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ASSESSMENT OF CERVICAL SPINE CT SCANS IN PATIENTS WITH HEAD TRAUMA: A RETROPERSPECTIVE ANALYSIS

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LIST OF ABBREVIATIONS

TBI - Traumatic Brain Injury

CT - Computed Tomography

MRI - Magnetic Resonance Imaging

ED - Emergency Department

GCS - Glasgow Coma Scale

EMS - Emergency Medical Services

NICE - National Institute for Health and Care Excellence

CHIP - CT in Head Injury Patients

SAH - Subarachnoid Hemorrhage

EDH - Epidural Hematoma

SDH - Subdural Hematoma

TMJ - Temporomandibular Joint

C1 - Atlas (First Cervical Vertebra)

C2 - Axis (Second Cervical Vertebra)

kV - Kilovolt

CTDI - Computed Tomography Dose Index

DLP - Dose Length Product

NOAK - Novel Oral Anticoagulants

ASS - Acetylsalicylic Acid (Aspirin)

1. INTRODUCTION

1.1. Epidemiological Data

Head trauma remains one of the most significant medical and socioeconomic challenges in contemporary society with over 1.7 million administrations in the U.S. each year, marking a substantial concern within the landscape of hospitalizations (1). In Germany during the year 2016 419.507 patients were admitted to hospitals for traumatic brain injury (TBI) across all severity grades, implying that the annual incidence rate is approximately 300 cases per 100.000 inhabitants in Germany, which is comparable to the European average (2,3). In Germany, slightly over 350.000 patients were hospitalized for TBI of any severity in 2021. It is estimated that the annual costs associated with treatment and long-term consequences exceed 2.5 billion euros each year. Approximately 5.3 million individuals in the United States and approximately 7.7 million individuals in the European Union are estimated to live with the long term consequences of TBI (3).

TBI stands as prominent contributor to severe disability, fatalities, and enduring consequences, potentially culminating in adult mortality (1). Epidemiological investigations have revealed elevated mortality rates even following mild TBI. A cohort study, conducted in Glasgow, UK, monitored patients presenting with TBIs of varying severities to emergency departments during the years 1995 and 1996 (4). These injuries range from mild afflictions such as bumps, bruises or superficial cuts to more moderate or severe conditions including concussions, deep lacerations, open wounds, fractures, or internal hemorrhaging (1).

The majority of head injuries are classified as mild TBI, with moderate TBI occurring in approximately 3% of cases and severe TBI in about 5% of cases (3). Mild TBI is often regarded as relatively harmless, with most patients recovering within the first three months. However, up to a third of individuals experience symptoms that persist beyond six months. Factors such as a more severe initial injury, pre-existing psychological issues, older age, female sex, and previous head injuries increase the likelihood of these persistent symptoms (4). Head trauma represents the predominant cause of mortality in trauma cases, despite numerous reports indicating a decline in mortality rates associated with TBI (5,6). This high fatality rate is due to the critical nature of brain injuries, which often result in severe neurological impairment and systemic complications. Consequently, effective management and timely intervention are crucial in reducing the mortality associated with traumatic brain injuries (6).

1.2. Definition of Traumatic Brain Injury

The term 'traumatic brain injury' (TBI) has supplanted the previously used term 'head injury/trauma' to emphasize the critical involvement of the brain. TBI is more precise and underscores the significance of brain pathology. Recently, TBI has been defined as an alteration in brain function or other evidence of brain pathology, caused by an external force that leads to temporary or permanent impairment of cognitive, physical, or psychosocial function. It constitutes a subset of acquired brain injuries and can be classified as either open (penetrating) or closed (non-penetrating) (7). This definition highlights the impact of external mechanical forces on brain structure and function, encompassing a spectrum of clinical presentations ranging from mild to severe neurological impairments (5). The optimal documentation of a TBI diagnosis occurs at the time of injury or within the initial 24 hours post-injury (7). Severity is typically assessed using the Glasgow Coma Scale (GCS), which evaluates three critical components: eye opening, verbal responses and motor responses. Based on these assessments patients are categorized into three groups: mild TBI (GCS score of 13–15), moderate TBI (GCS score of 9–12), and severe TBI (GCS score of 3–8). This classification system aids in determining the level of consciousness and neurological function of the patient, providing a standardized framework for assessing the severity of the injury (3).

1.3. Classification of Traumatic Brain Injury

Significant disparities in the management of TBI exist across different countries, highlighting the need for standardized approaches within community settings. This inconsistency is particularly evident in the approach to managing head injuries sustained. Beyond the United States, numerous regions lack clear, standardized guidelines for TBI management, while others struggle to effectively implement and enforce existing protocols These variations underscore the need for a more unified and evidence-based approach to the treatment and management of TBI globally (4). The objective is to establish a unified classification system for traumatic brain injury (TBI) severity, utilizing commonly employed severity measures and indicators. Firstly, the system aims to maximize the use of available evidence to categorize TBI severity into three distinct classifications: moderate-severe (definite), mild (probable), symptomatic (possible). Secondly, this system ensures that the classification framework reflects contemporary clinical understanding and relevance. Thirdly, it enhances the accuracy of classification by incorporating a more comprehensive range of cases, surpassing the limitations of systems that rely on single indicators, and thereby improving diagnostic precision and clinical applicability (4,8).

As illustrated in Figure 1, this classification system categorizes TBI severity into three distinct categories, based on well-defined clinical criteria. Moderate-Severe (Definite) TBI is characterized by severe outcomes such as death, loss of consciousness for 30 minutes or more, or post-traumatic amnesia lasting 24 hours or more. Furthermore, a Glasgow Coma Scale (GCS) score below 13 within the first 24 hours, unless affected by external factors, or the presence of serious conditions like intracerebral, subdural, or epidural hematomas, cerebral or hemorrhagic contusions, penetrating TBI, subarachnoid hemorrhage or brainstem injury also warrant classification under this category.

Mild (Probable) TBI is defined by less severe symptoms, provided none of the criteria for Moderate-Severe TBI are met. This includes brief loss of consciousness (lasting momentarily to less than 30 minutes), short-term post-traumatic amnesia (lasting momentarily to less than 24 hours) or specific types of skull fractures with an intact dura mater. Symptomatic (Possible) TBI is applied if neither Moderate-Severe nor Mild criteria are met and is based on the presence of symptoms such as blurred vision, confusion, daze, dizziness, focal neurological symptoms, headache, or nausea. This classification framework is designed to provide a precise and comprehensive categorization of TBI severity, utilizing clinically relevant criteria to ensure a nuanced and accurate classification of cases.

A. Classify as Moderate-Severe (Definite) TBI if one or more of the following criteria apply:
   1. Death due to this TBI
   2. Loss of consciousness of 30 minutes or more
   3. Post-traumatic anterograde amnesia of 24 hours or more
   4. Worst Glasgow Coma Scale full score in first 24 hours <13 (unless invalidataed upon review, e.g., attributable to intoxication, sedation, systemic shock)
   5. One or more of the following present:
      - Intracerebral hematoma
      - Subdural hematoma
      - Epidural hematoma
      - Cerebral contusion
      - Hemorrhagic contusion
      - Penetrating TBI (dura penetrated)
      - Subarachnoid hemorrhage
      - Brain Stem Injury

B. If none of Criteria A apply, classify as Mild (Probable) TBI if one or more of the following criteria apply:
   1. Loss of consciousness of momentary to less than 30 minutes
   2. Post-traumatic anterograde amnesia of momentary to less than 24 hours
   3. Depressed, basilar or linear skull fracture (dura intact)

C. If none of Criteria A or B apply, classify as Symptomatic (Possible) TBI if one or more of the following symptoms are present:
   - Blurred vision
   - Confusion (mental state changes)
   - Dazed
   - Dizziness
   - Focal neurologic symptoms
   - Headache
   - Nausea

Figure 1. Mayo Traumatic Brain Injury (TBI) Classification System.

Source: Malec JF, Brown AW, Leibson CL, Flaada JT, Mandrekar JN, Diehl NN, et al. The Mayo Classification System for Traumatic Brain Injury Severity. J Neurotrauma. 2007;24:1417–24.

1.4. Medical Approach in the Emergency Department

In patients presenting with cranio-cervical trauma, a thorough primary assessment is the initial step, providing a thorough evaluation of the situation. This process commences with the transfer of care from the emergency medical services (EMS) team, ensuring a seamless and comprehensive handover of pertinent clinical information. Immediate priorities include the stabilization of vital signs and immobilization of the cervical spine to mitigate the risk of exacerbating any spinal injuries. This approach is critical to preventing secondary damage and optimizing patient outcomes (9). A comprehensive medical history and physical examination are essential for the assessment of TBI patients, as is a thorough understanding of the underlying mechanism of injury. Furthermore, a detailed description of the accident, including the forces involved, is crucial for accurate categorization of TBI. Moreover, the onset and progression of symptoms, including their temporal evolution and any changes over time require attention, as they can indicate an underlying neurological injury. Additionally, the examination must include an assessment for potential associated injuries. This involves a systematic search for any secondary injuries that may not be immediately apparent but could complicate the patient's condition (9). The contemporary gold standard for the initial assessment and identification of common sequelae of head trauma is computed tomography (CT) imaging. While magnetic resonance imaging (MRI) may provide superior sensitivity in evaluating parenchymal damage, CT remains the preferred modality due to its efficacy in rapidly identifying acute traumatic injuries (10,11).

1.5. Approach in Diagnostic Imaging

To determine whether a patient should undergo a CT scan of the head or neck, several critical classifications and guidelines are employed. Notably, the National Institute for Health and Care Excellence (NICE) guidelines for cranial CT provide evidence-based diagnostic and quality standards, as illustrated in Figure 2.

According to these guidelines, a CT head scan should be performed within 1 hour, if the patient with a head injury presents with any one of several critical criteria. Firstly, a Glasgow Coma Scale (GCS) score of less than 13 on the initial assessment indicates a significant decrease in consciousness, necessitating urgent imaging. Secondly, if the GCS score remains below 15 two hours post-injury, it suggests persistent impairment in consciousness. Additionally, the presence of a a suspected open or depressed skull fracture, signs of a basal skull fracture, or post-traumatic seizures are urgent indicators. Further criteria include focal neurological signs indicating localized brain dysfunction and the occurrence of one or more episodes of vomiting since the injury.

A CT head scan within 8 hours is indicated if certain additional criteria are met. Specifically, patients currently receiving anticoagulant treatment are at increased risk of internal bleeding, requiring prompt imaging. Furthermore, a loss of consciousness or amnesia following the injury, combined with additional risk factors warrants a CT scan within 8 hours. These risk factors include age over 65 years, a history of bleeding or clotting disorders, a dangerous mechanism of injury or more than 30 minutes of retrograde amnesia of events preceding the injury (10).

Indications for CT head scan to be performed within *1 hour.*

Head injury and any one of:

> GCS <13 on initial assessment
> GCS <15 2 hours post-injury
> suspected open/depressed skull fracture
> signs of basal skull fracture
> post-traumatic seizure
> focal neurological signs
> one plus episodes of vomiting since injury.

Indication for CT head scan to be performed within *8 hours.*

Head injury with any one of:

> current anticoagulant treatment
> loss of consciousness or amnesia since injury plus one of:
  - age >65 years
  - history of bleeding/clotting disorder
  - dangerous mechanism of injury
  - >30 min retrograde amnesia of events preceding injury.

CT = computed tomography; GCS = Glasgow coma score.

Figure 2.: National Institute for Health and Care Excellence guidelines for CT head scan following head injury.
Source: Beedham W, Peck G, Richardson SE, Tsang K, Fertleman M, Shipway DJ. Head injury in the elderly – an overview for the physician. Clin Med. 2019;19:177–84.

Another system used in accordance with the GCS scoring system is presented in Figure 3. This system is designed to determine the necessity of a head CT scan based on clinical presentation and risk factors. The classifications are categorized into four severity levels: Mild, Moderate, Severe, and Critical. For mild head injuries, hospital admission is required if the GCS score ranges from 13 and 15 and if there is a loss of consciousness lasting 30 minutes or less.

Within the mild TBI category, there are further subdivisions. Category 1 includes patients with a GCS score of 15, no risk factors or only one minor risk factor as defined by the CHIP (CT in Head Injury Patients) rule. These patients have a head injury but no TBI, and a cranial CT scan is not immediately indicated. Category 2 includes patients with a GCS score of 15 who have one or more major risk factors, or two or more minor risk factors as defined by the CHIP rule. For these patients an immediate head CT scan is indicated due to the increased risk of complications. Moderate head injuries are characterized by a GCS score of 13 to 14. Patients within this range require an immediate head CT scan. Severe head injuries are identified by a GCS score of 9 to 12 and these patients also necessitate an immediate head CT scan to assess the extent of the injury. Critical head injuries are defined by a GCS score of 8 or below. Specifically, patients with a GCS score of 3 to 4, accompanied by the loss of pupillary reactions and absent or decerebrate motor reactions, are in critical condition and require an immediate emergency head CT scan and further evaluation.

Classification	Characteristics	Indication for immediate head CT[a]
Mild	Hospital admission GCS = 13–15 Loss of consciousness if present 30 min or less	
Category		
1	GCS = 15 No risk factors or only 1 minor risk factor present (CHIP rule) Head injury, no TBI	No
2	GCS = 15 With risk factors: ≥1 major risk factor(s) or ≥2 minor risk factors (CHIP rule)	Yes
3	GCS = 13–14	Yes
Moderate	GCS = 9–12	Yes
Severe	GCS ≤ 8	Yes
Critical	GCS = 3–4, with loss of pupillary reactions and absent or decerebrate motor reactions	Yes

Figure 3. Classification of traumatic brain injury and indication for immediate head CT.

Source: Vos PE, Alekseenko Y, Battistin L, Ehler E, Gerstenbrand F, Muresanu DF, et al. Mild traumatic brain injury. Eur J Neurol. 2012;19:191–8.

1.6. Diagnostic Imaging in Emergency Admission

Imaging techniques have become increasingly vital in the diagnosis and management of patients suffering from craniocerebral/cervical spine trauma. These advanced modalities not only enable precise assessment of injury severity but also inform critical life-or-death decisions that can significantly impact patient outcomes. Furthermore, the prognostic utility of imaging is well-established, providing valuable insights into the likely course and outcome of the injury. This aspect of imaging is of growing importance within the research area where it contributes to the development of predictive models and the identification of biomarkers for injury progression (11).

We have made significant progress beyond the use of projectional radiography. The diagnostic value of plain skull radiographs in head and neck trauma is markedly limited. Consequently, these radiographs are now reserved for instances where CT scans are unavailable due to their inferior diagnostic capabilities (11,13). Currently, plain X-ray films are obsolete in the management of patients with TBI due to their diagnostic limitations and inability to provide detailed information on intracranial pathology. As a result, CT imaging has become the gold standard in the current diagnosis for craniocervical trauma with modern medical advancement (11,13).

Unlike plain radiography, CT scans offer high-resolution, cross-sectional images of the brain, allowing clinicians to accurately assess the extent and nature of the injury. This advancement has revolutionized the acute management of TBI, enabling rapid diagnosis, guiding surgical planning and monitoring the effectiveness of interventions. Moreover, the integration of CT scans into emergency protocols ensures that patients receive timely and precise evaluations, which are crucial for optimizing outcomes (11).

CT imaging is readily available and typically located in close proximity to the trauma bay, allowing for rapid access. The CT examination itself can be performed in a matter of seconds, with image data capable of being reconstructed in multiple planes as well as in 3D views. Cranial CT is indispensable for evaluating all forms of intracranial hemorrhage, fractures, brain edema, herniation and other associated injuries as well as for assessing the presence of foreign bodies. CT angiography, a dynamic contrast-enhanced CT technique that visualizes vascular structures, may be indicated whenever vascular injury is suspected. It is also recommended for patients with high-risk mechanisms of trauma, such as intra-oral trauma, high-energy crashes, near-hanging incidents, and fractures of the skull base and midface. Additionally, it is utilized in cases with suspicious hemorrhage patterns, providing critical information for accurate diagnosis and management (11,14).

1.7. Computer Tomography vs Magnet Resonance Imaging

Although MRI exhibits greater sensitivity than CT in detecting parenchymal lesions, it is only recommended when there is a discrepancy between the patient's clinical neurological status and the CT findings, as it provides a more detailed and accurate assessment of intracranial pathology (11). MRI demonstrates increased sensitivity in detecting blood products such as subarachnoid hemorrhage (SAH), epidural hematoma (EDH), subdural hematoma (SDH), and hemorrhagic contusions. Additionally, it is superior in identifying non-hemorrhagic cortical contusions, brainstem injuries, and axonal injuries (15). MRI is recommended when CT scans appear normal, but patients continue to experience unexplained neurological symptoms that suggest a significant traumatic brain injury. In such instances, MRI is the preferred imaging modality for subacute or chronic traumatic brain injury presenting with neurological symptoms due to its higher sensitivity.

In the acute setting, CT has several advantages over MRI, including enhanced sensitivity for detecting relevant fractures, vascular injuries, and cerebrospinal fluid leaks. Furthermore, CT eliminates the need for MRI safety assessments , which is particularly beneficial in cases of penetrating injuries (11,15). MRI is reserved exclusively for cases of suspected acute hemorrhage in the N. facialis or the inner ear when a fracture line is not discernible on the CT scan (16).
Due to the significant logistical and operational challenges associated with MRI, as well as its prolonged scanning time, MRI is frequently not feasible for use in urgent emergency scenarios. The effectiveness of MRI in detecting subtle traumatic changes remains unclear, as the majority of existing research has focused primarily on the use of CT imaging (17–19).

1.7.1. Cervical Spine Imaging

In the context of cervical spine imaging, CT scans outperform conventional X-ray diagnostics due to their ability to provide distinct, non-overlapping images of bones and soft tissues, as well as enabling multiplanar image reconstructions. The paramount indications for CT include verifying the integrity of the bony spinal canal, detecting posterior edge fractures of the vertebral body (essential for assessing stability), and investigating potential spinal cord compression resulting from displaced fragments or hematomas (16).

The advantages of MRI lie in its ability to visualize disco-ligamentous injuries, spinal cord injuries (including edema, hematomyelia, transection, and vascular occlusion), and bone contusions. Its application is warranted for all ambiguous neurological findings (16).

1.8. Clinical Manifestations

In patients with head and cervical spine injuries, clinical manifestations can be systematically categorized either by individual symptomatic presentations or by the extent and severity of the sustained injury. Regarding the symptomatic spectrum, a diverse array of clinical signs can be observed, necessitating a thorough and detailed approach to classification. This stratification can be based on discrete symptomatologic evidence or on the severity of TBIs. Consequently, an in-depth understanding of the correlation between specific symptoms and the overall injury profile is essential for accurate diagnosis, prognosis, and therapeutic interventions. Certain signs and symptoms may manifest immediately following the traumatic event, while others emerge gradually over the course of several days or even weeks. It is crucial to remember that some symptoms may not appear until later, underscoring the importance of ongoing vigilance and monitoring for delayed onset of symptoms (12,20).

First and foremost, it is crucial to identify life-threatening signs and symptoms in patients presenting to the emergency department. These include pupillary dilation, impaired pupillary light reflex, acute onset hemiparesis, disrupted flexor and extensor synergy patterns, and circulatory dysregulation (1,21). Secondly, disturbances of consciousness represent a critical sign of TBIs which can include extensive impairments of brain function. These are divided into two subcategories that need to be clinically distinguished: coma and reduced state of consciousness. The latter includes reduced alertness, with an impairment or absence of orientation to person, place, and time, while the patient is still able to open their eyes. In contrast, a comatose state is characterized by decreased alertness, an inability to open their eyes spontaneously or in response to pain and in inability to follow commands, although patients may initiate spontaneous movements. This constellation of neurological symptoms represents a severe TBI with a GCS Score of <8 (1,21,22).

In addition to life-threatening signs and symptoms, it is essential to focus on indicators of neurological damage which may manifest as amnesia, disturbances of wakefulness, disorientation, vomiting, paralysis, speech and/or coordination impairments, cranial nerve dysfunctions, seizures, tonic spasms, and autonomic dysregulation (1,21). During the initial assessment of patients presenting to the emergency department, it is crucial to focus on observable signs and symptoms. Objective indicators of cranial injury include a range of presentations such as edema, hemorrhage, lacerations, avulsions and deformities of the skull. Moreover, the presence of extruded blood, cerebrospinal fluid, or brain tissue is a critical sign of severe trauma. Additionally, it is essential to observe for bleeding originating from the oral cavity, nasal passages or ears, as this can be indicative of significant internal injury or fractures (1,21).

An alternative approach to categorizing clinical manifestations is to classify them according to their extent and severity, aligning with the GCS classification of TBI into mild, moderate, and severe types. Signs of mild head or neck injuries can be systematically categorized into physical, sensory, and cognitive-behavioral symptoms. Physical symptoms include headaches, nausea or vomiting, fatigue or drowsiness, speech difficulties and dizziness or loss of balance. Sensory symptoms encompass blurred vision, tinnitus, altered taste, changes in olfactory function and heightened sensitivity to light or sound. Cognitive, behavioral, or mental symptoms may involve transient loss of consciousness (ranging from a few seconds to a few minutes) or intact consciousness with a concomitant state of being dazed, confused or disoriented. Patients may experience memory or concentration difficulties, mood changes or mood swings, feelings of depression or anxiety and sleep disturbances, which can manifest as either difficulty sleeping or sleeping more than usual (20,21).

1.9. Common Types of Injuries in Head Trauma

In the emergency setting patients with head trauma often present with a wide range of injuries that vary in severity and complexity, affecting multiple structures within the skull, brain and spine. A thorough understanding of the most common types of injuries associated with head trauma is crucial for accurate diagnosis and effective management of these potentially life-threatening conditions.

Concussion is a clinical syndrome resulting from mechanical force or trauma, characterized by an immediate and transient alteration in brain function, including changes in mental status or level of consciousness. This condition is a specific subtype of traumatic brain injury (TBI), known as a traumatically induced transient disturbance of brain function. While TBIs encompass a range of severities from mild, transient symptoms to prolonged periods of altered consciousness, concussions are generally considered mild traumatic brain injuries (mTBIs) due to their typically self-limited nature (23,24). Falls of any kind are the leading cause of concussions, accounting for a significant proportion of traumatic brain injuries. These incidents are particularly prevalent among young children and the elderly, who are more susceptible to losing their balance and sustaining head injuries (25,26).

Cervical spine distortion is characterized by sudden flexion and extension movements of the cervical spine due to rapid acceleration or deceleration of the head. This abrupt motion places significant strain on the neck's muscles, ligaments, and potentially bone structures (27,28). According to the Quebec Task Force classification, 90–95% of cervical spine distortion injuries are classified as mild to moderate corresponding to Severity Grades 0–II (27,29). Notably, these injuries are almost always experienced without memory loss, highlighting the significant role of psychological and psychosomatic aspects. A study demonstrated that approximately 20% of individuals reported symptoms after a simulated rear-end collision, despite the absence of any significant biomechanical injury (27). Patients with cervical spine distortion of any severity may experience a range of symptoms, including hearing impairments, dizziness, tinnitus, headaches, neck pain, concentration and memory difficulties, dysphagia, and temporomandibular joint (TMJ) pain (27,28).

Intracranial Hematoma is a collective term that encompasses various pathologies characterized by the extravascular accumulation of blood in diverse intracranial compartments, resulting in cerebral compression. This condition is predominantly precipitated by the rupture of a cerebral blood vessel which can occur spontaneously or as a result of traumatic head injuries, such as those incurred in motor vehicle collisions or falls. Although certain head injuries may be relatively benign, an intracranial hematoma poses a significant threat to life and typically requires prompt medical intervention (30,31).

Extradural hemorrhage, also known as epidural hematoma, refers to a collection of blood that forms between the inner surface of the skull and the outer layer of the dura mater, known as the endosteal layer. This type of hemorrhage is commonly associated with a history of head trauma, such as those incurred in falls, and frequently involve skull fractures. The bleeding source is typically arterial, most frequently originating from the middle meningeal artery. Extradural hematomas are characterized by a biconvex shape as illustrated in Figure 4 and can exert a mass effect, potentially leading to herniation. They are usually margined by cranial sutures but not by venous sinuses. Both CT and MRI are effective modalities for evaluating extradural hematomas (32,33).

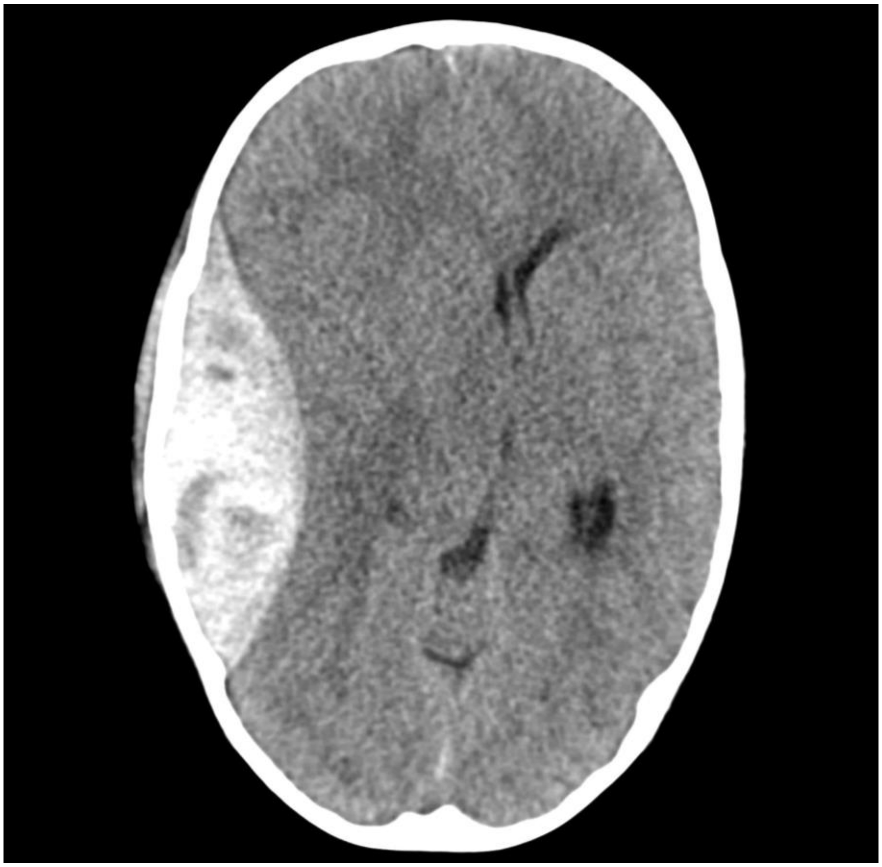

Figure 4. Title: Epidural Hematoma

Source: Regiomed Hospital Coburg Radiology Department (created by the author)

Commonly referred to as a subdural hematoma, it is a condition characterized by the accumulation of blood in the subdural space between the dura mater and the arachnoid mater as seen in Figure 5. This type of hematoma is typically crescent-shaped in appearance on imaging studies. In contrast to extradural hematomas, which are confined by cranial sutures, subdural hematomas are not restricted by sutural boundaries, allowing them to spread more extensively across the surface of the brain (34–36). Subdural hematomas are frequently associated with head trauma, such as falls, which lead to the rupture of bridging veins. The traumatic origin often coincides with brain contusions. Cerebral edema exacerbates the midline shift, which is typically pronounced in acute subdural hematoma cases. CT scans are generally sufficient for diagnosis. The prognosis varies significantly depending on the size and chronicity of the hemorrhage (31,36–38).

Figure 5. Title: Subdural Hematoma

Source: Regiomed Hospital Coburg Radiology Department (created by the author)

Cerebral contusion can result in irreversible damage to cerebral tissues, with the severity of this damage correlating with the primary injury and the subsequent cascade of secondary injury responses. The primary injury is initiated by the kinetic energy absorbed upon collision, which triggers a series of secondary injury responses that exacerbate the initial harm..(39,40) Hemorrhagic lesions develop immediately post-impact and can enlarge and proliferate over time, often accompanied by additional hemorrhagic contusions. These contusions overlie brain parenchyma, causing functional deficits. The continuous bleeding from injured microvessels during the initial trauma episode is believed to contribute to the formation of these contusions, potentially due to an underlying or overt coagulopathy. Cerebral contusions predominantly occur in the temporal and frontal lobes, although other areas can be affected by coup (directly beneath the impact) and contrecoup (opposite the impact) mechanisms as illustrated in Figure 6. These hemorrhagic lesions typically originate in the cortical areas of the brain, particularly at the crests of the gyri, and can extend to the subcortical white matter in more severe injuries (39–41).

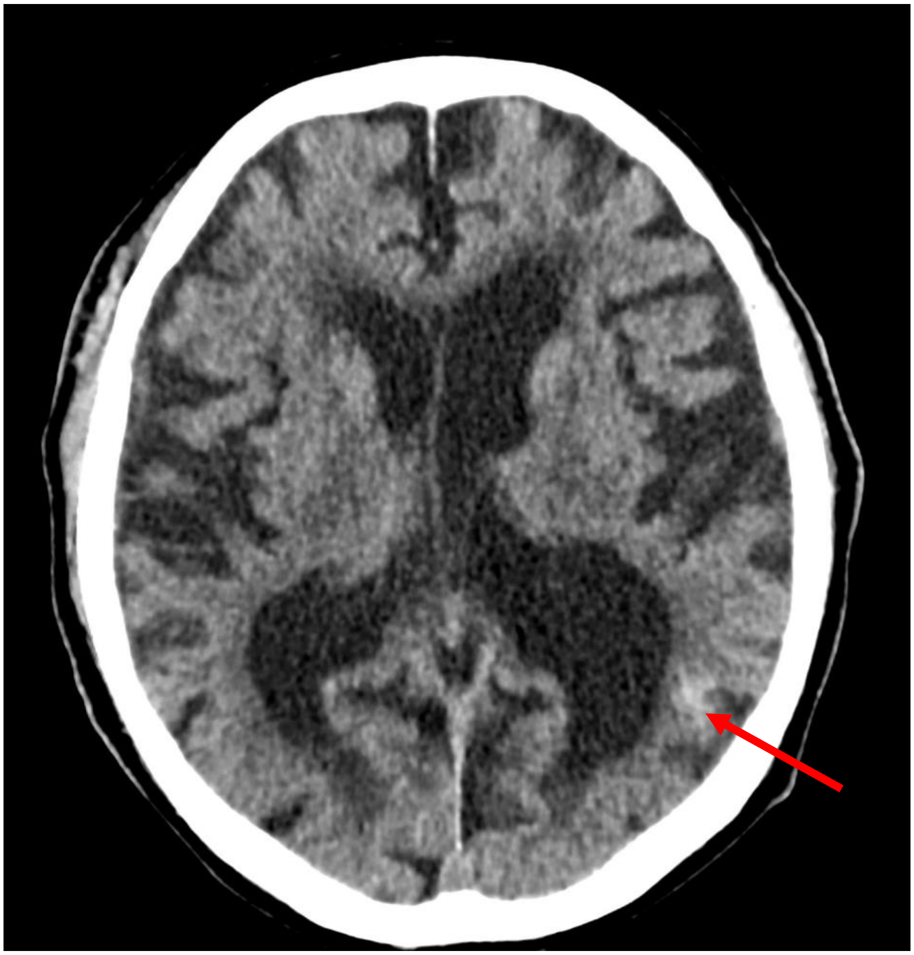

Figure 6. Title: Contrecoup

Source: Regiomed Hospital Coburg Radiology Department (created by the author)

In head trauma patients, the patterns of skull fractures are influenced by the initial impact location and direction, which can be categorized into three primary groups: anterior (frontal), lateral (lateral parietal), and posterior (occipital). Figure 6 demonstrates a fracture in the occipital region in a fall patient. The type of force applied can result in various fracture types on the calvaria, including linear fractures, impression fractures, comminuted fractures, hole fractures, and seam splits. The visibility of these fractures on X-ray images varies based on their location and degree of displacement (16,42,43). Notably, 50% of patients with intracranial hemorrhage do not exhibit fractures (16). Consequently, radiological exclusion of fractures is not only ineffective but can also create a false sense of security. Therefore, the decision to perform a CT scan should be based exclusively on the patient's symptoms, the severity of the trauma, and the potential for adequate monitoring (16,42).

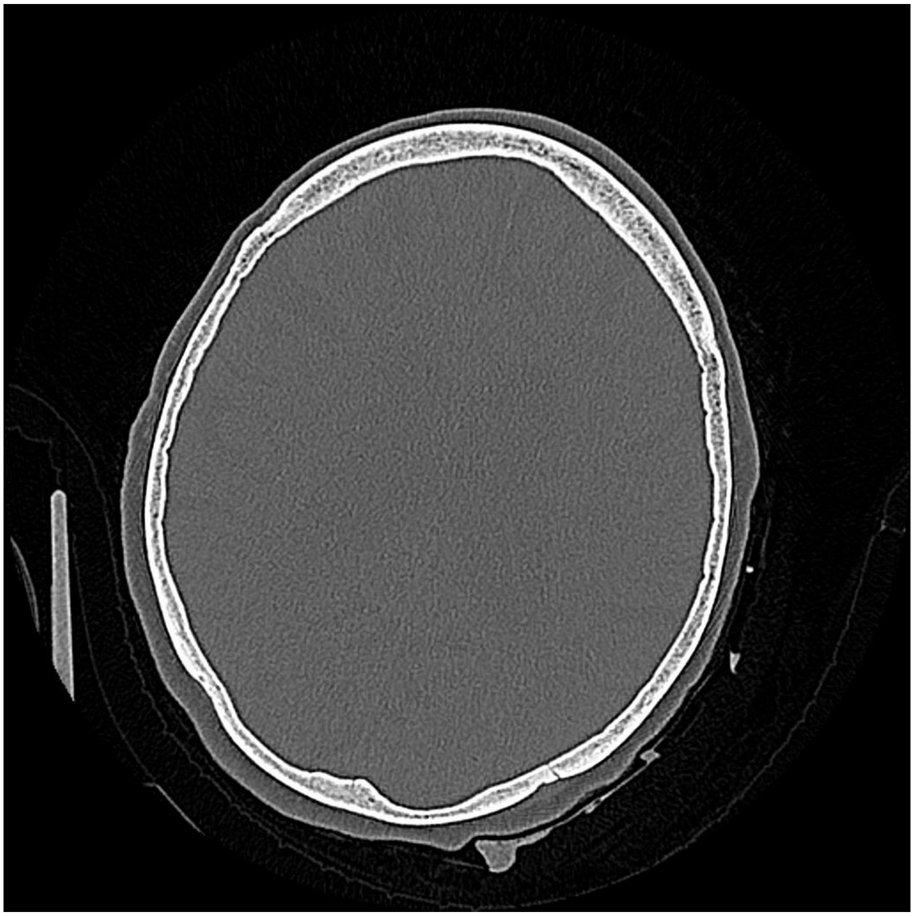

Figure 7. Title: Fracture of Skull

Source: Regiomed Hospital Coburg Radiology Department (created by the author)

The first cervical vertebra, also known as C1 or the atlas, is a uniquely structured cervical vertebra that plays a crucial role in facilitating essential movements of the head, including rotation, flexion, extension, and lateral flexion. Its distinct anatomical features enable it to articulate with both the dens of the axis (C2) and the occiput. A notable deviation from the structure of other cervical vertebrae, with the exception of the axis, is the posterior orientation of the anterior rami (44). In the context of cervical spine injuries, approximately 10% involve the axis vertebra (45) as can be seen in Figure 8.The diagnostic approach for these injuries is meticulous, focusing on the precise identification of the injury, evaluating joint congruency, and assessing the structural integrity of the atlas ring. Extensive research has consistently demonstrated that the incidence of concomitant cervical spinal injury in patients presenting with traumatic brain injury (TBI) is approximately 6.5%. This finding underscores the critical need for careful screening and evaluation of the cervical spine in all TBI cases, given the significant clinical implications of such dual pathology (46).

The Gehweiler and Dickman classifications provide comprehensive frameworks for classification purposes. Clinically, the Canadian C-spine rule is an invaluable tool for the screening of cervical spine injuries (44,45,47). For further evaluation, the Jefferson fracture classification system delineates the various fractures of the atlas. These fractures, particularly those associated with tears in the transverse ligament, pose a significant risk of cervical spine instability. If not accurately diagnosed and managed, such instability can lead to serious neurological injuries (48). Imaging modalities play a pivotal role in the diagnostic process, with CT being the preferred method due to its exceptional ability to provide detailed visualization of bone structures. In cases where the integrity of the transverse ligament of the atlas is compromised, magnetic resonance imaging (MRI) is essential for accurate evaluation, particularly in complete atlas ring fractures. Conservative treatment is often the preferred approach for managing atlas fractures, as it is considered suitable for a significant proportion of these cases. This approach emphasizes the importance of individualized patient care, taking into account the unique characteristics of the fracture and the overall clinical picture (45).

Figure 8. Title: Fracture of Atlas (C1)

Source: Regiomed Hospital Coburg Radiology Department (created by the author)

Fractures of the axis vertebra, like seen in Figure 9, account for 20% of acute cervical spine fractures and can be classified into three distinct injury patterns: odontoid fractures, hangman's fractures, and fractures of the axis body, which encompass all other fracture injuries to the C2 vertebra. These injuries are unique due to the anatomy and biomechanics of the occipito-atlanto-axial complex, also known as the craniovertebral junction. The association between head trauma and upper cervical spine injuries is well-documented. Upper cervical spine fractures that occur in conjunction with head injuries and/or skull base fractures often reflect the severity of the initial trauma. The odontoid process, also known as the dens, is a bony element extending superiorly from the second cervical vertebra (49). The Anderson and D'Alonzo classification is the most widely utilized system for categorizing fractures of the odontoid process of the second cervical vertebra (50,51). Fractures in the odontoid process region have paramount clinical significance due to their crucial role in enabling the most significant single component of lateral rotation in the cervical spine. The primary mechanism of injury involves hyperflexion of the cervical spine, which forces the head and C1 vertebra backward. Odontoid fractures typically arise from trauma, often resulting from hyperflexion of the cervical spine. High-energy accidents often cause these fractures in younger patients, whereas lower-energy impacts are more common in older individuals (49).

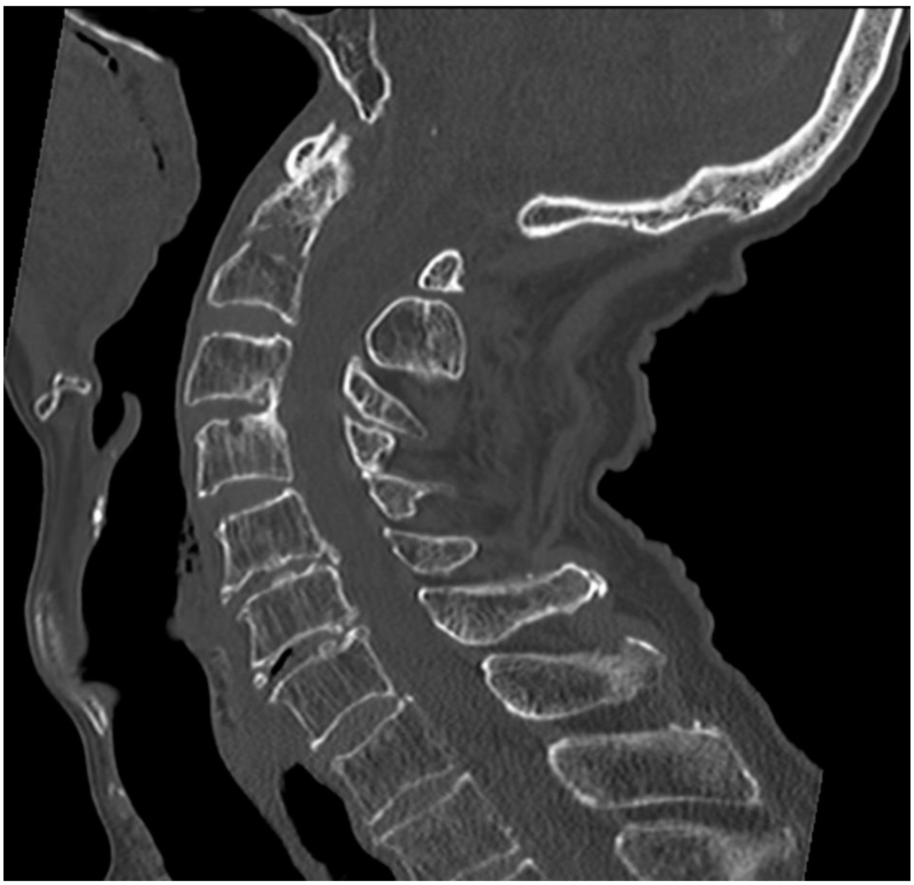

Figure 9. Title: Fracture of Axis (C2)

Source: Regiomed Hospital Coburg Radiology Department (created by the author)

1.10. CT Technique and Reference Values

This chapter provides an in-depth exploration of the technical aspects of CT imaging, focusing on the methods employed to acquire high-quality images and the reference values that serve as a framework for clinicians to interpret these scans accurately. A thorough understanding of these technical parameters and benchmarks is essential for ensuring accurate diagnoses and optimizing patient outcomes.

1.10.1. CT Technique and Significance in Trauma Patients

When assessing trauma patients, it is essential to exclude skull fractures, intracranial hemorrhages, and other related injuries. Given the urgency of these cases, sequential imaging techniques are typically not feasible and therefore a spiral CT technique is employed to optimize time efficiency. This approach involves post-contrast agent administration imaging, which extends from the cranial vertex to the upper thoracic inlet without employing a Gantry angle. Critical comprehensive evaluation of the patient's condition is ensured through assessments in both the soft tissue and bone windows as well as detailed vascular imaging (52,53). In clinical practice, medical professionals are presented with two distinct approaches for conducting comprehensive diagnostic imaging of the patient: one option involves performing separate examinations of the head and neck region as well as the torso and lower extremities, while the alternative is to acquire a single whole-body scan that encompasses the entire anatomical area from the cranium to the lower limbs (53–55).

1.10.2. Reference Values

In the context of computed tomography CT, the kilovolt (kV) value refers to the voltage applied to the X-ray tube, which has a significant impact on the energy of the generated X-ray photons. This, in turn, affects both image quality and the radiation dose administered to the patient (56,57). A higher kV value results in higher-energy X-rays, which exhibit enhanced penetration of dense structures such as bones. Conversely, a lower kV value enhances the contrast in soft tissue imaging due to reduced photon energy, which is more readily absorbed by less dense tissues (58,59). Historically, technical limitations necessitated a tube voltage of 120 kV in computed tomography (CT). However, when imaging native soft tissues, which are predominantly influenced by image noise, deviating from this standard offers negligible benefits (60).

The selection of the kV setting is a critical factor in optimizing diagnostic accuracy and patient safety in Ct imaging. Higher kV settings, typically ranging from 120 to 140 kV, are beneficial for imaging large or dense anatomical regions, where higher penetration power is required to obtain clear images. In contrast, lower kV settings, often in the range of 80 to 100 kV, are preferred for imaging soft tissues, as they provide better contrast resolution and reduce radiation exposure (60,61). In the field of pediatric radiology, meticulous calibration of imaging parameters is crucial to ensure both patient safety and diagnostic efficacy. The X-ray tube voltage is precisely adjusted according to the patient's age and body mass. Lower kilovolt peak (kVp) settings, typically around 80 kVp, are frequently employed to optimize image contrast while simultaneously minimizing radiation exposure.(62). The choice of kV setting is thus a delicate balance between achieving sufficient image quality and minimizing the radiation dose, tailored to the specific clinical indication and patient characteristics (56). Beam energy has the potential to significantly influence radiation dose. Nevertheless, its infrequent adjustment during clinical CT imaging protocols renders it the least impactful parameter in terms of practical radiation dose management (63).

The Computed Tomography Dose Index (CTDI) is the principal metric for measuring radiation dose in CT imaging. It quantifies the average absorbed dose from a series of contiguous irradiations. The CTDI is derived from a single axial CT scan represented by one complete rotation of the X-ray tube, by dividing the integrated absorbed dose by the nominal total beam collimation. The CTDI is consistently measured in the axial scan mode for a single rotation of the X-ray source. This measurement provides a theoretical estimate of the average dose within the central region of a scan volume, comprising multiple contiguous CT scans, assuming the scan length is sufficient for the central dose to reach its asymptotic upper limit (64). The CTDI enables medical professionals to compare the radiation emissions of different CT scanners, thereby providing a standardized framework for evaluating and optimizing patient safety across various imaging systems (65). The CTDI plays a crucial role in several aspects of CT imaging, including its use as a rapid and reproducible measure of equipment performance during routine quality assurance tests. Secondly, CTDI measurements play a crucial role in the acceptance testing of new CT scanners. They serve to verify that the scanner's dosimetric performance aligns with the manufacturer's specifications and to validate the accuracy of displayed dose metrics, such as the Dose Length Product (DLP). These metrics are vital for setting and complying with diagnostic reference levels, which are benchmarks for radiation doses in medical imaging. Thirdly, CTDI metrics are used to monitor patient doses and optimize scan protocols (66).

Dose Length Product (DLP) quantifies the radiation output/exposure from a CT scanner's tube, expressed in milligray-centimeters. It is associated with the volume CTDI, which denotes the dose through a slice of a standard phantom. However, DLP extends this by incorporating the length of radiation exposure along the z-axis, providing a more comprehensive assessment of the radiation dose (67). The relationship between DLP and CTDI is defined by the equation:

$$DLP = (CTDIvol\ in\ mGy) \times (scan\ length\ in\ cm)(58)$$

DLP does not adjust for patient size and does not represent the absorbed dose. Rather, it is one of two key parameters, alongside the CT dose index, that are used to establish diagnostic reference levels for radiation doses in different imaging modalities (68,69). A distinction must be made between the DLP and the patient’s effective dose as they are not equivalent. The effective dose considers additional factors, such as patient size and the specific body region being scanned. From a terminological perspective, the DLP appears to be analogous to the measurement used to determine the CTDI, essentially representing the product of the intensity and extent of a radiation beam. A key difference, however, exists between the application of DLP to the entire scan series, where length corresponds to the dimension of the scanned body section. In contrast, for the dose length product of an individual slice, "length" refers to the dimension over which the components of the dose profile are summed. The DLP represents the area under the cumulative dose profile for a scan series compromising n slices (58).

The typical scan range for the C-spine (Cervical spine) during a CT scan is approximately 13 cm, as indicated by reference values. However, this value may fluctuate depending on the individual patient's anatomy and clinical indications. As a result, the 13 cm range is primarily used as a guideline for orientation in clinical practice rather than a rigid standard (70).

2. OBJECTIVES

2.1. Aim of Study

This research aims to retrospectively conduct a comprehensive investigation into the clinical outcomes and diagnostic management of cervical spine injuries in patients admitted to the surgical emergency department of Regiomed Hospital, Coburg, with head trauma. The study population will comprise residents of Coburg and its neighboring towns in Bavaria. The primary objective of this study is to evaluate the necessity and clinical indications for performing cervical spine CT assessments in head trauma patients, with a focus on identifying specific associated symptoms and signs suggestive of cervical spine injury. Furthermore, this study aims to develop a thoughtful approach to the use of diagnostic tools in the emergency department setting, ensuring optimal patient care and resource allocation.

2.2. Hypothesis

Cervical spine imaging is only indicated in adult patients with isolated head trauma presenting to the surgical emergency department in the presence of clinical signs and symptoms suggestive of cervical spine injury.

1. Symptoms are a sign of Cervical Neck Injury
2. Mechanism of Injury is a predictive Value for Cervical Spine Injury in Head Trauma Patients

3. SUBJECTS AND METHODS

3.1. Study design

This retrospective cohort study analyzed 109 patients who were admitted to the Emergency Department of Regiomed Hospital Coburg between September 2022 and end of March 2024 with an initial diagnosis of TBI (ICD 10: S06). The patients underwent diagnostic procedure and were analyzed and compared according to their outcomes and types of injury. The medical histories of the 109 patients were collected from their records over the course of treatment, providing data on their disease and its progression. This data was evaluated for this study as part of the Thesis for the University of Split, School of Medicine. The study utilized anonymous, stored data from the ORBIS (Dedalus Healthcare Group, Bonn, Germany) system, a hospital information system used by Regiomed hospitals. Additional data was sourced from the Deep Unity system (Dedalus Healthcare Group, Bonn, Germany).

3.2. Variables

A comprehensive set of variables pertinent to this study was meticulously extracted from the relevant datasets. The baseline demographic information of the participants included gender, sex, and age, establishing a foundational context for the analysis. Additionally, the time and mechanism of injury were documented, providing critical insights into the circumstances of each case. Furthermore, the study recorded the Glasgow Coma Scale (GCS) score at the time of admission to the emergency department, along with the state of consciousness and the type of admission, to evaluate the initial severity and nature of the patients' conditions. To assess patient prognosis, clinical outcomes, and subsequent treatment, the study incorporated several key outcome variables. These included patients’ symptoms, additional diagnostic tools employed, the initial assessment by the physician, the use of anticoagulants, and the final diagnosis from both the CT scan and the discharge summary. Additionally, the radiation doses administered during the initial CT scans of the head and cervical spine at the time of emergency admission were meticulously recorded. These values included the kilovoltage (kV), the computed tomography dose index (CTDI), the dose-length product (DLP), and the range, ensuring a thorough evaluation of the radiological exposure each patient received.

3.3. Potential bias, confounding factors and limitations

It is essential to acknowledge the inherent limitations of this study, including the study design, sample size, and other factors that may bias the interpretation and generalizability of the findings. The retrospective design of the study is limited by its reliance on existing documentation, which may be incomplete, inaccurate or flawed. Although the data for this study were acquired through ORBIS, a well-structured electronic database integral to healthcare documentation, the potential for bias remains Furthermore, the analysis was constrained by the inability to account all possible confounding factors and specific variables such as exact GCS scores, alcohol levels, co-existing medical diagnosis that may have contributed to the falls. The small sample size also limits the generalizability of the findings, rendering, the results of this research potentially inapplicable to broader populations in other areas.

3.4. Calculation of minimal sample size

The sample size becomes irrelevant in the absence of a direct comparison between two hypotheses.

3.5. Statistical Analysis

The results of the study were meticulously analyzed using IBM SPSS Statistics 29.0.2.0 (IBM Deutschland GmbH, Böblingen, Germany), a robust and widely recognized software for statistical analysis. To assess the normality of the data, distribution was visualized via a histogram and further QQ plots. Quantitative data in the study are presented as mean ± standard deviation (SD) to represent the average values and their variability. Additionally, for data that do not follow a normal distribution, the median is reported, providing a measure of central tendency and dispersion that is less affected by outliers and skewed data. In contrast, qualitative data are presented as whole numbers and percentages, facilitating a straightforward understanding of the frequency and proportion of categorical variables within the dataset.

3.6. Ethical approval

The research project received approval from the Institutional Review Board (IRB) of the Medical School Regiomed Coburg on March 8th, 2024, in accordance with §2 of its Statutes. Given the retrospective nature of this project, additional study registration was not deemed necessary.

4. RESULTS

A total of 109 patients were included in this study and categorized according to various parameters. The median age at initial diagnosis was 79 years, with a range from 36 to 98 years. The gender distribution was comprised of 57 males (52.3%) and 52 females (47.7%). The majority of admissions (81 patients, 74.3%) were due to falls, while the remaining 28 patients (25.7%) were admitted for other reasons.

The analysis of admission timing revealed that Friday had the highest number of admissions, representing 19.3% of the total admissions. Overall, 34 patients (31.2%) were admitted during the weekend (Saturday and Sunday), while 75 patients (68.8%) were admitted on weekdays (Monday through Friday). This indicates that the majority of patient admissions occurred on weekdays, with Friday being the busiest day.

In summary, the majority of admissions to the emergency department occurred between 11:00 and 12:00 PM, followed by the intervals from 10:00 to 11:00 AM and 18:00-19:00 PM as well as 0:00 – 01:00 AM. Conversely, the early morning hours from 05:00 to 07:00 AM have the lowest number of admissions. This pattern suggests a higher likelihood of patient admissions during the midday hours, in the early evening and around Midnight.

Upon admission to the emergency department, the Glasgow Coma Scale (GCS) was assessed in 30 patients (27.5%), whereas 79 patients (72.5%) did not have a recorded GCS. The study found that 44 patients (40.4%) were on acetylsalicylic acid (ASA), 32 patients (29.4%) were taking novel oral anticoagulants (NOACs), and 33 patients (30.3%) were not taking anticoagulants.

To gain a deeper understanding of the distribution of our dataset, quantile-quantile (Q-Q) plots were utilized as a visual tool for exploratory data analysis.

Patient related data were extracted from respective Orbis files and analyzed. A summary was then prepared, presented in Table 1.

Table 1. Patients and Injury Characteristics

Variable		N (%)
All patients		109 (100)
Gender	Male	57 (52,3)
	Female	52 (47,7)
Age	Median	79 years
	Range	36-98 years
GCS-Score	Yes	30 (27,5)
	No	79 (72,5)
Anticoagulation	Ass	44 (40,4)
	NOAK	32 (29,4)
	No	33 (30,3)
Mechanism of Injury	Falls	81 (74,3)
	Others	28 (25,7)
Symptoms	Yes	7 (6,4)
	No	102 (93,6)
Weekday	Median	5 (Friday)
	Mean	4,29

Data are presented as absolute number of cases (%)

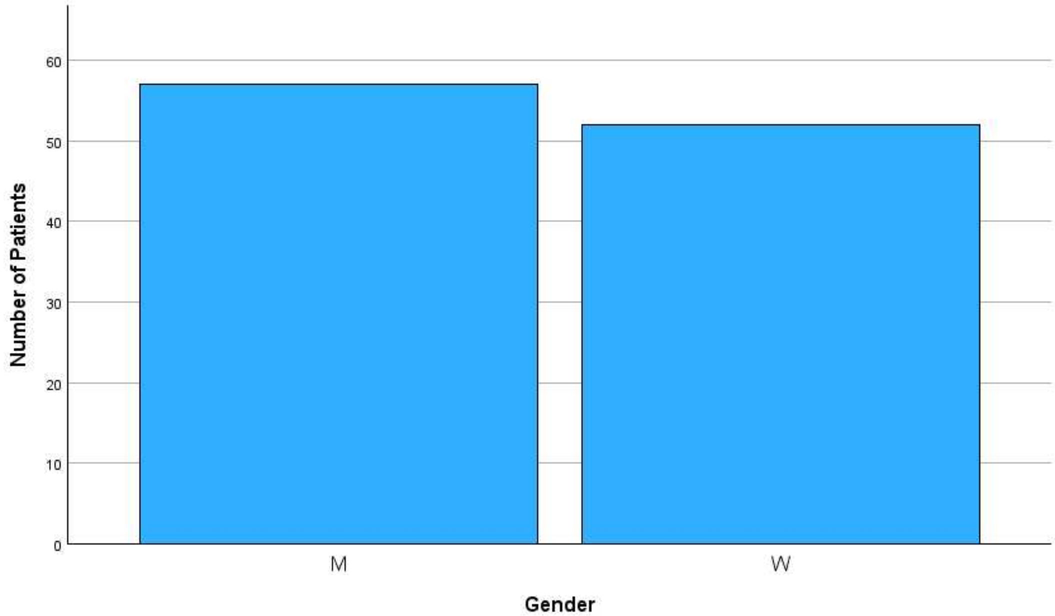

Figure 10. Histogram "Gender distribution"

M: male

F: female

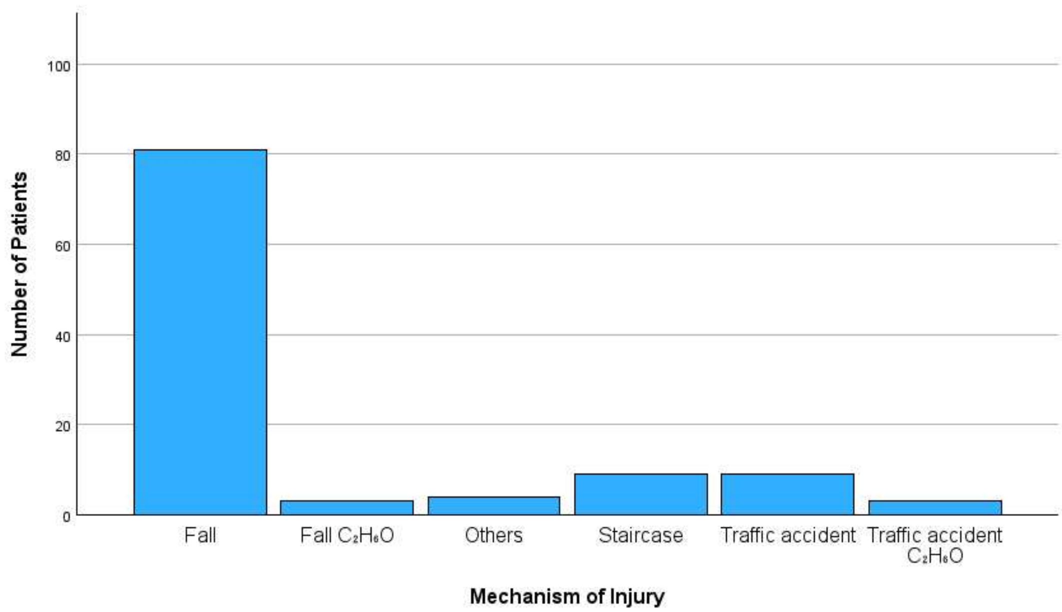

Figure 11. Histogram „Mechanism of Injury"

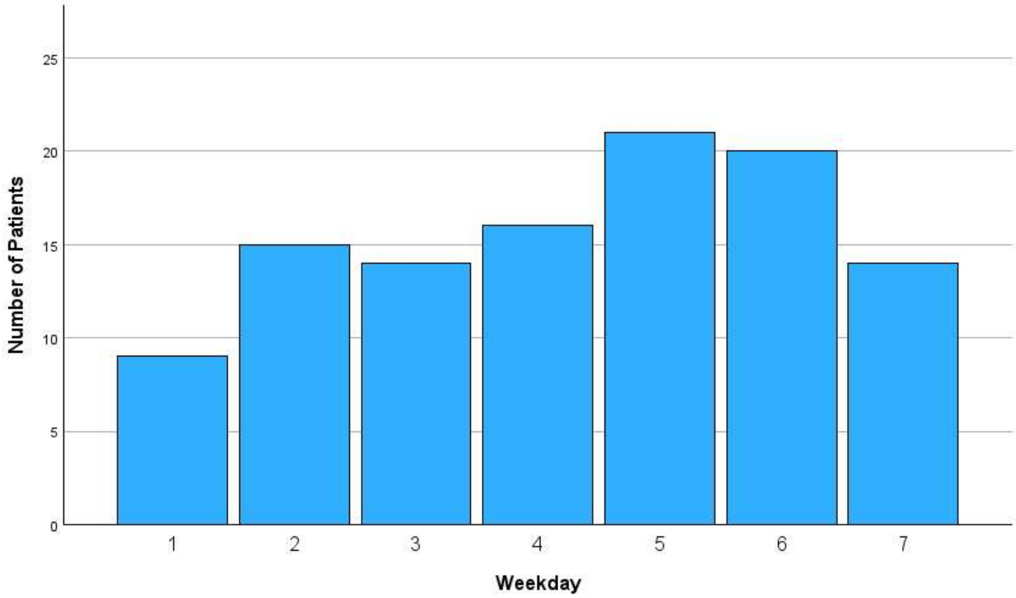

Figure 12. Histogram „Distribution of Weekdays"

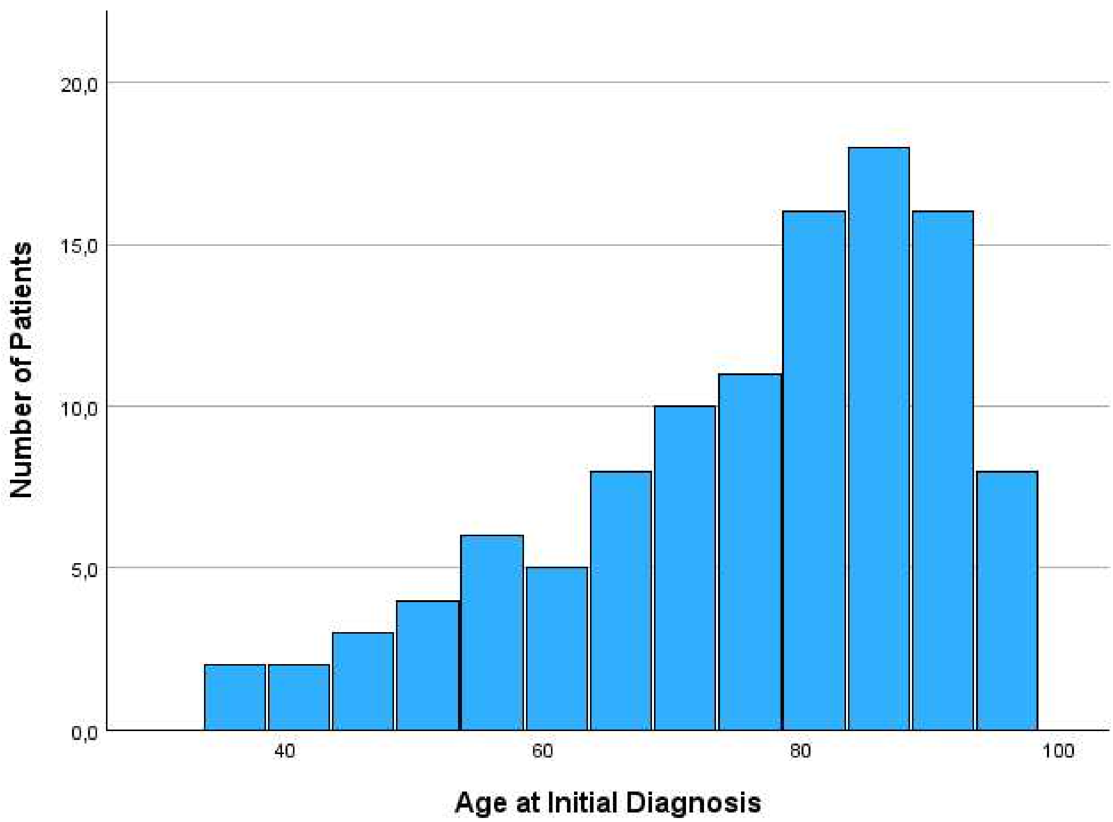

Figure 13. Histogram „Age at initial diagnosis"

The Normal Q-Q Plot of the "Age Distribution" illustrates the relationship between the observed age values and the expected normal values seen in Figure 14. The plot indicates that the data points deviate from the expected linear relationship, particularly at the lower and upper extremes of the age distribution. This suggests that the age data does not entirely correspond to a normal distribution. In contrast, the central values exhibit a better fit to the normal distribution, indicating a more normal-like distribution in the mid-range. However, the noticeable deviations in the tails of the distribution suggest skewness or the presence of outliers. Overall, the age distribution appears to be approximately normal, albeit with some deviations from normality.

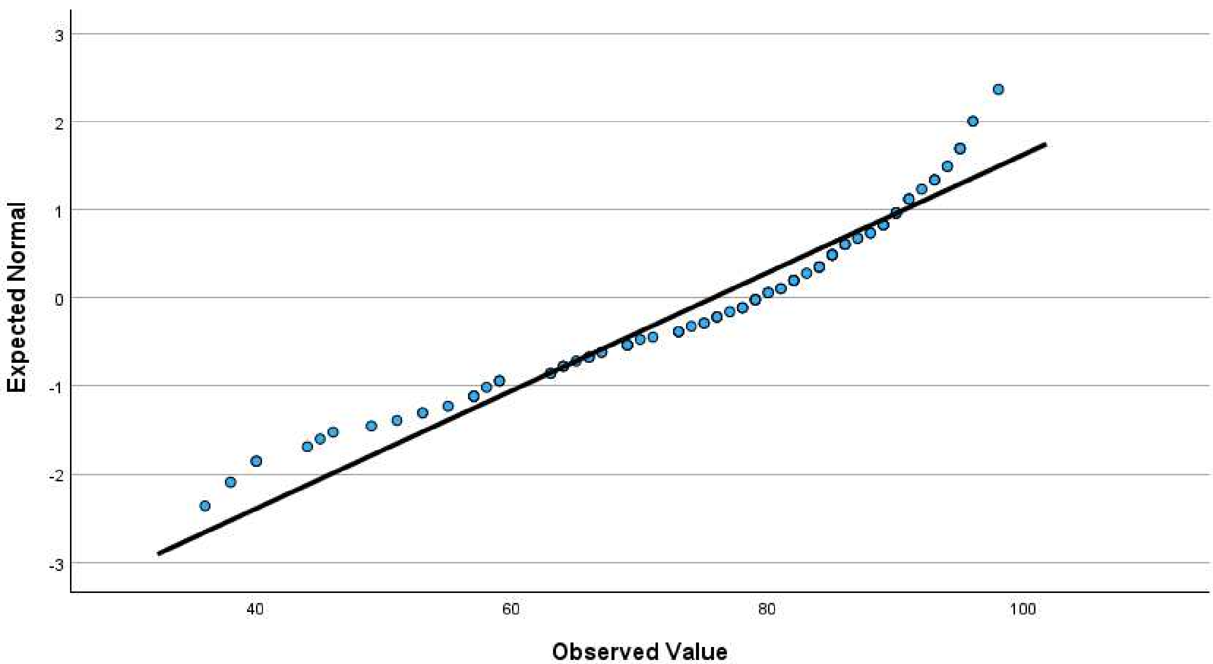

Figure 14. Q-Q Plot "Age Distribution"

The bar chart Figure 15. illustrates the distribution of patient admissions throughout the day, revealing clear patterns in patient inflow. Notably, there are two peak periods: the late morning between 10:00 AM and 11:00 AM, when ten patients were admitted, and the early evening between 6:00 PM and 7:00 PM, with eight admissions. In contrast, the early morning hours from 5:00 AM to 8:00 AM stand out as a quiet period with no patient admissions recorded**.**

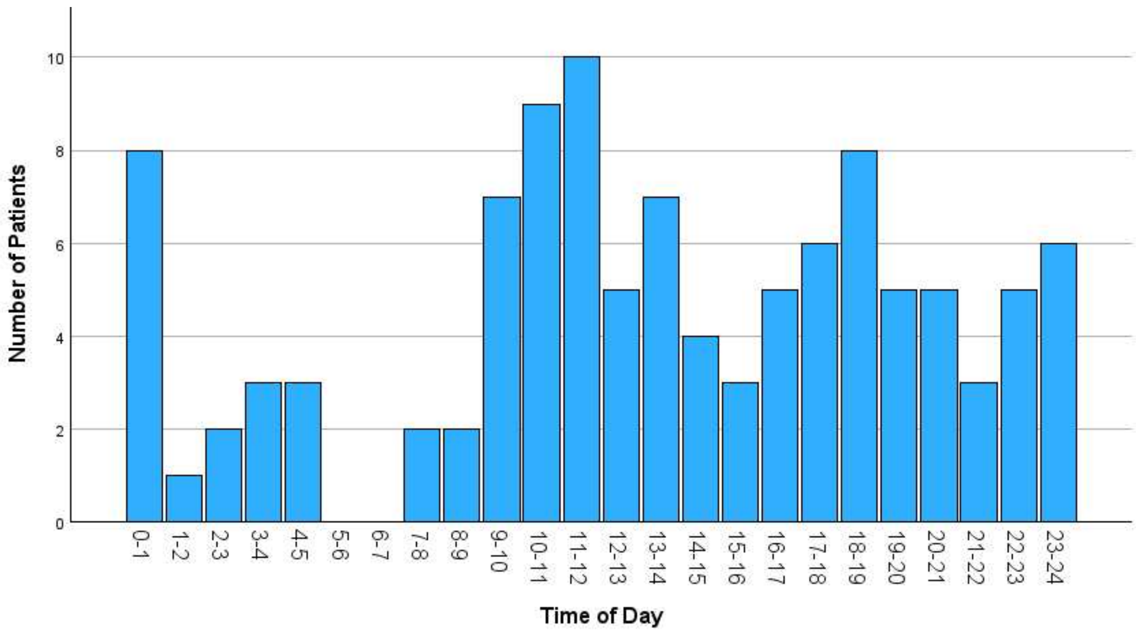

Figure 15. Histogram “Time of Day”

This study assessed the presence of signs and symptoms of cervical neck injury as can be seen in Figure 16 and 17. Of the 109 patients, seven (6.4%) exhibited signs and symptoms of cervical neck injury, whereas 102 patients (93.6%) did not display any signs or symptoms of such an injury. Further analysis that 104 patients (95.4%) had no cervical spine fractures while five patients (4.6%) received a clinical diagnosis of cervical fractures.

The crosstabulation table Figure 18. illustrates the relationship between the presence of clinical symptoms and the incidence of cervical spine fractures within the patient cohort. Among these asymptomatic individuals, 101 patients did not sustain a fracture, whereas only one patient did. In contrast, seven patients presented with symptoms indicative of a cervical spine injury. Within this symptomatic group, three patients did not have a fracture, while four patients were confirmed to have sustained a cervical spine fracture.

This distribution reveals that the presence of symptoms was relatively uncommon (6.4%), with the vast majority of asymptomatic patients not sustaining a fracture (92.7%). However, when symptoms did occur, the likelihood of a fracture increased significantly, with 57.1% of symptomatic patients having a fracture. As anticipated, this pattern underscores a strong correlation between the presence of symptoms and the incidence of cervical spine fractures in this patient sample.

A notable exception to the general trend was a patient who exhibited no symptoms but was found to have a fracture at the spinous process of the second cervical vertebra. This fracture was so minor that it was initially undetected during the physical examination and did not result in any acute symptoms or functional impairments. However, the fracture was subsequently diagnosed through a CT scan which provided more detailed visualization of the cervical spine. Given the minimal nature of the fracture and its lack of clinical significance, the medical team opted for conservative management after surgical consultation. The patient was fitted with a cervical orthosis to stabilize the affected area and facilitate healing without the need for invasive intervention. This case highlights the importance of thorough assessment, even in asymptomatic patients, as clinically silent fractures can still be present. Although the fracture in this instance did not cause significant symptoms and did not necessitate treatment in the traditional sense, conservative management ensured optimal healing. The decision to employ a cervical orthosis was appropriate in this context, serving to prevent potential complications and supporting the patient's complete recovery.

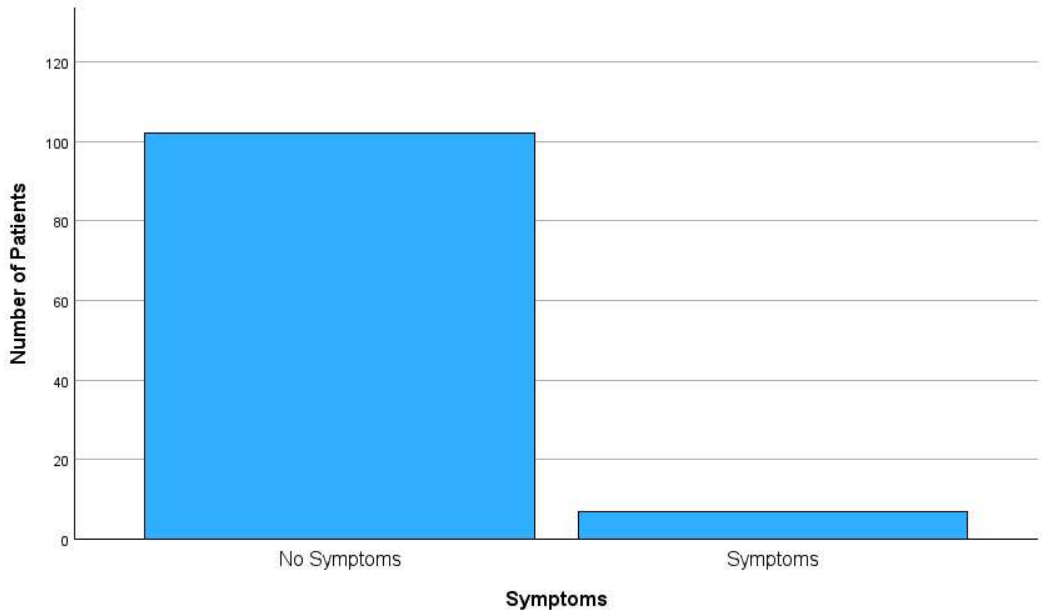

Figure 16. Histogram “Symptoms”

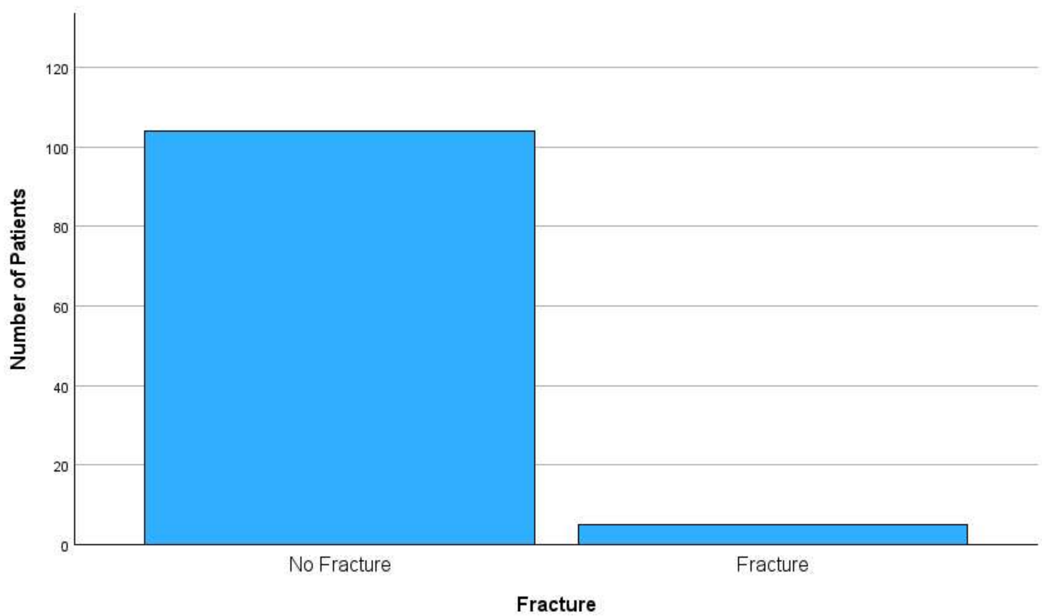

Figure 17. Histogram “Fracture”

		Fracture		
		No	Yes	Total
Symptoms	No	101	1	102
	Yes	3	4	7
Total		104	5	109

Figure 18. Contingency Table “Symptoms - Fracture”

The Chi-Square test results for the crosstabulation of symptoms and cervical spine fractures yield several noteworthy insights as seen in Figure 19 and the according Bar chart in Figure 20. The Pearson Chi-Square value is 47.208 with 1 degree of freedom (df), and the asymptotic significance (2-sided) is less than 0.001, indicating a highly significant outcome. These findings strongly suggest a statistically significant association between the presence of symptoms and the occurrence of cervical spine fractures.

The Continuity Correction value is 35.248 with 1 df, and its associated significance level is also less than 0.001. This correction is applied to account for the small sample size, yet it continues to indicate a significant association. The Likelihood Ratio value is 19.785 with 1 df, and its significance level is less than 0.001, providing further corroboration of the significant association between symptoms and fractures.

Fisher's Exact Test, frequently employed in analyses with small sample sizes, demonstrates a significance level of less than 0.001 for both two-sided and one-sided tests. This finding further corroborates the robustness of the association between symptoms and fractures. The Linear-by-Linear Association value is 46.775 with 1 df, yielding a significance level of less than 0.001, indicating a strong linear relationship between the presence of symptoms and the likelihood of cervical spine fracture occurrence. The total number of valid cases in this analysis is 109.

In conclusion, the Chi-Square test results substantiate a highly significant association between the presence of clinical symptoms and the occurrence of cervical spine fractures within the studied patient cohort. All tests, including the Pearson Chi-Square, Continuity Correction, Likelihood Ratio, and Fisher's Exact Test, yield significance levels of less than 0.001. This consistent statistical significance across multiple tests strongly indicates that the presence of symptoms serves as a reliable predictor of cervical spine fractures.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	47,208[a]	1	<,001		
Continuity Correction[b]	35,248	1	<,001		
Likelihood Ratio	19,785	1	<,001		
Fisher's Exact Test				<,001	<,001
Linear-by-Linear Association	46,775	1	<,001		
N of Valid Cases	109				

a. 2 cells (50,0%) have expected count less than 5. The minimum expected count is ,32.

b. Computed only for a 2x2 table

Figure 19. Chi-Square Test “Contingency Table Symptoms-Fracture”

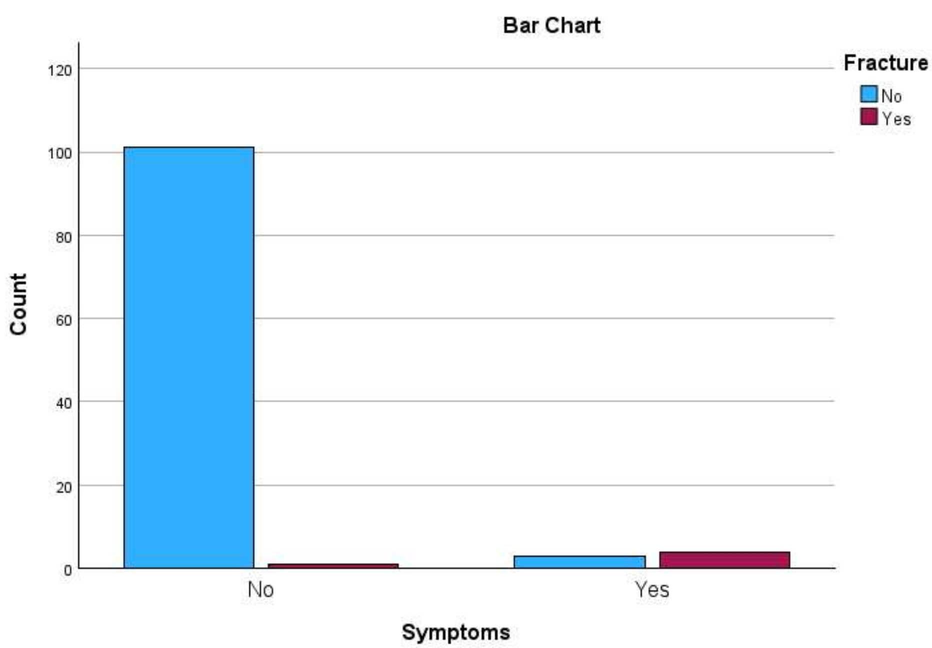

Figure 20. “Histogram Symptoms and Fracture”

The cross-tabulation analysis from Figure 21 elucidates the relationship between various mechanisms of injury and the occurrence of fractures among 109 patients. Specifically, the data indicate that out of 81 patients who experienced a fall, 77 did not sustain a fracture while four did. In cases of falls with alcohol involvement, all three patients were free of fractures. In the "Others" category, none of the four patients exhibited fractures. Similarly, among the nine patients who fell on staircases, no fractures were observed. Regarding traffic accidents, eight out of nine patients did not sustain fractures, with one patient presenting a fracture. In traffic accidents involving alcohol, all three patients were devoid of fractures.

The patient, a 36-year-old male, presented with retrograde amnesia post-accident a condition characterized by memory loss for events before preceding the injury. Additionally, he exhibited clinical signs of cervical spine tenderness upon percussion, indicative of potential trauma to this region. A CT scan was performed to assess the extent of his injuries, revealing a transverse process fracture at the level of the sixth cervical vertebra (HWK 6), accompanied by a disc protrusion at the C5/C6 level. While the transverse process fracture is generally considered a relatively stable injury, it can be associated with significant pain and discomfort, particularly due to its proximity to critical musculature and neural structures. The concurrent disc protrusion at C5/C6 further exacerbated his condition, likely contributing to his symptomatology. Given the nature of his injuries, the medical team opted for conservative management approach. The patient was treated with a Miami J collar, a cervical orthosis designed to immobilize the cervical spine, thereby providing stability and reducing pain while promoting healing. This non-invasive approach was deemed appropriate for his injuries which, although significant, did not require surgical intervention. This case highlights the importance of thorough diagnostic evaluation following high-impact trauma, such as a traffic accident and demonstrates the efficacy of conservative management in cases where immediate surgical intervention is not warranted.

In conclusion, while the cross-tabulation provides a descriptive overview of fracture distribution across different mechanisms of injury, the Chi-Square test results indicate that these observed differences are not statistically significant as can be seen in Figure 22. The Pearson Chi-Square value is 1.811 with 5 degrees of freedom, and the asymptotic significance (two-sided) is 0.875. This elevated p-value suggests the absence of a statistically significant association between the mechanism of injury and the occurrence of fractures. Consequently, the analysis of this patient cohort reveals no significant correlation between the mechanism of injury and the probability of sustaining a fracture.

		Fracture_Yes_No		
		No Fracture	Fracture	Total
Unfallmechanismus	Fall	77	4	81
	Fall C_2H_6O	3	0	3
	Others	4	0	4
	Staircase	9	0	9
	Traffic accident	8	1	9
	Traffic accident C_2H_6O	3	0	3
Total		104	5	109

Figure 21. Contingency Table "Mechanism of Injury – Symptoms"

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1,811[a]	5	,875
Likelihood Ratio	2,443	5	,785
N of Valid Cases	109		

a. 9 cells (75,0%) have expected count less than 5. The minimum expected count is ,14.

Figure 22. Chi Square Test " Mechanism of Injury – Symptoms"

The cross-tabulation analysis in Figure 23 elucidates the relationship between the Glasgow Coma Scale (GCS) and the incidence of Fracture. Among the 109 cases examined, 79 patients did not undergo GCS evaluation, of whom 77 were fracture-free and two presented with fractures. In the remaining (?) 30 cases where GCS was assessed, 27 patients exhibited no fractures, while three were diagnosed with fractures. In aggregate, 104 of the 109 cases were devoid of fractures, with the remaining five cases presenting fractures.

The second table in Figure 24 presents the results of various Chi-square tests examining the association between these two variables. The Pearson Chi-square value is 2.771, corresponding to a p-value of 0.096. Since this p-value exceeds the conventional significance level of 0.05, the null hypothesis - positing no association between GCS evaluation and the presence of a fracture - cannot be rejected. Similarly, the Likelihood Ratio Test, with a p-value of 0.119, also indicates no significant association. Fisher's Exact Test yields a two-sided p-value of 0.127, which likewise fails to suggest a significant association. The Linear-by-Linear Association Test exhibits a test statistic of 2.745 with a p-value of 0.098, further corroborating the absence of a significant linear association between the variables under investigation.

In conclusion, both the cross-tabulation analysis and the Chi-square tests demonstrate the absence of a statistically significant association between the evaluation of GCS and the presence of a fracture. The observed differences in the data are (more?) likely attributable to chance (random variation?) rather than a genuine underlying association between these variables.

		Fracture		
		No	Yes	Total
GCS	Not Conducted	77	2	79
	Conducted	27	3	30
Total		104	5	109

Figure 23. Contingency Table “GCS- Fracture"

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	2,771[a]	1	,096		
Continuity Correction[b]	1,327	1	,249		
Likelihood Ratio	2,427	1	,119		
Fisher's Exact Test				,127	,127
Linear-by-Linear Association	2,745	1	,098		
N of Valid Cases	109				

a. 2 cells (50,0%) have expected count less than 5. The minimum expected count is 1,38.

b. Computed only for a 2x2 table

Figure 24. Chi Square Test “GCS-Fracture”

The cross-tabulation in Figure 25 shows the relationship between the Glasgow Coma Scale (GCS) and the presence or absence of symptoms. It is apparent that among the 109 cases considered, the majority (102) show no symptoms, while only seven cases exhibit symptoms. Within the "Not Conducted" group, there are 79 cases, of which 74 are symptom-free and five show symptoms. In the "Collected" group, there are 30 cases, with 28 having no symptoms and two showing symptoms. Overall, the table suggests that most of the data falls under the "Not Conducted" category and that the distribution of symptoms does not strongly depend on whether data was collected.

The Chi-square test results provide further insights into the relationship between GCS data collection and the occurrence of symptoms as can be seen in Figure 26. The Pearson Chi-square value is 0.004 with a p-value of 0.949, indicating no statistically significant association between these two variables. The continuity correction and likelihood ratio tests corroborate this finding, yielding identical p-values. Furthermore, the Fisher's exact test demonstrates no significant difference, as indicated by the two-sided p-value of 1.000.

In conclusion, the statistical analysis suggests the absence of a significant relationship between GCS data collection and the presence of symptoms. These results imply that the collection of GCS data does not influence the likelihood of symptom occurrence.

Count

		Symptoms		
		No	Yes	Total
GCS	Not Conducted	74	5	79
	Conducted	28	2	30
Total		102	7	109

Figure 25. Contingency Table “GCS- Symptoms"

Chi-Quadrat-Tests

	Wert	df	Asymptotische Signifikanz (zweiseitig)	Exakte Sig. (zweiseitig)	Exakte Sig. (einseitig)
Pearson-Chi-Quadrat	,004[a]	1	,949		
Kontinuitätskorrektur[b]	,000	1	1,000		
Likelihood-Quotient	,004	1	,949		
Exakter Test nach Fisher				1,000	,623
Zusammenhang linear-mit-linear	,004	1	,949		
Anzahl der gültigen Fälle	109				

a. 1 Zellen (25,0%) haben eine erwartete Häufigkeit kleiner 5. Die minimale erwartete Häufigkeit ist 1,93.

b. Wird nur für eine 2x2-Tabelle berechnet

Figure 26. Chi Square Test “GCS - Symptoms”

5. DISCUSSION

The incidence of new cases of patients admitted to the ED with head trauma has been steadily increasing over several years. Against the backdrop of demographic changes and future challenges for medical staff and patients a significant problem emerges. To address this issue, numerous studies have been conducted on diagnostics, treatment and outcomes. This study provides a comprehensive retrospective analysis of head trauma patients admitted to the surgical emergency department of Regiomed Hospital Coburg. The primary objective was to assess the necessity and clinical indications for performing cervical spine CT assessments in head trauma patients with a particular focus on the relationship between clinical symptoms and the presence of cervical spine fractures. The study population comprised 109 patients, with a median age of 79 years, indicating that elderly individuals constitute a significant portion of those presenting with head trauma. This finding aligns with existing literature which highlights the vulnerability of older adults to falls and subsequent traumatic injuries. The gender distribution was relatively balanced, with a slight male predominance (52.3%), aligning with broader epidemiological trends in trauma.

A critical finding of this study is the limited use of the Glasgow Coma Scale (GCS) in the initial assessment, with only 27.5% of patients having documented GCS scores upon admission. This underutilization could potentially impede the early identification of severe traumatic brain injuries (TBIs) and underscores the necessity for standardized protocols to ensure consistent application of the GCS in emergency settings.

The results demonstrate that the vast majority of patients (93.6%) did not exhibit clinical symptoms of cervical spine injury, and correspondingly, most did not sustain cervical fractures. However, in the small subset of symptomatic patients, a significant correlation was observed between the presence of symptoms and the likelihood of a cervical spine fracture, as indicated by the Chi-square test results ($p < 0.001$). This finding reinforces the importance of clinical symptoms as a predictor of cervical spine fractures and supports current guidelines advocating for CT imaging in symptomatic patients. Notably, this study also identified cases where fractures were present despite the absence of clinical symptoms. This observation highlights the potential limitations of relying solely on clinical presentation to guide imaging decisions and suggests that a more nuanced approach, potentially incorporating routine imaging for high-risk populations, may be warranted to mitigate the risk of overlooking clinically silent yet significant injuries.

The analysis of the mechanism of injury revealed that falls were the predominant cause of trauma, accounting for 74.3% of cases. Despite the high incidence of falls, the study found no statistically significant association between the mechanism of injury and the occurrence of fractures ($p = 0.875$). This finding suggests that while the type of injury mechanism can provide valuable context information, it may not serve as a reliable standalone predictor of fracture risk Nevertheless, it can offer insight into potential injury patterns. A noteworthy case involving a patient with a transverse process fracture following a traffic accident exemplifies the heterogeneity of injury patterns and underscores the necessity for tailored assessment strategies. This case study reinforces the importance of comprehensive, individualized evaluations in trauma patients, irrespective of the apparent mechanism of injury.

The findings of this study have several implications for clinical practice. Primarily, the significant association between clinical symptoms and fracture presence underscores the importance of thorough clinical assessment in guiding imaging decisions. However, the detection of asymptomatic fractures through CT imaging suggests that relying exclusively on clinical presentation may be insufficient, particularly in high-risk populations such as the elderly or those with High Impact Injuries. Consequently, a balanced approach that integrates both clinical and imaging data is essential for optimal patient management. Moreover, the underutilization of the GCS in initial assessments highlights a critical area for improvement in emergency department protocols. Ensuring that all patients with head trauma undergo a standardized GCS assessment could enhance the early detection of severe TBIs, potentially improving patient outcomes and supporting the emergency team in their decision-making process.

From an economic perspective and considering the allocation of available resources, the probability of overlooking a clinically significant cervical spine fracture in patients with traumatic brain injury (TBI) who present without clinical signs or symptoms indicative of cervical spine injury is deemed negligible. This observation suggests that routine, comprehensive imaging may not be warranted in such cases, potentially allowing for more judicious utilization of medical resources. The opportunity to refine diagnostic protocols without compromising patient safety underscores the potential to enhance healthcare delivery efficiency, ensuring that resources are optimally allocated while minimizing unnecessary procedures in low-risk scenarios. This approach aligns with evidence-based practices that seek to balance clinical vigilance with cost-effectiveness in the management of trauma patients.

This study's retrospective design presents inherent limitations, including the potential for incomplete or inaccurate documentation. The relatively small sample size further constrains the generalizability of the findings, and the results may not be applicable to broader populations. Furthermore, all patients were recruited from the emergency department of a single hospital in a rural area. Consequently, the regional environmental influence may not be applied to a larger population or other geographical contexts. Additionally, the absence of data on certain confounding factors, such as blood alcohol levels and coexisting medical conditions, may have influenced the outcomes. This paucity of information renders it challenging to make definitive statements about the influence of other confounding factors. Addressing these aforementioned limitations presents considerable opportunities for improvement and further research.

Future research should prioritize prospective studies with expanded sample sizes to corroborate these findings and investigate the potential benefits of routine cervical spine imaging in asymptomatic yet high-risk populations. Additionally, concerted efforts should be directed towards standardizing the application of the Glasgow Coma Scale (GCS) and other assessment tools in emergency settings. Such standardization would ensure consistent and accurate evaluation of patients presenting with head trauma, thereby enhancing the quality and reliability of clinical assessments.

6. CONCLUSION

1. In conclusion, this study, encompassing 109 patients with head trauma treated in the Emergency Department of Coburg Hospital, demonstrates a statistically significant correlation between the presence of clinical symptoms and the likelihood of cervical spine fractures. Notably, 57.1% (four out of seven) of symptomatic patients presented with fractures in stark contrast to merely 0.98% (one out of 102) of asymptomatic patients ($p < 0.001$).

2. The study reveals that the majority of head trauma cases occurred in elderly patients, with a median age of 79 years, emphasizing the need for targeted prevention and management strategies in this demographic field.

3. The Glasgow Coma Scale (GCS) exhibited significant underutilization in initial assessments, with documentation in only 27.5% of cases, suggesting a substantial gap in standardized protocol adherence, potentially compromising the early detection of severe TBIs.

4. Despite the overall low incidence, 20% (one out of five) of detected cervical spine fractures occurred in asymptomatic patients, underscoring the inherent limitations of relying solely on clinical symptoms and suggesting the potential benefit of implementing more routine imaging protocols in high-risk groups.

5. Statistical analysis revealed no significant association between the mechanism of injury and the occurrence of fractures, as evidenced by a Pearson Chi-Square value of 1.811 ($p = 0.875$). This finding suggests that the injury mechanism alone may not serve as a reliable predictor of fracture risk.

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8. SUMMARY

Objectives: The primary objective of this study was to investigate the clinical outcomes and diagnostic management of cervical spine injuries in patients admitted to the surgical emergency department of Regiomed Hospital, Coburg, following head trauma. Specifically, the study aimed to evaluate the necessity and clinical indications for performing cervical spine CT assessments, with a particular focus on identifying the relationship between clinical symptoms and the presence of cervical spine fractures. The study hypothesized that cervical spine imaging is warranted only in adult patients with isolated head trauma who present with clinical signs and symptoms suggestive of cervical spine injury.

Material and Methods: This retrospective cohort study analysed 109 patients admitted to the emergency department for traumatic brain injury (TBI) between 2022 and 2024. Data were extracted from the ORBIS and Deep Unity hospital information systems, focusing on variables such as patient demographics, mechanism of injury, Glasgow Coma Scale (GCS) scores, clinical symptoms, and the presence of cervical spine fractures. Statistical analyses were conducted using IBM SPSS Statistics 29.0.2.0 to assess correlations between these variables. Additionally, the study documented radiation doses administered during initial CT scans, including kilovoltage (kV), Computed Tomography Dose Index (CTDI), and Dose Length Product (DLP).

Results: The study cohort exhibited a median age of 79 years, with a slight male predominance (52,3%). A significant finding was the substantial underutilization of GCS in initial assessments, with documentation in merely 27,5% of cases. Statistical analysis revealed a strong correlation between the presence of clinical symptoms and the incidence of cervical spine fractures, with 57.1% of symptomatic patients presenting with fractures compared to 0,98% of asymptomatic patients ($p < 0,001$). However, it is crucial to note that 20% of fractures occurred in asymptomatic patients, highlighting the potential risks of relying solely on clinical symptoms. Additionally, no statistically significant association was observed between the mechanism of injury and the occurrence of fractures ($p = 0,875$)

Conclusion: The study's findings demonstrate a significant correlation between clinical symptoms and cervical spine fractures. However, the occurrence of asymptomatic fractures indicates that symptom-based assessment alone may be insufficient for comprehensive diagnosis. These findings support the judicious application of cervical spine CT imaging in high-risk populations, even in the

absence of overt symptoms, to mitigate the risk of overlooking clinically silent injuries. Furthermore, the observed underutilization of the GCS underscores the necessity for more consistent adherence to standardized assessment protocols in emergency. This adherence is crucial for enhancing the early detection and management of severe TBIs. In conclusion, this study advocates for a balanced approach that integrates both clinical and imaging data to optimize patient outcomes.

9. CROATIAN SUMMARY

Naslov: Procjena CT snimaka vratne kralježnice kod pacijenata s ozljedama glave: Retrospektivna analiza.

Ciljevi: Primarni cilj ovog istraživanja bio je ispitati kliničke ishode i dijagnostičko upravljanje ozljedama vratne kralježnice kod pacijenata primljenih u kiruršku hitnu službu bolnice Regiomed, Coburg, nakon traume glave. Konkretno, istraživanje je imalo za cilj procijeniti potrebu i kliničke indikacije za provođenje CT pregleda vratne kralježnice, s posebnim naglaskom na utvrđivanje odnosa između kliničkih simptoma i prisutnosti prijeloma vratne kralježnice. Hipoteza studije bila je da je snimanje vratne kralježnice opravdano samo kod odraslih pacijenata s izoliranom traumom glave koji imaju kliničke znakove i simptome koji upućuju na ozljedu vratne kralježnice.

Materijal i metode: Ova retrospektivna kohortna studija analizirala je 109 pacijenata primljenih u hitnu službu zbog traumatske ozljede mozga (TBI) između 2022. i 2024. godine. Podaci su izvučeni iz bolničkih informatičkih sustava ORBIS i Deep Unity, s fokusom na varijable kao što su demografski podaci pacijenata, mehanizam ozljede, Glasgow koma skala (GCS), klinički simptomi i prisutnost prijeloma vratne kralježnice. Statističke analize provedene su korištenjem IBM SPSS Statistics 29.0.2.0 kako bi se procijenile korelacije između ovih varijabli. Također, studija je dokumentirala doze zračenja primljene tijekom početnih CT pregleda, uključujući kilovolt (kV), indeks doze računalne tomografije (CTDI) i proizvod duljine doze (DLP).

Rezultati: Srednja dob ispitanika iznosila je 79 godina, s blagom pretežnošću muškaraca (52,3%). Značajan nalaz bio je značajno nedovoljno korištenje GCS-a u početnim procjenama, s dokumentacijom u samo 27,5% slučajeva. Statistička analiza pokazala je snažnu korelaciju između prisutnosti kliničkih simptoma i učestalosti prijeloma vratne kralježnice, s 57,1% simptomatskih pacijenata s prijelomima u usporedbi s 0,98% asimptomatskih pacijenata ($p < 0,001$). Međutim, važno je napomenuti da je 20% prijeloma zabilježeno kod asimptomatskih pacijenata, što ukazuje na potencijalne rizike oslanjanja isključivo na kliničke simptome. Također, nije zabilježena statistički značajna povezanost između mehanizma ozljede i pojave prijeloma ($p = 0,875$).

Zaključak: Nalazi studije pokazuju značajnu korelaciju između kliničkih simptoma i prijeloma vratne kralježnice. Međutim, pojava asimptomatskih prijeloma ukazuje na to da procjena temel-

jena samo na simptomima može biti nedovoljna za sveobuhvatnu dijagnozu. Ovi nalazi podržavaju pažljivu primjenu CT snimanja vratne kralježnice kod visokorizičnih populacija, čak i u nedostatku očitih simptoma, kako bi se smanjio rizik od previđanja klinički tihih ozljeda. Nadalje, opaženo nedovoljno korištenje GCS-a naglašava potrebu za dosljednijim pridržavanjem standardiziranih protokola procjene u hitnoj službi. Ovo pridržavanje je ključno za poboljšanje rane detekcije i upravljanja teškim traumatskim ozljedama mozga. Zaključno, ova studija zagovara uravnotežen pristup koji integrira kliničke i slikovne podatke za optimizaciju ishoda pacijenata.