Effect of Sugammadex on Postoperative Pulmonary Complications and Rapid Recovery in Lung Cancer Patients Treated with Video-Assisted Thoracic Surgery: A Retrospective Cohort Study

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AIM: This study aimed to investigate the effects of sugammadex on postoperative pulmonary complications and rapid recovery in lung cancer patients undergoing video-assisted thoracic surgery (VATS).

METHODS: A retrospective analysis was conducted on the clinical data of 1131 lung cancer patients. Of these, 631 patients received sugammadex at the end of anesthesia, while 500 patients did not. To mitigate potential confounding factors, propensity score matching (PSM) was employed at a 1:1 ratio. After matching, 435 patients were obtained from each group. Patients who received sugammadex at the end of anesthesia were classified into Group S (n = 435) and those who did not receive sugammadex were Group P (n = 435). Postoperative pulmonary complications, indicators of recovery after surgery, nausea and vomiting, pain and lung infection scores and biochemical indices were compared between the two groups.

RESULTS: Compared to Group P, Group S demonstrated statistically significant improvements across multiple perioperative and postoperative outcomes. Group S exhibited a lower incidence of postoperative pulmonary complications ($\chi^2 = 9.52$, $p = 0.002$), as well as reduced durations for several key time intervals: from the cessation of muscle relaxation to extubation ($Z = 12.96$, $p < 0.001$), from the conclusion of surgery to extubation ($Z = 13.66$, $p < 0.001$), and total operating theatre occupancy ($Z = 5.81$, $p < 0.001$). Furthermore, Group S showed accelerated recovery in terms of time to first oral intake (drink: $Z = 3.80$, $p < 0.001$; eat: $Z = 3.80$, $p < 0.001$), time to defecate ($Z = 3.25$, $p = 0.001$), and time to chest tube removal ($Z = 5.04$, $p < 0.001$). Pain management outcomes were also superior in Group S, with lower motor visual analogue scale (VAS) scores at both 24 h ($Z = 4.71$, $p < 0.001$) and 48 h ($Z = 5.05$, $p < 0.001$) postoperatively. Group S additionally demonstrated a lower modified Clinical Pulmonary Infection Score (mCPIS) ($Z = 4.68$, $p < 0.001$), reduced complication rates during the general anesthesia awakening period ($\chi^2 = 23.54$, $p < 0.001$), and a lower incidence of renal function abnormalities ($\chi^2 = 12.65$, $p < 0.001$). Certain parameters, including total hospital stay duration and postoperative drainage volume, did not differ significantly between the two groups ($p > 0.05$).

CONCLUSIONS: Sugammadex can effectively reduce the incidence of postoperative pulmonary complications in lung cancer patients treated with VATS, and help promote their rapid postoperative recovery with significant clinical benefits.

Keywords: sugammadex; VATS; lung cancer; pulmonary complications

Introduction

Lung cancer is the leading cause of cancer-related mortality worldwide, with surgical intervention being the optimal treatment modality for early-stage disease [1]. Video-assisted thoracic surgery (VATS) has gained widespread clinical practice due to its advantages over traditional open thoracotomy, including rapid postoperative recovery and reduced incidence of postoperative pain and associated complications [2, 3]. Consequently, VATS has become a standard procedure for the treatment of lung cancer [4]. However, the technical demands of VATS necessitate precise manipulation within a limited surgical field. To facilitate optimal visualization and adequate operating space for the surgeon, general anesthesia with muscle relaxation is requisite [5, 6]. Neuromuscular blocking agents (NMBAs) are used to facilitate endotracheal intubation, reduce intra-abdominal pressure, and optimize surgical conditions [7]. However, several studies have shown that residual neuromuscular blockade following anesthesia is a significant risk factor for postoperative pulmonary complications, potentially necessitating reintubation in some cases [8, 9]. Appropriate reversal of neuromuscular blockade may reduce the risk of postoperative pulmonary complications [7]. Cholinesterase inhibitors, represented by neostigmine, are currently employed as reversal agents for muscle relaxants. These compounds increase acetylcholine concentrations at the neuromuscular junction, thereby competing with nondepolarizing muscle relaxants for receptor binding sites to an-

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tagonize muscle relaxation [10]. However, the administration of cholinesterase inhibitors can lead to acute respiratory adverse events, including hypoxemia and dyspnea, as well as postoperative pulmonary complications such as pneumonia, atelectasis, and prolonged air leak. Furthermore, these agents may lead to delayed tracheal extubation and residual muscle weakness [11, 12, 13, 14].

Sugammadex, the first selective relaxant binding agent to receive clinical approval in the United States in 2008, is a synthetically modified γ-cyclodextrin derivative. Its structure comprises a hydrophilic core and a lipophilic exterior, allowing for the encapsulation of neuromuscular blocking agents through hydrophobic interactions. This encapsulation results in the formation of a stable, water-soluble compound [15, 16]. Sugammadex exhibits a high affinity for free plasma steroidal neuromuscular blocking agents, forming a tightly bound 1:1 complex. This interaction leads to a rapid reduction in the concentration of the neuromuscular blocker at the neuromuscular junction, leading to a restoration of muscle relaxation [17]. The efficacy of sugammadex for neuromuscular blockade reversal is superior to that of traditional acetylcholinesterase inhibitors, with a more favorable side effect profile [17, 18, 19]. Therefore, the use of sugammadex for antagonism of neuromuscular blockade is hypothesized to reduce the incidence of postoperative pulmonary complications and enhance recovery in patients undergoing VATS for lung cancer. However, despite the established efficacy of sugammadex in neuromuscular blockade reversal, its effects in Chinese patients with lung cancer undergoing VATS have not been previously investigated. We hypothesized that the administration of sugammadex could alleviate postoperative pulmonary complications and promote rapid recovery in patients with lung cancer who underwent VATS. To investigate this hypothesis, we designed and implemented a retrospective cohort study to evaluate the efficacy of sugammadex in these patients.

Materials and Methods

Study Design and Study Population

In this retrospective cohort study, we analyzed 1131 lung cancer patients who underwent VATS from January 2020 to December 2022 at Jiangsu Cancer Hospital in China. The inclusion criteria were: (1) age $\geq$18 years; (2) no gender restrictions; (3) general anesthesia with tracheal or bronchial intubation; and (4) lung cancer diagnosis confirmed by postoperative pathological biopsy. Exclusion criteria encompassed: (1) severe adverse reactions to sugammadex or other anesthetics; (2) pregnancy and breastfeeding; (3) contraindications to neuromuscular blockade; (4) previous thoracic surgery; (5) significant preoperative hepatic, renal, cardiac, or pulmonary dysfunction; (6) multiple surgeries within 30 days; (7) simultaneous use of multiple antagonist drugs or reintroduction of inotropic drugs following sulforaphane administration; and (8) incomplete key medical records. Of the 1131 patients, 631 received sugammadex at the end of anesthesia, while 500 did not. The two groups were matched 1:1 using propensity score matching (PSM). After matching, each group comprised 435 patients. Patients who received sugammadex for the neuromuscular blockade at the end of anesthesia were designated as Group S (n = 435), while those who did not receive sugammadex at the end of anaesthesia were classified as Group P (n = 435).

The study was approved by the Medical Ethics Committee of Jiangsu Cancer Hospital (2021-003) 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).

Treatment

Following patient admission to the operating theatre and completion of preoperative preparations, the anesthesiologist determined the necessity of sugammadex administration. The dosage of sugammadex administered was 2 mg/kg, with a maximum daily dosage not exceeding 200 mg. Extubation was performed upon the patient's full return to consciousness. In the event of postoperative nausea and vomiting, metoclopramide was administered intravenously at a dose of 10 mg, with a maximum daily dose not exceeding 30 mg. Analgesic management was conducted in accordance with standard protocols, tailored to the patient's reported pain intensity.

Data Collection

The following data were collected from the patient's electronic medical record:

(1) Baseline characteristics: sex, age, body mass index (BMI), comorbidities, American Society of Anesthesiologists (ASA) classification, anesthesia type, and intraoperative conditions.

(2) Primary outcome measures: the occurrence of postoperative pulmonary complications. Postoperative pulmonary complications encompass a range of respiratory disorders, including, but not limited to: respiratory infections, respiratory failure, bronchospasm, pulmonary atelectasis, pleural effusion, pneumothorax, aspiration pneumonia, acute respiratory distress syndrome, pulmonary embolism, and other related conditions [18].

(3) Secondary outcome measures. Postoperative recovery indicators [20, 21]: time interval from inotropic discontinuation to extubation, duration from end of surgery to extubation, total operating room occupancy time, pre-extubation oxygen saturation, minimum post-extubation oxygen saturation, oxygen saturation at operating room discharge, utilization of additional pharmacological antagonists, total length of hospital stay (days), postoperative length of hospital stay (days), hospital costs, time to oral fluid intake, time to oral solid intake, time to defecate, duration of chest tube placement, and postoperative drainage volume. Postopera-

tive symptom and complication assessment: 24-hour postoperative nausea and vomiting, 24-hour resting pain score using visual analogue scale (VAS), 24-hour dynamic pain score using VAS, 48-hour postoperative nausea and vomiting score, 48-hour resting pain score using VAS score, 48-hour dynamic pain score using VAS, modified Clinical Pulmonary Infection Score (mCPIS).

(4) Perioperative complications: the incidence of complications during awakening from anesthesia and throughout the perioperative period was monitored and recorded.

(5) Biochemical parameters: biochemical analyses were conducted on postoperative day 3. The following parameters were evaluated: hepatic function [alanine aminotransferase (ALT), γ-glutamyl transpeptidase (GGT), alkaline phosphatase (ALP), total bilirubin (TBIL), direct bilirubin (DBIL)], renal function (urea, creatinine), hematological parameters [hemoglobin (HB), red blood cells (RBC), white blood cells (WBC)].

Statistical Analysis

Data management and statistical analyses were performed using SAS software version 9.4 (SAS Institute, Inc., Cary, NC, USA). Qualitative information was described using n (%), and comparisons between groups were conducted using chi-square test or Fisher's exact probability method. For normally distributed continuous variables, data were presented as mean $\pm$ standard deviation (SD) and analyzed using Student's *t*-test. For quantitative data that did not obey normal distribution, M (P25, P75) was used to describe the data, and the rank sum test was used for comparison between groups. The PSM method was used to achieve a 1:1 ratio between the study and control groups. Matching criteria included participants' demographic characteristics and comorbidities. A caliper width of 0.10 was implemented to ensure optimal matching precision. This process resulted in the pairing of 435 cases in each group. Unless otherwise specified, the significant level (α) was established at 0.05. Statistical significance was determined by $p < 0.05$.

Results

Baseline Information

A retrospective cohort study was conducted, encompassing 1131 patients who underwent thoracoscopic radical lung cancer surgery between January 2020 and December 2022, the study flowchart is shown in Fig. 1. Of these, 631 patients received sugammadex treatment, while 500 patients did not receive the antagonist. Baseline data included patient demographics, comorbidities, anesthesia details, and intraoperative conditions. Propensity score matching was employed to mitigate potential confounding factors, resulting in a final cohort of 870 patients equally distributed between the sugammadex group and the control group. The matching process effectively balanced covariates between the two groups. As shown in Table 1, no statistically significant differences in baseline characteristics were observed between the two groups after matching ($p > 0.05$).

Primary Observation Indicators

The data in Table 2 indicated that the incidence of postoperative pulmonary complications was significantly lower in Group S compared to Group P ($\chi^2 = 9.52$, $p = 0.002$). Specifically, the incidence of pulmonary atelectasis ($\chi^2 = 4.27$, $p = 0.039$) and pleural effusion ($\chi^2 = 5.78$, $p = 0.016$) was reduced in Group S relative to Group P. No significant differences were observed between the two groups concerning the incidence of pneumonia and pneumothorax. Additionally, there was one case of reintubation due to expiratory failure in Group P. However, there was no statistical difference between the two groups ($p > 0.05$).

Secondary Observation Indicators

Surgery-Related Indicators

As shown in Table 3, Group S exhibited significantly shorter durations compared to Group P in several key measures: the time from cessation of muscle relaxation to extubation ($Z = 12.96$, $p < 0.001$), the time from the end of surgery to extubation ($Z = 13.66$, $p < 0.001$), the total time occupying the operating theatre ($Z = 5.81$, $p < 0.001$), the time to drink ($Z = 3.80$, $p < 0.001$), the time to eat ($Z = 3.80$, $p < 0.001$), the time to defecate ($Z = 3.25$, $p = 0.001$), and the time to remove the chest tube ($Z = 5.04$, $p < 0.001$). No significant differences were observed between the two groups for the remaining indices ($p > 0.05$).

Nausea and Vomiting, Pain and Lung Infection Score

As shown in Table 4, the 24-hour exercise VAS score ($Z = 4.71$, $p < 0.001$), the 48-hour exercise VAS score ($Z = 5.05$, $p < 0.001$), and the mCPIS score ($Z = 4.68$, $p < 0.001$) were significantly lower in Group S compared to Group P. No significant differences were observed in the remaining scores between the two groups ($p > 0.05$).

Complications

As shown in Table 5, the complication rate during general anaesthetic awakening was significantly lower in Group S compared to Group P ($\chi^2 = 23.54$, $p < 0.001$). Additionally, the incidence of delayed awakening was reduced in Group S relative to Group P ($\chi^2 = 33.95$, $p < 0.001$). No significant differences were observed in the rates of other perioperative complications between the two groups ($p > 0.05$).

Biochemical Indexes

The data in Table 6 indicated that the incidence of renal function abnormalities was significantly lower in Group S compared to Group P ($\chi^2 = 12.65$, $p < 0.001$). No statistically significant differences were observed between the two groups for the remaining indicators ($p > 0.05$).

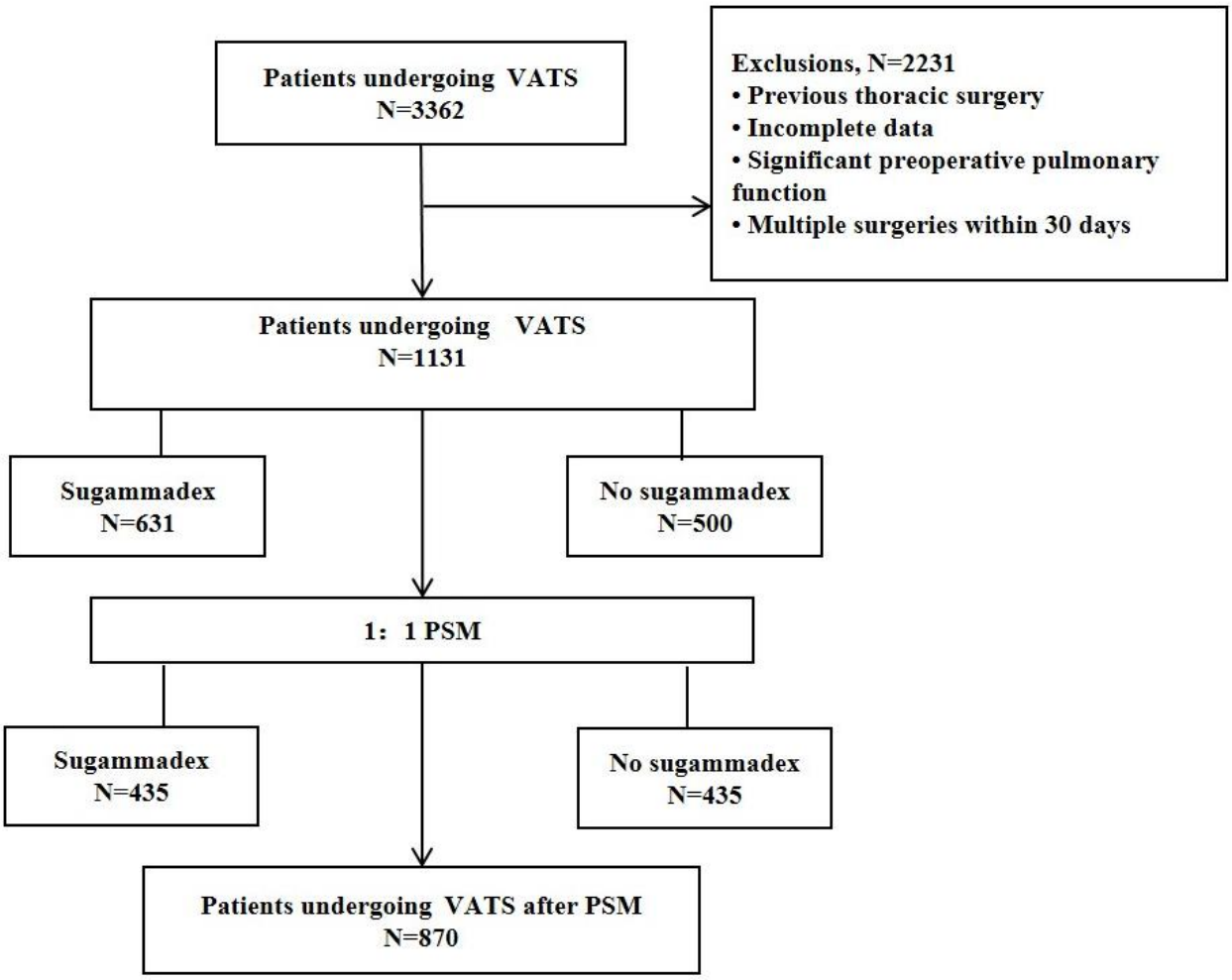

Fig. 1. The study flowchart. VATS, video-assisted thoracic surgery; PSM, propensity score matching.

Discussion

The results of this study indicated that the application of sodium sulforaphane in VATS for lung cancer patients could significantly reduce postoperative pulmonary complications compared to the use of sugammadex alone. This approach could also shorten the duration from cessation of musculoskeletal relaxation to extubation. Additionally, it could facilitate earlier resumption of oral intake and defecation in the postoperative period. Furthermore, it could decrease complications during the awakening period from general anesthesia, reduce pain during movement, and lower the incidence of pulmonary infections, thereby promoting rapid postoperative recovery.

Pulmonary complications were the primary focus of this study. Previous research has yielded conflicting results regarding the efficacy of sugammadex in reducing postoperative pulmonary complications following abdominal surgery. A retrospective analysis by Li G *et al*. [19] showed that the administration of sugammadex during general anesthesia for abdominal surgery did not lead to a reduction in postoperative pulmonary complications in patients undergoing abdominal surgery. The same conclusion was reached in a study by Kirmeier E *et al*. [22]. However, some studies have suggested that sugammadex may contribute to a reduction in postoperative pulmonary complications in patients undergoing general anesthesia for abdominal surgery [23, 24]. The findings of this study showed that the incidence of pulmonary complications was lower in Group S compared to Group P, mainly due to a reduced occurrence of pulmonary atelectasis and pleural effusion. It was confirmed that sugammadex effectively reduced postoperative pulmonary complications in lung cancer patients undergoing VATS. Pulmonary atelectasis is the most common respiratory complication after thoracic surgery and is a significant cause of early postoperative hypoxemia and respiratory distress [25, 26]. The administration of glucose and sodium can promote the recovery of deep neuromuscular block, improve the electromyographic activity of the diaphragm and intercostal muscles, increase tidal volume, and improve the ability to clear secretions. Concurrently, it can reduce the residual muscle relaxation, encourage the patients to awaken quickly and initiate spon-

Table 1. Comparison of patients' general conditions before and after matching.

Variable	Pre-match				Post-match			
	No sugammadex (n = 500)	Sugammadex (n = 631)	χ^2/Z	p	No sugammadex (Group P) (n = 435)	Sugammadex (Group S) (n = 435)	χ^2/Z	p
Age (years)	58.0 (50.0, 66.0)	60.0 (52.0, 67.0)	–3.35	<0.001#	59.0 (51.0, 66.0)	58.0 (51.0, 66.0)	0.04	0.968
BMI (kg/m^2)	23.8 (21.7, 25.7)	23.7 (21.6, 25.9)	0.07	0.942	23.8 (21.7, 25.7)	23.6 (21.4, 25.7)	0.75	0.453
Gender (n)								
Male	201 (40.20)	291 (46.12)	3.97	0.046	183 (42.07)	187 (42.99)	0.08	0.784
Women	299 (59.80)	340 (53.88)			252 (57.93)	248 (57.01)		
ASA (n)								
II	374 (74.80)	436 (69.10)	4.46	0.035	323 (74.25)	321 (73.79)	0.02	0.877
III	126 (25.20)	195 (30.90)			112 (25.75)	114 (26.21)		
Nutrient solution use (n)	78 (15.60)	112 (17.75)	0.92	0.337	71 (16.32)	71 (16.32)	0.00	1.000
Underlying disease diabetes (n)	24 (4.80)	57 (9.03)	7.52	0.006	24 (5.52)	25 (5.75)	0.02	0.883
Hypertension (n)	112 (22.40)	161 (25.52)	1.48	0.224	100 (22.99)	98 (22.53)	0.03	0.872
Heart disease (n)	19 (3.80)	32 (5.07)	1.05	0.306	17 (3.91)	17 (3.91)	0.00	1.000
Asthma (n)	6 (1.20)	5 (0.79)	-	0.551*	5 (1.15)	5 (1.15)	0.00	1.000
Post-radiotherapy (n)	4 (0.80)	12 (1.90)	2.43	0.119	4 (0.92)	4 (0.92)	-	1.000*
Post-chemotherapy (n)	21 (4.20)	30 (4.75)	0.20	0.655	21 (4.83)	22 (5.06)	0.02	0.876
COPD (n)	7 (1.40)	10 (1.58)	0.06	0.800	7 (1.61)	5 (1.15)	0.34	0.561
History of cerebral infarction (n)	9 (1.80)	9 (1.43)	0.25	0.618	8 (1.84)	7 (1.61)	0.07	0.795
Anaemia (n)	1 (0.20)	3 (0.48)	-	0.634*	1 (0.23)	1 (0.23)	-	1.000*
Hepatitis B (n)	3 (0.60)	2 (0.32)	-	0.660*	3 (0.69)	2 (0.46)	-	1.000*
Intraoperative infusion volume (mL)	1500 (1000, 2000)	1500 (1000, 1500)	1.40	0.160	1500 (1000, 1500)	1500 (1000, 1500)	–0.19	0.850
Bleeding volume (mL)	50 (20, 50)	50 (30, 50)	–0.94	0.346	50 (20, 50)	50 (20, 50)	0.84	0.403
Urine volume (mL)	200 (150, 300)	200 (150, 300)	–2.73	0.006#	200 (150, 300)	200 (150, 300)	–0.72	0.474
Total muscle relaxation (mg)	105.7 (86.7, 130.5)	118.0 (94.6, 140.0)	–5.51	<0.001#	108.7 (90.0, 132.7)	113.0 (92.5, 133.4)	–1.08	0.280
Length of surgery (min)	89 (59, 129)	107 (74, 145)	–5.16	<0.001#	95 (62, 133)	100 (70, 135)	–1.21	0.227
Admission oxygen saturation (%)	99.0 (98.0, 100.0)	99.0 (98.0, 100.0)	–0.02	0.983	99.0 (98.0, 100.0)	99.0 (98.0, 100.0)	0.17	0.864
OLV duration (min)	80 (50, 115)	90 (60, 129)	–3.77	<0.001#	83 (54, 120)	86 (59, 121)	–0.74	0.462
Surgical site (cases)								
Left	201 (40.20)	268 (42.47)	0.59	0.441	181 (41.61)	183 (42.07)	0.02	0.891
Right	299 (59.80)	363 (57.53)			254 (58.39)	252 (57.93)		
Type of surgery (n)								
Wedge excision	193 (38.60)	180 (28.53)	14.17	<0.001	145 (33.33)	145 (33.33)	0.14	0.935
Segmental lung resection	87 (17.40)	146 (23.14)			85 (19.54)	81 (18.62)		
Lobectomy (medicine)	220 (44.00)	305 (48.34)			205 (47.13)	209 (48.05)		
Type of catheter (n)								
Double lumen	130 (26.00)	161 (25.52)	0.03	0.853	114 (26.21)	109 (25.06)	0.15	0.698
Blocker	370 (74.00)	470 (74.48)			321 (73.79)	326 (74.94)		

Note: "*" uses Fisher's exact probability method; "#" uses the rank sum test. Abbreviations: BMI, body mass index; ASA, American Society of Anesthesiologists; OLV, One-lung Ventilation; COPD, chronic obstructive pulmonary disease.

taneous breathing, promote coughing and sputum expectoration, and promote the recovery of lung function, which can help reduce the occurrence of postoperative pulmonary atelectasis in the early postoperative period [24, 27]. Additionally, the rapid recovery of respiratory muscle strength can also help reduce the occurrence of pleural effusion. The incidence of complications during the awakening period was lower in Group S compared to Group P. This difference is primarily attributed to the reduced incidence of delayed awakening in Group S. The incidence of residual block caused by sugammadex was reported to be 0% to 3% [13]. Sugammadex facilitates more complete clearance of residual block, thereby promoting rapid awakening of patients after anesthesia. No significant differences were observed between the two groups concerning other complications, such as postoperative bleeding, suggesting that sugammadex does not offer the advantage of reducing other complications, such as postoperative bleeding, after VATS.

Table 2. Postoperative pulmonary complications in both groups [n (%)].

Variable	Group P (n = 435)	Group S (n = 435)	χ^2	*p*
Pulmonary complications (n)	168 (38.62)	125 (28.74)	9.52	0.002
Pulmonary atelectasis (n)	78 (17.93)	56 (12.87)	4.27	0.039
Pneumothorax (n)	1 (0.23)	3 (0.69)	-	0.624*
Pleural effusion (n)	90 (20.69)	63 (14.48)	5.78	0.016
Pneumonia (n)	41 (9.43)	35 (8.05)	0.52	0.471
Reintubation for expiratory failure (n)	1 (0.23)	0 (0.00)	-	1.000*

Note: "*" uses Fisher's exact probability method.

Table 3. Surgery-related indicators in both groups.

Variable	Group P (n = 435)	Group S (n = 435)	*Z*	*p*
Stop muscle relaxation to extubation (min)	58.0 (42.0, 80.0)	36.0 (26.0, 50.0)	12.96	<0.001
From end of surgery to extubation (min)	43.0 (27.0, 64.0)	20.0 (11.0, 35.0)	13.66	<0.001
Total operating theatre occupancy (min)	214.0 (173.0, 266.0)	191.0 (155.0, 231.0)	5.81	<0.001
Pre-intubation oxygen saturation (%)	100.0 (100.0, 100.0)	100.0 (100.0, 100.0)	0.27	0.789
Minimum post-extubation oxygen saturation (%)	100.0 (98.0, 100.0)	100.0 (97.0, 100.0)	0.67	0.500
Pre-exit oxygen saturation (%)	100.0 (99.0, 100.0)	100.0 (99.0, 100.0)	1.37	0.169
Total hospital days (d)	11.0 (8.0, 13.0)	10.0 (8.0, 13.0)	1.21	0.226
Post-operative hospitalization days (d)	6.0 (4.0, 7.0)	5.0 (4.0, 7.0)	0.46	0.642
Total cost of hospitalization ($)	61,252 (50,986, 74,600)	63,049 (52,582, 75,189)	–1.29	0.198
Drinking time (h)	14.0 (12.0, 17.0)	13.0 (12.0, 16.0)	3.80	<0.001
Feeding time (h)	14.0 (12.0, 17.0)	13.0 (12.0, 16.0)	3.80	<0.001
Defecation time (h)	90.0 (52.0, 97.0)	70.0 (48.0, 94.0)	3.25	0.001
Time to chest tube removal (h)	111.0 (68.0, 138.0)	88.0 (65.0, 114.0)	5.04	<0.001
Postoperative drainage (mL)	545.0 (320.0, 960.0)	582.0 (340.0, 910.0)	–0.29	0.775

Table 4. Nausea and vomiting, pain and lung infection scores in both groups.

Variable	Group P (n = 435)	Group S (n = 435)	*Z*	*p*
Nausea and vomiting score (24 h) (scores)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	–0.48	0.633
Resting VAS score (24 h) (scores)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	1.07	0.285
Exercise VAS score (24 h) (scores)	2.00 (2.00, 3.00)	2.00 (2.00, 3.00)	4.71	<0.001
Nausea and vomiting score (48 h) (scores)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	–1.08	0.282
Resting VAS score (48 h) (scores)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	1.06	0.288
Exercise VAS score (48 h) (scores)	2.00 (2.00, 3.00)	2.00 (2.00, 3.00)	5.05	<0.001
mCPIS (scores)	2.00 (1.00, 3.00)	1.00 (1.00, 2.00)	4.68	<0.001

Note: Abbreviations: VAS, visual analogue scale; mCPIS, modified Clinical Pulmonary Infection Score.

To investigate the effect of sugammadex on postoperative recovery in lung cancer patients undergoing VATS, various perioperative indicators were evaluated in both groups. The results showed that patients in Group S exhibited significantly shorter durations for several key parameters. These parameters included: time from neuromuscular blockade reversal to extubation, time from completion of surgery to extubation, total operating theatre occupancy time, time to oral fluid intake, time to solid food intake, time to defecate, and time to chest tube removal. These findings suggest that sugammadex may facilitate rapid recovery in lung cancer patients following VATS and improve the turnover rate of the operating theatre. The patients in Group S demonstrated accelerated recovery following VATS, due to the excellent de-blocking residuals, the excellent defecation time, and the good performance of sugammadex. The rapid recovery of Group S patients after VATS can be attributed to the excellent deblocking residue of sugammadex, facilitating rapid recovery of skeletal muscle function and pulmonary ventilation [28, 29, 30]. At the same time, sugammadex effectively reduces complications, which also helps promote the speedy removal of chest tubes, feeding, and defecation.

Table 5. Complications in both groups [n (%)].

Variable	Group P (n = 435)	Group S (n = 435)	χ^2	p
Complications during awakening from general anesthesia (n)	77 (17.70)	30 (6.90)	23.54	<0.001
Delay in awakening (n)	45 (10.34)	5 (1.15)	33.95	<0.001
Nausea and vomiting (n)	12 (2.76)	12 (2.76)	0.00	1.000
Hypoxaemia (n)	24 (5.52)	13 (2.99)	3.42	0.065
Other perioperative complications (n)	6 (1.38)	2 (0.46)	-	0.287*
Post-operative hemorrhage (n)	3 (0.69)	1 (0.23)	-	0.624*
Secondary surgery (n)	3 (0.69)	1 (0.23)	-	0.624*
Postoperative blood transfusion (n)	3 (0.69)	1 (0.23)	-	0.624*
Coeliac disease (n)	1 (0.23)	1 (0.23)	-	1.000*
Postoperative atrial fibrillation (n)	1 (0.23)	0 (0.00)	-	1.000*
Heart failure (n)	1 (0.23)	0 (0.00)	-	1.000*

Note: "*" uses Fisher's exact probability method.

Table 6. Laboratory indices of patients in both groups [n (%)].

Variable	Group P	Group S	χ^2	p
Liver enzyme abnormalities (n)	38 (15.64)	54 (16.36)	0.05	0.815
Bilirubinaemia (n)	19 (7.82)	22 (6.67)	0.28	0.597
Abnormal renal function (n)	108 (44.44)	99 (30.00)	12.65	<0.001
Anaemia (n)	70 (27.24)	97 (25.06)	0.38	0.538
WBC anomalies (n)	147 (49.66)	179 (45.32)	1.28	0.257

Note: There are some data missing in this part of indicators, "n" is actually less than 435. Because it is not a key outcome indicator, this part of observation indicators is not deleted. Abbreviation: WBC, white blood cells.

These outcomes are in line with Enhanced Recovery After Surgery (ERAS) protocols and promote fast recovery in patients undergoing VATS.

In addition, this study showed that postoperative exercise VAS scores were lower in patients who received sugammadex, suggesting that the addition of sugammadex was more likely to reduce postoperative pain in lung cancer patients treated with VATS. It is hypothesized that the reason for this may be that rapid postoperative extubation reduces the discomfort or pain level in the patient's throat [31].

However, there were some cases of missing postoperative biochemical test results among the included patients in this study. Given that biochemical indexes were not the main outcome measures in this study, patients with missing biochemical data were not excluded. Consequently, the potential of sugammadex to mitigate the incidence of postoperative renal impairment in lung cancer patients undergoing VATS needs to be further explored in subsequent studies.

Limitations

The limitations of this study are those associated with retrospective cohort studies and information bias due to uneven data collection. The significant reduction in pulmonary complications associated with sugammadex may be due to temporal factors. Although the 2-year study period did not include any other significant changes in clinical protocols for pulmonary care, natural improvements in clinical practice may be partly responsible for the reduction in complications. Additionally, the absence of stringent standardization in intraoperative ventilation parameters and anesthetic drug doses in both groups introduces a potential source of bias.

Conclusions

Sugammadex may reduce postoperative pulmonary complications in patients with lung cancer undergoing VATS, thereby facilitating rapid postoperative recovery and conferring significant overall benefits. However, more clinical trials are needed to verify whether sugammadex can be widely used and implemented in clinical practice.

Availability of Data and Materials

The data used and analyzed during the current study were available from the corresponding author on reasonable request.

Author Contributions

THS and LBG designed the research study. THS, LXX, YYD and LQ performed the research. THS, XLG and RG analyzed the data. THS wrote the original draft. All authors revised the manuscript critically for important intellectual content. All authors read and approved the final

manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The study was approved by the Medical Ethics Committee of Jiangsu Cancer Hospital (2021-003) and due to its retrospective nature, informed consent was waived by the Medical 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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Conflict of Interest

The authors declare no conflict of interest.

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