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Original Article

Ultra-early initiation of postoperative rehabilitation in the post-anaesthesia care unit after major thoracic surgery: case–control study

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Abstract

Background: Physiotherapy is a major cornerstone of enhanced rehabilitation after surgery (ERAS) and reduces the development of atelectasis after thoracic surgery. By initiating physiotherapy in the post-anaesthesia care unit (PACU), the aim was to evaluate whether the ultra-early initiation of rehabilitation (in the first hour following tracheal extubation) would improve the outcomes of patients undergoing elective thoracic surgery.

Methods: A case–control study with a before-and-after design was conducted. From a historical control group, patients were paired at a 3:1 ratio with an intervention group. This group consisted of patients treated with the ultra-early rehabilitation programme after elective thoracic surgery (clear fluids, physiotherapy, and ambulation). The primary outcome was the incidence of postoperative atelectasis and/or pneumonia during the hospital stay.

Results: After pairing, 675 patients were allocated to the historical control group and 225 patients to the intervention group. A significant decrease in the incidence of postoperative atelectasis and/or pneumonia was found in the latter (11.4 *versus* 6.7 per cent respectively; $P = 0.042$) and remained significant on multivariate analysis (OR 0.53, 95 per cent c.i. 0.26 to 0.98; $P = 0.045$). A subgroup analysis of the intervention group showed that early ambulation during the PACU stay was associated with a further significant decrease in the incidence of postoperative atelectasis and/or pneumonia (2.2 *versus* 9.5 per cent; $P = 0.012$).

Conclusions: Ultra-early rehabilitation in the PACU was associated with a decrease in the incidence of postoperative atelectasis and/or pneumonia after major elective thoracic surgery.

Introduction

Initially developed for patients undergoing colorectal surgery, enhanced recovery after surgery (ERAS) programmes are now commonplace in all areas of surgery[1,2]. Thoracic surgery is associated with a high incidence of postoperative complications, including atelectasis and pneumonia[3,4]. For this group of patients, ERAS care bundles have been found to decrease the incidence of postoperative complications[5,6].

Recent data showed an association between postoperative atelectasis and pleural effusion diagnosed in the post-anaesthesia care unit (PACU) and the subsequent development of postoperative pulmonary complications, suggesting that postoperative complications could start very early in the patient journey[7]. The ERAS programme, routinely implemented in the study centre since 2010, included postoperative rehabilitation initiated mostly the day after surgery. The aim of this study was to assess the impact of initiating rehabilitation during the PACU stay and to assess whether this ultra-early initiation of postoperative rehabilitation was feasible, safe, and beneficial for patients undergoing elective thoracic surgery.

Methods

Study design

A single-centred case–control study with a before-and-after design was performed in the departments of thoracic surgery,

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anaesthesiology, and intensive care of the Hospital Nord, a 650-bed hospital of Assistance Publique—Hôpitaux Universitaires de Marseille, Marseille, France. This study was performed according to STROBE guidelines[8].

Population

All patients admitted to the hospital for elective lung resection were eligible. The historical control group consisted of consecutive patients who underwent elective lung resection between 1 July 2015 and 27 May 2018. Patients undergoing pneumonectomy or non-elective lung resection were not included.

Ultra-early initiation of postoperative rehabilitation was started on 28 May 2018. The intervention group consisted of all consecutive patients included in the ultra-early rehabilitation programme after elective lung resection during the intervention interval, between 28 May 2018 and 23 September 2019. The length of the total study interval (1 July 2015 to 23 September 2019) was chosen to allow sufficient pairing with the historical control group at a ratio of 3:1.

Patients who underwent surgery during the intervention interval but were not treated with ultra-early rehabilitation were allocated to the contemporary control group. Those patients were not treated due to a shortage of either medical or nursing staff (especially in the evening when the night medical and nursing teams come on duty). Within the intervention group, the patients who were able to ambulate in the PACU or walked back to the surgical ward were identified for subgroup analysis.

Study protocol

Figure 1 shows the timeline differences between the control group and the intervention group. All patients included in the study (historical and contemporary control groups and intervention group) were treated with a standardized ERAS protocol. This protocol has not been modified since 2010 and is described in *Table S1*.

During their PACU stay and in the first hour following tracheal extubation, patients in the intervention group had the following elements in addition to standard care:

Patients were placed in a semi-recumbent position
The intravenous line was locked. If needed, analgesia was administered via the oral route
Clear fluids (water or apple juice) were offered
Respiratory rehabilitation derived from the I-COUGH program[9]:

- Incentive spirometry with the Spiro-Ball® system
- Education on efficient ways to cough and perform painless deep breathing exercises

When feasible, full ambulation in the PACU. Ambulation included a medically supervised walk around the PACU (80 m) and/or walking back to the surgical ward (150 m). This walk was supervised by a trainee or resident anaesthetist Completion of one or both tasks constituted allocation to the ambulatory subgroup.

All ultra-early rehabilitation activity occurred under the supervision of a resident anaesthetist and the patient's allocated nurse in the PACU.

Study outcomes

The primary outcome was the incidence of postoperative atelectasis and/or pneumonia (occurrence of either event was considered positive) during the hospital stay. Atelectasis and pneumonia were diagnosed on radiological and clinical criteria.

Atelectasis was diagnosed when a finding of lung collapse was made on chest X-ray, chest CT and/or lung ultrasound[10,11].

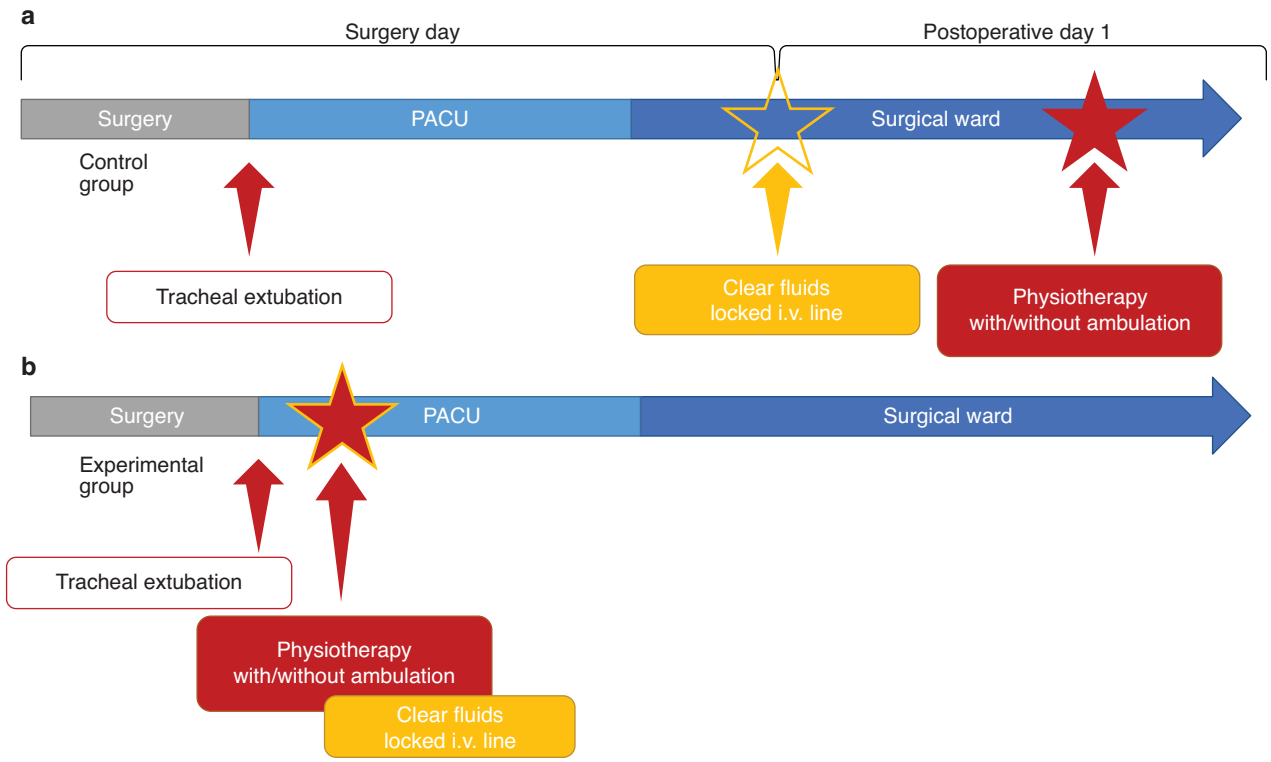

Fig. 1 Timelines of control (a) and intervention (b) group i.v., intravenous; PACU, post-anaesthesia care unit.

Pneumonia was diagnosed when the following criteria were met: radiological signs (two successive chest X-rays showing new or progressive lung infiltrates), at least one of the following signs (temperature more than 38.3°C without any other cause, leukocytes more than 4000 mm^3 or more than 12 000 mm^3) and at least two of the following signs (purulent sputum, cough, or dyspnoea, declining oxygenation or increased oxygen requirement, or need for respiratory assistance)[12].

The secondary outcomes were the duration of hospital stay, the comprehensive complication index (CCI) score of the index stay[13], the day-28 readmission, and mortality rate, ICU admission after surgery during the index stay, the day-28 postoperative pulmonary complications as defined by the European Society of Anaesthesiology[14], the incidence of postoperative mechanical ventilation, pneumothorax, pleural effusion, pulmonary embolism, and/or venous thromboembolism (VTE), the need for extended chest tube drainage (longer than 5 days), or the need for insertion of a new chest drain.

Data collection

Data were collected from the EPITHOR database. This database is an electronic French national registry of patients undergoing thoracic surgery and records the following for each patient: demographic features; WHO physical score (PS); ASA score; the presence of co-morbidities such as hypertension, cardiac failure, coronary disease, chronic obstructive pulmonary disease (COPD), tobacco use, oxygen therapy, and malnutrition; the modified Medical Research Council (mMRC) dyspnoea score; the type of surgery and anaesthesia performed; the length of surgery; early and late postoperative complications with Clavien–Dindo classification and CCI score. This database is completed in a prospective manner by the thoracic surgical team in real-time. The co-morbidities listed in the EPITHOR database were used to calculate the Charlson score.

To improve data quality and limit collection bias, access to the coding information of the patients included in this study via the hospital administrative system was also obtained. Screening for diagnoses such as ICU admission, onset of mechanical ventilation, hospital readmission, and hospital mortality was performed using the coding information. Screening for onset of atelectasis, pneumonia, cardiac arrhythmia, pneumothorax, new, or extended chest drainage, pulmonary embolism, or VTE was performed using the two databases. Occurrence of an event in either database was considered positive. Data were also collected regarding any incident occurring during the ultra-early rehabilitation process in the PACU stay. EPITHOR is registered on the CNIL (Commission Nationale de l'Informatique et des Libertés) under registration number 809833. This study was approved by the Ethics Committee of the French Society of Anaesthesia and Intensive Care (CERAR—IRB 00010254-2019-190). The patients were informed about the collection of their data, according to French Law and local ethical committee guidance[15].

Statistical analysis

The results are expressed as median (interquartile range (i.q.r.)), frequency (percentage) and OR with 95 per cent confidence interval (c.i.) as appropriate. Associations between variables were assessed using Student's *t* test or Mann–Whitney *U* test for continuous variables and chi-squared or Fisher's exact test for categorical variables.

To pair patients in the intervention group with patients from the historical control group, a greedy matching method was implemented. To optimize statistical power, a 3:1 ratio was chosen, and patients were matched according to the following variables: age (within 10 years); sex; anatomical or non-anatomical surgical resection; and open or minimally invasive surgery. The greedy matching method was chosen over the optimal matching method because of the 3:1 ratio.

Two multivariate conditional logistic regression models were created with the incidence of postoperative atelectasis and/or pneumonia as the dependent variable for one, and duration of hospital stay for the other. The independent variables chosen for these analyses were: WHO PS, Charlson score, tobacco use, type of regional analgesia, and mMRC dyspnoea score.

A supplementary unpaired analysis was performed on all consecutive patients who underwent surgery during the intervention interval but were not treated with ultra-early rehabilitation (shortage of either medical or nursing staff, mainly due to the difference of staffing between day and night teams). Within the intervention group, a subgroup analysis was performed on the patients treated with ultra-early rehabilitation stratified by their ability to fully ambulate in the PACU.

Statistical analysis was performed using SAS (version 9.4, SAS Institute, North Carolina, USA), STATA (version 10, StataCorp, Texas, USA) and XLSTAT (version 2021.3.1, Addinsoft, Paris, France) software.

Results

A flowchart of patient allocation for the study in shown in *Fig. 2*. During the study interval, 1528 patients underwent elective lung resection, including 1004 patients during the control interval. Five patients had incomplete or missing files and were excluded, resulting in 999 patients being included in the historical control group. During the intervention interval, 524 consecutive patients underwent elective lung resection. Among them, 243 (46.4 per cent) patients were treated with the ultra-early postoperative rehabilitation bundle and were allocated to the intervention group. The remaining 281 (53.6 per cent) patients were allocated to the contemporary control group.

After pairing, 675 patients were included in the historical control group and 225 in the intervention group. From the unpaired intervention group, 138 (56.8 per cent) patients ambulated in the PACU and/or walked back to the surgical ward. These patients were allocated to the ambulatory subgroup.

Demographics and patient characteristics

The historical control group and the intervention group were broadly similar (*Table 1*). Tobacco use was higher in the intervention group than in the historical control group (68.0 *versus* 49.3 per cent; $P < 0.001$). The intervention group had significantly higher rates of mMRC dyspnoea score of 0 (60.4 *versus* 48.4 per cent; $P = 0.002$), whereas the historical control group had higher rates of mMRC dyspnoea score of 3 (0 *versus* 3.1 per cent; $P = 0.004$).

Primary outcome

After pairing, the rate of postoperative atelectasis and/or pneumonia was significantly lower in the intervention group than in the historical control group (6.7 *versus* 11.4 per cent; $P = 0.042$) (*Table 2*).

Secondary outcomes

The median duration of hospital stay was shorter in the intervention group than in the historical control group (5 (i.q.r. 4.0–7.0) days *versus* 6 (i.q.r. 4.0–9.0) days; $P = 0.003$). The

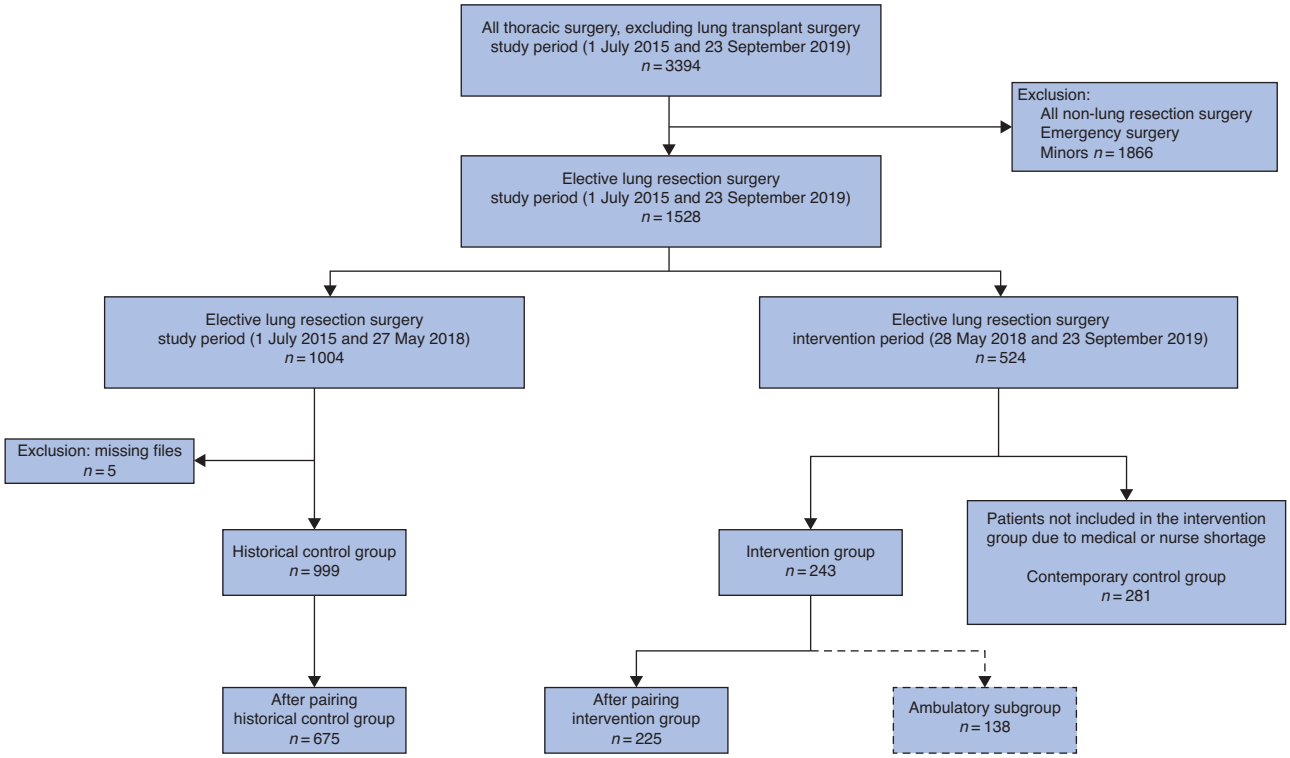

Fig. 2 Flow chart of patient allocation for the study

Table 1 Patients characteristics and demographics (paired analysis)

		Historical control group $n = 675$	Intervention group $n = 225$	P
Age, (years) median (i.q.r.)		64 (56.0–71.0)	64 (57–70.5)	0.870
BMI, (kg/m^2) median (i.q.r.)		25.2 (21.3–27.3)	24.8 (21.1–27.3)	0.240
WHO PS	WHO PS 0–1	454 (67.3)	158 (70.2)	0.420
	WHO PS > 1	221 (32.7)	67 (29.8)	0.420
ASA grade	ASA I–II	454 (67.3)	158 (70.2)	0.460
	ASA > II	221 (32.7)	67 (29.8)	0.460
Charlson score, median (i.q.r.)		5 (4.0–7.0)	6 (4.0–7.0)	0.120
Co-morbidities	Hypertension	209 (31.0)	71 (31.6)	0.870
	Heart failure	11 (1.6)	5 (2.2)	0.560
	Coronary disease	79 (11.7)	27 (12.0)	0.910
	COPD	107 (15.9)	38 (16.9)	0.690
	Oxygen therapy	7 (1.0)	1 (0.4)	0.750
	Malnutrition	5 (0.7)	1 (0.4)	1
	Tobacco use	333 (49.3)	153 (68.0)	**<0.001**
mMRC dyspnoea	Stage 0	327 (48.4)	136 (60.4)	**0.002**
	Stage 1	205 (30.4)	55 (24.4)	0.106
	Stage 2	117 (17.3)	34 (15.1)	0.472
	Stage 3	21 (3.1)	0 (0)	**0.004**
	Stage 4	3 (0.4)	0 (0)	0.577
	Stage 5	2 (0.2)	0 (0)	1
Lung disease	Primitive lesion	468 (69.3)	146 (64.9)	0.210
	Metastatic lesion	108 (16.0)	44 (29.6)	0.219
	Benign lesion	17 (2.5)	10 (4.4)	0.174
	Infectious/inflammatory	66 (9.8)	22 (9.8)	1
	Congenital	6 (0.9)	0 (0)	0.346
	Degenerative	10 (1.5)	3 (1.3)	1
Surgery length, (mins) median (i.q.r.)		127 (80.0–160.0)	123 (81.0–162.0)	0.420
Locoregional anaesthesia	Single shot paravertebral block	438 (64.9)	155 (68.9)	0.290
	Peridural analgesia	87 (12.9)	34 (15.1)	0.430
	Paravertebral catheter	146 (21.6)	35 (15.6)	0.055
	Not found	4 (0.6)	1 (0.4)	
Surgery type	Lobectomy	437 (64.8)	137 (60.9)	0.300
	Bi lobectomy	10 (1.5)	4 (1.8)	0.760
	Segmentectomy	78 (11.6)	34 (15.1)	0.160
	Unique partial resection	117 (17.3)	44 (19.6)	0.480
	Multiple partial resections	33 (4.9)	6 (2.7)	0.190
Approach	Invasive	126 (18.7)	42 (18.7)	1
	Minimally invasive	549 (81.3)	183 (81.3)	1

Bold values indicate $P < 0.005$. i.q.r., interquartile range; WHO PS, WHO physical score; mMRC: modified Medical Research Council. Values are *n* (%) unless stated otherwise.

Table 2 Comparison of outcomes between historical control and intervention groups (paired analysis)

	Historical control group ($n = 675$)	Intervention group ($n = 225$)	P
Postoperative atelectasis and/or pneumonia	77 (11.4)	15 (6.7)	**0.042**
Postoperative pulmonary complications at day 28	131 (19.4)	31 (13.7)	0.058
Duration of hospital stay, (days) median (i.q.r.)	6 (4.0–9.0)	5 (4.0–7.0)	**0.003**
Readmission rates at day 28	48 (7.1)	19 (8.4)	0.460
All-cause day-28 mortality	8 (1.2)	3 (1.3)	1
Comprehensive complication index, median (i.q.r.)	0 (0–8.7)	0 (0–8.7)	0.080
ICU admission during hospital stay	39 (5.8)	6 (2.7)	0.076
Mechanical ventilation	21 (3.1)	1 (0.4)	**0.039**
Pleural effusion	23 (3.4)	7 (3.1)	1
Need for extended chest drainage (> 5 days)	58 (8.6)	19 (8.4)	1
Need for new chest drainage	20 (3.0)	9 (4.0)	0.510
Pneumothorax	41 (6.1)	21 (9.3)	0.230
Pulmonary embolism or deep vein thrombosis	9 (1.3)	1 (0.4)	0.470

Bold values indicate $P < 0.005$. i.q.r., interquartile range. Values are *n* (%) unless stated otherwise.

Table 3 Comparison of outcomes between contemporary control and intervention groups (unpaired analysis)

	Contemporary control group ($n = 281$)	Intervention group ($n = 243$)	P
Postoperative atelectasis and/or pneumonia	46 (16.4)	16 (6.6)	**0.001**
Postoperative pulmonary complications at day 28	82 (29.2)	33 (13.6)	**<0.001**
Duration of hospital stay, (days) median (i.q.r.)	6 (4.0–10.0)	5 (4.0–7.0)	**0.002**
Readmission rates at day 28	21 (7.5)	20 (8.2)	0.748
All-cause day-28 mortality	6 (2.1)	3 (1.2)	0.429
Comprehensive complication index, median (i.q.r.)	0 (0-20.9)	0 (0–8.7)	**0.020**
Intensive care unit admission during hospital stay	21 (7.5)	8 (3.3)	**0.037**
Mechanical ventilation	13 (4.6)	2 (0.8)	**0.009**
Pleural effusion	14 (5.0)	7 (2.9)	0.221
Need for extended chest drainage (> 5 days)	45 (16.0)	20 (8.2)	**0.007**
Need for new chest drainage	18 (6.4)	10 (4.1)	0.245
Pneumothorax	37 (13.2)	22 (9.1)	0.137
Pulmonary embolism or deep vein thrombosis	5 (1.8)	1 (0.4)	0.142

Bold values indicate $P < 0.005$. i.q.r., interquartile range. Values are *n* (%) unless stated otherwise.

postoperative mechanical ventilation rate was lower in the intervention group compared with the historical control group (0.4 *versus* 3.1 per cent; $P = 0.039$). No differences were found among any of the other secondary outcomes (*Table 2*). For the 243 patients treated with ultra-early rehabilitation, two cases of orthostatic hypotension (resolved spontaneously) were recorded. No falls or serious incidents were noted.

Table 4 Comparison of outcomes between non-ambulatory and ambulatory subgroups

	Non-ambulatory intervention subgroup ($n = 105$)	Ambulatory subgroup ($n = 138$)	P
Postoperative atelectasis and/or pneumonia	10 (9.5)	3 (2.2)	**0.012**
Postoperative pulmonary complications at day 28	24 (22.9)	29 (21.0)	0.730
Duration of hospital stay, (days) median (i.q.r.)	6 (4.0–7.0)	5 (4.0–7.0)	**0.024**
Readmission rates at day 28	0 (0)	0 (0)	1
All-cause day-28 mortality	2 (1.9)	2 (1.5)	0.782
Comprehensive complication index, median (i.q.r.)	0 (0–20.9)	0 (0-0)	0.195
Intensive care unit admission during hospital stay	5 (4.8)	3 (2.2)	0.263
Mechanical ventilation	2 (1.9)	0 (0)	0.109
Pleural effusion	1(1.0)	6 (4.3)	0.117
Need for extended chest drainage (> 5 days)	8 (7.6)	12 (8.6)	0.762
Need for new chest drainage	5 (4.8)	5 (3.6)	0.658
Pneumothorax	5 (4.8)	17 (12.3)	0.042
Pulmonary embolism or deep vein thrombosis	0 (0)	1 (0.7)	0.382

Bold values indicate $P < 0.005$. i.q.r., interquartile range. Values are *n* (%) unless stated otherwise.

Multivariate analysis

Ultra-early rehabilitation was independently associated with a decreased rate of postoperative atelectasis and/or pneumonia risk (OR 0.53, 95 per cent c.i. 0.26 to 0.98, $P = 0.045$) and a shorter duration of hospital stay (OR 0.94, 95 per cent c.i. 0.90 to 0.98, $P = 0.013$).

Unpaired analyses

Contemporary control group

An unpaired analysis was performed on the 243 patients in the intervention group and the 281 patients in the contemporary control group. The intervention group had higher rates of single shot paravertebral block and lower rates of epidural analgesia. Those patients also had shorter surgery duration, higher rates of minimally invasive procedures, and lower rates of invasive surgical approach (*Table S2*).

The rate of postoperative atelectasis and/or pneumonia was significantly lower in the intervention group than in the contemporary control group (6.6 *versus* 16.4 per cent; $P = 0.001$). In the intervention group, there was a reduced duration of hospital stay (5 (i.q.r. 4.0–7.0) days *versus* 6 (i.q.r. 4.0–10.0); $P = 0.002$) and decreased rates of postoperative pulmonary complications at day 28 (13.6 *versus* 29.2 per cent; $P < 0.001$), CCI score (0 (i.q.r. 0–8.7) *versus* 0 (i.q.r. 0–20.9); $P = 0.020$), mechanical ventilation support (0.8 *versus* 4.6 per cent; $P = 0.037$), ICU admission (3.3 *versus* 7.5 per cent; $P = 0.037$) and extended chest drainage (8.2 *versus* 16.0 per cent; $P = 0.007$) (*Table 3*).

Ambulatory subgroup

Within the intervention group, unpaired subgroup analysis was performed between the ambulatory subgroup ($n = 138$) and the non-ambulatory intervention subgroup ($n = 105$). Patients in the ambulatory subgroup had lower BMI (23.8 (i.q.r. 20.9–27.1) *versus*

25.4 (i.q.r. 21.5–28.0) kg/m^2; $P = 0.028$) and were more likely to have received a single shot paravertebral block (74.6 *versus* 54.3 per cent; $P = 0.001$). The patients in the non-ambulatory intervention subgroup were more likely to have received a paravertebral catheter (9.4 *versus* 21.0 per cent; $P = 0.016$). Other demographics and characteristics variables were not significantly different (*Table S3*).

A significant decrease of postoperative atelectasis and/or pneumonia was observed in the ambulatory subgroup (2.2 *versus* 9.5 per cent; $P = 0.012$) and the duration of hospital stay was significantly shorter in the ambulatory subgroup (5 (i.q.r. 4.0–7.0) days *versus* 6 (i.q.r. 4.0–7.0) days; $P = 0.024$). In contrast, an increased incidence of pneumothorax was noted in the ambulatory subgroup (12.3 *versus* 4.8 per cent; $P = 0.042$) but this did not translate into an increased rate of new chest drain insertion (3.6 *versus* 4.8 per cent, $P = 0.658$) (*Table 4*).

Discussion

In this study ultra-early postoperative rehabilitation is shown to be feasible, safe, and associated with improved outcomes for patients undergoing elective lung resection surgery. Moreover, its implementation was independently associated with a reduction in the incidence of postoperative atelectasis and/or pneumonia and a shorter duration of hospital stay.

An association between general anaesthesia and atelectasis is well established. The causal mechanisms of atelectasis due to general anaesthesia, methods of perioperative prevention and treatment options have been previously described[10,11]. In an observational study previously published by Zieleskiewicz and colleagues, early postoperative atelectasis diagnosed in the PACU was associated with a longer duration of hospital stay, an increased need for postoperative mechanical ventilation, and an increase in postoperative mortality[7]. Similar findings were noted in a prospective study in which patients undergoing major surgery who were diagnosed with two or more areas of pulmonary consolidation were more likely to require postoperative mechanical ventilation, have a prolonged ICU stay, and suffer from ventilator-associated pneumonia[16].

Postoperative physiotherapy and ambulation may potentially be associated with the prevention of pulmonary complications and this study supports that the early implementation of postoperative rehabilitation is key to the outcomes described above. This novel finding contrasts the two case–control studies that previously evaluated the role of ERAS and postoperative rehabilitation in thoracic surgery. In both studies, the implementation of ERAS care bundles did not improve patient outcomes, as is reported in the present study; however, in both of these studies, postoperative rehabilitation was initiated on the first postoperative day, significantly later than in the present intervention group[17,18].

In the present study, the ultra-early initiation of postoperative rehabilitation was associated with a significant decrease in duration of hospital stay. These results are like those of two important retrospective studies from Khandhar and Kuroda and colleagues, showing that early ambulation (mobilization between 1–4 h after thoracic surgery) was associated with a 1-day reduction in duration of hospital stay[19,20]. Daskivich and colleagues also evaluated the effect of postoperative ambulation on the outcomes after major surgery. They showed an inverse relationship between the number of steps taken following surgery and the duration of hospital stay[21]. The present study did not measure the number of steps taken by patients; however, the benefits of ultra-early rehabilitation in terms of the incidence of pulmonary collapse and/or pneumonia and reduced duration of hospital stay seem to be enhanced in those patients who were able to ambulate in the PACU following surgery by either walking 80 m or returning on foot to the surgical ward. This finding strongly suggests the importance of early postoperative mobilization after major surgery as a tool to reduce the incidence of postoperative pulmonary complications. As such, these results emphasize the concept that early postoperative mobilization should be a key component in the ERAS bundle following elective thoracic surgery.

Regarding the safety of ultra-early rehabilitation, the present results are in line with those previously published in the literature[22]. In this cohort, only two cases of orthostatic hypotension were noted. These episodes spontaneously resolved and did not hinder further ambulation in the PACU. Although a higher rate of pneumothorax was reported in the ambulatory subgroup, the exact cause of this finding is not entirely clear. Therefore, it is suggested that this group of patients be monitored in the PACU for this complication and future studies should further assess this finding.

Regarding feasibility, only 46.4 per cent of patients undergoing elective lung resection surgery during the intervention interval were ultimately treated with ultra-early rehabilitation. The main reason for this was staff member shortage in the PACU, especially in the evenings when night medical and nursing teams come on duty. This reflects the need for trained medical staff, possibly around the clock, to ensure the success of such a programme. Nevertheless, 243 patients were successfully treated with ultra-early rehabilitation. This constitutes one of the largest cohorts of patients in the literature treated with this specific intervention. As several patients in the intervention group had poorer health (ASA grade above II), were treated with epidural analgesia, or underwent thoracotomy, these results emphasize the fact that frail patients and/or patients undergoing major open surgery can still be safely treated with ultra-early rehabilitation.

The median duration of hospital stay of 5 days for the current cohort was longer than the 4.8 days previously described[20]. This could be explained, in part, by limiting factors specific to the study institution. For instance, patients were admitted the day before surgery and when they were fit for discharge, 1, or 2 more days were needed before admission to a rehabilitation facility.

There are several limitations to this study. Due to its retrospective nature, the study is susceptible to several biases, but efforts were made to strengthen the statistical analysis to reduce the effects of covariates. Since 2010, the ERAS protocol used in the study institution has remained unchanged. By restricting the study interval to the last 4 years, the aim was to create a uniform patient cohort in terms of ERAS treatment adherence and patient characteristics. Patients were paired to reduce the differences between the historical control and intervention groups. To optimize the statistical power of the analysis, a limited number of matching criteria was available.

The continuous and prospective update of the EPITHOR database allows for a limitation of measurement and collections biases. The double checking of postoperative outcomes in both the EPITHOR and hospital databases allows for a limitation of the inaccuracy of historical data collection. Finally, the balance between the economic advantage of a shorter duration of hospital stay and the cost of supplemental staffing could not be assessed in this study and remain to be evaluated as no supplemental nursing or medical staff was recruited to initiate ultra-early rehabilitation.

This study found that ultra-early postoperative rehabilitation initiated during the PACU stay in patients undergoing elective thoracic surgery is feasible, safe, and associated with a decreased incidence of postoperative atelectasis and/or pneumonia and shorter duration of hospital stay. Although these results need to be confirmed by larger studies, these findings support that ultra-early rehabilitation (in the first hour following tracheal extubation) should form part of the ERAS bundle offered following elective thoracic surgery.

Collaborators

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Supplementary material

Supplementary material is available at *BJS Open* online

Data availability

The data that support the findings of this study are available from the corresponding author, B.P., upon reasonable request.

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