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The Repercussions of Healthcare-Associated Infections on Patients with Traumatic Brain Injuries: A Four-Years Study on Forensic Autopsies in Timiș County, Romania

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Highlights

What are the main findings?

- Even when patients with traumatic brain injuries and chronic illnesses receive appropriate care in the hospital, potential infectious complications may worsen their condition.
- The forensic autopsy findings in the studied cohort indicate a markedly increased prevalence of nosocomial infections in patients with cranial-cerebral injuries compared to those diagnosed clinically.

What is the implication of the main finding?

- In cases of intricate, multivariate pathology, forensic doctors may face challenges in ascertaining the cause of death and the influence of the patient's each condition on the determination of decease.
- Healthcare-associated infections frequently modify the causal relationship between traumatic injuries and the victim's demise, resulting in legal repercussions.

Abstract

Background/Objectives: When a patient dies and a complex pathology is identified, it can be difficult to ascertain the cause of death and the contribution of each ailment to the dying process. Patients with traumatic brain injuries often represent the best hosts for healthcare-associated infections, especially pneumonia or bronchopneumonia. Additionally, some of these ones also have pre-existing chronic diseases, which can influence their medical evolution. Therefore, many factors need to be carefully analyzed by the forensic doctor when establishing the cause of death. The purpose of this study is to demonstrate the crucial role a forensic autopsy plays in accurately identifying the cause of death and diagnosing all of a patient's ailments, particularly in cases involving nosocomial infections, while emphasizing the significant number of cases where healthcare-associated infections can lead to mortality. **Methods**: We conducted a retrospective analysis that included cases with

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cranial-cerebral traumas, pre-existing chronic diseases, and hospital-acquired infections that were autopsied at the Forensic Medicine Institute in Timișoara between January 1, 2018, and December 31, 2021. We studied the autopsy reports and the medical documentation of the patients. **Results:** Our research indicates that patients with traumatic brain injuries and non-traumatic conditions face a considerable risk of acquiring healthcare-associated infections, especially pneumonia or bronchopneumonia, even with adequate medical treatment. A significant part of these infectious issues remains unrecognized while hospitalization; however, autopsy can elucidate them. **Conclusions**: This study demonstrates a high prevalence of healthcare-associated infections in patients with brain injuries, as well as how these infections can alter the progression of traumatic disorders and their mortality rate.

Keywords: trauma; traumatic brain injuries; healthcare-associated infections; chronical diseases; mortality; causality

1. Introduction

Healthcare-associated infections (HAIs), also known as nosocomial infections, represent a major global public health concern, significantly affecting morbidity, mortality, and healthcare costs. According to the most recent WHO global report, in low- and middle-income countries, 1 in 4 hospitalized patients acquires at least one HAI, and up to 1 in 10 dies as a result. Globally, 7 out of 100 hospitalized patients in acute care settings develop an HAI, with this proportion increasing to 15% in intensive care units [1].

HAIs are a common problem in forensic practice due to the nature of the work, especially in patients who are hospitalized after suffering serious traumatic brain injuries that necessitate lengthy hospital stays, which frequently involve surgery.

Even with appropriate treatment during hospitalization, the impact of the traumatic agent may be exacerbated by possible infection problems. Furthermore, the patient's progression can frequently be adversely impacted by the prior pathological conditions. When determining the cause of death, these factors must be considered, as they play a crucial part in the death process.

Despite significant progress in prevention and treatment over the years, trauma remains a major global public health concern, with 60% of deaths happening during the first few hours of hospital admission [2].

Annually, around 10 million individuals are impacted by traumatic brain injuries (TBIs). Notwithstanding initiatives to enhance treatment for TBIs, they persist as a public health issue, resulting in elevated mortality and morbidity among the youth [3].

In terms of brain damage following a head injury, the development of TBI has been split into two main stages from a neuro-pathological perspective: primary damage, which happens at the time of the injury and includes things like scalp abrasions, skull fractures, contusions and brain lacerations, diffuse axonal injuries, and intracranial hemorrhage; and secondary damage, which is brought on by complex processes that are started at the time of the injury but are not immediately apparent, such as brain damage from increased intracranial pressure, ischemia, swelling, and infection [4].

Cranial trauma cases are categorized as minor, moderate, or serious in routine clinical practice based on a set of triage criteria for treatment. Such a classification won't apply in trauma forensics because a slight trauma that can be easily ignored may have huge medico-legal implications, whereas a major trauma may have little or no forensic significance. Therefore, forensic practitioners need to classify trauma in a way that is appropriate, understandable to the legal system, and could reveal the cause [5].

The fact that most patients may be at an age where they are more likely to suffer from chronic illness is one of the issues brought up by intracranial injuries. For similar levels of injury, elderly patients have twice the mortality rate and greater morbidity compared with young individuals, because of significant comorbidities and related therapies. Patients over 65 years of age are an

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increasingly affected group, and they are more likely to die of medical complications late during hospital admission [6].

Second, treating patients with intracranial injuries is made more challenging by the fact that they frequently also have injuries to other body areas. Even if they survive surgery, these individuals may pass away from both the decompensation of their body and complications from their injuries. Some of the victims pass away due to their bed conditions following their injuries—such as the onset of pneumonia—rather than their injuries itself [7].

About 6% of trauma patients experience HAIs, with pneumonia—including ventilator-associated pneumonia—being the most prevalent kind [8].

A nosocomial infection's likelihood is not always correlated with the extent of the traumatic injury. Even if a patient's damage is modest, they still need to pay more attention to infectious issues [9].

Over 25% of trauma victims suffer from an undiagnosed or untreated chronic medical and/or mental health condition, which might worsen their short- and long-term results. A chronic deadly trifecta of trauma may be created if these physiological and mental illnesses, which are aggravated or triggered by traumatic injuries, are exacerbated by unfavorable social circumstances or infectious complications [10].

A customized strategy and a comprehensive evaluation of the severity of traumatic injuries, the patient's medical history, and their clinical progression during hospitalization are necessary in situations of complicated and multifaceted pathology, especially traumatic. Therefore, many factors need to be carefully analyzed by the forensic doctor when establishing the cause of death in patients with severe injuries, concurrent chronic diseases, and healthcare-associated infections. The interpretation of all the patient’s conditions is then followed by the explanation of the findings pertaining to the cause of death, the type of death, the causal relationship between traumatic injuries and death, and the part played by each ailment in the death process.

Causality is crucial in forensic medicine when dealing with deceased patients because the patient's passing is always the first consequence we encounter. Causality aids in identifying the conditions and factors that resulted in the cause of death. This facilitates the formulation of a logical, rational, and objective response to inquiries presented by the judicial system [11].

A complication that arises as a direct result of an infection acquired during hospitalization, or in any case, while receiving medical care, may constitute grounds for liability on the part for the healthcare institution, potentially entitling the affected patient to compensation [12].

2. Materials and Methods

We conducted a retrospective analysis that included cases that were autopsied at the Timișoara' Forensic Medicine Institute between January 1, 2018, and December 31, 2021.

2460 autopsy reports were examined, and those that satisfied the following three inclusion criteria were chosen: suffered a cranial-cerebral trauma that required more than 48 hours in the hospital; presented with one or more chronic diseases upon admission, diagnosed during hospitalization, or identified at autopsy; and, acquired a healthcare-associated infection that was detected either clinically or postmortem. 165 cases met all three inclusion requirements.

Exclusion criteria include medical-legal autopsy records for people without a history of cranial-cerebral traumas, chronic illnesses, or nosocomial infections.

We studied the autopsy reports, including histopathological examination results, and the medical documentation of the patients.

The following parameters were examined: the patients' age and gender, the context of traumatic injuries, the health unit and ward where they were admitted, the length of their hospital stay, the type of traumatic injuries they experienced, any pre-existing illnesses prior to hospitalization, complications that occurred during hospitalization, whether the patient had undergone surgery or other invasive procedures, clinical diagnosis of healthcare-associated infection and microbiological test results, traumatic injuries found at autopsy, non-traumatic somatic conditions found at autopsy,

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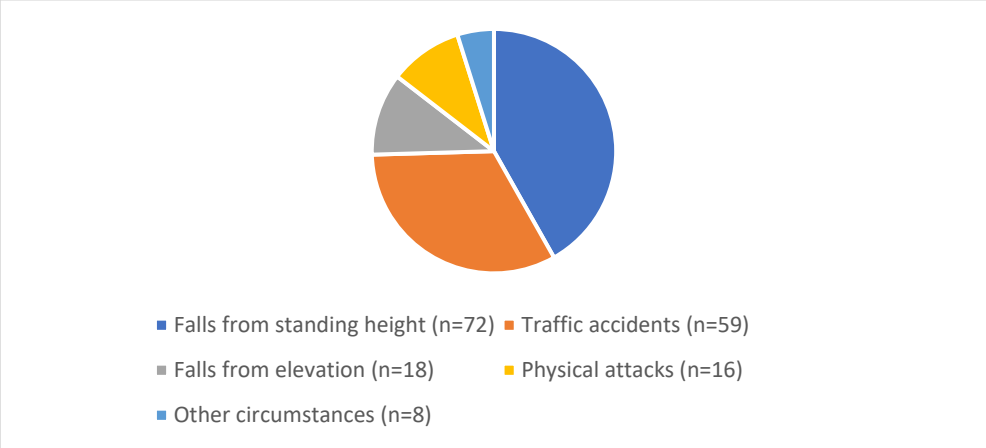
autopsy indicators of healthcare-associated infections, and results of histopathological examinations. Additionally, we analyzed the cause of death and the causal relationship between traumatic injuries, pathological states, nosocomial infections and death.

We are obliged to mention some limitations of the study, including the summary medical documentation, the lack of microbiological tests during hospitalization in some cases, the absence of testing for fungus and viruses, and the impossibility to perform postmortem microbiological tests in our institute, which could represent an objective proof of a nosocomial infection.

3. Results

We analyzed 165 cases autopsied at the Forensic Medicine Institute in Timișoara, which experienced cranial-cerebral injuries, acquired healthcare-associated infections, and exhibited non-traumatic diseases.

The circumstances surrounding traumatic injuries were: falls from standing height, traffic accidents, falls from elevation, and physical attacks.



The male-to-female ratio was 1.6:1 (102 male and 63 female patients).

The patients' ages varied from 7 to 103 years, with a median age of 68.

According to the hospital of admission, all patients were from Neurosurgery Department of the Emergency County Hospital "Pius Brânzeu" Timișoara (ECHPBT).

The average length of stay was 29.66 days, with a range of 2 to 297 days.

To improve the study's clarity, we categorized all patient information into the following categories: hospitalization data, autopsy findings, histological examination results, and autopsy reports conclusions.

3.1. Hospitalization Data

The Neurosurgery Department of the Emergency County Hospital "Pius Brânzeu" Timișoara (ECHPBT) was the hospital of admission for all of the 165 patients in our cohort.

The types of traumatic injuries that patients had at admission, pre-existing conditions found prior to or during hospitalization, complications that developed during hospitalization, whether the patient had surgery or other invasive procedures, clinical diagnoses of infections linked to healthcare, and microbiological test results were all examined in the medical records.

3.1.1. Traumatic Injuries Diagnosed Upon Admission

One hundred ant twenty-three individuals sustained solely brain traumas, 7 experienced spinal damage, and the remaining 35 patients presented with mixed injuries. Most patients exibited acute subdural hematomas, skull fractures, subarachnoid hemorrhage and cerebral contusions, in the vast majority of cases these being associated.

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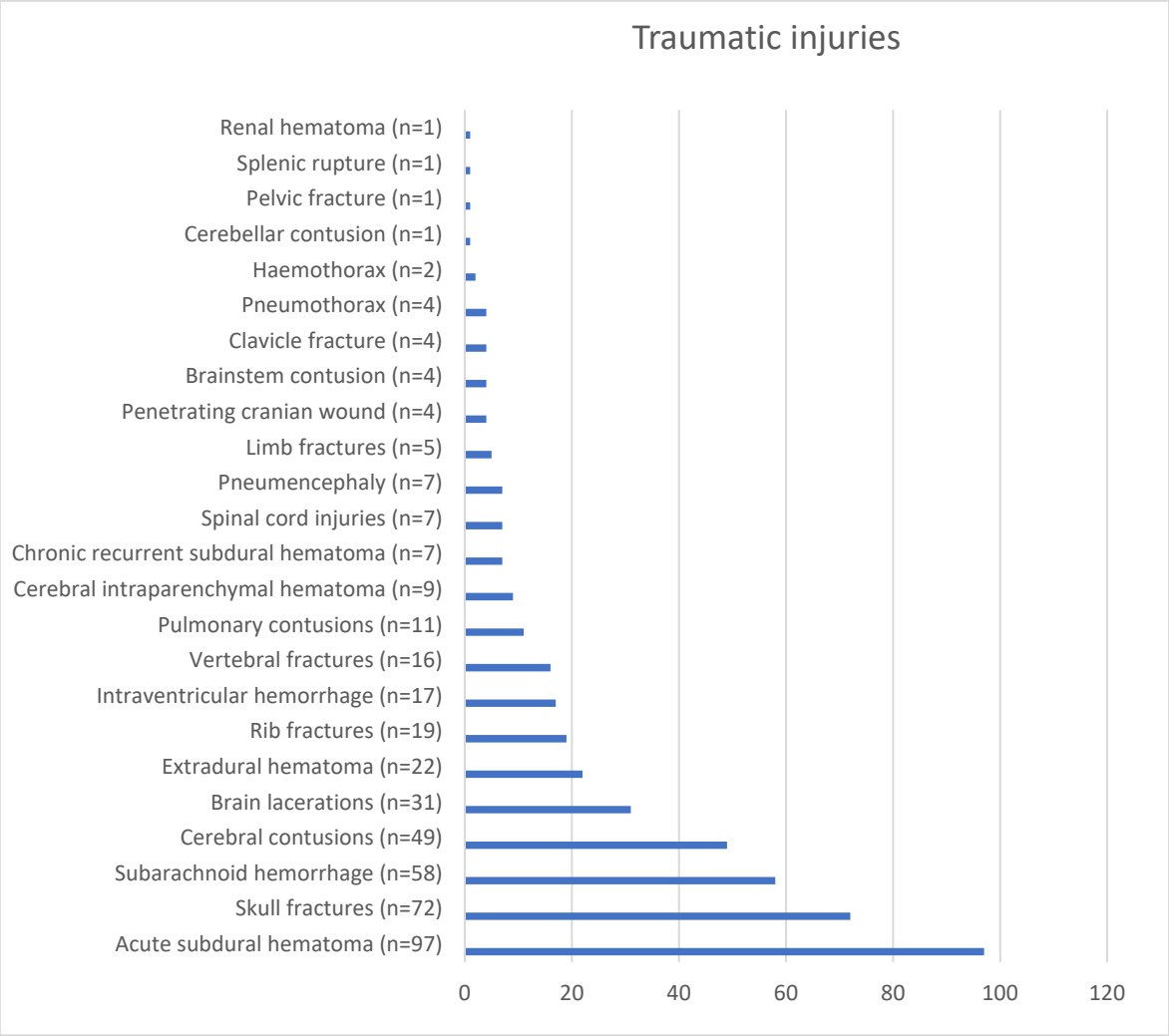

3.1.2. Non-Traumatic Chronic Conditions of the Patients

In 69.09% of cases (n=114), chronic illnesses were identified at or during hospital stays.

The most common were cardiovascular diseases, followed by diabetes and chronic alcoholism. Ischemic stroke and cerebral atrophy were the most prevalent non-traumatic brain disorders.

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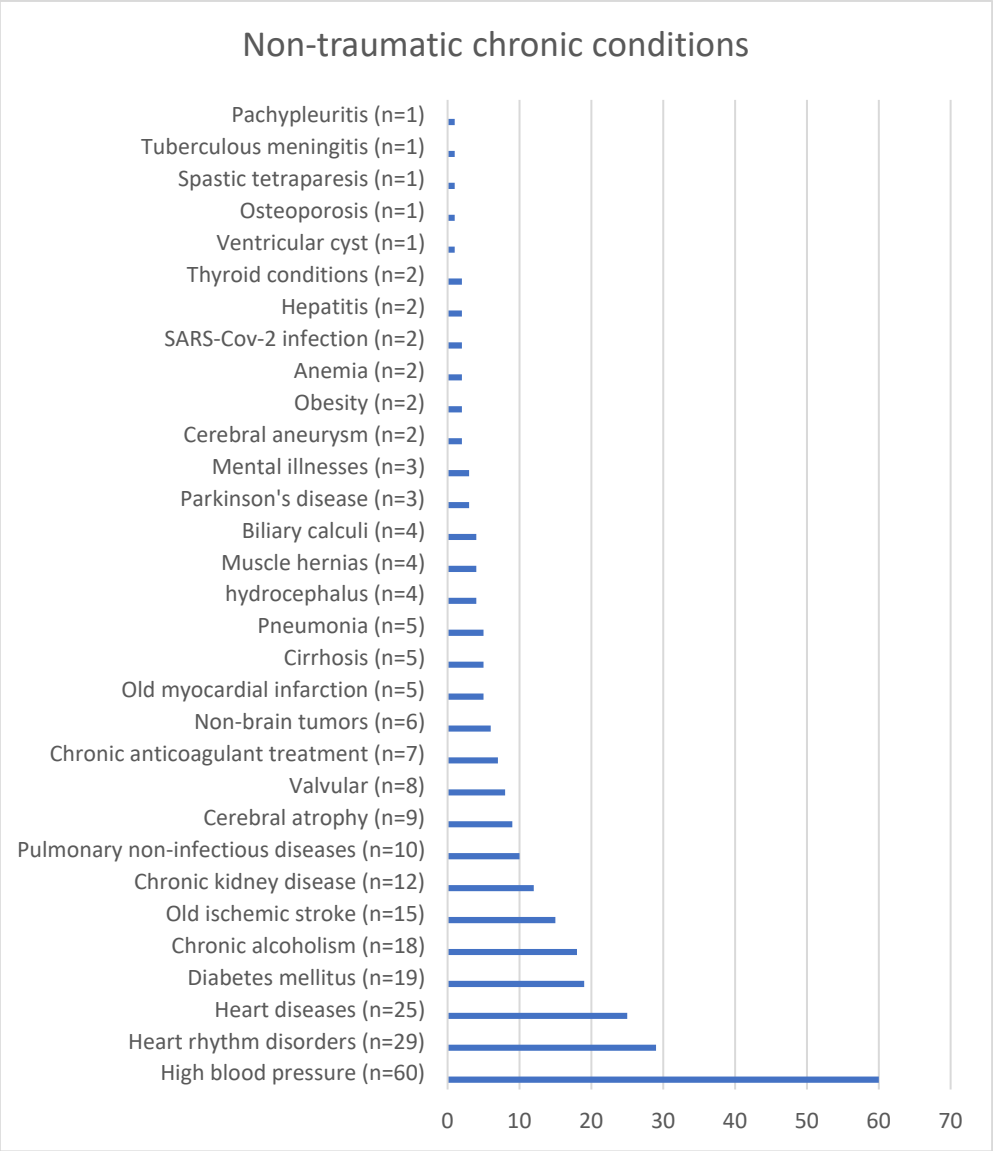

3.1.3. Surgical Procedures Conducted During Inpatient Care

71,51% of patients (n=118) had surgery while they were in the hospital.

79 of the 97 individuals with acute subdural hematomas and 16 of the 22 patients with acute extradural hematoma required surgical intervention.

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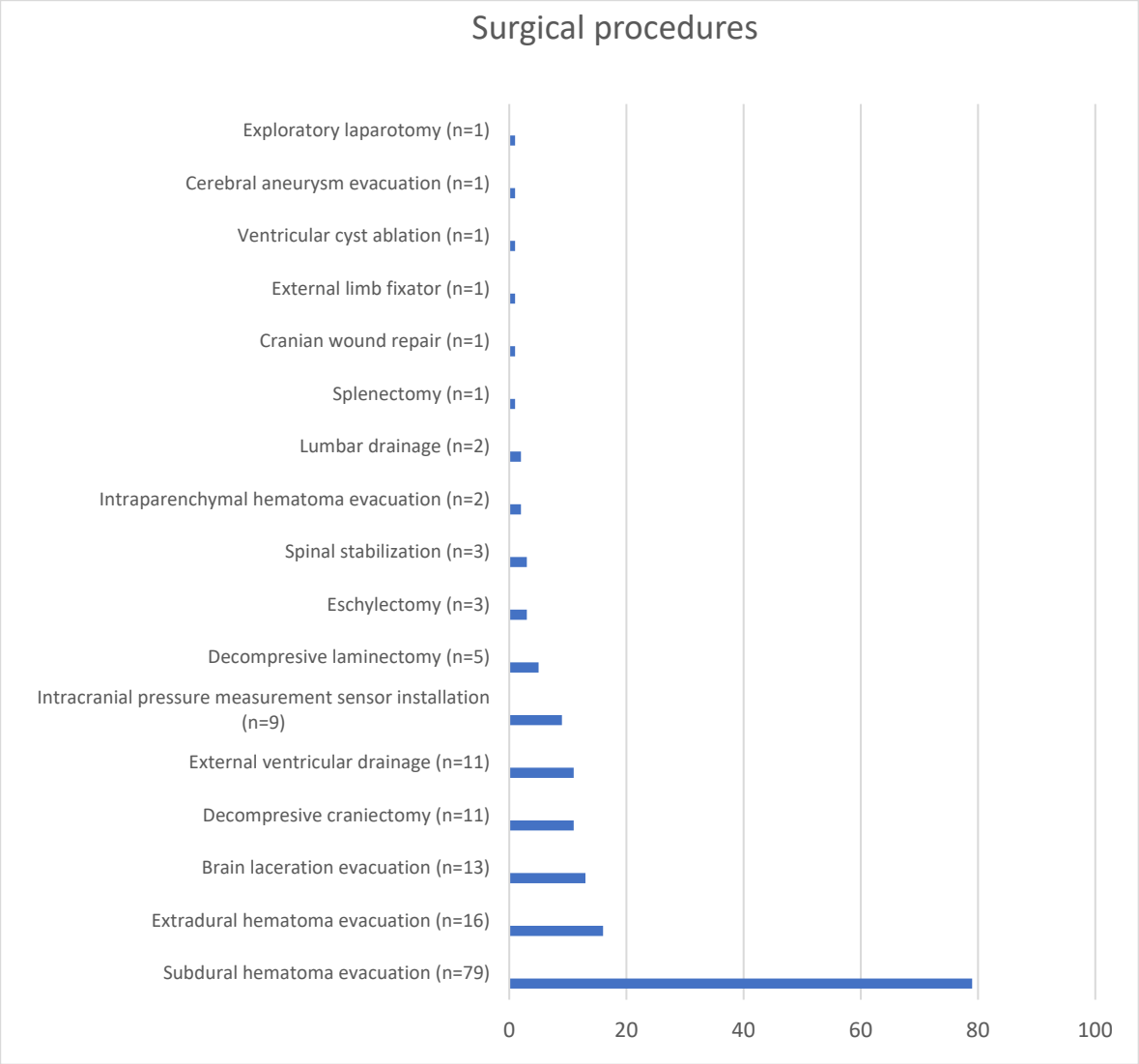
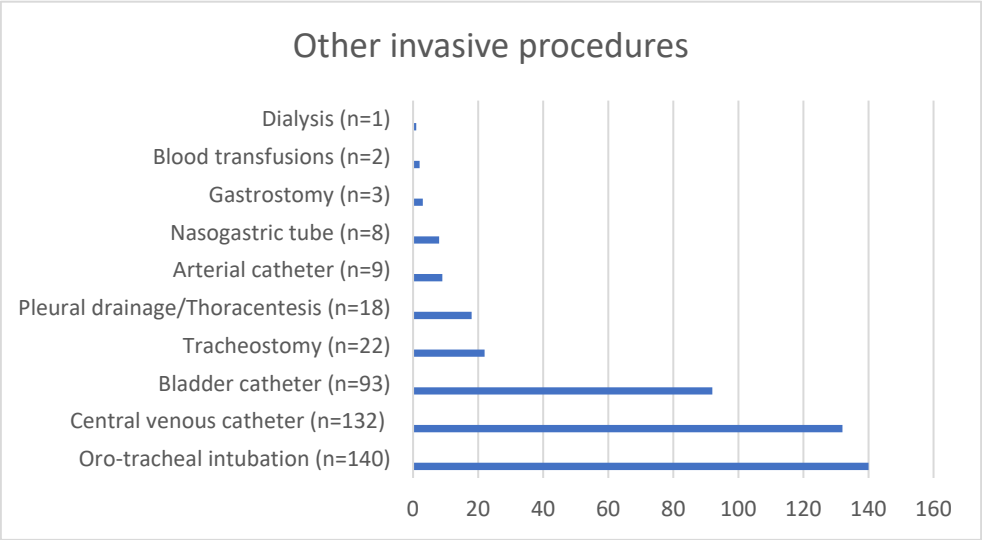


3.1.4. Additional Invasive Procedures Performed During Hospitalization

All patients in this research experienced one or more invasive procedures during their stay.

Outside of surgery, 140 patients needed orotracheal intubation; 23 of them needed it the entire time they were in the hospital.



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3.1.5. Infections Acquired During Hospitalization

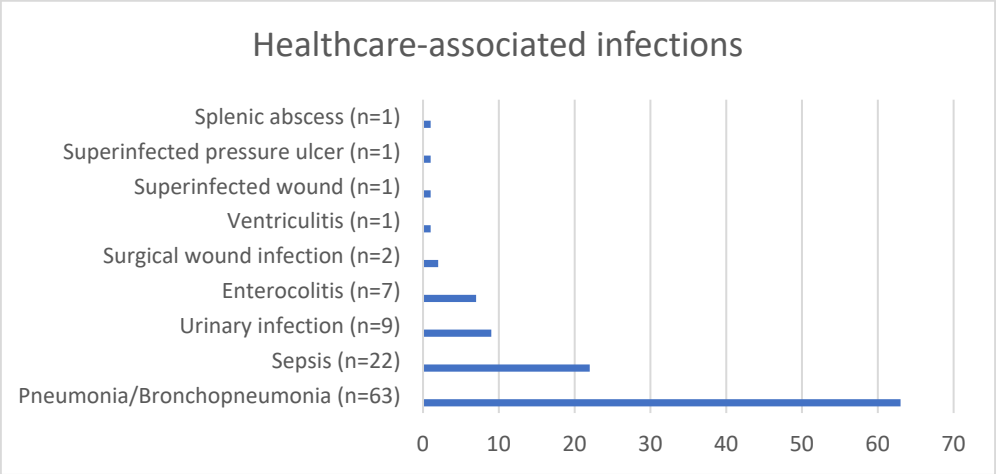
Microbiological assays were used to diagnose nosocomial infections in 76 individuals (46.06% of cases) while they were in the hospital. Bronchial aspirate, blood, urine, wound secretions, cerebrospinal fluid, and splenic abscess were among the samples examined.

60 individuals acquired a singular form of nosocomial infection, while the remaining 16 acquired two or more types.

Pneumonic-type condensation foci were found in 47 cases (28.48%) of those who did not undergo microbiological testing, according to imaging exams (lung X-ray, chest CT). Cases presenting pneumonia at admission, including SARS-CoV-2 pneumonia, were excluded.

The remaining 42 people were not diagnosed with hospital-acquired infections throughout their hospitalization.

According to microbiological or imaging testing, pneumonia was the most prevalent type of healthcare-associated infection, followed by sepsis.



Microbiological assays revealed a wide range of bacteria, the most common being Acinetobacter baumanii (Acinetobacter b.), Pseudomonas aeruginosa (Pseudomonas ae.), and Klebiella pneumoniae (Klebsiella pn.).

In cases with pneumonia/bronchopneumonia, 29 patients had a polymicrobial infection, whereas 34 patients had a single pathogen infection. 15 patients had sepsis caused by a single pathogen, while 7 cases were characterized by polymicrobial sepsis.

	Brochial aspirate culture	Blood culture	Urinalysis	Culture from surgical wound exudate	Cerebrospinal fluid culture	Culture from wound secretion	Culture from pressure ulcer secretion	Culture from splenic abscess
Acinetobacter b.	25	6		1	1	1		1
Pseudomonas ae.	16	1	1	1	1		1	
Klebsiella pn.	15	1	3	1				
Proteus mirabilis	11		1					
Staph. aureus	10							
Escherichia coli	3	1	1					
Enterococcus sp	2		3					
Other staphylococci	3	11						
Enterobacter ae.	2	2						
Providencia stuartii	2		3					
Klebsiella sp	2							
Candida albicans	2							
Proteus sp	1							
Serratia marcescens	1	1						
Klebsiella oxytoca	1		1					
Pseudomonas spp	1							
Bacillus cereus	1							
Stenotrophomonas m.	1							
Enterococcus faecalis		1						

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Candida parapsilosis	7	
Candida spp	3	1
Pseudomonas putida	1	

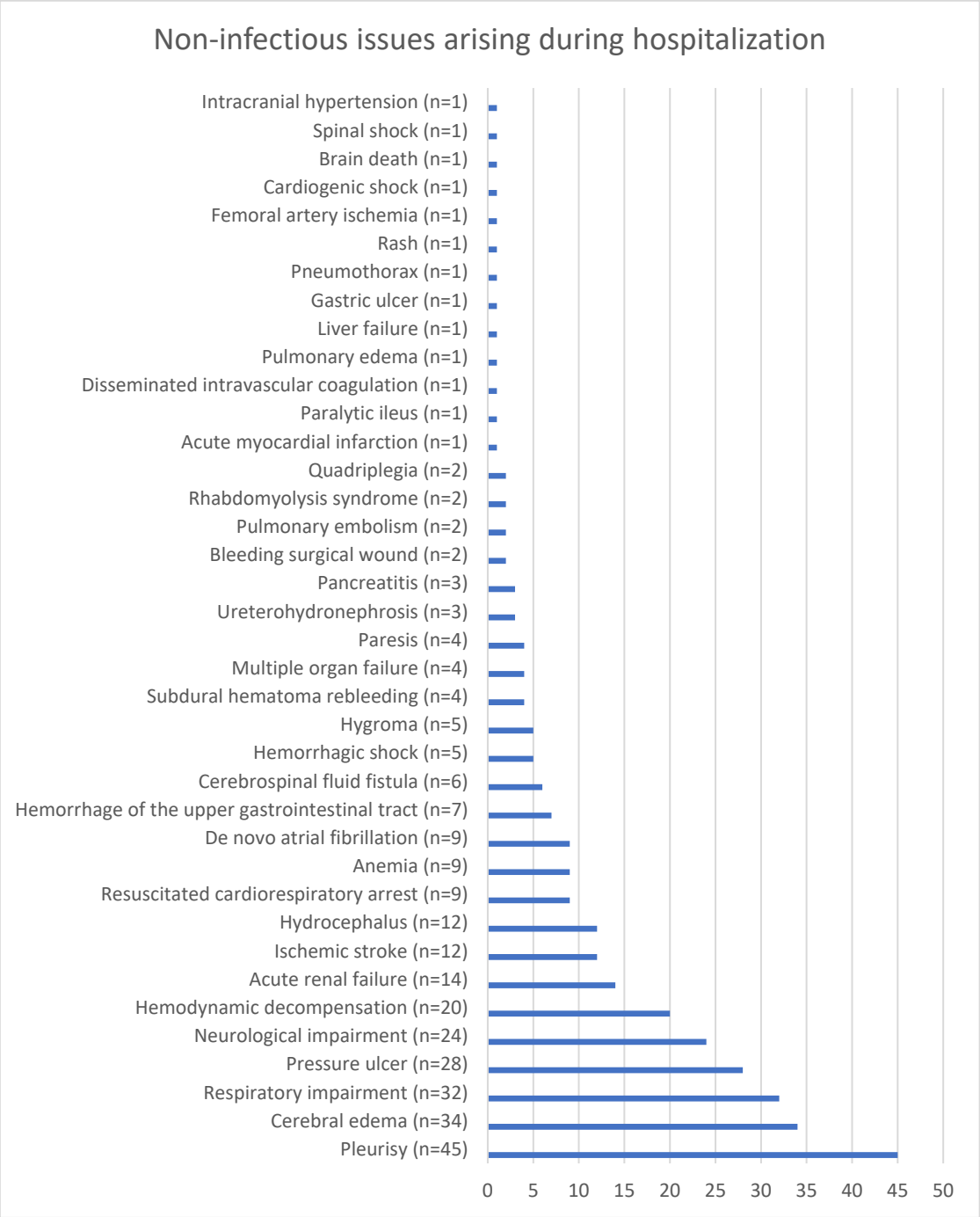
Additionally, nine patients had urinary infections and seven patients developed enterocolitis during hospitalization, corroborated by a positive Clostridium difficile toxin A+B test.

3.1.6. Non-Infectious Issues Occurring During Hospitalization

Besides HAIs, most patients experienced other problems during their hospitalization.

The predominant complication was pleurisy, frequently linked to bronchopneumonia, succeeded by cerebral edema, respiratory dysfunction, and pressure ulcers.

A few patients experienced potentially fatal complications while in the hospital, including pulmonary embolism, hemorrhagic shock, multiple organ failure, and resuscitated cardiorespiratory arrest.



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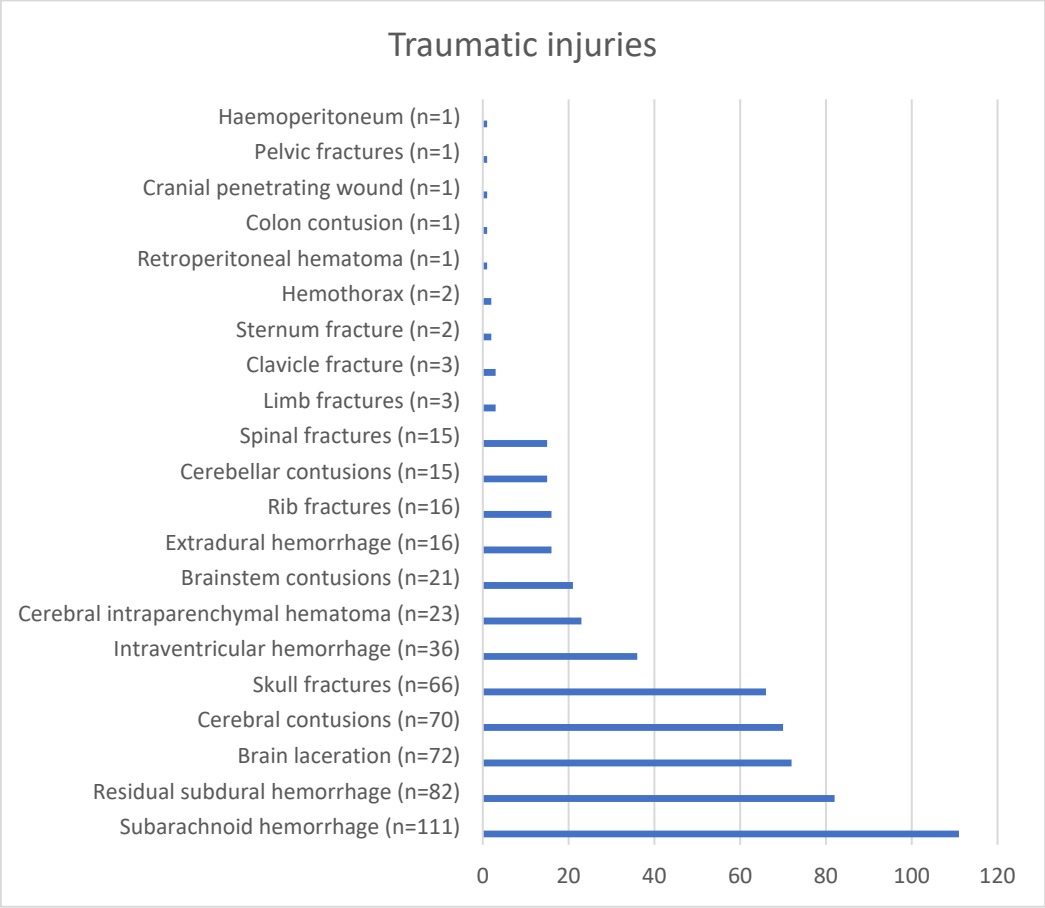
3.2. Autopsy Findings

Traumatic injuries, non-traumatic chronical conditions, healthcare-associated infection markers, non-infectious complications, and the cause of death were all tracked in autopsy reports of the above-mentioned cases.

3.2.1. Traumatic Injuries Identified During Forensic Autopsy

All patients involved had two or more types of traumatic injuries, except for two individuals who sustained simply a spinal fracture without any additional traumas. Subarachnoid hemorrhage was the most common traumatic injury discovered at autopsy, followed by subdural bleeding, brain contusions, brain lacerations, in the majority of instances corelated with skull fractures.

We mention that we did not include rib and sternum fractures that happened during resuscitation in the table with traumatic injuries.



3.2.2. Non-Traumatic Chronic Conditions Identified During Forensic Autopsy

The forensic autopsy identified one or more somatic disorders in each examined case. Myocardial fibrosis was observed in 75.75% of cases (n=125), predominantly in individuals over 50 years of age, followed by liver dystrophy, atherosclerosis, and chronic renal disease.

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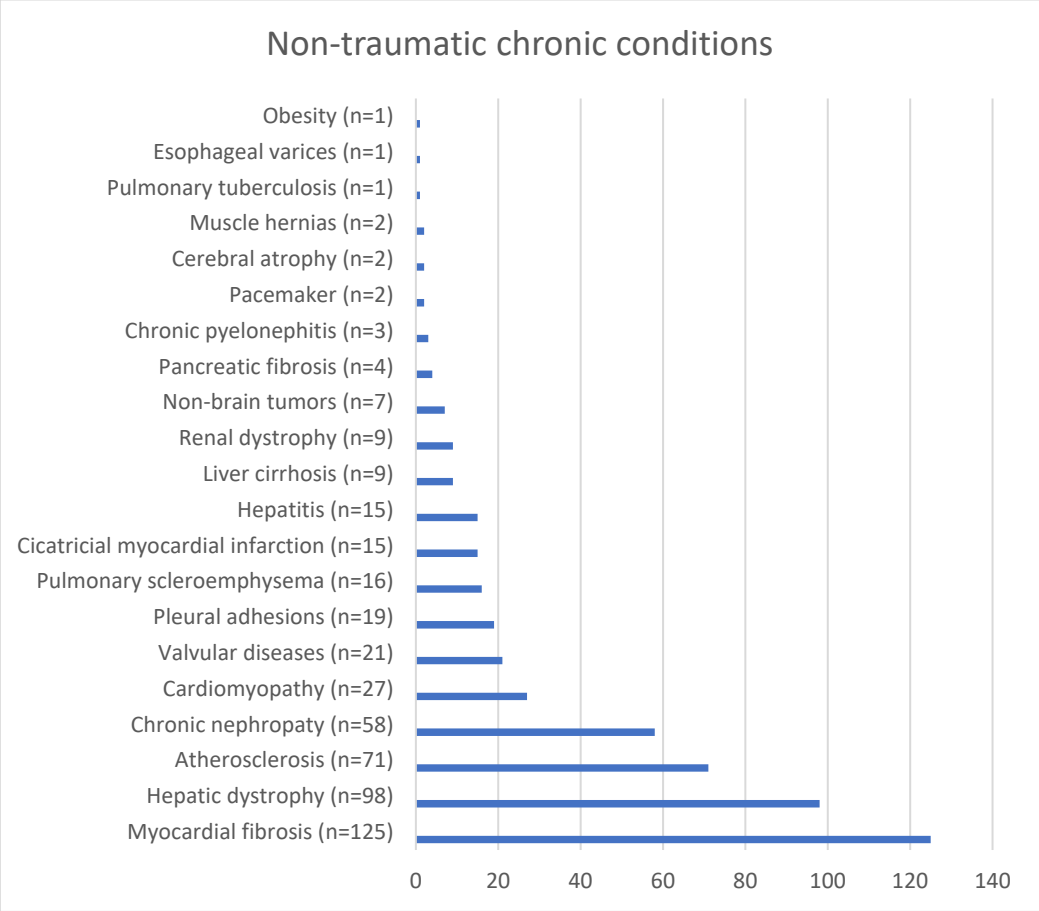
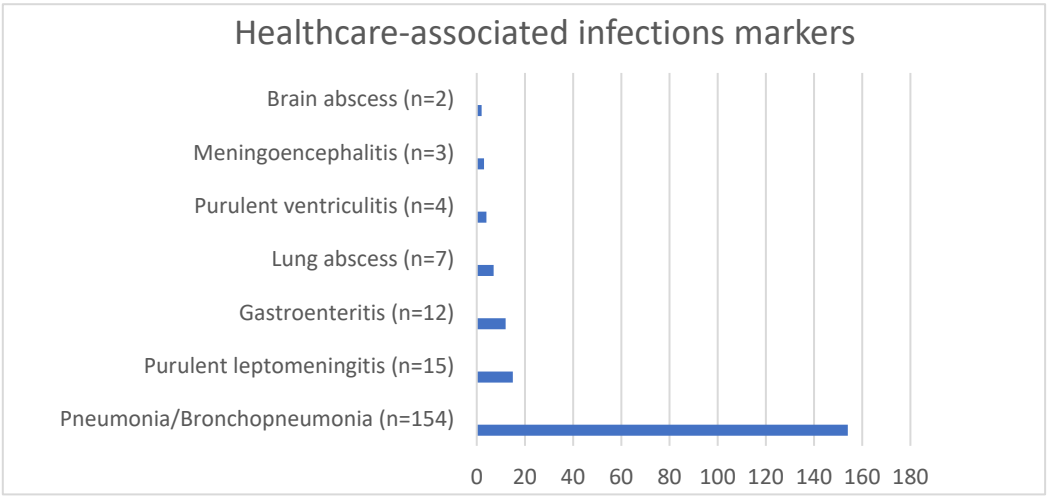


3.2.3. Healthcare-Associated Infection Markers Identified During Forensic Autopsy

In 154 of the 165 patients we looked at, we found indicators of infection. The most prevalent illness was pneumonia/bronchopneumonia, which was linked to another type of nosocomial infection in 22 cases. The presence of pus in the bronchioles, leptomeninges, cerebral ventricles, lung and brain abscesses, and localized inflammatory alterations was the most suggestive indicator of infection.



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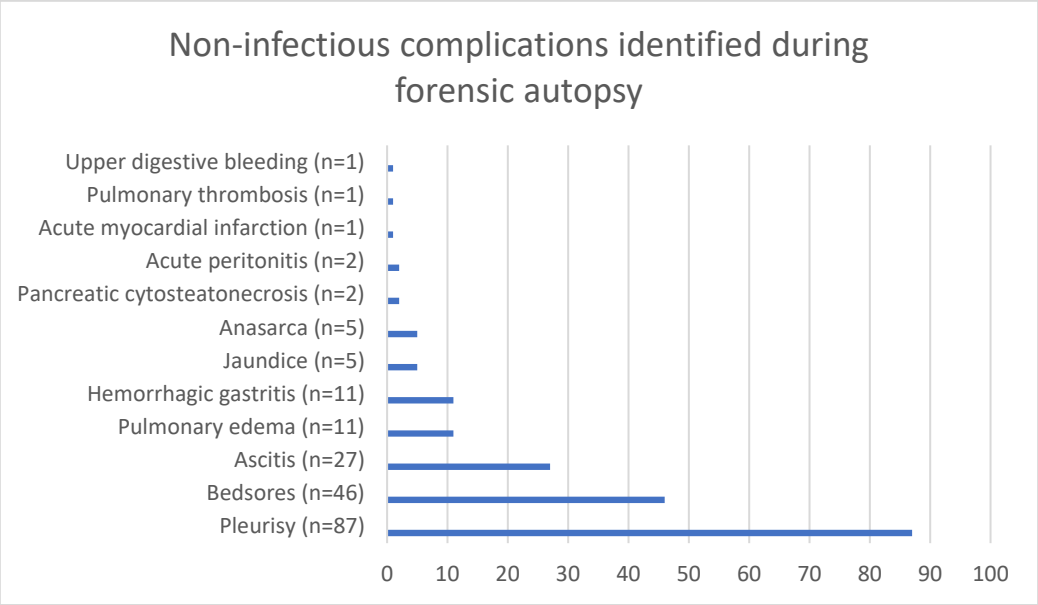
3.2.4. Non-Infectious Complications Identified Through Forensic Autopsy

Other acute diseases that did not fit the definition of traumatic injuries or infections were identified after the autopsy and were classified as complications that happened while the patient was in the hospital. Among these, pleurisy, bedsores, and ascites were the most prevalent.



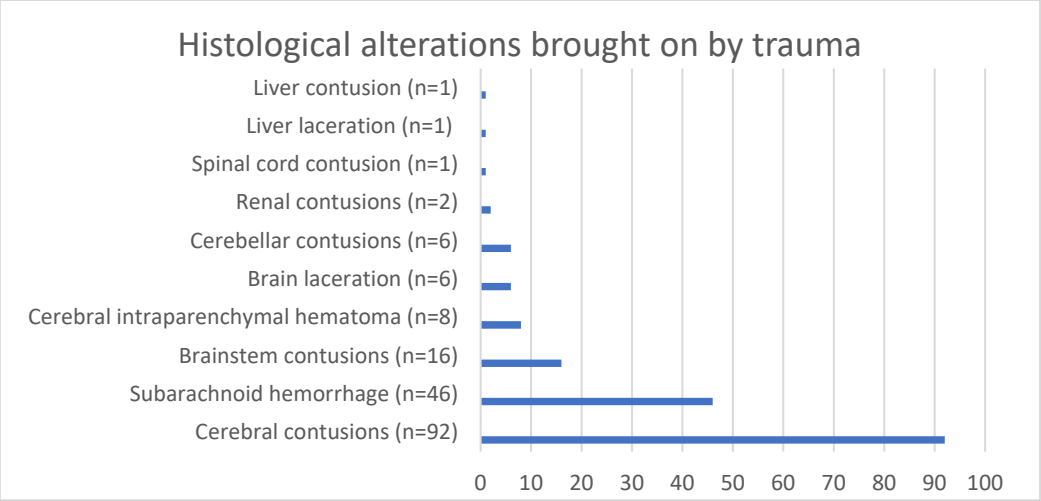
3.3. Histopathological Examination Results

In each instance of our cohort, a histological examination of organ fragments obtained after autopsy was pursued as an additional investigation. Paraffin was used to implant tissues, and 3 μm slides were cut and stained with hematoxylin and eosin.

The results of the histological examinations were divided into four groups: traumatic changes, non-traumatic chronic somatic disorders, nosocomial infection indicators, and markers of non-infectious hospitalization-related issues.

3.3.1. Histological Alterations Indicative of Trauma

In most cases, cerebral contusions and subarachnoid hemorrhage were found in the brain fragments that were examined. Additionally, macroscopic lesions in the cerebellum and brainstem were verified. In 46 cases traumatic brain injuries were accompanied by cerebral edema.



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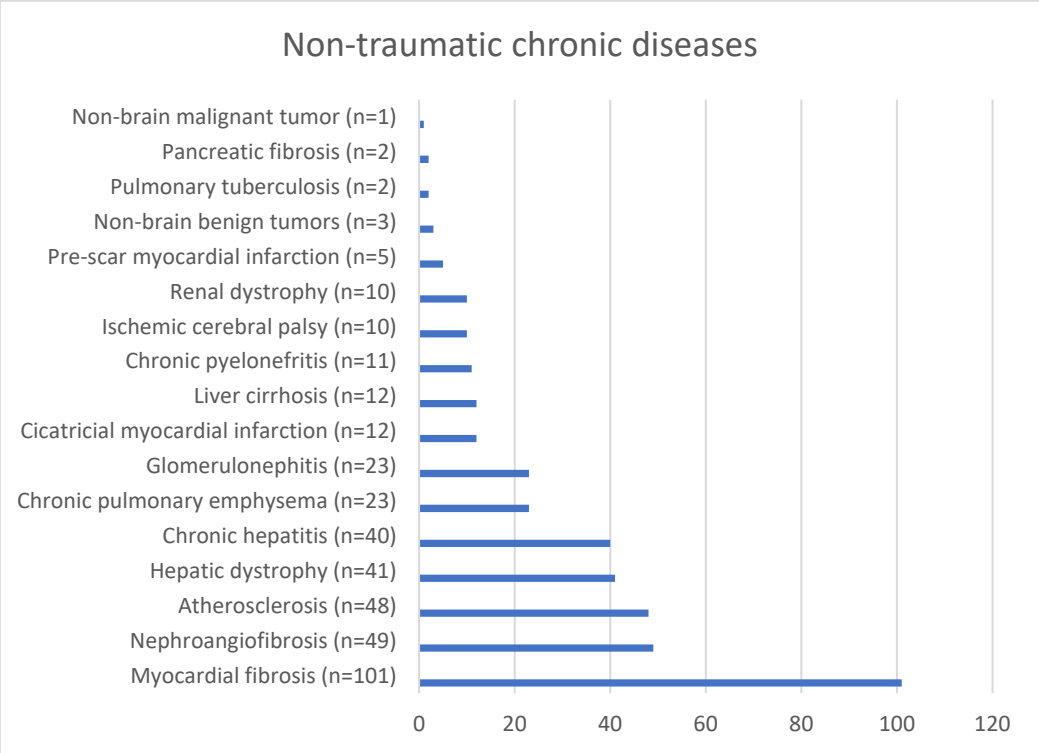
3.3.2. Non-Traumatic Chronic Somatic Disorders Identified Through Histological Analysis

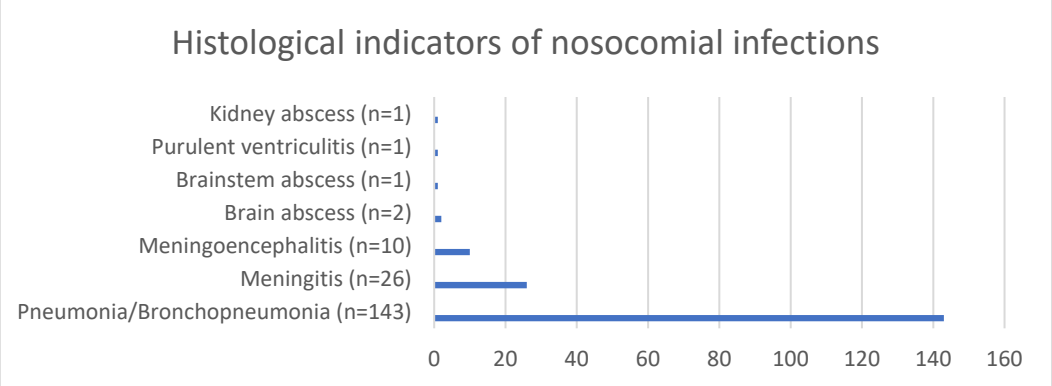
The most prevalent chronic condition seen under a microscope was myocardial fibrosis, which was followed by nephroangiofibrosis, atherosclerosis, hepatic dystrophy, and cirrhosis. In 10 cases, old ischemic cerebral palsies were evident.



3.3.3. Histological Indicators of Nosocomial Infections

Histopathological examination confirmed pneumonia in 143 cases out of the 154 diagnosed macroscopically. Meningitis, meningoencephalitis, and kidney, brain, and brainstem abscesses were further markers of infections acquired during hospitalization.

Hepatocyte necrosis in 26 instances and acute tubular necrosis in 82 cases were additional histological findings suggestive of infection, particularly septic shock. However, they were excluded from the following table due to their lack of specificity.



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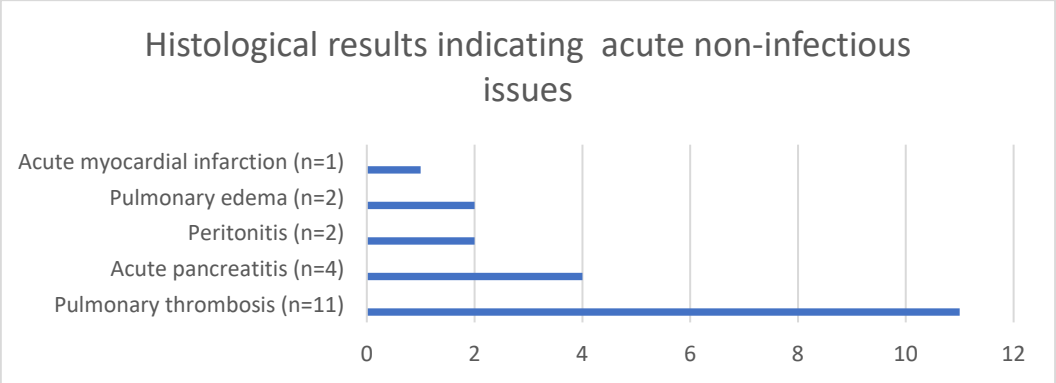
3.3.4. Histological Markers of Non-Infectious Hospitalization-Related Issues

Acute non-infectious illnesses that had no connection to traumatic circumstances were found in 20 instances. Pulmonary thrombosis was encountered in half of these cases, and in 2 cases acute pulmonary edema without associated bronchopneumonia was evident.



3.4. Autopsy Reports Conclusions

The causes of death from the forensic autopsy reports are shown in the table below.

Cause of death	**Number of cases**
Head trauma complicated with bronchopneumonia	46
Head trauma	41
Head trauma complicated with septic shock	16
Head trauma complicated with bronchopneumonia in an individual with pre-existing conditions	9
Head trauma complicated with bronchopneumonia and meningoencephalitis	7
Polytrauma complicated with bronchopneumonia	7
Head trauma complicated with bronchopneumonia and meningitis	6
Polytrauma complicated with septic shock	4
Head trauma complicated with meningitis	4
Head trauma complicated with bronchopneumonia and septic state	3
Polytrauma	3
Spinal cord trauma complicated with bronchopneumonia	3
Spinal cord trauma	2
Polytrauma complicated with bronchopneumonia in an individual with pre-existing conditions	2
Head trauma complicated with bronchopneumonia, meningoencephalitis, and ischemic stroke	1
Head trauma complicated with hydrocephalus, bronchopneumonia, and septic state	1
Head trauma complicated with bronchopneumonia, peritonitis, and septic shock	1
Head trauma in an individual with pre-existing brain conditions	1
Spinal cord trauma complicated with bronchopneumonia, septic state, and paralytic ileus	1
Polytrauma complicated with meningoencephalitis, bronchopneumonia, and septic shock	1
Hemorrhagic stroke	1
Hemorrhagic stroke complicated with bronchopneumonia	1
Brain tumor	1
Bronchopneumonia occurring in the evolution of a pulmonary neoplasm	1
Competing causes (head trauma and metastatic prostate neoplasm)	1
Competing causes (head trauma and SARS-COV-2 bronchopneumonia)	1

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Of the 165 deaths examined, we see that only 46 were attributable to traumatic injuries per se, 3 to pathological conditions unrelated to the trauma, and 2 to competing violent and non-violent causes. The patients' pre-existing pathological conditions contributed to death in 12 cases. Septic shock or different healthcare-associated infections, primarily pulmonary, interfered with death's process in the remaining 114 patients.

4. Discussion

Traumatic brain injury is a multifaceted and potentially life-altering condition, necessitating a thorough understanding of its etiology, classifications, initial evaluation, diagnosis, treatment, and long-term consequences to fully comprehend the associated medical and legal implications [13].

Patients admitted to the hospital following a moderate or severe traumatic brain injury (TBI) face an elevated risk of nosocomial infections, such as bacterial pneumonia and other upper respiratory tract infections. Hospital-acquired infections in TBI patients are most often bacterial in origin [14].

Due to their fragility, prolonged hospital stays, and weakened immune systems, patients with a history of colonization and underlying medical issues are thought to be at a higher risk of infections linked to healthcare. Additionally, intrahospital transfers, high body mass index, advanced age, and the use of indwelling devices make patients more vulnerable to nosocomial infections [9,15]. Being aged ≥65 years and male gender were also correlated with an increased probability of acquiring HAIs in some studies [16], while in our and other researches they do not show significant statistical importance [17].

TBIs in deceased individuals are assessed for severity by looking at their appearance at autopsy and by reviewing their medical records. A forensic autopsy is the final examination of a body and the main technique for ascertaining the cause of death. It also acts as a repository for relevant information, such as medical diagnoses, the circumstances surrounding serious injuries, and the identification of the connection between these injuries and death [18].

In this study, we examined cases with traumatic brain injuries who experienced various types of infections linked to healthcare and exhibited a negative progression toward death. Regardless of a patient's age, gender, length of hospital stay, type of traumatic injury, related chronic diseases, course of therapy, or invasive procedures during their hospitalization, the research aims to emphasize the critical role nosocomial infections play in deciding death.

The basic data elements that we analyzed in the hospital registries included the type and cause of injuries, pre-hospital care information, in-hospital care process information (treatment, major surgical procedures, invasive maneuvers), clinical items (symptoms, trauma scores), final anatomic diagnosis (from examination, X-rays/CT, or surgery), and outcome data (discharge status, hospital and ICU length of stay, complications occurring during hospitalization).

Although the association between longer hospital stays and higher risk of infection can be largely explained by the longer stays among those who have underlying morbidity and require invasive procedures [19], we did not find a correlation between length of stay and risk of acquiring a healthcare-associated infection in our cohort

After examining the patients' medical records, we attempted to distinguish between traumatic injuries, pre-existing chronic diseases, nosocomial infections, and non-infectious problems that arose during hospital stays.

The great majority of patients had multiple traumatic brain injuries, and 71.51% of them needed surgery while they were in the hospital. In 69.09% of cases, comorbidities were noted, with heart diseases, diabetes, and chronic alcoholism predominating. These illnesses, together with dementia and stroke, are thought to increase the chance of developing brain damage and contracting infections while in the hospital [20].

Specialized study indicates that nosocomial infections impact 19.40% to 70% of patients with traumatic brain injuries, with the most common types being ventilator-associated pneumonia, urinary tract infections, meningitis, and catheter-related infections [14,16,21,22].

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In our study, merely 36.36% of patients had a clinical diagnosis of nosocomial infection corroborated by microbiological analysis, whereas 28.48% exhibited imaging alterations indicative of pneumonia. Conversely, the forensic autopsy revealed indicators of lung infection in 93.33% of the examined cases, with histological investigation confirming bronchopneumonia in 86.66% of instances.

Although the current Romanian HAI legislation is fully aligned with the European standards [23], in Romania healthcare-associated infections (HAI) are significantly underestimated, with official prevalence rates ranging from 0.2% to 0.25%, attributable to several reasons that lead to their underreporting [24]. The lack of methods for rapidly identifying the bacteria causing HAI is one of the largest barriers to diagnosing and, consequently, preventing it [25].

HAIs have a very diverse etiology, including both Gram-positive and Gram-negative bacteria. The pathogens are typically antibiotic-resistant bacteria that are either imported from the general population or hospital-selected strains. Acinetobacter species are among the Gram-negative bacteria that are common in hospital settings, particularly intensive care units (ICUs), and produce highly pathogenic HAIs [26].

Pulmonary infections were the most common in our cohort, with Acinetobacter baumanii being the impressive emerging pathogen. Additionally, Acinetobacter baumanii was identified in blood cultures in 6 out of 22 sepsis cases. In particular, the risk of death is six times higher for trauma patients with sepsis, whereas the mortality rate is almost 1.5 to 2 times higher for patients with other HAIs than for those without a HAI [27].

Intubated patients had a greater mortality rate (45%) than non-intubated patients (6.3%), per specialized research. The level of neurological deterioration that leads to airway control and the requirement for advanced airway management to stabilize the patient are more likely to be reflected in this than in the first suggestion of an adverse effect of intubation [28]. 13.93% of patients in our study required intubation throughout their hospital stay.

Additionally, the forensic autopsy revealed the presence of leptomeningitis in 15 cases, purulent ventriculitis in 4 cases, and brain abscesses in 2 cases. Classifying meningitis as a nosocomial illness requires special consideration since meningitis-related brain injury is the result of not only the infection per se, but also the host's inflammatory response [29]. In our study, we only had the results of cerebrospinal fluid cultures available for 2 cases, which showed Acinetobacter b. in one case and Pseudomonas ae. in the other.

One of the most challenging aspects of forensic investigations is diagnosing sepsis. In addition to techniques on the body, an evaluation of the conditions and surroundings of the patient's death must be conducted using the findings of antemortem diagnostic tests and, if feasible, microbiological tests performed after necropsy in order to determine the type of infection [30].

In every case that was examined, at least one chronic condition that existed before the trauma was found clinically, during the forensic autopsy, or during the histological analysis. However, in only one case—a brain tumor—the pre-existing pathology was the cause of death, and in two cases, competitive causes between the trauma and non-traumatic diseases were found.

In two other cases, the hemorrhagic stroke was the cause of the cerebral hemorrhage, and the head trauma was not a decisive factor in the deaths.

While in the hospital, a few individuals suffered from potentially deadly consequences, such as multiple organ failure, hemorrhagic shock, pulmonary embolism, acute myocardial infarction, acute pancreatitis, and 9 cases experienced resuscitated cardiorespiratory arrest. However, prompt and appropriate treatment prevented their progression to death.

Despite the gravity of TBIs, in our cohort only 27.87% of patients died exclusively as a result of their traumatic injuries; the remainder instances also had additional causes, mostly infectious.

Analyzing the cause of death from the autopsy reports, we observed that in 114 cases, nosocomial infections played a decisive role in causing death, altering the causal relationship between trauma and the victim's death. When a complication that is thought of as a secondary cause

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that otherwise would not have occurred in evolution develops between the trauma and the effect, it is referred to as a secondary or indirect causal relationship [31].

Because of the potential legal repercussions, the causal relationship between trauma and death in cases of multifactorial disease must be carefully examined, taking into consideration all of the patient's conditions.

Establishing liability requires the use of forensic causal analysis. Because they offer proof of the link between an alleged illegal or careless act by one party and an observed adverse health effect in another, expert opinions on causal inference—particularly specific causation—are a crucial component of the majority of lawsuits involving injuries [11].

One issue we found in our research was that a large proportion of cases lacked microbiological tests while in hospitals, and postmortem microbiological analyses were not feasible. Defendant hospitals typically contest the fact that patients contracted the infection while in the hospital throughout legal proceedings, requiring the plaintiff to demonstrate beyond a reasonable doubt that the hospital was the cause of the infection and that the institution or medical personnel were at blame [32].

5. Conclusions

This study sought to emphasize that, despite adequate care, traumatic brain injuries frequently result in fatal outcomes due to untreated healthcare-associated infections.

The forensic autopsy is essential for deceased patients with traumatic brain injuries as it provides an analysis of all the patient's conditions and determines the cause of death, the manner of death, the causal relationship between traumatic injuries and death, and the contribution of each ailment to the death process.

In addition to being a useful tool for evaluating healthcare system performance, the conducted study may also provide data that can be used for clinical risk management and patient safety implementation.

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