Enhancing trauma laparotomy patient outcomes:

Comprehensive approaches to care improvement

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ABSTRACT

This thesis aims to enhance patient care for trauma laparotomy patients by focusing specifically on hospital length of stay (HLOS), a critical metric in resource-constrained healthcare systems. Although trauma laparotomy patients represent a relatively homogenous trauma cohort, they exhibit diverse needs and varied outcomes, necessitating targeted interventions. A series of studies was conducted to explore strategies, particularly the implementation of enhanced recovery protocols (ERPs), to optimize HLOS and improve patient care.

Chapter 2 analyzed data from 27,434 trauma laparotomy patients in the National Trauma Data Bank, a large trauma registry in the United States, to provide a clearer understanding of this patient population. The study found an overall median HLOS of 7.0 days, with 77% of patients having an HLOS of less than 11 days, indicating the potential applicability of ERPs for this population. Factors associated with HLOS, when stratified by length of stay, included injury type, complications, comorbidities, and insurance status, underscoring the value of this approach for targeted interventions.

Chapter 3 examined unnecessary hospital stays, a distinct type of prolonged HLOS that is particularly impactful in Canada's universal healthcare system. A retrospective analysis at Montreal General Hospital revealed that approximately 30% of trauma laparotomy patients experienced unnecessary stays, resulting in 513 additional hospital days during the study period. Delays were primarily due to limited availability in rehabilitation (42.2%) and psychiatric department (39.1%). These insights suggest potential interventions, such as improved access to post-acute care and enhanced inter-departmental coordination, to optimize resource efficiency.

Chapter 4 details the development and implementation of the Trauma Laparotomy Care Pathway (TLCP), an ERP specifically tailored for trauma laparotomy patients, followed by a prospective pilot study assessing adherence to pathway components and its impact on outcomes. A comprehensive literature review, covering both trauma laparotomy and emergency abdominal surgery due to the limited number of ERP studies specific to trauma laparotomy, was conducted as a foundation for TLCP development. The review identified 39 studies, highlighting an increase in ERP research over the past decade. However, only three studies to date have focused exclusively on trauma laparotomy, and none were conducted in North America, indicating an opportunity for ERP implementation in this context. A consensus-based TLCP was developed and implemented in our clinical setting. In the first six months post-implementation, adherence to pathway components ranged from 54.5% to 67.7%, and TLCP reduced HLOS by two days compared to the historical cohort (4.0 days [3.5, 6.5] vs 6.0 days [4.0, 10.0], p=0.0021) without an increase in complications or readmissions.

In conclusion, stratifying trauma laparotomy patients by HLOS effectively identifies subgroups with distinct characteristics and healthcare needs, highlighting the importance of targeted interventions. The newly developed TLCP can be applied to select trauma laparotomy patients, offering the potential for improved outcomes. Addressing factors contributing to unnecessary stays, along with pathway use, may further enhance patient outcomes. These efforts represent initial steps toward improving care for trauma laparotomy patients on a larger scale.

RÉSUMÉ

Cette thèse vise à améliorer la prise en charge des patients ayant subi une laparotomie pour traumatisme, en se concentrant spécifiquement sur la durée de séjour hospitalier (DSH), une mesure critique dans les systèmes de santé aux ressources limitées. Bien que les patients subissant une laparotomie pour traumatisme représentent une cohorte relativement homogène, ils démontrent des besoins et des résultats variés, nécessitant des interventions ciblées. Une série d'études a été menée pour explorer des stratégies de mise en œuvre de protocoles de récupération améliorée après une chirurgie (RAAC), afin d'optimiser la DSH et d'améliorer les soins aux patients.

Le chapitre 2 a analysé les données de 27 434 patients ayant subi une laparotomie pour traumatisme dans la *National Trauma Data Bank*, un registre de traumatologie aux États-Unis, afin d'apporter une meilleure compréhension de cette population de patients. L'étude a révélé une DSH médiane de 7.0 jours, avec 77 % des patients ayant une DSH de moins de 11 jours, indiquant l'applicabilité potentielle des protocoles RAAC. Les facteurs associés à la DSH comprenaient le type de blessure, les complications, les comorbidités et le statut d'assurance médicale, soulignant la valeur de cette approche pour des interventions ciblées.

Le chapitre 3 a examiné les séjours hospitaliers inutiles, un type spécifique de DSH prolongée impactant le système de santé universel du Canada. Une analyse rétrospective réalisée à l'Hôpital général de Montréal (HGM) a révélé qu'environ 30 % des patients ayant subi une laparotomie pour traumatisme ont fait des séjours inutiles, entraînant 513 jours d'hospitalisation supplémentaires au cours de la période étudiée. Les retards étaient principalement dus à la disponibilité limitée des services de réadaptation (42.2 %) et de psychiatrie (39.1 %). Ces observations suggèrent des interventions potentielles, telles qu'un meilleur accès aux soins post-

aigus et une meilleure coordination interdépartementale, afin d'optimiser le rendement des ressources.

Le chapitre 4 détaille le développement et la mise en œuvre du *Trauma Laparotomy Care Pathway* (parcours de soins pour laparotomie en traumatologie; PSLT), suivi d'une étude pilote prospective évaluant l'adhésion aux composants du parcours de soin et son impact sur les résultats cliniques. Une revue de littérature, couvrant à la fois la laparotomie pour traumatisme et la chirurgie abdominale d'urgence en raison du nombre limité d'études RACC spécifiques à la traumatologie, a été réalisée pour servir de fondement au développement du PSLT. La revue a permis d'identifier 39 études, soulignant l'augmentation de la recherche sur la RACC au cours de la dernière décennie. Cependant, seules trois études à ce jour se sont concentrées exclusivement sur la laparotomie pour traumatisme, et aucune n'a été menée en Amérique du Nord. Un PSLT basé sur le consensus a été développé et mis en œuvre dans notre environnement clinique. Au cours des six premiers mois suivant la mise en œuvre, l'adhésion aux composantes du PSLT a varié de 54.5 % à 67.7 %, réduisant la DSH de deux jours (4.0 jours [3.5, 6.5] vs. 6.0 jours [4.0, 10.0], p=0.0021), sans augmentation des complications ou des réadmissions.

En conclusion, la stratification des patients ayant subi une laparotomie pour traumatisme en fonction du DSH identifie effectivement des sous-groupes présentant des caractéristiques et des besoins de santé distincts, soulignant l'importance d'interventions ciblées. Le PSLT nouvellement développé peut être appliqué à des patients de laparotomie pour traumatisme sélectionnés, offrant ainsi un potentiel d’amélioration des résultats cliniques. La prise en compte des facteurs contribuant aux séjours inutiles, ainsi que l'utilisation de PSLT, peuvent améliorer davantage les résultats cliniques. Ces efforts représentent les premières étapes vers l'amélioration à plus grande échelle des soins pour les patients ayant subi une laparotomie pour traumatisme.

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I would like to extend special thanks to the SURE working group at Montreal General Hospital, with particular appreciation for the pathway coordinators, Sonia Sandberg and Debbie Watson, for their steadfast support in developing the *Trauma Laparotomy Care Pathway*, a central component of this thesis. Their dedication, meticulous oversight, and commitment to excellence were essential in the successful development and implementation of this pathway.

Their expertise and collaboration were instrumental in realizing this project and advancing patient care improvements.

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CONTRIBUTION TO ORIGINAL KNOWLEDGE

This thesis makes original contributions to the field of trauma surgery by introducing a novel stratification approach for the trauma laparotomy population, characterized by inherent heterogeneity. This approach identifies distinct subgroups with unique characteristics and healthcare needs, emphasizing the necessity and potential impact of targeted interventions for this patient group. Additionally, this work marks the first implementation of a consensus-based care pathway specifically tailored for trauma laparotomy patients in North America. This pathway development and implementation are distinct contributions that advance the field of enhanced recovery protocols for surgical patients. The studies presented in the following chapters represent my original research.

AUTHOR CONTRIBUTIONS

I am the primary author of each manuscript presented in the following chapters of this thesis. I was principally responsible for study concept generation, research proposal development, ethics applications and approvals, study design and methodology, data collection, data analysis, and manuscript drafting. Each manuscript was independently written, with drafts reviewed by my supervisor, committee members, and other co-authors. Specific contributions to each manuscript are detailed below.

Chapter 2.2

For this large trauma registry study, I developed the study design with input from Dr. Grushka and Dr. Wong, conducted data acquisition and analysis, interpreted the results, and drafted the manuscript, incorporating critical revisions. Dr. Wong contributed to data analysis, data interpretation, and provided a critical review. Dr. Grushka and Dr. Khwaja offered invaluable feedback on data interpretation and conducted a thorough revision of the final manuscript draft, focusing on coherence, readability, and clarity.

Chapter 3.2

For this retrospective analysis, I conceptualized the study and developed the study design in collaboration with Dr. Grushka and Dr. Wong. I conducted data acquisition with Tommy Lavoie-Turcotte and drafted the manuscript. Data analysis and interpretation were performed by myself, Dr. Khwaja, and Dr. Wong, with Prachi Patel specifically handling the geospatial analysis. Dr. Khwaja, Dr. Wong, and Dr. Grushka provided a critical review of the manuscript, and final approval was obtained from all authors.

Chapter 4.2

For this comprehensive literature review, I developed the study design with input from Dr. Grushka and Dr. Fiore, drawing on their expertise. Study selection and data extraction were conducted by myself, Philip Nguyen-Powanda, Dr. Tokuno, and Dr. Kouyoumdjian, while data analysis was performed by myself, Philip Nguyen-Powanda, and Dr. Fiore. I drafted the manuscript with support from Philip Nguyen-Powanda, and Dr. Fiore and Dr. Grushka provided critical revisions. Final approval was obtained from all authors.

Chapter 4.4

For this single-center pilot study, I developed the study design and conducted data acquisition and analysis in collaboration with William Davalan. I discussed the data extensively with Dr. Grushka and Dr. Wong. I drafted the manuscript, with Dr. Grushka, Dr. Wong, and Dr. khwaja providing critical review. Final approval was obtained from all authors.

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LIST OF ABBREVIATIONS

ACS	American College of Surgeons
AI	artificial intelligence
AIS	abbreviated injury scale
AKI	acute kidney injury
ARDS	acute respiratory distress syndrome
ASA	American Society of Anesthesiology
ATLS	advanced trauma life support
BMI	body mass index
CAUTI	catheter associated urinary tract infection
CBC	complete blood count
CI	confidential interval
CIHI	Canadian Institute for Health Information
ClinRO	clinician-reported outcome
CM	clinical modification
COA	clinical outcome assessment
COPD	chronic obstructive pulmonary disease
COS	comparative observational study
CPRC	clinical practice review committee
CUSUM	cumulative sum
CVA	cerebrovascular accident
CVP	central venous pressure
DPS	director of professional services

DU	duodenal ulcer
DVT	deep vein thrombosis
EAS	emergency abdominal surgery
ECG	electrocardiogram
ED	emergency department
ELAP	emergency laparotomy
EPOCH	enhanced peri-operative care for high-risk patients
ER	emergency room
ERAS	enhanced recovery after surgery
ERP	enhanced recovery protocol
GDP	gross domestic product
GI	gastrointestinal
GOAL-Trauma	Global Outcomes After Laparotomy for Trauma
GPR	Graham's patch repair
HIC	high income country
HIV	human immunodeficiency virus
HL	hyperlipidemia
HLOS	hospital length of stay
HR	hazard ratio
HT	hypertension
ICD	international classification of diseases
ICU	intensive care unit
IPC	intermittent pneumatic compression

IQR	interquartile range
ISS	injury severity score
LMIC	low-middle income country
LOS	length of stay
MAP	mean arterial pressure
MEWS	modified early warning score
MGH	Montreal General Hospital
MUHC	McGill University Health Centre
MVT	motor vehicle traffic-related
NPO	nil per os
NSAID	non-steroidal anti-inflammatory drugs
NTDB	National Trauma Data Bank
NTR	National Trauma Registry
ObsRO	observer-reported outcome
OECD	organization for economic co-operation and development
OR	odds ratio
OR	operating room
OSF	open science framework
PACU	post-anesthesia care unit
P & T	pharmacy and therapeutics
PCA	patient-controlled analgesia
PCS	procedure coding system
PE	pulmonary embolism

PerfO performance outcome

POD postoperative day

PONV postoperative nausea and vomiting

P-POSSUM Portsmouth-physiological and operative severity score for the enumeration of mortality and morbidity

PRISMA preferred reporting items for systematic reviews and meta-analysis

PRO patient-reported outcome

QI quality improvement

RCT randomized controlled trial

REB research ethics board

ROTEM rotational thromboelastometry

SIRS systemic inflammatory response syndrome

SSI surgical site infection

SURE surgical recovery

TEG thromboelastogram

TIVA total intravenous anesthesia

TL trauma laparotomy

TLCP trauma laparotomy care pathway

TOF train of four test

US United States

UTI urinary tract infection

VTE venous thromboembolism

WHO World Health Organization

CHAPTER 1: INTRODUCTION

1.1 – Current healthcare resources and trauma

The healthcare system faces substantial challenges due to resource limitations, as no system can provide unlimited resources to meet the diverse needs of all patients. Developed nations are particularly strained by factors such as the high cost of advanced medical technologies, rising public demand driven by increased access to health information, and the growing pressures associated with aging populations [1]. Additionally, many countries within the Organization for Economic Co-operation and Development (OECD) face fiscal constraints that shape their ability to address critical health policy challenges [2]. For example, economic growth in Canada has been sluggish, with GDP growth averaging just over 2% annually between 2011 and 2019 [3]. Consequently, provincial governments have focused on curbing the rise in healthcare expenditures. Furthermore, Canada's healthcare system faces a unique geographical challenge. Nearly 18% of the Canadian population resides in rural or remote areas, which cover 95% of the country's vast landmass. The need for remote care facilities and frequent medical transport to specialized centres presents significant logistical and financial challenges [4]. Thus, it is evident that available resources are insufficient to meet growing demands, underscoring the importance of efficient patient care management.

These challenges are equally evident in trauma care, a major global public health issue. Trauma accounts for approximately 4.4 million deaths annually, making it one of the leading causes of mortality worldwide. Of these deaths, 3.16 million result from unintentional injuries, while violence-related injuries claim 1.25 million lives each year. Although trauma affects individuals of all ages, it disproportionately impacts younger, productive populations. Among individuals aged 5-29, three of the five leading causes of death are injury related. Additionally, as the global population ages, fall-related injuries are becoming an increasingly significant concern,

contributing to over 684,000 deaths annually and representing a growing, under-recognized public health issue [5].

Trauma care has notably improved through the establishment of trauma systems [6, 7] and the standardization of care protocols, such as those taught in courses like Advanced Trauma Life Support (ATLS) [8-10]. These initiatives have led to substantial improvements in patient outcomes [11, 12]. However, such advancements come with increased resource demands. The development of more robust trauma systems has led to higher emergency department visits, acute care admissions, and hospitalizations. While these improvements have reduced mortality, they have also resulted in an increase in patients with temporary or permanent disabilities, creating an increased need for long-term physical and mental care, as well as rehabilitation services [5]. Consequently, trauma care now requires additional acute care beds, specialized multidisciplinary teams, cutting-edge medical technologies, greater quantities of blood products, and expanded post-acute care facilities. Effectively addressing these resource constraints is critical to sustaining and further improving the quality of trauma care.

1.2 – The rationale for focusing on trauma laparotomy patients

The trauma population is inherently heterogenous, exhibiting considerable variability in both clinical presentations and healthcare demands [13]. Trauma patients encompass all age groups and come from diverse backgrounds, with injuries affecting multiple organs and regions of the body. The mechanisms of injury, ranging from blunt and penetrating trauma to blast injuries, are highly diverse, as are the injury severities, which vary from relatively minor to life-threatening. Additionally, disparities in resource availability, both at national and local levels, further complicate trauma care. These complexities present significant challenges in conducting

research, interpreting results, and implementing care initiatives [9]. Therefore, focusing research and clinical efforts on more homogenous subgroups within the trauma population, such as trauma laparotomy patients, is crucial to gaining deeper insights into specific outcomes and optimizing care strategies.

Trauma laparotomy is a key, frequently performed procedure in trauma care. It provides surgical access to the intra-abdominal cavity, allowing for the identification and management of life-threatening conditions, such as hemorrhage from major vessels or solid organs, and contamination resulting from hollow viscus injuries. In addition to its therapeutic role, trauma laparotomy is also utilized for exploratory diagnostic purposes [14]. Several studies have examined key outcomes among trauma laparotomy patients, including mortality, morbidities, and complications [15-18]. Moreover, epidemiological research has explored the characteristics and outcomes of patients within this population [19-21]. However, there remain underexplored areas, such as variations in management, factors influencing hospital length of stay, and potential interventions to improve patient outcomes. These knowledge gaps emphasize the need for further detailed research. An international multicenter observational cohort study, Global Outcomes After Laparotomy for Trauma (GOAL-Trauma) [22], led by a research team from the University of Cambridge, is currently underway to assess variations in patient characteristics, management strategies, and outcomes in trauma laparotomy patients. Our institution is participating as a collaborator in this initiative. These ongoing research efforts, along with the underexplored aspects of trauma laparotomy care, highlight the necessity for more focused studies to optimize care and improve outcomes.

1.3 – Hospital length of stay as an outcome measure

Establishing the value of medical interventions or initiatives requires consideration from multiple stakeholders, including patients, healthcare providers, regulators, and payers. A critical component in determining the value of an intervention lies in the evidence generated by studies evaluating its effectiveness. Therefore, selecting appropriate outcome measures to define study endpoints is essential for conducting robust research or implementing clinical initiatives [23]. By ensuring these measures accurately reflect meaningful clinical improvements, researchers and healthcare practitioners can provide compelling evidence to support the broader adoption of interventions.

An outcome measure is an instrument used to assign a rating or score (categorical or continuous) to represent a particular aspect of a patient's status [23]. Outcome measures encompass survival, clinical outcome assessments (COAs), and biomarkers. A COA is any evaluation influenced by human choices, judgement, or motivation. COAs are further categorized into four types: patient-reported outcomes (PROs), clinician-reported outcomes (ClinROs), observer-reported outcomes (ObsROs), and performance outcomes (PerfOs) [24]. While emphasis on PROs has been increasing, along with their greater utilization [25, 26], ClinROs, such as postoperative complications and hospital length of stay (HLOS), remain widely reported outcome measures [27]. ClinROs provide critical insights into the clinical relevance of endpoints and offer consistency across multiple studies [24]. Additionally, clarity on treatment benefits is essential not only for regulatory approval but also for integrating new interventions into clinical practice and justifying reimbursement decisions based on demonstrated added value [28].

HLOS is one of the commonly assessed ClinROs in studies evaluating interventions aimed at enhancing postoperative recovery [29, 30]. It is also frequently used as an indicator for

assessing healthcare systems by evaluating various factors that influence HLOS and by serving as a potential target for quality improvement initiatives [31-35]. HLOS is considered a proxy measure that is less resource-intensive yet equally valid for evaluating in-hospital recovery [29]. However, it is invariably influenced by multiple factors, including nonclinical factors unrelated to a patient's physiological or functional recovery, such as surgeon practice preferences, healthcare resource availability, patient background, and financial status [36-38]. Consequently, these complexities can complicate the use of HLOS as a straightforward metric for quality improvement initiatives in elective surgery populations.

Nevertheless, HLOS can be leveraged as an outcome measure for trauma populations due to its reflection of not only in-hospital recovery but also various clinical and non-clinical factors. Given the heterogeneity of trauma populations, HLOS serves as a practical, real-world indicator and an ideal target for improving patient care. Indeed, previous studies have evaluated factors influencing HLOS in trauma populations with the aim of improving patient outcomes [39-42]. However, none of these studies specifically focused on trauma laparotomy patients. Therefore, this thesis seeks to improve patient outcomes by reducing HLOS in trauma laparotomy patients. Throughout the thesis, HLOS in this specific patient population is assessed from various perspectives to identify potential areas for intervention and improvement.

1.4 – Enhanced recovery protocols in trauma laparotomy patients

Enhanced recovery protocols (ERPs), commonly referred to as Enhanced Recovery After Surgery (ERAS) pathways, are evidence-based, multidisciplinary perioperative care strategies designed to minimize the surgical stress response, optimize physiological function, and expedite postoperative recovery [43, 44]. Originally conceived by Henrik Kehlet in 1995 as the concept of

"fast-track surgery" [45], ERAS has since evolved, with the first guideline being published in 2005 for elective colorectal surgery [46]. Patients managed under ERAS principles can expect faster recoveries, shorter hospital stays, fewer complications, and improved long-term survival. Furthermore, healthcare systems benefit from reduced care costs through ERAS implementation [43, 47]. Since its inception, ERAS has expanded significantly and is now adopted in over 25 countries, becoming the standard of care in elective surgical settings [43, 44]. The ERAS Society has published guidelines in more than 20 surgical specialties, reflecting its broad application across diverse fields [48-67]. ERAS-related research has grown exponentially, with over 4,000 publications, and the guidelines have been cited more than 6,000 times since the ERAS Society's foundation in 2010 [68, 69].

Patients undergoing emergency abdominal surgery, including trauma laparotomy, are considered high-risk due to a range of factors, such as diverse conditions, pre-existing physiological derangements (often involving sepsis or hemorrhage), the urgent nature of these cases, frequent open surgical procedures, and the complexity of their medical and social backgrounds [70, 71]. These factors complicate management, and it was previously believed that such patients were too critically ill to benefit from the core principles of ERAS. However, the recognition that these patients might actually benefit from a structured, protocolized approach led to the integration of ERAS into emergency settings, beginning in the early 2010s with its initial application in emergency colorectal surgery. This approach has since expanded worldwide, demonstrating significant improvements in outcomes across various emergency abdominal surgeries [72-79]. Following the accumulation of evidence supporting positive outcomes, the ERAS Society published guidelines for using ERAS protocols in patients undergoing emergency

laparotomy [80-82]. However, notably, these guidelines excluded patients undergoing trauma laparotomy.

In emergency general surgery, sepsis is the primary cause of physiological derangement, whereas in trauma laparotomy patients, hemorrhage is the most frequently observed cause of physiological instability. While both sepsis and hemorrhage can trigger inflammatory responses leading to systemic inflammatory response syndrome (SIRS), the underlying mechanisms differ between the two conditions. In sepsis, the inflammatory cascade is initiated by extrinsic factors such as infection or bacterial endotoxins, while in hemorrhage, the response is driven by intrinsic factors related to tissue damage and hypoperfusion [83, 84]. In cases of hemorrhage or hemorrhagic shock, prompt hemostasis and adequate resuscitation can significantly mitigate the systemic inflammatory response, often leading to faster recovery compared to patients suffering from sepsis or septic shock, where the inflammatory process may be more severe and prolonged. Additionally, trauma patients tend to be younger than those undergoing emergency general surgery, where the patient population is often older [5, 71]. Given these demographic differences and the unique physiological demands of trauma patients, the concept of ERAS may be more applicable to trauma laparotomy patients. However, to date, only three studies have evaluated the implementation of ERPs in abdominal trauma patients undergoing trauma laparotomy [85-87], in contrast to the extensive research on emergency general surgery populations. This highlights a significant opportunity to further develop and implement ERPs specifically tailored to trauma laparotomy patients.

1.5 – Thesis objectives

This thesis aims to enhance patient care within resource-constrained healthcare systems by specifically focusing on reducing HLOS in trauma laparotomy patients. Given the substantial variability in trauma patient outcomes and the unique challenges presented by the trauma laparotomy subgroup, this work seeks to explore opportunities for optimizing care delivery and patient outcomes through targeted interventions, particularly the implementation of ERPs.

In Chapter 2, the thesis delves into a comprehensive analysis of trauma laparotomy patients using a large trauma registry dataset. This analysis offers a population-level perspective on trauma laparotomy, enabling the identification of general trends and factors associated with HLOS. To enhance the depth of understanding, patients were stratified into cohorts based on HLOS, categorized as short, medium, and long length of stay. This approach allowed for the identification of both clinical and non-clinical factors contributing to their hospitalizations. This stratification serves as a foundation for identifying potential intervention points that could reduce HLOS in this patient population.

Chapter 3 focuses on local clinical contexts, particularly the issue of unnecessary hospital stays, which represent a distinct aspect of prolonged hospitalizations, by investigating the causes of delays after medical clearance in patient discharge at our institution. A retrospective analysis of trauma laparotomy cases was conducted to identify modifiable factors contributing to these extended stays. Understanding these factors is essential for improving hospital efficiency and patient care, as unnecessary stays represent a critical strain on our healthcare resources.

In chapter 4, the thesis details the development and implementation of an ERP tailored specifically for trauma laparotomy patients. A systematic scoping review was first conducted to map existing ERP evidence, not only in trauma laparotomy but also in emergency abdominal surgery populations, due to the limited research available on ERPs for trauma laparotomy

patients. Following this review, a new ERP was developed through a rigorous process that leveraged institutional expertise in ERAS. The newly developed protocol was then implemented at our institution, and a single-center pilot study was conducted to assess its potential for improving patient outcomes.

The specific objectives of this thesis are:

1. To stratify trauma laparotomy patients by HLOS into short, medium, and long length of stay groups, and identify the clinical and non-clinical factors associated with HLOS in each cohort, aiming to identify opportunities for targeted interventions that improve care.
2. To investigate the occurrence of unnecessary hospital stays among trauma laparotomy patients within our clinical settings and identify the contributing factors.
3. To systemically map existing ERP evidence in trauma laparotomy and emergency abdominal surgery populations, identifying key protocol components for the development of a new ERP for trauma laparotomy patients.
4. To describe the development and implementation process of a newly developed ERP for trauma laparotomy patients, assess adherence to protocol components during the early implementation phase, and evaluate its potential impact on patient outcomes.

CHAPTER 2: EXPLORING HOSPITAL LENGTHS OF STAY IN TRAUMA LAPAROTOMY PATIENTS

2.1 – Preamble

In the previous chapter, I outlined the rationale for selecting trauma laparotomy patients as the focus population and hospital length of stay (HLOS) as a key outcome measure for this thesis. To gain a deeper understanding of HLOS within this patient group, a comprehensive analysis was conducted using data from the National Trauma Data Bank (NTDB), the largest trauma registry in the world, managed by the American College of Surgeons (ACS). The NTDB aggregates data from over 900 registered trauma centers across the United States, capturing detailed information on injury types, clinical interventions, and patient outcomes [88, 89]. This extensive registry serves as a critical resource for advancing trauma care, shaping public health policies, and informing clinical guidelines [90-92]. The large sample size, diversity of patients, and comprehensive clinical data available in the NTDB enhance the generalizability of our findings.

Despite focusing on trauma laparotomy patients to minimize heterogeneity, this subgroup still exhibits substantial variability due to the wide range of injury severities and the complexity of procedures performed, from diagnostic interventions to life-saving surgeries [19, 20]. Additionally, factors beyond the nature of the injuries, such as comorbidities and socioeconomic status, further contribute to the heterogeneity of this population [21]. To address this variability and identify potential intervention points, stratifying trauma laparotomy patients by HLOS provides a valuable framework. Categorizing patients into short, medium, and long length of stay groups allows for a more granular understanding of the clinical and non-clinical factors influencing each cohort. This stratification also sets the stage for targeted interventions aimed at reducing HLOS and improving patient outcomes.

This manuscript introduces a novel approach by stratifying trauma laparotomy patients according to HLOS and focusing not only on factors associated with prolonged hospital stays but also on those linked to short stays, which have been previously unexplored in trauma populations. The insights gained from this comprehensive analysis have the potential to inform future care strategies, including the introduction of enhanced recovery protocols (ERPs) tailored specifically for trauma laparotomy patients. The manuscript has been submitted to the *Trauma Surgery and Acute Care Open* and is currently under review.

2.2 – Understanding Hospital Length of Stay in Trauma Laparotomy Patients: A National Trauma Database Study

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ABSTRACT

Introduction: The diverse procedures and varying patient conditions in trauma laparotomy cases lead to significant variability in hospital length of stay (HLOS), posing challenges for effective patient care. Strategies to reduce HLOS are varied, with multiple factors potentially modifiable through targeted interventions. These interventions are most effective when target populations and their associated factors are clearly defined. This study aimed to stratify trauma laparotomy patients by their HLOS and identify factors associated with HLOS to enhance patient care.

Methods: A retrospective analysis was conducted using the National Trauma Data Bank from January 2017 to December 2019. Adult trauma patients who underwent trauma laparotomy following blunt or penetrating abdominal injuries were identified using ICD-10 codes and abbreviated injury scales. HLOS was stratified into three groups based on the interquartile range of the study population: short (< 5 days), medium (5 to 11 days), and long (> 11 days).

Results: A total of 27,434 trauma laparotomy patients were identified. The overall median HLOS was 7.0 [5.0, 11.0] days. Penetrating mechanisms, particularly stab wounds were strongly associated with a short HLOS. Additionally, isolated abdominal trauma, splenic injuries, or spleen related procedure were more likely to result in a short HLOS. Patients with a long HLOS experienced higher rates of in-hospital complications and were more frequently discharged to home with home health services or to extended care facilities. Most comorbidities were associated with a long HLOS, and patients with Medicaid or Medicare had a higher likelihood of a long HLOS.

Conclusion: There was significant variability in HLOS distribution even within a relatively homogenous trauma population. Stratification based on HLOS revealed distinct factors associated with short and long HLOS categories, indicating that targeted interventions for each

category could potentially reduce HLOS and enhance patient outcomes in the current era of constrained healthcare resources.

What is already known on this topic: Prolonged hospital stays are associated with various negative consequences. Factors contributing to prolonged hospital stays have been studied in the broader trauma population.

What this study adds: This study specifically focuses on patients who underwent trauma laparotomy, a relatively homogenous subgroup within the trauma population. It highlights differences in patient characteristics and associated factors among groups stratified by hospital length of stay.

How this study might affect research, practice or policy: The findings suggest potential benefits from targeted interventions based on hospital length of stay.

Level of Evidence, study type: Level IV, therapeutic/care management

Introduction:

Healthcare systems worldwide face challenges stemming from resource constraints such as staff shortages, limited bed availability, and financial limitations. These issues are evident in the field of trauma surgery, as in many other medical disciplines [1]. Initiatives to eliminate waste in healthcare by reducing overuse or misuse are essential, and streamlining patient care effectively is crucial to achieving this goal [2].

A trauma laparotomy is a common procedure in trauma surgery for both blunt and penetrating abdominal injuries. It encompasses a range of interventions, including the control of life-threatening hemorrhage, management of contamination, and exploratory diagnostic procedures [3, 4]. Additionally, various factors beyond the injuries themselves contribute to the diversity of this patient population, including the urgency of the emergency situations, the resource-intensive nature of management, patients' intricate medical and social backgrounds, and institutional system limitations [5, 6]. These diversities pose challenges when implementing initiatives or conducting research in this population. There is a necessity to stratify this patient population to gain a deeper understanding and to implement interventions that ensure effective patient care.

Hospital length of stay (HLOS) has been utilized as a meaningful outcome measure and a potential target for quality improvement activities [7-9]. Prolonged HLOS can lead to harm, such as an increased risk of nosocomial infections, physical deconditioning, and diminished quality of life, and it is also a major driver of healthcare costs [10, 11]. Therefore, it is closely monitored by hospitals and healthcare systems [12]. In contrast to elective surgery, the HLOS for trauma laparotomy patients is influenced by numerous clinical and non-clinical factors, as mentioned earlier. This complexity complicates the use of HLOS as a measure for quality improvement initiatives [13]. Nevertheless, for the practical aim of enhancing patient care, utilizing HLOS can

be justified, as it reflects not only the severity of injuries and procedures performed but also various individual factors affecting their in-hospital clinical progress. Strategies to reduce HLOS are diverse, and multiple factors influencing HLOS can potentially be modified through these intervention efforts [14].

Building on these contexts, this study aimed to stratify trauma laparotomy patients according to their HLOS into short, medium, and long length of stay (LOS), and to identify the clinical and non-clinical factors associated with HLOS in these patients to ultimately achieve effective patient care.

Methods:

Data source

A retrospective analysis was performed using the National Trauma Data Bank (NTDB) from January 2017 to December 2019. The NTDB, managed by the American College of Surgeons (ACS), is the largest aggregation of trauma registry data in the United States (US), with participation from over 900 hospitals. It adheres to the National Trauma Data Standard, which defines the reporting of specific data elements and includes patient demographics, injury-related information, and patient outcomes [15-17].

Study population

Adult trauma patients (18 years and older) who underwent a laparotomy following blunt or penetrating abdominal injuries were included in this study. These patients were identified using the International Classification of Diseases, 10^{th} Revision, Procedure Coding System (ICD-10-PCS). ICD-10-PCS is a set of medical classification codes used for procedural coding in the healthcare industry, covering all procedural data in inpatient settings, including surgeries, diagnostic procedures, and other medical interventions. Each ICD-10-PCS code consists of seven

alphanumeric characters without decimal points (e.g., 0FT10ZZ: resection of the right lobe of the liver using an open approach) [18]. Coding details are explained in Supplemental Material 1. In this study, we used the following logic: character 1 (section) = 0 (surgical), character 2 (body system) = 1, 4, 6, 7, D, F, G, T, U, W, character 3 (operation) = ANY, character 4 (body part) = alphanumeric characters applicable when combined with character 2, character 5 (approach) = 0 (open approach), character 6 (device) = ANY, character 7 (qualifier) = ANY. Based on this logic, we identified 109 codes, all listed in Supplemental Material 2.

We excluded patients under 18 years old, those who underwent laparoscopic procedures, and those with missing HLOS data. Missing HLOS data were all due to administrative reasons. Patients who died during hospitalization were also excluded because severe injuries leading to early death could result in a short HLOS, skewing the results. Additionally, we excluded patients with severe trauma in regions other than the abdomen, as our objective was to focus on abdominal trauma patients who underwent laparotomy. Using the Abbreviated Injury Scale (AIS), we identified patients with polytraumas, and then excluded those with an AIS severity greater than 3 in other body regions. Among those with isolated abdominal injuries, injuries of all severities were included (Supplemental Material 3).

Data collection, definitions, and outcomes of interest

Variables collected included patient demographics (age, gender, and race), primary method of payment, patient comorbid conditions, body mass index (BMI), drug/alcohol screen, ICD-10-Clinical Modification (CM) codes, ICD-10-PCS codes, AIS predot code and severity, injury severity score (ISS), type of trauma (blunt or penetrating), injury intent, mechanism of injury, HLOS, blood transfusions (red blood cells, plasma, platelets), laparotomy for hemorrhage

control, in-hospital complications, hospital discharge disposition, hospital bed size, and trauma center ACS verification level.

ICD-10-CM describes diagnosis codes used for a variety of purposes, including hospital, ambulatory surgical, and clinic reimbursement [19]. Each code consists of 3 to 7 alphanumeric characters, starting with a letter and containing a decimal point after the third character. The first three characters specify the chapter of disease categories that includes the pathology in question. For instance, S36 represents injuries of intra-abdominal organs, with additional numeric values after the decimal point to describe specific anatomic locations (e.g., S36.0: injury of spleen, S36.1: injury of liver, gallbladder, and bile duct) [18]. We identified 39 applicable ICD-10-CM codes and categorized them into the following 10 systems: “Superficial”, “Major vessels”, “Abdominal blood vessels”, “Spleen”, “Hepatobiliary”, “Pancreas”, “Upper GI”, “Colon/Rectum”, “Kidney”, and “Genital/Urinary” (Supplemental Material 4). In the NTDB, the volume of blood transfusions was reported in either “Units” or “CCs (mLs)”. To standardize the data for analysis, we converted “CCs (mLs)” to “Units”. HLOS was defined as the cumulative amount of time spent in the hospital. Each partial or full day was measured as one calendar day, calculated as the discharge date minus the admission date plus one day. HLOS was stratified into three groups based on the interquartile range (IQR) of our study population: short (< 5 days), medium (5 to 11 days), and long (> 11 days) LOS groups. The IQR was used to define the medium LOS group, and the short and long groups were defined as HLOS less than or greater than the IQR respectively.

The primary outcomes of interest in this study were to identify factors associated with both short and long LOS in patients who underwent laparotomy following abdominal trauma.

Statistical analysis

HLOS is reported as median values to maintain consistency with ACS reports from the NTDB and the Trauma Quality Improvement Program [12]. Descriptive statistics were used to calculate proportions and means for characteristics among the short, medium, and long LOS groups. Fisher's exact test was used to assess statistically significant differences in categorical variables across the three HLOS groups, whereas a Kruskal-Wallis test with a Bonferroni correction was used for continuous variables. Logistic regression models were used to explore characteristics that were associated with short and long HLOS. For the short HLOS outcome, an HLOS of ≥ 5 days was used as the reference category, and for the long HLOS outcome, an HLOS < 11 days was used as the reference category. Models were adjusted for potential confounding variables, including age, gender, and ISS. Logistic regression models are presented as odds ratios (OR) with 95% confidence intervals (CI). Only the results of models that were statistically significant are presented in the results. P-values less than 0.05 and 95 % CIs that exclude the null OR were considered statistically significant. All analyses were performed using SAS® Studio, release 3.81 (Enterprise Edition), copyright© 2012-2020, SAS Institute Inc., Cary, NC, USA.

Results:

Baseline characteristics by HLOS

A total of 27,434 patients were identified as meeting the inclusion criteria during the study period. The overall median HLOS in our study population was 7.0 [5.0, 11.0] days, with a right-skewed distribution (Figure 1). There were 5,373 patients (19.6%) in the short LOS group (< 5 days), 15,621 patients (56.9%) in the medium LOS group (5 to 11 days), and 6,440 patients (23.5%) in the long LOS group (> 11 days).

Patient demographic characteristics and hospital characteristics, stratified by the three HLOS groups, are presented in Table 1. Approximately 80% of patients were male across all groups.

Patients with longer HLOS were significantly older, with a mean age of 41.03 years (95% CI: 40.63, 41.44), than those in the short and medium LOS groups. Around 50% of the patients were White, with a higher prevalence in the short LOS group. In contrast, approximately 30% of the patients were Black, with a higher prevalence in the long LOS group. The prevalence of patients using self-pay as their primary payment method was highest in the short LOS group (24.6%), whereas Medicare coverage was more prevalent in the long LOS group (12.5%). Those in the long LOS group had significantly higher proportions of comorbidities, including hypertension, diabetes mellitus, chronic obstructive pulmonary disease (COPD), congestive heart failure, cirrhosis, chronic renal failure, cerebrovascular accident (CVA), and anticoagulant therapy, compared to the short and medium LOS groups. Additionally, patients with longer LOS had a higher prevalence of functional dependency and obesity, and a lower prevalence of current smoking.

The long LOS group experienced significantly higher proportions of all reported in-hospital complications compared to the short and medium LOS groups. The majority (80.6%) of patients in the short LOS group were discharged to home or self-care. In contrast, approximately half (49.5%) of patients in the long LOS group were discharged to home, while others were more frequently discharged to home with organized home health services (17.7%) or to facilities requiring extended care, such as inpatient rehabilitation centers (11.1%), skilled nursing facilities (7.6%), or long-term care hospitals (3.4%).

Approximately 70% of the patients were treated at level 1 or 2 trauma centers with more than 400 beds across the three HLOS groups.

Trauma-related characteristics by HLOS

The trauma-related characteristics of the study population are presented in Table 2. Penetrating mechanisms were more frequent across all groups, with the highest proportion in the short LOS group (73.5%). Among the penetrating mechanisms, stab wounds were significantly more prevalent (55.7%) in the short LOS group, whereas firearm-related injuries were significantly more prevalent (44.0%) in the long LOS group. Most blunt mechanisms, such as falls and motor vehicle traffic-related (MVT) injuries, were more frequent in the long LOS group.

While superficial injuries were more common in the short LOS group, the prevalence of injuries to abdominal organs was successively higher as HLOS increased. The frequency of isolated abdominal injuries was highest (54.3%) in the short LOS group. Additionally, the mean injury severity score (ISS) was highest in the long LOS group, with a mean of 13.63 (95% CI: 13.4, 13.7). These patients also received more blood transfusions. The most frequent procedures performed, apart from exploratory laparotomy, were procedures involving the small bowels, followed by those involving the large bowels. Laparotomies for hemorrhage control accounted for 9.9% of the procedures performed in the short LOS group, 22.5% in the medium LOS group, and 41.7% in the long LOS group, showing a proportional increase across HLOS groups.

Factors associated with short and long HLOS

Patient, trauma-related, and hospital characteristics associated with short (LOS < 5 days vs ≥ 5 days) and long (LOS < 11 days vs ≥ 11 days) HLOS are presented in Tables 3 and 4. Presenting with a penetrating injury was associated with a higher likelihood of a short HLOS (adjusted OR (aOR) 1.13; 95% CI: 1.05, 1.21) compared to a long HLOS. Specifically, having a stab wound was strongly associated with a short HLOS (aOR 2.64; 95% CI: 2.46, 2.82). Patients who were self-paying or using other government payment methods were more likely to have a short HLOS (aOR 1.12; 95% CI: 1.04, 1.20 and aOR 1.24; 95% CI: 1.07, 1.43, respectively). Patients with

isolated abdominal trauma were more likely to have a short HLOS (aOR 1.16; 95% CI: 1.08, 1.23). In terms of specific injuries and procedures, patients with superficial wounds (aOR 1.61; 95% CI: 1.50, 1.71), splenic injuries (aOR 1.30; 95% CI: 1.17, 1.45), and spleen-related procedures (aOR 1.31; 95% CI 1.17, 1.47) were more likely to have a short HLOS.
Factors associated with long HLOS included identifying as Black (aOR 1.44; 95% CI: 1.35, 1.53) and presenting with penetrating injuries, particularly firearm-related injuries (aOR 2.57; 95% CI: 2.41, 2.74), MVT pedestrian incidents (aOR 2.00; 95% CI: 1.55, 2.58), and patients with Medicaid or Medicare (aOR 1.15; 95% CI: 1.08, 1.23 and aOR 1.34; 95% CI: 1.20, 1.49, respectively). Most comorbidities were associated with a long HLOS, with functional dependency (aOR 1.91; 95% CI: 1.48, 2.48), cirrhosis (aOR 1.68; 95% CI: 1.30, 2.18), and chronic renal failure (aOR 1.68; 95% CI: 1.16, 2.44) having the strongest association. Additionally, patients undergoing laparotomy for hemorrhage control (aOR 2.16; 95% CI 2.02, 2.30), those requiring more transfusions (all components), and those treated at level 1 trauma centers (aOR 1.07; 95% CI: 1.01, 1.14) had higher odds of long HLOS. Most injuries and procedures, except spleen-related ones, were positively associated with long HLOS. Notably, injuries to and procedures for major vessels (such as the aorta or inferior vena cava) and the pancreas were strongly associated with long HLOS (diagnoses: aOR 3.09; 95% CI: 2.52, 3.77 and aOR 3.33; 95% CI: 2.95, 3.76; procedures: aOR 3.84; 95% CI: 3.09, 4.78 and aOR 3.23; 95% CI: 2.78, 3.76, respectively).

Discussions:

In our large registry-based study of 27,434 adult patients undergoing laparotomy following abdominal injuries, the median HLOS was 7.0 [5.0, 11.0] days. Penetrating mechanisms, particularly stab wounds, were strongly associated with a short HLOS. Additionally, patients

with isolated abdominal trauma, superficial injuries, splenic injuries, or spleen-related procedures were more likely to have a short HLOS. Patients with Medicaid or Medicare showed a higher likelihood of a long HLOS. Most comorbidities were associated with a long HLOS, and the long LOS group experienced higher rates of in-hospital complications. Patients in the long LOS group were more frequently discharged to home with home health services or to extended care facilities.

HLOS is a widely used outcome measure and quality metric within healthcare systems. A reduction in HLOS implies enhanced efficiency and effectiveness of care, including improvements in bed turnover, alignment of demand with hospital capacity, operation room and intensive care unit (ICU) utilization, and facilitation of inter-hospital transfers [20]. This is particularly important as patients with prolonged HLOS tend to consume substantial hospital resources. Consequently, various interventions have been developed and evaluated to reduce HLOS [21-25]. A systematic review by Siddique et al. [14] identified eight strategies for reducing HLOS in high-risk populations and concluded that no single intervention was consistently associated with reduced HLOS. Our study indicates that even within a relatively homogenous patient population undergoing trauma laparotomy, there is significant variability in HLOS distribution, with distinctly different patient characteristics associated with different HLOS categories. This suggests that a tailored approach, considering both clinical and non-clinical factors associated with HLOS, is necessary to effectively reduce HLOS in these patients. Clinical pathways, including Enhanced Recovery After Surgery (ERAS) pathways, can be an effective intervention for patients in the short and medium LOS groups, where 77% of patients had a HLOS of less than 11 days. ERAS pathways are regarded as the standard of care in many elective surgical settings [26-28], and international ERAS society guidelines for emergency

laparotomy have been published [29-31]. However, these guidelines exclude trauma laparotomy patients. A recent scoping review on Enhanced Recovery Protocols (ERP) in trauma and emergency abdominal surgery found that only two studies have evaluated the implementation of ERAS pathways in abdominal trauma patients requiring laparotomy [32]. This limited implementation is likely due to the diverse range of patient conditions within this population. Our study identified several factors associated with short LOS, including penetrating mechanisms, particularly stab wounds, isolated abdominal trauma, superficial injuries, splenic injuries, and spleen-related procedures. These findings align with the study by Moydien et al. from South Africa, which included patients with isolated penetrating abdominal trauma and evaluated the effectiveness of ERP [33]. They demonstrated a significant reduction in HLOS without any increase in postoperative complications. This suggests that patients with penetrating mechanisms, especially stab wounds, and isolated abdominal trauma could greatly benefit from the implementation of these pathways. High-volume centers with a higher proportion of penetrating trauma, such as those in the United States or South Africa, should consider adopting this intervention to reduce HLOS. Additionally, given that splenic injury and related procedures were also associated with a short LOS, and many candidates for the pathways fall within the medium LOS group, there is potential for ERAS pathways to be effective across a broader range of trauma laparotomy patients, including those with blunt mechanisms, in multiple centers when the patient population is adequately selected. Further studies are needed to evaluate the effectiveness of ERAS pathways in trauma laparotomy patients, including the introduction of selection criteria for candidate patients.

Prolonged hospitalizations have been a critical issue in the healthcare system, as they can pose significant clinical risks, such as hospital-acquired infections and complications, and lead to

increased costs. The factors associated with prolonged hospitalizations have been extensively studied across various medical fields to better understand and mitigate these risks [34-37]. In this study, we identified several factors associated with a long HLOS. Many of these factors, particularly trauma-related ones such as the mechanism of injury, specific injuries and procedures, injury severity, and transfusion requirements, are unmodifiable. The association with long HLOS is likely correlative rather than causal, due to the numerous required interventions, high risk of complications, and disposition issues. However, several factors suggest potential interventions that could mitigate prolonged hospitalization. In our study, most comorbidities were associated with long HLOS, consistent with previous studies [34, 38, 39]. Although the mean age of the long LOS group was 41.03 years, the cohort includes older patients, and adults aged 65 years and older represent the fastest-growing trauma demographic [40]. These older trauma patients experience increased morbidity and mortality due to comorbidities, polypharmacy, and frailty. Given that trauma patients face similar challenges to those in other medical disciplines, it is crucial to involve a specialized multidisciplinary team for the initial assessment and management of these high-risk patients. Initiatives involving multidisciplinary teams to provide comprehensive care, including geriatric assessment and medication management, have been proposed [41, 42]. Such interprofessional collaboration enhances communication and coordination, aiming for better patient outcomes, reducing adverse events, and increasing the use of evidence-based practices [43]. Assessing trauma laparotomy patients early in their treatment, identifying high-risk individuals, and involving a multidisciplinary team, including physicians from various specialties, geriatricians, pharmacologists, physiotherapists, and nutritionists, ensures comprehensive management. Early involvement of specialists allows for better-tailored interventions, timely adjustments in treatment plans, and enhanced care

coordination, ultimately reducing HLOS and improving overall patient care quality, leading to better long-term outcomes for this patient population.

Demographic factors, including race and insurance status, have been reported as associated factors of HLOS [44]. In Hwabejire's study on excessively prolonged hospitalization [36], patients covered by Medicare or Medicaid exhibited a higher likelihood of extended HLOS, corroborating the findings of our study. Numerous studies across various medical disciplines have identified public insurance coverage, particularly Medicaid, as a significant factor associated with prolonged hospitalizations [34, 35, 45]. Insurance status is a crucial determinant of access to post-acute care services. Medicaid is characterized by challenges such as low reimbursement rates, regional variability, and administrative delays, including mandatory waiting periods [35]. Although Medicare is less frequently highlighted as a factor in HLOS due to its common role as a reference group, it also presents barriers to accessing post-acute care. These barriers include coverage limitations, reduced availability of Medicare-covered post-acute care services, and hospital readmission penalties imposed by the Hospital Readmission Reduction Program (HRRP) [46]. Our study results show that patients in the long LOS group were more frequently discharged to facilities requiring extended care. This suggests that public insurance status partly influences long HLOS and indicates the need for interventions to improve access to post-acute care services. Enhancing discharge planning is essential, and incorporating case mangers and social workers into the multidisciplinary team can significantly benefit trauma services by promoting seamless transitions to post-acute care [12, 47]. Fragmentation between acute and post-acute care settings often leads to communication breakdowns and care gaps. Promoting systematic collaboration and implementing care coordination programs can bridge this gap and enhance continuity of care [48].

Patients covered by Medicaid or Medicare are at a heightened risk for long-term financial strain, commonly referred to as financial toxicity. This term denotes the economic burden and stress that patients endure due to medical treatment costs, which can have significant implications for their financial well-being. The impact on injured patients is particularly substantial, as injuries are often unplanned and disruptive, frequently leading to short-term or long-term disability [49]. Additionally, patients on Medicaid or Medicare typically come from lower socioeconomic backgrounds, making them more susceptible to financial instability. Delays in their disposition can exacerbate these situations. Therefore, interventions aimed at mitigating financial toxicity, such as policy changes that expand coverage for post-acute care, increase the affordability of necessary follow-up care, enhance reimbursement rates, and reduce out-of-pocket costs, have the potential to decrease HLOS and ultimately improve long-term patient outcomes.

Limitations

This study utilized retrospective administrative data from a large registry and is subject to several limitations. The quality of the reported data relied entirely on the collection and reporting processes of each trauma center participating in the NTDB. Some patients had missing data, therefore caution should be used when interpreting the results, as pair-wise deletion was employed. Variations in the reporting of injuries and procedures among trauma centers posed challenges, particularly in assessing superficial injuries and exploratory laparotomies. For instance, some centers reported only the liver laceration and associated procedures for a patient with stab wound and a liver laceration, while others documented both the skin and liver lacerations, along with the exploratory laparotomy and liver-related procedures. This inconsistency led to an overestimation of exploratory laparotomies and hindered accurate assessment of patients requiring only an exploratory laparotomy.

The chosen patient cohort warrants careful consideration. We intentionally restricted the cohort to those who underwent laparotomy following abdominal injuries and excluded patients with severe injuries to body regions other than the abdomen. This approach aimed to facilitate the assessment of factors associated with HLOS in trauma laparotomy patients. However, this restriction resulted in a less representative dataset, particularly for polytrauma patients who underwent trauma laparotomy, thereby limiting the ability to evaluate this specific patient subgroup. Employing a unique logic to identify the patient cohort could also have led to potential over- or under-representation. Lastly, injuries and procedures were identified using ICD-10 codes, which, due to their detail and specificity, required categorization by organ for the purposes of this study. This approach may have limited the capture of all clinical nuances and context needed to comprehensively evaluate outcomes.

Conclusions:

This large registry study assessed patients who underwent laparotomy following abdominal injuries. Even within this relatively homogeneous trauma population, there was significant variability in HLOS distribution. Stratification based on HLOS revealed distinct clinical and non-clinical factors associated with short and long HLOS categories. This indicates that targeted interventions for each category, such as implementing ERAS pathways, proactively involving a multidisciplinary team, or initiating efforts to mitigate financial toxicity, could potentially reduce HLOS and ultimately enhance patient outcomes. Given the significant heterogeneity among trauma patients, this approach may be applicable to a broader range of trauma populations, particularly in the current era of constrained healthcare resources.

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Declarations of interest: The authors declare that they have no conflicts of interest.

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Table 1. Patient demographics and hospital characteristics by hospital length of stay category

	LOS <5 days (n=5,373)	LOS 5-11 days (n=15,621)	LOS >11 days (n=6,440)	p-value
Male, n (%)	4409 (82.1)	12163 (77.9)	5024 (78.0)	<0.0001
Mean age (95% CI)	35.03 (34.68, 35.39)	37.06 (36.82, 37.29)	41.03 (40.63, 41.44)	<0.0001
Racial background				
Asian	87 (1.6)	318 (2.0)	138 (2.1)	0.0937
American Indian	93 (1.7)	189 (1.2)	69 (1.1)	0.0032
Black	1550 (28.9)	4894 (31.3)	2211 (34.3)	<0.0001
White	2864 (53.3)	8143 (52.1)	3183 (49.4)	<0.0001
Other/pacific islander	6580 (12.7)	1772 (11.3)	698 (10.8)	0.0061
Primary payment method				
Medicaid	1585 (29.5)	4465 (28.6)	1835 (28.5)	0.3886
Medicare	293 (5.5)	1187 (7.6)	802 (12.5)	<0.0001
Not billed (for any reason)	53 (1.0)	89 (0.6)	48 (0.8)	0.0054
Self-pay	1321 (24.6)	3320 (21.3)	1183 (18.4)	<0.0001
Private/commercial insurance	1506 (28.0)	5033 (32.2)	1953 (30.3)	<0.0001
Other government	303 (5.6)	631 (4.0)	235 (3.7)	<0.0001
Comorbid conditions				
Anticoagulant therapy	47 (1.3)	303 (2.8)	236 (5.1)	<0.0001
Hypertension	579 (14.9)	2140 (18.5)	1285 (26.0)	<0.0001
Congestive heart failure	38 (0.7)	156 (1.0)	145 (2.3)	<0.0001
COPD	116 (3.1)	382 (3.5)	261 (5.6)	<0.0001
Diabetes mellitus	246 (6.5)	828 (7.4)	547 (11.5)	<0.0001
Chronic renal failure	8 (0.2)	62 (0.6)	56 (1.2)	<0.0001
Alcohol Use Disorder	335 (8.9)	970 (8.7)	509 (10.8)	0.0001
Cirrhosis	30 (0.8)	128 (1.2)	110 (2.4)	<0.0001
Cerebrovascular accident	19 (0.5)	79 (0.7)	59 (1.3)	0.0001
Mental/Personality disorder	776 (19.7)	1743 (15.3)	970 (19.9)	<0.0001
Functionally dependent health status	29 (0.8)	125 (1.1)	118 (2.6)	<0.0001
Current smoker	1769 (41.8)	4708 (38.3)	1702 (33.5)	<0.0001
Substance abuse disorder	734 (19.0)	2030 (17.8)	770 (16.2)	0.0026
Not Known/Not stated	1473 (27.4)	4512 (28.9)	1759 (27.3)	0.0210
Body mass index (BMI)				<0.0001
Underweight	90 (1.7)	359 (2.3)	128 (2.0)	
Normal	1745 (32.5)	5043 (32.3)	1829 (28.4)	
Overweight	1531 (28.5)	4601 (29.5)	1911 (29.7)	
Obese	1239 (23.1)	3926 (25.1)	1975 (30.7)	
Drug screen				
Positive	1274 (23.7)	3837 (24.6)	1490 (23.1)	0.0631
Alcohol screen	3702 (68.9)	10570 (67.7)	4324 (67.1)	0.1506
In-hospital complications				
Deep vein thrombosis	2 (0.1)	54 (0.5)	344 (7.4)	<0.0001
Pulmonary embolism	0 (0.0)	39 (0.4)	170 (3.7)	<0.0001

Acute kidney injury	5 (0.1)	43 (0.4)	314 (6.8)	<0.0001
Acute respiratory distress syndrome	0 (0.0)	14 (0.1)	117 (2.6)	<0.0001
Severe sepsis	0 (0.0)	17 (0.2)	226 (4.9)	<0.0001
Surgical site infection	5 (0.1)	101 (0.7)	771 (12.0)	<0.0001
Alcohol withdrawal syndrome	16 (0.4)	99 (0.9)	139 (3.0)	<0.0001
Unplanned return to the OR	8 (0.2)	235 (2.2)	821 (17.2)	<0.0001
Unplanned admission to the ICU	13 (0.4)	233 (2.1)	629 (13.3)	<0.0001
Not known/Not recorded	3571 (66.5)	9977 (63.9)	2606 (40.5)	<0.0001
Hospital discharge disposition				
Discharged/Transferred to a short-term general hospital for inpatient care	267 (5.0)	156 (1.0)	92 (1.4)	<0.0001
Discharged/Transferred to home under care of organized home health service	134 (2.5)	1321 (8.5)	1141 (17.7)	<0.0001
Discharged to home or self-care (routine discharge)	4328 (80.6)	12074 (77.3)	3186 (49.5)	<0.0001
Discharged/Transferred to skilled nursing facility	16 (0.3)	286 (1.8)	491 (7.6)	<0.0001
Discharged/Transferred to inpatient rehab or designated unit	15 (0.3)	395 (2.5)	712 (11.1)	<0.0001
Discharged/Transferred to long term care hospital	3 (0.1)	15 (0.1)	216 (3.4)	<0.0001
Discharged/Transferred to a psychiatric hospital or psychiatric distinct part unit of a hospital	266 (5.0)	625 (4.0)	247 (3.8)	0.0038
Left against medical advice or discontinued care	162 (3.0)	210 (1.3)	67 (1.0)	<0.0001
Hospital bed size				
<= 200	388 (7.2)	993 (6.4)	377 (5.9)	0.0096
201-400	1413 (26.3)	4101 (26.3)	1556 (24.2)	0.0033
401-600	1632 (30.4)	4661 (29.8)	1997 (31.0)	0.2183
> 600	1940 (36.1)	5866 (37.6)	2510 (39.0)	0.0058
Trauma center verification level				
Level I	2759 (51.4)	7742 (49.6)	3330 (51.7)	0.0047
Level II	1160 (21.6)	3416 (21.9)	1308 (20.3)	0.0361
Level III	231 (4.3)	470 (3.0)	145 (2.3)	<0.0001

COPD chronic obstructive pulmonary disease, OR operation room, ICU intensive care unit.

Table 2. Trauma-related characteristics by hospital length of stay category

	LOS <5 days (n=5,373)	LOS 5-11 days (n=15,621)	LOS>11 days (n=6,440)	p-value
Trauma type				
Blunt	1350 (25.1)	6259 (40.1)	2561 (39.8)	<0.0001
Penetrating	3947 (73.5)	9109 (58.3)	3773 (58.6)	<0.0001
Injury intent				
Unintentional	1734 (32.3)	6630 (42.4)	2690 (41.8)	<0.0001
Self-inflicted	647 (12.0)	1113 (7.1)	541 (8.4)	<0.0001
Assault	2840 (52.9)	7386 (47.3)	2965 (46.0)	<0.0001
Mechanism of injury				
Stab	2993 (55.7)	4142 (26.5)	939 (14.6)	<0.0001
Firearm	953 (17.7)	4964 (31.8)	2832 (44.0)	<0.0001
Fall	286 (5.3)	1077 (6.9)	472 (7.3)	<0.0001
Machinery	21 (0.4)	37 (0.2)	17 (0.3)	0.1734
MVT Occupant	551 (10.3)	3094 (19.8)	1305 (20.3)	<0.0001
MVT Motorcyclist	57 (1.1)	272 (1.7)	126 (2.0)	0.0003
MVT Pedestrian	18 (0.3)	127 (0.8)	120 (1.9)	<0.0001
MVT Unspecified/MVT other/pedal cyclist, other	113 (2.1)	516 (3.3)	167 (2.6)	<0.0001
ICD Diagnosis				
Major vessels*	18 (0.3)	165 (1.1)	259 (4.0)	<0.0001
Abdominal blood vessels	302 (5.6)	1235 (7.9)	1002 (15.6)	<0.0001
Spleen	533 (9.9)	2751 (17.6)	1241 (19.3)	<0.0001
Hepatobiliary	714 (13.3)	2446 (15.7)	1623 (25.2)	<0.0001
Pancreas	55 (1.0)	520 (3.3)	676 (10.5)	<0.0001
Upper GI	929 (17.3)	6750 (43.2)	3416 (53.0)	<0.0001
Colon/Rectum	651 (12.1)	4682 (30.0)	2799 (43.5)	<0.0001
Kidney	135 (2.5)	1115 (7.1)	906 (14.1)	<0.0001
Genital/Urinary	280 (5.2)	1192 (7.6)	638 (9.9)	<0.0001
Superficial	3233 (60.2)	6181 (39.6)	2324 (36.1)	<0.0001
ISS	6.5 (6.3, 6.7)	10.7 (10.6, 10.8)	13.6 (13.4, 13.7)	<0.0001
Isolated abdominal injury	2915 (54.3)	6657 (42.6)	2193 (34.1)	<0.0001
ICD Procedure				
Major vessels	11 (0.2)	133 (0.9)	231 (3.6)	<0.0001
Abdominal blood vessels	101 (1.9)	504 (3.2)	461 (7.2)	<0.0001
Spleen	448 (8.3)	2447 (15.7)	1057 (16.4)	<0.0001
Hepatobiliary	393 (7.3)	1488 (9.5)	1168 (18.1)	<0.0001
Pancreas	21 (0.4)	328 (2.1)	432 (6.7)	<0.0001
Stomach	329 (6.1)	1475 (9.4)	1075 (16.7)	<0.0001
Small intestine	1128 (21.0)	6992 (44.8)	3673 (57.0)	<0.0001
Large intestine	635 (11.8)	4916 (31.5)	3086 (47.9)	<0.0001
Kidney	44 (0.8)	477 (3.1)	463 (7.2)	<0.0001
Genital/Urinary	303 (5.6)	1085 (7.0)	555 (8.6)	<0.0001
Abdominal cavity**	4322 (80.4)	11845 (75.8)	5143 (79.9)	<0.0001
Laparotomy for hemorrhage control	496 (9.2)	3317 (21.2)	2570 (39.9)	<0.0001
Blood transfusions (unit)				
Red blood cell in 4 Hours	0.32 (0.29, 0.36)	0.89 (0.86, 0.93)	3.02 (2.87, 3.16)	<0.0001

Plasma in 4 hours	1.38 (1.16, 1.59)	2.03 (1.94, 2.13)	4.57 (4.34, 4.81)	<0.0001
Platelet in 4 hours	0.34 (0.22, 0.47)	0.51 (0.46, 0.56)	1.08 (1.00, 1.16)	<0.0001

* Abdominal aorta and inferior vena cava. **Exploratory laparotomy.

MVT motor vehicle traffic, ICD international classification of diseases, GI gastrointestinal, ISS injury severity score.

Table 3. Patient, trauma-related, and hospital characteristics associated with short hospital length of stay

	LOS <5 days vs. ≥5 days (ref.) OR (95% CI)	
	Univariate model	**Multivariate model**
Racial background		
American Indian	1.49 (1.17, 1.89)*	1.33 (1.03, 1.71)*
White	1.08 (1.02, 1.15)*	1.29 (1.21, 1.38)*
Other/pacific islander	1.15 (1.05, 1.26)*	1.05 (0.96, 1.16)
Mechanism of injury		
Stab	4.2 (3.95, 4.47)*	2.64 (2.46, 2.82)*
Fall	0.75 (0.65, 0.85)*	1.23 (1.07, 1.42)*
Machinery	1.60 (0.97, 2.65)	1.87 (1.08, 3.24)*
Trauma type		
Penetrating	1.97 (1.85, 2.11)*	1.13 (1.05, 1.21)*
Trauma center verification level		
Level I	1.05 (0.99, 1.11)	1.07 (1.01, 1.14)*
Level III	1.57 (1.34, 1.83)*	1.63 (1.38, 1.93)*
Primary payment method		
Not billed (for any reason)	1.60 (1.16, 2.19)*	1.36 (0.96, 1.91)
Self-pay	1.27 (1.19, 1.36)*	1.12 (1.04, 1.20)*
Other government	1.46 (1.28, 1.67)*	1.24 (1.07, 1.43)*
Comorbid conditions		
Mental/Personality Disorder	1.23 (1.12, 1.34)*	1.03 (0.93, 1.13)
Current Smoker	1.23 (1.15, 1.32)*	1.18 (1.10, 1.27)*
Substance Abuse Disorder	1.12 (1.02, 1.23)*	1.06 (0.96, 1.16)
ICD Diagnosis		
Superficial	2.41 (2.27, 2.56)*	1.61 (1.50, 1.71)*
Spleen	0.50 (0.45, 0.55)*	1.30 (1.17, 1.45)*
Isolated abdominal trauma	1.77 (1.67, 1.88)*	1.16 (1.08, 1.23)*
ICD Procedure		
Spleen	0.48 (0.43, 0.53)*	1.31 (1.17, 1.47)*
Abdominal cavity	1.23 (1.14, 1.32)*	1.08 (0.99, 1.16)

*: P-value less than 0.05 and 95% confident intervals that exclude the null OR.

MVT motor vehicle traffic, ICD international classification of diseases

Table 4. Patient, trauma-related, and hospital characteristics associated with long hospital length of stay

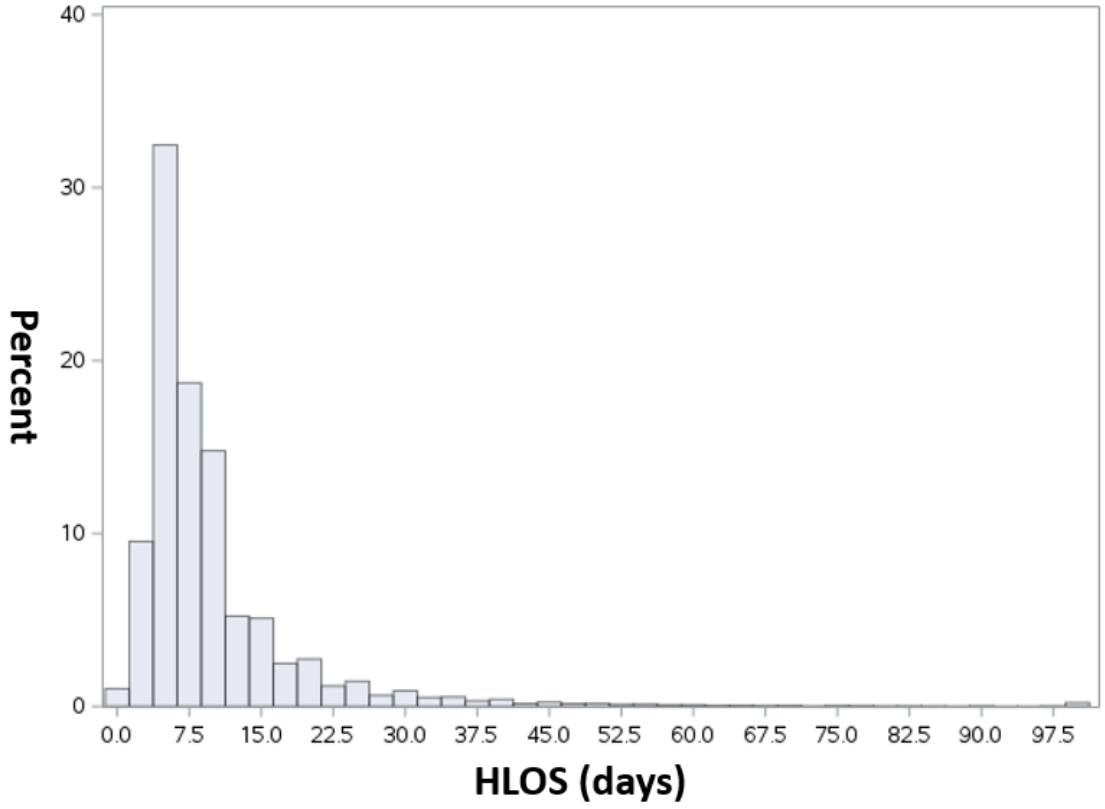
	LOS <11 days (ref.) vs. ≥11 days OR (95% CI)	
	Univariate model	**Multivariate model**
Racial background		
Black	1.18 (1.11, 1.25)*	1.44 (1.35, 1.53)*
Mechanism of injury		
Fall	1.14 (1.02, 1.27)*	0.68 (0.61, 0.77)*
Firearm	2.00 (1.89, 2.12)*	2.57 (2.41, 2.74)*
MVT Pedestrian	2.73 (2.14, 3.49)*	2.00 (1.55, 2.58)*
Trauma type		
Blunt	1.16 (1.10, 1.23)*	0.69 (0.65, 0.74)*
Penetrating	0.86 (0.81, 0.91)*	1.44 (1.35, 1.54)*
Body mass index (BMI)		
Normal (ref.)	Ref.	
Overweight	1.16 (1.08, 1.24)*	1.12 (1.03, 1.20)*
Obese	1.42 (1.32, 1.53)*	1.42 (1.32, 1.53)*
Blood transfusions		
Red blood cell 4 Hours	1.22 (1.21, 1.23)*	1.16 (1.15, 1.18)*
Plasma 4 hours	1.17 (1.15, 1.18)*	1.16 (1.14, 1.17)*
Platelets 4 hours	1.27 (1.22, 1.32)*	1.24 (1.19, 1.28)*
Laparotomy for hemorrhage control	2.20 (1.87, 2.58)*	2.16 (2.02, 2.30)*
Trauma center verification level		
Level I	1.07 (1.01, 1.13)*	1.07 (1.01, 1.14)*
Primary payment method		
Medicaid	0.98 (0.93, 1.05)	1.15 (1.08, 1.23)*
Medicare	1.88 (1.71, 2.05)*	1.34 (1.20, 1.49)*
Comorbid conditions		
Alcohol use disorder	1.26 (1.13, 1.41)*	1.17 (1.04, 1.31)*
Anticoagulant therapy	2.19 (1.85, 2.59)*	1.34 (1.11, 1.62)*
Cirrhosis	2.24 (1.75, 2.86)*	1.68 (1.30, 2.18)*
COPD	1.70 (1.46, 1.98)*	1.28 (1.08, 1.51)*
Cerebrovascular accident	1.93 (1.39, 2.67)*	1.27 (0.90, 1.79)
Diabetes mellitus	1.68 (1.51, 1.87)*	1.32 (1.17, 1.49)*
Functionally dependent health status	2.47 (1.94, 3.15)*	1.91 (1.48, 2.48)*
Congestive heart failure	2.47 (1.99, 3.07)*	1.54 (1.22, 1.94)*
Hypertension	1.64 (1.52, 1.77)*	1.25 (1.14, 1.37)*
Mental/Personality disorder	1.27 (1.17, 1.37)*	1.41 (1.29, 1.54)*
Chronic renal failure	2.57 (1.80, 3.66)*	1.68 (1.16, 2.44)*
ICD Diagnosis		
Major vessels	4.77 (3.94, 5.77)*	3.09 (2.52, 3.77)*
Abdominal blood vessels	2.33 (2.14, 2.54)*	1.77 (1.59, 1.90)*
Spleen	1.29 (1.20, 1.38)*	0.60 (0.55, 0.65)*
Hepatobiliary	1.90 (1.78, 2.04)*	1.64 (1.52, 1.76)*
Pancreas	4.17 (3.71, 4.67)*	3.33 (2.95, 3.76)*
Upper GI	1.96 (1.85, 2.07)*	2.05 (1.93, 2.18)*

Colon/rectum	2.26 (2.13, 2.39)*	2.42 (2.27, 2.57)*
Kidney	2.59 (2.36, 2.83)*	1.95 (1.77, 2.15)*
Genital/Urinary	1.46 (1.32, 1.61)*	1.41 (1.27, 1.56)*
ICD Procedure		
Major vessels	5.39 (4.37, 6.64)*	3.84 (3.09, 4.78)*
Abdominal blood vessels	2.60 (2.29, 2.94)*	2.14 (1.88, 2.44)*
Spleen	1.23 (1.14, 1.33)*	0.54 (0.50, 0.59)*
Hepatobiliary	2.25 (2.08, 2.44)*	1.91 (1.76, 2.08)*
Pancreas	4.25 (3.68, 4.91)*	3.23 (2.78, 3.76)*
Stomach	2.13 (1.97, 2.31)*	2.04 (1.87, 2.22)*
Small intestine	2.11 (1.99, 2.23)*	2.25 (2.12, 2.39)*
Large intestine	2.56 (2.42, 2.71)*	2.74 (2.58, 2.92)*
Kidney	3.04 (2.68, 3.46)*	2.02 (1.76, 2.32)*
Genital/Urinary	1.33 (1.20, 1.48)*	1.35 (1.21, 1.50)*
Abdominal cavity	1.18 (1.11, 1.27)*	1.30 (1.21, 1.40)*

*: P-value less than 0.05 and 95% confident intervals that exclude the null OR.

MVT motor vehicle traffic, COPD chronic obstructive pulmonary disease, ICD international classification of diseases, GI gastrointestinal.

Figure 1. Distribution of hospital length of stay (days) for the overall study population



Supplemental Material 1. International Classification of Diseases, 10th Revision, Procedure Coding System (ICD-10-PCS)

ICD-10-PCS is a set of medical classification codes used for procedural coding in the healthcare industry, covering all procedural data in inpatient settings, including surgeries, diagnostic procedures, and other medical interventions.
Each ICD-10-PCS code consists of seven alphanumeric characters without decimal points. The first character represents the "section" of ICD-10-PCS, with all surgical procedures starting with "0". The second character denotes the "Body System", such as "F" for hepatobiliary. The third character indicates the "Operation" describing the specific action performed, with "T" signifying "Resection". The fourth character specifies the "Body Part", with "1" representing the right lobe of the liver. The fifth character, "Approach", describes the surgical approach, such as "0" for open approach and "4" for percutaneous endoscopic approach. The sixth and seventh characters represents "Device" and "Qualifier", respectively, providing additional procedural details. For example, the code "0FT10ZZ" denotes the resection of right lobe of the liver using an open approach.

Supplemental Material 2. Identified organ-based procedure codes using the ICD-10-PCS classification system (109 codes)

□ **Spleen (3)**
07*P0** Spleen
04*40** Splenic artery
06*10** Splenic vein

□ **Hepatobiliary (13)**
0F*00** Liver
0F*10** Right lobe liver
0F*20** Left lobe liver
0F*40** Gallbladder
0F*50** Right hepatic duct
0F*60** Left hepatic duct
0F*70** Common hepatic duct
0F*80** Cystic duct
0F*90** Common bile duct
0F*B0** Hepatobiliary duct
04*30** Hepatic artery
06*40** Hepatic vein
06*80** Portal vein

□ **Lower esophagus and stomach (8)**
0D*30** Lower esophagus
0D*40** Esophagogastric junction
0D*50** Esophagus

0D*60** Stomach
0D*70** Stomach, pylorus
04*20** Gastric artery
06*20** Gastric vein
06*30** Esophageal vein

□ **Small intestine (6)**
0D*80** Small intestine
0D*90** Duodenum
0D*A0** Jejunum
0D*B0** Ileum
0F*C0** Ampulla of Vater
0W*P0** Gastrointestinal tract

□ **Large intestine (16)**
0D*C0** Ileocecal valve
0D*D0** Lower intestinal tract
0D*E0** Large intestine
0D*F0** Right large intestine
0D*G0** Left large intestine
0D*H0** Cecum
0D*J0** Appendix
0D*K0** Ascending colon
0D*L0** Transverse colon
0D*M0** Descending colon
0D*N0** Sigmoid colon
0D*P0** Rectum
04*60** Right colic artery
04*70** Left colic artery
04*80** Middle colic artery
06*70** Colic vein

□ **Pancreas (3)**
0F*D0** Pancreatic duct
0F*F0** Accessory pancreatic duct
0F*G0** Pancreas

□ **Kidney (14)**
0T*00** Right kidney
0T*10** Left kidney
0T*20** Bilateral kidneys
0T*30** Right kidney pelvis
0T*40** Left kidney pelvis
0T*50** Kidney
04*90** Right renal artery

04*A0** Left renal artery
06*90** Right renal vein
06*B0** Left renal vein
0G*20** Left adrenal glands
0G*30** Right adrenal glands
0G*40** Bilateral adrenal glands
0G*50** Adrenal glands

□ **Urinary tract (6)**
0T*60** Right ureter
0T*70** Left ureter
0T*80** Bilateral ureters
0T*90** Ureter
0T*B0** Bladder
0W*R0** Genitourinary tract

□ **Genitals (9)**
0U*00** Right ovary
0U*10** Left ovary
0U*20** Bilateral ovaries
0U*30** Ovary
0U*50** Right fallopian tube
0U*60** Left fallopian tube
0U*70** Bilateral fallopian tubes
0U*80** Fallopian tubes
0U*90** Uterus

□ **Major blood vessels (abdominal aorta and IVC) (5)**
04*00** Abdominal aorta
06*00** Inferior vena cava (IVC)
07*D0** Aortic lymphatic
0G*90** Para-aortic body
0G*D0** Aortic body

□ **Main branches of abdominal blood vessels (15)**
04*10** Celiac artery
04*50** Superior mesenteric artery
04*B0** Inferior mesenteric artery
04*C0** Right common iliac artery
04*D0** Left common iliac artery
04*E0** Right internal iliac artery
04*F0** Left internal iliac artery
04*H0** Right external iliac artery
04*J0** Left external iliac artery
06*50** Superior mesenteric vein

06*60** Inferior mesenteric vein
06*C0** Right common iliac vein
06*D0** Left common iliac vein
06*F0** Right external iliac vein
06*G0** Left external iliac vein

□ **Abdominal/Pelvic cavity, others (11)**
01*M0** Abdominal sympathetic nerve
06*H0** Right hypogastric vein
06*J0** Left hypogastric vein
07*B0** Mesenteric lymphatic
07*C0** Pelvis lymphatic
0D*U0** Omentum
0D*V0** Mesentery
0D*W0** Peritoneum
0W*G0** Peritoneal cavity
0W*H0** Retroperitoneum
0W*J0** Pelvic cavity

Supplemental Material 3: Abbreviated Injury Scale (AIS) body regions and severity codes

AIS numerical descriptor: AIS section descriptor [Body regions included]
1: Head [Cranium, brain]
2: Face [Eye, ear, lips]
3: Neck [Neck, throat]
4: Thorax [Thoracic contents, including rib-cage]
5: Abdomen/Pelvic contents [Abdominal/pelvic organs]
6: Spine [Spinal column/cord]
7: Upper extremities [Upper limbs including shoulder]
8: Lower extremities [Lower limbs including pelvis]
9: External [Integumentary system, including burns]

AIS severity codes
1: Minor injury
2: Moderate injury
3: Serious injury
4: Severe injury
5: Critical injury
6: Maximum injury, virtually unsurvivable
9: Not possible to assign

Supplemental Material 4: Identified organ-based diagnosis codes using the ICD-10-Clinical Modification (CM) classification system (39 codes)

□ **Superficial wounds of abdomen, lower back, pelvis, and genitals (including penetration into peritoneal cavity) (14)**

S30.1*** Contusion of abdominal wall
S30.8*** Other superficial injuries of abdomen, lower back, pelvis, and external genitals
S30.9*** Unspecified superficial injury of abdomen, lower back, pelvis, and external genitals
S31.0*** Open wound of lower back and pelvis
S31.1*** Open wound of abdominal wall without penetration into peritoneal cavity
S31.2*** Open wound of penis
S31.3*** Open wound of scrotum and testes
S31.4*** Open wound of vagina and vulva
S31.5*** Open wound of unspecified external genital organs
S31.6*** Open wound of abdominal wall with penetration into peritoneal cavity
S31.8*** Open wound of other parts of abdomen, lower back, and pelvis
S39.0*** Injury of muscle, fascia, and tendon of abdomen, lower back, and pelvis
S39.8*** Other specified injuries of abdomen, lower back, pelvis, and external genitals
S39.9*** Unspecified injury of abdomen, lower back, pelvis, and external genitals

□ **Major blood vessels (abdominal aorta and IVC) (2)**

S35.0*** Injury of abdominal aorta
S35.1*** Injury of inferior vena cava

□ **Main branches of abdominal blood vessels (8)**

S35.2*** Injury of celiac or mesenteric artery and branches
S35.3*** Injury of portal or splenic vein and branches
S35.4*** Injury of renal blood vessels
S35.50** Injury of unspecified iliac blood vessel(s)
S35.51** Injury of iliac artery or vein
S35.59** Injury of other iliac blood vessels
S35.8*** Injury of other blood vessels at abdomen, lower back, and pelvis level
S35.9*** Injury of unspecified blood vessels at abdomen, lower back, and pelvis level

□ **Spleen (1)**

S36.0*** Injury of spleen

□ **Hepatobiliary (1)**

S36.1*** Injury of liver, gallbladder, and bile duct

□ **Pancreas (1)**

S36.2*** Injury of pancreas

□ **Upper gastrointestinal tract (2)**

S36.3*** Injury of stomach
S36.4*** Injury of small intestine

□ **Colorectum (2)**

S36.5*** Injury of colon

S36.6*** Injury of rectum

□ **Kidney (1)**

S37.0*** Injury of kidney

□ **Genitourinary system (except kidney) (7)**

S37.1*** Injury of ureter
S37.2*** Injury of bladder
S37.4*** Injury of ovary
S37.5*** Injury of fallopian tube
S37.6*** Injury of uterus
S37.8*** Injury of other urinary and pelvic organs
S37.9*** Injury of unspecified urinary and pelvic organ

CHAPTER 3: ADDRESSING UNNECESSARY HOSPITAL STAYS AFTER TRAUMA LAPAROTOMY IN A CANADIAN HEALTHCARE CONTEXT

3.1 – Preamble

In Chapter 2, we analyzed hospital length of stay (HLOS) among trauma laparotomy patients using data from a large trauma registry in the United States (US). This analysis revealed significant variability in HLOS distribution, along with key factors associated with both short and long HLOS. The findings suggested that targeted interventions for each patient cohort have the potential to reduce HLOS and improve outcomes. However, since the study was based on data from the US healthcare system, certain factors, such as Medicaid and Medicare status, cannot be directly applied to the Canadian healthcare context.

The Canadian healthcare system fundamentally differs from that of the US. It is publicly funded, universally accessible, and based on need rather than the ability to pay. Established in 1947, the system ensures that core medical and hospital services are provided free at the point of care through taxation-based funding [2]. Additionally, Quebec, within Canada's ten provinces and three territories, has a unique cultural and linguistic context, often pursuing distinct healthcare policies [93]. Given these differences, it is essential to examine local clinical settings to identify modifiable factors that can be addressed to further enhance patient care.

In this chapter, we address the issue of prolonged hospital stays within our clinical context. Prolonged stays can occur under two distinct scenarios: patients who remain hospitalized for valid medical reasons, such as complications, and those who remain in the hospital after being medically cleared for discharge. When analyzing large registry data, distinguishing between these scenarios is often challenging, if not impossible. Although both scenarios strain the healthcare system, the latter, referred to as unnecessary stays or delayed discharges, poses a critical issue, especially within universal, publicly funded healthcare systems. It leads to inefficient bed utilization, increases the risk of preventable hospital-acquired infections or

deconditioning, prolongs wait times for emergency admissions or surgeries, and escalates healthcare costs [94-96].

Building on this context, this Chapter specifically focuses on unnecessary stays. By examining their incidence and contributing factors in our clinical setting, we aim to identify modifiable factors that contribute to inefficient resource utilization. Addressing these factors could help reduce unnecessary hospital stays, thereby optimizing resource allocation and improving patient care. To explore this issue, we conducted a retrospective analysis of trauma laparotomy patients admitted and treated at our institution. The manuscript has been submitted to the *Canadian Journal of Surgery* and is currently under review.

3.2 – Unnecessary Hospital Stays After Trauma Laparotomy: Insights from a Canadian Level 1 Trauma Center

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ABSTRACT

Background: Despite the strain on healthcare systems, patients experience unnecessary hospital stays after medical clearance, leading to resource misallocation and suboptimal care. This study aimed to identify the factors contributing to unnecessary stays among trauma laparotomy (TL) patients.

Methods: A retrospective cohort study was conducted using data from Montreal General Hospital, a level 1 trauma center. Adult trauma patients who underwent TL between January 2016 and February 2020 were included. An unnecessary stay was defined as hospitalization beyond the point when active treatment was no longer required, based on physician assessment. Patients were categorized into two groups: the timely group and the unnecessary stay group. The two groups were compared, and factors associated with unnecessary stays were identified.

Results: A total of 219 patients met the study criteria. Of these, 64 (29.2%) experienced unnecessary stays following TL, resulting in an additional 513 hospital days. Patients with unnecessary stays were significantly older and had a higher proportion of mental disorders, blunt injuries, and higher injury severity scores. The primary reasons for unnecessary stays were awaiting transfer to rehabilitation facilities (42.2%) and psychiatric departments (39.1%). Age, mental disorders, liver injuries, and orthopedic procedures were significant predictors of unnecessary stays.

Conclusion: Approximately 30% of our cohort experienced unnecessary stays, primarily due to issues related to patient disposition from acute care. This highlights the importance of improving early discharge planning and ensuring timely access to post-acute care.

Introduction

The realm of trauma surgery, like many other medical disciplines, is facing challenges arising from constrained resources, including staffing shortages, limited bed availability, and financial constraints, which are further compounded by Canada's unique geographic challenges [1]. Misuse of hospital beds is a recognized issue, particularly in acute settings such as trauma surgery, where delays in patient discharges contribute to a notable increase in hospital length of stay (HLOS) [2].

Prolonged hospital stays can be categorized into two distinct scenarios. The first encompasses situations where patients have valid medical reasons to remain hospitalized, often due to complications arising during their admission. The second scenario involves patients staying in the hospital beyond the point of requiring active treatment at the trauma center, essentially when they are deemed ready to leave the hospital. This situation is labeled as an "unnecessary stay". Previous literature has identified factors contributing to prolonged hospital stays, though these either fall under the first scenario or do not clearly distinguish between the two, even within the context of trauma surgery [3-8]. Various factors, including older age, comorbidities, insurance coverage, and socioeconomic background, have been reported as contributing factors of prolonged stays [6, 9-11]. However, limited information is available regarding unnecessary stays [12, 13], and the existing studies have focused on the entire trauma surgery population. The trauma surgery population is highly heterogenous, with patients differing widely in demographics, etiologies, injury patterns, and the urgent, unpredictable nature of trauma. This diversity complicates the interpretation of results and the implementation of targeted initiatives. Therefore, it is essential to focus on relatively homogenous subgroups within trauma surgery. Trauma laparotomy, a key and commonly performed procedure in trauma care, is one such area.

Yet, there remains a lack of specific data on unnecessary stays among patients undergoing trauma laparotomies. Bowie *et al.*, conducted a study to evaluate the association between "single-look trauma laparotomy" and corresponding outcomes [14]. They observed that advanced age and blunt trauma mechanism were significantly associated with prolonged hospital stays, mainly due to complications. However, this aligned with the first scenario, and there is no mention of unnecessary stays within this patient cohort.

Prolonged hospital stays expose patients to an increased risk of developing hospital-acquired infections [15]. Additionally, prolonged stays can contribute to physical deconditioning, ultimately diminishing long-term quality of life and life expectancy [15, 16]. Furthermore, unnecessary stays disrupt patient allocation (e.g., to rehabilitation facilities or other departments) and resource use, leading to delays in the overall recovery process. These consequences, coupled with the substantial costs they impose on healthcare systems, underscore the urgency of addressing this issue to enhance patient outcomes and optimize resource utilization. The aims of this study were to initially elucidate the current situation regarding unnecessary stays among trauma laparotomy patients in our clinical environment, and subsequently identify the factors that contribute to such unnecessary stays.

Methods

We conducted a retrospective cohort study of all adult patients admitted to the trauma service at the Montreal General Hospital (MGH) who underwent a trauma laparotomy between January 1, 2016, and February 29, 2020 (prior to the first COVID-19 wave), identified using our hospital-based trauma registry. The MGH is one of two level 1 trauma centers in Montreal, Canada, serving trauma patients from urban and sub-urban areas. MGH also receives all transferred patients from Northern Quebec. The study population comprised adult trauma patients aged 18

years and older who underwent a trauma laparotomy during the study period. Patients who died were excluded from the study. This study obtained approval from the McGill University Health Centre Research Ethics Board (Study No. 2024-9800). Given that the study involved retrospective chart reviewing, authorization to access patient medical records was obtained from the Director of Professional Services (DPS) of the MGH, in compliance with relevant privacy laws and regulations.

The research team extracted data from the trauma registry and patients' medical records, including operation notes. The data included demographic characteristics (age, gender, and postal code), injury-related characteristics (mechanism of injury, sustained injuries, operative procedures, and injury severity score (ISS)), as well as clinical information (comorbidities, in-hospital complications, HLOS, and hospital discharge disposition). Additionally, we recorded the date when patients were deemed ready for discharge to calculate unnecessary stay days and identify the reasons for these extended stays. In our regular practice, staff trauma surgeons indicate when patients are ready for discharge from the trauma department, and this is documented in the chart. Unnecessary stay days were defined as the difference between the actual length of stay and the length of stay calculated from the date of readiness for discharge, as recorded in the chart. We extracted postal codes to assess whether geographic location (e.g., Island of Montreal vs northern Quebec) influenced HLOS and to determine if patients' economic status affected HLOS. To estimate patients' economic status, we used the median household income of their place of residence, as determined by Census 2021 data for the province of Quebec available on the Statistics Canada website [17]. We entered patients' postal codes and household income data into ESRI ArcGIS Pro software. Using ArcGIS's geoprocessing tool, we

calculated the median household income based on population data and income levels within each geographic area.

The primary outcome was the incidence of unnecessary stays. Patients were categorized into two groups: those who were discharged promptly on the same day they were ready for discharge were classified in the timely group, while those who remained in the hospital after medical clearance were placed in the unnecessary stay group. According to this definition, patients who fell under the first scenario of prolonged hospital stays were classified in the timely group. Descriptive statistics were used to calculate proportions and medians for characteristics between the timely and unnecessary hospital stay groups. Two-tailed hypothesis tests (Wilcoxon rank-sum tests and chi-square tests) were used to assess differences between the two groups across characteristics. A multivariate logistic regression model was used to identify predictors of unnecessary hospital stay. Predictors in our model were based on a priori identified factors of patient HLOS, from the literature and clinical practice, such as age, sex, comorbidities, ISS and mechanism of injury as well as Bayesian information criterion testing to identify the variables in the best fitting model. Logistic regression models are presented as odds ratios with 95% confidence intervals (CI). P-values less than 0.05 and CIs that excluded the null odds ratio were considered statistically significant. All analyses were performed using R version 4.0.3.

Results

We identified 262 patients who underwent trauma laparotomy for abdominal injuries. Exclusions from the analysis comprised patients who died (38 patients), were initially managed in another country (1 patient), or had missing specific information (4 patients). A total of 219 patients met the study criteria for inclusion in the analysis. Patient demographic and clinical characteristics are shown in Table 1. The median age [IQR] was 33.0 years [25.0, 49.0], with 77.2% being male.

Approximately 8% were from northern Quebec, and the median household income [IQR] was $72,072 [58,300, 93.021]. About half of the cases involved blunt mechanisms, and median ISS [IQR] was 20.0 [10.0, 29.0].

Among the patients in our study, 64 (29.2%) experienced unnecessary stays following trauma laparotomy, resulting in a significantly longer HLOS (29.0 days [13.0, 45.3] vs 7.0 days [5.0, 16.0], $p < 0.001$) (Table 1). Despite accounting for the day they were medically cleared, without factoring in unnecessary stays, this group still exhibited a significantly longer HLOS (17.5 days [8.0, 35.0] vs 7.0 days [5.0, 16.0], $p = 0.005$). Patients in the unnecessary stay group, accumulated 513 additional days in hospital. Patients with unnecessary stays were significantly older than patients in the timely group. They also had a significantly higher proportion of mental disorders, blunt mechanism injuries, and a higher ISS compared to the timely group. Additionally, those in the unnecessary stay group had a significantly lower proportion of isolated abdominal trauma compared to the timely group.

The primary reasons reported for unnecessary stays were closely linked to patient disposition for post acute care, with the two main reasons being awaiting transfer to rehabilitation facilities (42.2%) and psychiatric departments (39.1%) (Table 2).

Table 3 summarizes the abdominal injury profile in both groups and did not show any significant differences, except for a higher prevalence of liver injuries in the unnecessary stay group (34.4% vs 16.8%, $p = 0.004$).

Table 4 summarizes the surgical procedures. There were no significant differences between the two groups in terms of abdominal procedures. The unnecessary stay group had a higher rate of non-abdominal procedures. There were significantly more orthopedic procedures performed in the unnecessary stay group (39.1% vs 14.2%, $p < 0.001$). The complications encountered during

their admission are listed in Table 5. The prevalence of postoperative delirium, acute kidney injury, and anastomotic leak was significantly higher in the unnecessary stay group. There was no significant difference between the two groups regarding the other in-hospital complications, with postoperative pneumonia being the most prevalent complication in the study cohort.

Our final multivariate logistic regression model included age, sex, comorbidity, mental disorder, ISS, blunt trauma, isolated abdominal trauma, liver trauma, orthopedic procedure, and delirium. However, only age, mental disorder, liver injury and orthopedic procedure were significant predictors of unnecessary hospital stay (Table 6). Our results show that patients diagnosed with a mental disorder were 8.6 times more likely to have an unnecessary hospital stay compared to patients without a mental disorder. Additionally, patients with liver injuries or who had orthopedic procedures were 4.4 and 4.7 times more likely, respectively, to experience an unnecessary hospital stay compared to patients without these conditions. Age was also a significant predictor in the model, as age increases, the odds of an unnecessary hospital stay also increase.

Discussion

In this study, we found that approximately 30% (64/219) of patients who underwent trauma laparotomy experienced unnecessary stays. This rate is higher than what had previously been reported for trauma patients [12, 18]. The primary reason for these unnecessary stays was systemic delays in discharging patients from acute care settings. These delays were not only related to the need for patient transfers to rehabilitation facilities but also revealed a significant psychiatric component contributing to discharge delays within our clinical context.

The Canadian healthcare system is grappling with an increased workload amid limited resources, a challenge that also affects the field of trauma surgery [19, 20]. Prolonged hospital stays

exacerbate this situation, and several studies have reported factors contributing to these extended stays. These factors include advanced age, existing comorbidities, severity of injury, the blunt mechanism of injury, and awaiting discharge to a rehabilitation facility [6, 7, 13, 21-24]. Furthermore, socio-economic backgrounds, including low income, insurance status, and certain ethnicities, have also been shown to impact HLOS, resulting in prolonged stay [9, 11]. However, the definition of prolonged stay varies in those studies, as described in the introduction. Our specific focus pertains to unnecessary stays, a topic that has not been previously assessed in studies concerning patients undergoing trauma laparotomy. Even within this limited cohort, our findings revealed that approximately 30% of these unnecessary stays accounted for a cumulative 513 days during the study period, significantly affecting both patients and the healthcare system. Unnecessary stays expose patients to avoidable risks, such as hospital-acquired infections, and they also lead to deconditioning due to delayed rehabilitation, resulting in a reduction of their long-term quality of life [15]. Unnecessary stays strain the healthcare system by causing bed shortages, increasing wait times for acutely ill trauma patients in emergency departments, occupying ICU beds unnecessarily, and leading to the cancellation of planned surgical procedures. Moreover, the admission of trauma patients can incur an average cost of up to $45,525. This expense includes patients who do not necessitate any surgeries, highlighting that these unnecessary stays contribute to a substantial financial burden for non-medical purposes [2, 25]. These concerns hold particular significance in publicly funded healthcare systems, such as the Canadian healthcare system.

This study revealed that unnecessary stays were primarily attributed to systemic delays. These delays encompassed waiting for transfer to a rehabilitation facility or a psychiatric department, as well as difficulties in disposition planning, such as inadequate housing or insufficient community

support. In a study conducted by Brasel et al. [12], the causes of discharge delays among a population of trauma patients were evaluated, and they found that a lack of rehabilitation or other subacute care beds constituted the primary reason for delays in 83% of their patients. Similarly, Irshad et al. reported that the lack of home support and the unavailability of convalescent facilities were the primary social factors contributing to delayed discharge in a thoracic surgery patient population [26]. These findings align with our primary reasons behind unnecessary stays within our patient cohort. Evidently, the reasons for unnecessary stays are more closely tied to systemic factors than patient-related factors. Nevertheless, it remains essential to delve into the specific details of these reasons to enable effective resolution of these issues. It is crucial to advocate not only at the hospital level but also within the community to enhance access to post acute care rehabilitation beds. By promoting collaboration between healthcare institutions and community resources, we can work towards ensuring timely and appropriate placement for patients in need of post acute care.

Another important intervention to mitigate unnecessary stays is the enhancement of early discharge planning, tailoring discharge to the individual patients care needs, and facilitating recovery and appropriate disposition. This approach will further contribute to the prevention of unnecessary stays. Our study identifies advanced age, presence of liver injuries, the need for orthopedic procedures, and psychiatric comorbidities as predictors of unnecessary stays. For geriatric populations, it is imperative to engage specialized medical teams, such as geriatrics experts, from the early phase of their admission when managing elderly trauma patients. This approach aligns with the recommendations in the enhanced recovery after surgery (ERAS) guidelines for emergency laparotomy [21] and we believe that the same concept should be applied to patients undergoing trauma laparotomy. Patients necessitating orthopedic procedures

often require a certain period of rehabilitation before they can be discharged to their home. Although we did not specifically examine the management of liver injury, patients who sustain liver injuries frequently undergo non-definitive surgical procedures. This often leads to an extended period of conservative management and a necessity for subacute care arrangements for their eventual disposition. We speculate that patients in need of rehabilitation or post acute care might be associated with discharge disposition challenges, rendering them potential candidates for early discharge planning. In contrast to prior studies, our findings highlight significant psychiatric components that contribute to discharge delays in our patient population. Patients with mental disorders showed a significant association with unnecessary stays, and one of the primary reasons for these unnecessary stays was the wait for transfer to a psychiatric department. This novel finding sheds light on the challenges within our clinical setting. This finding warrants advocacy and efforts to reduce delays in transferring patients to the psychiatric department, that could be advanced through early engagement with psychiatry and enhanced access to psychiatric beds. Such measures have the potential to influence patient outcomes including the HLOS.

One potential intervention to mitigate unnecessary stays involves the implementation of integrated care pathways that incorporate our study findings, including patients' risk assessment and their access to rehabilitation or psychiatric beds. This approach has demonstrated effectiveness in other fields, such as elective hip and knee surgeries [27]. However, trauma patients involve a diverse spectrum of conditions, including injury complexity and severity, pre-existing comorbidities, and socioeconomic backgrounds. These complexities introduce challenges in implementing these pathways and conducting research within these populations. The strength of our study lies in our focused cohort selection, specifically targeting trauma laparotomy patients within the broader population of trauma patients. This particular patient

population has not been extensively studied in comparison to those undergoing elective and emergency abdominal surgical procedures (9). Furthermore, our study extends beyond assessing injuries and comorbidities to explore socioeconomic factors, including residential area and economic status. Although these factors were not significantly associated with unnecessary stays, possibly due to the Canadian universal healthcare system, further investigation is needed to clarify this relationship. Nonetheless, our analysis helps filter out potential confounding factors in a broad trauma population and uncovers novel, previously unreported findings, particularly related to psychiatric components. The findings from this study may provide valuable insights into the components that can be incorporated into care pathways.

This study was subject to several limitations. While there is a positive aspect to focusing exclusively on trauma laparotomy patients, it is crucial to acknowledge that our research was conducted retrospectively at a single trauma center in Montreal, Canada. Consequently, this resulted in a small sample size and limited its generalizability. Despite Canada's universal healthcare system, it is important to recognize that regional differences persist. Due to the small sample size of our study, results of the logistic regression analysis should be interpreted with caution. We defined unnecessary stays as situations where patients remain in the hospital beyond the point when active treatment at the trauma center is necessary. However, we did not use specific discharge criteria for medical clearance during the study period, potentially impacting their HLOS. Nevertheless, we conducted a meticulous review of medical records and identified patients who were ready for discharge based on notes such as "patient medically cleared" or "patient awaiting disposition". This approach might underestimate, but would not overestimate, the number of patients who experienced unnecessary stays. While we chose to analyze pre-

COVID-19 pandemic data because the situations during the pandemic were highly variable, we acknowledge that the post-pandemic results could differ.

Conclusion

Approximately 30% of patients remained in the hospital unnecessarily following a trauma laparotomy. Their unnecessary stays, which impose a substantial burden on our healthcare system, were primarily attributed to systemic delays in discharging patients from acute care settings. Our findings emphasize not only the need for patient transfer to rehabilitation facility but also shed light on a significant psychiatric component contributing to discharge delays within our clinical context. Enhancing early discharge planning by targeting the factors associated with unnecessary stays may reduce discharge delays. Furthermore, it is crucial to advocate for improving timely and appropriate access to post acute care through fostering collaboration between departments, healthcare institutions, and community resources.

STATEMENTS AND DECLARATIONS

Declaration of interest: All authors declare that they have no conflicts of interest.

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Ethical consideration: Ethics approval was obtained from the McGill University Health Centre Research Ethics Board (Study No. 2024-9800).

Presentation: This study was presented at the 23rd European Congress of Trauma and Emergency Surgery, which took place in Lisbon, Portugal, in April 2024.

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Table 1. Patient demographic and clinical characteristics of trauma laparotomy patients

Characteristics	Overall (n=219)	Unnecessary stay (n=64)	Timely (n=155)	P value
Age, median [IQR]	33.0 [25.0, 49.0]	47.5 [28.0, 57.0]	31.0 [23.0, 42.0]	**0.002**
Male, n (%)	169 (77.2)	48 (75.0)	121 (78.1)	0.623
Northern Quebec, n (%)	18 (8.2)	6 (9.4)	12 (7.7)	0.758
Median household income, median [IQR]†	$72,072.0 [58,300.0, 93,021.0]	$69,005.0 [58,200.0, 97,167.0]	$75,000.0 [59,600.0, 93,000.0]	0.655
Comorbidity, n (%)				
Asthma/COPD	17 (7.8)	8 (12.5)	9 (5.8)	0.092
Diabetes mellitus	17 (7.8)	8 (12.5)	9 (5.8)	0.092
HT/HL	27 (12.3)	12 (18.8)	15 (9.7)	0.063
Coronary artery disease	7 (3.2)	1 (1.6)	6 (3.9)	0.377
Mental disorder	50 (22.8)	28 (43.8)	22 (14.2)	**<0.001**
Liver disease	8 (3.7)	3 (4.7)	5 (3.2)	0.600
HIV	1 (0.5)	1 (1.6)	0 (0)	0.119
Blunt mechanism, n (%)	109 (49.8)	39 (60.9)	70 (45.2)	**0.034**
ISS, median (IQR)	20.0 [10.0, 29.0]	24.0 [17.0, 34.0]	17.0 [9.0, 26.0]	**0.003**
Isolated abdominal trauma, n (%)	100 (45.7)	18 (28.1)	82 (52.9)	**<0.001**
Hospital LOS, median (IQR)	10.0 [6.0, 26.5]	29.0 [13.0, 45.3]	7.0 [5.0, 16.0]	**<0.001**
Corrected Hospital LOS‡, median (IQR)	10.0 [5.0, 23.0]	17.5 [8.0, 35.0]	7.0 [5.0, 16.0]	**0.005**
Unnecessary stay, total days	513	513	0	
Discharged to home, n (%)	140 (63.9)	18 (28.1)	122 (78.7)	**<0.001**

Notes: †Patients from northern Quebec were excluded. ‡Corrected Hospital LOS: Difference between the total LOS and the unnecessary stay days.

Abbreviations: COPD, chronic obstructive pulmonary disease; HT, hypertension; HL, hyperlipidemia; HIV, human immunodeficiency virus; ISS, injury severity score; LOS, length of stay.

P<0.05

Table 2. Reasons for unnecessary stay

Reasons	n (%)
Awaiting transfer to rehabilitation facility	27 (42.2)
Awaiting transfer to psychiatric department	25 (39.1)
Disposition planning difficulties†	12 (18.7)

†Inadequate housing or insufficient community support

Table 3. Abdominal organ injuries sustained in trauma laparotomy patients

	Overall	Unnecessary stay	Timely	P value
Abdominal organs		n (%)		
Spleen	61 (27.9%)	17 (26.6)	44 (28.4)	0.784
Liver	48 (21.9)	22 (34.4)	26 (16.8)	**0.004**
Small bowel	50 (22.8)	17 (26.6)	33 (21.3)	0.398
Large bowel	33 (15.1)	9 (14.1)	24 (15.5)	0.789
Pancreas	13 (5.)	4 (6.3)	9 (5.8)	0.900
Stomach	16 (7.3)	3 (4.7)	13 (8.4)	0.339
Kidney	8 (3.7)	3 (4.7)	5 (3.2)	0.600
Bladder	7 (3.2)	2 (3.1)	5 (3.2)	0.969
Diaphragm	38 (17.4)	9 (14.1)	29 (18.7)	0.409
Major vessels (Aorta/IVC)	18 (8.2)	7 (10.9)	11 (7.1)	0.347

Table 4. Surgical procedures performed in trauma laparotomy patients

	Overall	Unnecessary stay	Timely	P value
		n (%)		
Abdominal procedures				
Nontherapeutic laparotomy	32 (14.6)	7 (10.9)	25 (16.1)	0.323
Splenectomy	61 (27.9)	19 (29.7)	42 (27.1)	0.625
Liver resection or hepatorrhaphy	34 (15.5)	14 (21.9)	20 (12.9)	0.095
Bowel resection†	45 (20.5)	14 (21.9)	31 (20.0)	0.755
Stoma creation	12 (5.5)	5 (7.8)	7 (4.5)	0.330
Pancreatectomy	9 (4.1)	2 (3.1)	7 (4.5)	0.637
Nephrectomy	6 (2.7)	1 (1.6)	5 (3.2)	0.493
Diaphragmatic repair	36 (16.4)	8 (12.5)	28 (18.1)	0.312
Stomach repair	15 (6.8)	2 (3.1)	13 (8.4)	0.161
Bladder repair	7 (3.2)	2 (3.1)	5 (3.2)	0.969
Other procedures				
Orthopedic procedure	47 (21.5)	25 (39.1)	22 (14.2)	**<0.001**
Neurosurgical procedure‡	4 (1.8)	2 (3.1)	2 (1.3)	0.357
Angioembolization	16 (7.3)	6 (9.4)	10 (6.5)	0.450
Thoracotomy	12 (5.5)	5 (7.8)	7 (4.5)	0.330
IVC filter	10 (4.6)	3 (4.7)	7 (4.5)	0.956

†Small bowel or large bowel resections. ‡Craniotomy. IVC inferior vena cava.

Table 5. In-hospital complications among trauma laparotomy patients

	Overall	Unnecessary stay	Timely	P value
		n (%)		
Pneumonia	36 (16.4%)	15 (23.4%)	21 (13.5%)	0.073
ARDS	5 (2.3%)	1 (1.6%)	4 (2.6%)	0.646
Ileus	26 (11.9%)	11 (17.2%)	15 (9.7%)	0.118
DVT	7 (3.2%)	4 (6.3%)	3 (1.9%)	0.099
PE	11 (5.0%)	6 (9.4%)	5 (3.2%)	0.058
AKI	4 (1.8%)	3 (4.7%)	1 (0.6%)	**0.042**
Anastomotic leak	4 (1.8%)	3 (4.7%)	1 (0.6%)	**0.042**
Bile leak/Biloma	9 (4.1%)	3 (4.7%)	6 (3.9%)	0.782
UTI	7 (3.2%)	2 (3.1%)	5 (3.2%)	0.969
Superficial/Deep SSI	23 (10.5%)	9 (14.0%)	14 (9.0%)	0.270
Delirium	17 (7.8%)	10 (15.6%)	7 (4.5%)	**0.005**

Abbreviations: ARDS, acute respiratory distress syndrome; DVT, deep vein thrombosis; PE, pulmonary embolism; AKI, acute kidney injury; UTI, urinary tract infection; SSI, surgical site infection.

Table 6. Independent predictors of unnecessary stays

Predictors	OR (95%CI)	p-value
Age	1.03 (1.00, 1.06)	**0.018**
Sex	1.38 (0.60, 3.34)	0.455
Comorbidity	1.07 (0.38, 3.03)	0.892
Mental disorder	8.61 (3.83, 20.59)	**<0.001**
ISS	1.01 (0.98, 1.04)	0.666
Blunt trauma	0.93 (0.37, 2.26)	0.866
Isolated abdominal trauma	0.58 (0.24, 1.41)	0.232
Liver trauma	4.39 (1.94, 10.31)	**<0.001**
Orthopedic procedure	4.69 (1.77, 13.28)	**0.003**
Delirium	1.77 (0.53, 6.23)	0.355

CHAPTER 4: DEVELOPMENT AND IMPLEMENTATION OF TRAUMA LAPAROTOMY CARE PATHWAY

4.1 – Preamble

In Chapter 2, we identified several key factors associated with both short and long hospital length of stay (HLOS) among trauma laparotomy patients. In Chapter 3, we specifically examined a subset of prolonged stays, unnecessary stays, within the Canadian healthcare context, by analysing the cohort of patients treated at out institution. This analysis allowed us to identify the primary reasons for unnecessary stays, which were largely linked to challenges in patient disposition from acute care settings. Notably, these patients, who experienced unnecessary stays were predominantly those categorized in the long length of stay group from the analysis in Chapter 2. Therefore, in this chapter, we shift our focus to patient cohorts categorized in the short and medium length of stay groups within our clinical setting, with the aim of assessing whether the implementation of enhanced recovery protocols (ERPs) can improve outcomes for these patients.

Building on the introduction of this thesis, there is a significant opportunity to further develop and implement ERPs for trauma laparotomy patients. The findings from Chapter 2 support the application of targeted interventions through ERPs, particularly for patients in the short and medium length of stay groups. Historically, trauma laparotomy patients were considered high-risk, often associated with longer hospital stays [18]. However, our data indicated that 77% of patients in this cohort were categorized into short and medium length of stay groups, with stays of less than 11 days, highlighting a potential area for intervention.

Patient selection will be a crucial factor in the successful implementation of ERPs. Our findings suggest that patients with stab wounds, isolated abdominal trauma, and splenic injuries are strong candidates for such protocols. In fact, two previous studies evaluating ERPs in trauma laparotomy focused primarily on patients with isolated penetrating trauma [85, 87]. However,

based on the results from Chapter 2, we hypothesized that even patients with blunt trauma involving multiple body regions could benefit from ERPs, provided that appropriate criteria are applied. This approach has the potential to improve patient outcomes by optimizing recovery strategies across a broader trauma laparotomy population.

To build on this context, we initiated the development of an ERP for trauma laparotomy patients, termed the “Trauma Laparotomy Care Pathway”. To ensure that the pathway was grounded in the best available evidence, we first conducted a comprehensive literature review. Given the limited research specifically addressing ERPs for trauma laparotomy patients, we conducted a scoping review that included both trauma laparotomy and emergency abdominal surgery populations. These groups share many clinical characteristics, such as the need for emergency surgery, the frequent use of open surgery, and the presence of physiological derangement at admission, despite some differences [72, 80, 97]. This review provided valuable insights for creating our trauma laparotomy care pathway, and the findings were published in the *European Journal of Trauma and Emergency Surgery.*

4.2 – Enhanced Recovery Protocols in Trauma and Emergency Abdominal Surgery: A Scoping Review.

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ABSTRACT

Purpose: Enhanced recovery protocols (ERP) have been shown to improve patient outcomes and is now regarded as standard of care in elective surgical setting. However, the literature addressing the use of ERP in trauma and emergency abdominal surgery (EAS) is limited and heterogenous. A scoping review was conducted to comprehensively assess the literature on ERP in trauma laparotomy and EAS.

Methods: Three bibliographic databases were searched for studies addressing ERP in trauma laparotomy and EAS. We extracted the study characteristics including study design, country, year, surgical procedures, ERP components used, and outcomes. Reporting was according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Extension for Scoping Reviews.

Results: After screening of 1631 articles for eligibility, 39 studies were included in the review. There has been an increase in the number of articles in the field, with 44% of the identified studies published between 2020 and 2022. Fourteen different protocols were identified, with varying components for each operative phase (preoperative; 29, intraoperative; 20, postoperative; 27). The majority of the studies addressed the effectiveness of ERP on clinical outcomes (31/39: 79%). Only two studies (5%) included purely trauma populations.

Conclusions: Studies on ERP implementations in the EAS populations were published across a range of countries, with improved outcomes. However, a clear gap in ERP research on trauma laparotomy was identified. This scoping review indicates that standardization of care through ERP implementation has potential to improve the quality of care in both EAS and trauma laparotomy.

Introduction

Enhanced recovery protocols (ERPs) refer to patient-centered, evidence-based, standardised multimodal perioperative care pathways aimed to reduce the patients' surgical stress response, optimize their physiological function, and facilitate postoperative recovery [1]. ERPs were initially developed and applied in elective colorectal surgery [2] and have been shown to improve patient outcomes for elective procedures in many other surgical specialities [3-10]. Compared to those undergoing elective surgery, patients undergoing emergency abdominal surgery (EAS) are considered as "high-risk" due to the heterogenous etiology, physiological derangement on admission, frequent open procedures, older age, and presence of comorbidities. These populations are likely to benefit from a structured approach with defined care pathways and organizational resource allocation to prioritize management. However, the number of studies addressing the use of ERP in these high-risk surgical populations is limited and they are heterogeneous with regards to the patient populations, protocols used, and hospital resources [11-16]. Although guideline from International ERAS Society for emergency laparotomy was published in 2021, the recommendations cover the preoperative phase [17]. Furthermore, the guideline excluded trauma laparotomy as the literature on this topic seems limited.

Given this scenario, conducting a scoping literature review is indicated to systematically map the sources of ERP evidence currently available both in EAS and trauma laparotomy, identifying gaps, and highlight future steps for research and clinical practice. Hence, the objective of this scoping review was to comprehensively assess extent, range, and nature of the literatures on ERP in trauma laparotomy and EAS.

Methods

Our scoping review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Extension for Scoping Reviews [18] (Online Resource 1), and the review protocol was preregistered in the Open Science Framework (OSF; http://www.osf.io/ ID:10.17605/OSF.IO/452MD) on March 13, 2022. An amendment to protocol required after the review was initiated is available in Online Resource 2.

Literature search

The literature search strategies (Online Resource 3) were developed and run by an experienced research librarian and peer-reviewed by a second librarian according to the PRESS Checklist [19]. A comprehensive search was conducted in MEDLINE and EMBASE, both via Ovid, and Clarivate's Web of Science Core Collection. Searches were conducted on January 26, 2022, with no start date limitations and no language limitations applied. Conference proceedings were obtained from EMBASE and Web of Science, and reference lists of included publications were also assessed to ensure literature saturation. Duplicates were removed and a combined library of the retrieved articles was created using Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia).

Eligibility criteria

The included studies described and/or examined the effectiveness, adherence, and feasibility of ERPs for adult patients undergoing trauma laparotomy and EAS. For this review, "emergency abdominal surgery" was defined as a non-elective, intra-abdominal surgical procedures [17]. This includes EAS performed laparoscopically as this approach has been indicated and used in certain emergency abdominal conditions. "Trauma laparotomy" was defined as intra-abdominal procedures performed after both penetrating and blunt abdominal trauma to control hemorrhage, control contamination, and identify all injuries followed by definitive repair or damage control

management [20]. As not all studies use the term ERAS protocol or ERP, we included the studies using the concept of ERAS with at least 4 interventions used as a protocol, pathway, or bundle, and covering at least one of the operative phases: preoperative, intraoperative, and postoperative. This definition of ERP is based on previous reviews on ERP in elective surgeries [21]. Given the exploratory nature of this review, a broad range of methodological designs, including systematic reviews, meta-analyses, randomized controlled trials (RCTs), prospective and retrospective cohort studies, and guidelines were targeted.

We excluded studies on pediatric patients and studies that only focused on one specific component from the ERP. Narrative reviews, commentaries, and editorials were excluded. Conference abstracts that could not be traced into full-text papers were also excluded.

Selection of studies

The titles and abstracts of all articles identified by the search were independently screened in duplicate by two reviewers (HU and PNP). After abstract screening, full-text versions of the articles potentially suitable for inclusion were retrieved and independently evaluated in duplicate by two reviewers (HU and PNP) against the eligibility criteria. Disagreements regarding study eligibility were resolved by a consensus between the reviewers or by consulting an adjudicator (JFF).

Data extraction

Data extraction focused on relevant study characteristics (e.g., study design, country, year, populations, surgical procedures, ERP components used) and outcomes. A customized data-extraction form was constructed and integrated into the Covidence. Data extraction was conducted independently, in duplicate, by pairs of reviewers, and total of four reviewers were involved after a training session Discrepancies were resolved by consensus between the

reviewers after revisiting the full-text articles. Authors were contacted to obtain additional data if required.

Data synthesis

The results of this scoping review were synthesized by providing a descriptive and quantitative summary of the study characteristics using frequencies with percentages. The studies were grouped by included population (i.e., EAS or trauma (with or without EAS)) and summarized separately according to study characteristics. The components used in the ERPs were extracted and categorized into pre-, intra-, and postoperative phases. The studies were categorized according to their focus on effectiveness (i.e., assessing the effectiveness of ERPs on clinical outcomes), adherence (i.e., compliance or adherence to ERP components), implementation feasibility (i.e., patients' barriers/acceptability to ERP implementation), cost effectiveness (i.e., evaluating the impact on cost during ERP implementation), and guidelines (i.e., recommendations regarding ERP implementation).

Results

A total of 1631 unique articles were identified, 179 underwent full-text review, and 39 studies were included in the review (Figure 1). Among those, 35 studies (90%) included patients undergoing EAS, two studies (5%) included a mixed patient population undergoing EAS and trauma laparotomy, and only two studies (5%) evaluated only trauma laparotomy patients. The distribution of studies according to year of publication and study location is described in Table 1. While the first identified study assessing the implementation of ERP for patients undergoing EAS was published in 2010, there has been an exponential increase in the number of articles in the field, with 44% of the identified studies being published between 2020 and 2022. Studies were published from a total of 17 countries, from low-middle income countries (LMICs)

to high income countries (HICs) as defined by the World Bank [22]. They were most frequently conducted in Europe (41%), followed by Asia (33%), and North America (18%).

The methodological characteristics of the included studies are described in Table 2. One consensus guideline from the ERAS society was published in 2021 [17]and three knowledge synthesis articles (e.g., systematic review or meta-analysis) were identified [23-25]. Most of the studies assessed the effectiveness of ERPs (n=31; 79%). Six studies were categorized as implementation/feasibility studies, of which two evaluated the implementation of ERPs in parallel with a large clinical trial assessing the effectiveness of ERPs [26-28]. Ten studies evaluated adherence to ERPs and showed a wide range of adherence rates (0% to 92% adherence rate). Sample sizes were widely variable (n=36-31,511). Outcome measures frequently targeted were hospital length of stay (HLOS) (n=29; 74%), complications (n=25; 64%), readmission rates (n=21; 54%), return of bowel function (n=17; 44%), mortality (n=13; 33%), and adherence to the ERP (n=10; 26%).

The distribution of studies according to surgical approach and procedures is described in Table 1. The majority of the studies included open surgery (n=32; 82%). All four studies (10%) evaluating trauma populations involved open surgeries with bowel resection and anastomosis, primary repair of the bowel, and stoma creation.

Elements of the ERPs:

Fourteen different protocols were identified and listed in Table 3. Overall, 29 preoperative components, 20 intraoperative components, and 27 postoperative ERP components were identified (Table 4, 5, and 6). The details of the components of each perioperative phase are provided in Online Resource 4, 5, and 6.

Preoperative components

Thirty-five studies (EAS=32, Trauma/EAS=3) reported preoperative components. Among the 29 components identified, “early prophylactic antibiotics” (n=23; 66%) and “patient and family education and shared decision making” (n=22; 63%) were the most frequently used components in the preoperative phase. Components recommended by consensus guideline are highlighted in Table 3 and Online Resource 6; these included: “early identification of physiologic derangement and intervention” (n=14; 40%), “risk assessment” (n=10; 29%), “pre-anesthetic medication, anxiolysis, and analgesia” (n=18; 51%), “preoperative nasogastric intubation” (n=11; 31%), and “patient and family education and shared decision making” (n=22; 63%); the remaining recommended ERP components (e.g., “age-related evaluation of frailty, and cognitive assessment”, “reversal of antithrombotic medications”, “preoperative carbohydrate loading”) were infrequently used in the studies. Of the three articles containing trauma populations, different components were used among the studies and “early prophylactic antibiotics” and “preoperative nasogastric intubation” were the common components used in all three studies.

Intraoperative components

Thirty-four studies (EAS=31, Trauma/EAS=3) reported intraoperative components. The most common intraoperative component was “intraoperative multimodal analgesia” (n=22; 65%). Other frequently used components were “standard anesthetic protocol” (n=18; 53%), “prevention of hypothermia” (n=16; 47%), “prophylactic antiemetics” (n=14; 41%), “goal-directed fluid therapy” (n=13; 38%), and “avoidance of routine intra-abdominal drain placement” (n=13; 38%). Of the three articles containing trauma populations, “intraoperative multimodal analgesia” was the common component used in all three studies.

Postoperative components

Thirty-seven (EAS=33, Trauma/EAS=4) studies reported postoperative components. Four components: “postoperative nutritional care” (n=29; 78%), “postoperative multimodal analgesia” (n=27; 73%), “early mobilization” (n=23; 62%), and “early removal of urinary catheter” (n=22; 59%) were used most frequently. Some of the components, such as “multimodal analgesia”, “senior clinical input”, and “fluid management (goal-directed fluid therapy)” overlap multiple phases. Of the four articles containing trauma populations, in addition to the above four components, “early removal of NG tube”, “early removal of drains”, and “antibiotics” were the most frequently used components.

Impact of ERP on clinical outcomes

A total of 26 studies comparing ERP group vs traditional care group were identified. Ten studies were RCTs and 16 were observational studies. (Table 2). A summary of these 26 studies addressing the comparative effectiveness of ERPs is provided in Online Resource 7. Of the 10 RCTs, seven studies included EAS patients, two included both trauma and EAS patients, and one included trauma patients only.

Among these 26 studies, the most frequently assessed outcome measure was HLOS. Eighteen studies (69%) assessed it as the primary outcome, all of which reported a significant reduction. The second most frequently assessed outcome measure was postoperative complication rates. Twelve studies assessed them, in which 4 studies reported significant reduction, while 8 studies found no difference between ERP and non-ERP groups. Eight studies set mortality as an outcome measure, four studies reporting a significant reduction, and 3 studies showing no significant difference. Mortality could not be assessed in one study as only one patient died among the study groups. Of the three studies that showed no significant difference in mortality, two evaluated several different outcomes, including HLOS reporting a positive impact of ERP,

whereas one study by Peden et al, a stepped-wedge cluster-randomized trial included total of 15873 patients from NHS hospitals, only assessed mortality within 90 days following surgery and showed no survival benefit [28].

Discussion

This scoping review comprehensively summarized the currently available literature on ERPs for trauma laparotomy and EAS, revealing a limited amount of literature. The literature is growing, with 17 articles (44%) published in the last three years. Studies were published from LMICs to HICs and this growing body of literature around the world reflects the growing interest in ERP in EAS.

The majority of the identified studies addressed the effectiveness of ERP on clinical outcomes (31/39; 79%). HLOS was the most frequently assessed clinical outcome measure with consistent positive results, supporting the use of ERP in emergency abdominal surgery. A study by Peden et al. showed no survival benefit following ERP implementation [28]. However, this study group embedded a study evaluating the process of ERP implementation in parallel with their main forementioned clinical trial, which provided important lessons for development and implementation of ERP including: (i) clear introduction of the intervention and guide for implementation, (ii) enough time for implementation, (iii) simple and adaptable components, (iv) multidisciplinary team engagement/involvement, and (v) incremental/stepped approach to improvement [26].

Based on results from the identified literature, ERPs have been shown to be potentially feasible and beneficial for both elective and emergency abdominal surgery. However, the identified literature varied widely in study design, study population, and elements used in the ERPs. Two systematic reviews and meta-analyses including 3 (n=818) and 6 (n=1334) studies, respectively

concluded that implementation of ERPs in emergency abdominal surgery significantly reduced HLOS, but one of them included a limited population of obstructive colorectal cancer [24].

We identified the various ERP components used in the studies, some of which demonstrated clear applicability to emergency abdominal surgery, as more than 20 studies have used them in their ERPs. Such components include: “early prophylactic antibiotics”, “patient and family education”, “intra- and postoperative multimodal analgesia”, “postoperative nutritional care”, “early removal of urinary catheter”, and “early mobilization". However, the existence of various ERPs with varying components for each operative phase conversely suggests that the concept of ERP in EAS is still in development and not yet widely accepted or standardized. These diverse ERPs from individual institutions or collaborative groups, as well as the complex and heterogenous patient populations are likely to have contributed to the limited use of ERPs in emergency surgery settings. While the ERAS Society has published a guideline for ERP use in EAS [17], this scoping review revealed that more than half of components from the guideline were not frequently used in the identified literature. The use of ERPs in future studies should be better standardized to minimize heterogeneity.

Our scoping review revealed a clear gap in ERP research focused on trauma laparotomy. Among the 39 publications, only two studies by Moydien et al [29], and Purushotha et al [30] were focused on trauma laparotomy patients. These studies included stable patients with isolated penetrating abdominal trauma who underwent emergency laparotomy and acutely injured patients who underwent emergency laparotomy, respectively. Both studies showed a significantly shorter HLOS in the ERP group. The other 35 studies excluded the trauma populations as many studies defined emergency laparotomy in line with the criteria used in large cohort studies [31, 32]. The criteria included patients aged 18 years and over, who underwent an

expedited, urgent, or emergency abdominal procedure on the gastrointestinal tract with open, laparoscopic, or laparoscopically assisted procedures. However, the laparotomy/laparoscopy for pathology caused by blunt or penetrating trauma was excluded [32]. Given the favorable outcomes of ERP with standardization of care in the EAS population, we believe that the benefits of ERP may also be applicable to trauma populations, particularly trauma laparotomy. Patients requiring trauma laparotomy have potential life-threatening conditions and may be in a state of physiological derangement when receiving non-elective urgent surgery, which is similar to the state of patients receiving EAS [17, 33]. Additionally, many of the surgical procedures identified in this scoping review are procedures required in trauma laparotomy such as bowel resection and anastomosis, colorectal resection, primary repair of the bowel, and stoma creation. However, the development and implementation of ERP in trauma laparotomy may face several barriers that need to be taken into account: (i) diverse patients' condition including severity (i.e., from minor to severe trauma), complex injuries (i.e., isolated injury to polytrauma, blunt or penetrating injury), and baseline co-morbidities, (ii) variations in procedure complexity (simple bowel resection to complex damage control surgery), (iii) requires a high volume center with sophisticated trauma systems, and (iv) requires a dedicated multidisciplinary trauma team and specialists.

Based on our results, the standardization of care through ERP implementation could potentially enhance the quality of care for high-risk surgical patients, including trauma laparotomy patients. Our findings serve as a foundation on which we can begin to develop standardized protocols for trauma laparotomy. However, as we do not yet have data for ERPs in patients with intra-abdominal solid organ injuries (e.g., spleen, liver, kidney), or for patients with concomitant extraperitoneal injuries such as chest trauma, pelvic and limb fractures, and traumatic brain

injury; ongoing revision of the protocols based on the best available evidence for trauma laparotomy will be essential.

Scoping review limitations

A limitation of the scoping review is that it presents an extensive but relatively superficial description of the literature [34]. Beyond mapping the identified literature, we did not perform a quantitative analysis of the collected data, so that we were unable to draw firm conclusions as to whether the use of ERP is effective in EAS patients. This review included laparoscopic cholecystectomy and appendectomy, which are quite different from the intra-abdominal procedures with physiological disruptions requiring intensive care and might affected the results of the review. However, the process of including these procedures was necessary to achieve one of the objectives of this scoping review to map the currently available literatures on EAS to see its broad application from minor to major abdominal procedures. Lastly, the ERP components that are summarized in this study may be debatable, as the grouping of similar contents was an unprecedented attempt, and some overlapping components could have been grouped in different ways. However, the purpose of extracting the components used in the studies has been fulfilled by listing all their details in the Online Resources.

Conclusion

This scoping review shows that the implementation of ERPs to enhance the quality of care is now extending to emergency surgical settings. Studies on ERP implementation in the EAS populations were published across a range of countries, from LMICs to HICs. These studies provide evidence of improved outcomes, such as reduced HLOS. However, a clear gap in ERP research focused on trauma laparotomy was identified. Standardization of care through ERP implementation has potential to improve the quality of care in EAS as well as trauma

laparotomy. Further research with continued efforts towards the development and implementation of ERPs for these “high-risk” surgical populations will be an essential step prior to integrating such pathways into clinical practice.

STATEMENTS AND DECLARATIONS

Declaration of interest: The authors, Hayaki Uchino, Philip Nguyen-Powanda, Junko Tokuno, Araz Kouyoumdjian, Julio F Fiore Jr, and Jeremy Richard Grushka, declare that they have no conflicts of interest.

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Ethical consideration: Since scoping reviews do not involve direct interaction with individuals or the collection of new data, they are considered to be exempt from ethical approval requirements. However, the authors adhered to ethical principles when conducting this study.

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Table 1. Distribution of studies according to year of publication, study location, surgical approach, and surgical procedures

	Overall	Emergency Abdominal Surgery	Trauma +/- EAS
Number of studies, n	39	35	4
Publication year, n (%)			
2010 - 2014	3 (7%)	3 (9%)	0 (0)
2015 - 2019	19 (49%)	18 (51%)	1 (25%)
2020 - 2022	17 (44%)	14 (40%)	3 (75%)
Study location (country), n			
Europe, n (%)	**16 (41%)**		
United Kingdom	9	9	0
Denmark	2	2	0
Switzerland	2	2	0
France	1	1	0
Spain	1	1	0
Turkey	1	1	0
North America, n (%)	**7 (18%)**		
United States	6	6	0
Canada	1	1	0
Asia, n (%)	**14 (36%)**		
India	6	3	3
Thailand	3	3	0
Japan	1	1	0
China	1	1	0
Singapore	1	1	0
Nepal	1	1	0
Pakistan	1	1	0
Africa, n (%)	**1 (2.5%)**		
South Africa	1	0	1
Australia, n (%)	**1 (2.5%)**		
Australia	1	1	0
Surgical approach, n (%)			
Open	16 (41%)	12 (34%)	4 (100%)
Laparoscopy	6 (15%)	6 (17%)	0
Open + Laparoscopy	16 (41%)	16 (46%)	0
Not applicable (NA) *	1	1	0
Surgery performed, n (%) **			
Colorectal resections ***	13 (33%)	13 (37%)	0
Repair of peptic ulcer disease	8 (21%)	7 (20%)	1 (25%)
Bowel resection and anastomosis	12 (31%)	9 (26%)	3 (75%)
Primary repair of the bowel	9 (23%)	6 (17%)	3 (75%)
Lysis of adhesion	7 (18%)	7 (20%)	0
Major hernia repair	4 (10%)	4 (11%)	0
Abdominal drainage / lavage	5 (13%)	5 (14%)	0
Oversaw and ligation of bleeding	3 (8%)	3 (9%)	0
Stoma creation	9 (23%)	6 (17%)	3 (75%)
Laparoscopic cholecystectomy	3 (8%)	3 (9%)	0
Open / Laparoscopic appendectomy	5 (13%)	4 (11%)	1 (25%)
Exploratory laparotomy	4 (10%)	4 (11%)	0
Not reported (NR) ****	11	10	1

*Guidelines **Single study includes multiple procedures ***Including right hemicolectomy, left hemicolectomy, sigmoidectomy, anterior resection, segmental colectomy, Hartmann's, subtotal/total colectomy, abdominoperineal

resection. ****Specific procedures not reported (e.g., Emergency laparotomy, Emergency open abdominal surgery, Emergency colorectal operations). EAS emergency abdominal surgery.

Table 2. Methodological characteristics of studies addressing enhanced recovery pathway for trauma and emergency abdominal surgery

	Overall	Emergency Abdominal Surgery	Trauma +/- EAS
Number of studies, n	39	35	4
Study category*, n (%)			
Effectiveness	31 (79%)	27 (77%)	4 (100%)
Adherence	10 (26%)	10 (29%)	0
Implementation feasibility	6 (15%)	6 (17%)	0
Cost effectiveness	4 (10%)	4 (11%)	0
Description	2 (5%)	2 (6%)	0
Study design, n (%)			
Systematic review (+/- meta-analysis)	3 (8%)	3 (9%)	0
RCTs (ERP vs non-ERP)	10 (26%)	7 (20%)	3 (75%)
Comparative observational studies (ERP vs non-ERP)	16 (41%)	15 (43%)	1 (25%)
Comparative observational studies (Others**)	5 (13%)	5 (14%)	0
Non-comparative studies***	4 (10%)	4 (11%)	0
Guidelines	1 (2%)	1 (3%)	0
Sample size, n (%)			
<=100	14 (36%)	11 (31%)	3 (75%)
101-500	10 (26%)	9 (26%)	1 (25%)
501-1000	7 (18%)	7 (20%)	0
>1000	6 (15%)	6 (17%)	0
Not applicable (NA)	2 (5%)	2 (6%)	0
Multicenter study, n (%)	11 (28%)	11 (31%)	0
<10	6 (15%)	6 (17%)	0
>11	5 (13%)	5 (14%)	0
Outcome measures, n (%)			
Hospital length of stay	29 (74%)	25 (71%)	4 (100%)
Complications (SSI, CAUTI, pneumonia, VTE, AKI, repair site leakage)	25 (64%)	22 (63%)	3 (75%)
Readmission rate	21 (54%)	20 (57%)	1 (25%)
Return of bowel function	17 (44%)	13 (37%)	4 (100%)
Mortality	13 (33%)	13 (37%)	0
Functional recovery	8 (21%)	4 (11%)	4 (100%)
Unplanned return to ER/OR/ICU / Need for re-operation	8 (21%)	8 (23%)	0
Discharge from PACU/within 12 hours post PACU	2 (5%)	2 (6%)	0
Time to OR	1 (2%)	1 (3%)	0
CT scan use	1 (2%)	1 (3%)	0
Time interval from surgery to chemotherapy	3 (8%)	3 (9%)	0
Patient reported outcome	7 (18%)	6 (17%)	1 (25%)
Cost / Resource utilization	5 (13%)	5 (14%)	0
Adherence to protocol	10 (26%)	9 (26%)	1 (25%)
Process evaluation	2 (5%)	2 (6%)	0

*Effectiveness: Assessing the effectiveness of ERPs on clinical outcomes. Adherence: Compliance or adherence to ERPs components. Implementation feasibility: Acceptability/barriers for ERP implementation. Cost effectiveness: Impact on cost during ERP implementation. Description: guidelines/recommendations. **Studies assessing emergency vs. elective surgery, patients aged >=80 years vs. patients aged <80. ***Observational cohort study and

mixed method study. EAS emergency abdominal surgery, RCTs randomized controlled trials, ERP enhanced recovery pathway, SSI surgical site infection, CAUTI catheter associated urinary tract infection, VTE venous thromboembolism, AKI acute kidney injury, ER emergency room, OR operating room, ICU intensive care unit, PACU post-anesthesia care unit.

Table 3. Variety of Protocols/Bundles used in the studies

	Overall	Emergency Abdominal Surgery	Trauma +/- EAS
Number of studies, n	39	35	4
Enhanced Recovery After Surgery (ERAS) protocol	12	11	1
Enhanced (Postoperative) Recovery Pathway/Protocol (ERP)	5	4	1
Emergency Laparotomy Pathway Quality Improvement Care (ELPQuiC) bundle	4	4	0
Enhanced Peri-operative Care for High-risk (EPOCH) trial care pathway	3	3	0
Adapted ERAS pathway/protocol	3	1	2
Optimizing Major EmerGency Abdominal surgery (OMEGA) bundle	2	2	0
Fast Track (FT) pathway/protocol	2	2	0
Modified ERAS program	2	2	0
Emergency Laparotomy (ELAP) pathway	1	1	0
A standardized perioperative management protocol	1	1	0
A standardized pathway	1	1	0
A 6-point, evidence-based care bundle	1	1	0
An expedited discharge protocol	1	1	0
Early rehabilitation protocol	1	1	0

EAS emergency abdominal surgery.

Table 4. Preoperative components used in the studies

Preoperative	Overall	Emergency Abdominal Surgery	Trauma +/- EAS
Number of studies, n	35	32	3
Early identification of physiological derangement and intervention	14	12	2
Two large peripheral intravenous catheters	2	2	0
Arterial line/Central line insertion	5	3	2
Management of anemia and coagulopathy	5	5	0
Maintain normothermia	3	3	0
Preoperative fasting	7	7	0
Screen and monitor for sepsis and accompanying physiological derangement	4	4	0
Standardised preoperative blood analysis/ECG	5	5	0
Early imaging, surgery, and source control of sepsis	1	1	0
Prioritized imaging (CT scan)	5	5	0
Bedside ultrasound	1	1	0
Early prophylactic antibiotics	24	21	3
Direct surgical consultation	2	2	0
Early surgery	12	12	0
Senior clinical input (consultant anesthetist and surgeon)	5	5	0
Preoperative ostomy marking	3	3	0
Risk assessment	10	10	0
Age-related evaluation of frailty, and cognitive assessment	3	3	0
Reversal of antithrombotic medications	1	1	0
Assessment of venous thromboembolism risk	1	1	0
Venous Thromboembolism prophylaxis	7	7	0
Pre-anesthetic medication, anxiolysis and analgesia	18	16	2
Prevention of stress ulcer	4	3	1
Preoperative glucose and electrolyte management	5	5	0
Preoperative carbohydrate loading	6	6	0
Preoperative nasogastric intubation	11	8	3
Preoperative urinary catheter insertion	5	4	1
Avoid urinary catheter	1	1	0
Patient and family education and shared decision making	22	21	1

: Guidelines. Details for each components are described in supplementary results 2. EAS emergency abdominal surgery, ECG electrocardiogram.

Table 5. Intraoperative components used in the studies

Intraoperative	Overall	Emergency Abdominal Surgery	Trauma +/- EAS
Number of studies, n	34	31	3
Standard anesthetic protocol	18	17	1
Senior clinical input (consultant anesthetist and surgeon)	11	11	0
Goal-directed fluid therapy (including post-op)	13	12	1
Prophylactic antibiotics	7	7	0
Standardized surgical approach	7	7	0
Laparoscopic approach (minimal invasive)	7	7	0
Intraoperative multimodal analgesia	23	20	3
Prophylactic antiemetics	14	14	0
Prevention of hypothermia	16	15	1
Risk assessment (consider ICU/PACU)	5	5	0
Time out	2	2	0
Avoidance of routine NG tube or remove NG tube at the end of surgery	8	8	0
Routine NG tube placement	1	1	0
Avoidance of routine urinary catheter placement	2	2	0
Routine urinary catheter placement	1	1	0
Avoidance of routine intra-abdominal drain placement	13	12	1
WHO safe surgery checklist	3	3	0
Venous Thromboembolism prophylaxis	4	4	0
Measure arterial blood gases and serum lactate	3	3	0
Prevention of stress ulcer	1	1	0

Details for each components are described in supplementary results 3. EAS emergency abdominal surgery, ICU intensive care unit, PACU peri-anesthesia care unit, NG tube nasogastric tube, WHO World Health Organization.

Table 6. Postoperative components used in the studies

Postoperative	Overall	Emergency Abdominal Surgery	Trauma +/- EAS
Number of studies, n	37	33	4
Routine admission to ICU	7	7	0
Admission to ICU or PACU	4	4	0
Standardized discharge from PACU	2	2	2
Senior clinical input (consultant anesthetist and surgeon)	1	1	0
Postoperative nutritional care	29	25	4
Postoperative multimodal analgesia	27	23	4
Early removal of NG tube	14	10	4
Early removal of urinary catheter	22	18	4
Early removal of drains	10	7	3
Early removal of intravenous catheter	3	2	1
Early mobilization	23	20	3
Early physiotherapeutic assessment and intervention	9	7	2
Antibiotics	10	7	3
Fluid management	5	5	0
Targeted glucose control	4	4	0
Maintain normothermia	3	3	0
Prophylactic antiemetics	9	9	0
Prevention of postoperative ileus	6	6	0
Venous thromboembolism prophylaxis	9	8	1
Prevention of stress ulcer	5	3	2
Standardized postoperative blood analysis	6	6	0
Standardized postoperative surgical rounds	5	5	0
Standardized postoperative nurse observation	2	2	0
Postoperative geriatric assessment (65 years or older)	1	1	0
Information, education, and counselling	8	7	1
Discharge evaluation	8	8	0
Systematic audit (Bi-monthly meeting)	1	1	0

Details for each components are described in supplementary results 4. EAS emergency abdominal surgery, ICU intensive care unit, PACU peri-anesthesia care unit, NG tube nasogastric tube.

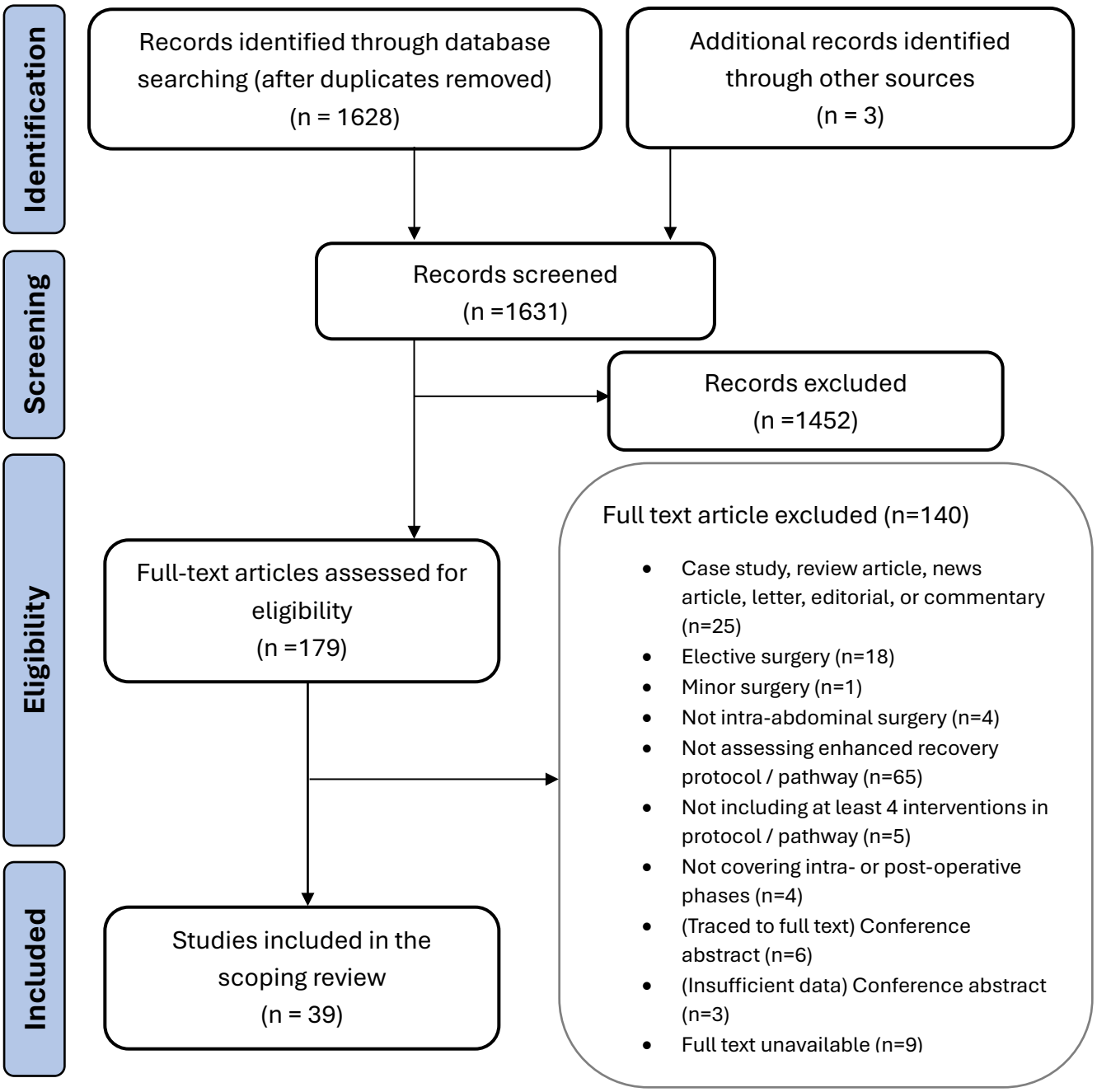

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram

Online Resource 1. Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Review (PRISMA-ScR) checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	#1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	#2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	#3
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	#3
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	#3-4
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	#4-5
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	#4
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	#4
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	#5
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	#5-6
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	#5
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	NA
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	#6

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	#6-7, Figure 1
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	#6-7
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	NA
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	#7-10, Online Resource 4-7
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	#7-10, Online Resource 4-7
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	#10-13
Limitations	20	Discuss the limitations of the scoping review process.	#13
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	#13-14
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	#15

Online Resource 2. protocol amendment

Change	Reason
May 2022. Team meeting (during full-text screening) *Eligibility criteria* Initial eligibility criteria: "covering at least both intra-, and post-operative phases." Was modified to: "covering at least one of the operative phases: preoperative, intraoperative, and postoperative."	Initially, we expected to find studies evaluating the ERPs without preoperative phase, as our focus is on emergency surgery and preoperative components are often difficult to implement for these populations. While conducting full-text screening, some studies were found to include only postoperative phase, but had 4 or more components with reasonable study designs and study populations. We also found that published guideline from International ERAS society only covered preoperative phase. Thus, the eligibility criteria have been changed.
Oct 2022. Team meeting (after data synthesis) *Study categorization (Data synthesis)* Our initial study category: "feasibility (i.e., patients' barriers/acceptability to ERP implementation, cost-effectiveness analysis)" Was modified to: "implementation feasibility (i.e., patients' barriers/acceptability to ERP implementation), cost-effectiveness (i.e., evaluating the impact on cost during ERP implementation)"	After data extraction and data synthesis, we found there was no study focused on trial feasibility, and only focused on feasibility on ERP implementation. We also found that studies evaluating cost-effectiveness were not intended to assess the feasibility of ERP implementation. They were focused more on the impact on the cost after ERP implementation. Therefore, we decided to add "implementation" to clarify what feasibility they are assessing and to categorize cost-effectiveness as a separate category to avoid misclassification.

ERP enhanced recovery protocol, ERAS enhanced recovery after surgery.

Online Resource 3. Search strategies

Strategy: Medline

	https://proxy.library.mcgill.ca/login?url=http://ovidsp.ovid.com/ovidweb.cgi?T=JS&NEWS=N&PAGE=main&SHAREDSEARCHID=47nXJpvGHZF1nEIVYtSrTSbbIKG1pLWRuqNKuafisR08XdgsqvDGL8svAxsFeRTYA	
	Ovid MEDLINE(R) ALL <1946 to January 26, 2022>	
1	Critical Pathways/	7361
2	Enhanced Recovery After Surgery/	992
3	exp *Postoperative Complications/pc [Prevention & Control]	58685
4	Patient Discharge/	35230
5	eras.tw,kf.	5418
6	(fasttrack* or fast-track*).tw,kf.	4944
7	(enhanc* adj3 recover*).tw,kf.	13524
8	(rapid* adj3 recover*).tw,kf.	11812
9	(care adj2 map?).tw,kf.	234
10	((clinical or critical or surger* or surgical* or patient or patients or care) adj2 (path* or path way*)).tw,kf.	128682
11	(earl* adj2 recover*).tw,kf.	7086
12	(accelerat* adj3 recover*).tw,kf.	4961
13	(erp or erps).tw,kf.	21800
14	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13	287883
15	(abdom?n* adj2 surg*).tw,kf.	23665
16	exp abdomen/su	24099
17	Laparotomy/ or laparotom*.tw,kf.	62287
18	exp Digestive System/su [Surgery]	116725
19	exp Digestive System Surgical Procedures/ or (appendectom* or cholecystectom* or colectom* or gastrectom* or hepatectom* or colostom*).tw,kf. [MeSH includes Appendectomy, Cholecystectomy, Colectomy, Gastrectomy, Hepatectomy, Colostomy]	434212
20	Splenectomy/ or splenectom*.tw,kf.	32477
21	exp Nephrectomy/ or (heminephrectom* or nephrectom* or nephroureterectom*).tw,kf.	55227
22	Bowel resect*.tw,kf.	5700
23	Adhesioly*.tw,kf.	1790
24	15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23	657267
25	14 and 24	22250
26	exp Emergency Medical Services/	158079
27	exp Emergency Service, Hospital/	91290
28	exp emergency treatment/	129340
29	Emergencies/	42329
30	exp Trauma Severity Indices/	36715

31	((trauma* or emergency or urgen* or critical*) adj6 ((abdom#n* adj2 surg*) or laparotom* or Appendectom* or Cholecystectom* or Colectom* or Gastrectom* or Hepatectom* or Colostom* or splenectom* or heminephrectom* or nephrectom* or nephroureterectom* or bowel resect* or adhesioly*)).tw,kf.	9740
32	26 or 27 or 28 or 29 or 30 or 31	335340
33	25 and 32	696
34	(exp child/ or exp infant/) not (exp adolescent/ or exp adult/)	1363825
35	33 not 34	669
36	remove duplicates from 35	664

Strategy: Embase

	https://proxy.library.mcgill.ca/login?url=http://ovidsp.ovid.com/ovidweb.cgi?T=JS&NEWS=N&PAGE=main&SHAREDSEARCHID=586gJq4WOBPAbM1msylo2d97F4g0A5JCv141CYNv191PXqu7joiLO6lKNgMaagwAD	
	Embase <1974 to 2022 January 26>	
1	clinical pathway/	9086
2	enhanced recovery after surgery/	2357
3	exp *postoperative complication/pc [Prevention]	34909
4	hospital discharge/	150615
5	eras.tw,kf.	9121
6	(fasttrack* or fast-track*).tw,kf.	7755
7	(enhanc* adj3 recover*).tw,kf.	19126
8	(rapid* adj3 recover*).tw,kf.	15147
9	(care adj2 map?).tw,kf.	353
10	((clinical or critical or surger* or surgical* or patient or patients or care) adj2 (path* or path way*)).tw,kf.	194309
11	(earl* adj2 recover*).tw,kf.	10489
12	(accelerat* adj3 recover*).tw,kf.	6508
13	(erp or erps).tw,kf.	28187
14	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13	466656
15	(abdom?n* adj2 surg*).tw,kf.	33212
16	exp abdomen/su [Surgery]	5629
17	exp abdominal surgery/ or (laparotom* or appendectom* or cholecystectom* or colectom* or gastrectom* or hepatectom* or colostom* or splenectom* or bowel resect*).tw,kf.	895223
18	exp Nephrectomy/ or (heminephrectom* or nephrectom* or nephroureterectom*).tw,kf.	83002
19	Adhesioly*.tw,kf.	3374
20	15 or 16 or 17 or 18 or 19	977587
21	14 and 20	45200

22	exp emergency health service/	115419
23	emergency treatment/ or exp emergency care/ or exp evidence based emergency medicine/	70152
24	emergency/	53760
25	exp injury scale/	58583
26	((trauma* or emergency or urgen* or critical*) adj6 (laparotom* or Appendectom* or Cholecystectom* or Colectom* or Gastrectom* or Hepatectom* or Colostom* or splenectom* or heminephrectom* or nephrectom* or nephroureterectom* or bowel resect* or adhesioly*)).tw,kf.	11954
27	22 or 23 or 24 or 25 or 26	288496
28	21 and 27	1457
29	limit 28 to (conference abstracts or embase)	1319
30	29 not (nonhuman/ not human/)	1305
31	30 not Veterinar*.af.	1300
32	23 or 24 or 26	132858
33	31 and 32	1057
34	33 not (child* or infan* or p?ediatr*).ti,jx.	987
35	remove duplicates from 34	983

Strategy: Web of Science

	Web of Science Core Collection	
1	TS=(eras)	240,251
2	TS=((fasttrack* or fast-track*))	9,617
3	TS=((enhanc* near/3 recover*))	33,397
4	TS=((rapid* near/3 recover*))	14,266
5	TS=((care near/2 map$))	357
6	TS=(((clinical or critical or surger* or surgical* or patient or patients or care) near/2 ((path* or (path near/0 way*)))))	175,392
7	TS=((earl* near/2 recover*))	10,017
8	TS=((accelerat* near/3 recover*))	6,444
9	TS=((erp or erps))	40,580
10	#9 OR #8 OR #7 OR #6 OR #5 OR #4 OR #3 OR #2 OR #1	521,080
11	TS=(((trauma* or emergency or urgen* or critical*) NEAR/6 (laparotom* or Appendectom* or Cholecystectom* or Colectom* or Gastrectom* or Hepatectom* or Colostom* or splenectom* or heminephrectom* or nephrectom* or nephroureterectom* or (bowel NEAR/0 resect*) or adhesioly*)))	7,745
12	#11 AND #10	275

Online Resource 4. Details for preoperative components used in the studies

Preoperative	
Early identification of physiological derangement and intervention	Optimization of preoperative physiological derangements, resuscitation, supplement oxygen, fluid replacement, CVP guided IV fluids, early goal-directed therapy.
Two large peripheral intravenous catheters	
Arterial line/Central line insertion	Arterial line unless in patients <50 years, ASA 1-2, and lactate <1mM. Central line if MAP< 65mmHg, sepsis, and continuous need for vasopressor. Central line for CVP guided fluid management
Management of anemia and coagulopathy	Transfusion upon indication, TEG/ROTEM guided, correction of coagulopathy.
Maintain normothermia	
Preoperative fasting	Clear fluid until 2h, solids 6h before surgery. Oral intake 2h before the anesthesia induction if possible. No preoperative fasting.
Screen and monitor for sepsis and accompanying physiological derangement	Sepsis screening and prophylactic sepsis intervention.
Standardised preoperative blood analysis/ECG	Laboratory data including lactate, CBC, blood type and antibody screen, C-reactive protein, urinalysis, beta human chorionic gonadotropin testing.
Early imaging, surgery, and source control of sepsis	
Prioritized imaging (CT scan)	CT imaging within 2 hours of decision to perform test. Prioritized contrast-enhanced CT scan with accelerated radiologic answer.
Bedside ultrasound	Bedside ultrasound for female gender and body mass index less than 26kg/m2 encouraged to prevent unnecessary CT scans.
Early prophylactic antibiotics	Treat with antibiotics within 1 hour of first medical assessment. Broad-spectrum antibiotics (covering aerobic and anaerobic bacteria) to all patients with suspicion of peritoneal soiling or with a diagnosis of sepsis.
Direct surgical consultation	General surgery review within 2 hours of referral. Direct surgical consultation with no imaging.
Early surgery	Move to operating room within 6 hours of decision to operate or scheduled in the next available operating room.
Senior clinical input	Consultant led decision making, Routine involvement of senior clinicians.
Preoperative ostomy marking	Preoperative bilateral ostomy marking.
Risk assessment	Using validated scoring model; Portsmouth Physiological and Operative Severity Score for the enumeration of Mortality and Morbidity (P-POSSUM), National Early Warning score, M(EWS).
Age-related evaluation of frailty, and cognitive assessment	Evaluation of frailty, and cognitive assessment. Preoperative 4AT delirium assessment.
Reversal of antithrombotic medications	
Assessment of venous thromboembolism risk	
Venous Thromboembolism prophylaxis	Low molecular weight heparin 12 hours before surgery, IPC device. For older than 45 years. For all cases.
Pre-anesthetic medication, anxiolysis and analgesia	Including non-opioid multimodal analgesia, thoracic/lumber epidural unless contraindicated, analgesia within 1 hour of first medical assessment, no or avoid anesthetic premedication, avoid long-acting pre-anesthetic medication, and IV pain relief with tramadol.
Prevention of stress ulcer	Intravenous proton pump inhibitor.
Preoperative glucose and electrolyte management	Active glucose management.
Preoperative carbohydrate loading	Ex. Carbohydrate drinks-800ml on evening, and 400ml 2h before surgery.
Preoperative nasogastric intubation	Nasogastric tube with suction, routine NG tube placement.
Preoperative urinary catheter insertion	Routine urinary catheter insertion.
Avoid urinary catheter	Avoided by having patients void immediately preoperatively.
Patient and family education and shared decision making	Standardized preoperative patient information. Preoperative counseling on postoperative care and restrictions. Education via video. Detailed information and education, including breathing exercise, mobilisation, dietary goal, and estimated hospital length of stay. Provided patient and relatives with oral and written information about treatment. Explained in brief while taking consent. Discussion of post-op pathway goals. When appropriate, treatment escalation plans and advance care plans should be discussed and documented.

CVP central venous pressure, IV intravenous, ASA American Society of Anesthesiology, MAP mean arterial pressure, TEG thromboelastogram, ROTEM rotational thromboelastometry, ECG electrocardiogram, CBC complete blood count, P-POSSUM Portsmouth-physiological and operative severity score for the enumeration of mortality and morbidity, MEWS modified early warning score, 4AT 4 'A's test, IPC intermittent pneumatic compression, NG nasogastric.

Online Resource 5. Details for intraoperative components used in the studies

Intraoperative	
Standard anesthetic protocol	Including baseline target MAP>65 mmHg, baseline vasopressor, invasive monitoring (if necessary), fluid optimization, transfusion, rapid sequence induction, TIVA, avoid benzodiazepines, non-depolarizing muscle relaxant, TOF monitoring, baseline ventilator management, oxygen supplement, glucose management, short-acting anesthetic agents. Balanced general anesthesia.
Senior clinical input	Consultant delivered surgery and anesthesia. Consultant surgeon and anesthesiologist in operating room. Senior clinicians' involvement.
Goal-directed fluid therapy	Fluid therapy guided by cardiac output monitoring. Continued for a minimum of 6 hours post-operatively. Peri-operative goal-directed fluid administration.
Prophylactic antibiotics	A single dose of parenteral antibiotic perioperatively. Continued if more than 6 hours from initial dose.
Standardized surgical approach	Standardized surgical incision and procedures (Ex. midline laparotomy or right transverse incision for right hemicolectomy) with the application of O-ring wound retractor. Routine skin antisepsis and use of wound protector.
Laparoscopic approach (minimal invasive surgery)	Laparoscopic surgery for colon resection, cholecystectomy, and appendectomy.
Intraoperative multimodal analgesia	Including epidural, PCA, truncal regional block, local anesthesia, non-opioid/short-acting opioid anesthesia.
Prophylactic antiemetics	Prevention of PONV, according to the Apfel's risk score.
Prevention of hypothermia	Core temperature>36°C measured by thermo-urine catheter. Active warming using warm intravenous fluid, warm air body heating device, and warm saline-soaked swab around the intestine)
Risk assessment (consider ICU/PACU post-op)	Risk scoring at the end of surgical procedure using modified Surgical Apgar Score (Surgical Apgar Score + ASA)
Timeout	Short structured half-hourly time-outs including input from all personal at the operating theatre with the focus of (1) surgical progress, (2) anaesthetic status, (3) anticipated critical phases, and (4) possible need for damage control.
Avoidance of routine NG tube or remove NG tube at the end of surgery	If present, NG tube will be removed before extubation or within <12 postoperative hours.
Routine NG tube placement	Schedule to remove on POD 2-3 except NG tube content > 800ml/day.
Avoidance of routine urinary catheter placement	Decrease urinary catheter use. If present, remove urinary catheter at the end of the case.
Routine urinary catheter placement	Schedule to remove on POD 2-3 if no contraindication.
Avoidance of routine intra-abdominal drain placement	Restricted use of intra-abdominal drains. No abdominal drains.
WHO safe surgery checklist	
Venous Thromboembolism prophylaxis	physical prophylaxis combined with low molecular weight heparin, prescribe post-operative venous thromboembolism prophylaxis.
Measure arterial blood gases and serum lactate	
Prevention of stress ulcer	Perioperative administration of proton pump inhibitor.

MAP mean arterial pressure, TIVA total intravenous anesthesia, TOF train of four test, PCA patient-controlled analgesia, PONV postoperative nausea and vomiting, POD postoperative day, WHO World Health Organization.

Online Resource 6. Details for postoperative components used in the studies

Postoperative	
Routine admission to ICU	ICU admission for all patients after surgery. Admission to critical care within 6 hours of surgery.
Admission to ICU or PACU	Patients recover in PACU postoperatively. All patients admitted to critical care when possible or held in PACU for at least 6 hours. Admission of high-risk patients to ICU.
Standardized discharge from PACU	Surgical and anesthesiologic plan upon discharge from PACU including fluids and pain treatment. Discharge to ward only between 7 AM to 10 PM. Discharge to designated part of surgical ward.
Senior clinical input	Consultant surgeon and anesthetist involvement throughout the pathway.
Postoperative nutritional care	Early postoperative enteral nutrition. Early ingestion of oral intake. Early dietitian review with consideration of benefits of enteral feeding. Liquid intake within 24 hours of operation. Liquid diet as tolerated; normal diet as tolerated within next 24 hours. Routine oral nutritional supplement on POD 1. Oral nutrition supplement if patient's calories intake <60% of target goal. NPO till passage of flatus.
Postoperative multimodal analgesia	Non-opioid (opioid sparing) analgesia, use NSAIDs, acetaminophen. Opioid analgesics only for rescue analgesia. Epidural anesthesia or PCA, removal on POD 2. Convert to oral medications once solid diet is initiated. Use pain protocol. Early review by acute pain team.
Early removal of NG tube	Quick and safe removal of NG tube when lack of nausea and ability to hold clear liquids. At 24-48 hours postoperatively unless there was >400/300ml/day drainage. Removal within 6-12 hours.
Early removal of urinary catheter	Removal within 12-48 hours. When output is adequate over 24 hours. Remove as soon as possible or when removal of thoracic epidural. Document reason for maintenance. If failed, educate selfcare.
Early removal of drains	Drain removal when 24h production less than 50/100ml/day. Remove drains 24-48 hours postoperatively.
Early removal of intravenous catheter	Early intravenous line removal. Remove IV therapy on POD 2.
Early mobilization	Mobilization as soon as possible. Mobilization within 12-24 hours of operation. Scheduled ambulation from POD 1 by trained nursing staff. With the goal of having all patients fully independent by day 3. Out of bed at least 6 hours/day. Patient is made to sit for 2 hours on POD 0 and ambulate after removal of epidural catheter after 24 hours postoperatively.
Early physiotherapeutic assessment and intervention	Regular mobilization with daily physiotherapy. Chest physiotherapy review on day 1 after surgery. Physiotherapy assisted walking, chest physiotherapy and incentive spirometry.
Antibiotics	Continue for 5 days, if discharge before 5 days, give orally. Discontinue if not needed. Continue where indicated with microbiology review.
Fluid management	Goal-directed fluid therapy. Strict fluid management postoperatively and early discontinuation of intravenous fluids with resumption of oral feeds. Balanced intravenous fluid management. Fluid therapy to keep a urine output of 0.5-1 ml/kg per hour, with deliberate administration of colloid solution if needed.
Targeted glucose control	Targeted glucose 80-200mg/dl. Active glucose management.
Maintain normothermia	
Prophylactic antiemetics	Prevention of postoperative nausea and vomiting. (e.g., metoclopromide)
Prevention of postoperative ileus	Stimulation of gut motility (use of oral magnesium oxide). Chewing gum. Use of prokinetic drugs (e.g., Metoclopramide, Domperidone, Mosapride)
Venous thromboembolism prophylaxis	Low molecular weight heparin throughout admission. Chemoprophylaxis within 12-48 hours of operation. Mechanical sequential compression device.
Prevention of stress ulcer	IV proton pump inhibitor. (e.g., Pantoprazole, Omeprazole, IV convert to oral)
Standardized postoperative blood analysis	Daily standardized biochemistry and hematology from POD 0-4 or risk is low (senior opinion): electrolytes, infection parameters, nutrition parameters, iron metabolism, troponin, blood sugar. C-reactive protein on POD 3.
Standardized postoperative surgical rounds	Critical care outreach review on standard ward with use of Early Warning Score. Focus areas of respiration, mobilization, abdominal function, fluids and electrolytes, nutrition, infection, analgesia.
Standardized postoperative nurse observation	Fluid balance chart, daily weight, focus areas of respiration, mobilization, abdominal function, fluids and electrolytes, nutrition, infection, analgesia, and 4AT delirium assessment twice daily.
Postoperative geriatric assessment	Postoperative geriatric assessment of patients aged 65 years or older.
Information, education, and counselling	Provide follow up plans, patient education regarding medication and complications. Counselling and written instructions. Repetition of patient information.

Discharge evaluation	Criteria led discharge. Direct discharge from PACU. Early discharge, aim to discharge on POD3-5.
Systematic audit (Bi-monthly meeting)	

ICU intensive care unit, PACU peri-anesthesia care unit, NPO nil per os, NSAID non-steroidal anti-inflammatory drugs.

Online Resource 7. Studies assessing the impact of enhanced recovery pathway on clinical outcomes

Study	Study design	Population	Sample size		Primary outcome(s)	Key findings
			ERP	Non-ERP		
Aggarwal 2017	COS	Patients underwent emergency laparotomy	9247	5562	Mortality / LOS	Unadjusted mortality rate decreased from 9.8% at baseline to 8.3% in year 2 of the project, and so did risk-adjusted mortality from a baseline of 5.3% to 4.5%. The baseline LOS mean was 20.1 days, which decreased to 18.9 days during year 1 and remained at 18.9 days during year 2 of bundle implementation.
Bada 2017	COS	Patients underwent laparoscopic appendectomy	93	82	CT scan use / LOS / Discharge from PACU / Complications / Readmission rate	14% decrease in CT scan use in the POST group. A significant decrease in LOS between the groups (PRE 1.3 vs POST 0.9 days; p=<0.001). No difference in subsequent ED visits for complications or 30-day readmission rate.
Doyle 2019	COS	Patients underwent emergency laparotomy	427	299	Incidence of AKI	The overall AKI incidence was 18.4% in the pre-bundle group versus 19.8% in the post bundle group (p=0.653). No significant differences were observed.
Ebm 2018	COS	Patients underwent emergency laparotomy	427	299	Cost effectiveness	In-hospital costs per patient were estimated at €14817.24 for standard treatment vs €15971.24 for the bundle treatment. Taking a societal perspective, lifetime costs of the patient in the standard group were €23058.87, compared with €19102.37 for patients receiving bundle care. Implementation of the bundle is associated with lower mortality and higher in-hospital costs but reduced societal costs.
Eveleigh 2016	COS	Patients underwent emergency laparotomy	108	144	Cost	The costs per patient and per survivor did not differ between the time periods, p=0.87 and p=0.17, respectively. Costs were similar for patients aged <80 years vs. >=80 years. Implementation of a bundle for emergency laparotomy has the capacity to save lives without increasing hospital costs.
Gonenc 2014	COS	Patients underwent laparoscopic Graham patch repair (LGPR)	21	26	LOS / Complications / Mortality	There were no significant differences in the morbidity and mortality rates, whereas the length of hospital stay was significantly shorter (6.9 +/- 2.2 (4-17) vs 3.8 +/- 1.9 (3-15) days, p=.0001) in ERAS group.
Huddart 2015	COS	Patients underwent urgent or emergency laparotomy	427	299	Mortality	Risk-adjusted CUSUM plots showed an increase in the numbers of lives saved per 100 patients, from 6.47 in the baseline interval to 12.44 after implementation (P<0.001). The overall case mix-adjusted risk of death decreased from 15.6 to 9.6 per cent (p=0.002)
Karunakaran 2016	RCT	Patients (age 10-80) with acute abdomen and planned for emergency laparotomy	25	25	LOS / Return of bowel function / Pain score	There was a significant difference in the mean day of return of bowel function between 2 groups (p,0.0001). Total LOS in standard care group 10.56 vs ERAS group 7.88 days. The mean difference of 2.68 with p<0.0001. Mean pain score was 2.08 in ERAS group compared to 3.12 in standard care group (p<0.0001)
Kuhlenschmidt 2021	COS	Patients underwent urgent/emergent laparoscopic cholecystectomy	430	49	Time to operating room / LOS / Resource utilization	The median time to operating room was not different: 14.1 hours for pathway group vs 18.5 hours for traditional group (p=0.316). The median LOS was shorter by 15.9 hours in the pathway cohort (p<0.001). 33.0% of

						patients were admitted to the hospital and 75.6% were discharged from the PACU, compared with 91.8% and 12.2% on traditional group (both p<0.001).
Lohsiriwat 2014	COS	Patients underwent emergency open surgery for obstructing colorectal cancer	20	40	LOS / Complications	Median or hospital LOS was significantly shorter in the ERAS group compared with non-ERAS group [5.5d (range:3-16) vs 7.5d (range:5-25), p=0.009]. Incident of overall postoperative complication tended to be reduced in the ERAS group (25% vs 48%, p=0.094).
Masood 2021	RCT	Patients underwent emergency repair using GPR or modified GPR	17	19	LOS / Pain score / Return of bowel function / Complications	Early oral feeding group showed a shorter LOS (4 days vs 10 days, p=.000), lower pain score (3 vs 8, p=.000), and shorter postoperative ileus duration (24 hours vs 48 hours, p=.000). There was no duodenal repair site leak in the early oral feeding group.
Mohsina 2018	RCT	Patients diagnosed with perforated duodenal ulcer underwent open simple closure	50	49	LOS	Length of hospitalization in ERAS group was significantly shorter (mean difference of 4.41+/- 0.64 days; p < 0.001). Seventy-three percent of patients in the standard care group had hospital stay of more than 7 days postoperatively, whereas 8% of patients in adapted ERAS group for more than 7 days.
Moydien 2016	COS	Patients with isolated penetrating abdominal trauma underwent emergency laparotomy	38	40	LOS / Complications	Mean hospital length of stay was 5.5 days in the ERAS group and 8.4 days in the non-ERAS group (p<0.00021). There were 11 and 12 complications in the non-ERAS and ERAS groups, respectively. When graded as per the Clavien-Dindo classification, there was no significant difference in the 2 groups (p<0.59).
Ong 2021	COS	Patients underwent emergency laparotomy	162	152	Mortality	There was an overall improvement in 30-day mortality rate found in the ELAP group, although it was not statistically significant (3.1% versus 5.3%, p = 0.40). In the subgroup of patients aged 65 years or more, the reduction in mortality was statistically significant (4.6% versus 8.8%, p = 0.03).
Peden 2019	RCT	Patients underwent emergency open abdominal surgery	7383	8490	Mortality	90-day mortality occurred in 1393 (16%) of 8482 patients in the usual care group compared with 1210 (16%) of 7374 patients in the QI group (HR 1.11, 95% CI 0.96-1.28). No survival benefit was observed from the QI programme to implement a care pathway for patients undergoing emergency abdominal surgery.
Pranavi 2022	RCT	Patients with perforation peritonitis planned for emergency laparotomy	61	59	LOS	LOS was significantly shorter in the adapted ERAS group, with a reduction of 3 days (8 vs 11 days, p < 0.001), in comparison to those in the standard care group. 45% of patients in the control group stayed in the hospital for more than 11 days, when compared to only 11% of adapted ERAS patients.
Purushothaman 2021	RCT	Trauma patients underwent primary emergency laparotomy	30	30	LOS	The mean duration of hospital stay in the ERAS group was 3.3±1.3days compared with 5.0±1.7days in the standard recovery group. There was a significant difference of 1.7days (p<0.01) between the two groups favoring the ERAS group.

Rochon 2019	COS	Patients underwent laparoscopic appendectomy	287	285	LOS / Discharge within 12 hours post-PACU / Patient satisfaction	The average LOS decreased 41.0% to 13.1 hours from 22.2 hours. The percentage of patients being discharged home within 12 hours of leaving the PACU was 11.9% at baseline and 50.2% during the project. Patient satisfaction was 3.72/4 compared to 3.74/4. The patient satisfaction remained high before and after interventions.
Saurabh 2020	RCT	Patients with small bowel pathology planned for emergency laparotomy	35	35	LOS	Compared with the standard care group, adapted ERAS group had a significantly shorter length of hospitalization (2.83 ± 0.56 days, p<0.001, CI 1.70 to 3.95).
Shang 2018	COS	Patients with obstructive colorectal cancer underwent unplanned emergency surgery	318	318	Return of bowel function	Modified ERAS was associated with postoperative gastrointestinal function recovery, including time to first flatus (P=.002), first defecation (P=.008), and prolonged ileus (P=.016).
Sharma 2021	RCT	Patients underwent emergency abdominal surgery for intestinal perforation and small bowel obstruction	50	50	LOS / Mortality / Complications	The median (IQR) of the LOS in the ERAS group was 4 (1) days while it was 7 (3) days in the conventional care group, which was statistically significant (p<0.001). Both the ERAS group and the conventional care group were similar in terms of 30-day mortality risk (p=0.678). Postoperative morbidities like a chest infection (p=0.028) and surgical site infections (p=0.015) were significant in the conventional care group.
Shida 2017	COS	Patients underwent colorectal resection for obstructive colorectal cancer	80 (49)*	42 (22)*	LOS / Complications /Readmission rate / Mortality	Median (IQR) LOS was 10 (10–14.25) days in the traditional group, and seven (7–8.75) days in the ERAS group, showing a 3-day reduction in hospital stay (p<0.01). Overall incidences of grade 2 or higher (Clavien-Dindo classification) postoperative complications for the traditional and ERAS groups were 15 and 10% (p=0.48), and 30-day readmission rates were 0 and 1.3% (p=1.00), respectively. As for mortality, one patient in the traditional group died and none in the ERAS group (p=0.34).
Thapa 2021	RCT	Patients with DU perforation underwent emergency surgery	50	50	LOS / Return of bowel function / Complications	The LOS in the ERAS group was 4.9 ± 0.76 days together with early functional recovery compared to 9.06 ± 2.44 days in the non-ERAS group (p<0.05). The overall complication rate was found to be higher in the non-ERAS group (80%) than in the ERAS group (44%) which was statistically significant (p=0.03)
Trevino 2016	COS	Patients underwent laparoscopic cholecystectomy and laparoscopic appendectomy	474	256	LOS / Readmission rate / Complications / Cost	LOS was significantly reduced by half a day (2.0 vs. 1.5 days, p<0.01). While the readmission rates were not statistically significant, there was an increase in the POST cohort, possibly due to low numbers (2.1 vs. 6.6 %, p=0.05), but complication rates were significantly less in the POST cohort (5.9 vs. 2.1 %, p<0.03). Total hospital charges were not significantly different between the PRE and POST groups ($26,422 vs. $28,335, p = 0.08)
Vinas 2020	COS	Patients with left colon perforation underwent emergency surgery	29	21	Complications	A reduction in the incidence of postoperative complications (20.7% vs. 38%; p>0.05) and in the postoperative hospital stay (7.7+/- 3.85 vs. 10.9+/- 5.6 days; p=0.009) were observed in the ERAS group.

Wisely 2016	COS	Patients underwent major emergency abdominal surgery	201	169	Unplanned return to OR/ICU / LOS / Readmission rate / Mortality / Complications	No significant difference was seen in the number of patients who had an unexpected return to theatre, with 32/370 (9%) of returning for a second operation (p=0.89). Median length of stay was 8 days, which remained constant throughout both time frames. Unplanned readmission occurred in 34/370 (9%) patients (p=0.88). Death during admission occurred in 38/370 (10%) of patients (p=0.9). Major complications (p=0.002) and individual minor complications such as urinary tract infections (p=0.02), urinary retention (p=0.001) and chest infections (p=0.001) were all significantly reduced in the post ERAS period.

COS comparative observational study, RCT randomized controlled trial, DU duodenal ulcer, GPR Graham's patch repair, ED emergency department, AKI acute kidney injury, LOS length of stay, IQR interquartile range, CUSUM cumulative sum, ELAP emergency laparotomy, QI quality improvement, HR hazard ratio, CI confidence interval. * () emergency cases

4.3 – Preamble

In our comprehensive literature review (Chapter 4.2), we identified 39 studies evaluating enhanced recovery protocols (ERPs) for both trauma laparotomy and emergency abdominal surgery [72-80, 85, 86, 98-125]. Of these, only two studies (5%) specifically focused on trauma laparotomy patients [85, 86]. Following the completion of our scoping review, only one additional study evaluating ERPs in trauma laparotomy patients was published [87]. Notably, none of these studies were conducted in North America, indicating a significant opportunity to explore and implement ERPs in this context. The primary outcome across all three studies was hospital length of stay (HLOS), with two studies also assessing in-hospital complications. These studies consistently demonstrated a significant reduction in HLOS with ERP implementation, while none reported a significant increase in complications. These findings support our initiative to develop and implement the 'Trauma Laparotomy Care Pathway', as they align with global evidence demonstrating the efficacy of ERPs in optimizing patient recovery without compromising safety.

One key objective of our scoping review was to extract protocol components used in previous studies to inform the development of an ideal framework for our pathway. In total, we identified 29 preoperative, 20 intraoperative, and 27 postoperative components. These components reflect current evidence on ERPs in emergency abdominal surgery and served as the foundation for developing our new pathway. For our pathway, we selected components most frequently utilized in previous studies that aligned with both our conceptual framework and local clinical settings. This selection process involved rigorous discussions with a multidisciplinary team to ensure that the chosen components were evidence-based and feasible for implementation. Further details are provided in the next section (Chapter 4.4).

The next section will outline the development and implementation process of the ‘Trauma Laparotomy Care Pathway’, an original protocol specifically tailored to trauma laparotomy patients. It will also examine adherence to pathway components during the early phases of implementation and evaluate its potential positive impact on patient outcomes. The manuscript has been submitted to the *Injury* and is currently under review.

4.4 – Implementing Enhanced Recovery Protocol to Improve Trauma Laparotomy Outcomes: A Single-Center Pilot Study

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ABSTRACT

Introduction: Enhanced Recovery Protocols (ERPs) are designed to improve postoperative recovery. Since their inception, ERPs have become the standard of care across multiple surgical specialities, with numerous guidelines established for elective procedures. While ERP principles have been extended to emergency abdominal surgeries, their application in trauma laparotomy remains limited. This study details the development of an ERP tailored for trauma laparotomy patients and evaluates outcomes following its implementation.

Methods: A multidisciplinary team developed an ERP, termed the Trauma Laparotomy Care Pathway (TLCP), grounded in best available evidence and adapted to our clinical setting through a rigorous consensus process. Following implementation, we conducted a prospective, single-center comparative study of trauma laparotomy patients meeting selection criteria and managed with TLCP from February to July 2024, using a historical cohort as the control group. We analyzed adherence to five key postoperative components and assessed impacts on postoperative outcomes.

Results: In the first six months post-implementation, 31 patients were managed using TLCP. The median age was 32.0 years, with males comprising 87.1% of patients. Stab wounds were the most frequent injury mechanism (64.5%), followed by motor vehicle-related accidents (12.9%) and falls (12.9%). Isolated abdominal injuries accounted for 64.5% of cases. Adherence to key pathway components ranged from 54.5% to 67.7%. The hospital length of stay was significantly shorter for the TLCP group, showing a two-day reduction compared to the historical cohort (4.0 days [3.5, 6.5] vs 6.0 days [4.0, 10.0], p=0.002). There was no significant difference in in-hospital complications or 30-day readmission rates between the groups.

Conclusion: Implementation of the TLCP reduced hospital length of stay without increasing in-hospital complications and 30-day readmission rates. These findings suggest that ERPs can be effectively applied to selected trauma laparotomy patients, with potential for improved clinical outcomes. Further large-scale studies are warranted to validate these results.

Introduction:

Enhanced Recovery Protocols (ERPs), also referred to as Enhanced Recovery After Surgery (ERAS) Pathways, are patient-centered, evidence-based, standardized multimodal perioperative care pathways designed to mitigate patients' surgical stress, optimize their physiological function, and enhance their postoperative recovery [1]. The first ERAS guidelines were published in 2005 for patients undergoing elective surgery [2]. Since then, numerous guidelines have been established for various elective procedures, and ERAS has become the standard of care across multiple surgical specialities [3-6]. The integration of ERAS principles into emergency abdominal surgery began in the early 2010s, initially focusing on emergency colorectal surgery [7, 8]. This initiative has since expanded to other emergency general surgeries [9, 10], and the ERAS Society has published consensus guidelines specifically for emergency laparotomy [11-13]. However, these guidelines exclude patients undergoing trauma laparotomy. Trauma laparotomy is a common and essential procedure in trauma surgery, performed following abdominal trauma. This procedure encompasses a wide range of interventions, from complex, life-saving surgeries to simpler diagnostic procedures. The diversity of injury patterns, the urgent nature of the clinical situations, and the complex social and medical backgrounds of the patients further contribute to the heterogeneity of this population. These variations present significant challenges in both conducting research and implementing initiatives aimed at improving patient outcomes [14-16]. Notably, only three studies have evaluated ERP implementation in abdominal trauma patients undergoing trauma laparotomy [17-19]. Moreover, two of these studies included only stable patients with isolated penetrating abdominal injuries, while only one study included both blunt and penetrating abdominal trauma. Additionally, the ERPs used in these studies varied

considerably, ranging from the application of ERAS guidelines for elective procedures to modified ERPs based on published emergency laparotomy ERAS guidelines.

Although these studies reported the potential effectiveness of ERP implementation, several issues must be addressed to successfully implement ERPs in trauma laparotomy patients. These include appropriate patient selection, the development of ERPs grounded in the best available evidence and tailored to the local context, practicality and ease of implementation, and the need for continuous pathway revisions. Considering these factors, we developed a multidisciplinary, consensus-based ERP for trauma laparotomy patients, called the "Trauma Laparotomy Care Pathway (TLCP)", which has been implemented within our clinical setting. The objectives of this study were to describe the development and implementation process of this pathway, evaluate the adherence to pathway components in the early implementation phase, and evaluate the pathways potential impact on improving patient outcomes by comparing it with historical patient cohorts.

Methods:

Development and implementation of the pathway

The development of the TLCP began in October 2022 under the guidance of the McGill University Health Centre (MUHC) Surgical Recovery (SURE) Working Group. This multidisciplinary team comprised surgeons, anesthesiologists, nurses, physiotherapists, pharmacists, and nutritionists. The development process was rigorously overseen by two dedicated pathway coordinators with extensive experience, who were responsible for overseeing all quality measures related to the development and implementation of the pathway at the MUHC. Before initiating the pathway development, we conducted a scoping review to systematically map the available evidence on ERPs in both trauma laparotomy and emergency

abdominal surgery [20]. In this review, we identified and extracted ERP components from the published literature across three operative phases: preoperative, intraoperative, and postoperative. Based on the findings of this scoping review, preliminary drafts of the pathway were developed, incorporating commonly used components aligned with our clinical context. These drafts were reviewed during iterative SURE working group meetings until consensus was reached, a process lasting approximately three months. Once consensus was achieved, the pathway underwent review by the institution's Clinical Practice Review Committee (CPRC) and subsequently by the Pharmacy and Therapeutics (P&T) committee for final approval. The entire development process took 15 months, and the pathway was officially launched on February 1st, 2024 (Figure 1). Prior to implementation, pathway introduction sessions were conducted by the respective leads: the surgical lead for surgeons, the anesthesiology lead for anesthesiologists, and the nurse coordinator for nurses and other specialists in the relevant wards.

Trauma Laparotomy Care Pathway

The pathway is structured into five distinct orders: preoperative antibiotic medication order, intraoperative medical recommendations, postoperative medication orders, postoperative medical orders, and external prescriptions (Figure 2). Additionally, the pathway includes a booklet, created in collaboration with the SURE team, provided to patients or their families postoperatively (Supplementary Methods 1). This booklet plays a crucial role in patient and family education and is an integral element of our pathway. Given the urgent nature of emergency surgery in patients requiring trauma laparotomy, and associated practical challenges, early antibiotic administration was the only component included in the preoperative phase. The intraoperative medical recommendations for anesthesiologists cover standard anesthetic management, including multimodal analgesia and transfusion management. Recommendations

related to the surgical approach, such as the avoidance of unnecessary drains, were excluded as these practices were already well established within our trauma team. Postoperative medication orders include prophylactic or empiric antibiotics, venous thromboembolism prophylaxis, and multimodal analgesia. The use of opioids for pain management was thoroughly discussed throughout the development process and follows current institutional guidelines, which also apply to external prescription orders. Postoperative medical orders encompass early nutritional care, early mobilization or physiotherapy assessment, early removal of tubes and catheters, and standardized postoperative blood tests. The pathway aims for patient discharge by postoperative day 4, with specific discharge criteria outlined within the pathway.

Study design and patient selection

Following the implementation of the pathway, we conducted a prospective, single-center comparative study using a historical cohort as the control group. This study evaluated the perioperative management of all adult patients (18+ years) admitted to the trauma service at the Montreal General Hospital (MGH) who underwent trauma laparotomy for either blunt or penetrating abdominal trauma between February 1, 2024, and July 31, 2024. The MGH is one of three adult level 1 trauma centers in the province of Quebec, serving trauma patients from urban and sub-urban areas of Montreal, as well as those transferred from northern Quebec. The included patients were managed with the newly developed TLCP. Exclusion criteria included patients with severe traumatic brain injury (AIS>2), those requiring open abdominal management, postoperative intensive care unit (ICU) stays longer than 48 hours, patients who underwent diagnostic laparoscopy, and those who died during hospitalization. Patient inclusion was determined after the decision for surgery was made by the attending trauma surgeon in the emergency department (ED).

We identified the historical cohort from our hospital-based trauma registry, consisting of consecutive patients who underwent trauma laparotomy between January 1, 2018, and February 29, 2020, and met the inclusion and exclusion criteria. We selected the pre-COVID-19 period to avoid the variability introduced by the pandemic, which affected ICU and ward bed management, operating room utilization, ED management, and discharge destinations. Otherwise, there were no significant changes in surgical staff, indications for surgery, or surgical techniques between the two periods.

As the study is part of our quality improvement initiatives, the protocol was submitted to the MUHC Research Ethics Board (REB) and received a waiver for ethics approval prior to study inception. For the retrospective review of the historical cohort, we obtained approval from the MUCH REB (Study No. 2024-9800) and authorization to access patient medical records from the Director of Professional Services (DPS) of the MGH, in accordance with relevant privacy laws and regulations.

Data collection and outcomes of interests

Data were collected from multiple sources, including the trauma registry, electronic medical records, anesthesia charts, and operative notes. The collected variables included patient demographics (age, gender, comorbidities), mechanism of injury, sustained abdominal and associated injuries, injury severity score (ISS), surgical procedures performed, operation time, and hospital discharge disposition. To evaluate adherence to pathway components after the first six months of implementation, we focused on five key postoperative components: (1) nasogastric (NG) tube removal, (2) urinary catheter removal, (3) epidural catheter removal, (4) early oral intake, and (5) early mobilization. Adherence to each pathway component was defined as the completion of the specified intervention by the targeted postoperative day (e.g., removal of the

urinary catheter by postoperative day 1). No predetermined adherence thresholds were set for individual components. Additionally, overall adherence was assessed by calculating the number of successfully completed components out of the five.

For the comparative analysis, patients were categorized into two groups: those managed with the newly developed TLCP (TLCP group) and those treated prior to the implementation of TLCP, representing the historical cohort (non-TLCP group). The primary outcome measure was hospital length of stay (HLOS), with the day of surgery defined as postoperative day 0. Secondary outcomes included in-hospital complications, time to NG tube, urinary catheter, epidural catheter, and chest tube removal, time to resume oral intake, and 30-day readmission rates. The severity of in-hospital complications was assessed using the Clavien-Dindo classification system.

Statistical analysis

Results are presented descriptively as counts, proportions, and medians for the characteristics of the TLCP and non-TLCP groups. Significant differences between the TLCP and non-TLCP groups were assessed using two-sample t-tests and chi-square tests, where the threshold for statistical significance was alpha=0.05. A subgroup analysis of the primary outcome was conducted after excluding patients who experienced unnecessary hospital stays, defined as hospitalization beyond the point at which patients were medically cleared, to explore the influence of non-medical factors. All statistical analyses were performed using R software version 4.0.3 [21].

Results:

Patient demographics

During the first six months following the implementation, 31 patients were managed using the newly developed TLCP (Table 1). The median age of the cohort was 32.0 years [IQR: 27.0,

37.5], with 87.1% of the patients being male. Penetrating injuries were more common than blunt injuries, accounting for 67.7% of cases. Stab wounds were the most frequent mechanism of injury (64.5%), followed by motor vehicle-related accidents (12.9%) and falls (12.9%). Isolated abdominal injuries were present in 64.5% of the patients, with a median ISS of 9.0 [IQR: 5.0, 9.5]. The most commonly injured abdominal organs were the small bowel (25.8%) and large bowel (22.6%), followed by splenic and hepatic injuries (16.1% each). Diaphragmatic injuries (12.9%) and rib fractures (6.5%) were frequently observed extra-abdominal injuries. Surgical procedures included bowel resection or repair (48.4%) and anastomosis (29%), followed by splenectomy (16.1%) and hepatic repair (16.1%), reflecting the injury patterns described. Over 90% of patients in the cohort were discharged home.

Pathway component adherence

The adherence rates for the selected pathway components are presented in Table 2. Adherence ranged from 54.5% to 67.7%, with the highest rates observed for NG tube removal and early mobilization, while epidural catheter removal had the lowest adherence. Approximately 90% of patients achieved NG tube removal, urinary catheter removal, early oral intake, and early mobilization within three days, and epidural catheter removal within five days. Only one patient required extended durations for urinary and epidural catheter use beyond six days. This patient, with a history of opioid use disorder, experienced difficulty in pain management, resulting in the need for nine days to remove the epidural catheter and eight days to remove the urinary catheter. Regarding overall adherence, 32.3% (10/31) of patients completed all five components, while the aforementioned patient did not complete any.

Comparative analysis

Regarding demographic characteristics, age, sex, injury types, mechanism of injury, and the rate of isolated abdominal injury were comparable between the two groups (Table 1). However, patients in the non-TLCP group had a significantly higher ISS compared to the TLCP group (13.0 [9.0, 20] vs 9.0 [5.0, 9.5], p = 0.001). Additionally, a lower proportion of patients in the non-TLCP group were discharged home (78.8% vs 93.5%). Although there were no statistically significant differences in the frequency of abdominal and extra-abdominal injuries between the groups, solid organ injuries, such as splenic and hepatic injuries, were more common in the non-TLCP group, whereas bowel injuries were more frequently observed in the TLCP group. These patterns are reflected in the types of surgical procedures performed.

The primary outcome, HLOS, was significantly shorter in the TLCP group compared to the non-TLCP group (4.0 days [3.5, 6.5] vs 6.0 days [4.0, 10.0], p=0.002) (Figure 3.1). After excluding patients with unnecessary hospital stays (n=54 in the non-TLCP group and n=30 in the TLCP group), HLOS remained shorter in the TLCP group, although the difference was not statistically significant (4.0 days [3.3, 6.0] vs 5.0 days [4.0, 7.0], p=0.065] (Figure 3.2).

Regarding secondary outcomes, no significant differences were observed in in-hospital complications or 30-day readmission rates between the groups (Table 3). Although not statistically significant, there was a higher utilization of epidural anesthesia in the TLCP group (71.0% vs 54.5%). Additionally, there was a reduction in the time to remove urinary catheters (1.0 day [1.0, 2.0] vs 2.0 days [1.0, 3.8], p=0.051) and epidural catheter (3.0 days [3.0, 4.0] vs 4.0 days [3.0, 6.0]), p=0.094), although these differences were not statistically significant.

Discussion:

In this study, we outlined the development and implementation of the “Trauma Laparotomy Care Pathway (TLCP)”, specifically designed for patients undergoing trauma laparotomy. This was

followed by a single-center pilot study, which demonstrated a significant two-day reduction in HLOS compared to a historical cohort, without increasing in-hospital complications or the 30-day readmission rate.

Although challenges in implementing ERPs for this population have been acknowledged, our comprehensive literature review identified opportunities for further ERP development and application in trauma laparotomy patients [20]. Trauma laparotomy and emergency abdominal surgery populations share certain clinical characteristics, such as the urgent nature of surgery, the frequent use of open procedures, and physiological derangements upon admission [7, 11, 22]. However, trauma patients present a unique potential for ERP implementation, as physiological insults in trauma are typically caused by hemorrhage, whereas in emergency abdominal surgery, they are often due to sepsis [23]. Achieving prompt hemostasis, along with adequate resuscitation, can substantially mitigate the physiological effects of trauma, leading to faster recovery. Additionally, trauma patients tend to be younger than those undergoing emergency abdominal surgery [24], with the median age in our cohort being 32 years. These factors further support the introduction of ERPs in trauma laparotomy patients.

Several factors must be carefully considered for the successful implementation of ERPs in trauma laparotomy patients, with patient selection being a key factor in effectively targeting this population. Even within the relatively homogenous subset of trauma laparotomy patients, variability exists due to factors such as the complexity and severity of injuries, the wide range of surgical procedures, and the diverse medical and social backgrounds of patients [16, 25, 26]. Therefore, ERPs cannot be universally applied to all trauma laparotomy patients. To reduce variability, previous studies have focused on selecting stable patients with penetrating trauma for inclusion [17, 19]. While this approach is both practical and reasonable, it poses the risk of

limiting the number of patients, particularly in regions where blunt trauma predominates, as seen in many countries [27-29]. Such restrictions could limit generalizability and applicability of ERPs. Certain injuries with blunt mechanism, such as isolated splenic injuries, simple small and large bowel perforations, and mesenteric injuries, can often be managed with relatively less invasive surgical interventions, potentially benefiting from ERPs. To broaden ERP applicability, our pathway included patients with both penetrating and blunt trauma, without setting specific preoperative conditions, such as hemodynamic status, as criteria for inclusion. Approximately 30% of our cohort sustained blunt trauma, with some patients presenting with injuries to other regions, such as the chest or extremities. This suggests that our criteria, which include both penetrating and blunt trauma, appropriately identified patients who could benefit from the pathway. However, further studies with larger sample sizes are necessary to fully assess the applicability of these criteria.

Practicality and ease of implementation are also critical in ERP development for these non-elective surgeries. For instance, the EPOCH trial evaluated the impact of a care pathway on survival and HLOS in emergency general surgery but did not demonstrate significant improvements in these outcomes [30]. A process evaluation of the trial found that the EPOCH pathway's 37 component interventions were impractical to fully implement, prompting study teams to prioritize key components [31]. This example underscores the balance needed between outcome improvements and the practical limitations of care delivery. Complex care pathways can lead to practical challenges, resulting in decreased motivation for utilization, reduced staff acceptance, and lower adherence rates. Therefore, during the iterative development process of our pathway, emphasis was placed on clearly defining the targeted population and designing a pathway that is both simple and practical. Stephens et al. also noted that implementing new

interventions within complex systems presents significant challenges, with numerous barriers to achieving intended outcomes [31]. Modern healthcare systems are indeed intricate, and hospitals are already managing numerous demands in routine practice. However, the Department of Surgery at McGill University has a well-established history of research and publication on ERAS pathways [32-38]. The foundational principles of ERAS have already been successfully integrated into McGill University-affiliated hospitals, with staff recognizing the importance of these pathways. This established framework provided a strong foundation for extending the concept to trauma laparotomy within our clinical settings.

During the initial implementation phase, adherence rates to pathway components in our cohort ranged from 54.5% to 67.7%. Previous studies have reported adherence rates from 30% to 100%, partly due to variations in how adherence is defined [7, 19, 39, 40]. Some studies measured adherence based on the completion of pathway components by a targeted postoperative day, while others focused solely on the completion of components regardless of timing. Studies using a definition similar to ours, specifically in the context of emergency colorectal surgery, reported overall adherence rates of 57%, while adherence to five key process measures, which include early mobilization, early liquid intake, early Foley removal, multimodal pain control, and venous thromboembolism prophylaxis, was 10.2% [7, 39], findings that align with our results. A critical aspect of ERPs is their potential to foster behavioural changes when implementation with consistent, multidisciplinary team assessments focused on shared patient care goals. Although not statistically significant, we observed an increase in the use of epidural anesthesia from 54.5% to 71.0%, reflecting efforts to promote multimodal anesthesia. Additionally, approximately 90% of pathway components, such as NG tube removal, urinary catheter removal, and initiation of early oral intake and mobilization, were completed within three days. This trend suggests that

pathway implementation may have contributed to improved adherence and care practices. Nonetheless, further efforts to enhance adherence rates, particularly through promoting the pathway concept among the multidisciplinary professionals involved in patient care, should be a priority in future interventions.

This study has several limitations. First, it was conducted at a single trauma center in Canada, resulting in a small sample size. Focusing exclusively on trauma laparotomy patients with specific inclusion criteria further constrained the sample size, preventing prospective recruitment for a control group. As a result, we used a historical cohort for comparative analysis, which introduces additional limitations. The retrospective nature of data collection in the historical cohort poses risks such as missing data and potential mismatch with the prospectively collected cohort, despite applying the same inclusion and exclusion criteria. Additionally, the small sample size from a single center familiar with the pathway implementation limits the generalizability of our findings. Another limitation is the lack of assessment of cost-effectiveness or qualitative analysis of patient and healthcare professional acceptance, which would have enhanced the study's robustness. Ideally, large-scale, prospective, multi-center studies with sufficient sample sizes are needed to more definitely assess the feasibility and effectiveness of implementing ERPs in trauma laparotomy patients.

Conclusions:

This study outlines the development and implementation process of a TLCP, highlighting key considerations for its successful application in trauma laparotomy patients. Following the implementation of the pathway, a reduction in HLOS was observed without an associated increase in complications or 30-day readmission rates. These findings suggest that ERPs can be applied to carefully selected trauma laparotomy patients, offering the potential for improved

clinical outcomes. Further large-scale, multicenter studies are warranted to validate these results and explore the broader applicability of ERPs in trauma surgery.

STATEMENTS AND DECLARATIONS

Declarations of interest: The authors declare that they have no conflicts of interest.

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Ethical consideration: The study protocol was submitted to the McGill University Health Centre Research Ethics Board (REB) and received a waiver of ethics approval, as the study is part of our quality improvement initiatives. For the retrospective review of the historical cohort, we obtained REB approval (Study No. 2024-9800).

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Table 1. Patient demographics and injury-related characteristics

	TLCP group N=31	Non-TLCP group N=66	P-value
Age, median [IQR], years	32.0 [27.0, 37.5]	32.5 [22.2, 49.2]	0.468
Sex, male – n (%)	27 (87.1)	54 (81.8)	0.719
Comorbidities			
Hypertension	2 (6.5)	6 (9.1)	0.964
Cardiac disease	1 (3.2)	3 (4.6)	1.0
Asthma/COPD	1 (3.2)	6 (9.1)	0.544
Diabetes mellitus	1 (3.2)	7 (10.6)	0.403
Dyslipidemia	1 (3.2)	7 (10.6)	0.403
GI disease	2 (6.5)	0 (0.0)	0.187
Mental disorders	4 (12.9)	10 (15.2)	1.0
DVT/PE	0 (0.0)	2 (3.03)	0.831
Injury type			
Blunt	10 (32.3)	26 (39.4)	0.651
Penetrating	21 (67.7)	40 (60.6)	
Mechanism			
Stab	20 (64.5)	33 (50.0)	0.117
Gun shot	1 (3.2)	6 (9.1)	
Motor vehicle related	4 (12.9)	16 (24.2)	
Bike/Pedestrian	2 (6.5)	0 (0.0)	
Fall	4 (12.9)	8 (12.1)	
Isolated abdominal injury – n (%)	20 (64.5)	41 (62.1)	0.998
ISS, median [IQR]	9.0 [5.0, 9.5]	13.0 [9.0, 20.8]	0.001
Abdominal organ injury			
Spleen	5 (16.1)	16 (24.2)	0.522
Liver	5 (16.1)	15 (22.7)	0.631
Stomach	1 (3.2)	4 (6.1)	0.923
Small bowel	8 (25.8)	11 (16.7)	0.433
Large bowel	7 (22.6)	5 (7.6)	0.078
Major vessels	0 (0.0)	4 (6.1)	0.394
Pancreas	1 (3.2)	1 (1.5)	1.0
Kidney	0 (0.0)	1 (1.5)	1.0
Bladder	0 (0.0)	2 (3.0)	0.831
Other injuries			
Rib fractures	2 (6.5)	10 (15.2)	0.377
Hemothorax/pneumothorax	1 (3.2)	5 (7.6)	0.706
Cardiac injury	0 (0.0)	1 (1.5)	1.0
Diaphragmatic injury	4 (12.9)	9 (13.6)	1.0
Spinal fractures	1 (3.2)	4 (6.1)	0.923
Upper extremity fractures	1 (3.2)	3 (4.6)	1.0
Lower extremity fractures	0 (0.0)	5 (7.6)	0.280
Peripheral vascular injury	1 (3.2)	1 (1.5)	1.0
Operative procedures (abdomen)			
Splenectomy	5 (16.1)	17 (25.8)	0.426
Hepatic repair	5 (16.1)	12 (18.2)	1.0
Stomach repair	1 (3.2)	4 (6.1)	0.923

Small bowel resection/repair	8 (25.8)	8 (12.1)	0.162
Large bowel resection/repair	7 (22.6)	3 (4.55)	0.018
Anastomosis	9 (29.0)	8 (12.1)	0.079
Pancreatic repair or distal pancreatectomy	1 (3.2)	1 (1.5)	1.0
Nephrectomy	0 (0.0)	1 (1.5)	1.0
Bladder repair	0 (0.0)	2 (3.0)	0.831
Pericardial window	2 (6.5)	0 (0.0)	0.187
Operative procedures (other)			
Diaphragmatic repair	4 (12.9)	10 (15.2)	1.0
Cardiac repair	0 (0.0)	1 (1.5)	1.0
Thoracotomy	0 (0.0)	2 (3.0)	0.831
Orthopedic procedures	2 (6.5)	5 (7.6)	1.0
Plastics procedures	2 (6.5)	4 (6.1)	1.0
Angioembolization	1 (3.2)	2 (3.0)	1.0
Operation time, median (IQR), mins	102.0 [80.0, 122.0]	100.0 [79.2, 130.0]	0.429
Discharge disposition			
Home	29 (93.5)	52 (78.8)	0.040
Transfer to rehabilitation facility	0 (0.0)	4 (6.1)	
Transfer to another department	0 (0.0)	9 (13.6)	
Other (police custody)	2 (6.5)	1 (1.5)	

Table 2. Adherence rates to pathway components

Key Pathway Components	POD	N	Adherence (%)
NG tube removal	1 (target)	31	21 (67.7)
	≤ 3		28 (90.3)
Urinary catheter removal	1 (target)	31	18 (58.1)
	≤ 3		27 (87.1)
Early oral intake	1 (target)	31	19 (61.3)
	≤ 3		27 (87.1)
Early mobilization	0 (target)	31	21 (67.7)
	≤ 3		29 (93.5)
Epidural catheter removal	3 (target)	22*	12 (54.5)
	≤ 5		21 (95.5)
Full adherence**		31	10 (32.3)

*22 patients used epidural anesthesia

** Number of patients who successfully completed five components by the targeted postoperative day

POD: postoperative day

Table 3. Postoperative outcome measures in TLCP and non-TLCP groups

	TLCP group N=31	Non-TLCP group N=66	P-value
Hospital length of stay, median [IQR], days	4.0 [3.5, 6.5]	6.0 [4.0, 10.0]	0.002
In-hospital complications			
Ileus	2 (6.5)	8 (12.1)	0.618
Pneumonia	3 (4.6)	1 (3.2)	1.0
Surgical site infection (SSI)	0 (0.0)	4 (6.1)	0.394
Postoperative bleeding	0 (0.0)	1 (1.5)	1.0
Delirium	0 (0.0)	1 (1.5)	1.0
C. difficile infection	0 (0.0)	1 (1.5)	1.0
Urinary tract infection	0 (0.0)	2 (3.0)	0.831
Pseudoaneurysm (other than abdomen)	1 (3.2)	0 (0.0)	0.697
Clavien-Dindo classification, Grade			
I	2 (6.5)	7 (10.6)	0.778
II	0 (0.0)	7 (10.6)	0.144
III a	1 (3.2)	2 (3.0)	1.0
III b	0 (0.0)	2 (3.0)	0.831
NG tube removal, median [IQR], days	0.0 [0.0, 2.0]	0.0 [0.0, 1.0]	0.472
Urinary catheter removal, median [IQR], days	1.0 [1.0, 2.0]	2.0 [1.0, 3.8]	0.051
Oral intake, median [IQR], days	1.0 [1.0, 2.5]	1.0 [1.0, 2.0]	0.126
Epidural anesthesia – n (%)	22 (71.0)	36 (54.5)	0.188
Epidural catheter removal, median (IQR), days	3.0 [3.0, 4.0]	4.0 [3.0, 6.0]	0.094
Chest tube requirements – n (%)	4 (12.9)	13 (19.7)	0.593
Chest tube removal, median [IQR), days	3.0 [2.0, 5.0]	3.0 [1.0, 5.0]	0.856
30-day hospital readmission – n (%)	2 (6.5)	1 (1.5)	0.496
Small bowel obstruction	1 (3.2)		
Wound hematoma	1 (3.2)		
Transverse mesocolon hematoma		1 (1.5)	

NG tube: nasogastric tube

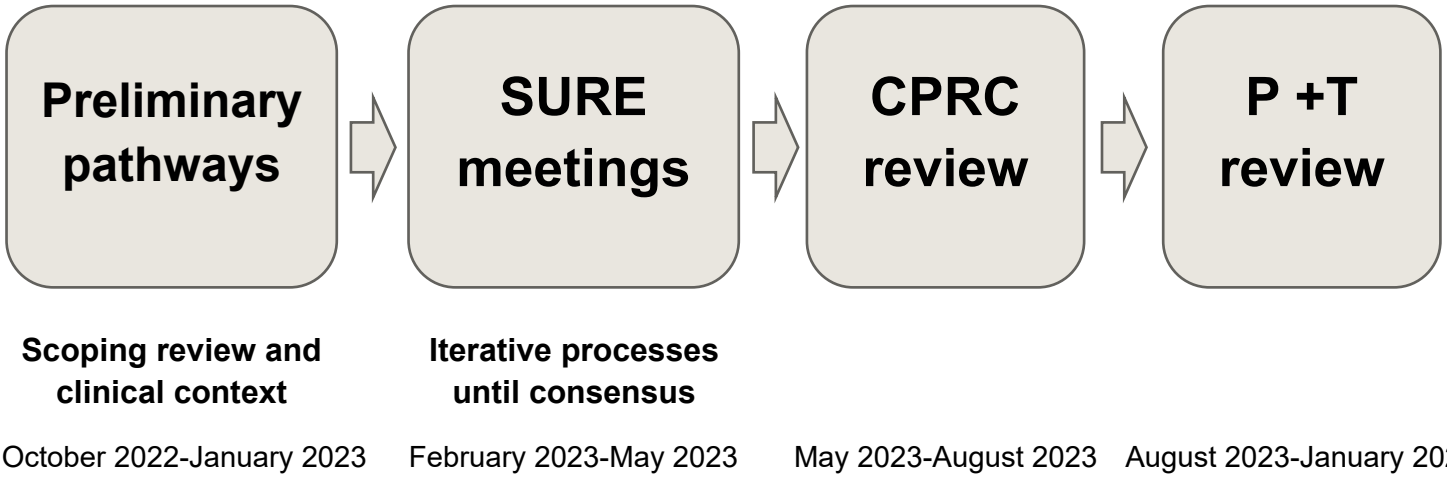
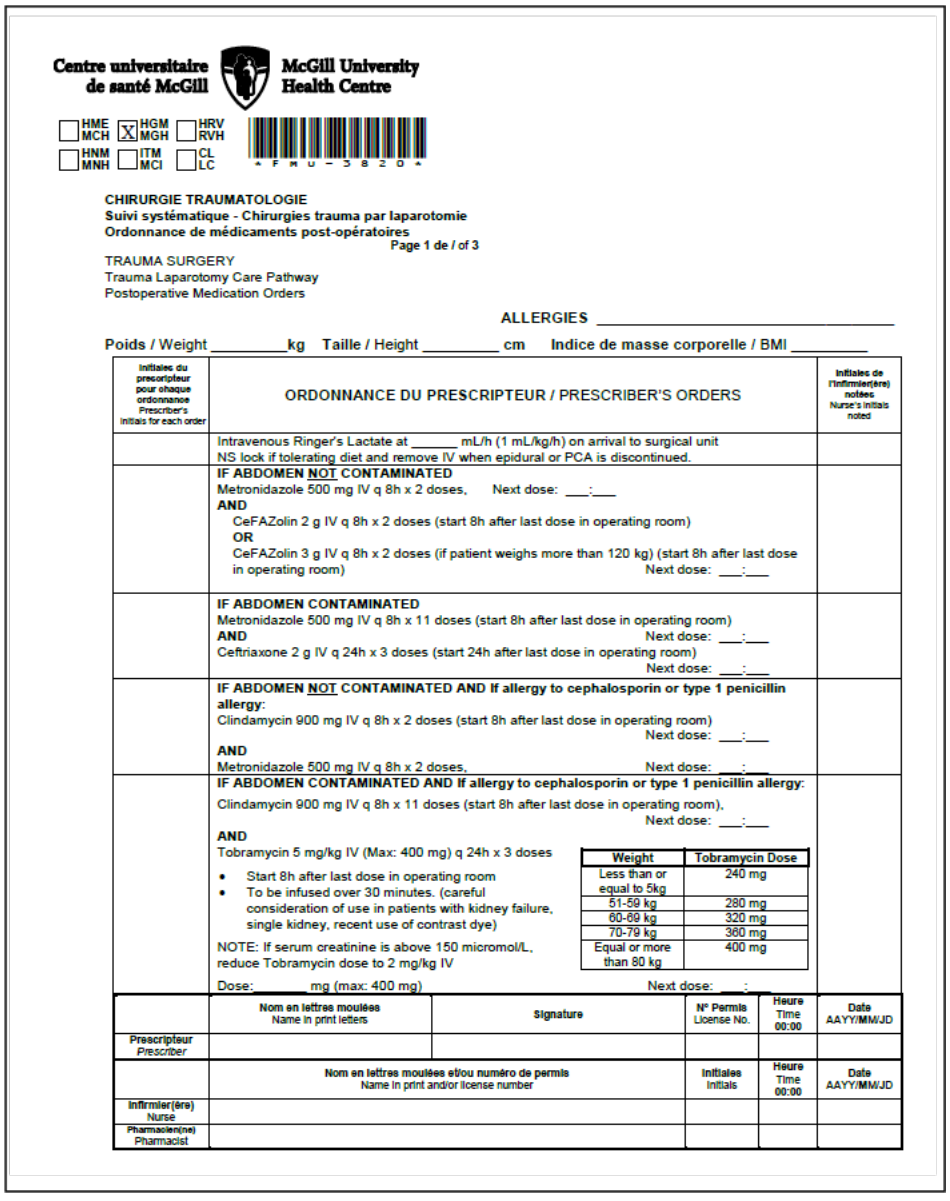


Figure 1. Development process of trauma laparotomy care pathway



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CHIRURGIE TRAUMATOLOGIE
Suivi systématique - Chirurgies trauma par laparotomie
Ordonnance de médicaments post-opératoires
Page 1 de / of 3

TRAUMA SURGERY
Trauma Laparotomy Care Pathway
Postoperative Medication Orders

ALLERGIES _____

Poids / Weight _____**kg** **Taille / Height** _____ **cm** **Indice de masse corporelle / BMI** _____

Initiales du prescripteur pour chaque ordonnance Prescriber's initials for each order	ORDONNANCE DU PRESCRIPTEUR / PRESCRIBER'S ORDERS	Initiales de l'infirmier(ère) notées Nurse's initials noted
	Intravenous Ringer's Lactate at _____ mL/h (1 mL/kg/h) on arrival to surgical unit NS lock if tolerating diet and remove IV when epidural or PCA is discontinued.	
	IF ABDOMEN NOT CONTAMINATED Metronidazole 500 mg IV q 8h x 2 doses, Next dose: ___:___ **AND** CeFAZolin 2 g IV q 8h x 2 doses (start 8h after last dose in operating room) **OR** CeFAZolin 3 g IV q 8h x 2 doses (if patient weighs more than 120 kg) (start 8h after last dose in operating room) Next dose: ___:___	
	IF ABDOMEN CONTAMINATED Metronidazole 500 mg IV q 8h x 11 doses (start 8h after last dose in operating room) **AND** Next dose: ___:___ Ceftriaxone 2 g IV q 24h x 3 doses (start 24h after last dose in operating room) Next dose: ___:___	
	IF ABDOMEN NOT CONTAMINATED AND If allergy to cephalosporin or type 1 penicillin allergy: Clindamycin 900 mg IV q 8h x 2 doses (start 8h after last dose in operating room) Next dose: ___:___ **AND** Metronidazole 500 mg IV q 8h x 2 doses, Next dose: ___:___	
	IF ABDOMEN CONTAMINATED AND If allergy to cephalosporin or type 1 penicillin allergy: Clindamycin 900 mg IV q 8h x 11 doses (start 8h after last dose in operating room), Next dose: ___:___ **AND** Tobramycin 5 mg/kg IV (Max: 400 mg) q 24h x 3 doses • Start 8h after last dose in operating room • To be infused over 30 minutes. (careful consideration of use in patients with kidney failure, single kidney, recent use of contrast dye) NOTE: If serum creatinine is above 150 micromol/L, reduce Tobramycin dose to 2 mg/kg IV Dose:_____mg (max: 400 mg) Next dose: ___:___	

Weight	Tobramycin Dose
Less than or equal to 5kg	240 mg
51-59 kg	280 mg
60-69 kg	320 mg
70-79 kg	360 mg
Equal or more than 80 kg	400 mg

	Nom en lettres moulées Name in print letters	Signature	N° Permis License No.	Heure Time 00:00	Date AAYY/MM/JD
Prescripteur *Prescriber*					

	Nom en lettres moulées et/ou numéro de permis Name in print and/or license number	Initiales Initials	Heure Time 00:00	Date AAYY/MM/JD
Infirmier(ère) Nurse				
Pharmacien(ne) Pharmacist				

Figure 2. Layout and Structure of the Trauma laparotomy care pathway

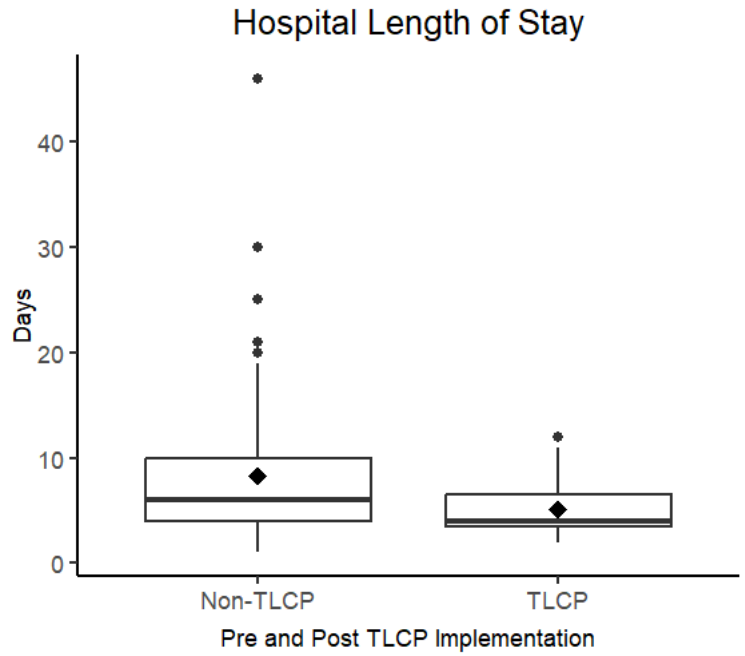


Figure* 3.1. Hospital length of stay in the TLCP and non-TLCP groups (4.0 days vs 6.0 days, p=0.002)

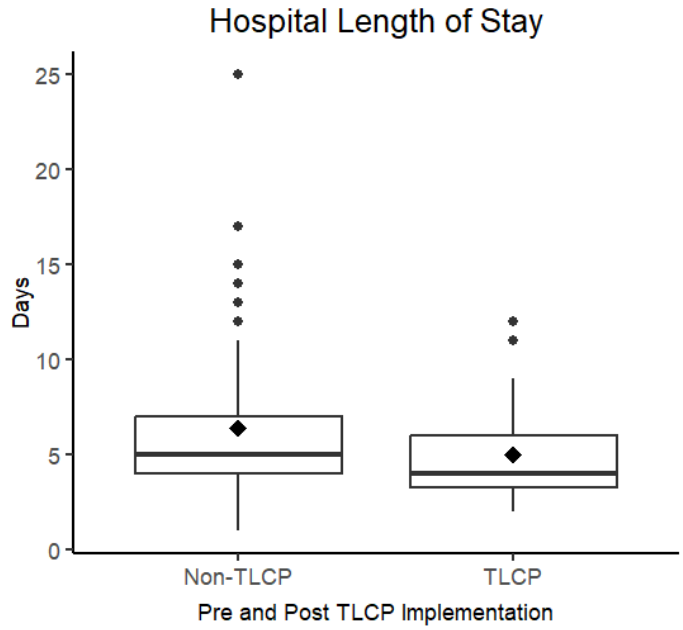
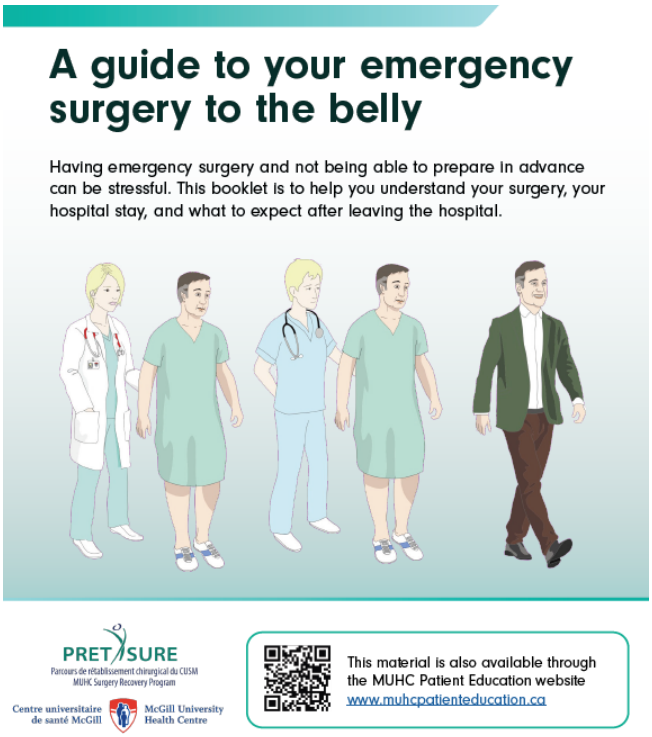
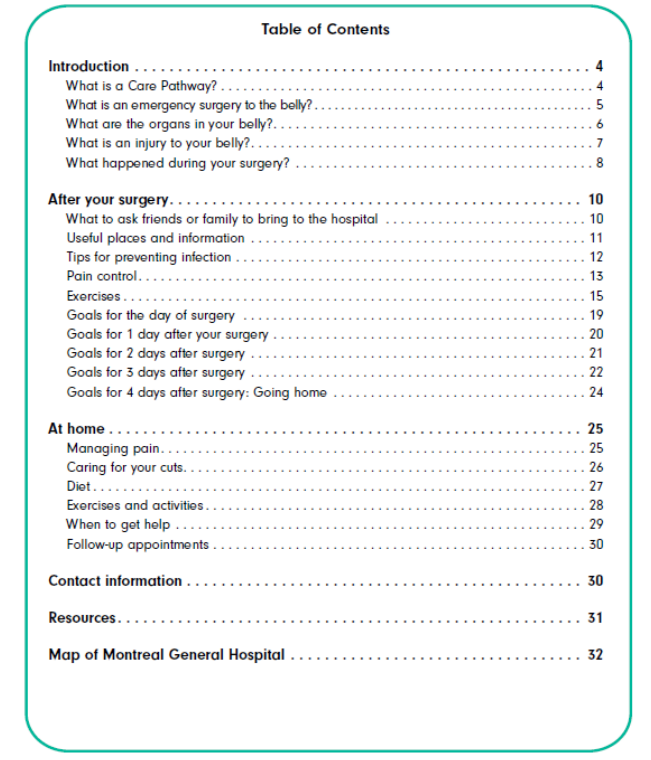


Figure* 3.2. Hospital length of stay after excluding patients who experienced unnecessary hospital stays (4.0 days vs 5.0 days, p=0.065)

*Results are presented as medians (horizontal lines within each box), interquartile ranges (boxes), ranges (whiskers), and outliers (circles)





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Supplementary Methods 1. Cover page and table of contents of the booklet

CHAPTER 5: DISCUSSION AND CONCLUSION

5.1 – General findings and limitations

In the current era of healthcare resource constraints, initiatives aimed at optimizing resource utilization while sustaining or enhancing patient care are essential to ensure the sustainability of healthcare systems. This is particularly relevant in trauma care, a critical and complex field that constitutes a major global health issue [5]. Addressing these challenges on a population-wide scale, however, is complicated due to the heterogeneity of healthcare needs across diverse patient groups, which necessitates varied approaches to care. Trauma populations, specifically, exhibit inherent variability in both clinical presentations and resource requirements [13], making a one-size-fits-all approach impractical. Moreover, disparities in resource availability between high-income and low- to middle-income countries add another layer of complexities to the implementation of universal initiatives. Focusing on relatively homogenous subgroups within the trauma population allows for a targeted approach to conducting research and developing interventions tailored to specific healthcare needs. When applied incrementally, this strategy can lead to broader, impactful improvements across the trauma care system. Accordingly, in this thesis, we focus specifically on trauma laparotomy patients, a distinct subset of the trauma population, with the goal of improving clinical outcomes, particularly hospital length of stay (HLOS). To accomplish this, we conducted a series of studies presented across the chapters of this thesis.

In Chapter 2, we leveraged a large trauma data registry to examine HLOS in trauma laparotomy patients. This analysis revealed notable variability in HLOS distribution, even within a relatively homogenous patient subgroup, underscoring the importance of exploring differential characteristics across trauma populations. To address this variability, we categorized patients into short, medium, and long HLOS groups, a stratification approach previously applied in cardiology

studies, where it has proven effective for characterizing patient subgroups [32, 34]. This approach, however, is novel within trauma research, particularly among trauma laparotomy patients, offering valuable insights into the distinct needs of this population. Using this stratification, we observed that HLOS in trauma laparotomy patients exhibited a right-skewed distribution, with a substantial proportion of patients (77% in our findings) having an HLOS of less than 11 days and a median HLOS of 7 days, shorter than anticipated for trauma populations considered high-risk. This insight challenges the prevailing notion that trauma patients inherently require prolonged hospitalization, instead suggesting the existence of diverse subgroups with distinct recovery profiles. Recognizing this heterogeneity is essential, as it indicates that even within a single trauma cohort, different subgroups with unique characteristics and healthcare needs emerge, underscoring the necessity for tailored interventions. Targeting these subgroups with specific, evidence-based strategies can optimize resource allocation and improve patient outcomes in a field where trauma populations are notably diverse.

While previous studies, including those on trauma populations, have primarily concentrated on factors contributing to prolonged HLOS [39, 40, 126-129], our study introduced a novel emphasis on the short-stay cohort. This focus, aimed at identifying characteristics associated with shorter hospital stays, offers crucial insights for developing the ‘Trauma Laparotomy Care Pathway (TLCP)’, which is a key intervention in this thesis for reducing HLOS [35]. The study identified patient factors most likely to benefit from TLCP interventions, including those with penetrating injuries, isolated abdominal trauma, and splenic injuries. Our approach effectively highlighted opportunities for developing the TLCP and identified patient characteristics most likely to benefit from its implementation. We believe this method could be

adapted for other trauma subgroups to facilitate targeted intervention strategies in a field marked by inherent patient heterogeneity.

A potential limitation of this study is its reliance on the National Trauma Data Bank (NTDB), a registry managed by the American College of Surgeons (ACS) that captures trauma data from designated trauma centers across the United States (US). The NTDB is the world's largest trauma registry, offering extensive data diversity and large sample sizes that support detailed analysis and enhance the generalizability of findings. However, it reflects the US healthcare system, which differs substantially from Canada's publicly funded, universal healthcare model [2]. While using NTDB data provides numerous advantages for trauma research, ideally, a Canadian national trauma registry would better align with the unique aspects of Canada's healthcare context. Canada formerly managed a National Trauma Registry (NTR), established in 1997 by the Canadian Institute for Health Information (CIHI), to provide national trauma statistics, educate the public on trauma, and support trauma care frameworks for trauma prevention efforts [130]. Unfortunately, the NTR was discontinued in 2014 due to shifting stakeholder priorities, limited jurisdictional usage, and data timeliness concerns. Currently, trauma research in Canada faces challenges due to the lack of a comprehensive national registry, with trauma data collection limited to provincial and institutional registries, such as Ontario Trauma Registry [131] and the Montreal General Hospital (MGH) Trauma Registry. These databases vary in scope and standardization, complicating the development and implementation of evidence-based practices at a national level. Although there have been efforts by provinces, the Canadian Trauma Society, and individual institutions to address these limitations, re-establishing a unified Canadian trauma registry would significantly enhance trauma research and care across the country.

To examine factors relevant to the Canadian and local healthcare context, we conducted a retrospective analysis of trauma laparotomy patients managed at our institution, as described in Chapter 3. This study specifically focused on 'unnecessary stays', defined as situations where patients remain hospitalized after being medically cleared for discharge, which represents one of two distinct scenarios contributing to prolonged hospital stays. Unnecessary stays are particularly impactful in a universal, publicly funded healthcare system where resources are finite. Reducing these stays can directly optimize HLOS, enhance patient care, and lower costs by addressing modifiable factors. Unlike large registry studies, our single-center, retrospective design allowed for the collection of detailed patient data, essential for analyzing factors associated with unnecessary stays in this specific population. Jerath et al. conducted a related study in Ontario using large administrative data, addressing unnecessary stays across a broad sample of patients aged over 40 undergoing both elective and emergency surgeries across multiple body regions [132]. Although this study highlighted general factors associated with unnecessary stays, its findings lack applicability to our targeted trauma laparotomy cohort due to the inclusion of a heterogenous patient population. Notably, Jerath et al. also suggested that future studies focus on evaluating variation at the hospital-level as a next step to enhance specificity. Furthermore, previous studies evaluating unnecessary stays in trauma have generally examined the trauma population as a whole, rather than focusing on specific subgroups. Our study represents the first to address unnecessary stays specifically in trauma laparotomy patients, revealing key factors within our clinical context, such as psychiatric components, which had not been previously reported. These findings underscore the importance of targeted research within homogenous patient subgroups to inform effective, tailored interventions.

One limitation of Chapter 2 and 3 in this thesis is that the studies primarily reflect trauma care in high-income countries (HICs), specifically in the US and Canada. Trauma care is a multifaceted system encompassing prehospital care, definitive in-hospital treatment, post-acute services including rehabilitation, and long-term follow-up, all influenced by healthcare infrastructure and available resources [133]. In low- and middle-income countries (LMICs), additional complexities such as under-resourced healthcare systems, limited social support networks, and inadequate infrastructure contribute to notable disparities in trauma management and outcomes compared to HICs. These challenges are particularly critical, given that approximately 90% of injury-related deaths occur in LMICs, underscoring trauma as a significant global health concern, as described in Chapter 1 [134]. The current body of clinical evidence, predominantly derived from HIC settings, may not be applicable to LMICs due to these contextual differences. Our findings, based primarily on HIC data, may therefore have limited relevance to LMICs. For trauma laparotomy specifically, global variations in standard care practices and clinical outcomes remain insufficiently understood, despite some existing research [135]. To address this knowledge gap, high-quality, granular data from LMICs as well as HICs are needed to inform effective, adaptable care strategies for trauma laparotomy patients on a global scale. In this regard, the Global Outcomes After Laparotomy for Trauma (GOAL-Trauma) study, an international multicenter observational cohort study, is a promising initiative aimed at evaluating trauma care across diverse settings [22]. This study represents a critical first step toward identifying disparities between HICs and LMICs, and our institution is actively participating in this effort. Such initiatives, along with the findings of this thesis, contribute incrementally to the overarching goal of improving trauma laparotomy outcomes.

In Chapter 4, we successfully developed our TLCP through a comprehensive literature review and a rigorous consensus process, which facilitated its clinical implementation. The extensive literature review conducted prior to TLCP development enabled us to map the current best available evidence and extract applicable pathway components. Subsequent studies following the TLCP implementation revealed a reduction in HLOS without a corresponding increase in complication or readmission rates, indicating that our TLCP can be effectively applied to trauma laparotomy patients. Nonetheless, there remain areas for further discussion regarding the application of ERPs in emergency surgery.

ERPs for emergency surgical populations, including trauma laparotomy patients, have been studied and gradually integrated into clinical practice. The Enhanced Recovery After Surgery (ERAS) Society has released specific guidelines for emergency laparotomy that advocate for ERP implementation in these populations, as evidenced by studies supporting their potential benefits [80-82]. However, despite this support, ERPs for emergency settings have not gained the same level of acceptance as those for elective surgeries. A recent systematic review and meta-analysis, comprising 20 studies with a combined total of 1,615 patients underwent emergency intra-abdominal surgeries, including trauma laparotomies, highlighted some promising outcomes associated with ERPs [136]. The review noted reductions in HLOS, postoperative complications, and recovery times. However, the overall certainty of evidence remained low to very low due to significant biases, inconsistencies, and imprecision in the studies included. Consequently, the authors were unable to provide strong recommendations, emphasizing the need for further research and implementation studies to strengthen the evidence base.

The challenges in implementing ERPs for complex emergency cases, such as trauma laparotomy, are evident. To date, only three studies have specifically implemented and evaluated

ERPs for trauma laparotomy patients, none of which have been conducted in North America. Developing and implementing ERPs for trauma laparotomy patients presents numerous challenges, stemming from factors such as patient volume, heterogeneity, conceptual unfamiliarity, and professional preconceptions.

Firstly, limited patient volume, particularly when applying strict inclusion criteria, restricts sample sizes and affects statistical power, generalizability, and subgroup analyses. The declining number of trauma surgical cases, influenced by shifts in injury patterns, advancements in clinical management strategies, technical and technological advances, and the impacts of the COVID-19 pandemic, has further exacerbated this issue [137-140]. In our retrospective analysis, 262 patients were initially identified over four years, yet only 111 met the criteria for inclusion in the TLCP. Overcoming this limitation is necessary to further validate the effectiveness of ERPs in this population.

Secondly, the considerable heterogeneity within trauma laparotomy patients, stemming from varied injury types and severity, a wide range of procedures performed, and factors beyond the nature of the injury, such as patients' complex medical and socioeconomic backgrounds, complicates standardized care. In Chapter 2, we identified broad variability within this cohort and addressed it by carefully refining selection criteria to balance inclusivity with practicality for TLCP application. While the results in Chapter 4 are promising, suggesting the TLCP can be effectively applied to carefully selected trauma laparotomy patients, further studies are warranted to assess the robustness and generalizability of these criteria within and beyond our institution.

Thirdly, the relative unfamiliarity with the concept of ERPs remains a significant barrier. This is critical when implementing such new interventions in a complex healthcare environment. Recognizing this, our pilot study was initiated at our institution, where foundational principles of

ERPs had already been integrated into broader clinical practice, facilitating smoother adaptation by healthcare professionals. For external application, however, this should be taken into consideration, and rigorous preparation for implementation is essential. One key aspect of mitigating this issue is the simplicity of the ERP. Ljungqvist et al. suggest that incorporating a manageable number of pathway components, ideally five to seven per phase, enhances feasibility and acceptance [69]. Our TLCP aligns with this principle.

Lastly, overcoming professional skepticism about the applicability of ERPs to emergency cases like trauma laparotomy is pivotal. During the development phase, team members initially expressed doubts about the feasibility of such standardization, given the variability and urgency in trauma care. Addressing these concerns required open communication about TLCP goals, the targeted patient population with relatively straightforward injuries, and the advantages of streamlined discharge planning during iterative team meetings. Furthermore, continuous monitoring, outcome sharing, and collaborative troubleshooting would be instrumental in fostering acceptance, gradually aligning the team's outlook toward TLCP's feasibility and its value in optimizing trauma laparotomy patient outcomes.

5.2 – Future directions

The findings presented in this thesis offer promising directions for future research and initiatives in trauma care. Chapter 2 demonstrated the value of stratifying patients based on HLOS, even within a relatively homogenous trauma subgroup. Trauma patients are inherently diverse, and clinical management is often guided by injury-specific protocols across different organ system. Additionally, even within the same anatomical region, like the neck, diagnostic and management guidelines vary depending on injury mechanisms, such as blunt versus

penetrating trauma [141, 142]. These guidelines aid clinicians in providing precise and effective care for trauma patients. However, such injury-based categorization is less practical for abdominal trauma, where multiple co-occurring injuries within the abdominal cavity present complex clinical challenges. Moreover, many trauma patients present issues beyond the injuries themselves that significantly impact their clinical course. Thus, simple stratification by injury type or procedure may overlook critical insights. Extending the stratification approach used here to other trauma populations has the potential to deepen understanding and facilitate the development of more targeted interventions.

Incorporating artificial intelligence (AI) presents a promising avenue for optimizing trauma care. Recent studies applying machine learning models to predict HLOS have shown the potential of AI to enhance decision-making in patient management [143-146]. However, there remains a need for ongoing research and careful evaluation of these models, as the complex and multifactorial nature of trauma care resists a standardized predictive approach. While no single model can universally address this complexity, rapid advancements in AI technology hold promise for streamlining processes, reducing analytical workload, and decreasing costs. With further refinement, AI-based approaches could provide impactful improvements in healthcare metrics and patient outcomes.

A primary challenge in implementing TLCP lies in the limited sample sizes associated with this specific patient population. To overcome this limitation and achieve robust validation of TLCP implementation and selection criteria, large-scale, multi-center studies with increased sample sizes are essential. This effort necessitates a stepwise approach, beginning with local trauma center involvement at the provincial level. If proven effective, the pathway could then be

expanded to a national scale and, ultimately, to an international level. This phased strategy is crucial for effectively establishing new interventions across diverse healthcare contexts.

Within our institution, several areas require further exploration. Our scoping review revealed that outcome measures primarily used in this field are clinician-reported outcomes (ClinROs), with 74% focusing on HLOS and 64% on complications rates. However, patient-reported outcomes (PROs) at 18% and cost/resource-related measures at 13% remain notably underexplored. Integrating these outcomes into TLCP evaluations could enhance pathway utilization by incorporating the patient perspective and addressing healthcare resource implications directly. Additionally, qualitative feedback from healthcare professionals could reveal both the strength and limitations of TLCP implementation, further supporting the pathway's feasibility and refinement.

Lastly, subgroup analysis in our pilot study revealed that only one patient (3.2%) experienced an unnecessary hospital stay, compared to 12 patients (18.2%) in the historical cohort. Removing these patients from analysis resulted in a one-day reduction in HLOS. This finding suggests that addressing factors such as access to post-acute care facilities, coordination with other departments, and the management needs of older, more comorbid populations could reduce unnecessary stays when paired with TLCP implementation. Achieving these improvements requires collaboration across departmental boundaries, partnerships with external healthcare organizations, and alignment with community resources.

5.3 – Conclusion

This doctorate thesis aimed to enhance outcomes for trauma laparotomy patients, with a particular focus on optimizing HLOS. Recognizing the inherent heterogeneity within this trauma cohort, the study introduced a novel approach by stratifying patients based on HLOS. This stratification proved valuable in identifying distinct subgroups with unique clinical characteristics and healthcare needs, underscoring the importance of targeted interventions in resource allocation and outcome improvement.

As a targeted approach aimed at patients with relatively short to moderate HLOS, a consensus-based TLCP was developed specifically for trauma laparotomy patients, incorporating precise patient selection criteria. The pathway was successfully implemented in our clinical settings. Following implementation, a reduction in HLOS was observed, without an associated increase in complications or readmission rates, suggesting that this pathway can be applied to selected trauma laparotomy patients with potential benefits for clinical outcomes. Furthermore, addressing factors identified through this thesis as contributing to unnecessary stays, alongside pathway use, may further optimize patient outcomes within our clinical settings.

While these efforts may currently impact patient outcomes only at the institutional level, they represent essential initial steps toward broader implementation at provincial, national, and international levels, aiming to standardize and improve care for trauma laparotomy patients on a larger scale.

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APPENDICES

Chapter 2. STROBE Statement—Checklist of items

Chapter 4. Trauma Laparotomy Care Pathway

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1-2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up (*b*) For matched studies, give matching criteria and number of exposed and unexposed	4-5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4
Bias	9	Describe any efforts to address potential sources of bias	NA
Study size	10	Explain how the study size was arrived at	NA
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding (*b*) Describe any methods used to examine subgroups and interactions (*c*) Explain how missing data were addressed (*d*) If applicable, explain how loss to follow-up was addressed (*e*) Describe any sensitivity analyses	6-7, 15
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	7
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest (c) Summarise follow-up time (eg, average and total amount)	7-9 Table 1,2
Outcome data	15*	Report numbers of outcome events or summary measures over time	9-10

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	7, 9-10 Table 3,4
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	10-11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15-16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	NA
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

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Chirurgie Traumatologie
Suivi systématique - Chirurgie trauma par laparotomie
Ordonnances Antibiotiques pré-opératoires

Trauma Surgery
Trauma Laparotomy Care Pathway
Preoperative Antibiotic Medication Order

ALLERGIES _____

Poids / Weight _____**kg** **Taille** / Height _____ **cm** **Indice de masse corporelle /** BMI _____

Initiales du prescripteur pour chaque ordonnance Prescriber's initials for each order	**ORDONNANCE DU PRESCRIPTEUR** / PRESCRIBER'S ORDERS	**Initiales de l'infirmier(ère) notées** Nurse's initials noted
	Metronidazole 500 mg IV X 1 dose, to be infused over 30 minutes and completed prior to first incision **AND** CeFAZolin 2 g IV x 1 dose, to be infused and completed prior to first incision **OR** **If patients weigh more than 120 kg** CeFAZolin 3 g IV x 1 dose, to be infused and completed prior to first incision ******Repeat CeFAZolin dose if blood loss more than 1500 mL******	
	If allergy to cephalosporin or type 1 penicillin allergy, replace CeFAZolin with: Clindamycin 900 mg IV x 1 dose over 30 minutes, to complete before incision ******Repeat Clindamycin dose if blood loss more than 1500mL****** **AND** Tobramycin 5 mg/kg IV x 1 To be infused over 30 minutes, start before incision (careful consideration of use in patients with kidney failure, single kidney, recent use of contrast dye) NOTE: If serum creatinine is above 150 micromol/L, reduce Tobramycin dose to 2 mg/kg IV x 1 dose Dose: _____(max : 400 mg/dose)	

Weight	**Tobramycin Dose**
Less than or equal to 50 kg	240 mg
51-59 kg	280 mg
60-69 kg	320 mg
70-79 kg	360 mg
Equal or more than 80 kg	400 mg

	Nom en lettres moulées Name in print letters	**Signature**	**N° Permis** License No.	**Heure** Time **00:00**	**Date** **AA**YY/**M**M/**J**D
Prescripteur *Prescriber*					

	Nom en lettres moulées et/ou numéro de permis Name in print and/or license number	**Initiales** Initials	**Heure** Time **00:00**	**Date** **AA**YY/**M**M/**J**D
Infirmier(ère) Nurse				
Pharmacien(ne) Pharmacist				

CHIRURGIE TRAUMATOLOGIE
Suivi systématique des chirurgies en trauma par laparotomie
Ordonnances médicales postopératoires

TRAUMA SURGERY
Trauma Laparotomy Care Pathway
Postoperative Medical Orders

ALLERGIES _____

Poids / Weight _____**kg** **Taille** / Height _____ **cm** **Indice de masse corporelle /** BMI _____

Initiales du prescripteur pour chaque ordonnance Prescriber's initials for each order	**ORDONNANCE DU PRESCRIPTEUR** / PRESCRIBER'S ORDERS	**Initiales de l'infirmier(ère) notées** Nurse's initials noted
	POD 0	
Diet and blood testing are programmed in OASIS under: Full Catalogue > Departmental > General Surgery > Trauma Laparotomy		
	Vital Signs (VS) Monitoring: In ICU: Follow ICU standards. In PACU: Follow PACU standards. On arrival in PACU: • CBC, BUN/Creat, Na/K/Cl, LFT, PTT/PT/INR, CRP • Nurse to place **patient education** booklet in patient chart Transfer to ward with VS monitoring: **VS q 4h x 24 hours then q 8h until discharge and notify physician if:** • Pulse: greater than 110 or lower than 50 beats per minute • Systolic BP: greater than 180 mmHg OR lower than 90 mmHg OR MAP lower than 65 mmHg • Resp rate: greater than 30 or lower than 10 respirations per minute • Temperature above 38.5°C • O_2Sat lower than 90% on room air	
	Test: Capillary blood glucose monitoring on arrival to ICU/PACU – inform service if blood glucose is greater than 10 mmol/L.	
	Diet: Keep NPO if NG tube in situ If no NG tube, enter [regular diet ERAS] in OASIS	
	Activity: Nurse to provide **patient education** booklet to patient and/or family member once transferred to unit Keep antiembolic stockings (AES) until fully ambulating, then D/C Out of bed (OOB) sitting in chair with assistance Incentive spirometer q 1h while awake until discharge	
	Tubes and Drains: Urinary catheter to straight drainage and record output q 4h • Call physician if urine output (U/O) less than 120 mL q 4h If no urinary catheter, follow the Post-Operative Urinary Retention (POUR) protocol NG tube to low wall suction, empty and record output q 8h Empty and record abdominal drain output (if in-situ) q 8h until drain removed by physician	
	If new or revised ostomy: Notify wound and ostomy nurse (**IMPORTANT:** Physician must write consult)	

	Nom en lettres moulées Name in print letters	**Signature**	**N° Permis** License No.	**Heure** Time **00:00**	**Date** **AA**YY/**M**M/**J**D
Prescripteur Prescriber					

	Nom en lettres moulées et/ou numéro de permis Name in print and/or license number	**Initiales** Initials	**Heure** Time **00:00**	**Date** **AA**YY/**M**M/**J**D
Infirmier(ère) Nurse				
Pharmacien(ne) Pharmacist	N/A	N/A	N/A	N/A

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CHIRURGIE TRAUMATOLOGIE
Suivi systématique des chirurgies en trauma par laparotomie
Ordonnances médicales postopératoires

TRAUMA SURGERY
Trauma Laparotomy Care Pathway
Postoperative Medical Orders

ALLERGIES _____

Poids / Weight _____**kg** **Taille** / Height _____ **cm** **Indice de masse corporelle /** BMI _____

Initiales du prescripteur pour chaque ordonnance Prescriber's initials for each order	ORDONNANCE DU PRESCRIPTEUR **/ PRESCRIBER'S ORDERS**	**Initiales de l'infirmier(ère) notées** Nurse's initials noted
	POD 1	
	Test : Capillary blood glucose at 06:00 a.m. – inform trauma service if blood glucose is greater than 10 mmol/L. CBC, BUN/creat, Na/K/Cl, Coag, CRP at 6:00 a.m.	
	Activity: Out of bed (OOB) sitting in chair TID for 30-60 minutes each until discharge Assist to walk in hallway TID Physiotherapy consult as needed (**IMPORTANT**: Physician must write physio consult)	
	Tubes: Remove urinary catheter (if present) at 6:00 a.m. and follow the POUR protocol Remove NG tube if output less than 300 mL over 8h	
	Diet: Keep NPO if NG tube in-situ If NG tube removed, enter regular diet in OASIS with an oral nutritional supplement TID	
	Additional orders not included in the trauma laparotomy care pathway:	
	POD 2	
	Diet: Keep NPO if NG tube in situ If NG tube removed, enter regular diet in OASIS with an oral nutritional supplement TID	
	Activity: Assist to walk in hallway QID until discharge	
	Tubes: Remove NG tube if output less than 300 mL over 8h	
	Other: Physician to remove initial surgical dressing Keep incision open to air (OTA) if dry and well approximated	
	Additional orders not included in the trauma laparotomy care pathway:	

	Nom en lettres moulées Name in print letters	**Signature**	**N° Permis** License No.	**Heure** Time **00:00**	**Date** **AA**YY/**M**M/**J**D
Prescripteur Prescriber					

	Nom en lettres moulées et/ou numéro de permis Name in print and/or license number	**Initiales** Initials	**Heure** Time **00:00**	**Date** **AA**YY/**M**M/**J**D
Infirmier(ère) Nurse				
Pharmacien(ne) Pharmacist	N/A	N/A	N/A	N/A

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CHIRURGIE TRAUMATOLOGIE
Suivi systématique des chirurgies en trauma par laparotomie
Ordonnances médicales postopératoires

TRAUMA SURGERY
Trauma Laparotomy Care Pathway
Postoperative Medical Orders

ALLERGIES _____

Poids / Weight _____**kg** **Taille** / Height _____**cm** **Indice de masse corporelle /** BMI _____

Initiales du prescripteur pour chaque ordonnance Prescriber's initials for each order	**ORDONNANCE DU PRESCRIPTEUR** / PRESCRIBER'S ORDERS	**Initiales de l'infirmier(ère) notées** Nurse's initials noted
	POD 3	
	Test: **Reminder for MD:** if patient had bowel anastomosis, order: CBC, CRP	
	Tubes: Start epidural stop test at 6:00 a.m. (**IMPORTANT**: Refer to APS and surgical team recommendations and follow MUHC anticoagulation guidelines for safe catheter removal.)	
	Additional orders not included in the trauma laparotomy care pathway:	
	POD 4	
	D/C planning: Physician must confirm D/C before 9:00 a.m.	
	D/C criteria	
	Patient may be discharged as soon as the following D/C criteria are met: • Tolerating oral diet without the need for antiemetics • Ambulating independently • Pain less than 4/10 or patient reports pain is tolerable with activity on oral meds • VS are within normal range • Voiding spontaneously • Wound appears to be healing well and no signs and symptoms of wound infection • Blood test results are within normal range **Prior to D/C:** • Review discharge/exit prescription with patient • Provide follow up appointment in clinic 2-4 weeks after discharge from hospital • Remove IV catheter • If clips not removed, CLSC to remove clips on ___/___/___yy/mm/dd • Review the "At Home" section in trauma laparotomy booklet with patient	
	Additional orders not included in the trauma laparotomy care pathway:	

	Nom en lettres moulées Name in print letters	**Signature**	**N° Permis** License No.	**Heure** Time **00:00**	**Date** **AA**YY/**M**M/**J**D
Prescripteur Prescriber					

	Nom en lettres moulées et/ou numéro de permis Name in print and/or license number	**Initiales** Initials	**Heure** Time **00:00**	**Date** **AA**YY/**M**M/**J**D
Infirmier(ère) Nurse				
Pharmacien(ne) Pharmacist	N/A	N/A	N/A	N/A

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CHIRURGIE TRAUMATOLOGIE
Suivi systématique - Chirurgies trauma par laparotomie
Ordonnance de médicaments post-opératoires

TRAUMA SURGERY
Trauma Laparotomy Care Pathway
Postoperative Medication Orders

ALLERGIES _____

Poids / Weight _____**kg** **Taille** / Height _____ **cm** **Indice de masse corporelle /** BMI _____

Initiales du prescripteur pour chaque ordonnance Prescriber's initials for each order	**ORDONNANCE DU PRESCRIPTEUR** / PRESCRIBER'S ORDERS	**Initiales de l'infirmier(ère) notées** Nurse's initials noted
	Intravenous Ringer's Lactate at _____ mL/h (1 mL/kg/h) on arrival to surgical unit NS lock if tolerating diet and remove IV when epidural or PCA is discontinued.	
	IF ABDOMEN <u>NOT</u> CONTAMINATED Metronidazole 500 mg IV q 8h x 2 doses, Next dose: ___:___ **AND** CeFAZolin 2 g IV q 8h x 2 doses (start 8h after last dose in operating room) **OR** CeFAZolin 3 g IV q 8h x 2 doses (if patient weighs more than 120 kg) (start 8h after last dose in operating room) Next dose: ___:___	
	IF ABDOMEN CONTAMINATED Metronidazole 500 mg IV q 8h x 11 doses (start 8h after last dose in operating room) **AND** Next dose: ___:___ Ceftriaxone 2 g IV q 24h x 3 doses (start 24h after last dose in operating room) Next dose: ___:___	
	IF ABDOMEN <u>NOT</u> CONTAMINATED AND If allergy to cephalosporin or type 1 penicillin allergy: Clindamycin 900 mg IV q 8h x 2 doses (start 8h after last dose in operating room) Next dose: ___:___ **AND** Metronidazole 500 mg IV q 8h x 2 doses, Next dose: ___:___	
	IF ABDOMEN CONTAMINATED AND If allergy to cephalosporin or type 1 penicillin allergy: Clindamycin 900 mg IV q 8h x 11 doses (start 8h after last dose in operating room), Next dose: ___:___ **AND** Tobramycin 5 mg/kg IV (Max: 400 mg) q 24h x 3 doses • Start 8h after last dose in operating room • To be infused over 30 minutes. (careful consideration of use in patients with kidney failure, single kidney, recent use of contrast dye) NOTE: If serum creatinine is above 150 micromol/L, reduce Tobramycin dose to 2 mg/kg IV Dose:_____ mg (max: 400 mg) Next dose: ___:___	

Weight	**Tobramycin Dose**
Less than or equal to 5kg	240 mg
51-59 kg	280 mg
60-69 kg	320 mg
70-79 kg	360 mg
Equal or more than 80 kg	400 mg

	Nom en lettres moulées Name in print letters	**Signature**	**N° Permis** License No.	**Heure** Time **00:00**	**Date** **AA**YY/**M**M/**J**D
Prescripteur *Prescriber*					

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Infirmier(ère) Nurse				
Pharmacien(ne) Pharmacist				

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CHIRURGIE TRAUMATOLOGIE
Suivi systématique - Chirurgies trauma par laparotomie
Ordonnance de médicaments post-opératoires

TRAUMA SURGERY
Trauma Laparotomy Care Pathway
Postoperative Medication Orders

ALLERGIES _____

Poids / Weight _____**kg** **Taille** / Height _____ **cm** **Indice de masse corporelle /** BMI _____

Initiales du prescripteur pour chaque ordonnance Prescriber's initials for each order	ORDONNANCE DU PRESCRIPTEUR/ **PRESCRIBER'S ORDERS**	**Initiales de l'infirmier(ère) notées** Nurse's initials noted
	THROMBOPROPHYLAXIS – Start at 10:00 a.m. on POD 1 □ Dalteparin 2,500 units SC daily if patient weights less than 45 kg OR □ Dalteparin 5,000 units SC daily if patient weighs between 45 kg and 100 kg OR □ Dalteparin 7,500 units SC daily if patient weighs more than 100 kg OR □ Heparin 5,000 units SC q 12h if creatinine clearance is less than 30 mL/min	
	On the day of epidural catheter removal, refer to the MUHC anticoagulation Guideline Appendix Table 1 (columns 4-5): Remove catheter no sooner than 12 h after the previous dose of Dalteparin Restart Dalteparin no sooner than 4 h after catheter removal Remove catheter no sooner than 4-6 h after the previous dose of Heparin Restart Heparin with no delay after catheter removal	
	While on EPIDURAL, follow anesthesia co-analgesic and side effect management pre-printed order (PPO). For the epidural stop test (EST): Send the surgical care pathway medication orders (page 3) to pharmacy and initiate the EST.	
	Within 4-6 hours of EST: • If pain score less than or equal to 4/10 at rest, remove catheter and restart Dalteparin/Heparin as per surgical pathway medication orders. If pain score greater than or equal to 5/10 at rest and the patient's functional status is limited by pain, restart epidural at the last infusion rate and notify anesthesia/Acute Pain Service (APS). Notify pharmacy via communication sheet that the infusion was restarted. Retrial of EST the following day.	

	Nom en lettres moulées Name in print letters	**Signature**	**N° Permis** License No.	**Heure** Time **00:00**	**Date** **AA**YY/**M**M/**J**D
Prescripteur *Prescriber*					

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Infirmier(ère) Nurse				
Pharmacien(ne) Pharmacist				

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CHIRURGIE TRAUMATOLOGIE
Suivi systématique - Chirurgies trauma par laparotomie
Ordonnance de médicaments post-opératoires

TRAUMA SURGERY
Trauma Laparotomy Care Pathway
Postoperative Medication Orders

ALLERGIES _____

Poids / Weight _____**kg** **Taille** / Height _____ **cm** **Indice de masse corporelle /** BMI _____

Initiales du prescripteur pour chaque ordonnance Prescriber's initials for each order	ORDONNANCE DU PRESCRIPTEUR/ **PRESCRIBER'S ORDERS** **Send this page only when the epidural/PCA/CPNB removed**	**Initiales de l'infirmier(ère) notées** Nurse's initials noted
When EST started: • Give Acetaminophen and first dose of opioid as per age category. • See criteria for epidural catheter removal on page 2.		
If patient younger than 65 years old, give:		
	Acetaminophen 975 mg PO q 6h x 48 hours, then acetaminophen 650 mg PO q 6h	
	HYDROmorphone 2 mg PO q 4h PRN (favor PO route) **OR** HYDROmorphone 1 mg SC q 4h PRN	
If patient 65-79 years old, give:		
	Acetaminophen 650 mg PO q 6h	
	HYDROmorphone 1 mg PO q 4h PRN (favor PO route) **OR** HYDROmorphone 0.5 mg SC q 4h PRN	
If patient 80 years old or older, give:		
	Acetaminophen 650 mg PO q 6h	
	HYDROmorphone 0.5 mg PO q 4h PRN (favor PO route) **OR** HYDROmorphone 0.25 mg SC q 4h PRN	
All ages:		
	Celecoxib 100 mg PO BID (Exception: Serum creatinine more than 150 micromol/L, peptic ulcer disease – current or remote, age 75 years old or older, allergy or intolerance to NSAIDs or ASA, Crohn's, previous Myocardial Infarction)	
	Ondansetron 4 mg PO/IV q 8h PRN	
	If Ondansetron given in the last 8 hours and patient nauseous or vomiting, give: **If patient is 75 years old and less:** • dimenhyDRINATE 25-50 mg IV/PO q 6h PRN **If patient older than 75 years old:** • dimenhyDRINATE 25 mg IV/PO q 6h PRN	
	Polyethylene glycol 17 g PO daily	
	Sennosides 8.6 mg PO q HS PRN	

	Nom en lettres moulées Name in print letters	**Signature**	**N° Permis** License No.	**Heure** Time **00:00**	**Date** **AA**YY/**M**M/**J**D
Prescripteur *Prescriber*					
	Nom en lettres moulées et/ou numéro de permis Name in print and/or license number		**Initiales** Initials	**Heure** Time **00:00**	**Date** **AA**YY/**M**M/**J**D
Infirmier(ère) Nurse					
Pharmacien(ne) Pharmacist					

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Suivi systématique
chirurgies trauma par laparotomie
Ordonnance Externe

Trauma Laparotomy Care Pathway
External Prescription

Date _____ **Service** **Traumatologie** / Traumatology
(AAYY/MM/JD)

Téléphone/Telephone:
■ Hôpital Général de Montréal (514) 934-1934 poste _____

No. du télécopieur du service / Service's fax number (514) _____-_____

Poids / Weight _____(kg) **Allergies**_____ **Indice de masse corporelle /** BMI _____

Médicament(s) * Posologie * Quantité * Durée / Medication * Dosage * Quantity * Duration **CROSS OUT MEDICATIONS THAT DO NOT APPLY**	**Nombre de renouvellement** Number of renewals
Acetaminophène 650 mg PO q 6h x 14 jours/days puis/then PRN # 112 comprimés / tabs de/of 325mg	1
Célécoxib 100 mg PO BID PRN x 14 jours/days # 28 comprimés/tabs **Exceptions: creatinine sérique de plus de 150 micromol/L, histoire d'ulcère peptique, age 75 ans ou plus, allergie ou intolerance aux AINS ou AAS, maladie de Crohn, histoire d'infarctus du myocarde /** serum creatinine more than 150 micromol/L, history of peptic ulcer disease, 75 years old or older, allergy or intolerance to NSAIDs or ASA, Crohn's disease, history of myocardial infarction	NR
Polyethylene glycol 17 g PO DIE/daily x 7 jours/days # 7 **Pendant l'utilisation d'opiacés** / while on opioids	NR
Sennosides 8.6 mg PO q HS PRN # 7 **Pendant l'utilisation d'opiacés** / while on opioids	NR
******Retournez tous les médicaments inutilisés à votre pharmacie /** Return any unused medications to your pharmacy********	

_____ _____ _____
Signature du médecin / Physician's signature **Nom en lettres moulées /** Print name **N° permis**/ License N°

Commentaires/Comments_____

À COMPLÉTER LORSQUE LA PRESCRIPTION DOIT ÊTRE TÉLÉCOPIÉE / TO BE COMPLETED IF PRESCRIPTION IS FAXED.

Le médecin doit compléter cette section pour se conformer aux règles émises par le Collège des médecins lors de prescription transmise par télécopieur. / To comply with the regulations of the Collège des médecins, this section must be completed by the physician if this prescription is to be faxed.

Nom du propriétaire de la pharmacie
Name of the pharmacy's owner_____

Date et heure de la télécopie
Fax date and time_____ _____
No. télécopieur **AA**YY/**M**M/**J**D 00:00
Fax number (_____)_____

Le médecin ci-haut mentionné certifie que:
1) Cette ordonnance est originale
2) Le pharmacien identifié précité est le seul destinataire
3) L'original de cette ordonnance ne sera pas réutilisé

The above-mentioned physician certifies that:
1) This is the original prescription
2) The aforementioned pharmacist is the only recipient
3) The original prescription will not be re-used

TRANSMISSION CONFIDENTIELLE PAR TÉLÉCOPIEUR / CONFIDENTIAL FAX TRANSMISSION

Ce message contient de l'information privilégiée, confidentielle et ne pouvant être divulguée. Si vous n'êtes pas le destinataire envisagé de ce message ou une personne autorisée à le recevoir, veuillez communiquer avec le soussigné et ensuite détruire ce message ainsi que toutes les copies pouvant exister. / This message contains privileged and confidential information, which is not to be disclosed. If you are not the intended recipient of this message, please contact the undersigned and destroy this message as well as all existing copies.

Annexer la confirmation par télécopieur à la copie jaune / Attach fax confirmation to Yellow copy

Original - Pharmacie / Original – Pharmacy **Copie jaune – Dossier médical** /Yellow copy - Medical Record

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Suivi systématique
chirurgies trauma par laparotomie
Ordonnance Externe

Trauma Laparotomy Care Pathway
External Prescription

Date _____ **Service** **Traumatologie** / Traumatology
(AAYY/MM/JD)

Téléphone/Telephone:
■ Hôpital Général de Montréal (514) 934-1934 poste _____

No. du télécopieur du service / Service's fax number (514) _____-_____

Poids / Weight _____(kg) **Allergies**_____ **Indice de masse corporelle /** BMI _____

Médicament(s) * Posologie * Quantité * Durée / Medication * Dosage * Quantity * Duration **CROSS OUT MEDICATIONS THAT DO NOT APPLY** **Recommandation CUSM pour les opiacés /** MUHC Recommendation for opioids: **-Quantité maximale de 30 comprimés /** Maximum supply of 30 tablets **-Diviser la quantité à servir (fractionnement) /** Split the supply quantity	**Nombre de renouvellement** Number of renewals
☐ **Patient de moins de 65 ans** / Patient younger than 65 years old: HYDROmorphone 2 mg PO q 6h PRN **Qté /** Qty **:** _____**co. /** tabs **de/**of **2 mg** ☐ **Patient de 65 à 79 ans /** Patient 65-79 years old: HYDROmorphone 1 mg PO q 6h PRN **Qté /** Qty **:** _____**co. /** tabs **de/**of **1 mg** ☐ **Patient de 80 ans et plus /** Patient 80 years old or older: HYDROmorphone 0.5 mg PO q 6h PRN **Qté /** Qty **:** _____**co. /** tabs **de/**of **1 mg** ☐ **SVP diviser** /please split in: **2 Services** ➢ **Considérer 30 comprimés (15 co. si 80 ans et plus) : Si 4 comprimés ou plus ont été utilisés au cours des dernières 24 heures** Consider 30 tablets (15 tabs if 80 years old or older) : If 4 or more tablets were used over last 24h ➢ **Considérer 15 comprimés (7 co. si 80 ans et plus : Si 1 à 3 comprimés ont été utilisés au cours des dernières 24 heures)** Consider 15 tablets (7 tabs if 80 years old or older) : If 1 to 3 tablets were used over last 24h ➢ **Si aucun comprimé n'a été utilisé au cours des dernières 24 heures ☐ éviter de prescrire** If no tabs used in last 24h ☐ avoid prescribing	NR
☐ Naloxone 0.4 mg/mL vaporisateur nasal / nasal spray ➢ **Si le patient reçoit 15 comprimés ou plus d'HYDROmorphone 2 mg** if patient receives 15 tablets or more of HYDROmorphone 2 mg **Qté/**Qty **: 1**	NR
******Retournez tous les médicaments inutilisés à votre pharmacie /** Return any unused medications to your pharmacy********	

_____ _____ _____
Signature du médecin / Physician's signature **Nom en lettres moulées /** Print name **N° permis/** License N°

Commentaires/Comments_____

À COMPLÉTER LORSQUE LA PRESCRIPTION DOIT ÊTRE TÉLÉCOPIÉE / TO BE COMPLETED IF PRESCRIPTION IS FAXED.

Le médecin doit compléter cette section pour se conformer aux règles émises par le Collège des médecins lors de prescription transmise par télécopieur.
To comply with the regulations of the Collège des médecins, this section must be completed by the physician if this prescription is to be faxed.

Nom du propriétaire de la pharmacie
Name of the pharmacy's owner_____

Date et heure de la télécopie
Fax date and time_____ _____
No. télécopieur **AA**YY/**M**M/**J**D 00:00
Fax number (_____)_____

Le médecin ci-haut mentionné certifie que:
1) Cette ordonnance est originale
2) Le pharmacien identifié précité est le seul destinataire
3) L'original de cette ordonnance ne sera pas réutilisé

The above-mentioned physician certifies that:
1) This is the original prescription
2) The aforementioned pharmacist is the only recipient
3) The original prescription will not be re-used

TRANSMISSION CONFIDENTIELLE PAR TÉLÉCOPIEUR / CONFIDENTIAL FAX TRANSMISSION

Ce message contient de l'information privilégiée, confidentielle et ne pouvant être divulguée. Si vous n'êtes pas le destinataire envisagé de ce message ou une personne autorisée à le recevoir, veuillez communiquer avec le soussigné et ensuite détruire ce message ainsi que toutes les copies pouvant exister. / This message contains privileged and confidential information, which is not to be disclosed. If you are not the intended recipient of this message, please contact the undersigned and destroy this message as well as all existing copies.

Annexer la confirmation par télécopieur à la copie jaune / Attach fax confirmation to Yellow copy
Original - Pharmacie / Original – Pharmacy **Copie jaune – Dossier médical** /Yellow copy - Medical Record