

Perioperative emergency laparotomy pathway for patients undergoing emergency laparotomy: A propensity score matched study

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ABSTRACT

Introduction: Emergency laparotomy (EL) is associated with high morbidity and mortality, often exceeding 10%. This study evaluated the impact of the EMERGENCY Laparotomy Audit (EMLA) interdisciplinary perioperative pathway on patient outcomes, hospital costs and length of stay (LOS) within a single centre.

Method: A prospective cohort study was conducted from August 2020 to July 2023. The intervention team included specialist clinicians, hospital administrators and an in-hospital quality improvement team. Patients who underwent EL were divided into a pre-intervention control group (n=136) and a post-intervention group (n=293), and an 8-item bundle was implemented. Propensity scoring with a 1:1 matching method was utilised to reduce confounding and selection bias. The primary outcomes examined were LOS, hospitalisation costs and surgical morbidity, while secondary outcomes included 30-day mortality and adherence to the intervention protocol.

Results: The utilisation of the EMLA perioperative care bundle led to a significant reduction in surgical complications (34.8% to 20.6%, $P<0.01$), a decrease in LOS by 3.3 days (15.4 to 12.1 days, $P=0.03$) and lower hospitalisation costs (SGD 40,160 to 30,948, $P=0.04$). Compliance with key interventions also showed improvement. However, there was no difference in 30-day mortality.

Conclusion: This study offers insights on how surgical units can implement systemic perioperative changes to improve outcomes for patients undergoing emergency laparotomy.

Ann Acad Med Singap 2024;53:713-23

Keywords: emergency medicine, general surgery, laparotomy, perioperative care, short-term outcomes

CLINICAL IMPACT

What is New

- This single-centre study successfully implemented a perioperative care pathway for emergency laparotomy (EL) patients, leading to sustained improvements including decreased length of stay, surgical complications and hospitalisation costs.
- This study supports the incorporation of a standardised perioperative EL pathway to achieve improved patient outcomes.

Clinical Implications

- This study can help shape future healthcare policy especially for patients undergoing EL.
- A systematic approach to the implementation of the pathway, driven by systematic Plan-Do-Study-Act cycles, continuous data monitoring and quarterly feedback is key in achieving sustained improvements.

INTRODUCTION

Patients requiring emergency laparotomy (EL) are a vulnerable subset within general surgery, with reported 30-day mortality rates ranging from

9% to 18%, which is 3 times higher than similar elective operations.¹⁻³ Unlike elective surgeries, the care for EL patients is time-sensitive as they move from the emergency department, radiology suite, operating theatres, and intensive care units (ICUs) or general wards. These patients are at risk of rapid deterioration without timely interventions. Furthermore, EL patients represent a diverse group with various surgical needs, and their care entails a disproportionately high healthcare cost burden.⁴ A multidisciplinary approach to the implementation of a specific perioperative pathway that limits variability while allowing tailored treatment for each patient is postulated to improve patient's outcome.^{1,5-7}

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Accepted: 3 December 2024

In recent years, observational studies have shown improvement in clinical outcomes with the implementation of an EL care bundle. The Emergency Laparotomy Pathway Quality Improvement Care bundle, introduced in 2015, reported a reduction in mortality from 15.6% to 9.6%.⁸ The Emergency Laparotomy Collaborative demonstrated a decrease in mortality from 9.8% to 8.3% as well as a decrease in length of stay from 20.1 to 18.9 days across 28 National Health Service hospitals in the UK.³ The National Emergency Laparotomy Audit (NELA), through the provision of high-quality comparative data and the tracking of key process measures, showed a sustained reduction in mortality rates for patients undergoing EL from 11.8% to 9.2% over the past 8 years.¹ The benefits of the EL care bundle have also been published in Swedish, Danish and Australian cohort studies.^{6,9,10} In a Singapore context, Ong et al. studied the effectiveness of an EL pathway in their hospital that has an acute care surgery team and a low 30-day mortality rate of 5.3% pre-intervention.¹¹ In their study, the EL pathway did not show a significant reduction in mortality.

In our study, we implemented our EL pathway by addressing barriers and facilitators in implementing change, in the Singapore context.¹² This included obtaining endorsement from the hospital senior management, getting familiar with quality improvement (QI) practices and building interpersonal relationships among clinicians. This approach aligns with the “hard clinical core” supported by “soft QI periphery” as suggested by Stephens et al.¹³ Our main outcome measures were the length of hospitalisation, postoperative surgical complications,, inpatient hospitalisation cost and

30-day mortality. Additionally, we evaluated the 2-year compliance with the EEmergency Laparotomy Audit (EMLA) bundle to gauge the sustainability of its implementation.

METHOD

Study design

A prospective single-institution intervention study was carried out at a 700-bed general hospital in Singapore. The study included all patients aged 18 years and above who underwent EL between 1 August 2020 and 31 July 2023. After receiving approval from hospital senior management, the hospital QI team framed the effort within standard QI methodology. Stakeholder QI leads from emergency medicine, intensive care, anaesthesia and general surgery departments were identified, and basic QI training based on the Institute for Healthcare Improvement Model for Improvement was provided. An 8-step intervention bundle (Table 1) based on the Enhanced Peri-Operative Care for High-risk patients (EPOCH) 37-component care-pathway recommended processes of care was agreed upon after obtaining consensus, which became the standard of care for EL patients within the surgical department.⁵

In our study, the emergency physicians lead was responsible for improving antibiotics administration within 60 minutes; the general surgery lead was responsible for preoperative NELA scoring and ensuring timely arrival in the operating theatre; and the anaesthesia lead was tasked with goal-directed fluid therapy and maintaining normothermia. Lastly, the intensivist lead oversaw postoperative care in the high dependency/intensive care (HD/ICU)

Table 1. Pre-set clinical interventions.

No.	Phase	Clinical interventions
1	Emergency department	Administration of intravenous antibiotics within 60 mins from diagnosis of intra-abdominal sepsis
2	Preoperative	Performing NELA scoring at consent for risk stratification
3		Decision on emergency laparotomy is made by consultant surgeon
4		Moving patients to the operating theatre in a time-appropriate fashion based on their priority (P) status (i.e. ≤1 hour for P1 cases, ≤6 hours for P2 cases)
5	Intraoperative	Presence of consultant anaesthesiologist and surgeon in the operating theatre
6		Monitoring of cardiac output and ensuring goal-directed fluid therapy
7		Monitoring of intraoperative body temperature and ensuring normothermia
8	Postoperative	Transferring of patients to high dependency or intensive care unit if calculated mortality is >5% and to general ward when calculated mortality is ≤5%

NELA: National Emergency Laparotomy Audit

unit setting. Each speciality planned its own QI initiatives to enhance compliance with these clinical quality indicators (Table 1).

The pre-intervention phase was from 1 August 2020 to 30 June 2021, with all consecutive patients who underwent EL identified as the control group. The formal introduction of the EMLA perioperative care bundle occurred in July 2021. The inclusion and exclusion criteria for patients undergoing EL followed the NELA protocol.¹⁴ Briefly, patients undergoing EL involving the stomach, small intestine, large intestine or rectum were included. The indications included perforation, ischaemia, intra-abdominal sepsis, bleeding or postoperative complications. EL procedures related to trauma; vascular pathology; laparotomies where primary pathology is appendicitis or cholecystitis; laparotomy for repair of incarcerated hernia without division of adhesions or bowel resection/repair and emergency stoma via trephine incision or via laparoscopic procedure were excluded.

The diagnosis of intra-abdominal sepsis was made based on clinical examination findings of peritonitis or pneumoperitoneum observed on imaging. The NELA preoperative risk score was computed using the online NELA risk calculator.¹⁵ The outcomes measured were the length of hospitalisation, defined as the duration from surgery until discharge; surgical complications categorised according to the Clavien-Dindo classification system; hospitalisation costs; and 30-day mortality.

For patients undergoing EL, normothermia was maintained through pre-warming with forced-air systems for 20 to 30 minutes before surgery, maintaining the operating room temperature $\geq 22^{\circ}\text{C}$, and utilising active intraoperative warming strategies. These included surgical access warming blankets (3M Bair Hugger Warming Blanket 57000; 3M, Saint Paul, MN, US), warmed intravenous fluids, underbody warming mattresses and continuous core temperature monitoring. For high-risk patients (NELA $>5\%$), goal-directed fluid therapy involved arterial line placement for continuous monitoring of blood pressure and pulse pressure variation. Fluid challenges with crystalloid solutions or 5% albumin were administered to maintain pulse pressure variation $<15\%$, and vasopressors were used to sustain a mean arterial pressure ≥ 65 mmHg.

Process and outcome measures were defined in the electronic medical records and collected by the surgical clinical reviewer (SCR) as part of ongoing participation in the American College of Surgeons National Surgical Quality Improvement Program (NSQIP). Diagnostic criteria for perioperative morbidity used definitions from NSQIP's Operations

Manual.¹⁶ Data veracity was ensured by weekly meetings between SCR and department surgical leads.

We collaborated with our in-house quality QI and data analytics team to ensure accurate data tracking. Feedback on compliance was provided to each speciality team during quarterly EMLA meetings, where Plan-Do-Study-Act (PDSA) cycles were employed to deepen process insight and improve performance of process outliers. The QI and data analytics team helped to track compliance for each of the clinical interventions, with monthly data evaluations to assess improvement following each PDSA cycle. If sustained improvement was observed for 3 consecutive months, the PDSA cycle was deemed successful. Conversely, if no improvement in compliance was noted within 3 months, the PDSA cycle was re-evaluated and modified accordingly.

A specialised database was set up in August 2020 after approval from the National Healthcare Group Domain Specific Review Board (NTFGH-JHS 2020-00052). Data integration was achieved through 3 primary sources: (1) EMLA Redcap Database, which contains detailed patient data entered by SCRs; (2) Epic Electronic Medical (Epic Systems Corporation, Wisconsin, US), which provides demographic information, clinical histories and outcomes; and (3) Health System Administrative Databases, which offer detailed cost metrics. Cost data for each EL encounter (up to 30 days post-discharge) were provided by the hospital finance department and adjusted for inflation. These costs comprise all relevant costs related to the encounter, including consultation, surgeon and anaesthetist costs, occupational therapy costs, room charges as well as costs of investigative equipment, medications and supplies.

Statistical analysis

To mitigate temporal and selection biases in comparing control and treatment groups, we utilised propensity score matching.¹⁷ This method aligns groups by their intrinsic risk profiles, adjusting for systemic differences, such as demographics and other non-controllable confounders that arise across different periods. The matching criteria were age, American Society of Anaesthesiologists (ASA) score, NELA score, Portsmouth Physiological and Operative Severity Score for the enUmeration of Mortality and morbidity score, operative indications and counts of pre-1-year hospital admissions.

Our study's observational design naturally dictated its sample size, capturing all EL cases

within the specified period. We conducted propensity score matching using a 1:1 nearest neighbour without replacement approach, utilising the MatchIt package version 4.5.5 (Ho, Imai, King, & Stuart et al., 2011) in R software version 4.3.2 (R Core Team, 2023). The propensity scores were estimated through a probit regression model, selected over logistic regression for its effectiveness in achieving a better covariate balance in our dataset. Post-matching balance was assessed to ensure comparability between groups to minimise selection bias.

Categorical variables were presented as frequency counts with percentages and analysed using Pearson's χ^2 test or Fisher's Exact test—selected for their appropriateness in assessing the association between categorical variables. Continuous variables were expressed as mean with $\pm$ standard deviation and differences were assessed using Student's t-test, chosen for comparing means between 2 groups under the assumption of normal distribution. All reported *P*-values were two-sided, and *P*-values <0.05 were considered statistically significant. All analyses were undertaken using RStudio Version 1.3.1093 (R Core Team, R Foundation for Statistical Computing, Vienna, Austria) due to its comprehensive statistical tools and reproducibility of results. The preparation of this paper adhered to the STROBE guidelines.¹⁸

RESULTS

Between August 2020 and July 2023, 429 patients underwent EL and were included in the study. Of these, 136 underwent EL before the implementation of the EMLA bundle (EL pre-intervention/control group) and 293 underwent EL following its implementation (EL post-intervention group). We matched 136 patients from the control group with an equivalent number from the intervention group, resulting in an overall cohort size of 272.

The mean age of patients was 61 years, with a slightly higher proportion of males than females. Nearly half of all patients were classified as ASA III and above, and close to 40% were identified as high risk (NELA ≥ 5) (Table 2). Intestinal obstruction was the most common indication for EL in both the control group and intervention group (53.7% versus [vs] 54.4%). Sepsis was also prevalent (44.1% vs 43.4%). Other indications include ischaemia (10.3% vs 8.1%) and haemorrhage (7.4% vs 8.8%). No significant difference was noted in surgical indications.

The perioperative efficiency outcomes, presented in Table 3, were adjusted for outliers identified using the interquartile range (IQR) method, which was meticulously applied to time difference

calculations—a crucial metric in assessing perioperative efficiency. Notably, there was a significant increase in the time from decision to surgery in the post-intervention group (from 136 minutes to 166 minutes, $P=0.02$). However, this increase in time was not statistically significant for patients requiring P1 (i.e. to be performed within 2 hours) or P2 (i.e. to be performed within 6 hours) operations.

Length of stay and postoperative complications

We observed a significant reduction in the average length of hospitalisation, with the EMLA intervention group having a shorter hospitalisation post-surgery as compared to the pre-intervention group (12.1 days vs 15.4 days, $P=0.03$) (Table 4). In addition, we observed a decrease in surgical complications from 34.8% to 20.6%, $P<0.01$). This extended across all grades of surgical complications as classified by the Clavien-Dindo system, with the percentage of patients experiencing major complications (Clavien-Dindo ≥ 3) decreasing from 19.9% to 11.8% (Table 4).

Hospitalisation costs

From the hospital's perspective, the improvements in clinical outcomes led to substantial cost savings. The average same-admission in-hospital bill size saw a notable decrease of 22.9%, from SGD 40,160 to 30,948 (approx. USD 29,998 to 23,117) ($P=0.04$). Furthermore, these cost reductions were sustained up to 30 days post-discharge, declining from SGD 44,023 to 33,380 (approx. USD 32,883 to 25,669, $P=0.05$).

Thirty-day mortality

In the assessment of 30-day mortality rates, our study revealed no difference between the pre- and post-intervention groups. In both cohorts, the mortality rate stood at 5.1%, with 7 deaths recorded within 30 days of discharge in each group. There were 4 in-hospital deaths in the post-intervention group compared to 6 deaths in the pre-intervention group.

Compliance with EMLA bundle

The introduction of the EMLA bundle within a formal QI framework significantly enhanced compliance rates in perioperative care practices. Following the intervention, there were statistically significant improvements observed in the preoperative assessment of patient mortality as determined by the NELA score (24.3% to 82.4%, $P<0.01$), as well as in the involvement of consultant surgeon and anaesthetists during surgery (74.3% to 86.8%, $P<0.01$). While not statistically significant, the percentage of antibiotics administered within 60 minutes of intra-abdominal sepsis diagnosis

Table 2. Patient demographics.

	Pre-intervention	Post-intervention	P value
	Mean $\pm$ SD / no. (%)		
Total cases, no.	136	136	NA
Mean age, years	61 $\pm$ 17	61 $\pm$ 17	0.88
Patients $\geq$ 65 years old	64 (47.1%)	71 (52.2%)	
Gender			0.21
Male	78 (57.4%)	88 (64.7%)	
Female	58 (42.6%)	48 (35.3%)	
Race			0.80
Chinese	97 (71.3%)	90 (66.2%)	
Malay	15 (11.0%)	18 (13.2%)	
Indian	9 (6.6%)	12 (8.8%)	
Others	15 (11.0%)	16 (11.8%)	
ASA			0.92
I	15 (11.0%)	12 (8.8%)	
II	52 (38.2%)	52 (38.2%)	
III	42 (30.9%)	47 (34.6%)	
IV	25 (18.4%)	24 (17.6%)	
V	2 (1.5%)	1 (0.7%)	
NELA			0.83
Absolute NELA score, %	10 $\pm$ 15	9 $\pm$ 15	
Low (<5%)	82 (60.3%)	84 (61.8%)	
High ($\geq$ 5%)	54 (39.7%)	52 (38.2%)	
Indication for surgery ^a			NA
Obstruction	73 (53.7%)	74 (54.4%)	
Ischaemia	14 (10.3%)	11 (8.1%)	
Sepsis	63 (46.3%)	60 (44.1%)	
Haemorrhage	10 (7.4%)	12 (8.8%)	
Others	9 (6.6%)	17 (12.5%)	
Procedure approach			0.53
Laparoscopic	17 (12.5%)	22 (16.2%)	
Laparoscopic assisted	2 (1.5%)	5 (3.7%)	
Laparoscopic converted to open	23 (16.9%)	22 (16.2%)	
Open	94 (69.1%)	87 (64.0%)	

ASA: American Society of Anaesthesiologists; NA: not applicable; NELA: National Emergency Laparotomy Audit; SD: standard deviation

^a Some patients have more than 1 indication for surgery.

Table 3. Perioperative efficiency outcomes.

	Pre-Intervention	Post-intervention	
	Mean $\pm$ SD / no. (%)		P value
Preoperative (post-adjustment for outliers)			
Time from decision for surgery to start of surgery, min	136 $\pm$ 93	166 $\pm$ 106	0.02
P1 operations (to be performed within 2 h), min	65 $\pm$ 33	76 $\pm$ 29	0.15
P2 operations (to be performed within 6 h), min	153 $\pm$ 88	183 $\pm$ 101	0.06
Arrival in theatre within timescale appropriate to urgency	123 (96.1%)	111 (92.5%)	0.28
CT scan reported before surgery	121 (89.0%)	128 (94.1%)	0.24
Risk of death documented preoperatively	33 (24.3%)	112 (82.4%)	<0.01
Intraoperative			
Consultant surgeon present in operating theatre	128 (94.1%)	121 (89.0%)	0.19
Consultant anesthetist present in operating theatre	107 (78.7%)	133 (97.8%)	<0.01
Postoperative			
NELA $\geq$ 5% patients admitted to critical care (high dependency/intensive care unit)	39/49 (79.6%)	32/38 (84.2%)	0.58

CT: computed tomography; NELA: National Emergency Laparotomy Audit; P: priority; SD: standard deviation
P values in bold are statistically significant.

Table 4. Comparison of clinical outcomes measures for matched patient cohort.

		Pre-intervention	Post-intervention	P value
Length of stay, days	Mean (SD)	15.4 (14.9)	12.1 (10.8)	0.03
	Median (IQR)	10 (6.0–19.3)	8 (5.0–12.25)	
Inpatient cost, SGD	Mean (SD)	40,160 (42,196)	30,948 (31,008)	0.04
	Median (IQR)	25,028 (16,667–43,822)	20,374 (13,725–33,782)	
Inpatient cost up till 30 days post-discharge, SGD	Mean (SD)	44,023 (52,337)	33,380 (33,978)	0.05
	Median (IQR)	25,123 (17,321–44,763)	20,805 (14,093–37,684)	
30-day mortality rate (all deaths), no. (%)		7 (5.1%)	7 (5.1%)	1.00
30-day mortality rate (in-hospital deaths only), no. (%)		6 (4.4%)	4 (2.9%)	0.75
Presence of surgical complications, no. (%)		47 (37.8%)	28 (20.6%)	<0.01
Clavien-Dindo classification (only for surgical complications), no. (%)				0.94
Grade 1 or 2		20 (42.6%)	12 (42.9%)	
Grade 3		23 (48.9%)	13 (46.4%)	
Grade 4		2 (4.3%)	2 (7.1%)	
Grade 5		2 (4.3%)	1 (3.6%)	

IQR: interquartile range; SGD: Singapore dollars; SD: standard deviation
P values in bold are statistically significant.

improved (55.6% to 68.3%, $P=0.27$). Unexpectedly, we observed a decrease in compliance with surgery performed within an appropriate time (96.3% to 83.1%, $P<0.01$). However, the clinical significance is limited as arrival to theatre for P1 and P2 operations remained similar (Table 3). The other perioperative care practices remained similar (Table 5).

DISCUSSION

Our study evaluated the clinical impact of introducing and sustaining an EMLA perioperative pathway within a formal QI framework for a heterogeneous cohort of patients undergoing EL. The results of the study showed a decrease in surgical complications, length of hospital stay and hospitalisation costs. However, no difference was observed in 30-day mortality. Our institution has been operating with an established emergency surgery unit (ESU), akin to an acute care surgery unit since 2016. The American College of Surgeons reported a potential reduction in mortality of up to 31% for patients requiring emergency surgery under this model of care.¹⁹ In our department, the ESU is led by subspecialty surgical consultants on a rotational basis. The ESU team is responsible for promptly evaluating all acute admissions and in-hospital referrals. Under this system, patients slated for admission to the general surgery department were reviewed by the ESU team within a 4-hour window. For most patients requiring EL, surgical consultation commenced in the emergency department. Additionally, expedited access to computed tomography (CT) imaging was readily

available, with reporting conducted by an in-house radiology team. Our surgical team has a dedicated emergency operating theatre that can be utilised 24 hours a day, 7 days a week. EL procedures were mainly performed by consultant surgeons on the ESU roster, except for cases requiring subspecialty surgical expertise.

From our control group, we noted that our pre-intervention baseline mortality for patients undergoing EL was lower than international norms of 6.5% to 16.5%.^{1,3,6,10} Our reported 30-day mortality of 5.1% was similar to other Singapore hospital reported rates of 3.1 to 5.6%.^{11,20} This is often attributed to Singapore's healthcare where patients have easy and prompt access to healthcare facilities equipped with CT imaging and operating theatres. Our baseline length of hospitalisation of 15.4 days was also similar to international norms of 10 to 16.7 days.^{1,6,9,21}

The EMLA pathway was introduced to provide standardised evidence-based care for patients undergoing EL. Through this process, we were able to capture data that allowed us to optimise underperforming key process measures. For example, a rapid intravenous broad-spectrum antibiotic is standard practice upon diagnosing sepsis,²² however, there was no formal audit on the timing of antibiotic administration. Before implementation, antibiotics administration within 60 mins was only achieved in slightly more than half of our patients (55.6%). Likewise, there was no routine assessment of patients' surgical risk profiles, with only 24.3% of patients having a risk assessment score at consent.

Table 5. Care bundle compliance.

	Pre-intervention	Post-intervention	P value
	No. (%)	No. (%)	
Antibiotics within 60 mins of sepsis diagnosis	35/63 (55.6%)	41/60 (68.3%)	0.27
NELA scoring documented at consent	33 (24.3%)	112 (82.4%)	<0.01
Surgery decision by consultant surgeon	118 (86.8%)	113 (83.1%)	0.40
Surgery performed within appropriate time	131 (96.3%)	113 (83.1%)	<0.01
Senior surgeon and anaesthetist present during surgery	101 (74.3%)	118 (86.8%)	<0.01
Normal body temperature taken intraoperatively	109/124 ^a (87.9%)	111/129 ^a (86.0%)	0.66
Goal-directed haemodynamic therapy for high-risk cases	49/54 (90.7%)	43/52 (82.7%)	0.22
Transfer to high dependency/intensive care unit for high-risk cases	39/53 ^b (73.6%)	32/52 (61.5%)	0.19

NELA: National Emergency Laparotomy Audit

^a Excluding missing cases.

^b Excluding 1 case of intraoperative death.

P values in bold are statistically significant.

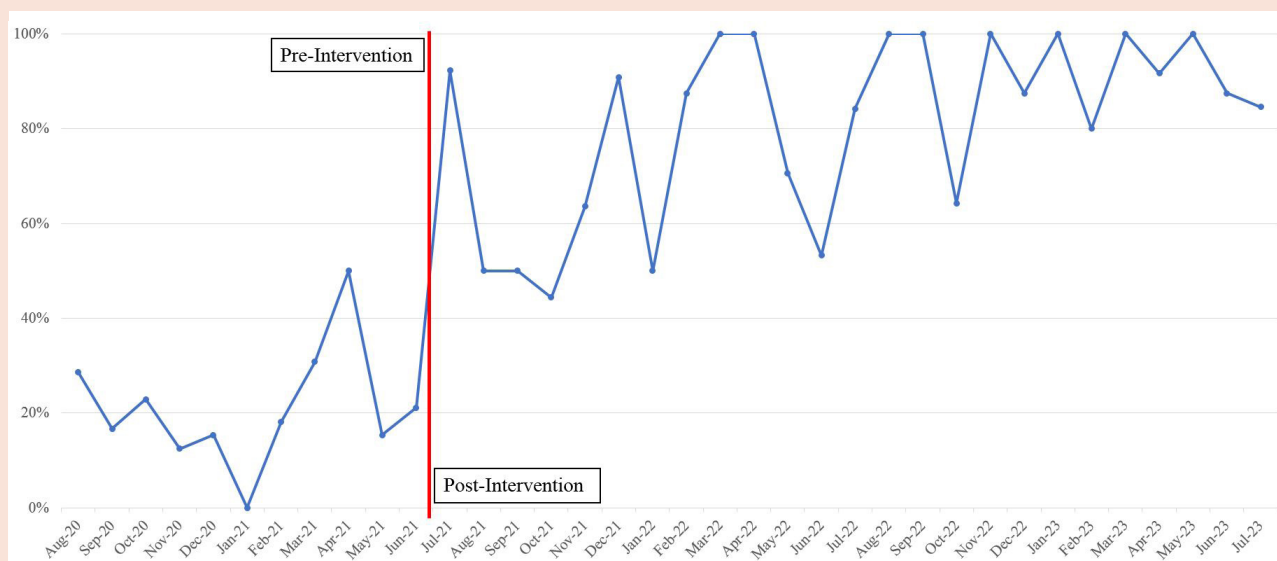
Improvement of process performance was carried out with the use of PDSA cycles within a standard QI framework, although this was not always achieved at the first attempt. For example, in the case of preoperative risk stratification with NELA scoring, the first PDSA cycle involved the introduction of a NELA smart phrase shortcut on the Epic computer system, which automated NELA scoring on entering relevant preoperative variables. Despite the convenience, compliance fluctuated between 50–100% with variations owing to the frequent rotation of junior doctors (Fig. 1). Subsequently, as a second cycle of PDSA, cases with missing NELA scores were highlighted during the weekly department morbidity and mortality meetings. With frequent communication, we were able to facilitate behavioural change where NELA scoring became part of our department consent process for EL patients. We observed an improvement in compliance, from 24.3% to 82.4%, during our study period which continues to be sustained without the need for weekly enforcement.

In our study, a risk assessment scoring at consent and having both consultant surgeon and anaesthetist involvement for EL cases showed a statistically significant improvement. There was also a trend for improved antibiotics administration within 60 minutes, but this was not statistically significant (Table 5). These improvements were postulated to be the factors that led to a reduction in surgical complications. For patients requiring EL, early administration of antibiotics, prompt resuscitation and timely source control are crucial aspects of the surviving sepsis guidelines.^{22,23}

Patients undergoing EL would require collaborative involvement of clinicians from various subspecialty. The use of a documented risk assessment at the time of consent allowed for high-risk patients (NELA >5%) to be identified early and for implementation of downstream interventions. In our study, all high-risk patients were allocated a HD/ICU bed at the time of consent. The department heads mandated a senior surgeon and anaesthetist to be involved in EL cases, which was crucial in improving compliance. Notably, surgical complications were reduced from 34.8% to 20.6% ($P<0.01$). The reduction in surgical complications served as a pivotal factor, contributing to our study cohort achieving a decreased mean length of stay of 3.3 days (15.4 to 12.1 days, $P=0.03$) and a 23% reduction in inpatient cost ($P=0.04$) (Table 4).

The reduction in inpatient cost was noteworthy as this is not uniformly reported in the literature. Studies have raised concerns regarding the potential for increased costs associated with the use of perioperative care bundles. The use of a perioperative care bundle involving routine use of a goal-directed therapy and postoperative ICU monitoring may excessively inflate inpatient costs.²⁴ In the EPOCH study, the implementation of a perioperative bundle was deemed not cost-effective.²⁵ In our study, by risk-stratifying patients, we were able to provide appropriate levels of care. The patients at high risk of mortality were usually older (age >65 years), had higher ASA scores and were hemodynamically unstable at presentation.^{10,26,27} For these patients, the implementation of goal-directed therapy and

Fig. 1. Run chart depicting compliance to preoperative NELA score risk assessment pre-intervention and post-intervention.



NELA: National Emergency Laparotomy Audit

postoperative admission to the HD/ICU were routine. This approach ensured that higher-cost interventions were reserved for high-risk patients, which helped to mitigate costs.

In our study, we found no difference in 30-day mortality at 5.1%. We postulate that the lack of improvement may be attributed to a weakness in having only preoperative NELA scoring done. This may have underestimated the severity of illness by not incorporating intraoperative data including the severity of intra-abdominal contamination, need for intraoperative vasopressor support or missed diagnoses. Numerous other factors influence 30-day mortality, which cannot be addressed solely by the perioperative care bundle. Intraoperative surgical decisions, such as choosing between open versus laparoscopic surgery, handsewn versus stapled bowel anastomosis, or the creation of a stoma versus upfront bowel anastomosis, can significantly impact clinical outcomes. These decisions are often individualised based on the patient's risk profile and intraoperative haemodynamics. In our study, 17 patients (12.5%) underwent laparoscopic surgery in the pre-intervention group while 22 patients (16.2%) underwent laparoscopic surgery in the intervention group ($P=0.53$). Each consultant surgeon was able to individualise surgical decisions at their discretion.

Furthermore, the preoperative NELA scoring is limited as it does not take frailty into account. Frailty is associated with doubling of mortality rates, increased morbidity rates and worsened functional outcomes after EL.^{1,28,29} A routine clinical frailty scale (CFS) assessment should be advocated to aid patient's decision-making and surgery strategy. When CFS is used in conjunction with preoperative risk assessment scores, mortality prediction can be improved for older patients.³⁰ In our institution, we have embarked on routine CFS assessment for patients aged more than 65 years and incorporated a geriatrics speciality consultant into our clinical core group.

Our study is limited by our single-centre experience whereby generalisability to other institutions may be limited. Nonetheless, the detailed implementation process and outcomes provide a framework that could inform similar interventions elsewhere. We support the call for early engagement of a QI framework in the design phase, where change can be driven by a "hard" clinical core supported by a "soft" QI periphery.⁵ The use of data tracking on process measures and patient outcomes can serve as a tool to drive behavioural changes—crucial for the effective

implementation of clinical interventions.

Another limitation is that our control and intervention groups were not randomised. We employed propensity score matching and conducted a sensitivity analysis, which helped to partially control for unobserved patient-level confounders. However, we acknowledge that this approach adjusts only for observed confounders, leaving room for unmeasured variables (i.e. social determinants of health) to impact outcomes. Although formal multiplicity adjustments were not applied, our key findings showed statistical significance remained robust even with conservative corrections. Moreover, the consistent direction of effect across multiple outcomes strengthened our conclusions. Ideally, patients should be randomised to usual care versus "bundled" care (i.e. compliance to pre-determined interventions). However, our study population involves patients subjected to time-sensitive EL, making recruitment, randomisation and consent-taking logistically challenging.

Moving forward, we aim to extend the EMLA perioperative framework to a national scale, addressing the challenge of widespread implementation. Expanding a care bundle to a national level presents significant challenges. The complexity of such endeavours was illustrated by the EPOCH trial group's experience across 93 National Health Service hospitals in the UK, involving 15,873 patients.³¹ In their study, there were 10 pre-defined process measures to be implemented for patients aged greater than 40 years undergoing EL. Their study methodology involved a stepped-wedge cluster randomised trial with QI intervention varying from 5 to 80 weeks. Despite their efforts, Peden et al. reported no significant differences in 90-day mortality, length of hospital stay, or hospital readmission within 180 days.³¹ Their struggles to achieve consistent intervention fidelity due to time and resource constraints underscore the formidable obstacles in scaling such initiatives.

To facilitate this process, we plan to integrate a behavioural implementation science and intervention team—providing a robust framework for supporting the rollout and evaluating its effectiveness. Also, the team will need to develop adaptable, scalable interventions tailored to the diverse environments of various institutions. It is crucial to secure an endorsement from all specialities involved in the care of EL patients and customise care bundles to align with each institution's unique operational context. By incorporating behavioural strategies into the implementation process, we aim to enhance healthcare professionals' adherence to

the care bundle and optimise patient outcomes. This comprehensive approach aims to ensure that the benefits observed at our centre can be replicated and adapted across different settings, ultimately leading to improvements in patient clinical care on a national scale.

CONCLUSION

Our single-centre study successfully implemented a perioperative care pathway for EL patients, leading to sustained improvements over 2 years. The index length of stay was reduced by 3.3 days, surgical complications decreased by 14.2% and hospitalisation costs fell by 22.9%. The success of the EMLA bundle that is driven by systematic PDSA cycles, continuous data monitoring and quarterly feedback underscores the long-term potential of structured perioperative care models to enhance healthcare delivery. Our future work will involve expanding this initiative nationwide and standardise care pathways for EL patients across diverse healthcare settings.

Funding

This study was conducted by the Department of Surgery in JurongHealth Campus and supported by JurongHealth Fund.

Ethics statement

This study was approved by the National Healthcare Group Domain Specific Review Board (NTFGH-JHS 2020-00052).

Declaration

The authors declare they have no affiliations or financial involvement with any commercial organisation with a direct financial interest in the subject or materials discussed in the manuscript.

Acknowledgements

We thank all the consultant surgeons in our department who have contributed their expertise in the care of the patients in this study. They include members of the Emergency Laparotomy Group: Hang Liang Christopher Keh, Jia Jing Edwin Yang, Aung Lwin, Sian Ying Heidi Chang, Chern Yuen Cheong, Hon Ian Chong, Shulin Jesse Hu, Kang Ee Gregory Heng, Liling Kwek, Joel Wen Liang Lau, Ishara Maduka, Han Boon Oh, Choon Sheong Seow, Yuen Soon, Chuan Chien Tan, Man Hon Tang, Wee Ming Tay, Jun Liang Teh and Yongxian Thng. We thank Mr Francis Phng who helped with data validation, and Ms Sheryl Yong and Ms Valerie Seah who helped with data collection.

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