IOSUD – UNIVERSITATEA „DUNĂREA DE JOS” DIN GALAȚI

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The Role of Radio-Imaging Investigations in Diagnosing and Assessing the Severity of Craniocerebral Trauma in Children

PHD THESIS SUMMARY

PhD student,

Cristina-Mihaela Popescu

Scientific superviser,

Prof.dr. NECHITA AUREL

Seria M Nr 14

GALAȚI

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Chairman	Prof. univ. dr. habil TUTUNARU Dana
Scientific supervisor	Prof. univ. dr. NECHITA Aurel
Scientific referents	Prof. univ. dr. HABA Danisia
	Conf. univ. dr. BRATU Ana-Magdalena
	Prof. univ. dr. SÂRBU Nicolae

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INTRODUCTION

Radiology and medical imaging are two medical specialties that have experienced remarkable development over the past half-century. Research in this field is becoming increasingly numerous and detailed, and the results achieved are presented in posters, communications at various national or international scientific events, and high-quality scientific articles. The medical community's interest in and refinement of traditional investigative equipment, especially the development of human body examination technologies and software, has supported this progress.

Like any professional in the contemporary world who must solve numerous and complex challenges, radiology and medical imaging specialists must evaluate the case completely using only their resources.

Despite the inherent risks, radiology and medical imaging are the most direct, effective, and often the sole route to an accurate diagnosis. The challenges encountered while working in a children's hospital sparked my interest in delving deeper into radiology and medical imaging to understand better the achievements presented in the literature and, most importantly, for my continuous professional development. From the onset of my work at the 'Sf. Ioan' Emergency Clinical Hospital for Children, I noticed that most investigations were generally related to trauma, with CT scans being predominantly performed for cranio-cerebral trauma. These observations, coupled with my discussions with Professor Aurel Nechita, led me to choose this topic of study and enroll in the doctoral school to develop this thesis.

My involvement in this doctoral project focused equally on all three radiology and medical imaging specializations applied at the "Sf. Ioan" Emergency Clinical Hospital for Children in Galați, namely radiography, computed tomography (CT), and magnetic resonance imaging (MRI).

Throughout the three studies conducted during the doctoral research, I meticulously followed a rich case series, analyzing the investigations performed and their results and providing descriptive and/or comparative interpretations. I highlighted the aspects of common cases without omitting the rarer cases encountered in daily practice and the specialized literature. Moreover, I consistently explored the literature to accurately assess where our medical practice stands compared to other countries, the multidisciplinary approach to various cases, and, of course, to identify international practices closest to ours.

Thus, in the case of the first study, "The Study of Radiographic Examinations," I observed the following paradox: although this method accounts for the highest number of investigations during the period in which I conducted the research, it is constantly losing ground to computed tomography (CT) investigations. I also noticed that only mild traumas are investigated radiologically, confirming or not the presence of skull vault fractures.

The second study, "The Study of CT Examinations," constitutes the most substantial component of the entire thesis. This is explained by several factors, such as the utility of the investigation, which I will limit myself to describing as the "gold standard" for investigating cranio-cerebral traumas. The patients who benefited from this investigation were primarily boys. In addition to the results that indicated no post-traumatic changes, I encountered 40 unique or associated lesions, denoting more or less severe injuries. I grouped the lesions or associations of the same type, obtaining categories with multiple or just one case. Statistical calculations allowed me to establish the relationships between the CT-described lesions and the Glasgow Coma Scale (GCS) scores, the severity grade of the trauma, and the strength of these associations.

The study of MRI examinations mainly provided the opportunity to confirm or complement the CT studies. As with the other types of investigations, male patients were more numerous. Many MRI investigations showed the absence of intracranial post-traumatic lesions. The statistical analysis provided a suitable framework for formulating conclusions and identifying new directions for further research.

Finally, the study of concordance-discordance between the lesions described in CT examinations and those described in MRI examinations allowed for a parallel between the two methods and for understanding when to choose one over the other. Thus, the statistical calculations allowed this sample to confirm the data obtained in other published studies.

THE CURRENT STATE OF KNOWLEDGE

CHAPTER 1. CRANIOCEREBRAL TRAUMA IN CHILDREN

Due to the increasing incidence of trauma worldwide, the study of trauma has become a significant point of interest in the medical scientific community. The subject's theoretical importance has become so profound that various theories of trauma have been proposed (Bloom, 2018; Black and Flynn, 2022, pp. 133-140). In medical terminology, trauma (T) represents any injury to living tissues that occurs more or less suddenly, either accidentally or intentionally (Dumovich, 2022).

The focus of our study is on a specific type of trauma, more precisely, physical trauma, specifically cranio-cerebral trauma. Based on the above definitions and narrowing the meaning of the terms, we will propose our working definition, describing the concept of cranio-cerebral trauma (CCT) as a sudden, accidental, or intentional injury that affects the cranio-cephalic region.

Regardless of the type of CCT (as classified in the following subchapter), the forces that can cause post-traumatic cranio-cerebral injuries are divided into two main categories: (a) impact forces and (b) impulsive forces (Keating, 2020). Impact forces occur when a force acts directly on the head, either when a moving object strikes the head or when it strikes a stationary object (Popescu, 2024a). Impulsive forces occur when the body is struck and moves in one direction while the head moves in the opposite direction to the body (Popescu, 2024a). These forces generated by the impact will affect cranial and intracranial structures differently.

Regardless of the patient's age, CCT can be classified according to the following criteria:

- the type of traumatic agent causing the injury
- the mechanism of injury
- the location of post-traumatic lesions
- the types of post-traumatic lesions
- the etiology and pathogenesis of the lesions
- the distribution of post-traumatic lesions

According to the first criterion, the type of traumatic agent, CCT, can be accidental or non-accidental (Peace et al., 2023). From the perspective of the mechanism of injury, CCT can be (a) penetrating (involving skin wounds or fractures) or (b) non-penetrating (Hawryluk and Manley, 2015).

Another type of classification can be made strictly based on the location of the post-traumatic lesions (Quach et al., 2019; Barr, Gean, and Le, 2012). In this situation, CCT can be classified as producing lesions in specific locations:

- ***intra-axial***: cortical contusions, intracerebral hematomas, vascular injuries, diffuse axonal injuries
- ***extra-axial***: extradural hemorrhages, intraventricular hemorrhages, subarachnoid hemorrhages, and subdural hemorrhages

From an etiopathogenic perspective, CCTs can involve the following injuries (Osborn, 2016; Appelboom et al., 2011; Hawryluk and Manley, 2015; Capizzi, Woo, and Verduzco-Gutierrez, 2020):

- ***primary***: fractures, extra-axial hematomas, diffuse axonal injuries, vascular injuries. These occur at the moment of the traumatic event.
- ***secondary***: cerebral edema, herniations, vascular injuries of large vessels (middle meningeal arteries, internal carotid arteries, vertebral arteries). These are a direct consequence of the primary injuries.

Regarding craniocerebral distribution, post-traumatic injuries can be (Capizzi, Woo, and Verduzco-Gutierrez, 2020):

- ***focal injuries***: extradural hematoma, subdural hematoma, subarachnoid hemorrhage, intraventricular hemorrhage, intraparenchymal hematoma
- ***diffuse injuries***: traumatic axonal injuries

From the perspective of trauma severity, CCTs are classified by severity based on the score obtained using the Glasgow Coma Scale (GCS).
Concerning the severity of craniocerebral injuries, they are categorized as follows:

- ***mild injuries***, where the GCS score is between 13-15 points
- ***moderate injuries***, where the GCS score ranges from 9 to 12 points
- ***severe injuries***, where the GCS score is between 3-8 points

Based on when they occur, post-traumatic injuries are classified as (a) primary or (b) secondary. Primary post-traumatic injuries appear immediately as a direct effect of the trauma and are already present when the emergency room physician evaluates the patient. Secondary injuries result from primary injuries; they can be acute or subacute (such as cerebral edema, ischemia, and brain herniation) and/or chronic (such as hydrocephalus, leptomeningeal cyst, cerebrospinal fluid fistula, or encephalomalacia).

Regarding the location of post-traumatic injuries, they can be (a) intra-axial or (b) extra-axial. Intra-axial post-traumatic injuries are located within the brain or cerebellar parenchyma. These include cortical contusions, traumatic axonal injuries, intraparenchymal hematomas, and vascular injuries (carotid dissections, thromboses, or lacerations of venous sinuses). Extra-axial post-traumatic injuries are located outside the cerebral or cerebellar parenchyma. This category includes extradural, subdural, post-traumatic subarachnoid, intraventricular hemorrhages, and skull fractures.

CHAPTER 2. THE IMAGING OF CRANIOCEREBRAL TRAUMA IN CHILDREN

Drake, Vogl, and Mitchell, the authors of the third edition of "Gray's Anatomy for Students" (2015), begin the first chapter, "The Body," by answering the question "What is anatomy?" before providing a brief overview of the field of imaging (Drake, Vogl, and Mitchell, 2015, pp. 5-11). This is likely a natural consequence of the view that "radiology plays an important role in various medical specialties" (Holmes and Misra, 2004, p. vii), or perhaps since "today, radiology is a vital specialty without which no other medical specialty could function" (Al-Tubaikh and Reiser, 2009, p. vii).

In the context of cranio-cerebral trauma, various structures can be damaged by the traumatic agent. Depending on the chosen investigation, we may or may not need additional examinations. For example, if we choose a cranial X-ray, we will be able to visualize fracture paths at the cranial vault level or opacification of the anterior paranasal sinuses or mastoids, an essential clue in the context of trauma, but incomplete in terms of exploring the brain or cerebellar parenchyma, as well as pericerebral spaces. If we choose magnetic resonance imaging (MRI), we can visualize even the smallest details, including microhemorrhages, but we cannot evaluate cranial fractures.

The radiologic appearance of post-traumatic lesions depends not only on their location but also on their age. All post-traumatic lesions occur in a body subjected to various pathophysiological processes following the trauma, whether it's the development of surrounding edema (as in the case of cortical contusions), transformations of the heme groups in hemorrhage foci, or minor bone resorption at the periphery of the fracture site.

To diagnose cranio-cerebral post-traumatic lesions, we must know their radiologic appearance according to the type of investigation chosen. The radiologic appearance of the lesions must take into account the age of the trauma; in other words, imaging investigations can not only assess the extent of traumatic injuries but also determine the age of the bleeding.

Conventional radiography has a limited role in investigating cranio-cerebral post-traumatic injuries; the only changes that can be objectified are fractures of the cranial vault. Although special projections allow the evaluation of the skull base, the petrous part of the temporal bone, the mastoid, or the anterior paranasal sinuses, their use belongs to the past.

We must consider that the patients we investigate are young, scared, uncooperative, and in pain and that positioning them and maintaining these positions is practically impossible. From my experience, I know that obtaining skull X-rays correctly at a young age is quite a challenge. Aside from all these details, the crucial limitation of radiography is the inability to evaluate the brain or cerebellar parenchyma and extra-axial spaces (de Campo and Patty, 1980).

Computed tomography (CT) remains the gold standard in the investigation of cranio-cerebral trauma (Mutch, Talbott, and Gean, 2016; Sarioglu et al., 2018; du Plessis, Gounden, and Lewis, 2022). This method allows a comprehensive visualization of cerebral structures. In trauma cases, CT scans are performed without contrast (native CT).

Cranio-cerebral post-traumatic lesions that can be visualized using native CT scans are present in all compartments, with the majority represented by hemorrhagic lesions.

In the hyperacute phase, before the blood has coagulated, the density of the hematoma is below 60 Hounsfield units (HU), isodense with the gray matter (Hillal et al., 2022); the density value also depends on the patient's hematocrit (Prokop, 2003).

In the acute phase of bleeding, the density increases when the clot has formed, reaching values between 60-90 HU (Rao et al., 2016). This is when most patients undergo CT investigation, as the blood is sufficiently hyperdense to be distinguished from adjacent structures. If the collection is not large enough to be easily visualized with the parenchymal window, adjusting the window can help the radiologist's eye discern the thin layer of hemorrhage.

In the subacute phase, which occurs a few days after the trauma, the clot becomes less dense, and the density approaches that of the cortex again (Rao et al., 2016). This is when the hematoma becomes isodense with the brain or cerebellar parenchyma and can be easily missed.

In the chronic stage, hemorrhagic collections and cerebrospinal fluid have similar densities.

Scalp injuries that can be highlighted with CT include skin lacerations, subgaleal hematomas, cephalhematomas, and radiopaque foreign bodies.

Bone lesions are revealed on the bone windows of native craniocerebral CT acquisitions. For skull vault fractures, sagittal and coronal reconstructions and Volume Rendering Technique (VRT) images provide important insights (Chawla et al., 2015). In routine practice, if lesions raise suspicions of skull base fractures, fine reconstructions (less than 1 mm) are necessary for a definitive description (Chawla et al., 2015).

Extradural hematomas are most commonly located supratentorially (Evaggelakos et al., 2022; Bisen et al., 2023). They appear as well-defined, hyperdense, fusiform, or biconvex collections. In the acute phase, their appearance is hyperdense. However, if there is active hemorrhage at the time of scanning, the already-formed hematoma will have increased density, and areas of fresh blood will appear hypodense. The mixture of densities within the hemorrhagic collection gives a heterogeneous appearance to the areas of active bleeding, known as the "whirl sign," "blend sign," and "black dot sign" (Kopacz et al., 2021). Identifying these signs draws attention to the fact that the collection is undergoing rapid volumetric expansion, posing the risk of causing a mass effect on the underlying parenchyma and the potential for a range of complications.

Subdural hematomas are crescent-shaped collections, thinner than extradural hematomas, and their increase in size can lead to a mass effect. Unfortunately, subdural hemorrhagic collections can increase in volume quickly, which explains the severe risk of mass effect and the associated risk of herniation (Vitali et al., 2023; Winkler et al., 2023). Like extradural collections, their appearance can be hyperdense in the acute phase, with a homogeneous or heterogeneous structure if active bleeding is present during imaging. As mentioned for extradural collections, subdural collections can also have infratentorial location, associated with a worse prognosis than supratentorial locations (Vega and Valadka, 2017).

Subarachnoid hemorrhage can be evident in the basal cisterns, ventricles, or on the surface of the cortical gyri. At the level of the gyri, it will be apparent in the acute phase, with a reduced volume. In the subacute phase, when the hematoma decreases in density, the hemorrhage on the convexities of the hemispheres can no longer be visualized with computed tomography (CT).

Intraventricular hemorrhage appears as a fluid-fluid level within the ventricular system, with the denser clot settling inferiorly, posterior to the rest of the normal-density fluid in the ventricular system positioned anteriorly.

Cortical contusions are areas of hemorrhage on the surface of the cerebral hemispheres, with increased density on native examinations (similar to any organized hematoma), surrounded by an area of edema that appears spontaneously hypodense. Over time, these areas tend to increase in size and number. This is because hemorrhagic petechiae on the cortex surface become extensive and hyperdense enough to be detected on a CT scan.

Diffuse axonal injuries are tears in the white matter that, if sufficiently large (approximately one centimeter) and containing hemorrhagic areas, will be visible on a CT scan.

Intraparenchymal hemorrhages are well-defined collections within the cerebral parenchyma resulting from the rupture of blood vessels (either arteries or veins). They most commonly occur in the frontotemporal areas and less frequently in the basal ganglia regions (Khandelwal, 2010).

Some lesions may not be detectable by CT during the evaluation of acute craniocerebral trauma. If extra-axial hemorrhagic lesions requiring immediate surgical drainage are detected, magnetic resonance imaging (MRI) is not the next necessary step. However, if the clinical status contradicts the paucity of lesions described on CT, MRI takes over (Gentry, Godersky, and Thompson, 1988; Gentry, Thompson, and Godersky, 1989; Gentry, 1994).

There are post-traumatic lesions for which MRI is most useful. When these lesions are widespread, they are known as diffuse axonal injuries (Krieg et al., 2023). These lesions can be hemorrhagic or non-hemorrhagic, and their signal in various sequences depends on the composition of the lesions. Non-hemorrhagic lesions will appear as hyperintense on T2, T2SE, FLAIR, and DWI-weighted sequences and hypointense on T1-weighted sequences.

PERSONAL CONTRIBUTION

CHAPTER 3. WORK HYPOTHESIS AND OBJECTIVES

For decades, the study of cranio-cerebral trauma (CCT) has been a topic of interest both in the specialized literature and in medical practice. Whether we talk about the adult population or focus on the pediatric population, CCT has been extensively, intensely, and thoroughly researched. The perspective differs in that these can be analyzed from various viewpoints: epidemiological, emergency physician, neurosurgeon, anesthetist, neurologist, radiologist, rehabilitation specialist, or forensic expert. The studies do not only consider epidemiological, preventive, or curative research but also the optimization of investigations. Regardless of their perspective, all studies recognize that CCT in children remains the number one cause of emergency room visits in pediatric hospitals worldwide and represents a significant cause of mortality and morbidity in this age group.

As a radiologist working in a pediatric hospital, I have found that a large proportion of the investigations requested from the emergency room are related to trauma in various regions of the body. By far, the highest percentage is represented by cranio-cerebral trauma. Additionally, the most dramatic cases I have encountered over the years, with associated life-threatening risks, have been CCT, whether as isolated injuries or within the context of polytrauma.

The high frequency of cranio-cerebral trauma is also observed at the "Sf. Ioan" Emergency Clinical Hospital for Children in Galați, reflecting a heterogeneous spectrum of its epidemiology. Furthermore, the increased incidence of this cause of presentation to our hospital's Emergency Room is also because we are the only mono specialty unit within approximately 300 km, serving not only the county of Galați but also the counties of Brăila, Vaslui, Vrancea, and Tulcea.

Consequently, choosing this topic was a natural consequence of the realities observed in the field.

As I mentioned, the investigation of CCT in children is a subject extensively researched by specialist groups worldwide, who have studied cohorts of different sizes or compositions. The aim has been to develop clinical guidelines and protocols to direct the child towards the most comprehensive radiologic investigation method, with the least risks and which provides the necessary information to guide therapeutic management quickly.

These developed protocols offer, at least theoretically, the steps for clinical evaluation to determine the optimal investigation method for each individual case. However, even within these protocols, a note can tip the balance toward whether or not to conduct an investigation. This note is represented by the clinician's experience and the parent's preference.

The ultimate goal of radiological imaging investigations is to provide complete information about all the anatomical structures of the head as quickly as possible to guide the patient on the optimal path. This path could mean either discharge, admission for observation, or surgical intervention. Thus, the role of the radiologist is crucial, as their findings are the switch that directs the patient in one of the mentioned directions.

Regarding radiological imaging in CCT, two major components are described: choosing the appropriate type of investigation for each case and evaluating the discovered lesions from the perspective of the management approach that should be adopted.

In this study, I sought to analyze the imaging investigations performed on children who suffered from CCT and were patients at the "Sf. Ioan" Emergency Clinical Hospital for

Children in Galați. I aimed to correlate the lesions found in CT and/or MRI investigations with the neurological status of the patients (evaluated using the Glasgow Coma Scale, GCS).

The primary goal of this study is to formulate an algorithm for investigating CCT in children that can be applied in the unit where the research was conducted, based on the analysis of the present cohort. Additionally, I compared the data from this study with those reported in the specialized literature to place the obtained results on the global map of findings. Thirdly, I aimed to identify unique elements of CCT within the cohort, whether related to the mechanisms of injury or the lesions discovered. The study may also serve as a starting point for developing preventive strategies for CCT in children that could be implemented at least at the local level.

The objectives of the study were:

- determine the incidence of CCT according to age, gender, and GCS scores
- evaluate the types of lesions discovered following radiographic investigations
- evaluate the types of lesions discovered following CT investigations
- evaluate the types of lesions discovered following MRI investigations
- correlate the results of CT investigations with those of MRI

CHAPTER 4. RESEARCH METHODS. MATERIALS

The research underlying this thesis follows a series of logically sequenced steps, designed to achieve all the study's objectives.

The first step involved a thorough exploration of the specialized literature, serving as a starting point to establish a foundation upon which this study could be built.

The next step in the methodology was defining the target cohort. For this, I developed inclusion and exclusion criteria as presented below.

The inclusion criteria were as follows:

- Referral diagnosis - cranio-cerebral trauma (either as an isolated injury or within the context of polytrauma involving the cranial region)
- First investigation of the patient at that presentation or admission
- Patients who presented with cranio-cerebral injuries due to abuse

The exclusion criteria were:

- ➢ Follow-up investigation (imaging monitoring of a patient for an already investigated trauma)
- ➢ Referral diagnosis that is not cranio-cerebral trauma

Data collection was carried out by reviewing the patients' data from:

- ➢ The hospital's electronic system (Atlas)
- ➢ The electronic database that stores radiological imaging investigations
- ➢ The investigation registers of the Clinical Laboratory of Radiology and Medical Imaging at the "Sf. Ioan" Emergency Clinical Hospital for Children in Galați

The data obtained through these means were analyzed using descriptive statistics, association tests, and correlation tests, followed by interpretation in the context of our cohort and the objectives of this study. This final step allowed me to formulate pertinent conclusions based on the data from our cohort, which may be helpful to my clinical colleagues. At the same time, the end of the study aims to acknowledge its limitations and suggest possible directions for future research.

The research plan for this study was implemented in compliance with the norms of scientific, professional, and academic ethics, in accordance with the provisions of the codes of ethics and professional conduct of the "Dunărea de Jos" University of Galați and the "Sf. Ioan" Emergency Clinical Hospital for Children in Galați. Additionally, the legal guardians of the patients included in this study completed the informed consent form.

This study is a mixed, prospective and retrospective study conducted between 01.06.2016 and 31.05.2024, covering an eight-year period and analyzing patients investigated in the Clinical Laboratory of Radiology and Medical Imaging at the "Sf. Ioan" Emergency Clinical Hospital for Children in Galați.

The target group of this study comprised patients who underwent radiological imaging investigations in the Clinical Laboratory of Radiology and Medical Imaging at the "Sf. Ioan" Emergency Clinical Hospital for Children in Galați for isolated cranio-cerebral trauma or as part of polytrauma that included head trauma.

Data obtained in Excel format were entered into the IBM SPSS 29.0.2.0 program. Descriptive statistics allowed for the analysis of the cohort and each sub-cohort separately, as well as the distribution of various variables for a complete demographic characterization.

Association tests highlighted the relationships between different variables and, at the same time, helped form a comprehensive practical perspective. The correlation tables obtained formed the basis for the chi-square calculation, an important measure in evaluating the association between different data. Additionally, we used one-way ANOVA tests to compare means. Correlation analysis was based on Spearman's tests, as our sub-cohorts were not homogeneously distributed. Where applicable, Cohen's Kappa test was used for assessing concordance, and the McNemar test was used for assessing discordance.

The study included a target group of 4,807 patients who had a referral diagnosis of "cranio-cerebral trauma" and for whom radiological imaging investigations were requested. All subjects met the previously mentioned inclusion criteria. Their distribution by types of investigations was as follows: 2,669 cranial X-rays, 2,131 computed tomography (CT) scans, and 81 magnetic resonance imaging (MRI) investigations. Consequently, the large cohort was divided into sub-cohorts based on the investigations performed.

The patients included in the study are divided into four categories:

- Those who were investigated radiographically
- Those who were investigated with CT
- Those who were investigated with MRI
- Those who were investigated with both CT and MRI

Between 01.06.2016 and 31.05.2024, a total of 4,807 patients were included in the study. Of these, 3,046 were boys (63.37%), and 1,761 were girls (36.63%). As reported in other studies, the percentage of male patients is higher than that of female patients (Macpherson et al., 2014; Arbogast et al., 2016; Zogg et al., 2018).

CHAPTER 5. THE STUDY OF RADIOGRAPHICAL INVESTIGATIONS

In the patient cohort between June 1, 2016, and May 31, 2024, a total of 2,669 patients underwent cranial X-rays in frontal and lateral views. Of these, 1,730 were male patients (64.8%), and 939 were female patients, representing 35.2%.

The number of cranial X-rays represents more than half of the investigations conducted for CCT, consistent with the specialized literature (García García et al., 2009). As with the overall cohort, the majority in this sub-cohort were male patients, with 1,730 representing 64.8%, while female patients numbered 939, representing 35.2%. Overall, there is a male predominance, in line with studies from the specialized literature (Melo et al., 2010; Slade et al., 2024). The only age group where this ratio is reversed is among children under one year old.

All patients who underwent cranial X-rays had a GCS score of 15, and the vast majority had no radiographically visible post-traumatic lesions, a situation also confirmed by other authors (de Campo and Petty, 1980).

The seasonal distribution of trauma in this cohort shows a predominance during the warm months. In the Northern Hemisphere, most CCTs occur between April and October (Saulitis et al., 2024), while in the Southern Hemisphere, they are more frequent between November and May (Gudeman et al., 2021; Cevik et al., 2024).

Our distribution confirms the findings of these studies.

CHAPTER 6. THE STUDY OF CT INVESTIGATIONS

Between June 1, 2016, and May 31, 2024, a total of 4,808 radiological imaging investigations were performed for CCT. Among these, there were 2,131 CT examinations, representing approximately 44% of all investigations for CCT. This percentage is partly explained by the fact that CT examination is considered the gold standard in CCT investigations (Prayer and Rametsteiner, 2001), gradually replacing radiographic investigations (Zaitceva, Mamatkulov, and Akhadov, 2022). The percentage found in this study is confirmed by Wazir et al. (2022), although other authors report higher percentages in their cohorts (García García et al., 2009; Harvell et al., 2018) or much lower ones (Lacerda Gallardo and Abreu Pérez, 2003). Another factor contributing to the high number of CT investigations is the experience of the recommending physicians (Meehan and Mannix, 2010).

During this study, a trend of increasing numbers of investigations was observed from year to year. The only disruption in the upward trend between 2018-2022 was in 2020, which was heavily impacted by the SARS-CoV-2 pandemic and the lockdown period. Just as patient visits to doctors were low across all specialties during that period (except in laboratories, especially those conducting coronavirus tests), the number of children presenting to the emergency room at the "Sf. Ioan" Emergency Clinical Hospital for Children in Galați was also reduced. I do not deny that CCT cases existed among the pediatric population during that period, but the reluctance of parents to bring their children to the hospital environment and expose them to the potential risk of SARS-CoV-2 infection led to fewer investigations that year.

Additionally, as described in the specialized literature, CT examinations have clear indications depending on the mechanism of trauma and the clinical condition of the patient (Expert Panel on Neurological Imaging et al., 2021). However, as mentioned in the PECARN algorithm (Kuppermann et al., 2009), the request will also be influenced by the experience of the ordering physician and the preferences of the child's legal guardian.

In other words, we are in a situation where, although the patient's clinical condition (reflected by the GCS or pGCS score) does not warrant exposure to radiation-based investigations, clinicians or guardians request cranio-cerebral CT scans.

Additionally, it is worth noting the annual distribution of cranio-cerebral CT investigations in the context of CCT. Although it may seem that the number of investigations in the last year is lower, it should be remembered that the database includes investigations conducted in the first 5 months of 2024.

As stated in the specialized literature (Shao et al., 2012; Stewart, Gilliland, and Fraser, 2014; Yaşar, Kirik, and Durmaz, 2020), the number of male patients with CCT is higher than that of female patients. The age range included in our cohort covers many levels, each with its own psycho-emotional characteristics. There are sufficient reasons why boys are more often victims of CCT than girls. The most straightforward explanation is that boys are more adventurous, more reckless, and participate in more sports that predispose them to accidents compared to girls. Additionally, they often aim to prove either to their peers or themselves that they are "tough," "skillful," and "invincible."

While the average age of the patient cohort is eight years, we cannot overlook the extremes of the age histogram, which shows a considerable number of infants. It is at least concerning to note that the highest number of CT investigations in the context of CCT is conducted on children under one year of age. Not only does this raise serious questions regarding parental care and responsibility in raising their children, but it is also alarming in terms of the level of ionizing radiation exposure experienced by such young children. We are talking about patients with structures sensitive to radiation, with a long life expectancy that needs to be protected as much as possible. As demonstrated by Pearce et al. (2012), Mathews et al. (2013), Miglioretti et al. (2013), and Li et al. (2020), cranio-cerebral CT examinations following CCT are associated with a higher risk of leukemia, lymphoma, and malignant brain tumors. This consideration applies both to those who care for them at home and to those who are in a position to request investigations that could be at least postponed, if not excluded.

However, the specialized literature shows a distribution similar to that of this cohort. Thus, a large proportion of CCTs affect the population segment aged 0 to 4 years (Schneier et al., 2006; Majdan et al., 2014; Amaranath et al., 2014; Greene et al., 2014; Harvell et al., 2018; Lorton et al., 2016).

Of the 2,131 CT investigations performed during the aforementioned period, 1,477 did not reveal any post-traumatic lesions. In other words, approximately 70% of the children who underwent CT examinations only incurred the radiation-associated risk. This percentage is supported by data from previous studies (Fundaró et al., 2012; Bako, Özer, and Beydoğan, 2024).

The other lesions, described after cranio-cerebral CT scans, were of varying severity. They were either isolated or associated; some required monitoring in the Intensive Care Unit or even immediate surgical evacuation. In many cases over the years, the latter situation often meant transferring the patient to another hospital equipped for such procedures.

When examining the distribution of post-traumatic lesions by the patients' gender, we find that a greater variety of lesion categories were present among boys compared to girls.

Categorically, the most common post-traumatic lesions found in this cohort were scalp hematomas, followed, in second place, by scalp hematomas accompanied by skull fractures, and in third place, the association of scalp hematoma with skull fracture and extradural hematoma.

I found that a series of lesions or combinations of lesions are present in both genders, but with a male predominance: 1) scalp hematomas, 2) scalp hematomas with fracture, 3) scalp hematomas with fracture and hemorrhagic contusions, 4) scalp hematomas with dehiscent suture, 5) scalp hematomas with fracture and subdural hematoma, 6) intraventricular hemorrhage, 7) hemorrhagic contusion, 8) scalp hematomas with scalp injuries, 9) scalp hematomas with fracture, extradural hematoma, and hemorrhagic contusion, 10) subdural hematomas. Other lesions or combinations have a female predominance in the studied cohort: 1) scalp hematomas with hemorrhagic contusion and 2) scalp hematoma with fracture and extradural hematoma.

Some lesions or combinations are found exclusively in boys: 1) scalp hematoma with subdural hemorrhage and subarachnoid hemorrhage, 2) scalp hematoma with depressed fracture and hemorrhagic contusions, 3) scalp hematoma with depressed fracture and extradural hematoma, 4) scalp hematoma with skull fracture, mastoid fracture, and extradural hematoma, 5) scalp hematoma with skull fracture and subarachnoid hemorrhage, 6) scalp hematoma with skull fracture, subdural hematoma, and subarachnoid hemorrhage, 7) scalp hematoma with skull fracture, hemorrhagic contusion, and intraparenchymal hematoma, 8) mesencephalic hematoma associated with thalamic hematoma and intraventricular hemorrhage, 9) subdural hemorrhage, subarachnoid hemorrhage, and retinal hemorrhage, 10) intraparenchymal hemorrhage associated with intraventricular hemorrhage, 11) scalp hematoma with hemorrhagic contusion and intraventricular hemorrhage, 12) intraparenchymal hematoma, 13) scalp hematoma with hemorrhagic contusion and subarachnoid hemorrhage, and 14) scalp hematoma with skull fracture, dehiscent suture, and subdural hematoma.

Few lesions are exclusive to female patients, namely: 1) scalp injury, 2) scalp hematoma with fracture, hemorrhagic contusion, and intraventricular hemorrhage, 3) scalp hematoma with extradural hematoma, hemorrhagic contusion, and intraparenchymal hematoma in the brainstem, and 4) scalp hematoma with fracture and scalp injury.

As observed, the range of lesions and combinations is extremely varied and numerous. For these reasons, as mentioned at the beginning of this chapter, I grouped the post-traumatic lesions into hemorrhagic and non-hemorrhagic categories.

The primary motivation for this grouping is the connection between the types of lesions and the patient's clinical condition, more specifically, their state of consciousness. The state of consciousness is assessed, as presented in Chapter 1, using the Glasgow Coma Scale (GCS) and then quantified by the score obtained.

Therefore, post-traumatic lesions are related to the patient's state of consciousness. Moreover, the magnitude of the forces acting on the head, as well as the mechanism of trauma, are responsible for the post-traumatic lesions that occur. Thus, as previously stated, patients exposed to or exposing themselves to dangerous situations where significant forces are involved are most often male.

It is a logical consequence to find male patients in this cohort with lesions or combinations of lesions indicative of significant trauma. Of course, this does not completely exclude girls from the categories of more severe trauma, but they will be represented in smaller numbers.

In this cohort, we had patients with GCS scores ranging from 3 to 15. The distribution of these scores by gender is quite interesting. GCS 15 is the most common score, with boys being much more numerous in this category compared to girls. For scores of 13 and 14, the male predominance remains, but the difference between girls and boys is not as large. At a score of 12, the ratio between girls and boys is as much in favor of boys as it is at score 15. At a score of 11, the number of girls and boys is equal, while at scores of 10 and 9, we find only boys. At a score of 8, there are twice as many boys, and at a score of 3, there is only one girl.

When we use the degrees of trauma severity, grouping the scores into three major classes, the distribution of these degrees will differ between the two genders, although it will be similar to the distribution of individual scores within the patient cohort.

There is a predominance of mild trauma, as confirmed by numerous studies conducted so far (Kraus et al., 1986; Hawley et al., 2003; Tsai et al., 2004; Agrawal et al., 2008; Crowe et al., 2009; Işık et al., 2011; Koepsell et al., 2011; Fekih Hassen et al., 2012; Kim et al., 2012; Ferreros et al., 2012; Yousefzadeh Chabok et al., 2012; Amaranath et al., 2014). Moderate trauma occupies the second place, as in other studies (Kraus et al., 1986; Emanuelson and Wendt, 1997; Hawley et al., 2003; Tsai et al., 2004; Agrawal et al., 2008; Crowe et al., 2009; Işık et al., 2011; Kim et al., 2012), while severe trauma is the rarest (Kraus et al., 1986; Hawley et al., 2003; Tsai et al., 2004; Crowe et al., 2009; Işık et al., 2011; Kim et al., 2012).

However, there are studies that present different distributions of trauma severity levels. Greene et al. (2014) and Udoh and Adeyemo (2013) reported the highest percentage for severe trauma in their cohorts, followed by moderate trauma, with mild trauma being the least frequent. Emanuelson and Wendt (1997), Bowman et al. (2008), and Amaranath et al. (2014) found that, after mild trauma, severe trauma was the second most frequent, with moderate trauma representing the smallest percentage in their cohorts.

In cases of mild trauma, the ratio of male to female patients is nearly 3:2; this type of trauma represents the majority of the cohort. The same majority percentage is present in other studies (Cassidy et al., 2004; Zorilă et al., 2017). In moderate and severe trauma, the male predominance persists but not at the same high ratio as in mild trauma. The male predominance at these trauma levels is also confirmed by international studies (Murphy et al., 2017; Mulder, Helfferich, and Kneyber, 2024).

Interestingly, the distribution of ages by gender differs between girls and boys. The youngest average age for girls is found in cases of moderate trauma, while the oldest is found in cases of severe trauma.

If we classify cranio-cerebral post-traumatic lesions based on the risk they pose, hemorrhagic lesions are the most severe. Hemorrhagic lesions, as described in Chapter 2, can be localized or diffuse. The localized ones are either extra-axial or intra-axial. Extra-axial hemorrhages can pose significant challenges due to the mass effect they exert on adjacent structures. Whether we are talking about blood vessels, cerebral parenchyma, or cerebral ventricles, the compression caused by an expanding process can lead to serious complications, even death, often necessitating surgical evacuation. It is also always important to consider the potential complication with immediate adverse effects — the deviation of the midline and the engagement of the cerebral or cerebellar parenchyma. Intra-axial hemorrhages generally do not have surgical indications, but their effects may manifest at a distance from the traumatic event.

Due to these inherent risks posed by hemorrhagic collections, I decided to divide the lesions described in the patient cohort into hemorrhagic and non-hemorrhagic lesions. I then used statistical calculations to analyze the distribution, associations, and concordances between these lesions and other cohort variables. Whether using the t-test for independent samples, ANOVA, or chi-square test, all confirmed the initial working hypothesis of this study.

In this cohort of patients, there is a statistically significant relationship between the GCS score and the type of lesion detected by CT, as well as a strong association between these variables. The data obtained in this study have also been found by other authors (Gittleman et al., 2005; Nayebaghayee and Afsharian, 2016).

Regarding the relationship between the types of lesions and trauma severity levels, the statistical analysis applied to this cohort confirms that there is a statistically significant relationship between the GCS score and the severity levels of trauma, as well as a strong association between these two variables.

It is very easy to view these calculations as mere numbers, but all of this data should lead to a clinically relevant conclusion. Based on the existing data, we understand that a very large number of investigations conducted on patients with GCS scores corresponding to mild trauma could and should have been avoided. I have demonstrated that GCS scores correlate with hemorrhagic lesions. Spearman's correlation coefficients show an inverse proportional relationship between the decrease in the GCS score and the presence of hemorrhagic lesions. The logical deduction is that implementing the PECARN protocol and the criteria proposed by the ACR Appropriateness Criteria® (Expert Panel on Neurological Imaging, 2021) would result in CT scanning only for patients who would benefit from it.

The association between GCS scores and age, or trauma severity levels and age, did not produce the same results as the analyses of interrelations with other variables. The calculations led to the following conclusion regarding CCT and patient age: the occurrence of trauma of any severity is possible at any age.

The conclusion of this chapter indicates that the data obtained validate the working hypothesis. Beyond the theoretical model, all these numbers, scores, and ages actually represent children who need specialized medical personnel to investigate them appropriately and then treat them with individualized therapeutic strategies tailored to each case. We return to the Hippocratic oath, which, in its original form, requires us "to do no harm." I find that, as in other studies (Melnick et al., 2012; Kauffman et al., 2018), there is a tendency for the overuse of CT investigations, and adopting protocols to protect children from unnecessary exposure to the harmful effects of ionizing radiation, in line with the ALARA principles (Roehrig, Krupinski, and Hulett, 1997), is a first step toward this moral duty to our patients.

CHAPTER 7. THE STUDY OF MR INVESTIGATIONS

Between June 1, 2016, and May 31, 2024, 81 MRI investigations were performed in the context of CCT. As observed in Chapters 5 and 6, the majority of patients who underwent such investigations were boys. The male predominance is also reported by Pavlov et al. (2019). Additionally, as with radiographic and CT examinations, more than half of the investigations did not reveal post-traumatic changes (n = 53; 65.43%).

Among the normal examinations, 15 categories of lesions were recorded, either as isolated lesions or in various combinations. These categories had varying frequencies over the years. The most common lesions detected by MRI were extradural hematomas (7; 8.64%), followed by subdural hematomas (3; 3.7%) and hemorrhagic contusions (3; 3.7%). Next are groups of lesions found in two patients each, representing 2.47%. These groups of lesions are: scalp hematoma, the combination of scalp hematoma-subdural hematoma, and scalp hematoma accompanied by hemorrhagic contusion. The last category of post-traumatic lesion combinations is represented by single cases, each reaching a percentage of 1.23%: scalp hematoma with hemorrhagic contusion, subdural hematoma, and Grade II DAI; extradural hematoma with hemorrhagic contusion; subarachnoid hemorrhage and Grade II DAI; scalp hematoma, hemorrhagic contusion, subarachnoid hemorrhage, and Grade II DAI; scalp hematoma with extradural hematoma, hemorrhagic contusion, intraparenchymal hematoma in the brainstem, and Grade III DAI; subarachnoid hemorrhage; Grade II DAI;

hemorrhagic contusion with Grade III DAI; scalp hematoma, hemorrhagic contusion, and subdural hematoma.

Overall, some lesions are more common in male patients: hemorrhagic contusions and extradural hematomas. Some lesions or combinations of lesions are found exclusively in girls: Grade II DAI, hemorrhagic contusion accompanied by Grade III DAI, scalp hematoma, and the combination of scalp hematoma, extradural hematoma, hemorrhagic contusion, intraparenchymal hematoma in the brainstem, and Grade III DAI. On the other hand, there are lesions or combinations of lesions exclusively found in male patients: scalp hematoma with subdural hematoma; scalp hematoma with hemorrhagic contusion; subdural hematoma; scalp hematoma with hemorrhagic contusion and subdural hematoma; scalp hematoma with hemorrhagic contusion, subdural hematoma, and Grade I DAI; scalp hematoma with hemorrhagic contusion, subarachnoid hemorrhage, and Grade II DAI; extradural hematoma with hemorrhagic contusion; subarachnoid hemorrhage; subarachnoid hemorrhage with Grade II DAI.

Since many of the lesions described in MRI investigations correspond with those detected by CT, I considered it appropriate to keep the categorization of lesions in the same groups as in Chapter 6: hemorrhagic and non-hemorrhagic lesions. Categorizing MRI lesions into these two major categories was partially possible. The newly appeared category in MRI lesions (compared to those already described in Chapter 6) is represented by diffuse axonal injuries (DAI). Even though fewer than 20% of diffuse axonal injuries are hemorrhagic, if these hemorrhages are not macroscopic, they will not be detected by CT; however, MRI can describe them (Parizel et al., 1998). Consequently, in addition to the categories of hemorrhagic and non-hemorrhagic lesions, a third category appears that includes diffuse axonal injuries (DAI).

As in Chapter 6, we considered not only the GCS scores but also the degrees of trauma severity.

It is worth mentioning that, overall, there is a discrepancy between the number of lesion categories detected by CT examinations compared to those described by MRI. One explanation lies in the intrinsic qualities of each diagnostic method. CT examinations can detect fractures, whereas MRI cannot.

Additionally, an important group of lesions, both clinically and radiologically, is represented by diffuse axonal injuries (DAI). The vast majority of these injuries are not diagnosed by CT; MRI is the preferred method for detecting them. According to the imaging investigation criteria for CCT, MRI is most often necessary for evaluating patients with low

GCS scores that contrast with a CT examination that does not reveal post-traumatic lesions. As stated by Lee et al. (2021), who conducted a meta-analysis of 67 studies, MRI provides the most benefits in moderate and severe trauma. The study also highlights the role of MRI in establishing the medium- or long-term prognosis (Lee et al., 2021). However, the retrospective study published by Pavlov et al. (2019), which included 80,000 patients (over 35,000 of whom were under 18), showed that MRI was performed only on patients with GCS scores of 13-15, including not only those admitted to the hospital following CCT but also those who came from outpatient settings. Pavlov et al. (2019) mention that in the pediatric group, those between 11 and 17 years old were frequently investigated as outpatients. This indicates that although the utility of MRI in trauma cases with GCS scores of 13-15 is limited, it is still practiced, as seen in the sub-cohort of my study. However, even when MRI is performed in this situation and intracranial hemorrhagic lesions are discovered, a consensus on their clinical relevance has not been reached (Yuh et al., 2013).

Hemorrhagic contusions, although partially detected by CT examination, are underestimated in number and size by CT. This happens because the time from the traumatic event to the moment of scanning is too short, and the contusions have not had enough time to develop sufficiently to be detected by CT. In contrast, the time elapsed before the MRI investigation allows hemorrhagic lesions to organize, expand, and thus create the false impression that their number and size are increasing. Moreover, MRI detects molecular-level changes and is the gold standard in diagnosing microhemorrhages (Datta et al., 2005; Kemp et al., 2009; Bertsimas et al., 2019). In other words, small hemorrhages go undetected by CT but are identified on MRI images.

Thus, there are lesions described by CT that do not have a corresponding finding on MRI.

The reverse is also true because there are lesions or combinations of lesions that are not described by CT but are detected by MRI. There is no perfect overlap between the groups of CT and MRI lesions.

Moreover, in this cohort, there are lesions or combinations of lesions detected by CT that could be further monitored with MRI. Many patients fell into this category but did not benefit from this additional imaging examination. The "Sf. Ioan" Emergency Clinical Hospital for Children in Galați operated for many years without a neurosurgery specialist. This meant that patients with CCT who presented with lesions requiring neurosurgical supervision were transferred to other specialized units that could provide the necessary services. Due to the transfer, these children's diagnostic process often stopped at the CT investigation performed upon their presentation to the Emergency Room. This also explains the discrepancy between the number of CT and MRI examinations in the study period.

In conclusion, the small number of MRI examinations is only a consequence of the fact that patients who would have benefited from this type of imaging surveillance were transferred.

All these details, however, must be integrated into the general context of the "Sf. Ioan" Emergency Clinical Hospital for Children in Galați. As already mentioned in Chapter 6, the examinations to which the children will be subjected are the result of the requests made by the clinicians who examine the patients. Additionally, it is important to note that in June 2022, the hospital team was joined by a specialist neurosurgeon. One consequence of this is a decrease in the number of patients transferred. As a result, while moderate and severe traumas were not previously investigated with MRI before the neurosurgeon's arrival, most of these patients are now kept under observation at the "Sf. Ioan" Emergency Clinical Hospital for Children in Galați.

The cohort's distribution by gender according to the GCS score can be analyzed for each specific GCS score or by categories of trauma severity.

When we analyze the distribution of trauma severity classes by age and gender, we find that most MRI examinations were performed on patients with mild trauma. Moderate trauma affected only boys, with ages at the extremes (5 and 16 years). Regarding severe trauma, we observe that only girls experienced such trauma, and the ages are young (8 and 9 years).

Mild trauma is found in both genders. The demographic data of this sub-cohort contrasts with the study by Torres et al. (2019), which reported a higher percentage of female patients than male patients in their cohort. Moderate trauma is present only in boys, while severe trauma is only found in girls. There are many valid explanations for this situation, already discussed in previous paragraphs. Looking at the overall distribution by gender and age of the CCT severity classes, we can imagine that girls are more likely to sustain severe traumatic injuries with GCS scores between 3 and 8. One possible explanation is that the severe traumatic injuries found in male patients are fatal, so they do not reach the hospital for MRI investigation. Indeed, some severe CCT cases identified by CT that were not transferred resulted in death because the post-traumatic lesions were incompatible with survival.

On the other hand, MRI is, by definition, a lengthy investigation that requires the patient to remain still for a longer period than with a CT scan. We must not forget that our cohort consists of children, who are inherently difficult and non-compliant patients. Behavioral characteristics related to age are compounded by the fact that any contact this population group has with the hospital is frightening, especially when their clinical condition is not at its best. Additionally, the patient's clinical condition must allow for transportation from the intensive care unit to the radiology department. An unstable patient cannot be transported, which provides a valid explanation for the lack of moderate or severe trauma cases in our cohort. Moreover, it should be noted that there are situations when MRI is helpful, but the patient requires sedation (Mutch, Talbott, and Gean, 2016). A series of risks associated with sedation in the context of trauma must be considered, as well as the limitations imposed by sedation equipment, which must be MR-safe to be used in the MRI room.

The seasonal distribution of MRI-associated trauma lesions is at least surprising. Although the highest incidence of CCT in radiological and CT examinations occurs during the warmer months, MRI examinations show a peak incidence in spring. This is true for mild, moderate, and severe trauma. While mild traumas are spread across all four seasons, with the highest incidence in spring, moderate and severe traumas occur only in spring and autumn. This distribution could be explained by the severe traumas encountered by CT in summer, which are either transferred or result in death; in either case, they are not further evaluated by MRI.

Comparative and correlation analyses provided additional data on the associations between types of lesions and GCS scores or trauma severity levels, as well as between patient ages and trauma severity levels. For comparative analysis, I used ANOVA and chi-square tests, and I explored correlation by calculating Spearman's rho coefficient.

The ANOVA and chi-square tests applied to the types of lesions detected by MRI and GCS scores highlighted a statistically significant relationship between the two variables. The correlation test also showed a moderate to strong correlation between these lesions and GCS scores.

Regarding the relationship between MRI lesions and trauma severity levels, the same statistically significant relationship is observed. Moreover, the correlation coefficient indicated a moderate link between the two variables.

The only statistically non-significant calculations were those evaluating the relationship between patient age and trauma severity levels.

In conclusion, the analysis of MRI examinations shows that the number of MRI scans has increased significantly in recent years within the study period. The trend observed in

Chapter 6 persists, where children with high GCS scores are examined, even when they do not meet the criteria for such investigations (Expert Panel on Neurological Imaging et al., 2021). However, it should be noted that CCT with GCS scores of 13-15 in children can be accompanied by various symptoms, including headaches, vestibulo-ocular symptoms, and fatigue (which is closely associated with cognitive and emotional symptoms) (Lyons et al., 2022). Since the appearance of lesions in the acute phase may not allow the radiologist to evaluate them (Hesselink et al., 1988), MRI is recommended to be performed in the subacute phase of trauma. Parizel et al. (1998) recommend that the investigation be done 7-10 days after the trauma. Children with trauma represent a population segment that could benefit from this type of investigation because any potential lesions discovered could be integrated into the post-traumatic care plan.

Additionally, the arrival of a neurosurgeon on the team at the "Sf. Ioan" Emergency Clinical Hospital for Children in Galați has led to MRI examinations for severe patients who would have previously been transferred, thereby altering the somewhat linear distribution observed up until June 2022. The correlations between the considered variables in this cohort confirm the information extracted from the specialized literature (Datta et al., 2005; Kemp et al., 2009; Bertsimas et al., 2019; Pavlov et al., 2019; Lee et al., 2021; Parizel et al., 1998).

CHAPTER 8. THE CONCORDANCE STUDY BETWEEN CT AND MRI LESIONS

From the sub-cohort of children who underwent CT examination, an extremely small percentage benefited from a complementary MRI examination — specifically, 74 out of 2131, representing 3.5%. There are many reasons for this distribution, many of which have already been mentioned in the previous chapters. The most important among them are, firstly, the transfer of patients with low GCS scores to other hospitals; secondly, the addition of a specialist doctor to the team who requests MRI investigations, even when patients have suffered mild trauma.

The specialized literature is somewhat divided regarding the investigation of mild cranio-cerebral trauma in children. First, it should be mentioned that although this class comprises three GCS scores and the criteria by which lesions are assigned to this category (Yue et al., 2024), there are many levels of mild trauma (Esselman and Uomoto, 1995). Thus, Bonow et al. (2017) believe that mild trauma does not require high-performance investigation because, in most cases, no lesions are discovered that are related to previous

CCT. Even if brain lesions are detected, their clinical impact is not significant (Yuh et al., 2013; Bonow et al., 2017). Mittl et al. (1994) and Toledo et al. (2012) state that lesions discovered by MRI post-trauma may be the substrate for future post-traumatic symptoms with important implications, especially since the age group 0-18 includes individuals who are still developing, both physically and psychologically. Therefore, MRI evaluation of mild trauma could bring medium- and long-term benefits.

The patients in this sub-cohort are predominantly male.

Regarding the distribution of ages, we find that for female patients, the range is much broader than for male patients. The girls represented the extremes in terms of both GCS score distribution and trauma severity levels. Boys, on the other hand, are the sole representatives in the moderate trauma category.

Since I sought to determine the concordance between lesions visible on CT and those on MRI, I used statistical tests to help me in this regard.

For the category of hemorrhagic/non-hemorrhagic lesions on CT, I explored the correlation with hemorrhagic/non-hemorrhagic/DAI lesions discovered on MRI. The chi-square test showed a moderate correlation between the two types of investigations. This moderate correlation can be explained by the timing of the CT investigation relative to the moment of trauma, as well as the interval between the MRI and CT examinations. As some specialists, such as Datta et al. (2005), Kemp et al. (2009), and Bertsimas et al. (2019), mention, MRI detects many more microhemorrhagic lesions compared to CT, as well as non-hemorrhagic lesions (DAI) (Gentry et al., 1988). Additionally, another factor that must be taken into account is the size of the hemorrhagic lesions. All these variables that can influence the presence or absence of certain lesions in a specific type of investigation will be the subject of further post-doctoral studies. Besides the simple calculation of concordance between the lesions identified on CT examinations and their potential correspondence with those detected on MRI, I used Cohen's Kappa test and the McNemar test. While the Kappa test provides information about the strength of concordance, the McNemar test completes the picture by analyzing discordant data.

Thus, I obtained the following results:

- **Moderate concordance between CT and MRI for extradural hematomas.** The explanation for this in our cohort is that some of the extradural hematomas discovered by MRI were not detected by CT. Either their size was small at the time of the CT scan, or they developed in the interval between the two examinations. Conversely, the discordance between the two types of investigations in diagnosing these lesions underscores the superiority of MRI for detecting this type of hemorrhagic collection.

- **Strong concordance for subdural hematomas** — there are few subdural collections that were not detected by CT.
- **High concordance for the absence of cortical contusions on both CT and MRI images.** From another perspective, the discordance between diagnosing these on MRI vs. CT confirms the additional information provided by MRI examinations in evaluating these lesions. The data obtained from these calculations are supported, for example, by the study conducted by Hesselink et al. (1988), who observed in their cohort that 11 hemorrhagic contusions not visualized by CT were confirmed by MRI.

Based on the data from this study, subarachnoid hemorrhages can be diagnosed by both imaging methods, without identifying a superior method for investigating this type of hemorrhage.

Diffuse axonal injuries observed in the patients from our cohort were described only in MRI examinations. The specialized literature indicates that a percentage of these lesions are hemorrhagic and can also be detected by CT (Parizel et al., 1998) if they are large enough and if the timing of the CT scan allowed for the formation of a clot that could be detected by CT. The patients in this cohort did not present hemorrhagic diffuse axonal injuries. The detection of these lesions through MRI investigations confirms previously published data indicating that magnetic resonance imaging is the gold standard for their diagnosis (Provenzale, 2010; Linsenmaier et al., 2016; Gentry, Godersky, and Thompson, 1988). The correlation study between CT and MRI examinations highlighted the superiority of the latter in diagnosing intracranial post-traumatic lesions, especially in the case of cortical contusions and diffuse axonal injuries, obtaining data comparable to those published in the specialized literature.

CONCLUSIONS OF THE DOCTORAL THESIS

1. GENERAL CONCLUSIONS AND REFERENCES TO THE PERSONAL CONTRIBUTION

The study of cranio-cerebral trauma in children from a radiological imaging perspective, applied to a cohort of patients investigated at the "Sf. Ioan" Emergency Clinical Hospital for Children in Galați, involved thorough documentation conducted over an extended period, as well as the development of a strategy described in the chapter detailing the research methodology. The database obtained allowed for an overall understanding of the demographic data of the population that suffered cranio-cerebral trauma, the various GCS scores observed in the cohort, and their seasonal distribution. I was also able to form a detailed and well-documented opinion regarding the distribution of radiological imaging investigations in cranio-cerebral trauma in the children from the cohort. On several occasions, being part of the multidisciplinary team that managed some of the severe cases included in this study, I perceived the true magnitude of the radiologist's role. Similarly, I understood the need for a uniform protocol that could be applied by members of all involved departments, prioritizing the patient. Gaining an overall perspective, acquiring statistical skills, and applying these practically to the patient cohort allowed me to achieve the proposed objectives.

From the perspective of the conclusions, the following findings were made:

1. Cranio-cerebral traumas affect boys more than girls, probably due to psycho-behavioral characteristics.
2. Accidental traumas represent the overwhelming majority of cases.
3. The most vulnerable ages are between 0 to 4 years and adolescence.
4. Moderate and severe traumas, which have medium- and long-term effects (including extended hospital stays), affect children starting from school age.
5. Cranio-cerebral X-rays, even when they showed skull fractures or suture dehiscence, were requested for children without changes in consciousness and were not followed by additional investigations. Their contribution was limited in terms of therapeutic management.
6. CT investigations are increasingly requested as the first method of investigating cranio-cerebral traumas in children in the current cohort, with over 90% being performed on children with GCS scores of 15. Even if this may seem like an

overzealous approach with a negative impact on children, I have found, based on an in-depth study of the specialized literature, that we are not unique in this practice, which is also found in other countries. Therefore, I can assert that the radiological imaging situation at the "Sf. Ioan" Emergency Clinical Hospital for Children in Galați is not unique, isolated, or individualized. This situation is also found in Scandinavian countries and the United States, to name just these examples.

7. The statistical data obtained from the doctoral research show that CT investigations provide sufficient information to guide the multidisciplinary team toward the optimal therapeutic approach. In children with mild trauma, even if hemorrhagic lesions were detected, they did not require emergency surgical evacuation. For children with moderate and severe trauma, the GCS scores were correlated with the discovered lesions, with statistical data confirming that as the score decreases, the likelihood of intracranial hemorrhagic lesions increases.

8. MRI examinations, although increasing in number, are applied to a small number of children who have suffered cranio-cerebral trauma.

9. The statistical data obtained from our study indicate that MRI investigations provide the most confirmations for cases with moderate and severe trauma. Diffuse axonal injuries and hemorrhagic cortical contusions were the main causes of discordance between the CT examinations performed before the magnetic resonance evaluation. The reason is the significantly superior capabilities of MRI in detecting such lesions.

2. FUTURE RESEARCH DIRECTONS

I have identified numerous future research directions, including:

- Research on the various MRI sequences used in our protocols and their correlation with the lesions detected, compared to the specialized literature, represents one direction that could be pursued in the future. This could allow the "Sf. Ioan" Emergency Clinical Hospital for Children in Galați to develop short-duration protocols specifically aimed at detecting hemorrhagic and diffuse axonal injuries to assess the impact of trauma on cranial contents.
- Another possibility for scientific exploration is the impact of time duration on lesions detected or undetected by CT and their MRI correspondence. At

this moment, there is no uniformity in the unit where we conducted the study regarding the time interval between the two types of investigations.

- Additionally, the medium- and long-term impact of trauma with GCS scores of 13-15 at hospital presentation represents another possible research direction. Such a study would require a multidisciplinary team, including a clinical psychologist who would evaluate, using scientifically validated methods from the specialized literature, the psychological status and any disorders that are part of the "post-concussion" syndrome.

This study highlights two unique features that ensure its uniqueness among other research of the same magnitude. Thus, in addition to the exclusively pediatric composition of the cohort studied, the radiological imaging perspective brings an added level of originality and contributes to the development of knowledge in this field. The conclusions allow me to outline a few recommendations applicable to the healthcare unit where the study was conducted and which could probably be implemented in other similar locations. Therefore, I will highlight the following:

- I propose that cranio-cerebral X-rays in children with GCS not be performed, as obtaining them does not change the therapeutic approach.
- Children with CCT and a GCS score of 15 could be investigated by MRI in the subacute phase in an outpatient setting, contributing to a complete cranio-cerebral evaluation of possible post-traumatic effects. Hospitalization in these situations is not necessary; such a measure would not only reduce psychological discomfort for both patients and their parents but also optimize the financial impact on the system.
- Children with GCS scores of 13 and 14 should be thoroughly evaluated and triaged so that those who have suffered trauma with risk are examined by CT.
- Moderate and severe traumas certainly benefit from CT examination in the acute phase.
- Post-trauma MRI evaluation for children hospitalized with hemorrhagic lesions not associated with changes in consciousness should be performed 72 hours after the initial CT examination.

To answer the question behind the thesis title, the radiologist's role is crucial in the trauma team. Yes, the patient's state of consciousness is assessed by emergency physicians who intuit the presence of intracranial lesions. CT scanning confirms the presence, location, number, and effect of these lesions on intracranial structures. The severity of these lesions is, in some cases, intrinsic, requiring vigorous and rapid therapeutic measures, while in other cases, it is determined by their mere location or size. Continuing CT examinations with MRI complements the clinicians' perspective on the case and can provide additional data that justify (documented) the clinical condition of the patients.

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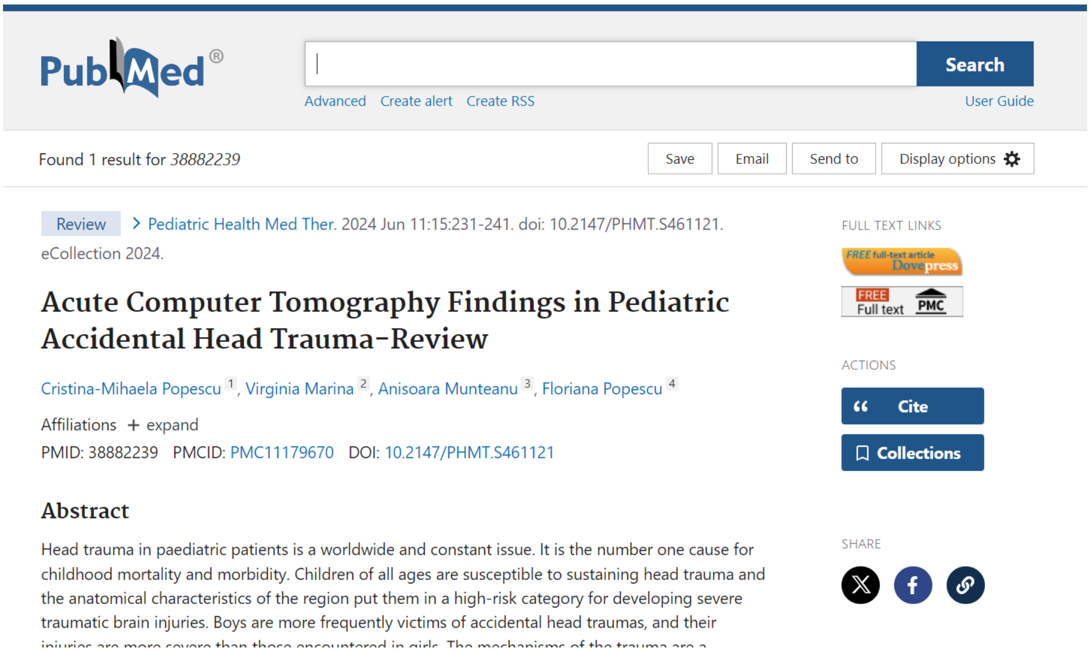
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Acute Computer Tomography Findings in Pediatric Accidental Head Trauma-Review

Cristina-Mihaela Popescu [1], Virginia Marina [2], Anisoara Munteanu [3], Floriana Popescu [4]

Affiliations + expand

PMID: 38882239 PMCID: PMC11179670 DOI: 10.2147/PHMT.S461121

Abstract

Head trauma in paediatric patients is a worldwide and constant issue. It is the number one cause for childhood mortality and morbidity. Children of all ages are susceptible to sustaining head trauma and the anatomical characteristics of the region put them in a high-risk category for developing severe traumatic brain injuries. Boys are more frequently victims of accidental head traumas, and their

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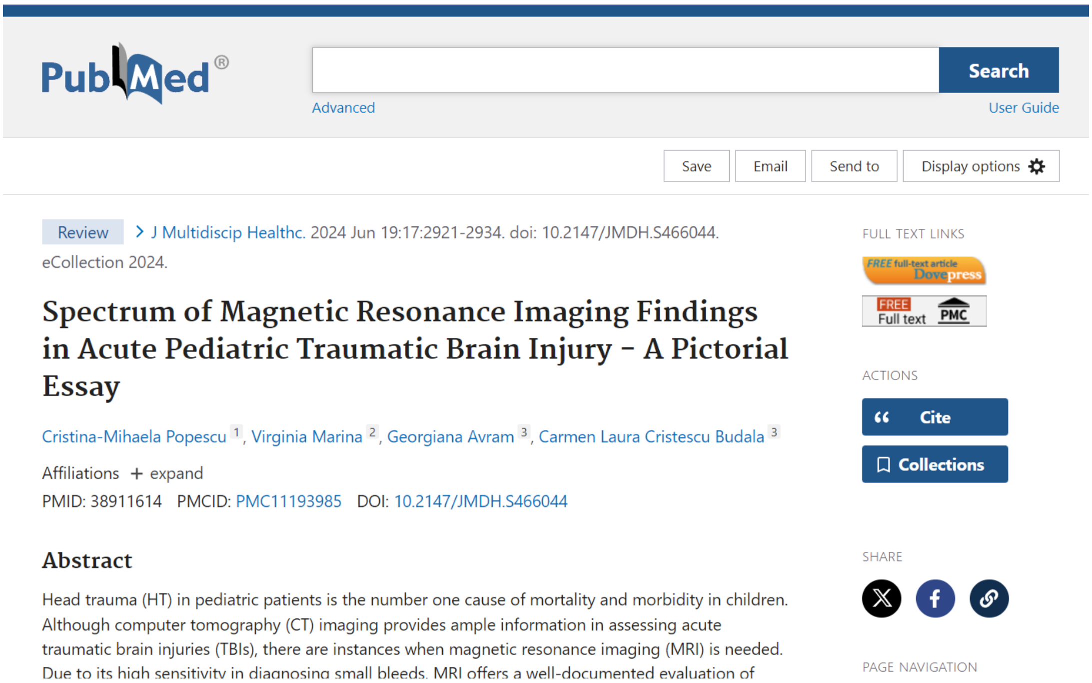

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Abstract

Head trauma (HT) in pediatric patients is the number one cause of mortality and morbidity in children. Although computer tomography (CT) imaging provides ample information in assessing acute traumatic brain injuries (TBIs), there are instances when magnetic resonance imaging (MRI) is needed. Due to its high sensitivity in diagnosing small bleeds, MRI offers a well-documented evaluation of

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