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Ante mortem CT aspects *versus* autopsy findings in head trauma

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Abstract: Head trauma is one of the leading causes of death worldwide, the main circumstances for occurrence in Europe being road traffic accidents and falls.

CT examination is considered to be "the gold standard" for the diagnosis and non-invasive assessment, as well as for the management of head trauma. Autopsy represents "the gold standard" for the postmortem diagnosis and assessment of head injuries. Nevertheless, the ante-mortem CT examinations performed during hospital admissions are likewise important in the postmortem evaluation of the head injuries, and the comparison between the ante-mortem and post-mortem CT examinations may help for a better understanding of the post-mortem findings.

In this paper, the authors present the results of a retrospective study which aimed to analyze the correspondence between the injuries diagnosed by CT imaging while the patients who suffered head trauma were admitted in the hospital and the injuries identified at the autopsy of these patients in order to establish which injuries are missed on CT imaging, as well as the factors influencing the discrepancies between antemortem and postmortem diagnosis.

The results of our study show a significant discrepancy in most cases between the injuries identified by CT examination and the injuries identified during autopsy, both regarding the missed injuries and the over-diagnosed injuries, a total agreement being recorded only in 4 of the 114 cases. The analysis of the potentially involved factors resulted in a direct link with the number of injuries, the risk to overlook a fracture being higher as the number of injuries is higher. The most frequently missed injuries during CT examination were: ventricular hemorrhage, brain contusion and the fractures in the anterior and posterior floors of the base of the skull, while the most over-diagnosed injuries during CT examination were the extradural hematoma and fractures of the skull sutures. The authors underline the importance of studies aimed to identify the factors that contribute to the discrepancies between the results of the CT examination and the autopsy findings in the victims with head trauma, in order for the measures to decrease the discrepancies between the two examinations to be identified.

Key Words: head trauma, diagnosis, CT scan, autopsy, agreement/disagreement rate.

INTRODUCTION

Head trauma is one of the leading causes of death [1], with the main circumstances for occurrence in Europe being road traffic accidents and falls [2]. Worldwide, road traffic accidents are the leading cause of head trauma in low- and middle-income countries (covering most of the world's population), while falls are quickly following, especially in children aged 0-14 years and adults over 65 years in high-income countries [3].

For a more accurate assessment of the condition of the patient with head trauma, in order to diagnose and treat the injuries, the clinician relies heavily on the results of the imaging tests [4]. CT examination allows non-invasive, accurate and prompt diagnosis and assessment of intracranial injuries [5] for a better assessment of clinical status [6]. These advantages are especially important for patients who have suffered

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trauma in the cephalic region resulting in serious injuries and need urgent diagnosis and treatment [5-7]. Thus, this examination is considered to be the "gold standard" and the basis for the management of head trauma in emergency departments [7], being part of the investigations performed to almost all patients with injuries in the cephalic region [1]. Moreover, digital data can be easily stored, and cases reviewed many years later, even after the burial or release of the crime scene [6].

In the case of fatal cranial-cerebral lesions, the autopsy allows determining the cause of death [6], and the correct assessment of the victim's injuries contributes to the evaluation of their involvement in the death by establishing their nature and the mechanism that has led to their occurrence [7]. For an accurate detection of head injuries in the dead body, the autopsy is the "gold standard". However, the forensic pathologist also takes into account pre-mortem CT examinations performed during hospital admission, and where possible, comparison of ante-mortem and post-mortem CT imaging may help to better understand the latter [6, 7]. In case the victim survives a certain amount of time, during which lesions can change their appearance, the ante-mortem imaging diagnosis becomes essential [7].

During the autopsy, every injury is important, regardless of size and gravity [8, 9]. For example, the aspect of the fractures has a major role in determining the mechanism and the way the trauma and other injuries have occurred- the fractures are the witnesses of the intensity of trauma, and offer information regarding the characteristics of the traumatic agent and the conditions in which trauma occurred [10-12], even if the fracture has been isolated or was not accompanied by injuries with significant clinical expression. This aspect (low clinical expression) sometimes makes the clinician give less importance to the identification of the fracture [7]. On the other hand, the autopsy allows assessments of the correctness of the diagnosis established in the hospital and, at the same time, the identification of the injuries with the highest risk to be overlooked and the factors that facilitate some injuries to remain un-diagnosed, being, thus, a genuine clinical audit tool, by providing the elements that might improve the clinical practice [13-16].

The aim of the study was to analyze the correspondence between the injuries diagnosed by CT imaging while the patient who suffered head trauma was admitted in the hospital and the injuries identified at the autopsy of these patients in order to establish which injuries are missed on CT-imaging and, likewise, the factors that intervene for these injuries to be missed. We also aimed to compare our results with other studies in the literature and to analyze the factors influencing the misdiagnosis.

MATERIAL AND METHOD

We performed a retrospective analysis of the consecutive hospital deaths of patients admitted in the hospital with head trauma, that were assessed post-mortem by means of autopsy at the Institute of Legal Medicine of Iasi. Inclusion criteria were: hospital admission due to head trauma or polytrauma that included head injuries, the existence of a head CT scan in the patient's medical file and occurrence of death during the hospital stay. For each patient, we compared the written conclusions of the CT exam with the autopsy findings and created a score that indicated to what extent the two assessments concurred. The four resulting categories were:

1. Total agreement between CT and autopsy findings;
2. Lesions that were only found by the CT scan;
3. Lesions only found during autopsy;
4. Total disagreement between CT and autopsy findings.

Two forensic physicians independently reviewed each case and decided in which category/ies the lesions best fit. Cases where there were over-diagnosed lesions at the CT scan and also lesions found only at autopsy (corresponding to both categories two and three of the score) were counted twice – once for each category. The final results of the forensic physicians' analysis were compared and if any disagreements were noted they were discussed with all the members of the project until a consensus was reached.

For each case, we collected several other parameters pertaining to patient characteristics (age, gender, residence) and trauma type and management (hospital stay, cause of the head trauma, associated lesions). Additionally, each lesion was separately analyzed in order to identify those that are most often misdiagnosed during CT exam and the clinical scenario most often associated with likely-to-misdiagnose lesions. If two or more scans were performed throughout the patient's hospital admission, we compared the autopsy results to the imaging exam performed last before the patient's death.

Statistical analysis was performed by means of SPSS v20. Descriptive data is presented as percent of total or as average ± standard error mean where applicable. All data were assessed for correlation coefficient and Fischer Exact Test and Chi square analysis were performed when appropriate. Statistical significance was a priori set at .05. Graphs were created with the aid of Prism v6 software.

RESULTS

Descriptive analysis

We analyzed 114 cases that matched our inclusion criteria. Most patients were male (78.1%), came from

rural areas (61.4%) and were under 65 years at the time of death (58.8%). About half of the cases (50.1%) were admitted in the hospital after a fall, while the remaining cases most often suffered trauma due to traffic accidents (26.3%) or aggression (10.5%). Hospital stay was variable – from 1 to 23 days, with a mean of 6.01±4.80 days.

Most of the patients were examined by CT scan at the "Prof. dr. N. Oblu" Hospital of Iasi, which is a regional Neurosurgery Hospital (87.7%). Accordingly, almost three quarters of the patients suffered only head trauma (74.6%) as opposed to polytrauma patients (25.4%) that usually had an initial CT scan in the Emergency Department followed by a second scan in the Neurosurgery ward. Average number of lesions described by the radiologist after CT scan was 2.97±1.95 (range 1-9). Average number of lesions described at autopsy was 5.28±2.56 (range 1-12).

CT scan-autopsy agreement rates

Of the 114 cases that matched our inclusion criteria, 38 cases had both lesions diagnosed only through imaging and lesions identified only at autopsy and were assigned in two categories. A total agreement between CT and autopsy findings was recorded in 2.6% of the entries (4 cases) and total disagreement between CT and autopsy findings was noted in 7.2% (11 cases). In most cases (64.5% - 98 cases), we identified several lesions diagnosed only during autopsy and in 25.7% instances (39 cases) we found lesions that were noted after imaging exam but were not observed at autopsy.

Regarding potential predictive factors, the strongest correlation was observed between agreement rates and the number of lesions identified at the CT scan – the higher the number of lesions, the more likely it was for a partial or complete disagreement. Also, we found that individuals that resided in rural areas had a lower agreement rate than those from urban areas.

Hospital stay and the mechanism by which head trauma was inflicted did not correlate with agreement rates.

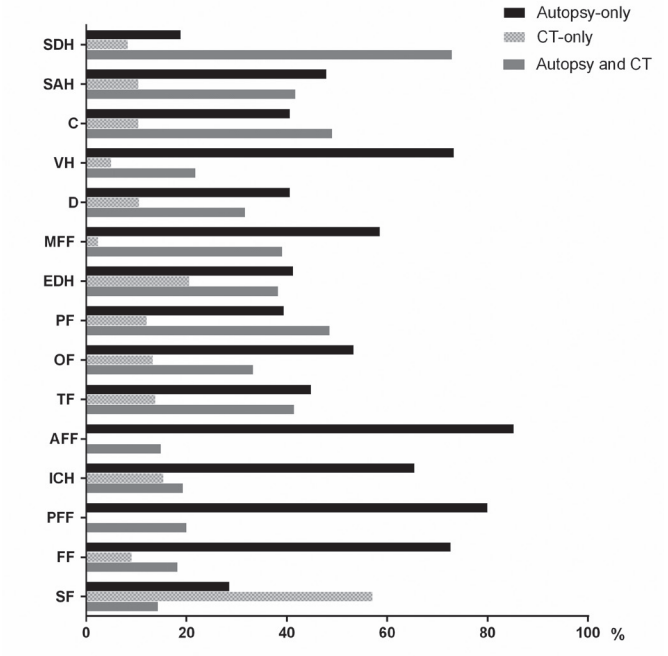
Regarding individual types of lesions, the presence of either contusion or ventricular hemorrhaging was a strong indicator for CT-autopsy disagreement. As such, ventricular hemorrhage (VH) was recorded in 60 cases (52.6%), but the CT scan and the autopsy only concurred in 13 cases (21.7%), with false positive lesions (identified by CT, but absent at autopsy) in 5% (3 cases) and false negative lesions (identified only at autopsy) in 73.3% (44 cases). Similarly, cerebral contusion was recorded in 96 cases (84.2%) but the CT scan and the autopsy concurred in less than half of those (47 cases - 49%), with false positive lesions in 10.4% (10 cases) and false negative lesions in 40.6% (39 cases).

The lesions often missed by the CT scan included fractures of the posterior floor of the base of the skull (PFF) that were noted in 25 cases, with an agreement rate of 20% and a false negative rate (lesions identified only at autopsy) of 80% (20 cases). Of note, there were no fractures identified at the CT in the posterior floor of the base of the skull and absent at autopsy. Similarly, fractures of the anterior floor of the base of the skull (27 cases) also had a low agreement rate (14.8%), with 85.2% cases diagnosed only at autopsy.

In terms of lesions most likely to be diagnosed by the CT scan only (i.e. over-diagnosed), extradural hematomas (EDH) and fractures involving sutures of the cranial bones (SF) were most likely to be over-diagnosed, both with false positive rates exceeding 20%. As such, EDH was recorded in 34 cases (29.8%), with an agreement rate of 38.2% (13 cases), a false-positive rate of 20.6% (7 cases) and a false-negative rate of 41.2% (14 cases), whereas SF were recorded in 7 cases (6.1% of total), with a 57.1% false-positive rate. The complete list of lesions and their frequency, together with agreement rates can be seen in Figure 1. Lesions are listed in reverse order of frequency – from most frequent to least frequent.

Subgroup descriptive analysis

The 4 cases with 100% agreement were all males, more frequently younger than 65 years (3 cases) and with head trauma only (3 cases). Maximum number



	SDH	SAH	C	VH	D	MFF	EDH	PF	OF	TF	AFF	ICH	PFF	FF	SF
No. of cases	96	96	96	60	57	41	34	33	30	29	27	26	25	11	7

Figure 1. Percent distribution for methods by which each lesion was diagnosed.

Legend: SDH – subdural hematoma; SAH – subarachnoid hemorrhage; C – contusion; VH – ventricular hemorrhage; D – dilaceration; MFF – middle floor fracture; EDH – extradural hematoma; PF – parietal fracture; OF – occipital fracture; TF – temporal fracture; AFF – anterior floor fracture; ICH – intracerebral hematoma; PFF – posterior floor fracture; FF – frontal fracture; SF – fractures involving sutures of the cranial bones.

of lesions identified was 4 and among the lesions most often encountered were subdural hematoma (SDH), subarachnoid hemorrhage (SAH), ventricular hemorrhage (VH) and parietal fracture (PF). The 11 cases with 100% disagreement were also more frequently younger (63.3%) and males (63.6%) with a maximum hospital stay of 18 days. The most frequent trauma mechanism was road traffic accidents (54.5%). Lesions most often encountered in the 100% disagreement category were SDH, SAH, EDH, VH, intracerebral hematoma (ICH) and fractures of the base of the skull.

When analyzing patients that were admitted with head injuries after experiencing a fall (n=57), we found that they were more often older, female and less likely to have polytrauma when compared with the general characteristics of the group. Also, we found that total agreement rates were lower – only one of the four cases with 100% concurrence was the result of a fall. In terms of specific lesions, cerebral contusions were identified in 95.9% of all the patients, victims of fall, a significantly higher incidence than the incidence of the whole group. For the second subgroup analysis that included only patients that were admitted as a result of a road traffic accident, we found that they were younger and more likely to have polytrauma after impact, but we did not identify any specific cranial lesions correlated with road traffic accidents.

DISCUSSION

The imaging examination of the cases included in our study was performed using a CT Siemens ARC, with axial sections. The technique by which the injuries are examined on CT is of particular relevance to the accuracy of the diagnosis, the literature data emphasizing the hindrances of the axial plan compared to the cross-sectional technique. Thus, in terms of bone lesions, examination only through the axial plane predisposes to missing linear fractures or with minimal dehiscence or when the section is parallel to the fracture [7]. In contrast, the cross-sectional technique allows examination with high spatial resolution as well as reconstruction in different planes [6]. Also, with regard to bone lesions, the use of techniques such as CT multi-detector with sagittal and coronary reconstruction can add extra accuracy to CT examinations of the skull [7].

Regarding the bone lesions, in our study, CT examination missed especially fractures of the base of the skull: 20 out of 25 posterior floor fractures, 23 of the 27 anterior floor fracture; however, 4 of the 7 cases with fractures of the cranial sutures were over-diagnosed at the ante-mortem CT scan. For vault fractures, CT examination missed mainly frontal and occipital bone fractures, but there was an important concordance for parietal bone fractures. Our results compare favorably with the results of similar studies published in the literature. Sharma and Murari's study (2006) found that 23.7% of skull fractures were missed during CT examination, with a 100% correspondence between CT and autopsy in the rest of 76.3% of the cases [1], while Goyal *et al.* (2007) identified that 55.2% of the fractures remained undetected after CT scan [5], a similar percentage being obtained by Alexis *et al.* (2018), who discovered that CT scan missed 51.71% of the total of 205 cases [17]. Likewise, Anand *et al.* (2015) revealed a ratio between CT and autopsy of 20:39 and 11:31 for fractures of the vault and of the base of the skull, respectively [18]. On the other hand, a study performed by Chawla *et al.* (2015) on 60 cases revealed that CT scan missed only 6 of 41 fractures (14.6%), most of them linear (5 of 6) and located at the level of vault (4 of 5), the authors underlining the limitation of their study- the examination in the axial plane- which is otherwise still used in many of the developing countries [7]. Although the presence of a fracture does not always have clinical relevance, its detection is important for the forensic pathologist to determine the mechanism of injury [7, 17]. Besides the problems occurring as a result of the examination in the axial plane, another problem for the CT examination of the traumatized patients and which poses problems for the visualization of a fracture, particularly if it is linear, is their clinical condition [7]. For a pertinent examination, it is important that the patient remains completely still during the examination, but sometimes patients with head trauma are uncooperative and restless [7].

Regarding the intracranial blood collections, the results varied. An important discordance in our study was found in cases with extradural hematoma. Of the 27 cases in which the extradural hematoma was identified during autopsy, only in 13 cases it was identified also by CT. On the other hand, the falsely positive diagnosis of CT is of greater relevance, given that in 7 cases the EDH was identified only at CT. Unlike our study, the results obtained by Chawla *et al.* (2013) and Sharma and Murari (2006) show a larger discrepancy of about 1/3, with 15 cases in which the EDH was identified during autopsy, whereas the CT examination identified it in only 4 of these cases [19], respectively 66.7% with total concordance and 33.3% undetectable by CT [1]. For progressive injuries, an important element explaining the discrepancy is the survival time between CT examination and death, since blood collections may be formed during this period [21]. For the subdural hematoma, the results of our study show a low percentage of cases in which the diagnosis was either false positive or false negative in CT as compared with autopsy, but in the study performed by Sharma and Murari (2006) the concordance was 100%, as there were no discrepancies between the two diagnostic methods [1]. Another study performed in India shows that in 98 out of 228 cases, the SDH was not diagnosed during autopsy [17].

Blood accumulation in the subarachnoid space, i.e. subarachnoid hemorrhage (SAH), presented in our

study a significant difference between the CT and autopsy in favor of the latter, similar to Alexis *et al.* (2018), who identified that 153 of the total of 247 were missed during CT examination [17] and unlike Sharma and Murari (2006), where only 35.7% remained unidentified following CT examination [1]. Similar to extradural hematoma, the absence of identification during CT examination of the SAH does not rule out the possibility of formation in the survival interval after CT examination.

Unlike Sharma and Murari (2006), who identified the concordance between CT and autopsy in 70% of intracerebral hemorrhages and 30% remained undiagnosed by CT scan [1], our study showed the opposite, most of this type of lesions being missed on the CT scan.

Brain contusion was a strong indicator for CT-autopsy disagreement in our study, with only half of the cases being diagnosed both in CT and autopsy. Of the 124 patients with brain contusion discovered at the autopsy in the study performed by Alexis *et al.* (2018), 63 were diagnosed also during antemortem CT scan, but 61 injuries were missed. Added to these 124 cases, in 52 of the patients it was recorded a false positive diagnosis on CT examination, as the brain contusion was not confirmed during the autopsy. The low accuracy is being imputed by the authors to the possible confusion that may arise among the treating physician and radiologist when is to distinguish the SAH from the brain contusion [17]. Sharma and Murari's (2006) results revealed a bigger ratio, with 80% of the cases being diagnosed in both CT scan and autopsy, in comparison with 20% that were missed by CT examination [1].

We consider that the discrepancies between some of our results and the results of other published studies can be explained by the different inclusion criteria, some studies excluding the cases where a surgical intervention was performed. However, an accurate CT diagnosis is very important in an emergency setting since head trauma is often encountered in young patients and is frequently the result of road traffic accidents [20].

In conclusion, the results of our study show that in most cases there was a discrepancy between the lesions identified by CT examination and the lesions identified during the autopsy, both for missed lesions - 64.5% and for overdiagnosed lesions - 25.7%, total agreement being recorded only in 4 out of the 114 cases analyzed.

Analysis of the possible factors that contributed to missing injuries by CT identifies a direct link with the number of injuries, the risk to miss injuries being increased as their number increases.

Most injuries missed during CT examination were ventricular hemorrhage, contusion and bone fractures, especially those in the anterior and posterior floor of the base of the skull, while the most over-diagnosed injuries during CT examination were extradural hematoma and fractures of the skull sutures.

There is a lack of studies in the literature to analyze the correspondence between the injuries identified by CT and those identified during autopsy, and among the studies that are already published there are sometimes significant differences in the results. Given that situations where CT injuries do not coincide with those identified during autopsy could become a sensitive issue especially when cases are brought to court, it is necessary to address this issue in depth in order to be able to determine the accuracy of the CT scan, identifying in the same time the factors that contribute to the emergence of discrepancies, as well as the measures that can be taken to reduce these cases (eg, improving CT assessment methods, combining careful clinical examination with radiological examination).

Conflict of interest. The authors declare that there is no conflict of interest.

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