

Association of Early Postoperative Mobilization with Length of Hospital Stay and Postoperative Complications after Abdominal Surgery: A Patient-Level Cohort Analysis

A Retrospective Cohort Study

Keywords: early mobilization, abdominal surgery, length of stay,
postoperative complications, ERAS, cohort study

Sample size: $N = 320$ (180 early mobilization; 140 no early mobilization)

Study type: Retrospective cohort study (STROBE)

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Abstract

Background: Early postoperative mobilization is a core element of enhanced recovery pathways, but patient-level evidence on its association with hospital stay and complications after abdominal surgery needs to be examined with attention to confounding. We evaluated whether early mobilization was associated with length of hospital stay (primary outcome) and postoperative complications (secondary outcome).

Methods: This retrospective cohort analysis included 320 patients after abdominal surgery, of whom 180 received early mobilization and 140 did not. Length of stay (LOS) was available for 314 patients (6 with missing LOS were excluded from LOS analyses). LOS was compared with the Welch *t*-test and with multiple linear regression adjusted for age, sex, Charlson comorbidity score and ASA class. Complications (59 events) were compared with the chi-square test and multivariable logistic regression. Exposure-by-subgroup interactions (ASA class, age) were tested. Two-sided $\alpha = 0.05$.

Results: Mean LOS was 7.08 ± 1.93 days with early mobilization versus 9.13 ± 1.99 days without (crude mean difference -2.04 days, 95% CI $[-2.48, -1.60]$, $p < 0.001$; Cohen's $d = -1.04$). After adjustment, the difference was -1.94 days (95% CI $[-2.29, -1.59]$, $p < 0.001$). The complication rate was 17.2% with early mobilization and 20.0% without; this difference was not statistically significant (crude $p = 0.525$; adjusted OR = 0.82, 95% CI $[0.46, 1.46]$, $p = 0.494$). The association with LOS did not differ significantly by ASA class (interaction $p = 0.310$) or age group (interaction $p = 0.948$).

Conclusions: In this observational cohort, early mobilization was associated with a shorter hospital stay of about two days, which persisted after adjustment for measured confounders. No statistically significant association with postoperative complications was detected, but the study had limited power for this outcome. Because of the observational design and unmeasured confounding (for example, by indication), causality cannot be inferred.

Keywords: early mobilization; abdominal surgery; length of stay; postoperative complications; ERAS; cohort study

1 Introduction

Prolonged immobility after surgery is associated with muscle loss, functional decline and a range of postoperative problems. Multimodal enhanced recovery programmes, introduced to attenuate the physiological stress response to surgery and accelerate rehabilitation, have made early postoperative mobilization a routine recommendation in perioperative care pathways [1–3].

Evidence supporting early mobilization comes from several settings. Reviews of mobilization protocols in medical–surgical inpatients suggest that early mobilization may prevent functional decline and hospital-associated complications [4], and systematic reviews and meta-analyses in critically ill patients have examined its effect on functional recovery and on the length of ICU and hospital stay [5–8]. Much of this literature concerns intensive care units, where implementation, safety and barriers to mobilization have been studied extensively [9–12]. Evidence that is specific to patients after abdominal surgery, and that accounts for baseline risk, is comparatively less accessible in routinely collected patient-level data.

Length of stay is a widely used measure of recovery and resource use, and it is influenced by clinical and non-clinical factors [17]. Postoperative complications prolong hospitalization and affect patient-centred outcomes [13,14], and they remain common after major abdominal procedures such as rectal cancer surgery and after abdominal surgery in general, for example through pulmonary complications [15,16]. Because patients selected for early mobilization may differ systematically from those who are not (for example, in comorbidity or physiological status), observational comparisons require careful adjustment for baseline confounders.

The objective of this study was to evaluate, in a patient-level retrospective cohort of patients after abdominal surgery, the association of early postoperative mobilization with (i) length of hospital stay (primary outcome) and (ii) postoperative complications (secondary outcome), both unadjusted and after adjustment for age, sex, Charlson comorbidity score and ASA class, and to explore whether the association with length of stay differed by ASA class and age.

2 Methods

2.1 Study Design and Participants

This was a retrospective cohort study of patient-level data, reported in accordance with the STROBE statement [18]. The analysed dataset contained 320 patients who underwent abdominal surgery, with one record per patient. No records were removed during

data cleaning (no duplicates, all-null rows or out-of-range clinical values were identified; age range 35–81 years). The dataset did not include information on the study setting, calendar period, surgical procedure type or surgical urgency; therefore these characteristics are not described.

2.2 Interventions / Exposure

The exposure was early postoperative mobilization, recorded as a binary variable (yes/no). Of the 320 patients, 180 (56.3%) were in the early mobilization group and 140 (43.8%) in the no early mobilization group (reference). The dataset did not include the operational definition (for example, the time threshold) or the process by which patients were allocated to early mobilization; allocation was therefore not randomized and is treated as an observed characteristic of care.

2.3 Outcomes and Definitions

The primary outcome was length of hospital stay in days (continuous). The secondary outcome was the occurrence of a postoperative complication (binary, yes/no; 1 = event). The dataset did not specify the type or severity grading of complications. Length of stay was missing for 6 patients (1.9%); these were not imputed and were excluded from LOS analyses (complete-case analysis, $n = 314$). The complication outcome was available for all 320 patients. Covariates were age (years), sex, Charlson comorbidity score (numeric, range 0–6) and ASA class (II, III, IV; categorical). No patients were recorded as lost to follow-up. No safety outcomes other than postoperative complications were available.

2.4 Statistical Analysis

Analyses were performed in Python (SciPy and statsmodels). Baseline characteristics are presented as mean $\pm$ SD or median (Q1, Q3) for continuous variables, depending on distribution, and as n (%) for categorical variables. Groups were compared with the Mann–Whitney U test (continuous variables with non-normal distribution) or the chi-square test (categorical variables), and standardized mean differences (SMD) were calculated.

For the primary outcome, normality (Shapiro–Wilk) and homogeneity of variance (Levene) were checked, and LOS was compared between groups with the Welch t -test; the Mann–Whitney test and a one-way ANOVA (equivalent to the Student t -test for two groups) were used as checks. Effect sizes were Cohen's d with 95% CI, Hedges' g , and η^2 . The adjusted mean difference with 95% CI was estimated by multiple linear regression including early mobilization, age, sex, Charlson score and ASA class. Regression

diagnostics comprised residual normality (Shapiro–Wilk), heteroscedasticity (Breusch–Pagan test) and variance inflation factors. Sensitivity analyses were: heteroscedasticity-robust (HC3) standard errors, log-transformed LOS (reported as geometric mean ratio), Huber robust regression, and the model omitting ASA class.

For the secondary outcome, complication proportions were compared with the chi-square test (Yates-corrected result also computed), and the crude and adjusted odds ratios (OR, 95% CI) were estimated by logistic regression with the same covariates. Model discrimination was assessed with the receiver operating characteristic (ROC) curve (area under the curve, AUC, with bootstrap 95% CI from 1000 resamples; optimal cutoff by the Youden index) and calibration with the Hosmer–Lemeshow test. With 59 events and six model parameters, the events-per-variable ratio was 9.8.

Subgroup analyses by ASA class (II vs III–IV) and age (< 65 vs ≥ 65 years) were performed by stratified adjusted models and by testing an exposure-by-subgroup interaction term. Subgroup analyses of complications were exploratory. All tests were two-sided with $\alpha = 0.05$; no adjustment for multiplicity was applied, and secondary and subgroup findings should be interpreted accordingly.

3 Results

3.1 Baseline Characteristics

A total of 320 patients were included: 180 (56.3%) received early mobilization and 140 (43.8%) did not. Baseline characteristics are shown in Table 1. Age, sex and ASA class distributions did not differ significantly between groups (all $p > 0.05$; all SMD < 0.20). The Charlson comorbidity score differed significantly between groups ($p = 0.025$, SMD = -0.22), with a slightly lower score in the early mobilization group, indicating that this covariate was not balanced and was therefore included in all adjusted models.

Table 1 Baseline characteristics by early mobilization status

Variable	No early mob. ($n = 140$)	Early mob. ($n = 180$)	SMD	p
Age (years), median (Q1, Q3)	58.0 (45.0, 69.0)	61.0 (49.0, 70.0)	0.177	0.113
Sex, n (%)			0.092	0.413
Female	78 (55.7%)	92 (51.1%)		
Male	62 (44.3%)	88 (48.9%)		
<i>Comorbidity and risk</i>				

Table 1 (continued)

Variable	No early mobi- lization	Early mobiliza- tion	SMD	<i>p</i>
Charlson score, median (Q1, Q3)	1.0 (1.0, 2.0)	1.0 (0.0, 2.0)	−0.221	0.025
ASA class, <i>n</i> (%)			0.078	0.788
II	52 (37.1%)	72 (40.0%)		
III	70 (50.0%)	83 (46.1%)		
IV	18 (12.9%)	25 (13.9%)		

Continuous variables were compared with the Mann–Whitney *U* test and categorical variables with the chi-square test. SMD: standardized mean difference; mob.: mobilization.

3.2 Primary Outcome

Length of stay was analysed in 314 patients (137 without and 177 with early mobilization). LOS was approximately normally distributed in both groups (Shapiro–Wilk $p = 0.358$ and $p = 0.482$) with homogeneous variances (Levene $p = 0.662$). Mean LOS was 7.08 ± 1.93 days (median 7.2, IQR [5.8, 8.2]) in the early mobilization group and 9.13 ± 1.99 days (median 8.9, IQR [7.9, 10.5]) in the group without early mobilization (Figure 1). The crude mean difference was -2.04 days (95% CI $[-2.48, -1.60]$; Welch $t(288.4) = -9.14$, $p < 0.001$; Cohen's $d = -1.04$, 95% CI $[-1.28, -0.81]$; Hedges' $g = -1.04$). The one-way ANOVA gave $F(1, 312) = 84.14$, $p < 0.001$, $\eta^2 = 0.21$, and the Mann–Whitney test was consistent ($p < 0.001$).

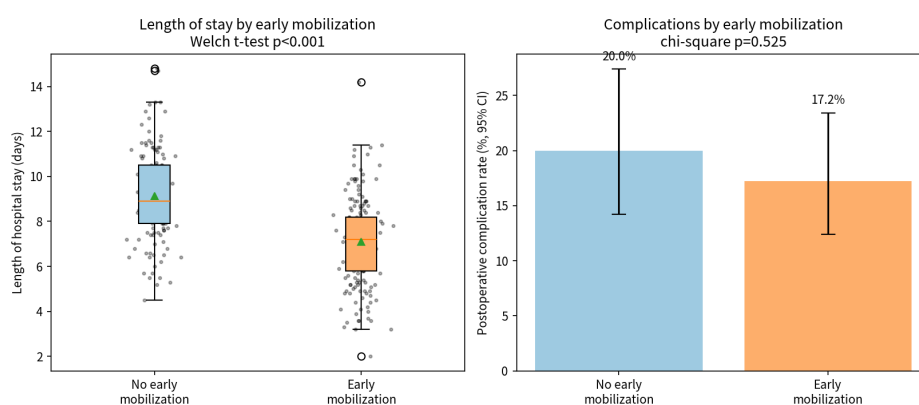


Figure 1 Length of stay (left; Welch t -test $p < 0.001$) and postoperative complication rate with 95% CI (right; chi-square $p = 0.525$) by early mobilization status

In the multiple linear regression model (Table 2; $n = 314$, $R^2 = 0.516$, adjusted $R^2 = 0.507$), early mobilization was associated with an adjusted mean difference in

LOS of -1.94 days (95% CI $[-2.29, -1.59]$, $p < 0.001$), i.e. almost identical to the crude estimate. Older age (0.04 days per year) and a higher Charlson score (0.94 days per point) were also associated with longer stay; sex and ASA class were not statistically significant in this model.

Table 2 Multiple linear regression for length of stay (days), $n = 314$

Variable	B (days)	95% CI	p
Early mobilization (vs. none)	-1.94	$-2.29 - 1.59$	<0.001
Age (per year)	0.043	$0.030 - 0.056$	<0.001
Charlson score (per point)	0.936	$0.781 - 1.091$	<0.001
Sex: male (vs. female)	0.233	$-0.115 - 0.581$	0.188
ASA III (vs. II)	-0.135	$-0.508 - 0.238$	0.477
ASA IV (vs. II)	0.120	$-0.428 - 0.667$	0.668
Intercept	5.365	$4.488 - 6.242$	< 0.001

Diagnostics did not indicate violations of the model assumptions: residuals were consistent with normality (Shapiro–Wilk $p = 0.466$), there was no evidence of heteroscedasticity (Breusch–Pagan $p = 0.836$) and the maximum variance inflation factor was 1.20 (Figure 2). Sensitivity analyses gave consistent results: HC3-robust $B = -1.94$ (95% CI $[-2.29, -1.59]$); log-transformed LOS geometric mean ratio 0.77 (95% CI $[0.73, 0.81]$, $p < 0.001$), corresponding to an approximately 23% shorter stay; Huber robust regression $B = -1.91$ ($p < 0.001$); and omitting ASA class $B = -1.93$ (95% CI $[-2.28, -1.58]$).

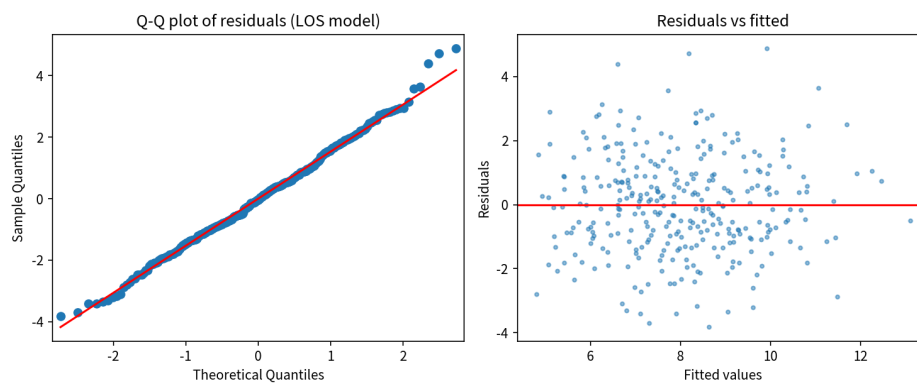


Figure 2 Diagnostics of the adjusted linear regression model for length of stay: Q–Q plot of residuals (left) and residuals versus fitted values (right); residual Shapiro–Wilk $p = 0.466$, Breusch–Pagan $p = 0.836$

3.3 Secondary Outcomes

Postoperative complications occurred in 59 of 320 patients: 31 of 180 (17.2%, 95% CI $[12.4, 23.4]$) with early mobilization and 28 of 140 (20.0%, 95% CI $[14.2, 27.4]$) without (absolute

difference -2.8 percentage points). The difference was not statistically significant (chi-square $\chi^2 = 0.40$, $p = 0.525$; Yates-corrected $p = 0.624$). The crude odds ratio was 0.83 (95% CI $[0.47, 1.47]$, $p = 0.525$). After adjustment for age, sex, Charlson score and ASA class, the odds ratio was 0.82 (95% CI $[0.46, 1.46]$, $p = 0.494$), which was not statistically significant (Table 3, Figure 3). The confidence interval is compatible with both a substantial reduction and a substantial increase in the odds of complications. None of the covariates was significantly associated with complications. The post-hoc power of this comparison was low (about 0.10), and a much larger sample would be needed to detect a difference of this magnitude.

Table 3 Multivariable logistic regression for postoperative complication ($n = 320$, 59 events)

Variable	β	OR	95% CI	p
Early mobilization (vs. none)	-0.201	0.82	$0.46-1.46$	0.494
Age (per year)	-0.008	0.99	$0.97-1.01$	0.440
Charlson score (per point)	-0.102	0.90	$0.69-1.18$	0.454
Sex: male (vs. female)	0.207	1.23	$0.69-2.18$	0.478
ASA III (vs. II)	-0.134	0.88	$0.47-1.61$	0.670
ASA IV (vs. II)	-0.084	0.92	$0.37-2.27$	0.856

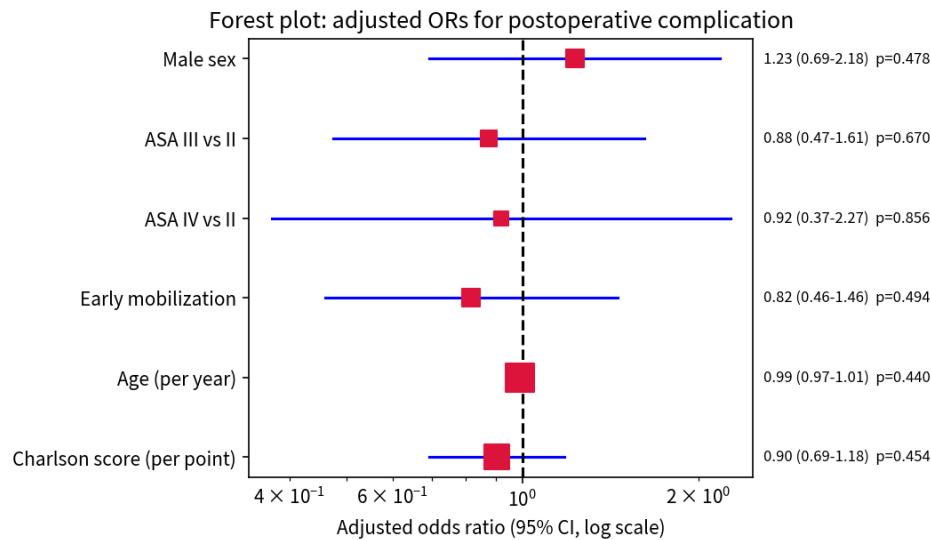


Figure 3 Forest plot of adjusted odds ratios (95% CI) for postoperative complication; early mobilization: OR = 0.82 , 95% CI $[0.46, 1.46]$

The adjusted logistic model had poor discrimination (Figure 4; AUC = 0.58 , 95% CI $[0.50, 0.66]$); at the Youden-optimal cutoff (predicted probability 0.19), sensitivity was 54.2% and specificity 66.3% (accuracy 64.1%). Calibration was acceptable (Hosmer–Lemeshow $\chi^2(8) = 6.66$, $p = 0.574$), but the model explained very little variation (McFadden pseudo- $R^2 = 0.007$).

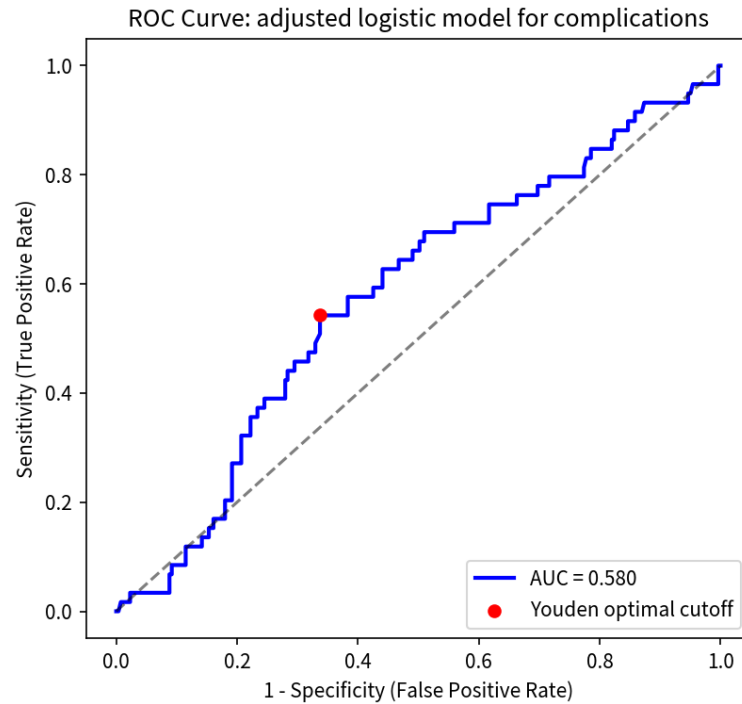


Figure 4 ROC curve of the adjusted logistic model for postoperative complication (AUC = 0.58, 95% CI [0.50, 0.66])

3.4 Subgroup Analysis

The association between early mobilization and LOS was present in all prespecified strata (Figure 5). In ASA class II ($n = 121$) the adjusted difference was -1.65 days (95% CI $[-2.27, -1.04]$, $p < 0.001$), and in ASA class III–IV ($n = 193$) it was -2.06 days (95% CI $[-2.50, -1.63]$, $p < 0.001$). The exposure-by-ASA interaction was not statistically significant ($p = 0.310$; interaction coefficient -0.37 days, 95% CI $[-1.10, 0.35]$), so the data do not show a stronger association in higher-risk patients. By age, the adjusted difference was -1.90 days (95% CI $[-2.35, -1.44]$) in patients younger than 65 years ($n = 197$) and -1.98 days (95% CI $[-2.60, -1.35]$) in patients aged 65 years or older ($n = 117$); the interaction was not statistically significant ($p = 0.948$).

For complications (exploratory), the adjusted OR was 0.75 (95% CI [0.30, 1.89]) in ASA II and 0.85 (95% CI [0.40, 1.81]) in ASA III–IV (interaction $p = 0.938$), and 0.68 (95% CI [0.34, 1.35]) in patients < 65 years and 1.29 (95% CI [0.40, 4.15]) in patients ≥ 65 years (interaction $p = 0.329$). None of the stratum-specific complication estimates or interaction tests was statistically significant.

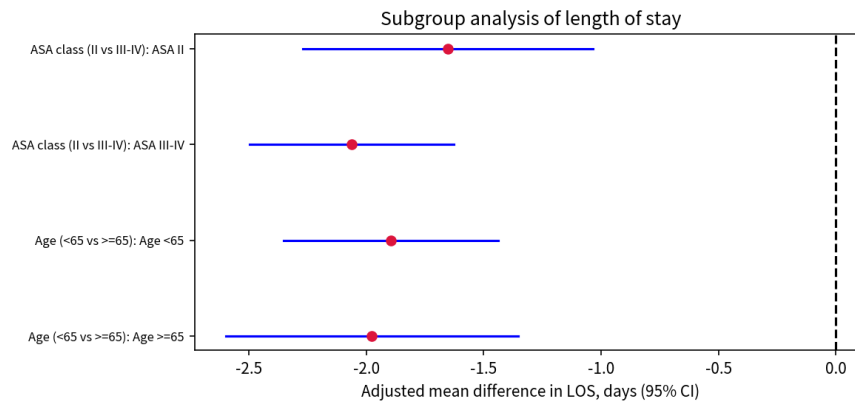


Figure 5 Subgroup analysis of the adjusted mean difference in length of stay (days, 95% CI) by ASA class (interaction $p = 0.310$) and age group (interaction $p = 0.948$)

3.5 Safety Analysis

No safety outcomes other than the postoperative complication endpoint reported above (e.g. adverse events attributable to mobilization) were available in the dataset, so a separate safety analysis could not be performed.

3.6 Summary of Hypothesis Tests

Table 4 Summary of prespecified hypothesis tests

Hypothesis	Content	Method	Conclusion
H1	Early mobilization is associated with shorter LOS, unadjusted and adjusted (crude -2.04 days; adjusted -1.94 days; both $p < 0.001$)	Welch t -test; linear regression	Supported
H2	Early mobilization is independently associated with lower mean LOS after adjustment (adjusted -1.94 days, 95% CI $[-2.29, -1.59]$)	ANOVA and linear regression	Supported
H3	Early mobilization is associated with fewer complications (adjusted OR = 0.82 , 95% CI $[0.46, 1.46]$, $p = 0.494$)	Chi-square and logistic regression	Not supported
H4	The LOS association is stronger in ASA III–IV than ASA II (interaction $p = 0.310$)	Linear regression with interaction	Not supported

4 Discussion

In this retrospective cohort of 320 patients after abdominal surgery, early postoperative mobilization was associated with a shorter hospital stay: the crude difference was -2.04 days and the covariate-adjusted difference was -1.94 days (95% CI $[-2.29, -1.59]$), corresponding to roughly a 23% shorter stay on the ratio scale. The estimate was robust to alternative specifications (robust standard errors, log transformation, Huber regression, omission of ASA class). In contrast, the difference in postoperative complications (17.2% vs 20.0%) was not statistically significant, and the association with LOS did not differ significantly by ASA class or age group. The hypothesis that the LOS association is stronger in ASA III–IV patients was therefore not supported, and absence of a statistically significant interaction should not be read as proof of homogeneity, since the interaction test may have limited power.

A difference of about two days on a baseline mean stay of about nine days is likely to be clinically meaningful for patients and for bed utilization, and the standardized effect (Cohen's $d \approx -1.04$) is large. The size of this association is, however, large relative to what would normally be expected from a single care-process element, and it should be interpreted with caution. Early mobilization is a component of enhanced recovery pathways [1–3], and a length-of-stay benefit is biologically and organizationally plausible: mobilization may limit deconditioning and muscle loss, support pulmonary function and gastrointestinal recovery, and often accompanies other pathway elements that facilitate earlier discharge. Reviews and meta-analyses, mainly in critically ill populations, similarly report associations of early mobilization with shorter hospital stay and better functional recovery [4–8], although these populations and interventions differ from our cohort and our results cannot be directly compared. Implementation research emphasises that mobilization is delivered in the context of team practices, culture and barriers [9–12], which may also influence discharge timing independently of mobilization itself.

The lack of a statistically significant association with complications is compatible with several explanations. The crude and adjusted odds ratios (0.83 and 0.82) pointed in the expected direction, but the 95% confidence intervals (0.46–1.46) included 1.0 and were wide, and the post-hoc power was low, so the study cannot distinguish a moderate protective association from no association or from a modest increase in risk. Complications are heterogeneous (for example, pulmonary complications and surgical-site problems [14–16]) and the dataset did not separate their types or severity, which may dilute any association with a mechanism-specific effect of mobilization. Complications are also related to length of stay [13], so the shorter stay observed here cannot be attributed to a lower complication rate; the data do not allow us to explore mediation.

Strengths of this study include a clear contrast, complete data on exposure, covari-

ates and complications, low missingness for LOS (1.9%), the use of both crude and adjusted analyses, extensive sensitivity analyses and diagnostics for the primary model, and the prespecified interaction tests.

Several limitations must be acknowledged. First, the retrospective, non-randomized design is vulnerable to selection and information bias. In particular, confounding by indication is likely: patients who are clinically stable or recover well may be more likely to be mobilized early, and patients who develop problems may be mobilized later, which would produce a shorter stay in the early group irrespective of any effect of mobilization (reverse causation). Adjustment was limited to four variables; the Charlson score was imbalanced at baseline, and residual confounding by unmeasured variables, including type and extent of surgery, open versus minimally invasive approach, urgency, diagnosis, analgesia, nutrition, other enhanced recovery components and hospital or surgeon factors, cannot be excluded. Second, the dataset did not include the definition or timing of early mobilization, the setting or the study period, which limits interpretation and generalizability. Third, complications were analysed as a single binary outcome without type or severity grading, and with 59 events (events-per-variable 9.8) the logistic model was at the lower limit of what is considered adequate; power for this outcome was low, and the subgroup analyses of complications were exploratory and underpowered. Fourth, six patients (1.9%) with missing LOS were excluded; as they could not be compared with the others on LOS, a small bias cannot be excluded. No multiplicity correction was applied across secondary and subgroup analyses. Finally, discharge destination, readmission and mortality were not available.

5 Conclusions

In this retrospective cohort of patients after abdominal surgery, early postoperative mobilization was associated with a statistically significant and clinically relevant reduction in length of hospital stay of about two days (adjusted difference -1.94 days, 95% CI $[-2.29, -1.59]$), which did not differ significantly by ASA class or age group. No statistically significant association with postoperative complications was found (adjusted OR = 0.82, 95% CI $[0.46, 1.46]$, $p = 0.494$), although the study was underpowered for this outcome. Given the observational design and the possibility of confounding by indication, these findings show association rather than causation; prospective studies or randomized trials with a clear definition of mobilization timing and graded complication outcomes are needed.

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