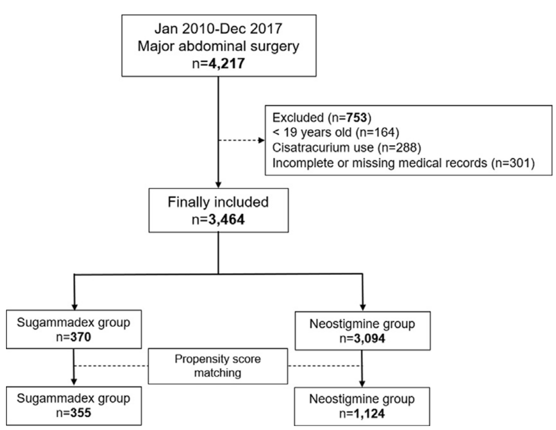

Fig 1. Flow chart of patient selection.