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ORIGINAL PAPERS

A Retrospective Forensic Study in Head Trauma Patients with Undiagnosed Skull Fractures at Computerised Tomography (CT) Scans

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Abstract

Introduction and objectives: Evaluation of injuries in emergency departments is based on CT scans. The objective of this forensic study is to reveal certain types and location of skull fractures that can escape CT diagnosis. **Methods:** This study was conducted by retrospective analysis of 115 cases of hospitalized traumatic brain injury autopsied at INML "Mina Minovici" Bucharest during the year 2011. **Results and discussions:** In 35 cases were discovered that skull fractures have not been highlighted in CT examinations. Undiagnosed skull fractures were predominantly linear fractures. A linear fracture that comes in the plane of a CT slice may not be visualized if is not depressed or separated. **Conclusion:** Skull fractures were mostly undiagnosed in men, over the age of 50 with serious traumatic brain injury, with a survival period of less than 5 days and with a single CT examination. In 30.43% of studied cases were detected skull fractures that were not diagnosed on CT. The most common was involved the cranial vault from temporal-parietal areas, followed by frontal area, with irradiation in the anterior and medium fossa. A good accuracy of imaging diagnostic was in the occipital region, and in the posterior fossa of the skull base.

Keywords: CT examination, autopsy, undiagnosed skull fractures, linear skull fractures.

Rezumat

Introducerea și obiectivul studiului: Evaluarea leziunilor în departamentele de urgență se bazează pe examenul CT. Obiectivul acestui studiu medico-legal este evidențierea anumitor tipuri și localizări ale fracturilor craniene, care pot scăpa diagnosticului CT. **Material și metodă:** Acest studiu a fost realizat prin analiza retrospectivă a 115 cazuri de leziuni traumatice cerebrale la pacienți spitalizați, ulterior autopsiați la INML „Mina Minovici" București, în cursul anului 2011. **Rezultate și discuții:** În 35 de cazuri s-au descoperit fracturi craniene ce nu au fost evidențiate la examenul CT. Fracturile craniene nediagnosticate au fost predominant fracturi liniare. O fractură liniară care vine în planul unei secțiuni CT nu poate fi vizualizată dacă nu este deprimată sau separată. **Concluzii:** Fracturile craniene nediagnosticate au fost frecvente la bărbați, în vârstă de peste 50 de ani, cu leziuni cerebrale grave, cu perioadă de supraviețuire sub 5 zile și cu o singură examinare CT. În 30,43% din cazurile studiate au fost depistate fracturi craniene care nu au fost diagnosticate pe CT, frecvent fiind implicată bolta craniană din zonele temporo-parietale, urmată de zona frontală, cu iradiere în etajul anterior și mediu al bazei craniului. O precizie bună a diagnosticului imagistic a fost în regiunea occipitală şi în fosa posterioară a bazei craniului.

Cuvinte cheie: examen CT, autopsie, fracturi craniene nediagnosticate, fracturi craniene liniare.

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INTRODUCTION AND OBJECTIVES

Computerized tomography (CT) scan is the primary screening modality of investigations in head trauma victims[1]. Since 1971 when it was invented, CT scan has advanced significantly from time-intensive single-section scanning to multi-detector row CT[2]. Nowadays, rapid and accurate assessment of injuries in emergency departments is based on CT scans. There is a high degree of difficulty in terms of causal link, between the injury and the death causing mechanism in patients, with multiple affections and head trauma[3].

CT is the standard evaluation of patients with traumatic brain injury (TBI), helping not only to assess head injuries but primarily to estimate the severity of brain lesions, evaluation hematic accumulation and achieving a lesion balance very important for neurosurgical treatment. CT scans performed during patient's hospitalization are important in forensic investigations of head trauma. In some cases, when external head injuries are minimal, the patient is unconscious and in the absence of survey data, medical examiners are faced with a case of "Traumatic brain injury in unspecified conditions". Therefore, cranial imaging evaluations help to establish the posttraumatic interval and the mechanism involved in the biomechanics of the head injury.

When patient hospitalization is followed by death, forensic autopsy is required by law. When the survival period of the patient is increased, and are performed neurosurgical interventions, significant changes appear in original cranio-cerebral injuries. In these cases the medical examiner must investigate carefully the medical records of the victim to recreate the initial lesions and be able to differentiate lesions that occurs in fall or precipitation as against physical attacks, followed or not by victim fall.

When victim recovers after hospitalization and goes to forensic examination, CT examinations performed during hospitalization are also important, helping forensic expert to reconstruct the way of processing the trauma, especially when the victim presents for examination long after the initial trauma. In the absence of external injury, skull fractures often help in identifying the point of head impacts. Evaluation of the severity of traumatic injuries will take into account the CT scans for quantifying the number of days of medical care, the traumatic consequences, and establish correlations between lesion topography and the mechanism of production the trauma.

When there is linear skull fractures, simple, missed on CT examination it can be error factors in forensic evaluation, even if they are insignificant in terms of the clinical course. Therefore, this study has forensic importance drawing attention to certain types and location of skull fractures that can escape through CT diagnosis.

Law 95/2006 in art 642 defines "professional malpractice as the error committed in the exercise of the medical or medical-pharmaceutical, tortious the patient, involving civil liability of medical personnel and medical products and services provider, healthcare or pharmaceutical". Subjective error, also known as diagnostic fault, are caused by poor medical training and the misapplication of specialized techniques and maneuvers. Objective error occurs frequently due to the imperfections of medical science at a time, to a particular situation of the patient, and any doctor would have done the same in similar circumstances[4].

Therefore, both in forensic evaluation of traumatic consequences and in assessing responsibility related to medical act, it is important to study the accuracy, sensitivity and specificity of medical diagnostic methods in order to make the disjunction between objective and subjective errors, and distinguish them from medical malpractice.

METHODS

This study was conducted by retrospective analysis of 115 cases of traumatic brain injury autopsied at INML "Mina Minovici" Bucharest between 01.01.2011-01.01.2012. Were included the cases of traumatic brain injury with skull fractures diagnosed in autopsy, who were hospitalized with a range of survival varied between 1 hour and 20 days in which CT exams were performed. Were excluded the cases of TBI with skull fractures which have undergone neurosurgery decompression procedures, that can generate in some cases additional cracks or skull fractures, which had been a factor of error in the study.

A detailed examination and dissection of the head as per standard forensic autopsy procedure was carried out. For comparative purposes the neuro-cranium was divided in two major anatomic regions: the vault and the cranial base. The cranial base was subdivided into the posterior fossa, the medial fossa and the anterior fossa, fractures of skull were noted on after removal of the brain and dura mater. The fractures found at autopsy with characteristics, extension and anatomic location were photographed, noted down and compared with CT results from hospital records of the deceased.

Additionally, in all studied cases were carried out one or more CT examinations linked on the survival period by using spiral CT scan that were performed in continuous, multiple sections by 5mm in the axial plane. In this study the cases with CT that performs images in reconstructive sagittal and coronal plans were not included.

RESULTS

There were analyzed 115 cases of TBI and it was discovered that skull fractures have not been highlighted in CT examinations in 35 cases (representing 30.43% of all studied cases) (Figure 1).

Most of the undiagnosed skull fractures were highlighted especially in men -27 cases, representing 77.15% of all undiagnosed fractures. Regarding distribution by age, undiagnosed CT skull fracture stands out mainly over the age of 50 years- 25 cases, representing 71.42% of all undiagnosed fractures. In the range 70-80 years were reported 9 cases, 25.71%, in the range 0-10 years were reported 4 cases of pediatric patients, representing 11.42%.

In most of the cases where skull fractures have been omitted on CT, only one imagistic examination was performed, for example, in a patient survival period less than 5 days were revealed 18 cases. With survival period of 5-10 days were reported 12 cases of undiagnosed fractures. In patients who survived more than 10 days and with multiple CT exams were revealed only 5 cases of undiagnosed fractures (Figure 2).

Referring to severity of head trauma, it was noted that in 31 cases patients experienced serious TBI, with GCS: 3-4 points (68.57%); GCS: 4-7 points (20%) and a lower average of patients had moderate TBI, revealed in 4 cases with GCS: 11 points (11.42%) (Figure 3).

Regarding the mechanisms in producing of the undiagnosed CT skull fractures were prevalent road accidents in 12 cases (34.28%) and accidental drops to the same level in 12 cases (34.28%). Precipitation were found in 6 cases (17.14%) and assaults in 5 cases (14.28%).

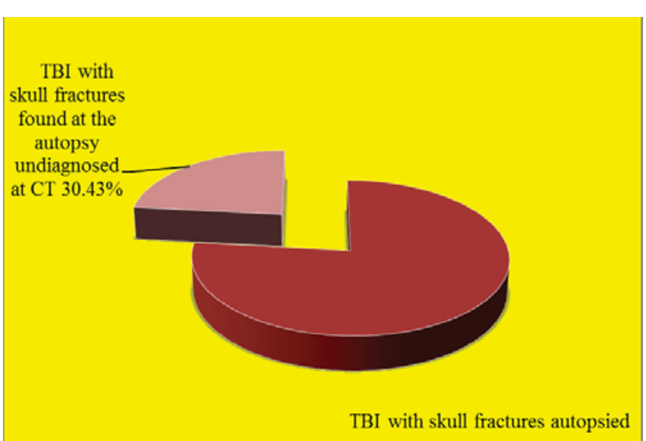

Figure 1. Skull fractures undiagnosed at CT examination in cases of traumatic brain injury (TBI) autopsied.

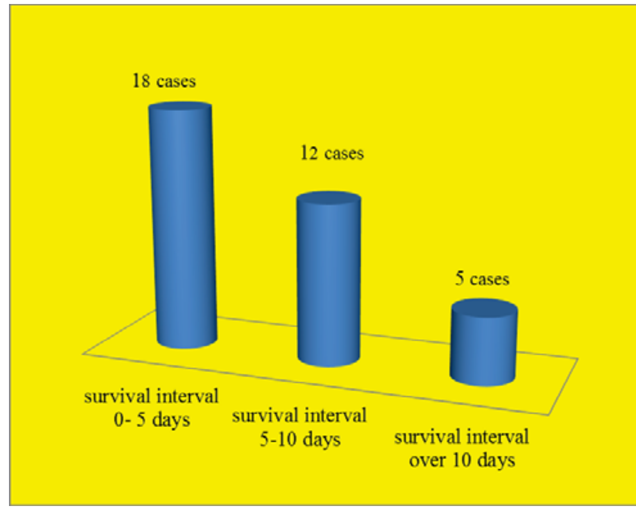

Figure 2. Survival period of patients with skull fractures missed on CT.

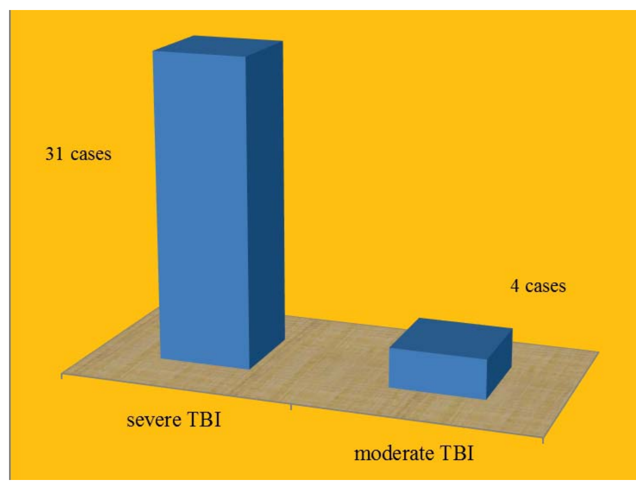

Figure 3. Severity of traumatic brain injury (TBI) in patients with skull fractures missed on CT examination.

The forensic autopsy revealed fractures that were not diagnosed both in neuro-cranium (77.14% of total undiagnosed fractures), and in viscero-cranium (22.85% of total undiagnosed fractures) (Figure 4).

In viscerocranium were detected 8 cases of skull fractures, 4 cases in the orbit (3.47% of all cases studied) and 4 cases in the nasal bone (3.47% of total cases studied).

Most cases of undiagnosed fractures involved the neurocranium, 27 cases, located mostly on the cranial vault with or without irradiation at the base of the skull. They were also highlighted isolated fractures of the skull base in 6 cases. Comminuted fracture of neurocranium was revealed in 1 case. The skull fracture was

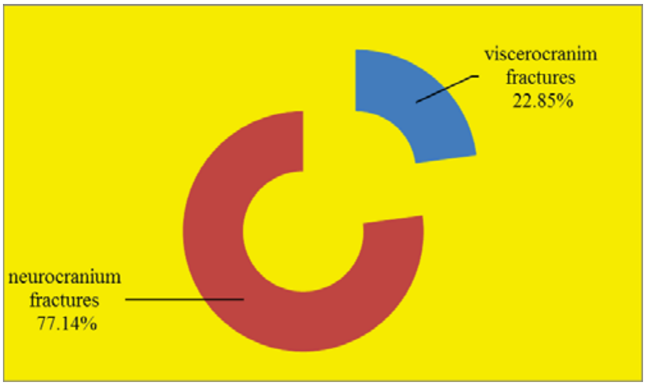

Figure 4. Distribution of skull fractures undiagnosed at CT examination witch were detected at autopsy.

discovered in the right fronto-temporal region with irradiation both in anterior and medium fossa (Figure 5).

Simple linear fractures, without displacement of the calvarium, without irradiation to the base were detected in 8 cases, which represents 6.95% of all cases (22.85% of all undiagnosed fractures) and involves with predilection parietal bone followed by front location (Table 1). Were discovered 2 cases of fractures in each of the regions: parietal area, temporo-parietal bones and fronto-parietal bones, representing 1.7% of all investigated cases, and 5.71% of all undiagnosed fractures. In addition, were detected two cases of fracture in frontal bone, 1.7% of the analyzed cases and 5.71% of total undiagnosed fractures.

Simple linear fractures without displacement of the calvarium and irradiated to the base of the skull, were highlighted in 12 cases, representing 10.43% of the cases analyzed and 34.28% of the undiagnosed fractures. They were located mostly in the parietal and temporal areas, with frequently irradiation in medial fossa (Table 2).

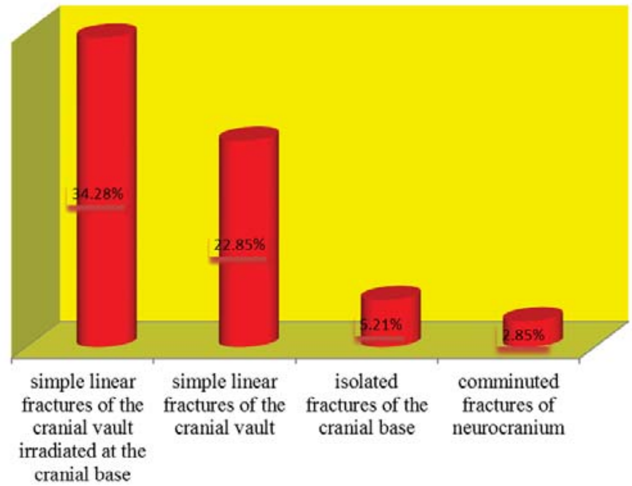

Figure 5. Distribution by anatomical regions of the skull fractures diagnosed at autopsy.

Isolated cranial base fractures were highlighted in 6 cases (5.21% of all cases) representing 17.14% of undiagnosed fractures. They frequently involved anterior and medium fossa of the cranial base floor with linear path, without displacement. Autopsy revealed: 2 cases of fractures in anterior fossa, 2 cases both in anterior and medium fossa and 2 cases in medium fossa (Table 3).

Table 1. Simple linear fractures, without displacement of the calvarium without irradiation to the base

Case number	Anatomic region of the cranial vault	Appearance and fracture path	Undiagnosed associated lesions on CT
1.	Temporal right bone, squamous part	Linear fracture without displacement, meridional, parallel paths with large wing of sphenoid bone	Extradural hematoma in right temporal region
2.	Temporal left bone, squamous part	Linear fracture without displacement, equatorial situated in left, the middle part of the squamous part of temporal, parallel with temporo-parietal suture	No associated injuries
3.	Median frontal region and parietal paramedian left region	Linear fracture without displacement, situated medial in frontal bone, passes sagittal suture and ends up in left paramedian parietal bone	Sagittal suture disjunction
4.	Left paramedian fronto-parietal region	Linear fracture without displacement, meridional path	No associated injuries
5.	Right fronto-parietal region	Linear fracture without displacement, equatorial level obliquely trajectory from the right parietal bone, downward in temporal-parietal right suture and traversing large sphenoid wing, irradiating in the front in the upper wall of the right orbit	Right temporo-parietal suture disjunction
6.	Right temporo-parietal region	Linear fracture without displacement, meridional path with downward oblique trajectory	No associated injuries
7.	Right temporo-parietal region	Linear fracture without displacement, equatorial path crossing the posterior right temporal-parietal suture	No associated injuries
8.	Right parietal region	Linear fracture without displacement, equatorial paths parallel with sagittal suture	No associated injuries

Table 2. Simple linear fractures without displacement of the calvarium and irradiated to the base of the skull

Case number	The path of the fracture in the cranial vault	The path of the irradiation fracture at the base of the skull
1.	Left fronto-parietal region	Left anterior fossa of the skull base, oblique aspect of the fracture in orbital left bone and sphenoidal body
2.	Right fronto-parietal region	Bilateral anterior fossa of the skull base, horizontal aspect extended in the bilateral orbital roof and ethmoid bone
3.	Bilateral parietal-occipital region	Bilateral medium fossa, horizontal aspect in the bilateral base of pars petrosa of temporal bone, crossing the posterior pituitary fossa.
4.	Right parietal-occipital region	Right medium fossa of the skull base, obliquely aspect, extended in pars petrosa of right temporal bone and in the large wing of right sphenoid bone
5.	Temporo-parietal right region	Right medium fossa of the base, obliquely aspect in squamous part of right temporal bone, large wing of sphenoid bone and pituitary fossa
6.	Temporo-parietal left region	Bilateral medium fossa of the base, oblique aspect from anterior wall of pars petrosa of left temporal bone to the pituitary saddle and large wing of right sphenoid bone
7.	Left parietal region	Left medium fossa, oblique aspect in the squamous part of left temporal bone
8.	Left parietal region	Bilateral medium fossa, horizontal aspect from the left part squamosa of temporal bone to the pituitary fossa and large wing of sphenoid bone
9.	Left temporal region	Left medium fossa of the base, horizontal aspect, extended in the large wing of left sphenoid bone
10.	Right temporal region	Right medium fossa of the base, obliquely aspect, extended in the right wing of right sphenoid bone and pituitary fossa
11.	Temporo-occipital left region	Left posterior fossa of the base, obliquely aspect to the left paramedian occipital clivus
12.	Temporo-occipital right region	Right posterior fossa the base, looking obliquely from the right cerebellar occipital fossa to the posterior margin of the occipital hole

In one case the extent of skull fracture was underestimated on CT scans, that was not highlighted in the left occipital region, but only in her path in temporo-parietal area.

Associated with undiscovered skull fractures at autopsy, there were also highlighted other cranio-cerebral injuries that were not diagnosed on CT examination (Figure 6).

Cranial fissures were found in 3 cases, representing 2.60% of the total analyzed cases and 8.57% of total undiagnosed skull fracture. Autopsy reveals two internal fissures in frontal bones and one external fissure in fronto-temporal region. Disjunction of cranial bone were associated with undiagnosed fractures in 5 cases (4.34% of all analyzed cases). They were found one case of disjunction of the intraparietal suture, 2 cases of disjunctions in temporo-parietal sutures and 2 cases of disjunction at the lambdoid suture. In autopsy, it was not reveal macroscopic any suture dehiscence in coronary suture. They were found five cases of extradural hematoma associated with undiagnosed fractures, 4 cases located in fronto-parietal area unilaterally associated with linear fronto-parietal fracture irradiated in medium fossa, 1 case located in mid frontal region associated with medio-sagittal fracture in frontal bone.

Table 3. Isolated cranial base fractures

Case number	Fracture path at the base of the skull	The appearance of the fracture path
1.	Right anterior fossa	Linear fracture without displacement, oblique, transverse in the right orbital bone and in the ethmoidal bone
2.	Bilateral anterior fossa	Linear fracture without displacement, horizontal aspect in the little wing of right sphenoid bone, right orbit crossing ethmoid bone straight to the middle of the left orbit
3.	Right anterior and medium fossa	Linear fracture without displacement, oblique transverse path at the ceiling of right orbit, crossing the sphenoid body to the front pars petrosa of right temporal bone
4.	Left anterior and medium fossa	Linear fracture without displacement, oblique transverse aspect from the ethmoidal bone to the small and large wing of left sphenoid bone
5.	Bilateral medium fossa	Linear fracture without displacement, horizontal aspect situated in the large wing of sphenoid bone bilateral and crossing pituitary fossa
6.	Bilateral medium fossa	Linear fracture without displacement, oblique semicircular aspect, from the lower part of the pars petrosa in left temporal bone to the large wing of left sphenoid bone crossing pituitary fossa to posterior part of pars petrosa of right temporal bone

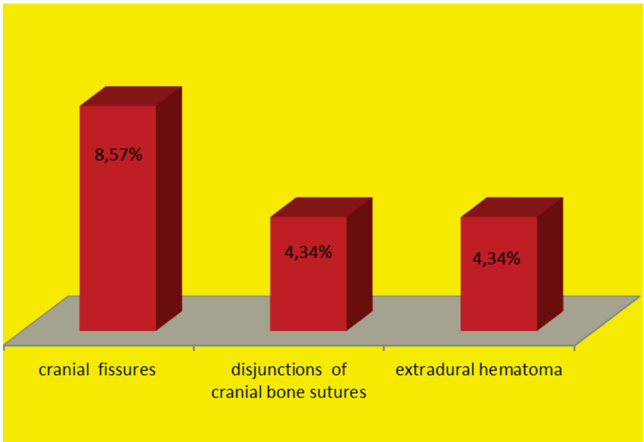

Figure 6. Cranio-cerebral injuries associated with skull fractures also missed on CT examination.

DISCUSSIONS

Many times, forensic evaluation of clinical cranial CT is the only reliable source of morphological evidence in head injuries. When death is delayed in trauma cases, autopsy findings are then characterized by secondary changes. Moreover, when the injured survives, the evaluation of CT images is the only valuable source of evidence of head trauma available to forensic experts[5].

Situations do occur when no significant abnormality is evident on a CT scan, whereas the autopsy report suggests otherwise. In such circumstances, a forensic pathologist may find himself in an awkward situation. He is unable to give an accurate opinion regarding the presence or absence of fractures based on reporting of radiological investigations. Often conflict also arises in the court of law when a CT scan report shows no fracture, while the autopsy report reveals a skull fracture. Studies are needed to know the precision and accuracy of a CT scan, which can be achieved only by comparing a CT scan with post-mortem revaluations.

"The Charter of Fundamental Rights of the EU" written by the European Parliament is the foundation of the jurisprudence in the Court of Justice of EU and in the European Court of Human Rights (ECHR). The Charter of Fundamental Rights of the EU explicitly stipulates in art. 47 the following: that any person is entitled to a fair, public and reasonably timed trial, in any independent and impartial court, previously established by law and has the right of being advised, defended and represented. Therefore, according to current ECHR jurisprudence regarding the right of a fair trial, each party is able to have a reasonable opportunity to exhibit in court in conditions that are not significantly disadvantageous relative to the adverse side, according to the principle of equality of arms and contradictory[6].

Results of this study are related with other studies that stated the discrepancies that exist between CT and autopsy findings with regard to skull fractures. In Sharma and Murari observations, 23.7% of skull fractures remained undiagnosed by CT scan[7]. Goel et al observed that CT scans have not detected fractures of skull in 44.8% of cases compared to conventional autopsy findings[8]. Anand et al study pointed that CT scans do not reveal fractures of the vault in 25.65% of cases and fractures of the base of the skull in 64.52% of cases in comparison with autopsy results[9]. Hitesh Chawla et al study showed that 14.6% of skull fractures are being missed on CT scans compared to autopsy[10].

Analysis of the cases with undiagnosed skull fractures showed predominantly linear fractures, unless depressed or separation, unbranched frequently both in the vault and the base of the skull. A linear fracture that comes in the plane of a CT slice may not be visualized[11].

Linear fracture of the skull are difficult to be identified by CT scan if are not depressed or separated[12].

In neurosurgical diagnosis, most of hairline fractures are not essential as long as they have no clinical symptoms or complications[13]. The results of this study show omissions in CT scans imaging diagnostic of the skull base fractures when they are located in anterior and medium fossa. The difficulties regarding the diagnosis of this fractures is also known in the clinical setting[14]. In this study both the fractures of cranial vault irradiated at the base of the skull and also isolated fractures of the cranial base that were not highlighted in CT images were located in medium fossa of the skull base often unilateral predominantly in the large wing of the sphenoid bone and in pars petrosa of the temporal bone.

Clinical studies of Unger et al found that fractures of the cranial base predominantly were located in the large wing of sphenoid bone and some extent in the temporal bone[15].

Jacobsen et al showed that forensic important information about the whole fracture system, possible impact points and the causative forces may be lost in the cases in which we rely on the interpretation of CT scan in the absence of autopsy[16].

Schuknecht et al showed that the use of multi-detector CT (MDCT) with coronal reformats and high resolution can improve the diagnose fractures of the bones in the medial and anterior fossa and can be very effective in evaluation of the pars petrosa of the temporal bone[17].

CONCLUSION

In 30.43% of all the case, skull fractures were detected that were not diagnosed on CT. In most cases when skull fractures have been omitted, a single CT examination was performed and patients experienced serious traumatic brain injury (88.57%) with a range of survival less than 5 days (51.42%).

The vast majority of undiagnosed cases were represented by neurocranial linear fractures without displacement and without depression. Most cases of undiagnosed fractures involved the neurocranium, representing 77.14% of imaging undiagnosed fracture. Viscerocranium fractures were detected in 22.85% of cases.

Fractures of the cranial vault irradiated at the base of the skull were highlighted in most cases representing 34.28% of all undiagnosed fractures. The vast majority of irradiated base skull fracture was located at the temporal and parietal regions involved predominantly medium fossa, fewer cases involved the frontal area, with irradiation in anterior fossa and occipital area with irradiation in anterior fossa.

Linear fractures of the cranial vault without displacement represented 22.85% of total undiagnosed fractures that predominantly involved parietal region, in some cases in association with frontal and temporal regions. Only in two cases fractures were found in frontal region.

Comminuted neurocranial fractures that were frequently diagnosed correctly, have outlined at the skull only one undiagnosed comminuted fracture that involved fronto-temporal right region with irradiation at the right side of anterior and medium fossa.

Isolated base skull fractures, represented 17.14%% of undiagnosed fractures with linear path without moving, predominantly situated unilaterally in the anterior and medium fossa with transverse path, crossing over the orbit and sphenoid bone to pars petrosa of the temporal bone.

Imaging of cranial undiagnosed fissures was found in three cases, representing 8.57% of total undiagnosed cranial fractures, involving mostly the frontal area.

A percentage of 14.28% of the skull undiagnosed at CT fractures was associated with the disjunctions of cranial bones, and interested intraparietal suture, temporo-parietal sutures and lambdoid suture. No suture dehiscence was observed in the coronal suture.

Autopsy revealed extradural hematic collections associated with undiagnosed fractures. In five cases, extradural hematomas were found, also none detectable on CT scans. Extradural hematic accumulation undetected at CT scans were unilateral located in fronto-temporal regions. No extradural hematic collections were detected in occipital area.

All undiagnosed skull fractures showed no displacement, the most common involved the cranial vault from temporal-parietal areas, followed by the ones located in the frontal area, with irradiation in the skull base in anterior and medium fossa. It has been found a good accuracy of imaging diagnostic in the occipital region, and in the posterior fossa of the skull base.

No isolated fracture of the cranial base in the location of posterior fossa has been undiagnosed.

For a better delineation of fractures, the use of multi-detector CT with sagittal and coronal reformations should be recommended in the routine interpretation of a CT scan head, so that forensically important fractures are not missed.

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