

TRIINU KESKPAIK

Quality indicators and  
non-ischemic myocardial injury in  
emergency medicine



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Department of Anaesthesiology and Intensive Care, Institute of Clinical Medicine, University of Tartu, Tartu, Estonia.

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Supervisors: Professor Joel Starkopf, MD, PhD  
Professor of Anaesthesiology and Intensive Care, Department of Anaesthesiology and Intensive Care, Institute of Clinical Medicine, University of Tartu, Tartu, Estonia

Professor Peep Talving, MD, PhD  
Professor of Surgery, Department of Surgery, Institute of Clinical Medicine, University of Tartu, Tartu, Estonia  
Director, Division of Acute Care Surgery, Department of Surgery, North Estonia Medical Centre Foundation, Tallinn, Estonia

Reviewers: Professor Urmas Lepner, MD, PhD  
Professor of Surgery, Department of Surgery, Vice Dean, Institute of Clinical Medicine, University of Tartu, Tartu, Estonia

Mai Blöndal, MD, PhD  
Department of Cardiology, Institute of Clinical Medicine, University of Tartu, Tartu, Estonia  
Department of Cardiology, Heart Clinic, Tartu University Hospital, Tartu, Estonia

Opponent: Professor Beat Schnüriger, MD, PhD  
Professor of Surgery, Department of Visceral Surgery and Medicine, Bern University Hospital, University of Bern, Bern, Switzerland

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## LIST OF PUBLICATIONS

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- II **Keskpaik, T.**, Talving, P., Kirsimägi, Ü., Mihnovitš, V., Ruul, A., Marandi, T., & Starkopf, J. (2023). Associations between elevated high-sensitive cardiac troponin t and outcomes in patients with acute abdominal pain. *European Journal of Trauma and Emergency Surgery*, *49*(1), 281–288.
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## ABBREVIATIONS

ACS	acute coronary syndrome
AF	atrial fibrillation
AIS	Abbreviated Injury Scale
AMI	acute myocardial infarction
ATLS®	Advanced Trauma Life Support
BCI	blunt cardiac injury
CAD	coronary artery disease
CCI	Charlson Comorbidity Index
CHF	chronic heart failure
cTnI	cardiac troponin I
cTnT	cardiac troponin T
CVD	cardiovascular disease
EAST	Eastern Association for the Surgery of Trauma
ECG	electrocardiogram
ED	emergency department
ED LOS	emergency department length of stay
EM	emergency medicine
eGFR	estimated glomerular filtration rate
GCS	Glasgow Coma Scale
GOS	Glasgow Outcome Scale
Hgb	hemoglobin
HLOS	hospital length of stay
Hs-cTn	high-sensitivity cardiac troponin
ICU	intensive care unit
IQR	interquartile range
ISS	Injury Severity Score
MACE	major adverse cardiovascular event
MAP	mean arterial blood pressure
MINS	myocardial injury after non-cardiac surgery
OMI	occult myocardial injury
OR	odds ratio
QI	quality indicator
SD	standard deviations
TEE	transoesophageal echocardiography
TTE	transthoracic echocardiography
Tn	troponin

# 1. INTRODUCTION

Emergency medicine (EM) is an integral component of the contemporary healthcare system. Its framework encompasses care provided at the point of injury or illness, during transportation, within the emergency department (ED), and during early inpatient care (WHO, 2018). Emergency medicine comprises a system that offers multidisciplinary capabilities for the initial care of a broad spectrum of patients and conditions. This system bears the responsibility of preventing mortality and alleviating morbidity. Additionally, EM serves a vital healthcare safety-net function for society (WHO, 2019).

Emergency medicine was recognized as an independent specialty in Estonia in the year of 2000. During the following years, a network of EDs, accepted triage system, emergency medicine specialty residency program, and first steps towards quality assessment have been established.

There are two major referral hospitals for adults, providing highest level of care for emergency patients, including patients with major trauma – North Estonia Medical Centre Foundation, with approximately 80 000 ED visits per year, and Tartu University Hospital, with approximately 45 300 ED visits per year. Roughly half of the admissions to major referral EDs in Estonia are triaged as urgent, very urgent or critical. In addition to tertiary hospitals, there are central, general and local hospitals, and EDs with diversity in proportion of trained EM physicians, and in different availability of 24/7 consultations, laboratory testing and radiology capabilities.

Predictably, EDs at Estonian medical facilities are encountering similar difficulties well described worldwide, including growing demand, crowding leading to assessment and treatment delays (Pines et al., 2011; Morley et al., 2015). Since the year 2000, acute care beds have decreased from 600 to approximately 340 per 100 000 inhabitants in Estonia (Habicht et al., 2022), while the reports from the major referral hospital shows an annual increase in ED visits. The International Federation for Emergency Medicine has stated that crowding and access block are major issues with potentially lethal consequences, illustrating dysfunction and limited capability of the health care (Javidan et al., 2021).

Following World Health Assembly resolution, all countries should assess and develop their emergency care systems, including the creation of mechanisms to improve the coordination, quality and safety of emergency care (WHO, 2019). Countries with well-established EM are now focusing on quality definition and assurance (Hansen et al., 2020). The first step to improve the quality of care is to measure the actual care provided. Two accepted frameworks for quality assessment are Donabedian (Donabedian et al., 1966), and Institute of Medicine domains (IOM, 2001) including different aspects of care at individual and system level. There are emergency medicine quality indicators endorsed by the Estonian Health Insurance Fund (OECD, 2022), but not systematically analyzed.

In a busy ED, timely and adequate triage, diagnostics of organ failures, initiation of treatment, and interdisciplinary consultations are required to provide high quality of care for the patients.

The present dissertation concludes studies scrutinizing urgent patients presenting with acute abdominal pain, and patients with major blunt trauma. The studies are focusing on quality indicators endorsed by the Estonian Health Insurance Fund, and on myocardial injury as one of the essential organ failure feasible to detect with a novel biomarker assays. Pain is a prevalent complaint in the ED (Mura et al., 2017), with abdominal pain ranking as the most frequent reason for adult ED visits (Bhuiya et al., 2010; Gervellin et al., 2016; Moore et al., 2017). Notably, 17% of visits for abdominal pain lead to serious diagnosis, and approximately 20% of these visits result in admission, transfer, or fatality (Bhuiya et al., 2010). Injuries represent a significant cause of both global mortality and morbidity worldwide (WHO, 2021). In Estonia, injuries are the third leading cause of death, significantly contributing to a high burden of morbidity and long-term disability (EuroSafe, 2016). Non-ischemic myocardial injury is frequent and prognostically relevant event in ED patients (Shah et al., 2017) potentially unnoted in patients with primary non-cardiac cause for admission. Main indication for obtaining cardiac troponins is to rule-in or rule-out acute myocardial infarction (AMI). There are many potential contributors to myocardial injury including mechanical trauma to the heart, anaemia, sepsis, and tachycardia in patients investigated in the studies of this dissertation, nevertheless, these patients are currently not routinely screened for myocardial injury.

## 2. REVIEW OF THE LITERATURE

### 2.1. Quality Indicators in Emergency Medicine

Quality of care and patient-safety are paramount values in the emergency department, focusing on the provision of urgent care for patients presenting with a broad spectrum of undifferentiated conditions.

There are two broadly accepted frameworks to measure healthcare performance, depicted in Table 1 (Donabedian, 1966; IOM, 2001).

**Table 1.** Quality domains by Donabedian and Institute of Medicine

<b>Donabedian domains</b>	
Domain	Description
Structural	Organizational and physical characteristics
Process	Care delivered, diagnostics, treatment
Outcome	Change in the status of the patient/population
<b>Institute of Medicine domains</b>	
Domain	Description
Safe	Avoiding injuries to the patients
Effective care	Providing evidence-based care
Patient-centered	Respectful and responsive care to individual patient preferences, needs, and values and ensuring that patient values guide all clinical decisions
Timely	Reducing waits and sometimes harmful delays for both those who receive and those who give care
Efficient	Avoiding waste, including waste of equipment, supplies, ideas, and energy
Equitable	Providing care that does not vary in quality because of personal characteristics such as gender, ethnicity, geographic location, and socioeconomic status

The landmark paper in the field of quality measurement was published in the 1960s by Donabedian introducing three domains of quality indicators (QI) including structure, outcome, and process indicators (Donabedian, 1966). In addi-

tion, the Institute of Medicine has defined six domains to ensure high quality of care (IOM, 2001).

In 2011, the International Federation of Emergency Medicine, representing more than 70 countries, introduced a quality-of-care framework (Lecky et al., 2014), in 2020 an updated document was published. In this international consensus document, it is stated that patients should expect from an ED qualified personnel, the right decision-making, timely management specially for patients requiring immediate care, the right approach emphasizing relief of suffering, and the right location of care (Hansen et al., 2020). For guidance, it is stated that QI should be pragmatic, measurable, and focused on health care priorities. Furthermore, key elements for establishing and preserving quality and safety are audits, guidelines, incident monitoring, morbidity and mortality meetings, and integration and communication with other sections of the patient care system (Hansen et al., 2020).

There are more than a hundred individual indicators covering all the domains of quality of care described in the literature. Forty-eight relevant ED QIs were identified from 170 candidate indicators raised from the literature through Delphi panel process by the comprehensive steering committee and expert panel in Canada, published in 2011. Among others, emergency department length of stay (ED LOS), assessment of pain, and analgesia in patients presenting with painful conditions have been suggested as key QIs for evaluation of ED performance (Schull et al., 2011), and these represent indicators developed by the Estonian Health Insurance Fund (OECD, 2022).

### **2.1.1. Emergency department length of stay**

Emergency department length of stay, defined as the time from patient's arrival to the ED till the departure time (Yiadom et al., 2020), is a general characteristic of ED performance, associated with crowding (Henneman et al., 2010). ED crowding is defined as a condition of having more ED patients than designated treatment places available (Yiadom et al., 2020). Crowding impacts directly patients' quality of care and outcomes (Hansen et al., 2020). Jones et al conducted a systematic review to identify relevant metrics for crowding assessment, and ED LOS was associated with worse care across all six quality domains. It is concluded that ED LOS at departmental level is a reliable indicator of overall system performance, and is suited as a quality measure to drive long-term system changes (Jones et al., 2021).

A four-hour target was introduced in 2000 by the National Health Service in England in order to relieve crowding epidemic in EDs. The initial goal was to discharge 100% of the patients within 4 hours after arrival to the ED (Royal College of Emergency Medicine, 2019), following different national targets from 4 to 8 hours (Ngo et al., 2018; Royal College of Surgeons in Ireland, 2012). After introduction, time-based QIs are criticized for potential unintended harmful effects. Jones et al conducted a systematic review on the implementation of these quality indicators. They concluded that ED LOS targeting time-

based QIs have a potential to reduce crowding, improve care and reduce mortality. On the other hand, authors emphasize that targets must be realistic in order to avoid potential rushing and harm to the patients (Jones et al., 2021).

It is demonstrated in the literature how prolonged ED LOS has a negative impact on the individual and system level, however, there are controversial data regarding ED LOS and in-hospital mortality. Lauque and colleagues conducted a systematic review and meta-analysis and found that ED LOS over 24 hours and less than three hours are associated with increased short-term mortality. Authors concluded their study stating how long stay in the ED should not be allowed, and special attention should be given to patients admitted after a short stay in the emergency department (Lauque et al., 2023). In case of the elderly, prolonged ED LOS is associated with the new onset of delirium (Bo et al., 2016). Furthermore, a prospective study was conducted by Emond and colleagues. They studied non-delirious community-dwelling older adults exposed to the ED LOS more than eight hours. Incidence of delirium was 12% and it increased hospital length of stay (HLOS) for four days compared to patients without an episode of delirium (Emond et al., 2018). At the emergency medicine framework level, extended ED LOS, resulting in department crowding, results also in delays for ambulance offload and affects emergency medical service systems' ability to provide timely response (Eckstein et al., 2004; Li et al., 2017).

There are many contributors to ED LOS. Driesen and co-authors analyzed extended ED LOS and found that the root-causes for ED stay >360 minutes were mostly organizational and not modifiable by the ED (Driesen et al., 2018). To conclude, ED LOS is an important and relevant process QI for ED care reflecting crowding. Crowding is potentially leading to inadequate care in ED, and with crowded EDs there is also a risk for compromising community access to the prehospital emergency services.

### **2.1.2. Assessment and management of pain**

Pain is defined as an unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage (IASP, 2020).

Pain is a frequent complaint in patients seeking emergency care (Chang et al., 2010). In an analysis of all patient visits over a 7-day period at a large urban emergency department, pain was present in 61% of the patients, and the abdomen was the most frequent location of pain (Cordell et al., 2002). Mura et al demonstrated in a prospective study that prevalence of pain in the ED was 70%, and abdominal pain is a frequent cause of non-traumatic pain (Mura et al., 2017).

Appropriate and adequate pain assessment is vital to effective pain management, and method for evaluation should be relevant to the individual patient. Pain is a subjective complaint, affected by biological, psychological, and behavioral factors. Nevertheless, there are many feasible and accepted tools for pain

assessment including verbal and visual scales (Hachimi-Idrissi et al., 2020). All emergency departments should ensure patients with moderate and severe pain receive adequate analgesia within 15 minutes of arrival (Beal et al., 2021).

Undertreated acute pain could lead to complications both, at individual and system level, including delirium in the elderly (Daoust et al., 2020), translation to chronic pain and behavioral disorders, leading to decreased ability to work and extended health costs (Sinatra et al., 2010; Cohen et al., 2021). Also, shorter time to analgesia was associated with significantly shorter ED LOS in patients reporting severe pain (Sokoloff et al., 2014). Therefore, rapid and effective treatment of acute pain is essential.

Inadequate relief of patients' suffering is stated as an ethical concern for the ED profession (Venkat et al., 2013). Many guidelines emphasize adequate analgesia including initial assessment of pain during the triage process, followed by timely and effective analgesia, and continuous reassessment (Schug et al., 2020; Hachimi-Idrissi et al., 2020; Beal et al., 2021). Oligoanalgesia in the ED was introduced in 1989 (Wilson et al., 1989). Decades later, concerns over insufficient treatment have arisen from the novel guidelines (Hachimi-Idrissi et al., 2020), and failure in pain management is frequently debated as one of the important limitations in emergency setting. In 2002 Todd and colleagues demonstrated in a multicenter study conducted in the United States and Canada how half of all patients with pain complaint, and only 63% of the patients reporting severe pain, received analgesia in the ED (Todd et al., 2022). In prospective study from a university hospital, pain was assessed in almost 80% of the ED patients but analgesia was provided only for 14% of individuals reporting severe pain (Dale et al., 2015). Audit from New Zealand concluded inadequate pain recording and insufficient analgesia in their emergency departments (PRiZED 1, 2017).

Many barriers to pain management have been described at individual and system level. Modified scores should be implemented to objectivize pain in vulnerable groups including the elderly and people affected by cognitive dysfunction (Hachimi-Idrissi et al., 2020), as these are the patients less likely to receive analgesia (Hwang et al., 2010; Hwang et al., 2014; Daoust et al., 2014). In addition, there have been concerns over analgesia masking important clinical findings in patients with abdominal pain. The results of a meta-analysis published in 2019 support the early pain relief in patients presenting with acute abdominal pain as opioid analgesic did not interfere with diagnostic accuracy of these patients (Gavriilidis et al., 2019).

Also, in the literature, ED crowding has shown to negatively affect time to analgesia. Pines et al conducted a retrospective study that higher waiting room number and total ED occupancy rate were independently associated with treatment delays and failure to treat (Pines et al., 2008). Mills et al also concluded in their prospective analysis that crowding is associated with delays in analgesic treatment from the time of triage in patients presenting with acute abdominal pain (Mills et al., 2009).

It has been stated that the first step towards improvement of pain management is to assess the actual care provided (Stang et al., 2014). Therefore, QIs assessing EM pain assessment and management are essential in order to relieve individuals' suffering and to avoid short- and long-term complications.

## **2.2. Non-ischemic myocardial injury in Emergency Medicine**

In the latest definition of myocardial infarction, the new concept of myocardial injury is established. The cornerstone for diagnosing myocardial injury is an elevated cardiac biomarker, preferably cardiac troponins, measured with high-sensitivity assays. Myocardial injury in the context of ischemia is a myocardial infarction, divided into various subtypes. Myocardial injury in the settings of non-ischemic events is defined as acute or chronic myocardial injury, based on the presence or absence of the dynamic pattern of biomarker values (Thygesen et al., 2018).

There are many contributors for non-ischemic myocardial injury documented in the literature, for example, tachycardias, hypotension, sepsis, renal failure, cardiac contusion, pulmonary embolism, perimyocarditis, and endocarditis (Age-wall et al., 2011).

In addition to biomarkers, other bedside diagnostic methods regarding cardiac function are performed in the ED – electrocardiogram (ECG) and bedside transthoracic echocardiography (TTE), both having minimal harm to the patients. Firstly, ECG is a feasible and fundamental test for initial diagnosis of ischemic myocardial injury (Ibanetz et al., 2017; Thygesen et al., 2018). In the settings of non-ischemic myocardial injury, ECG could provide information for the underlying or contributing cause, and suggest mechanical cardiac trauma (Clancy et al., 2012). Secondly, bedside TTE is a reliable method for detecting pericardial effusion, contractility, and valve dysfunction of the heart but probably not a feasible procedure to be performed for all patients in the busy ED. Transthoracic echocardiography should be performed in patients with cardiovascular emergencies, including undifferentiated shock and chest trauma (Nescovite et al., 2013). In trauma patients suspected with blunt cardiac injury (BCI), TTE is not recommended as a screening tool but should be reserved to patients with clinical signs of significant injury including arrhythmias and haemodynamic instability (Clancy et al., 2012).

### **2.2.1. Cardiac troponins as a markers of myocardial injury**

#### **2.2.1.1. Troponins and cardiac troponins**

Troponin (Tn) complex is located on the contractile apparatus of the striated muscle cells. The complex composes of three subunits – troponin T, troponin I and troponin C. Troponin T and troponin I are encoded by individual genes including cardiac, and two types of skeletal troponins. Various isoforms have

unique amino acid sequences discriminating cardiac isomers from the troponins expressed in the skeletal muscles making cardiac troponins highly sensitive and specific biomarkers for myocardial cell damage. Troponin C has identical amino acid sequences in all muscle types (Gaze et al., 2008).

Cardiac troponin T (cTnT) and cardiac troponin I (cTnI) are regulatory proteins in the myocardium mediating interaction of actin and myosin. Troponins are primarily located on the thin filament of myosin, but also a small amount of troponins (6–8% for cTnT and 2–8% for cTnI) exist unbound in the cytoplasm (Collison et al., 2001).

It is observed in the experimental animal model that following ischemia and necrosis of myocardial cells, loss of troponins in cardiac cells is detected as early as 30 minutes preceding histological evidence of necrosis (Fishbein et al., 2002). In another former paper, the half-life of cTnT in the circulation was described to be 120 minutes (Katus et al., 1991). A more recent animal study by Weil and colleagues demonstrated elevated cTnI 60 minutes after a brief episode of ischemia without evidence of necrosis, explained by the cell death via apoptosis (Weil et al., 2017). In addition to ischemia induced myocardial injury, other potential mechanisms of troponin release are described in experimental animal studies, including release of troponin after increases in left ventricular preload, and myocardial stretch without necrosis (Feng et al., 2001; Hessel et al., 2008; Weil et al., 2018).

#### 2.2.1.2. Cardiac troponins assays

Troponin assays were introduced into clinical practice in 1987. First generation tests detected only marked elevations of biomarkers in the blood serum and cardiac troponins were applied exclusively for diagnosing ischemic myocardial injury. Over the decades, novel and more sensitive assays with significantly decreased limits of detection have been developed and implemented into the clinical practice. The sensitivity of the assays has been increased to the extent that it allows quantifying troponin value within the majority of the healthy population. Criteria for high-sensitivity assays include, firstly, having a coefficient of variance of <10% at the 99th percentile value in the population of interest, and secondly, detecting concentrations below the 99th percentile above the assay's limit of detection for >50% of healthy individuals (Apple et al., 2012; Apple et al., 2012).

Multiple commercial high sensitivity assays, using different antibodies directed against various epitopes of troponins are available (Apple et al., 2012), and age-, gender- and assay-specific cut-offs are under lively debate (Kimenai et al., 2017; Apple et al., 2020; Giannitsis et al., 2020). In the aspect of false positive results, there is a scarce risk for non-cardiac cause of elevated cTnT in patients with myopathies (Jaffe et al., 2011; Schmid et al., 2018), and other pre- and analytical issues including heterophilic antibodies, are noted in the literature (Lippi et al., 2013).

### 2.2.1.3. High-sensitivity cardiac troponins and diagnosis of myocardial injury

According to current knowledge and guidelines cTn value exceeding the 99th upper reference limit is essential for diagnosing myocardial injury but not for detailing the exact underlying mechanism of the cell damage (Thygesen et al., 2018). Cardiac troponins are preferred biomarkers for diagnosing acute myocardial infarction but importantly, the term acute myocardial infarction should be used only when there is acute myocardial injury with clinical evidence (symptoms of ischemia, ECG changes, and imaging evidence of new loss of viable myocardium) of myocardial ischemia. Different subtypes of acute myocardial infarction include type 1, 2, 3, 4 and 5. There are detailed guidelines for the diagnosis (Thygesen et al., 2018), and management of acute coronary syndrome, including AMI (Byrne et al., 2023), but there are no clear guidelines how to manage patients with elevated troponins without coronary disease. In addition, type 2 myocardial infarction and non-ischemic myocardial injury have overlapping causes and it could be challenging to discriminate specific types of myocardial injury in patients with acutely elevated troponin. Gard and colleagues validated the diagnosis of type 2 AMI classification in the Swedish registry for the myocardial infarction and demonstrated disparities in distinguishing different types of AMI, and also myocardial infarction from myocardial injury (Gard et al., 2019).

After the introduction of high-sensitive cardiac troponin (hs-cTn) assays, the occurrence of myocardial injury has been frequently described, and non-ischemic myocardial injury is the leading cause for elevated hs-cTn in different populations of ED patients. The implementation of high-sensitivity assays has led to a disproportionate increase in diagnosis of type 2 myocardial infarction and myocardial injury (Chapmann et al., 2020). Shah and co-authors demonstrated in a prospective study how elevated hs-cTn reflects dominantly myocardial injury if measured in unselected ED patients (Shah et al., 2017). Contrarily to detecting myocardial injury, cTn also provides a reliable rule-out strategy for myocardial damage, allowing the implementation of early rule-in and rule-out strategies for acute ischemic myocardial injury in patients presenting with chest pain (Westwood et al., 2021), and with major trauma (Clancy et al., 2012).

**Table 2.** Aspects of different causes for elevated cTn (Agewall et al., 2011; Thygesen et al., 2018)

Elevated cTn with clinical signs of ischemia*	Elevated cTn without clinical signs of ischemia
<b>Acute myocardial infarction</b>	<b>Non-ischemic myocardial injury</b>
Type 1 myocardial infarction Atherosclerotic CAD with plaque rupture/erosion and thrombous	Cardiac causes for elevated cTn <ul style="list-style-type: none"> <li>– Cardiac contusion</li> <li>– Tachycardias</li> <li>– Heart failure</li> <li>– Myocarditis</li> <li>– Takotsubo syndrome</li> </ul>
Type 2 myocardial infarction Mismatch between oxygen supply and demand with or without underlying stable CAD	Systemic conditions for elevated cTn <ul style="list-style-type: none"> <li>– Sepsis</li> <li>– Critically ill patients</li> <li>– Chronic kidney disease</li> <li>– Stroke</li> <li>– Strenuous exercise</li> </ul>
Type 3 myocardial infarction Sudden cardiac death	
Type 4 myocardial infarction Associated with coronary intervention	
Type 5 myocardial infarction Associated with coronary artery bypass grafting	

\* Clinical signs of ischemia including chest discomfort, dyspnea, fatigue, nausea and vomiting, ECG changes, and imaging evidence of new loss of viable myocardium.  
*cTn* – cardiac troponin; *CAD* – coronary artery disease; *ECG* – electrocardiogram.

#### 2.2.1.4. Prognostic value of a myocardial injury

In addition to being a diagnostic marker for myocardial injury, troponins carry a significant prognostic value (DeFilippis et al., 2019). De Lemos and colleagues demonstrated in the population-based cohort study, enrolling patients aged 30–65 years, how high-sensitive assays enormously extend the prevalence of detectable troponins and allow to identify individuals with increased cardiovascular risk compared to older generation assays (De Lamos, et al., 2010). The prognostic value of detectable hs-cTnT for the new onset of heart failure and cardiovascular mortality is also shown in ambulatory community-dwelling older adults without previously known heart failure (deFilippi et al., 2010).

Chapman et al identified all consecutive in-hospital patients with elevated hs-cTn and found that patients diagnosed with myocardial injury had a higher all-cause mortality and higher risk for heart failure hospitalization compared to patients with type 2 myocardial infarction, and major adverse cardiovascular event (MACE) occurred in one third of the patients with elevated biomarker (Chapmann et al., 2018). In another study by Chapmann, a large cohort of patients with suspected acute coronary syndrome (ACS) were studied. Majority of the patients were classified as having acute or chronic myocardial injury,

patients with acute myocardial injury were at highest risk of non-cardiovascular death compared to acute myocardial infarction and chronic myocardial injury (Chapmann et al., 2020).

Kadjesö et al studied all ED patients with elevated hs-cTnT during almost four years. Most frequent cause for myocardial injury was chronic myocardial injury, following acute injury, type 1 myocardial infarction, and type 2 myocardial infarction, respectively. Aetiologies of acute myocardial injury were mainly multifactorial, hypoxia, and tachycardia. In the prognostic aspect, acute and chronic myocardial injury had similar and very high risks of death compared with type 2 myocardial infarction (Kadjesö et al., 2019).

In surgical patients, a large international study VISION – Vascular Events In Noncardiac Surgery Patients Cohort Evaluation was conducted. Authors concluded that measuring hs-cTn is essential in detecting perioperative ischemic myocardial injury. Patients with elevated postoperative hs-cTn had significantly higher 30-day mortality compared to the normal troponin group. Also, non-ischemic troponin elevations were observed in 14% of the patients with higher 30-day mortality compared to the normal troponin group (Devereaux et al., 2017).

In the literature, it is recommended to screen patients with blunt chest trauma for cardiac injury but the advantage of biomarker, including hs-cTn assessment for establishing the diagnosis of BCI is not fully clear (Clancy et al., 2012; ATLS<sup>®</sup>, 2018).

### **2.2.2. Occult myocardial injury in patients with acute abdominal pain**

Abdominal pain is the most frequent cause for ED visit in adult patients (Bhuiya et al., 2010; Moore et al., 2017). In the United States, approximately 11 percent of non-injury related ED visits for adult patients are due to abdominal pain, while up to 20 percent of these patients are triaged as immediate or emergent. Seventeen percent of visits for abdominal pain result in a serious diagnosis, and around 20% of these visits result in admission, transfer, or death (Bhuiya et al., 2010). Among others, upper abdominal pain and nausea or vomiting are listed as common symptoms associated with myocardial ischemia (Gulati et al., 2021). Detection of acute ischemic myocardial injury with dynamic pattern of cardiac biomarker and with ECG, and additional imagining studies for example TTE, if indicated, is essential to diagnose AMI in patients presenting without classical symptoms of myocardial ischemia. In addition, immediate and urgent patients with acute abdominal pain suffer potentially from hypotension, anaemia, sepsis, tachycardia, renal insufficiency, all contributing to myocardial injury (Madjid et al., 2007; Lindner et al., 2014; Wilhelm et al., 2014; Pfortmueller et al., 2013; Liem et al., 2020). Also, older patients with concomitant coronary disease presenting with an acute abdominal condition coupled with a significant physiological and cardiovascular burden may result in an unexpected

myocardial injury. Nevertheless, literature documenting occult myocardial injury (OMI) in the setting of acute abdominal pain remains scarce.

### **2.2.3. Blunt cardiac injury in chest trauma**

Injuries are a major cause for mortality and morbidity worldwide (WHO, 2021). In Estonia, injuries are the third leading cause of death. Over the decades, the mortality rate has declined, but it is still one of the highest in the European Union. Also, injuries contribute to a high burden of morbidity and long-term disability (EuroSafe, 2016). In a population-based trauma fatality study, it is shown that injuries affect mostly younger people, blunt injuries accounted for 75% of trauma related deaths, and almost half of the fatalities suffered severe chest injury (Saar et al., 2017).

Blunt cardiac injury may result in a variety of lesions and clinical presentations ranging from silent injury to death. Different lesions include dysrhythmias, myocardial contusion, pericardial rupture, septal injuries, valvular and chorda tendinea lesions, myocardial rupture, and commotio cordis (Huis In 't Veld et al., 2018). Significant injury to the heart is often fatal at site. In a study by Saar et al, 10% of the fatalities were related to mechanical cardiac injury (Saar et al., 2017). If not instantly fatal, BCI clinical spectrum varies from asymptomatic ECG changes to life-threatening cardiac complications. It has been noted that severe complications including arrhythmias requiring treatment, hypotension, cardiogenic shock or hemopericardium requiring pericardiocentesis occur most frequently within 24 hours of admission (Salim et al., 2001). In a recent meta-analysis by Kyriazidis and co-authors, the weighted mean mortality rate for patients suffering BCI was almost 8% (Kyriazidis et al., 2023).

Although the clinical relevance of BCI is recognized the diagnostic criteria for BCI are not well defined (Sybrandy et al., 2003; Kyriazidis et al., 2023) leading to broad disparity in the reported incidence of BCI in the literature (Kyriazidis et al., 2023). Also, it is concerned that the results of the high-sensitivity assays in trauma patients will cause more questions than answers when slightly elevated levels of troponins are detected (Schnüriger et al., 2011). The Eastern Association for the Surgery of Trauma (EAST) guidelines recommend admission ECG and cTnI screening in all patients with suspected BCI combined with echocardiography, computed tomography or magnetic resonance imaging, on demand. In hemodynamically stable patients, negative cTn and normal ECG are sufficient to rule out myocardial injury and these patients could be discharged if there are no other indications for inpatient care (Clancy et al., 2012). According to international trauma management guidelines, true diagnosis of BCI could be established only in the direct inspection of injured myocardium, and troponins do not provide additional information to the ECG (ATLS<sup>®</sup>, 2018). However, the EAST and Advanced Trauma Life Support (ATLS<sup>®</sup>) recommendations are exclusively based on studies utilizing conventional cardiac troponin assays.

### **2.3. Summary of the literature review**

Routine monitoring and analysis of quality of care are emphasized by the international community of emergency medicine experts. There are many evidence-based indicators covering different domains of quality. Emergency department length of stay, pain assessment and management are relevant indicators reflecting performance of the system developed for emergency patients and indicate patient centered care. Studies investigating QIs in the cohort of acute abdominal pain is needed.

Non-ischemic myocardial injury is a prognostically relevant event in different populations of ED patients. In patients presenting with acute abdominal pain or major trauma, cardiac injury could be obscured by the other symptoms or injuries. Biomarkers are feasible to obtain, and high specificity of cardiac troponins detecting myocardial injury is well endorsed.

Literature regarding myocardial injury and high-sensitivity cardiac troponins in patients presenting with acute abdominal pain or chest trauma, is scarce. In addition, guidance for further diagnostic, therapeutic and secondary prevention strategies in patients identified with non-ischemic myocardial injury is controversial.

Detecting myocardial injury in patients with acute illness may provide an opportunity to reduce the risk of major cardiovascular events through closer monitoring and diagnostic tests if indicated.

### **3. AIMS OF THE RESEARCH**

The extended purpose of this research is to promote analysis of emergency medicine care performance in Estonia, focusing on the management and prognostic aspects of surgical patients. The research was aimed analyzing the quality of emergency care in patients admitted with acute abdominal pain, and clarifying if elevated serum cardiac troponin T has prognostic value in patients with acute abdominal pain as well as in the setting of thoracic trauma.

The specific aims were the following:

1. To evaluate three prominent quality indicators – ED LOS, pain assessment, and analgesia in patients reporting severe pain – in adult patients requiring immediate or urgent care due to acute abdominal pain.
2. To describe, in which patients with acute abdominal pain as main reason for immediate and urgent referral to the emergency department myocardial injury is suspected. To analyze whether an elevated troponin level is associated with a worse prognosis in this group of patients.
3. To evaluate the predictive value of elevated high-sensitivity cardiac troponin T levels in patients with severe chest injuries after major blunt trauma.

## 4. MATERIALS AND METHODS

This dissertation is based on three original studies including emergency medicine patients admitted with acute abdominal pain, and patients suffering from major blunt trauma. The main characteristics of the studies are depicted in Table 3.

**Table 3.** Main characteristics of the studies included in this dissertation

	<b>Study cohort, ED</b>	<b>Study aim</b>	<b>Study design</b>	<b>Period</b>
<b>Study I QI in EM</b>	Urgent adult patients with acute abdominal pain (n=1000) *	To evaluate patient-centered, and prognostically relevant QIs for quality improvement initiatives	Retrospective	2018
<b>Study II OMI</b>		To evaluate the incidence and prognostic value of OMI in surgical patients	Retrospective	2018
<b>Study III BCI</b>	Adult patients with major blunt chest trauma, ISS >15, thorax AIS $\geq$ 3 (n=147)	To evaluate associations between hs-cTnT, myocardial injury and outcomes in trauma patients	Retrospective	2015–2017

\* The same cohort of ED patients was investigated for I and II study.

*ED – emergency department; QI – quality indicators; EM – emergency medicine; OMI – occult myocardial injury; BCI – blunt cardiac injury; ISS – Injury Severity Score; AIS – Abbreviated Injury Scale; hs-cTnT – high-sensitivity cardiac troponin T.*

### 4.1. Ethics

Studies I and II were approved by the Research Ethics Committee of University of Tartu (approval no 271/T-18).

Study III patients were identified from the electronic major trauma database, approved by the Research Ethics Committee of University of Tartu – Major Trauma Epidemiology of Estonia (approval no 247/T-1). Investigators associated with the current study were added to the approval.

## **4.2. Patients and study design**

### **4.2.1. Urgent adult patients with acute abdominal pain (Study I and II)**

Analysis of quality indicators and occult myocardial injury were performed on the same cohort of the ED patients. One thousand consecutive patients, treated at two major referral hospitals in Estonia – 500 patients from North Estonia Medical Centre Foundation, and 500 patients from Tartu University Hospital between 01. January 2018 and 07. March 2018 were retrospectively identified by screening of all ED admissions during the study period at both institutions.

Study inclusion criteria were:

- Age  $\geq 30$  years
- Abdominal pain as the main chief complaint on admission
- Triage category yellow, orange, or red

Data from revisit in 72 h, if present, were excluded from the study.

Before the study, troponins were included only in a chest pain laboratory orders panel. For the purpose of the study II, recommendation for extended use of hs-cTnT measurements was implemented. A specific new electronic set of laboratory orders was created, and ED personnel were advocated to apply it in patients admitted with a chief complaint of abdominal pain at both institutions. The ultimate set of blood samples collected from the patients, including hs-cTnT testing, remained at the discretion of the attending physician.

### **4.2.2. Adult patients with major blunt chest trauma (Study III)**

This is a retrospective study, conducted between 01. January 2015 and 01. July 2017 at two major referral hospitals in Estonia – North Estonia Medical Centre Foundation and Tartu University Hospital.

One hundred and forty-seven adult patients with concomitant severe chest trauma were identified from the electronic major trauma database. Both, admissions from the scene of injury and interhospital transfers were included.

Inclusion criteria were:

- Age  $\geq 18$  years
- Injury Severity Score (ISS)  $>15$
- Chest Abbreviated Injury Scale (AIS)  $\geq 3$

Patients with penetrating trauma, patients deceased in ED, and cases with insufficient medical data were excluded. For confounder analysis, a respective group of all consecutive major trauma admissions (ISS  $>15$ ) without severe chest injury (chest AIS  $<3$ ) was identified.

## 4.3. Data collection

### 4.3.1. Quality Indicators in Emergency Medicine (Study I)

Data were collected from the electronic health care databases, through chart review and from the National Causes of Death Database.

#### *Admission and outcome parameters*

Collected data included admission details (age, sex, triage category), baseline characteristics (vital signs at admission), time intervals including ED LOS, time to analgesia, time to surgeon consultation, and final diagnosis at hospital discharge.

QIs analyzed and their outcomes are depicted in Table 4.

**Table 4.** Quality indicators and their outcomes in patients presenting with acute abdominal pain

QI	Outcomes
ED LOS $\geq 360$ min vs. $< 360$ min	<ul style="list-style-type: none"> <li>- 30-day all-cause mortality</li> <li>- One-year mortality</li> <li>- Time to surgical intervention</li> <li>- Time to analgesia</li> <li>- Time to antibiotic administration in patients with sepsis</li> <li>- HLOS</li> </ul>
Documented pain assessment	<ul style="list-style-type: none"> <li>- Pain intensity documented vs. not documented</li> </ul>
Analgesia in patients reporting severe pain	<ul style="list-style-type: none"> <li>- Analgesic drug administered vs. not administered in patients reporting severe pain</li> <li>- Time to analgesia in patients reporting severe pain</li> </ul>

*ED LOS – emergency department length of stay; HLOS – hospital length of stay; QI – quality indicator.*

#### *Definitions*

Emergency department length of stay – time period (presented in minutes) from arrival time to the ED to departure time as documented in the medical chart.

Triage – the triage category is applied to all patients according to their vital signs and complaints on admission to the ED. A five-level triage system, adapted from the Medical Emergency Triage and Treatment System (Widgren et al., 2011), is used at study hospitals (Table 5 and Table 6).

Pain intensity – pain intensity was documented on a 10-point scale, 0 defined as no pain and 10 is the worst pain. Severe pain – pain scale  $\geq 7$  points (Beal et al., 2021).

**Table 5.** Triage categories according to patient's vital signs

<b>Clinical parameter</b>	<b>Red (immediate)</b>	<b>Orange (very urgent)</b>	<b>Yellow (urgent)</b>	<b>Green (nonurgent)</b>
Time to assessment and treatment	Immediate	15 minutes	30 minutes	180 minutes
Airways	Airway obstruction, not breathing			
Respiratory rate (breaths/minute)	>30 or <9	>25 or	<25 or	9–25 and
SpO <sub>2</sub> (%)	<90 with oxygen supply	<90 on room air	91–95 on room air	>95 on room air
Pulse rate (beats/minute)	>120 or <40 and/or	>120 or <40 and	>110 or <50 and >90	51–109 and >90
Systolic BP (mmHg)	<90	>90		
Level of conscious	Unconscious or epileptic status	Somnolence	Disorientated	Alert
Body temperature (° C)		>41 or <35	38.5–41	35.1–38.4

*SpO<sub>2</sub>* – hemoglobin oxygen saturation; *BP* – blood pressure.

**Table 6.** Triage categories according to emergency symptoms and signs, abdominal pain

Red (immediate)	Orange (very urgent)	Yellow (urgent)	Green (nonurgent)
Pale, cold sweat, disorientated or weakness	Sudden strong pain radiating to the back or legs, age >50 years	Right upper quadrant pain with anorexia, nausea and vomiting or fever	Intermittent pain
Active labor (second stage)	Abdominal pain with signs of dehydration	Rapidly intensifying pain	Very mild pain without other signs and symptoms
	Pain with syncope	Inability to pass gas	Abdominal edema
	Severe pain lasting over one hour	Hematochezia	Flatulence
	Peritonitis	Under two years old child with strong intermittent pain	Dysuria
	Hematemesis	Child with melena	Pain related with meals
	Melena	Plant/chemical or drug intoxication	Recurrent ascites
	Child with rapidly progressive pain	Pregnant with abdominal pain	Recurrent vomiting
	Child with abdominal pain and rash	Patient with coagulation disorder	
	Child with unknown substance ingestion	Recent surgical intervention	
	Massive vaginal bleeding	Macrohematuria	
	Vaginal bleeding in possible pregnancy	Recent trauma	
	Penetrating abdominal trauma	Urinary retention	
	Epigastric pain possibly acute coronary syndrome origin		
	Active labor (first stage, contractions < five minutes)		

### **4.3.2. Occult myocardial injury in patients with acute abdominal pain (Study II)**

Medical data were collected from the electronic health care databases, and through chart review. Mortality data were retrieved from the National Causes of Death Database, and diagnosis of AMI was collected from the Estonian Myocardial Infarction Registry.

#### *Admission and outcome parameters*

Collected data included baseline characteristics (age, sex, triage category, previous medical history), vital signs, and laboratory data at admission, hospitalization details, and final diagnosis at hospital discharge.

#### *Primary study outcome*

- Thirty-day, six-month, and one-year mortality

#### *Secondary study outcomes*

- Hospital length of stay
- Diagnosis of acute myocardial infarction during the observation period – from ED visit to 01. January 2020.

#### *Definitions*

Occult myocardial injury – serum hs-cTnT level exceeding the 99<sup>th</sup> percentile upper reference limit (>14 ng/L) (Thygesen et al., 2018).

Sepsis – suspected or confirmed infection with the presence of two or more systemic inflammatory response syndrome criteria and laboratory and/or clinical signs of the end organ dysfunction (Singer et al., 2016; Song et al., 2018).

### **4.3.3. Blunt cardiac injury in chest trauma (Study III)**

Data were collected from the electronic trauma database, through chart review, and from the National Causes of Death Database for mortality.

#### *Admission and outcome parameters*

Data collection included demographics, previous cardiovascular disease history, Charlson Comorbidity Index (CCI), vital signs and laboratory markers on admission, ISS and AIS score. Diagnostics and treatment procedures performed within 72 h from admission including ECG, ultrasound, computed tomography, TTE/transoesophageal echocardiogram (TEE), vasopressors, inotropes and anti-arrhythmic drug use, synchronized electrical cardioversions, blood components transfusion, and pericardiocentesis were accrued.

The AIS© version 2005 Update 2008 was utilized to calculate ISS (Gennarelli et al., 2008).

### *Primary study outcome*

- In-hospital and one-year mortality

### *Secondary study outcomes*

- Intensive care unit (ICU) LOS
- Duration of mechanical ventilation (days)
- Antiarrhythmic intervention
- Vasopressor and inotropic agent use
- Glasgow Outcome Scale (GOS) at hospital discharge

### *Definitions*

Blunt cardiac injury – serum hs-cTnT level >14 ng/L combined with abnormal ECG or echocardiography findings.

Clinically significant BCI – BCI and one of the following interventions required: vasoactive, inotropic, antiarrhythmic agent used, pericardiocentesis or surgical management of cardiac injury.

Abnormal ECG findings – arrhythmias (other than sinus rhythm), a pattern of bundle branch block, a prolonged QT-interval, Q-wave formation, ST-segment depression or elevation more than 1 mm and a flat or inverted T-waves or both, in two or more leads (Salim et al., 2001; Bertinchant et al., 2000; Edouard et al., 2004).

Abnormal echocardiography findings – pericardial effusion, regional wall motion abnormality, acute valvular dysfunction, right or left ventricle dilatation, ventricular septal rupture, and intracardiac thrombus (Sybrandy et al., 2003).

Antiarrhythmic intervention – medical or electrical cardioversion.

## **4.4. Statistical methods**

All statistical analyses were performed with Statistica version 13 (TIBCO Software Inc., CA, USA). For normally distributed values, means and standard deviations (SD) are reported. For not normally distributed data, medians and interquartile range (IQR) are used. Comparisons between groups were performed using the Student's t-test (two-sided) in normally distributed variables and Mann–Whitney U-test in not normally distributed variables, respectively. For categorical data, Pearson ChiSquare and Fisher's exact tests were deployed. P-values were calculated as double the exact one-tailed probability. For all statistical tests, a p value <0.05 was considered significant.

Kaplan-Meier curve and log-rank test were used to compare survival of patients with OMI and BCI. The difference between two Kaplan–Meier survival curves was calculated using the log-rank test.

#### **4.4.1. Quality Indicators in Emergency Medicine (Study I)**

Univariate and multivariable analyses were performed to determine independent risk factors for QI performance.

For ED LOS the following factors were tested in univariate analysis: sex (male vs. female), age ( $\geq 65$  years vs.  $< 65$  years), triage category (red and orange vs. yellow), mean arterial blood pressure (MAP) ( $< 65$  mmHg vs.  $\geq 65$  mmHg), sepsis in ED (yes vs. no), Glasgow Coma Scale (GCS) score ( $< 15$  vs.  $\geq 15$ ), blood lactate level ( $\geq 2$  mmol/L vs.  $< 2$  mmol/L), estimated glomerular filtration rate (eGFR) ( $< 30$  mL/min/1.73m<sup>2</sup> vs.  $\geq 30$  mL/min/1.73 m<sup>2</sup>), surgeon consultation (yes vs. no), and surgical intervention (yes vs. no).

ED LOS  $\geq 360$  minutes was adjusted to sex (male vs. female), age ( $\geq 65$  years vs.  $< 65$  years) and triage category (red and orange vs. yellow) in univariate analysis determining risk factors for mortality.

Variables included in univariate analysis of pain assessment and analgesia were sex (male vs. female), age ( $\geq 65$  years vs.  $< 65$  years), triage category (red and orange vs. yellow), MAP ( $< 65$  mmHg vs.  $\geq 65$  mmHg), sepsis in ED (yes vs. no), GCS score ( $< 15$  vs.  $\geq 15$ ), blood lactate level ( $\geq 2$  mmol/L vs.  $< 2$  mmol/L), eGFR ( $< 30$  mL/min/1.73m<sup>2</sup> vs.  $\geq 30$  mL/min/1.73m<sup>2</sup>), surgeon consultation (yes vs. no), surgical intervention (yes vs. no), and total time spent in ED ( $\geq 360$  min vs.  $< 360$  min).

Sex and variables with significance level  $p < 0.2$  in univariate analysis were included into multivariable analysis. The best performing model, also suitable for practical use, and without incomplete data was identified and reported.

#### **4.4.2. Occult myocardial injury in patients with acute abdominal pain (Study II)**

Univariate and multivariable analyses were performed to determine independent risk factors for mortality. The univariate analysis included sex (male vs. female), age ( $\geq 65$  years vs.  $< 65$  years), presence of previous cardiovascular disease (CVD) history (yes vs. no), triage category (red vs. yellow and orange), sepsis in ED (yes vs. no), MAP ( $< 65$  mmHg vs.  $\geq 65$  mmHg), hemoglobin (Hgb) level (continuous variable), hs-cTnT ( $> 14$  ng/L vs.  $\leq 14$  ng/L), eGFR ( $< 30$  mL/min/1.73m<sup>2</sup> vs.  $30-59$  mL/min/1.73m<sup>2</sup> and  $\geq 60$  mL/min/1.73m<sup>2</sup>). All variables different at a  $p < 0.2$  level in the univariate analysis were subjected to multivariable analysis.

#### **4.4.3. Blunt cardiac injury in chest trauma (Study III)**

Univariate and multivariable analyses were performed to find independent risk factors for one-year mortality. Sex (male vs. female), age ( $< 60$  years vs.  $\geq 60$  years), previous CVD history (yes vs. no), CCI ( $< 2$  vs.  $\geq 2$ ), arterial blood lactate level ( $< 2$  mmol/L vs.  $\geq 2$  mmol/L), troponin level ( $\leq 14$  ng/L vs.  $> 14$  ng/L), ISS ( $< 25$  vs.  $\geq 25$ ), GCS ( $< 8$  vs.  $\geq 8$ ), MAP and Hgb level (continuous variable) were included in the univariate analysis. All variables different at a  $p < 0.2$  level in the univariate analysis were subjected to multivariable analysis.

## 5. RESULTS

### 5.1. Quality Indicators in Emergency Medicine

One thousand consecutive patients were identified for the QI study. Readmissions to ED within 72 h were excluded (n = 35), yielding 965 patients for the analysis. There were 464 (48%) female and 501 (52%) male patients. Mean age was 61.8 (17.1) years. Seventeen percent (167/965) were triaged as immediate or very urgent. Almost half (445/965) were admitted to the hospital, and surgical interventions, including operation, endoscopy, angiography or nephrostomy/epicystostomy, were required in 23.9% (231/965) of patients. Final diagnoses at hospital discharge are depicted in Table 7.

**Table 7.** Final diagnoses at hospital discharge of the study I and study II patients

<b>Major disease category</b>	<b>ICD-10 code</b>	<b>n (%)</b>
<b>Diseases of the digestive system</b>	K00–K93	364 (37.7)
Diseases of oesophagus, stomach and duodenum	K20–K31	76 (7.9)
Disorders of gallbladder and biliary tract	K80–K83	47 (4.9)
Diseases of pancreas	K85–K86	44 (4.6)
Diseases of appendix	K35–K38	31 (3.2)
Ileus	K56	23 (2.4)
Diseases of liver	K70–K77	20 (2.1)
Gastrointestinal haemorrhage	K92	19 (2.0)
Vascular disorder of intestine	K55	3 (0.3)
<b>Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified</b>	R00–R99	195 (20.2)
Abdominal and pelvic pain	R10	128 (13.3)
<b>Diseases of the genitourinary system</b>	N00–N99	153 (15.9)
<b>Neoplasms</b>	C00–D49	112 (11.6)
<b>Certain infectious and parasitic diseases</b>	A00–B99	41 (4.2)
<b>Diseases of the circulatory system</b>	I00–I99	33 (3.4)
<b>Diseases of the respiratory system</b>	J00–J99	10 (1)
<b>Injury, poisoning and certain other consequences of external causes</b>	S00–T98	26 (2.7)
<b>Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism</b>	D50–D89	11 (1.1)
<b>Other</b>		20 (2.1)

#### 5.1.1. Emergency department length of stay

Among 965 patients analyzed, 265 (27.5%) had ED LOS exceeding 360 minutes. These patients were significantly older (median age 64.8 years vs. 60.7 years,  $p < 0.001$ , respectively), and were more often admitted to the hospital –

54.0% (143/265) compared to 43.2% (302/700),  $p = 0.003$ . Patients with ED LOS  $\geq 360$  min had significantly higher one-year mortality, longer time to surgical intervention, and longer time to analgesia when compared to patients with shorter stay (Table 8).

**Table 8.** Comparison of patients with different length of stay in the emergency department

	<b>ED LOS &lt;360 min (n = 700)</b>	<b>ED LOS <math>\geq 360</math> min (n = 265)</b>	<b>p-value</b>
30-day mortality, n (%)	37 (5.3)	22 (8.3)	0.09
One-year mortality, n (%)	117 (16.9)	61 (23.2)	<b>0.02</b>
Time to surgical intervention, min (IQR)	787 (348–1783) (n = 171)	1636 (678–3018) (n = 60)	<b>&lt;0.001</b>
Time to antibiotic <180 min in patients with sepsis, n (%)	14 (36.8)	5 (26.3)	0.627
Time to analgesia in patients with severe pain, min (IQR)	55 (30–78) (n = 52)	91 (65–173) (n = 25)	<b>0.003</b>
HLOS, days (IQR)	5 (3–9) (n = 302)	5 (3–11) (n = 143)	0.28

*ED – emergency department; LOS – length of stay; HLOS – hospital length of stay.*

Univariate and multivariable analyses identified age  $\geq 65$  years and need for surgical consultation as independent risk factors for prolonged stay in ED (OR 1.48, 95% CI 1.12–1.97  $p = 0.008$  for age  $\geq 65$  vs.  $<65$  years, and OR 1.34, 95% CI 1.01–1.79,  $p = 0.043$  for need for surgeon consultation vs. no surgeon consultation, respectively). Adjusted ED LOS  $\geq 360$  min was found to be an independent risk factor for 30-day mortality (Table 9).

**Table 9.** Multivariate logistic regression model of independent risk factors for 30-day mortality

		<b>Univariate analysis</b>			<b>Multivariable analysis</b>		
		HR	95% CI	p-value	HR	95% CI	p-value
Sex	Male vs. Female	1.01	0.56–0.79	0.986	1.00	0.56–1.79	0.995
Age (years)	$\geq 65$ vs. $<65$	1.54	0.86–2.75	0.149	1.42	0.78–2.56	0.248
Triage category	Red and Orange vs. Yellow	3.17	1.74–5.76	<b>&lt;0.001</b>	3.13	1.71–5.70	<b>&lt;0.001</b>
ED LOS (min)	$\geq 360$ vs. $<360$	1.91	1.06–3.43	0.031	1.89	1.71–3.40	<b>0.034</b>

*ED LOS – emergency department length of stay.*

### 5.1.2. Assessment and management of pain

There were 965 patients in the pain assessment group, 106 patients reported severe pain, and were enrolled in the analgesia group.

Pain intensity was recorded in 55% of patients in the entire study cohort (533/965). Failure of compliance with pain documentation occurred significantly more in older patients (median age 65.6 years vs. 58.8 years,  $p < 0.001$ ), and among subjects with higher triage category (proportion of red and orange patients 22.5% in the pain not documented vs. 13.1% in the pain documented group,  $p < 0.001$ ). Patients with non-compliant pain documentation had shorter ED LOS (235 min vs. 266 min,  $p < 0.001$ ), higher rate of hospital admission (54.4% vs. 39.4%,  $p < 0.001$ ), and higher rate of surgical intervention (27% vs. 21%,  $p = 0.04$ ). Independent risk factors for failure of pain documentation included age  $\geq 65$  years, and red and orange triage categories. Emergency department LOS  $\geq 360$  min was associated with reduced risk of non-compliance with pain documentation in the ED (Table 10).

Overall, 106 patients reported severe pain, 78 of them (74%) received analgesia during the ED visit. The median time from admission to analgesia was 64 min (IQR 35–105). Pain severity was the single difference when patients with severe pain were stratified by analgesia provided vs. not, numerical rating scale 7.9 (1.0) vs. 7.6 (0.8),  $p < 0.001$ , respectively. The univariate analysis of 106 patients with severe pain did not identify any risk factors for not receiving analgesia in ED.

**Table 10.** Multivariate logistic regression model of independent risk factors for pain not assessed in ED

		Univariate analysis			Multivariable analysis		
		OR	95% CI	<i>p</i> -value	OR	95% CI	<i>p</i> -value
Sex	Male vs. Female	0.92	0.71–1.18	0.494	0.93	0.72 – 1.21	0.601
Age (years)	$\geq 65$ vs. $< 65$	2.04	1.58–2.64	$< 0.001$	2.09	1.61–2.73	<b><math>&lt; 0.001</math></b>
Triage category	Red and Orange vs. Yellow	1.92	1.37–2.69	$< 0.001$	1.78	1.25–2.53	<b>0.001</b>
ED LOS (min)	$\geq 360$ vs. $< 360$	0.62	0.46–0.82	0.001	0.56	0.42–0.76	<b><math>&lt; 0.0001</math></b>

*ED* – emergency department; *ED LOS* – emergency department length of stay.

## 5.2. Occult myocardial injury in patients with acute abdominal pain

A total of 1000 consecutive patients with a presenting complaint of abdominal pain (excluding obstetric and gynecological emergencies) were identified during the study period. Thirty-five patients had ED readmission visits within 72 hours and their data are excluded. After experimental recommendation for extended troponin measurement, hs-cTnT was obtained in 38.9% (375/965) of patients with acute abdominal pain. Patients subjected to troponin testing were older (median age 64.6 years vs. 60.1 years,  $p < 0.001$ ), had a higher percentage of patients with red and orange triage categories (21.3% vs. 14.7%,  $p = 0.027$ ), higher prevalence of cardiovascular disease history (62.9% vs. 49.7%,  $p < 0.001$ ) and sepsis in ED (9.9% vs. 4.2%,  $p < 0.001$ ), and were more likely admitted to the hospital (55.5% vs. 40.2%,  $p < 0.001$ ) (Table 11). The groups with hs-cTnT obtained in the ED versus not did not differ in 30-day and one-year mortality. However, the patients subjected to troponin measurement in ED had a higher six-month mortality rate and longer HLOS. None of these patients had AMI diagnosed at the initial assessment in the ED.

**Table 11.** Comparison of the characteristics of the groups with troponin obtained vs. troponin not obtained in the ED

Characteristics	hs-cTnT measured in ED (n = 375)	hs-cTnT not measured in ED (n = 590)	p-value
Age, years (SD)	64.6 (16.4)	60.1 (17.4)	<0.001
Male, n (%)	180 (48.0)	321 (54.4)	0.052
Triage category, n (%)			<b>0.027</b>
Red	20 (5.3)	19 (3.2)	
Orange	60 (16.0)	68 (11.5)	
Yellow	295 (78.7)	503 (85.3)	
Previous CVD history, n (%)	236 (62.9)	293 (49.7)	<0.001
Arterial hypertension	223 (59.5)	263 (44.6)	<0.001
Permanent AF	83 (22.1)	76 (12.9)	<0.001
CHF	71 (18.9)	54 (9.2)	<0.001
CAD	50 (13.3)	38 (6.4)	<0.001
Other	33 (8.8)	26 (4.4)	<b>0.005</b>
Sepsis in ED, n (%)	37 (9.9)	25 (4.2)	<0.001
eGFR, mL/min/1.73m <sup>2</sup> (IQR)	79 (54–99) (n = 374)	87 (63–104) (n = 526)	<b>0.005</b>
Hs-cTnT, ng/L (IQR)	12.0 (5.0–24.0)		
BE, mmol/L (IQR)	-1.75 (-5.6–1.6) (n = 90)	-3.0 (-5.2– -0.9) (n = 75)	<b>0.038</b>
Lactate, mmol/L (IQR)	2.1 (1.4–3.1) (n = 90)	2.1 (1.4–3.3) (n = 75)	0.892

Characteristics	hs-cTnT measured in ED (n = 375)	hs-cTnT not measured in ED (n = 590)	p-value
Hospital admission, n (%)	208 (55.5)	237 (40.2)	<0.001
ICU admission, n (%)	21 (10.1)	13 (5.5)	0.075
Ventilator days, n (%)	9 (4.3)	5 (1.8)	0.276
Surgical intervention, n (%)	95 (25.3)	136 (23.1)	0.418
Operation	39	62	
Endoscopy	45	57	
Other	9	11	
Angiography	0	3	
Nephrostomy/epicystostomy	2	3	

*Hs-cTnT* – high-sensitivity cardiac troponin T; *CVD* – cardiovascular disease; *AF* – atrial fibrillation; *CHF* – chronic heart failure; *CAD* – coronary artery disease; *ED*, emergency department; *eGFR* – estimated glomerular filtration rate; *BE* – base excess; *ICU* – intensive care unit.

For the main analysis, patients not subjected to hs-cTnT testing (n = 590), were excluded, yielding 375 cases for the final analysis. There were 180 male (48%) and 195 (52%) female patients. Mean age was 64.6 (16.1) years. Overall, 62.9% of these patients (236/375) had a history of previous cardiovascular disease including arterial hypertension, permanent atrial fibrillation (AF), chronic heart failure (CHF) and/or coronary artery disease (CAD) [59.5% (223/375), 22.1% (83/375), 18.9% (71/375), 13.3% (50/375), respectively]. Median hs-cTnT value was 12.0 (5.0–24.0) ng/L. Approximately one-fifth of the patients were potentially in a critical condition, according to their triage category. Two hundred and eight (55.5%) patients were admitted to the hospital with 21 patients (10.1%) admitted to the ICU. Surgical interventions were required in 95 (25.3%) patients. Final diagnoses at the hospital discharge are depicted in Table 7.

For further analysis, patients were divided according to their admission troponin level: normal (hs-cTnT ≤14 ng/L) and elevated troponin group (hs-cTnT >14 ng/L). Patients with elevated troponin were significantly older and had a higher triage category. These patients had higher prevalence of previous CVD, lower MAP on admission, and they were more likely admitted to the hospital and ICU compared to the normal troponin group (Table 12).

**Table 12.** Comparison of elevated and normal hs-cTnT patients' characteristics

Characteristics	hs-cTnT >14 ng/L (n = 156)	hs-cTnT ≤14 ng/L (n = 219)	p-value
Age, years (SD)	73.5 (13.4)	58.3 (15.3)	<0.001
Male, n (%)	79 (50.6)	101 (46.1)	0.403
Triage category, n (%)			<0.001
Red	17 (10.9)	3 (1.4)	
Orange	30 (19.2)	30 (13.7)	
Yellow	109 (69.9)	186 (84.9)	
Previous CVD history, n (%)	128 (82.1)	108 (49.3)	<0.001
Arterial hypertension	121 (77.6)	102 (46.6)	<0.001
Permanent AF	60 (38.5)	23 (10.5)	<0.001
CHF	58 (37.2)	13 (5.9)	<0.001
CAD	34 (21.8)	16 (7.3)	<0.001
Other	21 (13.5)	12 (5.5)	0.009
Sepsis in ED, n (%)	29 (18.6)	8 (3.7)	<0.001
SpO <sub>2</sub> , % (SD)	96 (3)	97 (2)	<0.001
MAP, mmHg (SD)	94 (21)	104 (16)	<0.001
Hgb, g/L (SD)	119 (29) (n = 155)	136 (20) (n = 218)	<0.001
eGFR, mL/min/1.73m <sup>2</sup> (IQR)	55 (31–81)	71 (59–85)	<0.001
Hs-cTnT, ng/L (IQR)	27.7 (20.0–45.9)	5.1 (3.2–10.0)	<0.001
BE, mmol/L (IQR)	-2.8 (-7.0–1.6)	-0.2 (-2.5–1.6)	0.095
	(n = 64)	(n = 26)	
Lactate, mmol/L (IQR)	2.2 (1.5–3.2)	1.6 (1.4–3.0)	0.233
	(n = 64)	(n = 26)	
Hospital admission, n (%)	116 (74.4)	92 (42.0)	<0.001
ICU admission, n (%)	19 (16.4)	2 (2.2)	0.001
Ventilator days, n (%)	7 (6.0)	2 (2.2)	0.304
Surgical intervention, n (%)	49 (31.4)	46 (21.0)	0.030
Operation	17	22	
Endoscopy	17	28	
Other	6	3	
Angiography	0	0	
Nephrostomy/epicystostomy	2	0	

*Hs-cTnT* – high-sensitivity cardiac troponin T; *CVD* – cardiovascular disease; *AF* – atrial fibrillation; *CHF* – chronic heart failure; *CAD* – coronary artery disease; *ED* – emergency department; *SpO<sub>2</sub>* – hemoglobin oxygen saturation; *MAP* – mean arterial pressure; *Hgb* – hemoglobin; *eGFR* – estimated glomerular filtration rate; *BE* – base excess; *ICU* – intensive care unit.

Patients with elevated troponin had significantly higher 30-day, six-month and one-year mortality compared to the normal troponin level group (Table 13). Elevated troponin group had a longer HLOS (median HLOS 8 days vs. 3 days,  $p < 0.001$ ). None of the patients were diagnosed with AMI during the index visit and hospitalization period, but seven out of 375 patients suffered AMI within two years after study enrollment with significantly higher prevalence in elevated troponin group compared to normal troponin group.

**Table 13.** Comparison of outcomes in patients with normal and elevated troponin levels

	<b>hs-cTnT &gt;14 ng/L (n = 156)</b>	<b>hs-cTnT ≤14 ng/L (n = 219)</b>	<b>p-value</b>
30-day mortality, n (%)	20 (12.8)	8 (3.7)	<b>0.001</b>
6-month mortality, n (%)	53 (34.0)	15 (6.9)	<b>&lt;0.001</b>
One-year mortality, n (%)	61 (39.1)	20 (9.2)	<b>&lt;0.001</b>
Hospital LOS, days (IQR)	8 (5–12) (n = 116)	3 (2–6) (n = 92)	<b>&lt;0.001</b>
ACS*, n (%)	6 (3.9)	1 (0.5)	<b>0.045</b>

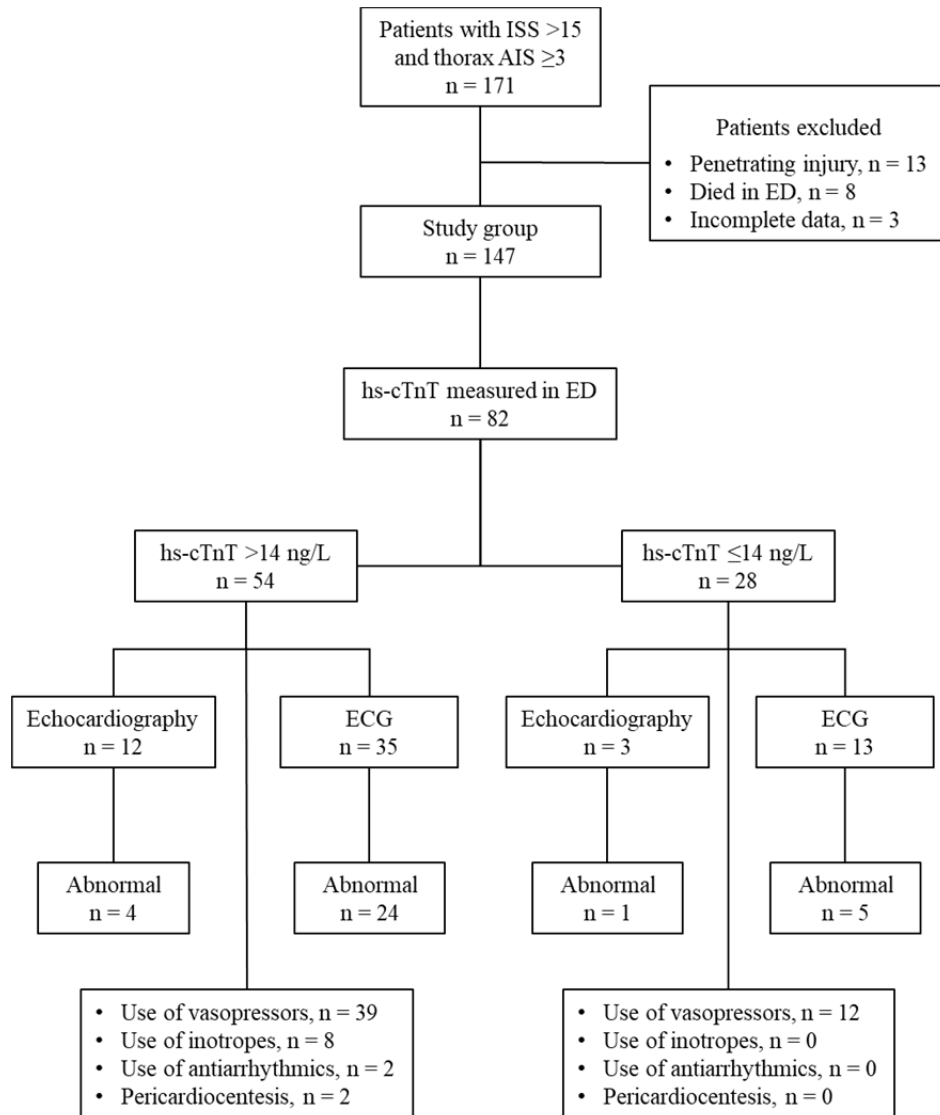
\*Follow-up period for ACS was from index ED visit to 01. January 2020.

*Hs-cTnT* – high-sensitivity cardiac troponin T; *LOS* – length of stay; *ICU* – intensive care unit; *ACS* – acute coronary syndrome, *ED* – emergency department.

The univariate analysis revealed a possible relationship with all depicted factors with some variation in short- and long-term mortality. Independent risk factors for 30-day mortality on multivariable Cox proportional hazard model were red triage category (hazard ratio 2.99, 95% CI 1.09–8.20,  $p = 0.033$ ), sepsis (hazard ratio 2.65, 95% CI 1.09–6.40,  $p = 0.031$ ) and hs-cTnT value >14 ng/L (hazard ratio 2.68, 95% CI 1.02–7.05,  $p = 0.046$ ). Independent risk factors for six-month mortality on multivariable Cox proportional hazard model were age  $\geq 65$  years (hazard ratio 2.52, 95% CI 1.14–5.56,  $p = 0.022$ ), MAP <65 mmHg (hazard ratio 2.23, 95% CI 1.05–4.76,  $p = 0.038$ ) and hs-cTnT value >14 ng/L (hazard ratio 3.94, 95% CI 2.09–7.43,  $p < 0.001$ ). Independent risk factors for one-year mortality on multivariable Cox proportional hazard model were age  $\geq 65$  years (hazard ratio 2.44, 95% CI 1.20–4.97,  $p = 0.014$ ), Hgb level (hazard ratio 0.99, 95% CI 0.98–1.00,  $p = 0.031$ ) and hs-cTnT value >14 ng/L (hazard ratio 3.01, 95% CI 1.69–5.34,  $p < 0.001$ ).

### 5.3. Blunt cardiac injury in chest trauma

During the 30-month study period, 171 patients with ISS  $\geq 15$  and chest AIS  $\geq 3$  were identified. Patients with penetrating injuries ( $n = 13$ ), patients deceased in ED ( $n = 8$ ) and cases with deficient medical information ( $n = 3$ ) were excluded with 147 cases included for the final analysis (Figure 1).



*ISS – Injury Severity Score; AIS – Abbreviated Injury Scale; ED – emergency department; hs-cTnT – high-sensitivity cardiac troponin T; ECG – electrocardiogram.*

**Figure 1.** Patient inclusion and group allocation of the study cohort

Overall, 137 patients were admitted from the scene and 10 patients were transferred from outside hospitals. Table 14 shows demographics and admission data of patients with thorax AIS  $\geq 3$ . Majority of patients were male with a mean age of 49.0 years. Median ISS was 24. Thirty-two percent (47/147) of patients had a history of previous cardiovascular disease with arterial hypertension being the

most frequent comorbidity. Serum troponin levels on admission were obtained in 82 (56%) patients with elevated hs-cTnT levels found in 66% (54/82).

**Table 14.** Demographics and admission data of all major trauma patients with severe chest injury

<b>Characteristics</b>	<b>Value</b>
Age, years (SD)	49.0 (19.1)
Male, n (%)	110 (74.8)
Charlson Comorbidity Index (CCI), n (%)	
CCI = 0	66 (44.9)
CCI = 1	29 (19.7)
CCI = 2	21 (14.3)
CCI = 3	11 (7.5)
CCI = 4	10 (6.8)
CCI $\geq$ 5	10 (6.8)
Previous cardiovascular disease, n (%)	47 (31.9)
Arterial hypertension	45 (30.6)
Chronic heart failure	10 (6.8)
Permanent atrial fibrillation	7 (4.8)
Coronary artery disease	5 (3.4)
Injury Severity Score, median (IQR)	24.0 (18.0–34.0)
Glasgow Coma Scale, median (IQR)	15.0 (7.0–15.0)
Systolic blood pressure, mmHg, mean (SD)	124.6 (33.2)
Diastolic blood pressure, mmHg, mean (SD)	75.2 (22.9)
SpO <sub>2</sub> , %, median (IQR)	97.0 (93.0–99.5)
Hgb, g/L, mean (SD)	128.1 (22.4)
Arterial blood pH (n=111), median (IQR)	7.334 (7.256–7.385)
Lactate, mmol/L (n=111), median (IQR)	2.3 (1.8–3.8)
Hs-cTnT, ng/L (n=82), median (IQR)	22.5 (10.0–65.8)
eGFR, mL/min/1.73m <sup>2</sup> , median (IQR)	87.0 (68.5–104.5)
ICU admission, n (%)	95 (64.6)

*SpO<sub>2</sub> – hemoglobin oxygen saturation; Hgb – hemoglobin; Hs-cTnT – high-sensitivity cardiac troponin T; eGFR – estimated glomerular filtration rate; ICU – intensive care unit.*

Overall, median hs-cTnT level was 22.5 ng/L (IQR 10.0–65.8), however, median troponin level in the subgroup with elevated hs-cTnT (>14 ng/L) was 41.7 ng/L (IQR 23.0–83.0 ng/L). Admission ECG was performed in 73 (50%) patients with abnormal findings in 34 cases (47%). Echocardiography was performed in 24 (16%) patients resulting in abnormal findings in 9 patients (38%). Six patients were found to have pericardial effusion with three requiring urgent thoracotomy for cardiac injury repair (two patients with right atrial rupture and one patient with right pulmonary vein rupture). Overall, in-hospital mortality was 17% (25/147). For further analysis, the thorax AIS  $\geq$ 3 patients were divided into two subgroups based on their troponin values (n = 82): elevated troponin

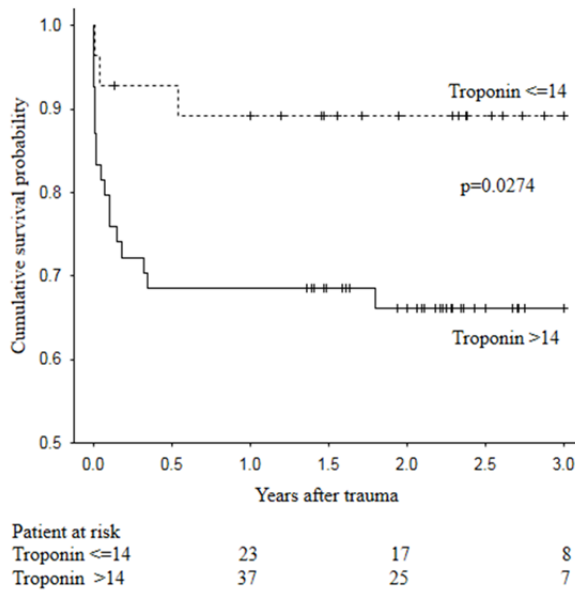
group (hs-cTnT >14 ng/L) and normal troponin group (hs-cTnT ≤14 ng/L), respectively (Fig. 1). Comparison between the groups is depicted in Table 15.

**Table 15.** Comparison of elevated and normal hs-cTnT patients characteristics

	hs- cTnT >14 ng/L (n=54)	hs-cTnT ≤14 ng/L (n=28)	p-value
Age, years (SD)	50.1 (20.6)	50.5 (18.1)	0.936
Previous CVD, n (%)	23 (42.6)	8 (28.6)	0.214
Charlson Comorbidity Index (CCI), n (%)			0.600
CCI = 0	24 (44.4)	11 (39.3)	
CCI = 1	8 (14.8)	7 (25.0)	
CCI = 2	6 (11.1)	5 (17.9)	
CCI = 3	3 (5.6)	2 (7.1)	
CCI = 4	6 (11.1)	3 (10.7)	
CCI ≥5	7 (13.0)	0 (0)	
Severe brain or spinal cord injury, n (%)	25 (46.3)	9 (32.1)	0.217
Injury Severity Score, median (IQR)	29.0 (22.0– 38.0)	23.0 (18.0– 29.0)	<b>0.032</b>
Lactate level, mmol/L, median (IQR)	3.1 (2.1–5.5)	2.2 (1.6–3.4)	<b>0.008</b>
Systolic blood pressure, mmHg, mean (SD)	118.8 (31.0)	135.6 (31.4)	<b>0.026</b>

*hs-cTnT – high-sensitivity cardiac troponin T; CVD – cardiovascular disease.*

Eighteen patients had clinically significant BCI per the study definition. Patients with elevated hs-cTnT had significantly higher ISS (29 vs. 23,  $p = 0.032$ ), lower systolic blood pressure on admission (119 mmHg vs. 136 mmHg,  $p = 0.026$ ) and higher arterial blood lactate level (3.1 mmol/L vs. 2.2 mmol/L,  $p = 0.008$ ) compared to the subgroup with normal hs-cTnT. In-hospital mortality in the elevated troponin group and in the group with normal troponin level was 26% (14/54) and 4% (1/28), respectively ( $p = 0.02$ ). One-year mortality was 32% (17/54) in the elevated troponin group and 11% (3/28) in the group with normal troponin level ( $p = 0.063$ ). Kaplan–Meier survival estimates are shown in Figure 2.



**Figure 2.** Kaplan–Meier survival curves in patients with elevated and normal high-sensitivity cardiac troponin T levels

Patients with elevated troponin had lower GOS at hospital discharge (median GOS 3 vs. 4,  $p = 0.001$ ), longer ventilator days (median ventilator days 4.0 vs. 0.0,  $p = 0.005$ ) and trend towards longer stay in the ICU (median ICU days 7.0 vs. 4.5,  $p = 0.051$ ) compared to the normal troponin group. Vasopressor agent support was required in 39 (72%) and 12 (43%) patients in the elevated troponin group and normal troponin level group, respectively ( $p = 0.019$ ). Inotropic and antiarrhythmic agents were utilized only in the elevated troponin group with no statistical significance compared to the group with normal troponin (Table 16).

**Table 16.** Outcomes of patients with elevated and normal troponin levels

	hs-cTnT >14 ng/L (n=54)	hs-cTnT ≤14 ng/L (n=28)	p-value
In-hospital mortality	25.9 (n=14)	3.6 (n=1)	<b>0.013</b>
One-year mortality	31.5 (n=17)	10.7 (n=3)	<b>0.038</b>
ICU days, median (IQR)	7.0 (3.0–18.0)	4.5 (0.0–11.5)	0.051
Ventilator days, median (IQR)	4.0 (2.0–13.0)	0 (0.0–7.0)	<b>0.005</b>
GOS, median (IQR)	3.0 (1.0–4.0)	4.0 (4.0–5.0)	<b>0.001</b>
No (%) of antiarrhythmic drug use	2 (3.7)	0	0.545
No (%) of vasoactive drug use	39 (72.2)	12 (42.9)	<b>0.009</b>
No (%) of inotropic drug use	8 (16.0)	0	<b>0.046</b>
No (%) of pericardiocentesis	2 (3.7)	0	0.431

hs-cTnT, high-sensitivity cardiac troponin T, ICU, intensive care unit, GOS, Glasgow Outcome Scale.

Independent risk factors for one-year mortality on multivariable Cox proportional hazard model were MAP on admission (hazard ratio 0.98, 95% CI 0.96–1.00,  $p = 0.03$ ), CCI  $\geq 2$  (hazard ratio 7.63, 95% CI 2.66–21.95,  $p < 0.001$ ) and GCS  $< 8$  (hazard ratio 3.74, 95% CI 1.47–9.49,  $p = 0.005$ ).

For the confounder group 118 patients were eligible. Serum troponin levels on admission were obtained in 50 patients. Comparison of thorax AIS  $< 3$  and thorax AIS  $\geq 3$  groups revealed that patients were similar in age, sex, CCI and previous cardiovascular disease history. Also, two groups did not differ per their admission hemoglobin levels or systolic blood pressures. The thorax AIS  $\geq 3$  group had significantly higher troponin level [median hs-cTnT 22.5 ng/L (IQR 10.0–65.8) vs. 18.0 ng/L (IQR 5.0–20.0),  $p < 0.001$ ], lower ISS [median ISS 24 (IQR 18–34) vs. 25 (IQR 17–25),  $p = 0.003$ ], higher GCS score [median GCS score 15 (IQR 7–15) vs. 12 (IQR 6–15),  $p = 0.002$ ], higher arterial blood lactate level [median lactate level 2.3 mmol/L (IQR 1.8–3.8) vs. 2.1 mmol/L (1.4–3.2),  $p = 0.011$ ], lower hemoglobin oxygen saturation [median SpO<sub>2</sub> 97% (IQR 93–100) vs. 98% (96–100),  $p < 0.001$ ], and lower estimated glomerular filtration rate [median eGFR 87.0 mL/min/1.73m<sup>2</sup> (IQR 68.5–104.5) vs. 103.0 mL/min/1.73m<sup>2</sup> (IQR 84.0–114.0),  $p < 0.001$ ] compared to the thorax AIS  $< 3$  group. Two groups had similar in-hospital mortality, one-year mortality and GOS at hospital discharge. Patients in thorax AIS  $\geq 3$  group had longer ventilator days compared to thorax AIS  $< 3$  group [median ventilator days 3.5 (IQR 1.0–10.5) vs. 2.0 (IQR 0.0–5.0), respectively,  $p = 0.041$ ].

## 6. DISCUSSION

### 6.1. Quality Indicators in Emergency Medicine

In this dissertation, three relevant quality indicators, including ED LOS, assessment of pain and administration of analgesia in patients suffering severe pain were investigated in a common subset of urgent adult patients presenting to the ED with a chief complaint of abdominal pain. One could expect that after primary workup in the ED these patients are rapidly treated, and admitted to the hospital, if indicated.

#### 6.1.1. Emergency department length of stay

Results of the study of this dissertation demonstrates a significant proportion of urgent patients to experience an extended ED LOS at major referral hospitals in Estonia, especially patients requiring hospital admission indicating critical shortfalls in clinical pathways at our EDs.

In the contemporary literature, different time frames of ED LOS ranging from 4 to 6 hours have been suggested for quality assessments. In the study of this dissertation, a six-hour cut-off was investigated due to the following reasons: first, a 4 hour-period was considered to be too short LOS in ED potentially rushing patients without appropriate workup to ward beds, and secondly, 6 hours would also allow international benchmarking of QIs introduced for ED performance in Estonia. Twenty seven percent of the study patients had a LOS exceeding six hours. Multiple investigators have noted failures to meet the ED LOS standards. Royal College of Emergency Medicine has declared the failure to meet the four-hour standard since 2015 (Royal College of Emergency Medicine, 2019), and in New Zealand not all patients met the six-hour goal but not to the extent noted in this dissertation (PRiZED 1, 2017).

Prolonged ED LOS leads to crowding with multiple negative consequences. In a meta-analysis by Morley and colleagues, negative effects of crowding identified were adverse outcomes for patients, including treatment delays and increased mortality (Morley et al., 2018).

Many adverse outcomes of longer ED LOS were observed in the study of this dissertation. There was significantly higher one-year mortality among patients with extended LOS; however, this outcome may be confounded by age. Nevertheless, ED LOS  $\geq 360$  min proved to be an independent risk factor for 30-day mortality after adjustment to sex, age, and triage category. Likewise, patients with extended ED LOS were subjected to longer time to analgesia and surgical intervention.

In the literature, prolonged ED LOS was independently associated with higher in-hospital mortality among septic patients who required ICU admission (Zhang et al., 2019). A retrospective study conducted by Choi et al found that in elderly patients with infection admitted to the ICU, extended ED LOS was independently associated with longer HLOS and higher in-hospital mortality

(Choi et al., 2021). Controversially, in a recent retrospective study by Wessman, positive association between ED LOS 7- and 30-day mortality rate in patients with lower medical urgency and patients not admitted to in-hospital care was noted. Still, this was not observed in patients with high medical urgency and in patients admitted to in-hospital care (Wessman et al., 2022). A retrospective population-based study from Canada analyzed associations between ED LOS and adverse outcomes, defined as death or hospital admission within seven days after index visit, in patients who were not admitted (seen and discharged or left without being seen). An increase in both outcomes was associated with longer mean LOS (Guttman et al., 2011).

Regarding treatment delays, ED crowding is associated with delays or no treatment of severe pain (Pines et al., 2008), and in patients presenting with acute abdominal pain (Mills et al., 2009). Also, shorter stay in the ED is associated with better patient experience (Chang et al., 2017).

There are many factors contributing to ED crowding. Older age and need for surgical consultation were independently associated with extended LOS. In both study hospitals surgeon(s) are available 24/7 and therefore, it could be expected that the patients in need of surgical consultation and procedures be quickly hospitalized. However, patients admitted to the hospital constituted a significant proportion in the group of staying in ED for more than 360 min. Similar findings with additional risk factors, like need for radiological and blood tests, have been reported in the literature (Vegting et al., 2015; Dadeh et al., 2020). Other investigators have found that elderly patients spend more time in the ED that is associated with multiple tests or consultations and low seniority of treating physician (Brouns et al., 2015). Dadeh et al studied prolonged ED LOS in patients presenting with acute abdominal pain and factors identified were older age, need for interdepartmental consultation, blood testing, and ultrasonography (Dadeh et al., 2020).

### **6.1.2. Assessment and management of pain**

Study of this dissertation revealed that roughly in every second individual admitted with a short complaint of abdominal pain, the severity of their pain is not recorded in the medical documentation, and one fourth of patients reporting severe pain did not receive analgesia during ED stay. Median time to analgesia was one hour in patients reporting severe pain. Triage category should be assessed to every admission within 10 minutes after arrival to the ED, and time to the physician is immediate, 15 minutes and one hour in red, orange, and yellow patients', respectively. Results of this paper are reflecting an inadequate practice at EDs of two major referral hospitals in Estonia.

Pain is a common reason for seeking ED care. Pain intensity is considered to be a vital sign and pain recording is a basic tenet of the triage system. In some triage systems, patients with severe pain are triaged very urgent in order to initiate treatment within 10 minutes of presentation (SATS, 2012). Pain should be assessed using validated and appropriate scales also considering patient age

and cognitive function (Schug et al., 2015; Hachimi-Idrissi et al., 2020). Understanding and assessment of pain are fundamentals of adequate treatment. Vazirani et al conducted a prospective interventional study implementing mandatory pain score registration to their triage system. Median time to analgesia decreased significantly from 123 minutes to 73 minutes (Vazirani et al., 2011).

Similar findings regarding malpractice in pain management are reported in the national audits and in the literature. In 2011, a prospective study was conducted in 50 EDs in France. Authors noted oligoanalgesia and treatment delays in patients with abdominal pain (Gueant et al., 2011). The PRiZE 1 study analyzed data from different EDs in New Zealand and found that pain was not documented in 15% of the patients presenting with a painful condition. One fourth of them did not receive analgesia. Documentation was sufficient only in 32% of the patients to estimate the adequacy of analgesia. Median time to analgesia was 62 minutes (PRiZE 1, 2017).

Multiple barriers for pain management in emergency medicine including advanced age (Hwang et al., 2010; PRiZE 1, 2017), and number of concomitant patients, ED occupancy rate, age  $\geq 65$  years and female sex have been described (Daoust et al., 2014). Sampson and colleagues noted that pain management is not prioritized within the process of the ED and was not included in the educational process in three EDs in North of England (Sampson et al., 2020).

Another cause for nontreatment of pain is a patient's refusal to take pain medication. Kant et al demonstrated that causes for refusal were mild pain, recent analgesic intake or concerns over side effects and drug interactions (Kant et al., 2019), and fear of side effects of the analgetic drugs (Janati et al., 2018).

Independent risk factors for pain not assessed in this dissertation were age  $\geq 65$  years and higher triage category. No independent risk factors for omitted analgesia were identified.

It is noted by the International Federation for Emergency Medicine geriatric emergency medicine special interest group, that older people are a core population of service users. Minimum standards were introduced including EDs should actively support patient-centered care that leads to optimal outcomes for older people (Ellis et al., 2018).

There are many QIs proposed and used for analgesia. Time to first dose of analgesia in all painful conditions requiring analgesia and percentage of patients with documented pain assessment were included in the final set of suggested ED QIs by the Canadian expert panel (Schull et al., 2010). In a systematic review, Stang et al identified 20 indicators specific to pain management, including process indicators implying aspects of pain assessment, administration of analgesics, and time to analgesia. Also, outcome indicators including patient satisfaction (Stang et al., 2014).

For improvement initiatives, a systematic review was performed by Sampson et al. There are many quality initiatives studied for ED, for example, the use of pain scoring tools, and removing structural, behavioral and knowledge barriers. Still, the authors concluded that evidence is insufficient to recommend

any interventions for widespread adoption, and it is likely that interventions need to be tailored to individual settings (Sampson et al., 2014).

Data of this dissertation support the need for quality improvement measures for patients admitted with acute abdominal pain. Documented pain assessment during triage process and time to analgesic drug administration are measurable process indicators in this cohort of ED patients.

## **6.2. Non-ischemic myocardial injury in Emergency Medicine**

Studies of the current dissertation reveal the high incidence and prognostic value of myocardial injury, reflected by the elevated high-sensitivity cardiac troponin, in critical patients with abdominal pain and with serious blunt chest trauma.

Analysis of routine clinical practice reveals that hs-cTn assessment is not a standard of care in surgical patients, although there is growing evidence supporting surveillance of cardiac biomarkers in patients with chest trauma (Kyriazidis et al., 2023), and it is recommended to consider perioperative hs-cTn assessment in high-risk patients (De Hert et al., 2018; Beattie et al., 2021). Not all patients studied in this dissertation suffered abdominal pathology or required surgical intervention, therefore current results and recommendations apply to all patients presenting with a chief complaint of abdominal pain, regardless of the final diagnosis.

In addition to biomarkers, 12-lead ECG, and echocardiography, if indicated, have an important role for early detection of traumatic cardiac injury (Kyriazidis et al., 2023).

In the literature, elevated hs-cTn, not associated with acute myocardial infarction, is well documented in different populations of ED patients. Lindner and co-authors performed a cross-sectional analysis including all patients with serial troponin measurements in the ED. They concluded that more than 50% of elevated biomarker was not associated with MI, and commonly observed causes for elevated troponin were renal insufficiency, cerebral ischemia, trauma, and heart failure (Lindner et al., 2014). Wilhelm et al conducted a prospective study enrolling all adults with sepsis in the ED, elevated troponin was detected in 60% of the patients with higher prevalence in patients suffering from more severe sepsis (Wilhelm et al., 2014).

### **6.2.1. Occult myocardial injury in patients with acute abdominal pain**

The study of this dissertation demonstrates that extended troponin measurements in patients admitted to ED with acute abdominal pain resulted in detection of a significant proportion of patients with myocardial injury, 42% of the patients subjected troponin measurement experienced a myocardial injury per

their elevated biomarker profile. None of the patients were diagnosed with AMI during ED admission although upper abdominal pain could also be a symptom of AMI. Myocardial injury was screened in patients who were older and with known CVD history, and more in patients with higher triage category and sepsis.

The term myocardial injury was extended to occult myocardial injury to reflect non-ischemic myocardial cell damage in patients with elevated hs-cTnT, because this study cohort did not present with cardiac problem and without biomarker screening the concomitant myocardial damage could be left unnoted. Like in the literature, median troponin level was lower than generally observed in AMI (Jarolim et al., 2014), still, even small elevations of hs-cTn have a prognostic impact and higher levels of troponins indicate higher risk for mortality (Writing Committee for the VISION Study Investigators, 2017).

The clinical utility of troponin measurement in patients with abdominal pain in the ED is not fully clear. One argument for hs-cTn screening is a differential diagnosis of myocardial infarction as many of AMI patients could suffer from gastrointestinal symptoms. Brieger and colleagues demonstrated in a large multinational prospective study based on a Global Registry of Acute Coronary Event how 8.4% of patients diagnosed with acute coronary syndrome presented without chest pain, (Brieger et al., 2004) causing delay in reperfusion therapy and increased mortality (Nakahashi et al., 2021). Another indication for troponin monitoring is to detect ischemic myocardial injury after non-cardiac surgery (MINS) in a high-risk patient as majority of patients suffering from MINS do not experience ischemic symptoms (Botto et al., 2014; Writing Committee for the VISION Study Investigators, 2017). Also, interpreting the results of the hs-cTnT value in the context of older age and comorbidities is challenging. There are many potential contributors for chronic and acute myocardial injury in the current study cohort comparing elevated and normal biomarker groups including older age, previous cardiovascular disease history, lower renal function, and lower MAP, lower Hgb and sepsis, respectively.

Prognostic value of OMI was observed, including significantly higher adjusted 30-day, six-month and one-year mortality, and longer HLOS in the OMI group compared to patients with normal hs-cTnT. The negative prognostic value of hs-cTn has been well described in the literature in different patients. For instance, higher mortality in critically ill patients with coronavirus 19 infection (Dawson et al., 2020). Humble et al concluded a meta-analysis that preoperative cTn predicts MACE and/or all-cause mortality in adult non-cardiac surgical patients (Humble et al., 2019). Garcia and co-authors studied patients with sepsis and noted that elevated troponins were associated with higher risk for post sepsis cardiac complications during one year follow-up in patients without previously known cardiovascular disease (Garcia et al., 2021).

Following the data of poor outcomes in patients with OMI, and increased risk for cardiovascular adverse events, further cardiovascular imaging and secondary-prevention strategy may improve prognosis of these patients (Foucrier et al., 2014). Nevertheless, there is no clear evidence and guidance on how to

manage patients identified with acute or chronic myocardial injury. Secondary-prevention strategy has been investigated with conflicting results regarding mortality benefit in the perioperative myocardial injury cohort. Devereaux and co-authors investigated the effect of perioperative beta blocker therapy compared to placebo for a 30-day outcome. The authors noted that although treatment reduces the risk for AMI, higher risk for mortality and stroke in the beta blocker group was observed compared to placebo. Also, higher incidence of clinically significant hypotension and bradycardia were observed in the beta blocker group compared to placebo (Devereaux et al., 2008). Results of the later studies have shown support, and secondary preventive therapy in patients diagnosed with MINS should be considered (Devereaux et al., 2020).

To conclude, triage category, age, previous cardiovascular disease history and sepsis are all routinely detectable characteristics on ED admission. According to data of the current dissertation, patients older than 65 years with a chief complaint of abdominal pain, allocated to red or orange triage category and/or with previous CVD history and/or with sepsis/suspected sepsis might be considered for hs-cTnT screening as they likely suffer OMI. Further follow-up and focused investigations, including cardiovascular risk stratification, are proposed for patients with elevated hs-cTnT in hospital settings.

### **6.2.2. Blunt cardiac injury in chest trauma**

Study of this dissertation reveals that a high proportion of people affected by major trauma are young and without serious comorbidities. Most of the severe chest injuries resulted from the blunt mechanism. It is recommended to screen patients suffering severe blunt trauma to the anterior chest for BCI (Clancy et al., 2012), or when the mechanism of injury to the thorax involves rapid deceleration, and if there are fractures to the sternum or scapula (ATLS<sup>®</sup>, 2018). Recommended first line diagnostics for BCI vary, including ECG and biomarkers (Clancy et al., 2012; ATLS<sup>®</sup>, 2018). In this dissertation, BCI was defined as an elevated hs-cTnT with ECG and/or echocardiographic changes. Firstly, it was noted that current practice is not in compliance with international recommendations for managing severe chest trauma according to occurrence of troponin measurement and ECG recording on admission. Secondly, more than half of the patients whom hs-cTnT was obtained, suffered myocardial injury per the elevated biomarker, and eighteen patients suffered clinically significant BCI. Thirdly, troponin values were significantly higher in severe chest trauma group compared to other patients suffering severe trauma without chest trauma, and fourthly, elevated hs-cTnT was associated with poor prognosis of these patients compared to the normal troponin group.

In the literature, there are different diagnostic criteria and prevalence, ranging from 3% to 56%, for BCI. In a recent systematic review and meta-analysis by Kyriazidis et al, 51 studies investigating cardiac injury after blunt trauma were included. The accuracy of different methods for diagnosing BCI in the ED were analyzed. Initial ECG, cTnI, cTnT, and TTE all exhibited high

specificity but lower sensitivity for diagnosing cardiac contusion (Kyriazidis et al., 2023). In the study of this dissertation, approximately half of the patients with blunt chest trauma demonstrate ECG changes, however, aberrant ECG findings do not indicate a significant BCI in patients with severe chest trauma (Salim et al., 2001; Velmahos et al., 2003). The prognostic value of cTn is controversial according to the previous reports. Still, in concordance with EAST guidelines (Clancy et al., 2012), meta-analysis revealed that normal ECG and cardiac troponins rule out cardiac injury (85% sensitivity). The algorithm proposed by the authors for the initial assessment of BCI is firstly to obtain admission troponin I and ECG, if normal then repeat after 4–6 hours. If both are still normal, BCI can be ruled out. If any abnormalities occur, further diagnostic tests, including echocardiography are indicated (Kyriazidis et al., 2023).

In the study of this dissertation, patients with elevated hs-cTnT had significantly higher mortality, longer ventilator days and they needed more cardiovascular support including vasoactive and inotropic drugs. Similar findings regarding prognostic value and prediction of major adverse cardiac events of the troponins are reported in the literature, although it is argued is the elevated troponin result from the overall injury rather than mechanical chest trauma (Martin et al., 2005; Burrell et al., 2017).

To conclude, according to the literature and the results of this dissertation, patients suffering from severe chest trauma should be screened for BCI on admission. Hs-cTnT and ECG are feasible first line diagnostics. Patients with elevated hs-cTnT have poorer prognosis compared to patients with normal biomarker level, further diagnostic tests and monitoring should be considered for these patients.

### 6.3. Limitations

Studies of this dissertation have inherited limitations of the retrospective design. Studies were conducted at two major referral hospitals and the results might not be applicable to all EDs. Also, patients included in the QI and OMI studies were limited with chief complaint of abdominal pain, age, and triage category, therefore the results are not generalizable to all ED referrals.

Detailed limitations of the QI study are firstly, omitted pain intensity documentation was translated into lack of pain assessment; however, these are not exclusive events. Not all patients were able to adequately report the pain intensity, for instance the patients with altered level of consciousness or with cognitive dysfunction. Likewise, the patients who refused analgesia, received pre-hospital analgesia or had contraindication for analgetic medications were all stratified as not receiving analgesia. Thirdly, there are potential unmeasured confounders other than ED LOS  $\geq 360$  minutes for one-year mortality.

Detailed limitations of the OMI study are firstly, hs-cTnT values were obtained at the discretion of the treating physician. It is an assumption that these were the patients in whom OMI was suspected. Secondly, because of previously mentioned selection bias, incidence of OMI is not representative for all patients.

Thirdly, data of this dissertation include admission troponin only, barring the distinction between acute and chronic myocardial injury. Fourthly, current investigation does not provide management strategies other than a possible prognostication tool. Fifthly, troponin was not adjusted to all mortality predictors e.g. Charlson Comorbidity Index and elevated hs-cTnT could be a general marker of co-morbidity explaining the higher mortality rate in the elevated troponin group.

Detailed limitations of the BCI study are firstly, hs-cTnT values were not obtained routinely in this study cohort. Secondly, BCI was defined as a combination of elevated hs-cTnT and ECG or echocardiography findings with BCI considered to be clinically important when the condition required specific interventions. However, ECG was performed only in 65% (35/54) and echocardiography in 22% (12/54) of patients with elevated hs-cTnT translating into potential underestimation of clinically significant BCI prevalence. Hs-cTnT samples were obtained on admission, thus, the exact time from trauma to blood sampling remains undetermined. Also, 10 patients were transferred from other hospitals and this may have an impact on their admission data. Finally, current study is lacking data for serial hs-cTnT measurements, thus, the trend of hs-cTnT values is not reported.

Nonetheless, the major strengths of the studies of this dissertation are to scrutinize the current management of a representative cohort of urgent patients presenting at two major referral EDs in Estonia and to provide important opportunities for evolution of healthcare and EM in Estonia.

## 7. CONCLUSIONS

Results of the studies support the clinical relevance of assessment of quality of care for ED patients, and indicate the high prevalence and prognostic value of non-ischemic myocardial injury in surgical patients. Clear areas for quality improvement and diagnosis of myocardial injury were identified.

1. At the two major referral hospitals of Estonia a non-compliance with three prominent quality indicators including ED LOS, pain assessment and analgesia exists among immediate and urgent patients with acute abdominal pain.
  - A high proportion of patients experienced prolonged ED LOS.
  - Patients who required admission to the hospital constituted a significant proportion among those who stayed in ED for more than 360 min. This indicates important deficits in processes and capacities in the care of these patients.
  - Independent risk factors for ED LOS  $\geq 360$  min were older age and the need of surgical consultation suggesting the complexity of the management of the elderly, potentially multimorbid patients and shortfalls in clinical pathways in our EDs.
  - A prolonged ED LOS was an independent risk factor for 30-day mortality in this group on ED referrals.
  - Patients who are older and have a higher triage category are at risk of failure of pain documentation.
2. Patients with acute abdominal pain subjected to troponin testing are older, have previous cardiovascular disease history, are septic and admitted to the hospital compared to the patients not subjected to troponin testing.
  - Significant proportion of immediate and urgent patients admitted with acute abdominal pain screened for OMI suffered myocardial injury per biomarker profile.
  - Elevated hs-cTnT is an independent risk factor for short- and long-term mortality in this group of emergency medicine patients.
  - Extended use of the high-sensitivity troponin testing may constitute as a valuable risk assessment tool.
3. In patients suffering major blunt trauma with severe chest injuries elevated hs-cTnT is a clinically significant event requiring medical and/or surgical interventions, and is associated with detrimental prognosis of these patients.
  - Troponin and ECG are accessible primary screening tools for BCI, but compliance with guidelines regarding biomarker and ECG screening for myocardial injury is limited in Estonian hospitals.
  - Elevated hs-cTnT is an independent risk factor for mortality in this group of ED patients.

**Future directions**

Quality of care is a paramount value in the emergency medicine. Future research exploring implementation of evidence-based quality initiatives at individual and system level improving the assessment and management of pain and reducing ED LOS for urgent patients with acute abdominal pain is warranted.

Troponin is a highly sensitive and prognostically relevant biomarker detecting myocardial injury. Further studies validating screening for myocardial injury, and its prognostic significance in different cohorts of ED patients, and guidance for management of non-ischemic myocardial injury are needed. Patients above 65 years of age with a chief complaint of abdominal pain, allocated to immediate or urgent triage categories and/or with previous CVD history and/or with sepsis/suspected sepsis warrant hs-cTnT screening as they may suffer an OMI. The suggested clinical algorithm requires further prospective investigations.

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## 9. SUMMARY IN ESTONIAN

### **Kvaliteediindikaatorid ja südamelihase mitte-isheemiline kahjustus erakorralises meditsiinis**

Erakorraline meditsiin on oluline osa tervishoiust, mille funktsioonideks on ennekõike kriitiliste seisundite esmane käsitus, elundipuudulikkuste diagnoosimine ja ennetamine ning seeläbi suremuse ja invaliidistumise vähendamine. Eestis saavutas erakorraline meditsiin iseseisva arstliku eriala staatuse 2000. aastal. Järgnevatel aastatel on loodud erakorralise meditsiiniabi võrgustik, haigete triaažisüsteem, eriala residentuuriprogramm ning astunud on esimesed sammud ravikvaliteedi hindamise poole. Sarnaselt muu maailmaga on ka Eestis järjest suurenenud nõudlus erakorralise meditsiini järele. See on kaasa toonud osakondade ülerahvastuse, mis põhjustab potentsiaalselt tervist kahjustavaid viivitusi inimese raviteekonnal.

#### **Uurimustöö eesmärgid**

Käesoleva uurimistöö laiendatud eesmärk oli erakorralise meditsiini ja erakorralise kirurgia ravitulemuste teadusliku analüüsi laiendamine Eestis. Fookuses olid kvaliteediindikaatorid ning kõrgtundlik troponiin kui mitte-isheemiline südamelihase kahjustuse marker kirurgilisel haigetel, sealhulgas erakorralised ägeda kõhuvaluga pöördunud patsiendid ning raske traumaga patsiendid.

Konkreetsed eesmärgid olid järgnevad:

1. Hinnata kolme kvaliteediindikaatorit – aeg erakorralise meditsiini osakonnas, valu hindamine ja dokumenteerimine ning valu leevendamine täiskasvanud patsientidel, kes pöördusid erakorralise meditsiini osakonda ägeda kõhuvalu kaebusega.
2. Kirjeldada, millistel ägeda kõhuvalu kaebusega pöördunud erakorralistel patsientidel kahtlustatakse südamelihase kahjustust praeguses kliinilises praktikas. Analüüsida, kas vereseerumi tõusnud kõrgtundliku troponiini tase on seotud halvema prognoosiga selles patsientide rühmas.
3. Hinnata kõrgtundliku troponiini taseme tõusu prognostilist väärtust patsientidel, kellel esineb raske rindkere tõmprauma.

#### **Patsiendid ja meetodika**

Uurimustöö põhineb kahel erakorralise meditsiini patsientide kohordil. Esiteks, täiskasvanud patsiendid, kes pöördusid ägeda kõhuvalu kaebusega ja teiseks raske rindkere tõmpraumaga patsiendid. Haiged kaasati retrospektiivselt Tartu Ülikooli Kliinikumist ning Põhja-Eesti regionaalhaiglast.

Ägeda kõhuvaluga patsiendid, sissearvamiskriteeriumid:

- Äge kõhuvalu kaebus
- Vanus üle 30 eluaasta
- Triaažikategooria kollane, oranž või punane

Ajavahemikul 01. jaanuar 2018 – 07. märts 2018 identifitseeriti 1000 patsienti, 500 patsienti mõlemast haiglast.

Raske rindkere tõmpraumaga patsiendid, sissearvamiskriteeriumid:

- Raske tõmprauma (ISS >15)
- Raske rindkeretrauma (rindkere AIS  $\geq 3$ )
- Vanus  $\geq 18$  eluaasta

Ajavahemikul 01. jaanuar 2015 – 01. juuli 2017 identifitseeriti 147 patsienti.

Võrdlusgrupina identifitseeriti raske tõmpraumaga patsiendid (ISS >15) ilma kaasuva raske rindkere tõmpraumata (rindkere AIS <3).

- I Uuringus hinnati retrospektiivselt kolme kvaliteediindikaatorit – aeg erakorralise meditsiini osakonnas, valu hindamine ning valuravi rakendamine ägeda kõhuvaluga patsientidel.
- II Uuringus uuriti retrospektiivselt südamelihase kahjustuse testimist biomarkeri, kõrgtundliku südamespetsiifilise troponiini abil praeguses kliinilises praktikas ägeda kõhuvaluga patsientidel. Samuti südamelihase kahjustuse esinemist ning selle prognostilist väärtust mitte kardiaalse profiiliga haigetel. Troponiini tase vereseerumis määrati 375 patsiendil.
- III Uuringus hinnati retrospektiivselt kõrgtundliku südamespetsiifilise troponiini määramist potentsiaalselt traumaatilise südamelihase kahjustusega patsientidel ning biomarkeri prognostilist väärtust raske traumaga patsientidel. Troponiin oli määratud 82 tõsise rindkere vigastusega patsiendil.

## Tulemused ja järeldused

### 1. Kvaliteediindikaatorid

- Suur osa kõrge triaazikategooriaga patsiente viibis erakorralise meditsiini osakonnas kauem kui 360 minutit.
- Suur osa patsientidest, kes viibisid erakorralise meditsiini osakonnas üle 360 minuti, olid hospitaliseerimist vajavad patsiendid. See viitab olulistele puudustele erakorraliste haigete raviteekonnal.
- Riskifaktorid pikaks erakorralise meditsiini osakonnas viimise ajaks olid vanem iga ning kirurgi konsultatsiooni vajadus. See viitab vanemate, potentsiaalselt mitmete kaasuvate haigustega patsientide ravikeerukusele ning puudustele käsitluse protsessis.
- Pikem aeg erakorralise meditsiini osakonnas on iseseisev suremuse riskifaktor.
- Valu tugevus oli dokumenteeritud veidi rohkem kui pooltel patsientidest. Neljandik patsientidest, kes hindasid oma valu tugevaks või väga tugevaks (valu tugevus  $\geq 7$  10 palli skaalal), ei saanud valuravi erakorralise meditsiini osakonnas. Vanurid on riskigrupp, kelle valu tugevus ei ole dokumenteeritud ning on seetõttu ka potentsiaalselt alaravitud.

### 2. Praeguses kliinilises praktikas hinnatakse mitte-isheemiline südamelihase kahjustuse esinemist pigem vanematel ja kaasuvate kardiovaskulaarsüsteemi

haigustega patsientidel, samuti sepsisega ning haiglaravi vajavatel patsientidel. Südamelihase kahjustus esines märgataval osal patsientidest ning vere-seerumi tõusnud troponiini tase oli iseseisev suremuse riskifaktor.

3. Rindkere raske tõmptraumaga patsientidel esineb sageli kaasuv kliiniliselt oluline südamelihase kahjustus, mis võib vajada kirurgilist sekkumist või vasoaktiivset ja inotroopset ravi. Troponiini määramine ja elektrokardiogrammi registreerimine on hästi kättesaadavad, kuid alakasutatud esmased testid südamelihase vigastuse identifitseerimiseks. Tõusnud kõrgtundliku troponiini tase on seotud suurema suremusega tõsise rindkeretraumaga patsientidel.

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## **PUBLICATIONS**

# CURRICULUM VITAE

Name Triinu Keskpaik  
Date of birth December 5, 1987  
E-mail triinu.keskpaik@kliinikum.ee

## Education

1994–2003 Tori Primary School  
2003–2006 Pärnu Sütevaka Humanitaargümnaasium  
2006–2012 University of Tartu, Faculty of Medicine  
2012–2016 University of Tartu, residency in emergency medicine  
2017–2023 University of Tartu, doctoral studies, medicine

## Professional career

2012–2016 Tartu Ambulance, physician  
2013–2019 Pärnu Hospital, physician, emergency medicine physician  
2013–2016 Estonian Military Academy, department of War and Disaster  
Medicine, lecturer  
2014–2021 Tartu Health Care College, lecturer  
2016 Estonian Defence Forces, 1st Infantry Brigade, medical officer/  
emergency medicine physician at UN peacekeeping mission in  
South Lebanon  
2019 Estonian Defence Forces, Joint Headquarters, medical branch  
officer at European Union operation *EU NAVFOR Med opera-  
tion SOFIA*  
2017– Tartu University Hospital, emergency medicine department,  
emergency medicine physician  
2017– North Estonia Medical Centre Foundation, ambulance centre,  
emergency medicine physician  
2018– University of Tartu, Institute of Clinical Medicine, lecturer  
2022– University of Tartu, Faculty of Medicine, emergency medicine  
residency programme director

## Research and development work

Main fields of research: Emergency medicine quality indicators. Non-ischemic myocardial injury in emergency medicine.

## A list of publications

Keskpaik, T., Starkopf, J., Kirsimägi, Ü., Mihnovitš, V., Lomp, A., Raamat, E. M., Saar, S., & Talving, P. (2020). The role of elevated high-sensitivity cardiac troponin on outcomes following severe blunt chest trauma. *Injury*, 51(5), 1177–1182.  
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### **Scholarships**

2014 Estonian Society of Emergency Physicians scholarship

2015 Estonian Medical Association scholarship

2022 Estonian Society of Emergency Physicians scholarship

### **Other administrative and professional activities**

2012– Estonian Society of Emergency Physicians, member

2012– Estonian Junior Doctors', member

2016– Union of Estonian Medical Emergency, board member

# ELULOOKIRJELDUS

Nimi Triinu Keskpaik  
Sünniaeg 5. detsember 1987  
E-post triinu.keskpaik@kliinikum.ee

## Haridus

1994–2003 Tori Põhikool  
2003–2006 Pärnu Sütevaka Humanitaargümnaasium  
2006–2012 Tartu Ülikool, meditsiiniteaduste valdkond  
2012–2016 Tartu Ülikool, erakorralise meditsiini residentuur  
2017–2023 Tartu Ülikool, meditsiiniteaduste valdkond

## Teenistuskäik

2012–2016 SATartu Kiirabi, üldarst  
2013–2019 SA Pärnu Haigla, üldarst, erakorralise meditsiini arst  
2013–2016 Kaitseväge Akadeemia, Sõja- ja katastroofimeditsiinikeskus, lektor  
2014–2021 Tartu Tervishoiu Kõrgkool, lektor  
2016 Eesti kaitseväge, 1 jalaväebrigaad, meditsiiniohvitser/Eesti kontingendi arst ÜRO rahuvalvemissioonil Lõuna-Liibanonis  
2019 Eesti Kaitseväge, Peastaap, Euroopa Liidu operatsioon *EU NAVFOR Med operation SOFIA*, staabiohvitser  
2017– Tartu Ülikooli Kliinikum, erakorralise meditsiini osakond, arst-õppejõud erakorralise meditsiini erialal  
2017– Põhja-Eesti Regionaalhaigla, reanimobiili osakond, erakorralise meditsiini arst  
2018– Tartu Ülikool, Kliinilise meditsiini instituut, assistent  
2022– Tartu Ülikool, Meditsiiniteaduste valdkond, erakorralise meditsiini residentuuri üldjuhendaja

## Teaduslik ja arendustegevus

Peamised uurimisvaldkonnad: Erakorralise meditsiini kvaliteediindikaatorid. Südamelihase mitte-isheemiline kahjustus erakorralise meditsiini patsientidel.

## Publikatsioonid

Keskpaik, T., Starkopf, J., Kirsimägi, Ü., Mihnovitš, V., Lomp, A., Raamat, E. M., Saar, S., & Talving, P. (2020). The role of elevated high-sensitivity cardiac troponin on outcomes following severe blunt chest trauma. *Injury*, 51(5), 1177–1182.

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**Saadud uurimistoetused ja stipendiumid**

- 2014 Eesti Erakorralise Meditsiini Arstide Seltsi koolitusstipendium
- 2015 Eesti Arstide Liidu koolitusstipendium
- 2022 Eesti Erakorralise Meditsiini Arstide Seltsi koolitusstipendium

**Muu teaduslik organisatsiooniline ja erialane tegevus**

- 2012– Eesti Erakorralise Meditsiini Arstide Seltsi liige
- 2012– Eesti Nooremarstide Ühenduse liige
- 2016– Eesti Kiirabi Liidu juhatuse liige

## DISSERTATIONES MEDICINAE UNIVERSITATIS TARTUENSIS

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