Eras Protocols for Pulmonary Complication Prevention After Major Abdominal Surgery

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ABSTRACT:

Background: Postoperative pulmonary complications are associated with substantial morbidity and mortality. They are a common outcome after emergency major abdominal surgery. Enhanced Recovery After Surgery (ERAS) pathways reduce pulmonary risk through specific perioperative interventions. Evidence from emergency abdominal surgery is still limited. This study assessed the implementation of ERAS and its association with reduced pulmonary complications within seven days of emergency major abdominal surgery.

Methods: This is a prospective single center study that included 240 adult patients undergoing emergency abdominal surgeries. These included colorectal, gastric, bowel, hepatobiliary and pancreatic surgeries. All patients received usual perioperative care during the pre and post ERAS phases (n=240), they were equally divided into two pre and post ERAS groups. The primary outcome was at least one postoperative pulmonary complication within seven days of surgery. Secondary measures included ERAS compliance. Risk ratios and absolute risk differences with 95% confidence intervals were used to compare pulmonary complication risks.

Results: Among the total study participants in the pre ERAS group only 28 (23.3%) patients had postoperative pulmonary complications while the post ERAS phase saw only 17 out of 120 patients (14.2%). The risk ratio was 0.61 (95% CI 0.35 -- 1.05) with an absolute risk difference of −9.2 percentage points (95% CI −19.0 to 0.6; p = .069). ERAS compliance increased from 53.9% (SD 12.4) before training and implementation to 85.7% (SD 9.4). There was a mean increase of 31.7 percentage points (95% CI 28.9–34.5; p < .001) in compliance after training. In the post-

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ERAS phase sepsis was more common compared to the pre ERAS phase (33.3% vs. 21.7%).

Conclusions: Protocol compliance was significantly improved after ERAS implementation and was accompanied by a clinically important reduction in seven-day pulmonary complications. The primary comparison however, was statistically inconclusive.

Keywords: AI-driven marketing; digital real estate; Bangalore; residential housing; market dynamics.

Introduction

One of the major and worst complications of the respiratory system that occurs after surgery are Postoperative pulmonary complications (PPCs). These complications are associated with respiratory infection, atelectasis, pleural effusion, bronchospasm, aspiration pneumonitis and respiratory failure. Modelling analysis demonstrated that approximately 312.9 million surgical procedures were performed, showing a rise of 38.2% from the estimated number of procedures performed in 2004. (Weiser et al., 2016). In low- and middle-income countries, PPCs are an important cause of postoperative morbidity. A recent systematic review and meta-analysis found that PPCs occurred in 22.4% of patients, while the in-hospital mortality rate among affected patients was 33.1%. This analysis also showed that, as the complications increase,the rate of death also increases (odds ratio [OR] 18.20, 95% confidence interval [CI] 11.01–30.09) and an average hospital stay is 6.5 days (Earle et al., 2024). The patients undergoing emergency abdominal surgery are at high risk because they may have conditions such as sepsis, bowel obstruction or perforation, aspiration risk, physiological instability and limited time for preoperative optimization.

To reduce the risk of PPCs, coordinated interventions are required during preoperative, intraoperative and postoperative periods. Enhanced Recovery After Surgery (ERAS) is a multidisciplinary, evidence-based approach that involves rapid preoperative assessment, physiological resuscitation, sepsis management, antimicrobial therapy, risk stratification, avoidance of unnecessary fasting, lung-protective ventilation, individualized fluid administration, maintenance of normothermia and opioid-sparing multimodal analgesia (Peden et al., 2021; Scott et al., 2023). Postoperative respiratory impairment can be reduced through anaesthetic measures, including quantitative neuromuscular monitoring and appropriate reversal of residual neuromuscular blockade (Fuchs-Buder et al., 2023). Some ERAS measures included in postoperative phase are adequate analgesia, respiratory monitoring, coached deep-breathing exercises, physiotherapy, early enteral nutrition, early mobilization and timely removal of unnecessary tubes and catheters (Scott et al., 2023; Willner et al., 2023). Some upper-abdominal procedures, including gastric, hepatobiliary and pancreatic operations, as well as long-duration procedures, such as colorectal or small-bowel operations performed for obstruction, perforation, ischaemia or intra-abdominal sepsis are associated with the high risk of PPCs. In a cohort of 1,100 patients undergoing upper-abdominal surgery, the incidence of PPC was 7.7%, and emergency surgery was associated with almost threefold greater risk of developing PPC (OR 2.84, 95% CI 1.39–5.83) (Nithiuthai et al., 2021).

The present sample-size calculation was based on a prospective international cohort study which included 507 patients undergoing emergency abdominal surgery across 45 hospitals.The incidence of PPCs and severe PPCs was approximately 22.5% and 7.5%. Patients undergoing laparotomy are at the high risk of developing PPC (OR 2.29, 95% CI 1.06–5.01), whereas reversal of neuromuscular blockade was protective (OR 0.36, 95% CI 0.16–0.82) (Ferrando-Ortolá & iPROVE Research Network Group for the PEALS Study, 2025).Despite

including some lower-risk emergency operations, this study provides PPC estimates relevant for patients undergoing emergency abdominal surgery.In the recent single-centre study of 1,080 patients undergoing emergency abdominal surgery, the incidence of PPCs and severe PPCs was 39.9% and 13.9%. The 30 day mortality rates were 21.0% among the patients with PPC and 46.3% among the patients with severe PPCs (Nærum et al., 2026). According to the systematic review of 20 studies involving 3,548 patients, the ERAS protocols may reduce the hospital length for stay and postoperative morbidity after emergency intra-abdominal surgery, although the certainty of evidence remains low to very low (McKechnie et al., 2024). A meta-analysis of six randomized clinical trials involving 509 patients, suggested that ERAS may lower the odds of PPCS after emergency laparotomy compared with conventional care (OR 0.43, 95% CI 0.24 -- 0.75) (Amir et al., 2024).

According to all these findings, the supporting evidence of ERAS in emergency abdominal surgery is more established than in elective surgery. Previous studies demonstrate substantial differences in patient selection, operative indications, ERAS components, protocol adherence and definitions of PPCs. Multicentre studies may not fully reflect the staffing limitations, available perioperative resources and implementation challenges faced by small single-centre hospitals. There is a need for locally generated evidence to assess whether a feasible ERAS pathway can reduce PPCs among patients undergoing major emergency colorectal, gastric, small-bowel and hepatobiliary procedures. A stratified analysis is required to identify differences between operative categories. The aim of this study is to determine whether ERAS protocols reduce PPCs occurring within the first seven postoperative days among adults undergoing major emergency abdominal surgery at a single centre.

Methods

This prospective, single-centre study was conducted at Mother Theresa Hospital, Tirana, Albania, between January 2025 and June 2026. The patients were recruited after obtaining informed consent into the study consecutively during pre and post-ERAS phase. A two-week implementation period was excluded for staff training. Adult patients undergoing emergency major surgery of the abdominal area including colorectal, gastric, small-bowel, hepatobiliary/pancreatic systems were included in the study. Elective, minor, trauma-related, obstetric, vascular and transplant procedures were excluded.

Pre ERAS patients received the hospital's existing perioperative care while the post ERAS phase patients received care after staff training. ERAS pathways included timely resuscitation, antimicrobial therapy, lung protective ventilation, normothermia, fluid therapy, non opioid analgesia, early extubation, respiratory exercises, physiotherapy and early mobilization. Most of these practices were already followed in pre eras patients but after specialized training was supposed to improve the overall results of the patients. ERAS compliance was recorded as the percentage of applicable pathways were completed. A standardized pre-designed proforma was used to collect all information. The recorded variables included demographic, comorbid, history, clinical frailty scores, ARISCAT categories, sepsis, shock, pre operative ICU admission, lab findings and operative approach among others. Followups were done for all patients from day of the surgery till postoperative day seven.

The occurrence of at least one postoperative pulmonary complication (PPC) within the first seven days after surgery was considered the primary outcome for this study. PPC included respiratory infection, requirement of respiratory support, pneumonitis, bronchospasm, pleural effusion, pneumothorax and any pulmonary complication. The principal secondary outcome was ERAS compliance. The sample size calculation was based on the prospective study by Ferrando-Ortola et al,. Where they reported a 22.5% seven day incidence of PPCs following emergency abdominal surgery (Ferrando-Ortolá & iPROVE Research Network Group for the PEALS Study, 2025). The sample size used for

this study assumed a reduction of incidence after ERAS implementation to 9.0% with an 80% power, a two sided alpha of 0.05 and equal allocation of participants into two groups. A total of 114 patients were required per group/phase. The final sample size was increased to 120 patients per group considering a drop out rate of approximately 5%.

All data was analysed using IBM SPSS version 26.0 and continuous variables were presented as means with standard deviations. Categorical variables were presented as frequencies and percentages. A Pearson's chi-square test was used to compare primary outcome between both groups with a 95% confidence interval. ERAS compliance was examined using Welch's independent samples t-test. The association between study phase and PPCs after adjustment for variables such as demographic and clinical was assessed using a multivariable logistic regression model. A p-value of <0.05 was considered statistically significant. The study was conducted in accordance with the Declaration of Helsinki.

Results

The following results include records of a total of 240 patients, with 120 in each study phase and complete data for the primary pulmonary outcome. Albumin was missing in 8 records (3.3%) and creatinine in 2 records (0.8%), variables used in the reported primary model were complete.

Table 1. Continuous cohort and process characteristics by study phase

Characteristic	Pre-ERAS	Post-ERAS	SMD
Age, years	56.0 (15.6)	55.4 (16.7)	-0.04
BMI, kg/m2	26.3 (4.6)	27.0 (4.9)	0.14
Haemoglobin, g/dL	11.9 (1.8)	11.7 (2.0)	-0.10
Albumin, g/L	34.2 (5.7)	34.2 (6.1)	-0.00
Creatinine, micromol/L	90.5 (32.4)	90.3 (26.4)	-0.01
ASA class	2.3 (0.9)	2.3 (0.8)	0.07
Clinical Frailty Scale	2.3 (1.0)	2.2 (1.2)	-0.05
ARISCAT score	34.9 (14.0)	34.6 (14.8)	-0.02
Surgery duration, min	150.0 (42.7)	147.1 (46.2)	-0.07
ERAS compliance, %	53.9 (12.4)	85.7 (9.4)	2.88

**Values are mean (SD). Positive SMDs indicate higher values post-ERAS. SMD, standardized mean difference.*

Continuous demographic and clinical characteristics were similar between phases. The principal change was ERAS compliance, which increased from 53.9% to 85.7%. Table 2 shows the detailed categorical patient characteristics.

Table 2. Categorical patient characteristics by study phase

Characteristic	Pre-ERAS (N = 120)	Post-ERAS (N = 120)
Male sex	56/120 (46.7)	59/120 (49.2)
Smoking: never	65/120 (54.2)	74/120 (61.7)
Smoking: former	21/120 (17.5)	19/120 (15.8)
Smoking: current	34/120 (28.3)	27/120 (22.5)
COPD	3/120 (2.5)	3/120 (2.5)
Obstructive sleep apnoea	4/120 (3.3)	1/120 (0.8)
Hypertension	33/120 (27.5)	34/120 (28.3)
Ischaemic heart disease	3/120 (2.5)	4/120 (3.3)
Diabetes	15/120 (12.5)	16/120 (13.3)
Chronic kidney disease	6/120 (5.0)	12/120 (10.0)
Chronic liver disease	5/120 (4.2)	3/120 (2.5)
Active malignancy	13/120 (10.8)	15/120 (12.5)
ARISCAT: low risk	29/120 (24.2)	31/120 (25.8)
ARISCAT: intermediate risk	67/120 (55.8)	61/120 (50.8)
ARISCAT: high risk	24/120 (20.0)	28/120 (23.3)
Sepsis	26/120 (21.7)	40/120 (33.3)
Septic shock	8/120 (6.7)	10/120 (8.3)
Preoperative ICU admission	9/120 (7.5)	5/120 (4.2)

**Values are n/N (%). Percentages use the phase-specific denominator. COPD, chronic obstructive pulmonary disease; ICU, intensive care unit.*

Sepsis was more frequent post-ERAS (33.3% vs 21.7%; p = 0.043).

Table 3. Operative characteristics by study phase

Characteristic	Pre-ERAS (N = 120)	Post-ERAS (N = 120)
Procedure category		
Colorectal	46/120 (38.3)	45/120 (37.5)
Gastric/upper GI	14/120 (11.7)	13/120 (10.8)
Hepatopancreatobiliary	21/120 (17.5)	14/120 (11.7)
Small bowel	34/120 (28.3)	38/120 (31.7)
Mixed/other	5/120 (4.2)	10/120 (8.3)
Approach		
Open	85/120 (70.8)	80/120 (66.7)
Laparoscopic	35/120 (29.2)	40/120 (33.3)
Indication		
Perforation	36/120 (30.0)	35/120 (29.2)
Obstruction	52/120 (43.3)	47/120 (39.2)
Ischaemia	11/120 (9.2)	16/120 (13.3)
Bleeding	9/120 (7.5)	9/120 (7.5)
Other	12/120 (10.0)	13/120 (10.8)
Wound contamination		
Clean-contaminated	56/120 (46.7)	54/120 (45.0)
Contaminated	41/120 (34.2)	37/120 (30.8)
Dirty	23/120 (19.2)	29/120 (24.2)

**Values are n/N (%). GI, gastrointestinal.*

There was no strong evidence of differences in both phases according to the procedure mix, operative approach, indication and wound-contamination distributions (all overall $p > 0.48$) as shown in Table 4.

Table 4. Primary postoperative pulmonary outcome

Measure	Pre-ERAS	Post-ERAS	Effect (95% CI)
No PPC	92/120 (76.7)	103/120 (85.8)	-
Any PPC, days 1350-02	28/120 (23.3)	17/120 (14.2)	-
Risk ratio, post vs pre	-	-	0.61 (0.1350-02.05)
Risk difference, percentage points	-	-	-9.2 (-19.0 to 0.6)
Odds ratio, post vs pre	-	-	0.54 (0.1350-02.05)

**Pearson chi-square p = 0.069.*

The estimated 9.2 % point reduction was clinically relevant, but its confidence interval included no difference and the unadjusted comparison was not statistically significant.

Table 5. Exploratory multivariable logistic regression for any PPC

Predictor	aOR	95% CI	p value
Post-ERAS vs pre-ERAS	0.45	0.1350-02.97	0.041
Age, per year	0.99	0.1350-02.02	0.378
Sex: SPSS category 1 vs reference	1.00	0.1350-02.07	0.995
Smoking status, overall	-	-	0.067
ASA class, per category	0.74	0.1350-02.35	0.329
ARISCAT category, overall	-	-	0.019
Clinical Frailty Scale, per point	1.66	1.1350-02.58	0.023
Sepsis	1.27	0.1350-02.19	0.616
Septic shock	3.86	0.1350-02.01	0.074
Preoperative ICU admission	0.66	0.1350-02.47	0.622
Open vs laparoscopic approach	2.31	0.1350-02.91	0.081
Surgery duration, per min	1.00	0.1350-02.01	0.872
Wound contamination, overall	-	-	0.658
RBC transfusion, per unit	0.54	0.1350-02.78	0.310

Predictor	aOR	95% CI	p value
Procedure category, overall	-	-	0.537

**The phase coefficient was reciprocated to present post-ERAS versus pre-ERAS. aOR, adjusted odds ratio; RBC, red blood cell.*

The post-ERAS phase was associated with lower odds of PPC and greater frailty with higher odds in the logistic regression model.

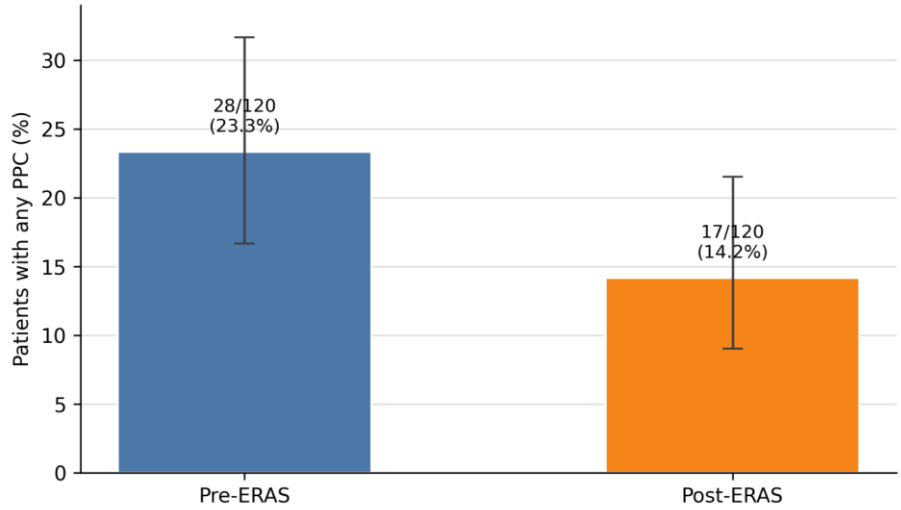

Fig 1. Incidence of any postoperative pulmonary complication by study phase. Error bars show Wilson 95% confidence intervals calculated from the supplied SPSS counts.

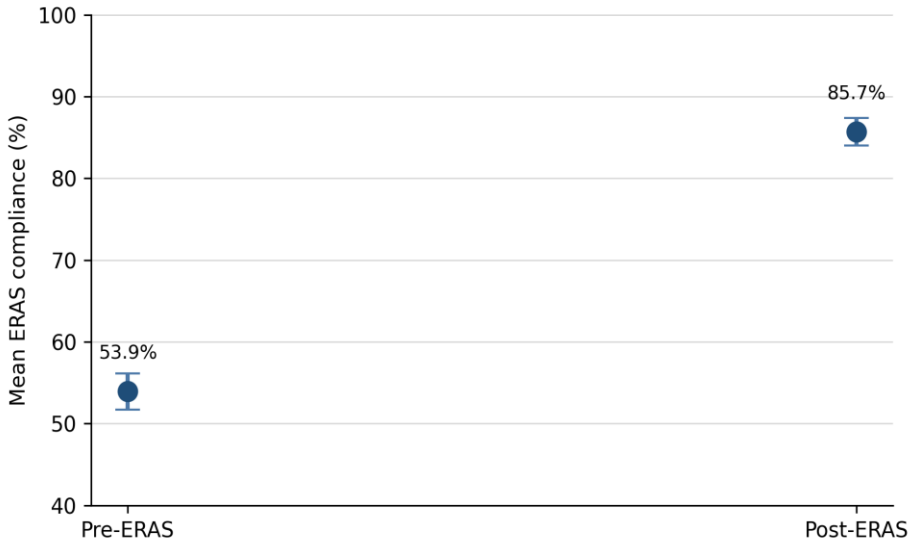

Fig 2. Mean ERAS compliance by study phase. Error bars show 95% confidence intervals for the mean calculated from the SPSS means, standard deviations and sample sizes.

Mean compliance increased by 31.7 percentage points (95% CI 28.1350-02.5; Welch $t(221.7) = 22.27$, $p < 0.001$).

Discussion

In our pre-post, single-centre study, the incidence of PPCs before and after ERAS phase implementations was 23.3% and 14.2% respectively, corresponding to an absolute risk reduction of 9.2 percentage points and a relative risk of 0.61. The primary comparison was not statistically significant (p=.069), with 95% of confidence intervals including the null value (0.1350-02.05).Our findings suggest a clinically important association, but they do not provide final evidence that ERAS prevented PPCs.

These findings are consistent with the recent emergency-surgery trials. Sharma et al. (2021) reported that ERAS implementation in emergency laparotomy is associated with faster recovery and fewer complications. Pranavi et al. found that ERAS pathway was achievable and support the better recovery in patients undergoing emergency surgery for perforation peritonitis.The previous studies involve more specific surgical populations, while the present study includes colorectal, gastric, small-bowel and hepatopancreatobiliary procedures.The variance in the relative risk calculated in this study is attributed to the differences in operative severity, contamination, respiratory risk and the applicability of individual ERAS elements .

ERAS rates improved from 53.9% to 85.7%, which showed that structured pathway implementation was possible in an emergency setting. This finding is important because ERAS is not a single treatment, but a coordinated series of multiple interventions. In the meta-analysis of 74 randomized trials, Sauro et al. (2024) found that ERAS pathways reduce the postoperative complications. According to Kokotovic and Burcharth (2023), ERAS implementation after emergency laparotomy depends on multidisciplinary coordination, flexibility with respect to physiological instability and limited preoperative preparation.Our study supports the possibilities of achieving high compliance, without compresing resuscitation or surgical source control.

Possible reasons behind the relationship observed in the study include lung-protective ventilation, opioid-sparing analgesia, respiratory physiotherapy, early mobilisation, early enteral intake and timely removal of unnecessary tubes.Early mobilisation might help with ventilation, functional recovery and resistance to long-term immobilisation, but definition and practices vary across studies (Tazreean et al., 2022). Because the present analysis concluded that ERAS is a complete pathway and did not assess complete adherence to each element in relation to PPCs, it was unable to determine which components contributed most strongly to the observed difference

The pre-ERAS PPC rate was clinically acceptable in the setting of emergency abdominal surgery. In general-surgery population study from a middle-income country Morris et al. (2022) states that PPC occurred in 11.7% of patients and that age, comorbidity, and operative factors were all associated with increased risk. That population is not directly comparable with emergency major abdominal surgery, it highlights the importance of patient and procedural risk of surgery. Ylimartimo et al. (2023) states that postoperative complications were common following emergency laparotomy and were linked with long-term hospitalization and increasing rate of mortality.According to Kvist et al. (2024), pulmonary complications were reported in 20.2% of emergency-laparotomy patients without burst abdomen, and in 45.8% of patients with burst abdomen.These differences show significant variation in the incidence of PPC across case selection, operative complexity and outcome definitions.

The best sub-set regression produced an adjusted odds ratio of 0.45 for the post-ERAS phase and higher level of frailty was associated with greater odds of PPCs. This finding is biologically plausible because physiological reserve may be compromised, while mobility and respiratory-muscle weakness can restrict the recovery after major emergency surgery. According to Snitkjær et al. (2024), frail patients who underwent major emergency abdominal surgery are at the greater risk of surgical and non-surgical complications. Tracy et al. (2024) reported that older patients who underwent emergency-laparotomy had more

complications and respiratory failure, while Kyaruzi et al. (2023) found that worse physiological status during laparotomy was linked to increased complication severity.

The adjusted analysis included many parameters despite only 45 PPC events, which may have increased the risk of overfitting, unstable coefficients and exaggerated associations. These findings should be interpreted as hypothesis-generating without superseding the nonsignificant result of primary unadjusted analysis.A large study would enable the use of parsimonious models with clinically prespecified confounders or the application of penalized regression.

This sample-size calculation concluded that incidence of PPC reduced from 22.5% to 9.0%, while the observed post-ERAS incidence was 14.2%.This study was not large enough to establish certainty regarding a smaller observed effect, with the confidence interval ranging from substantial benefit to little or no benefit. A Lack of statistical significance should not be interpreted as evidence that ERAS has no effect, nor should it be considered proof of effectiveness.

The most frequent limitations that occur after ERAS implementation, include non-randomized design, possible secular changes in clinical practice and the baseline imbalance in sepsis. Despite adjustment for these factors some residual confounding may remain. Generalisability was limited by single-centre study, unblinded outcome assessment and variation of surgical procedures, which made the procedure-specific analyses unreliable. (Khanderia et al., 2024) stated that long-term recovery and quality of life may remain affected for several months after emergency laparotomy.

Conclusion

ERAS implementation improved pathway compliance and was associated with fewer PPCs, but the primary result remained statistically inconclusive. Larger prospective studies are needed to confirm the effect.

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