

# The Experience of a Protocol for the Management of Pediatric Minor Head Injury: A Three Years Longitudinal Study



## A Experiência dum Norma de Atuação no Traumatismo Crânio-Encefálico Ligeiro em Idade Pediátrica: Estudo Longitudinal de Três Anos

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### ABSTRACT

**Introduction:** Head injury is common in children, with mostly being minor and not resulting in intracranial injury. Computerized tomography head scan is the preferred exam, but implies exposure to radiation; the indications for computerized tomography head scan in minor injuries are not consensual. An expectant approach is a good option in most cases. The aim was to compare the patients hospitalized and subjected to computerized tomography head scan with patients hospitalized but not subjected to computerized tomography head scan in order to assess the safety of our institution's practice protocol.

**Material and Methods:** Analytical longitudinal retrospective study, during three years, including patients younger than 15 years of age with minor head injury, admitted for in hospital surveillance through a paediatric emergency room. We defined two study groups: group A (hospitalized with computerized tomography head scan) and group B (hospitalized without computerized tomography head scan).

**Results:** Study sample consisting of 206 patients: 81 (39%) group A and 125 (61%) group B. Symptoms, including vomiting, were more frequent in group B (91% and 61% vs 75% and 35%,  $p < 0.05$ ); large scalp hematoma and palpable fracture in group A (11% and 12% vs 0%,  $p < 0.05$ ). We performed computerized tomography head scan in 39% of the study patients (children with red flags in the physical examination or unfavourable course during hospitalization); 43% had traumatic brain injury (29 patients had fracture, 18 patients had intracranial injury). Three patients underwent neurosurgery. We did not register deaths, readmissions or neurologic sequelae.

**Discussion:** Significant intracranial injury was infrequent. The hospitalization and surveillance of children and adolescents with symptomatic minor head injury, without red flags in the physical examination, did not seem to result in additional risks.

**Conclusion:** The careful selection of patients for computerized tomography head scan enabled a decrease in the number of these exams and the exposure to ionizing radiation.

**Keywords:** Brain Injuries/diagnostic imaging; Child; Craniocerebral Trauma; Tomography, X-Ray Computed

### RESUMO

**Introdução:** Os traumatismos crânio-encefálicos são frequentes em Pediatria, habitualmente ligeiros e sem lesões intracranianas. A tomografia computadorizada crânio-encefálica é o exame de eleição, implicando radiação ionizante, não existindo consenso nas indicações nos traumatismos crânio-encefálicos ligeiros. Uma atitude expectante é uma opção adequada na maioria dos casos. Os autores pretenderam comparar os doentes internados e submetidos a tomografia computadorizada crânio-encefálica com os doentes internados sem tomografia computadorizada crânio-encefálica, inferindo a segurança da norma de atuação em vigor na nossa instituição.

**Material e Métodos:** Estudo analítico longitudinal retrospectivo, durante três anos, de doentes com menos de 15 anos admitidos na Urgência Pediátrica e internados por traumatismos crânio-encefálicos ligeiros. Amostra organizada num grupo A (internados com tomografia computadorizada crânio-encefálica) e num grupo B (internados sem tomografia computadorizada crânio-encefálica).

**Resultados:** Amostra de estudo constituída por 206 doentes: 81 (39%) grupo A e 125 (61%) grupo B. Sintomas, nomeadamente vómitos, foram mais frequentes no grupo B (91% e 61% vs 75% e 35%,  $p < 0,05$ ); hematoma epicraniano volumoso e afundamento ósseo no grupo A (11% e 12% vs 0%,  $p < 0,05$ ). Realizou-se tomografia computadorizada crânio-encefálica em 39% dos doentes estudados (crianças com sinais de alarme à observação ou evolução não favorável durante o internamento); 43% tinham alterações (29 doentes apresentavam fratura, 18 doentes apresentavam lesões intracranianas). Três doentes foram submetidos a neurocirurgia. Não registámos óbitos, reinternamentos ou sequelas neurológicas.

**Discussão:** As lesões intracranianas clinicamente significativas foram pouco frequentes. A atitude preconizada de vigilância hospitalar das crianças e adolescentes com traumatismos crânio-encefálicos ligeiros sintomáticos, sem alterações significativas ao exame objetivo, não pareceu ter implicado riscos acrescidos.

**Conclusão:** A utilização criteriosa da tomografia computadorizada crânio-encefálica permitiu reduzir o número de exames e a exposição a radiação ionizante.

**Palavras-chave:** Criança; Lesões Encefálicas/diagnóstico por imagem; Tomografia Computorizada; Traumatismos Craniocerebrais

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## INTRODUCTION

Traumatic brain injuries (TBI) are frequent and potentially severe events in childhood and a public health issue<sup>1-3</sup> with a real incidence that is difficult to be determined.<sup>4,6</sup> Recent data published by the National Institute for Health and Care Excellence showed that children aged under 15 years are involved in 33-50% of the 1,4 million admissions to emergency and of the 200,000 hospital admissions for TBI occurring annually in the UK.<sup>7,8</sup> The incidence of TBI in Portugal is currently unknown while a 137 per 100,000 rate has been found between 1996 and 1997, all age groups involved.<sup>5,6</sup>

Between 75 and 90% of the patients with TBI having attended paediatrics emergency with mild TBI (i.e., Glasgow coma scale (GCS) scores  $\geq 13$ ).<sup>2,4,7,9,10</sup> Low morbidity and mortality rates have been reported and deadly and complicated events usually occur in patients presenting with moderate or severe TBI, related to clinically-important traumatic brain injury (ci-TBI).<sup>4,7,11</sup>

Computed tomography (CT) scanning of the head/brain is the main imaging test used for the identification of ci-TBI.<sup>11-17</sup> The indications for a CT head scan in patients with mild TBI is the current challenge.<sup>3,8,16,18</sup> A very low incidence of ci-TBI has been found in patients with mild TBI, mainly considering the presence of any damage with the need for an urgent surgical approach.<sup>3,9,18-21</sup> In addition, the deleterious and cumulative effects of radiation exposure in childhood must be taken into consideration, involving an increased risk of cancer (leukaemia and brain tumours), global developmental delay, endocrine disorders and moyamoya disease. Therefore, careful management of neuroimaging is crucial in this population.<sup>16,22-25</sup>

Different clinical algorithms for the use of CT head scanning in children with mild TBI have been recommended by different population-based studies such as PECARN (*Pediatric Emergency Care Applied Research Network*, carried out in North-America), CHALICE (*Children's Head Injury Algorithm for the Prediction of Important Clinical Events*, in the United Kingdom) and CATCH (*Canadian Assessment of Tomography for Childhood Head Injury*, in Canada) over the past few years.<sup>8,11,16,19,24-28</sup> Recommendations have not been uniform, though.<sup>13,18,20,21,28</sup> CT head scan is recommended (i) by the PECARN study in children aged  $< 2$  years with mild TBI and presenting with GCS scores  $\leq 14$ , palpable skull fracture, scalp haematoma in occipital, parietal or temporal regions,  $\geq 5$  second loss of consciousness, severe injury mechanism or suspected ill-treatment, as well as in children aged  $\geq 2$  with mild TBI, GCS scores  $< 14$ , with signs of basilar skull fracture, severe symptoms at admission (loss of consciousness, vomiting or headache) associated with worsening symptoms or signs during emergency department observation and by physician or parental preference,<sup>11</sup> (ii) by the CHALICE study in patients with mild TBI and  $> 5$  minute loss of consciousness,  $> 5$  min amnesia, drowsiness, vomiting  $\geq 3$  times, suspicion of non-accidental injury, seizures, GCS score  $< 14$  (or  $< 15$  in children aged under 1 year), penetrating or depressed skull fracture suspected or

tense fontanelle, signs of basilar skull fracture, focal neurological deficits,  $> 5$ cm scalp haematoma or contusion in children less than one year of age or high-impact mechanism of injury (high-speed car accident as a pedestrian, bicyclist or passenger, fall of more than 3 m or head struck by a high-speed object)<sup>25</sup> and (iii) by the CATCH study in patients with mild TBI, GCS score  $< 15$  at 2 hours after injury, suspected open or depressed skull fracture, history of worsening headache, irritability on examination, any sign of basilar skull fracture, large haematoma of the scalp or high-impact mechanism injury (motor vehicle crash, fall from elevation  $\geq 0.91$  m or fall from a bicycle with no helmet).<sup>19</sup>

Recent studies showed that the presence of drowsiness, vomiting or headache is not associated with higher probability of ci-TBI, mainly when these were transitory and self-limited.<sup>3,13,17,30,33,34</sup>

Portuguese scientific literature is still scarce in this area.

A guideline aimed at the approach to mild TBI is in use since 2004 in our hospital, with the recommendation for hospital admission and monitoring of any patient presenting with certain red-flag signs at the initial medical examination, as an alternative to the immediate use of a CT head scan (Table 1).

This study aimed at the analysis of a group of children and adolescents admitted to a polyvalent paediatric emergency department with mild TBI. The comparison of clinical characteristics and progression of in-patients submitted vs. those non-submitted to a CT head scan was the study's main endpoint, showing the safety of complying with the current guideline. The evaluation of the frequency of skull fracture and/or ci-TBI and the evaluation of the use of head X-ray imaging in hospitalised patients with mild TBI were the secondary endpoints.

## MATERIAL AND METHODS

This was a three-year (1 Jan 2011 to 31 Dec 2013) analytical retrospective longitudinal study of a group of patients aged under 15 years attending the paediatric emergency department of a level-II hospital with polyvalent emergency (including a neurosurgery department) and admitted with mild TBI for monitoring at the Emergency Short-Stay Unit (ESSU).

Mild TBI has been defined as a blunt head trauma with preserved or mildly depressed level of consciousness (GCS score 13-15) at the initial medical examination. In line with the PECARN study, a ci-TBI has been defined as the presence of life-threatening brain damage, with an indication for surgery, associated with the use of invasive ventilation for over a 24-hour period or associated with a long hospital stay (at least two nights) for clinical or imaging monitoring.<sup>11</sup>

The TBI guideline in use at the paediatric emergency department was developed by a group of experienced paediatricians working at the department (based on the available scientific evidence) in cooperation with the team of neurosurgery at our hospital and has been approved for use at the whole Department of Paediatrics in 2004 (Table 1),

**Table 1** – Clinical guideline in use at the paediatric emergency department in our hospital for the approach to patients with mild traumatic brain injury (i.e. with GCS scores 13-15 in the initial medical examination)**Discharged home with no further ancillary tests** (monitoring of red-flag signs):

- Low-impact mechanism
- GCS score = 15
- Haemodynamic stability
- Normal neurological examination
- With no indirect signs of skull fracture (large haematoma in patients under the age of two, depressed skull, bilateral periorbital haematoma, retroauricular haematoma, cerebrospinal fluid leakage from the ear and haemotympanum)

**Admission to the ESSU** (analgesia, clinical monitoring):

- GCS score 13-14
- < 5-min loss of consciousness
- Amnesia
- Persistent vomiting
- Persistent headache

**CT head scan:**

- > 5-min loss of consciousness
- Post-traumatic seizure
- Suspected ill-treatment
- Neurological focal deficits
- Indirect signs of skull fracture
- Head X-ray imaging suggesting the presence of fracture
- Clinical worsening while at the ESSU

**Head X-ray:**

- Age under 2 years and large epidural haematoma

ESSU: Emergency Short-Stay Unit

involving the following recommendations:

- Admission to the ESSU for clinical monitoring (monitoring of heart rate, blood pressure and GCS score) and analgesia in patients with mild TBI and GCS score 13-14, < 5-min loss of consciousness, amnesia, persistent vomiting or headache.
- CT head scan in patients with mild TBI and > 5-min loss of consciousness, neurological focal deficits, post-TBI seizures, indirect signs of skull fracture, head X-ray showing signs of fracture or clinical worsening during monitoring. The presence of any large haematoma of the scalp (mainly in children under the age of 2), bilateral periorbital or retroauricular haematoma, presence of cerebrospinal fluid leakage from the nose or ear, otorrhagia or haemotympanum and the presence of depressed skull are considered as indirect signs of head fracture.
- Head X-ray in children under the age of 2 with mild TBI and presenting with a large epidural haematoma.
- Discharge home without any imaging test and with an indication for monitoring of red-flag signs in patients with TBI related to low-impact mechanism, GCS score of 15 at admission, haemodynamic stability, normal neurological examination and no indirect signs of skull fracture.

The following study inclusion criteria were considered: patients with a TBI admitted to the ESSU in our hospital during the study period. The presence of GCS score  $\leq$  12 at the initial hospital examination, patient referral from another hospital for neurosurgical examination, personal history of

chronic neurological disorder, blood dyscrasia and the use of anticoagulant or antiplatelet drugs were defined as exclusion criteria from the study.

Patient identification was based on the ESSU clinical database (computer record including personal record number, identification and diagnosis regarding admitted patients). Data have been collected from hospital computer clinical records (involving the analysis of emergency episodes of TBI and any subsequent emergency episode and/or outpatient visit in order to rule out any re-admission and the presence of neurological complications in patients having at least once subsequently attended our hospital). All information regarding patients with TBI involving no admission to the ESSU was obtained from the hospital's patient management database.

Our group of patients was divided into two groups: inpatients having (group A) and not having been submitted to a CT head scan (group B).

Demographic (gender and age) and clinical variables were analysed: injury mechanism (fall from one's own height, fall of < or > 3 m in height, pedestrian struck by a vehicle, traffic accident as bicyclist, as a passenger or other injury mechanism); location of scalp haematoma (frontal, parietal, temporal, occipital or  $\geq$  2 locations); post-TBI symptoms (vomiting, sleepiness, < or > 5-min loss of consciousness, amnesia, dizziness, vision deficit or disorientation); abnormalities in initial examination (< or > 5 cm epidural haematoma, depressed skull, bruises or neurological focal deficits).

Imaging data were also recorded, including head X-ray imaging and any abnormality found (presence or absence of signs of fracture), CT head scanning and abnormality

found (head fracture, epidural haematoma, subdural haematoma or cerebral contusion), as well as an indication of the unit where the patient was admitted to (ESSU, Paediatrics ward and/or Paediatrics ICU), patient's outcome (persistent or worsening symptoms, deterioration of the level of consciousness or new neurological signs), need for neurosurgery approach, re-admission and presence of post-TBI neurological consequences (in patients with subsequent examination at the emergency department or at outpatients).

A univariate statistical analysis has been carried out by using Chi-square test for the comparison of categorical variables from two independent groups and Mann-Whitney test for the comparison of numerical variables from two independent groups. A significance threshold of 0.05 has been considered and the IBM® SPSS® Statistics 20.0 for Windows® software has been used.

**RESULTS**

In total, 128,554 children and adolescents aged under 15 years were admitted to the Paediatric Emergency Department over the three-year study period. Approximately 3% of the total number of admissions (3,393) presented with TBI (unspecified head injury diagnosis: this was the generic term used by the encoder paediatricians who were responsible for the codification of patients admitted to the paediatric emergency department). A total of 285 patients

(8%) were admitted to the ESSU (Fig. 1). A total of 79 patients (28%) were excluded from the initial group: 55 were referred to neurosurgery at another hospital, 13 presented with GCS score <13 (i.e. with no mild TBI), nine with a history of chronic neurologic disorder and two patients with a history of blood dyscrasia.

A percentage of 98% of the patients who attended the paediatric emergency department over the study period due to head injury presented with mild TBI (3,314). A 6% admission rate has been found in patients with mild TBI (n = 206). Apart from the patients admitted to the ESSU, 40 patients underwent a CT head scan at the paediatric emergency department and were not admitted (1.2% of the total number of patients with mild TBI), according with the protocol in use at the department. In total, 121 of the patients with mild TBI (3.6%) examined at the paediatric emergency over the study period underwent a CT head scan.

A final group of 206 patients was included in the study and patients were subsequently ranked into two groups (Fig. 1): in-patients submitted (group A, n = 81) and non-submitted to CT head scan (group B, n = 125). The demographic, clinical and imaging data of our group of patients are shown in Table 2.

Considering the total group of patients, 61% (126 / 206) were male and a median age of 6.5 years has been found (range 11 days – 14 years and 11 months), with a mean of

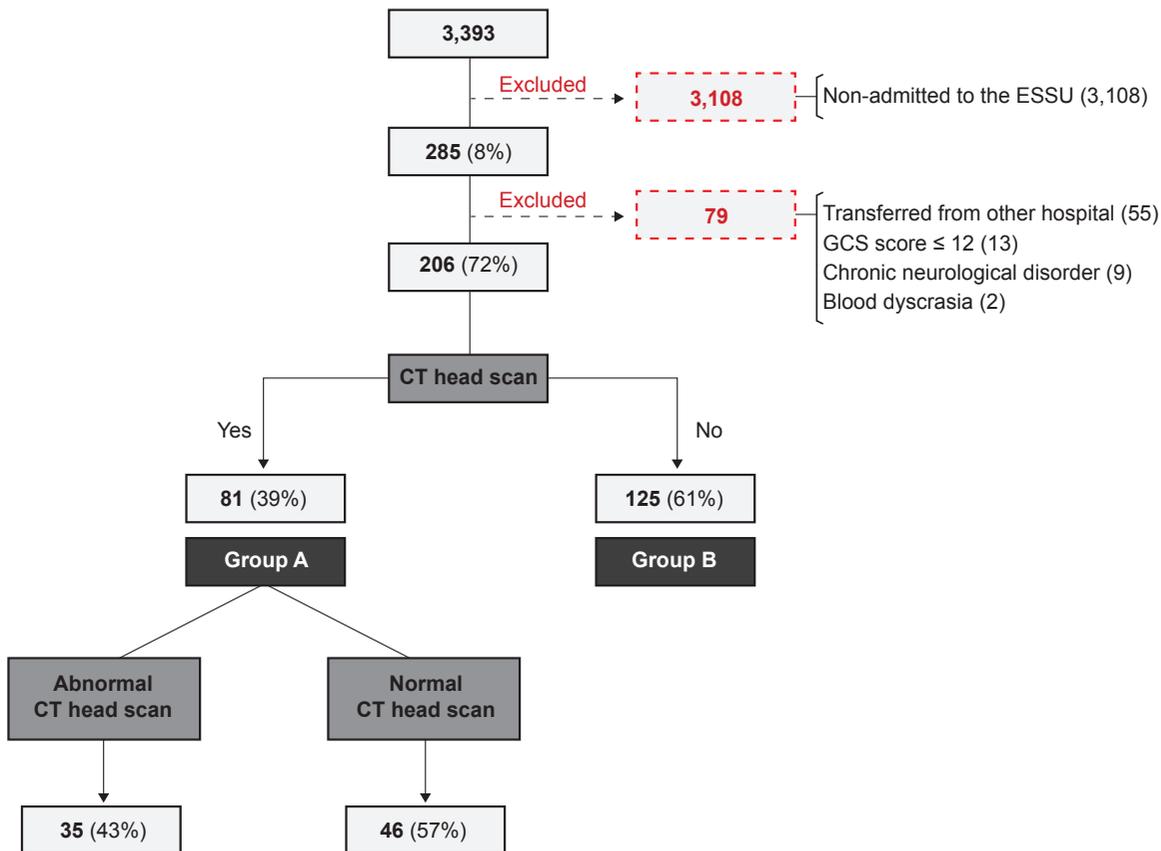


Figure 1 – Group of patients and study groups. In total, 3,393 patients were admitted to the paediatric emergency department over the study period diagnosed with unspecified traumatic brain injury.

ESSU: Emergency Short-Stay Unit

6.32 years (standard deviation: 4.78 years). Thirty-one per cent of the patients (64 / 206) were aged under 2 years. No significant differences regarding patient's gender or age group were found between both groups.

Falls of <3m in height (34%) and from one's own height (28%) were the most frequently found injury mechanisms. Traffic road accidents (as pedestrian, bicyclist or passenger) corresponded to 18%. An 18-month old patient attended emergency due to having suffered from closed-fist injuries to the head, face and thorax (victim of ill-treatment). Falls from one's own height were significantly more frequent in patients who did not undergo a CT head scanning [38% (48 / 125) in group B vs. 11% (9 / 81) in group A ( $p < 0.001$ )] while falls of >3m in height were significantly more frequent in patients who did not undergo a CT head scan (group A

[6% (5 / 81) vs. 1% (1 / 81) in group B ( $p = 0.023$ )]; 'other mechanisms' were also significantly more frequent in the group of patients who underwent a CT head scan [26% (21 / 81) in group A vs. 10% (13 / 125) in group B ( $p = 0.009$ )].

Frontal scalp haematoma (52% of the patients) was most frequently found in patients with TBI, while parietal was significantly more frequent in group A patients (submitted to a CT head scan): 53% (43 / 81) vs. 22% (28 / 125) in group B ( $p < 0.001$ ), such as temporal: 14% (11 / 81) in group A vs. 4% (5 / 125) in group B ( $p = 0.012$ ) and  $\geq 2$  locations: 37% (30 / 81) in group A and 18% (23 / 125) in group B ( $p = 0,003$ ).

The presence of post-TBI symptoms was found in 85% of the patients: 50% presented with vomiting (104 / 206), 48% with sleepiness (98 / 206) and 25% with headache (51

**Table 2** –Characteristics of our group of patients (patients with mild TBI admitted for monitoring to the ESSU) and both study groups: in-patients who underwent (group A) and who did not undergo a CT head scan (group B)

	Total (n = 206)	Group A (n = 81)	Group B (n = 125)	p-value
<b>Age</b> [Mean $\pm$ Standard deviation (years)]	6.32 $\pm$ 4.78	6.00 $\pm$ 5.20	6.52 $\pm$ 4.48	NS
<b>Male</b> [n (%)]	126 (61%)	51 (63%)	75 (60%)	NS
<b>Injury mechanism</b> [n (%)]				
- Fall from one's own height	57 (28%)	9 (11%)	48 (38%)	< 0.001
- Fall of < 3 m in height	70 (34%)	26 (32%)	44 (35%)	NS
- Fall of > 3 m in height	6 (3%)	5 (6%)	1 (1%)	0.023
- Pedestrian struck by a vehicle	17 (8%)	10 (12%)	7 (6%)	NS
- Traffic accident as a bicyclist	7 (3%)	3 (4%)	4 (4%)	NS
- Traffic accident as a passenger	15 (7%)	7 (9%)	8 (6%)	NS
- Other	34 (17%)	21 (26%)	13 (10%)	0.009
<b>Location of haematoma of the scalp</b> [n (%)]				
- Frontal	108 (52%)	38 (47%)	70 (56%)	NS
- Parietal	71 (34%)	43 (53%)	28 (22%)	< 0.001
- Temporal	16 (8%)	11 (14%)	5 (4%)	0,012
- Occipital	62 (30%)	23 (28%)	39 (31%)	NS
- $\geq 2$ locations	53 (26%)	30 (37%)	23 (18%)	0.003
<b>Asymptomatic</b> [n (%)]	31 (15%)	20 (25%)	11 (9%)	< 0.001
<b>Symptoms</b> [n (%)]	175 (85%)	61 (75%)	114 (91%)	< 0.001
- Vomiting	104 (50%)	28 (35%)	76 (61%)	0.001
- Drowsiness	98 (48%)	37 (46%)	61 (49%)	NS
- Headache	51 (25%)	16 (20%)	35 (28%)	NS
- < 5-min loss of consciousness	38 (18%)	17 (21%)	23 (18%)	NS
- > 5-min loss of consciousness	2 (1%)	0 (0%)	2 (2%)	NS
- Amnesia	35 (17%)	17 (21%)	18 (14%)	NS
- Dizziness	13 (6%)	5 (6%)	8 (6%)	NS
- Vision deficit	4 (2%)	1 (1%)	3 (2%)	NS
- Disorientation	7 (3%)	4 (5%)	3 (2%)	NS
<b>Normal initial medical examination</b> [n (%)]	62 (30%)	18 (22%)	44 (35%)	NS
<b>Abnormal initial medical examination</b> [n (%)]	144 (70%)	63 (78%)	81 (65%)	NS
- Haematoma < 5 cm	104 (50%)	42 (52%)	62 (50%)	NS
- Haematoma > 5 cm	9 (4%)	9 (11%)	0	0.001
- Depressed skull	10 (5%)	10 (12%)	0	< 0.001
- Bruising	42 (20%)	17 (21%)	25 (20%)	NS
- Neurological focal deficits	5 (2%)	4 (5%)	1 (1%)	NS
<b>Head X-ray</b> [n (%)]	44 (21%)	20 (25%)	24 (19%)	NS
- Normal	29 (14%)	5 (6%)	24 (19%)	< 0.001
- Signs of fracture	15 (7%)	15 (19%)	0	< 0.001
<b>Neurosurgery</b> [n (%)]	3 (2%)	3 (4%)	0	0.029
<b>Neurological consequences</b> [n (%)]	0	0	0	NS

NS: statistically non-significant difference ( $p$ -value > 0.05)

/ 206). The presence of symptoms was significantly more frequent in in-patients who were not submitted to a CT head scan: 91% in group B (114 / 125) vs. 75% (61 / 81) in group A ( $p < 0.001$ ), namely the presence of vomiting: 61% in group B (76 / 125) vs. 35% (28 / 81) in group A ( $p = 0.001$ ).

The presence of abnormalities in the initial medical examination has been found in 70% of the patients: an epidural haematoma was mostly found, in 55% (113 / 206) of the patients. The presence of a >5 cm diameter haematoma was significantly more frequent in the group of patients who were submitted to a CT head scan: 11% in group A (9 / 81) vs. 0% (0 / 125) in group B ( $p = 0.001$ ); the presence of depressed skull fracture was also more frequent in group A patients: 12% (10 / 81) vs. 0% (0 / 125) in group B ( $p < 0.001$ ). Only five patients were found with neurological focal deficits in the initial examination, all of whom underwent a CT head scan, except an eight-year old child with dysmetria in the finger-to-nose test which improved over the first hour within the ESSU. Two patients with > 5-min loss of consciousness were not submitted to a CT head scan, as both showed a favourable clinical progression over the monitoring period.

The patients who underwent a CT head scan (group A) were on average submitted to the test 4.95 hours upon the head injury event and neuroimaging abnormalities were found in 35 patients (43%; 35 / 81) (Table 3): skull fracture in 36% (29 / 81) and ci-TIB in 25% (20 / 81). The presence of ci-TIB was mainly found in patients with epidural haematoma (9), subdural haematoma (7) and cerebral contusion (4). As regards abnormal CT head scans, 77% (27 / 35) were found in a group of children under the age of 2 ( $p < 0.001$ ).

A total of 44 patients (21%; 44 / 206) underwent a head X-ray.

A total of 22 patients in this group were under the age of 2 and 17 presented with an epidural haematoma at the medical examination (one patient presented with a 5 cm haematoma) showing that the guideline criteria were met by 53% of the patients who underwent a head X-ray (23 / 44). The presence of signs suggesting a skull fracture was found in 34% (15 / 44) of the children who underwent an X-ray, which was confirmed in all these patients with the CT head scan. Six patients presented with an epidural haematoma and two patients with a subdural haematoma related to the fracture found in the CT head scan. In addition, two patients

with basilar skull fracture (both were ci-TBI-related) were not identified by the X-ray imaging and were only found in the CT head scan: an eight-year-old child who underwent a CT head scan due to worsening of vomiting during the period of clinical monitoring and a six-year-old child with an epidural haematoma at the examination who underwent a CT head scan due to an exuberant imaging; none of these patients presented with any clinical sign suggesting the presence of a basilar skull fracture.

A total of 190 patients (92%; 190 / 206) from our group of patients were specifically admitted to the ESSU and remained for less than a 24-hour monitoring. A total of 16 patients in group A with an abnormal CT head scan needed for a longer monitoring period: one patient admitted to the PICU (six-year-old child with fracture and epidural haematoma with no indication for surgery) and 15 to the paediatric ward.

Three patients (1.5% of our group of patients and 0.1% of the total of attending patients with mild TBI over the study period) underwent cranioplasty: a five-month-old baby with a parietal TBI (fall of < 3m in height), < 5-min loss of consciousness, < 5cm epidural haematoma with depressed skull fracture and CT head scan showing an isolated parietal fracture; 10-month-old baby with a frontal and parietal TBI (fall of < 3m in height), incoercible vomiting, normal examination and CT head scan showing a parietal fracture and epidural haematoma; asymptomatic 10-month-old-baby with a parietal TBI (direct injury against a hard surface) and signs of depressed skull fracture in the examination and CT head scan showing an isolated parietal fracture. These three patients showed a favourable outcome with no postoperative complications.

No deceased patients were found over the study period.

Emergency episodes and post-TBI hospital attendances regarding over 95% of the patients were analysed and no patients with TBI were re-admitted to hospital or presented with any neurological consequences.

## DISCUSSION

TBI was the most frequent reason for attending the paediatric emergency department over the study period and 98% of the patients presented with mild TBI (3,314 / 3,393). This was a higher percentage than those described in literature (75 to 90% with mild TBI).<sup>2,4,7,9,10</sup>

Patients admitted to the ESSU with mild TBI were included into our group of patients, corresponding to 6% of all patients with TBI having attended the hospital over that period of time (206 / 3,393). In line with other studies, mostly male patients were involved and more than one quarter of the patients were under the age of two.<sup>1,4,13,14,18,29</sup> Only 39% (81 / 206) of these underwent a CT head scan.<sup>11,13,21</sup>

When comparing patient's clinical characteristics, group A patients were involved in higher-impact mechanisms of injury when compared to patients in group B. Parietal, temporal or  $\geq 2$  locations of a scalp haematoma were significantly associated with the use of a CT head scan. Even though the scalp haematoma location has not been considered

**Table 3** – CT head scan obtained in group A patients (in-patients with mild TBI who underwent a CT head scan) and major abnormalities found

CT head scan	n = 81
Normal	46 (57%)
Abnormal	35 (43%)
- Skull fracture	29 (36%)
- Epidural haematoma	9 (11%)
- Subdural haematoma	7 (9%)
- Cerebral contusion	2 (5%)

by the clinical guideline in use at our department, those locations were more frequently related to the presence of a large haematoma and/or signs of depressed skull fracture in the medical examination and therefore with a higher risk for the presence of fracture, explaining for the use of a CT head scan. This may be explained by the mechanism of injury that is usually associated with these locations in a TBI: unsupported backwards falls and road traffic accidents, for instance.

The presence of symptoms was more frequent in patients not submitted to a CT head scan (mainly with vomiting and headache). This difference is explained by the fact that the admission and monitoring of patients with symptoms (as long as no red-flag signs existed at the medical examination) has been favoured rather than submitting the patients to any early neuroimaging assessment. These patients showed a clinical improvement during monitoring and upon analgesia and therefore had no indication for a CT head scan. In fact, even though the presence of vomiting has been frequently found, different studies have suggested that this symptom is not a strong indicator of the presence of ci-TBI in children.<sup>3,13,17,30</sup> The presence of headache is also frequently found and often severe, persistent and difficult to manage.<sup>6,10,31,32,33</sup> However, different studies have proven that this symptom, in the absence of any other red-flag sign, is also not related to ci-TBI.<sup>33,34</sup>

In addition, the presence of any abnormality in medical examination mainly regarding large epidural haematoma (> 5cm) and signs of depressed skull fracture was associated with the use of a CT head scan, reflecting the compliance with the guideline in use at the paediatric emergency department. Patients who were not submitted to a CT head scan presented with minimal abnormalities in the medical examination (nearly always bruising and small scalp haematomas). Different studies have shown that large haematomas and depressed skull fracture are risk factors for the presence of fracture and/or ci-TBI.<sup>3,13,19,35</sup> In fact, these signs are considered as red-flag signs by the three mostly used clinical algorithms for the approach to mild TBI in childhood (PECARN, CHALICE and CATCH).<sup>11,19,25</sup>

The fact that two patients presenting with >5-min loss of consciousness and one with neurological focal deficits at admission were not submitted to a CT head scan should be mentioned, as the guideline has not been complied with in these cases. Nevertheless, a favourable progression has been found, with no further neurological consequences. In addition, only half of the children having been submitted to a head X-ray had an indication for its use, according with the guideline. This appears to reflect old practices non-evidence based and not included in the current guideline.

In total, 35 of the 81 patients who underwent a CT head scan (43%) and 17% of the patients in our study group (in-patients with mild TBI) (17%; 35 / 206) presented either with ci-TBI or skull fracture. The comparison between these results and those found in literature is not feasible due to the heterogeneous definition of the different study samples. Most studies were aimed at the determination

of the frequency of fracture and/or ci-TBI in patients with mild TBI who did not undergo a CT head scan (around 5% rate).<sup>18,30</sup> Large international series, including PECARN and CATCH studies also found lower frequencies of abnormal CT head scan when compared to our study. The presence of an abnormal CT head scan (intracerebral haemorrhage or contusion, cerebral oedema, post-traumatic cerebral infraction, diffuse axonal injury, sigmoid sinus thrombosis, midline shift of intracranial contents or signs of brain herniation, diastasis of the skull, pneumocephalus and depressed skull fracture) has been found in 4-10% of the patients with mild TBI in PECARN study. The presence of abnormalities in CT head scan (epidural haematoma, cerebral contusion, pneumocephalus, subdural haematoma, diffuse cerebral oedema, cerebellar haematoma and intraventricular haemorrhage) has been found in 4% of the patients with mild TBI in CATCH study.<sup>11,19</sup> The higher frequency of abnormalities found in our study reflects the careful criteria used in the selection of patients with an indication for neuroradiology imaging. Altogether, these results become more relevant in the absence of any re-admission or neurological consequence, at least in patients in whom the analysis of the emergency episode or subsequent medical examination in our hospital was available (over 95% of the total group of patients).

The presence of a skull fracture was the most frequently found abnormality in neuroimaging, in 36% (29 / 81) of the patients who underwent a CT head scan and in 14% (29 / 206) of the patients in the whole study group. A 22% rate of ci-TBI (18 / 81) has been found in patients who underwent a CT head scan and 9% in our group of patients (18 / 206). In line with other studies, most patients with abnormal CT head scan were aged under two years.<sup>9,14</sup> The clinical assessment is more difficult in this age group, there is a higher risk of skull fracture and ci-TBI (even with mild TBI) and ci-TBI is often asymptomatic. In addition, there is a higher risk of ill-treatment in this age group.<sup>1,3,16</sup>

A head X-ray has been performed in a significant number of patients, leading to a suspected fracture in 15 patients, eight from which presented with ci-TBI in the CT head scan. Two patients presented with a basilar skull fracture and ci-TBI in the CT head scan, with normal X-ray. In fact, the interpretation of the head X-ray imaging is never an easy task and associated with scarce benefits for the initial assessment of mild TBI, due to the fact that any image suggesting the presence of a fracture does not allow for the identification of any ci-TBI and a normal X-ray does not rule it out.<sup>3,9,14</sup> The usefulness of the head X-ray seems scarce for the assessment of children and adolescents with TBI considering these data. Therefore, the use of a CT head scan is recommended in children under the age of two and with a large scalp haematoma. The head X-ray may be useful in institutions unable to perform a CT head scan.<sup>3,6,14</sup>

Only 1.5% of the patients in our study group (3 / 206) and 0.1% (3 / 3,314) of the total number of patients with mild TBI having attended the paediatric emergency over the three-year study period underwent neurosurgery.

This percentage is lower than those described in literature (1 to 5%),<sup>3,11,13,30</sup> showing a low risk for severe head injuries in mild TBI affecting children.

There is still no consensually recommended duration for clinical monitoring in the hospital. This was individually taken into consideration, according with patient's clinical progression. Some studies have proven that a six-hour period would be enough, considering that clinically-important TBI would produce some manifestation throughout that period of time.<sup>15,16</sup>

Finally, the limitations of the study are worth mentioning. This was a retrospective study not always based on fully-completed computerized clinical records. The study sample was small and patients with mild TBI and who were not admitted to hospital (the largest group of patients with such a diagnosis) were not analysed. Finally, the methodology that was used in the study, involving the search for any subsequent emergency episode or medical examination in order to rule out any neurological consequence, despite most of the patients had subsequently at least once attended our department, does not allow for the identification of mild or late consequences in patients that did not re-attend our hospital.

Further prospective studies involving a larger group of patients and including subsequent neurological and neuropsychological assessment are crucial in order to rule out the presence of consequences, allowing for checking the safety of this conservative attitude and for establishing the optimal duration of the monitoring period at the hospital.

## CONCLUSION

The presence of clinically-important brain injury related to mild TBI is not common. The careful use of a CT head scan in patients with mild TBI either with relevant abnormalities in the medical examination or unsolved symptoms while

staying at the hospital allowed for a higher percentage of patients diagnosed with clinically-important brain injury in the CT head scan, reducing any unnecessary exposure to radiation. No additional risk seems to have been related to the wait-and-see approach involving the clinical monitoring of children and adolescents with mild TBI presenting with symptoms and with no significant abnormalities in the medical examination. The use of the head X-ray imaging was not useful in these patients.

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## HUMAN AND ANIMAL PROTECTION

The authors declare that the followed procedures were according to regulations established by the Ethics and Clinical Research Committee and according to the Helsinki Declaration of the World Medical Association.

## DATA CONFIDENTIALITY

The authors declare that they have followed the protocols of their work centre on the publication of patient data.

## CONFLICTS OF INTEREST

The authors declare that there were no conflicts of interest in writing this manuscript.

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