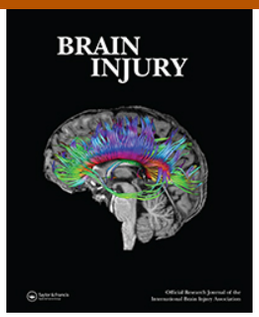

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Evaluation of management and guideline adherence in children with mild traumatic brain injury

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ABSTRACT

Aim: To evaluate the management and guideline adherence in children with mild traumatic brain injury (MTBI) in emergency departments (ED) in the Netherlands.

Methods: A multicentre cohort study was conducted, including children younger than 18 years with MTBI who presented within 24 hours after trauma in the ED of hospitals in the southwest region of the Netherlands, in 2014. Primary outcome measures for management were percentages of performed computed tomography (CT) scans and hospital admissions. Guideline adherence was defined as percentages of correctly following the guideline. Secondary outcome measures were differences in management and guideline adherence between hospitals.

Results: About 563 patients were analysed. Hospital admission was the most frequently performed management type (49.2% hospital admission vs. 30.9% CT). In only 49.7% of patients, the guideline was followed correctly. A substantial overuse of hospital admission (35%) and underuse of CT (40.1%) were found. Percentages of hospital admission and CT varied between 39.4–55.6% and 23.3–44.1%, respectively, across hospitals. Percentages of correctly following the guideline varied between 39.2–64.9% across hospitals.

Conclusion: These findings suggest that physicians in the participating hospitals prefer hospital admission of children with MTBI instead of CT despite the current recommendations of the national MTBI guideline in the Netherlands.

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Mild traumatic brain injury; minor head trauma; brain computed tomography; hospital admission; guideline compliance

Introduction

Mild traumatic brain injury (MTBI) is a common health problem, also in the Netherlands. The estimated annual incidence rates for children with MTBI in the emergency department (ED) of hospitals in the southwest region of the Netherlands are 271 (0–14 years) and 262 (15–24 years) per 100 000 (1).

Traumatic brain injury (TBI) is the leading cause of mortality and disability in childhood around the world (2). TBI that results in death or needs neurosurgery, intubation for more than 24 hours or hospital admission for two nights or more because of intracranial complications, are generally mentioned in the literature as clinically important TBI (ciTBI) (3–7). Correct identification of children with ciTBI is needed because they may require acute intervention. Brain computer tomography (CT) scan is the reference standard for reliable and rapid diagnosis of intracranial complications after MTBI (8). However, in children with MTBI, ciTBI is rare (0.9%) and neurosurgery is rarely needed (0.1%) (3). Furthermore, brain CT in children increases the risk of malignancies (incidence rate ratio (IRR) 1.23; 95% CI, 1.18–1.29), in particular brain cancer (IRR 2.97, 95% CI, 2.28–3.66), at a higher age (9). This risk is higher for brain CT exposures in children <5 years of age and increases with each additional CT (increased by IRR 0.16, 95% CI, 0.13–0.19) (9).

In the last decade, an increasing number of studies described guidelines for risk-stratifying children with MTBI in order to identify children who do or do not need CT (3,6,10–27). However, a widely accepted guideline is still a matter of debate. Previous studies in adults describe a poor guideline adherence in Scandinavian countries (28–30). A wide variety of application of CT in children with MTBI has been described in Canada and the USA (31–35).

In the Netherlands, the guideline of the Dutch society of Neurology (NVN) published in 2010 [Figure 1] is generally accepted as management tool for children with MTBI visiting the ED of hospitals. Limited data about the management of MTBI and the guideline adherence in children is available (36–38). Therefore, the aim of this study is to evaluate the management and the Dutch guideline adherence, subdivided in overuse and underuse in children with MTBI in ED in the southwest region of the Netherlands. Based on clinical experience, we expected that (1) brain CT is the most performed management, (2) poor guideline adherence and (3) differences in management and guideline adherence between hospitals.

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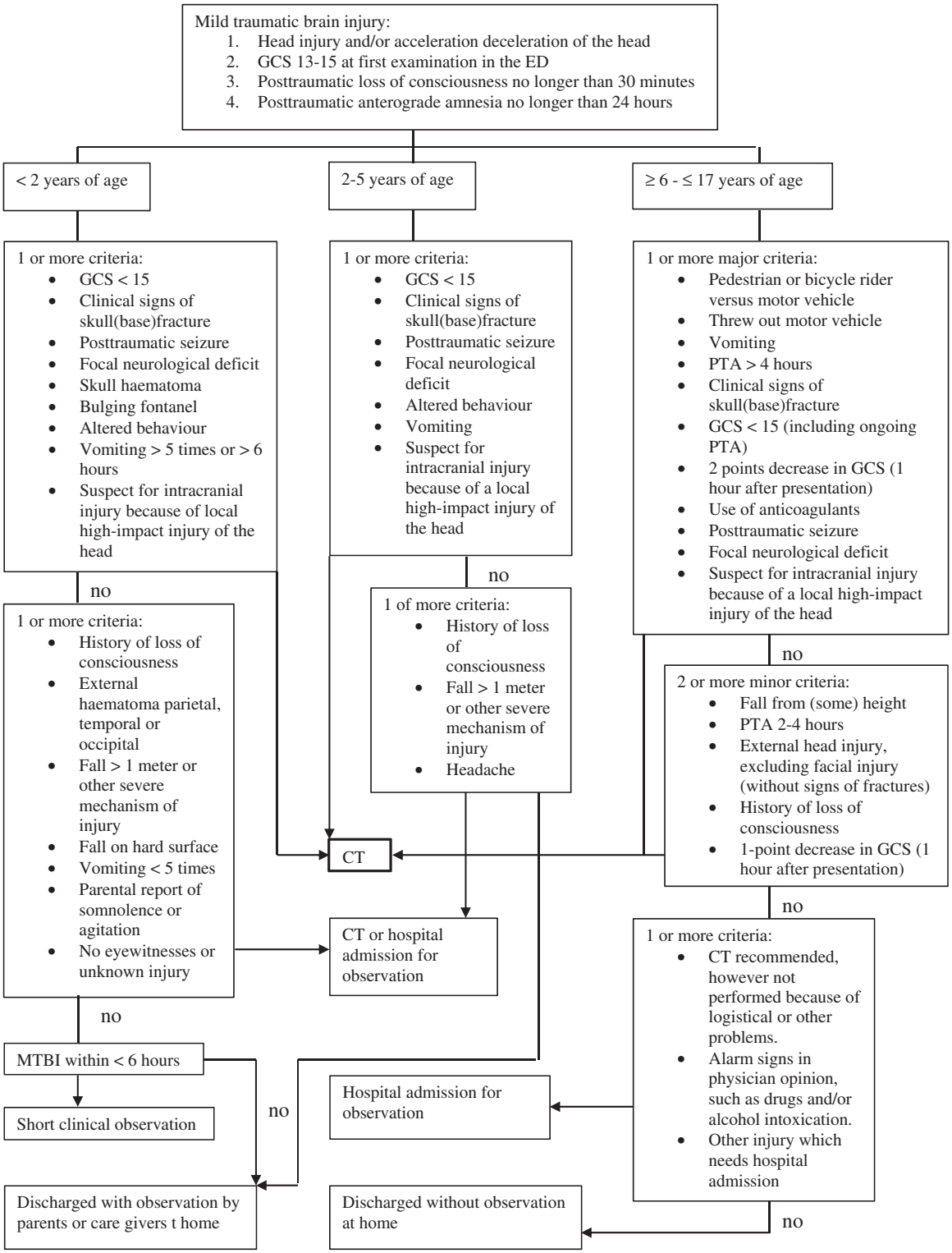

Figure 1. Flowchart of the Dutch guideline for MTBI management.
GCS = Glasgow coma scale, ED = emergency department, CT = computed tomography, PTA = post-traumatic anterograde amnesia, MTBI = mild traumatic brain injury.

Method

Study design and setting

This is a retrospective multicentre cohort study. Inclusion criteria are children younger than 18 years who presented within 24 hours after MTBI in the ED of one of the participating centres (one University hospital (Erasmus University Hospital, including Sophia Children's Hospital, Rotterdam) and two large regional general hospitals (Amphia Hospital, Breda and Elisabeth-TweeSteden Hospital, Tilburg) in the southwest region of the Netherlands between 1st January 2014 and 31st December

2014. We have chosen this time range for presentation in the ED and this age group to facilitate comparison with international studies (3,6,11,12,17,27,37).

This study was approved by the medical ethical committee of the Erasmus University Hospital (MEC-2016-145).

Patients

In the Netherlands, all persons are obliged by law to participate in basic health insurance. Every patient entering the ED is registered with the current diagnosis (diagnosis treatment combination (DBC codes), in Dutch: diagnose-behandel-combinatie) enabling the hospitals to claim the appropriate refund for treatment from health insurances companies. DBC codes are used to specify finances in health care. They are derived from the International Statistical Classification of Disease and Related Health Problems (ICD codes) (39). We identified children younger than 18 years who are registered by a neurologist or paediatric neurologist with the following diagnosis codes: concussion, TBI, skull fracture and multi-trauma ED. Because there is no diagnosis code to specify MTBI in the Netherlands, we have chosen general TBI diagnoses codes to capture all MTBIs.

We included all MTBI patients younger than 18 years who presented in the ED within 24 hours of the traumatic incident. TBI was defined as all forms of head injury, excluding superficial facial injury following direct head contact and/or acceleration/deceleration of the head. MTBI was defined as TBI which included the following criteria: (1) Glasgow Coma Scale (GCS) 13–15 at first examination in the ED, (2) post-traumatic loss of consciousness no longer than 30 minutes and (3) post-traumatic anterograde amnesia no longer than 24 hours, according to the Dutch guideline and the WHO Collaborating Centre for Neurotrauma Task Force on MTBI (8,40). GCS in children aged ≤4 years was defined according to the paediatric GCS (8). GCS for children aged >4 years was defined according to the GCS.

We excluded children with penetrating brain injury, impression fracture (closed or complicated) of the skull, children with known chronic generalized development delay and/or children with an internal or external spinal fluid shunt or previous neurosurgery. We also excluded children if they had neuroimaging at another than the participating hospital before transfer to the ED.

Data collection

Data were derived from digital medical files by MB. Information concerning age at date of trauma, gender, hospital of presentation and first performed management at the ED were collected. Personal data of the children were anonymised. Patients were subdivided into three age groups: (1) <2 years of age, (2) 2–5 years of age and (3) ≥6 to ≤17 years of age, corresponding with the flowcharts of the Dutch guideline for MTBI management. We reviewed the medical records of patients to determine in which patients a brain CT or hospital admission should have been performed (yes/no) if the flowcharts of the Dutch MTBI guideline (Figure 1) had been followed based on clinical variables mentioned in the Dutch guideline (see Appendix I for definitions clinical variables). To determine adherence, we compared these records with the actually performed management. If a clinical variable was not mentioned in the medical reports, we assumed that this clinical variable was not present.

Outcome measures

The primary outcome measures were (1) percentages of first performed management in the ED, especially for CT and for hospital admission and (2) percentages of Dutch guideline (8) adherence for brain CT and hospital admission. Adherence was defined as a correct performed and correct not performed brain CT/hospital admission according to the Dutch MTBI guideline. None adherence was defined as incorrect performed and incorrect not performed brain CT/hospital admission according to the guideline. None adherence was subdivided in underuse (brain CT/hospital admission was recommended according to guideline, but not performed) and overuse (brain CT/hospital admission was performed, but not recommended according guideline).

The secondary outcome measures were differences in percentages of management in the ED and percentages of guideline adherence between hospitals.

Data analyses

We used IBM SPSS statistical software (version 21) to analyse the data. We performed multiple frequency analysis to study patient characteristics for gender, hospital of presentation and age groups. Patient characteristics for age were expressed as median and interquartile range. Descriptive analyses were performed to study the primary objectives of this study. Differences in percentages between involved hospitals were tested with the chi-squared test. Performed statistical analyses were two-tailed tested.

Results

Between 1st January 2014 and December 31st 2014, 959 children younger than 18 years with corresponding DBC codes (concussion, TBI, skull fracture or multi-trauma ED) presented in the ED of the participating hospitals. Of these patients, 366 patients were not included, because they did not meet the inclusion criteria (Figure 2). Thirty patients were excluded, because they had an internal or external spinal fluid shunt or previous neurosurgery (n = 3), penetrating brain trauma (n = 1), chronic generalized development delay (n = 7) or had neuroimaging at another hospital before transfer to the ED of the participating hospitals (n = 19). Hence, 563 patients were analysed.

Patient characteristics

Patient characteristics are shown in Table 1. Most patients were male. The median age was 6.02 (range 0.04–17.96; ICR 9.92). Of all 563 analysed patients, 104 (18.5%) were younger than 2 years of age, 177 (31.4%) were 2–5 years of age and 282 (50.1%) were ≥6 to ≤17 years of age. Number of patients that

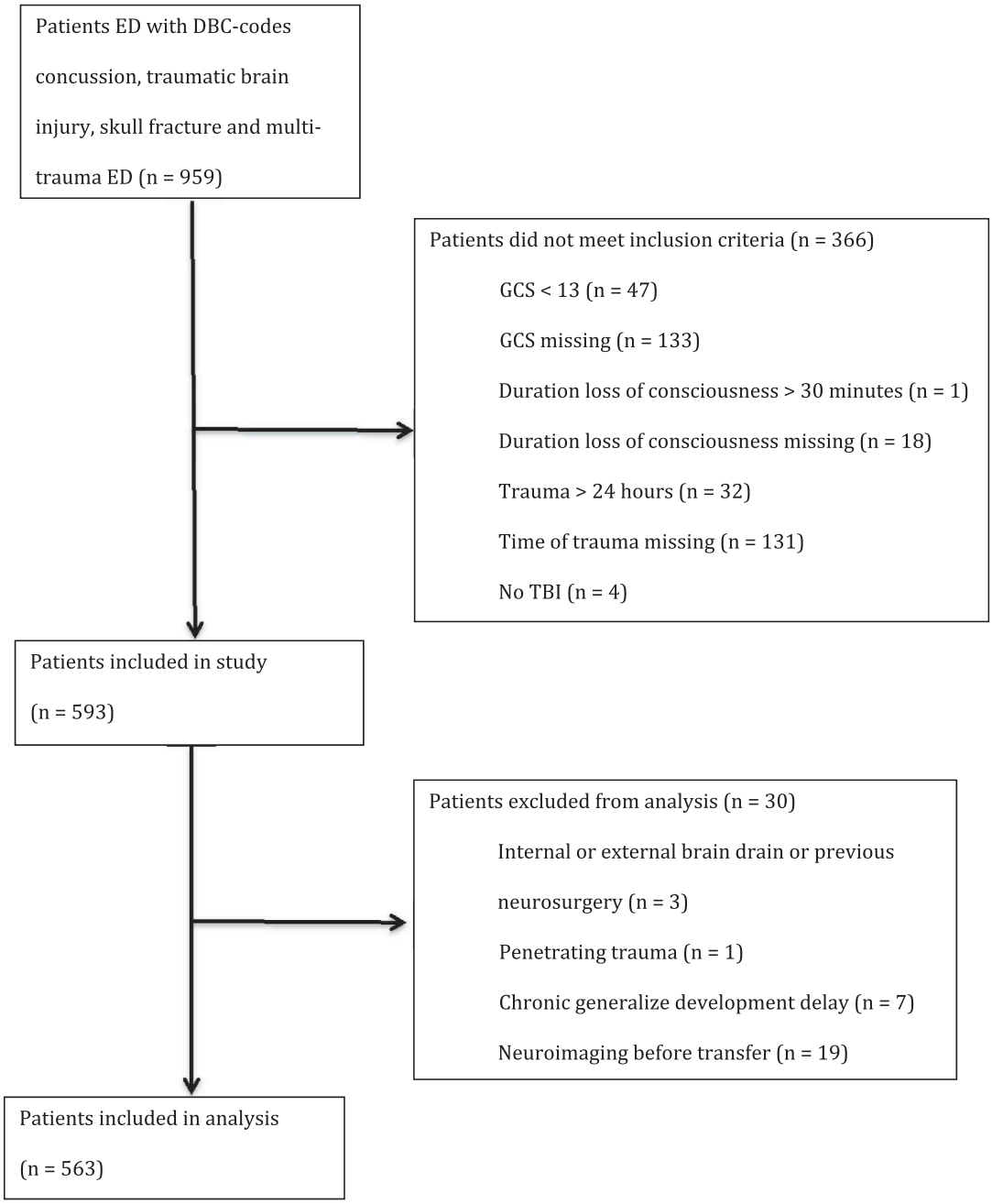

Figure 2. Study flowchart.

presented at the participating hospitals were 188 (33.4%) Erasmus University Hospital (including Sophia Children's Hospital), 143 (25.4%) Amphia Hospital and 232 (41.2%) Elisabeth-TweeSteden Hospital. Hospital characteristics are shown in Table 2.

Primary outcome measures

Percentages of first performed management in the ED are shown in Table 3. The most common performed management for MTBI was hospital admission (49.2%). Brain CT was performed in 30.9% of children. Percentages for the remaining management strategies recommended in the Dutch guideline were 8.2%, 11.0% and 0.5% for discharged with observation at home, discharged without observation at home and short clinical observation in the ER, respectively. In one patient (1.0%) 11 weeks of age, an echography of the brain was performed. Hospital admission was the most performed management in children younger than 2 years of age and 2–5 years of age, 73.1% and 65.0%, respectively. Brain CT was the most performed management in children ≥6 to ≤17 years of age (48.9%).

Percentages of guideline adherence for hospital admission, brain CT and for adherence for both hospital admission and brain CT are shown in Table 4. In 283 (49.7%) of all 563 analysed patients, Dutch guideline recommendations concerning both hospital admission and brain CT were followed correctly. A substantial overuse of hospital admission (35%)

Table 1. Patient characteristics (n = 563).

Characteristics	EMC	ETZ	Amphia	Total
Gender				
Female n (%)	85 (45.2)	89 (38.4)	59 (41.3)	233 (41.4)
Male n (%)	103 (54.8)	143 (61.6)	84 (58.7)	330 (58.6)
Median age (years; IQR, range)	3.6 (8.2, 0.04–17.96)	7.6 (10.6, 0.11–17.92)	6.6 (9.7, 0.87–17.70)	6.0 (9.9, 0.04–17.96)
Age groups				
<2 years of age, n (%)[a]	56 (29.8)	30 (12.9)	18 (12.6)	104 (18.5)
2–5 years of age, n (%)[a]	59 (31.4)	70 (30.2)	48 (33.6)	177 (31.4)
≥6 to ≤17 years of age, n (%)[a]	73 (38.8)	132 (56.9)	77 (53.8)	282 (50.1)
Number of MTBI patients, n (%)[b]	188 (33.4)	232 (41.2)	143 (25.4)	563 (100)

n = number of patients, IQR = interquartile range. EMC = Erasmus University Hospital, ETZ = Elisabeth-TweeSteden Hospital, Amphia = Amphia Hospital.
[a]Percentages were calculated as proportion of the total performed management of the hospital: Erasmus University Hospital (n = 188), Elisabeth-TweeSteden Hospital (n = 232) and Amphia Hospital (n = 143).
Percentages were calculated as proportion of all analysed patients (n = 563).

Table 2. Hospital characteristics.

Characteristics	EMC	ETZ	Amphia
University vs. general hospital	University	General	General
Teaching vs. non-teaching hospital	Teaching	Teaching	Non-teaching
Specialist at ED	Neurologist/child neurologist	Paediatrician and neurologist/paediatric neurologist	Paediatrician or resident ED, if needed also a neurologist/ paediatric neurologist
Availability CT technicians	24/7 in-house availability	24/7 in-house availability	24/7 in-house availability

EMC = Erasmus University Hospital, ETZ = Elisabeth-TweeSteden Hospital, Amphia = Amphia Hospital, ED = emergency department, CT = computed tomography.

Table 3. Performed management subdivided into age groups.

	<2 years, n (%)[a]	2–5 years, n (%)[a]	≥6 to ≤17 years, n (%)[a]	Total, n (%)[b]
Brain CT	11 (10.6)	25 (14.1)	138 (48.9)	174 (30.9)
Hospital admission	76 (73.1)	115 (65.0)	86 (30.5)	277 (49.2)
Short clinical observation	2 (1.9)	1 (0.6)	0 (0.0)	3 (0.5)
Discharged with observation at home	9 (8.7)	21 (11.9)	16 (5.7)	46 (8.2)
Discharged without observation at home	5 (4.8)	15 (8.5)	42 (14.9)	62 (11.0)
Other	1 (1.0)	0 (0.0)	0 (0.0)	1 (0.2)
Total	104	177	282	563

n = number of patients, CT = computed tomography.
[a]Percentages were calculated as proportion of the age groups: <2 years of age, 2–5 years of age and ≥6 to ≤17years of age, respectively.
[b]Percentages were calculated as proportion of all analysed patients (n = 563).

and underuse of CT (40.1%) were found. In 225 (40%) of all 563 analysed patients, Dutch guideline recommendation concerning hospital admission was not followed, 197 (87.6%) of whom due to overuse of hospital admission. Dutch guideline recommendation concerning brain CT was not followed in 247 (43.9%) of all 563 patients, 226 (91.5%) of whom due to underuse of brain CT. Guideline adherence subdivided into guideline adherence, underuse and overuse is shown in Table 5. Guideline adherence subdivided into patients younger than 2 years, 2–5 years and 6–17 years is shown in Tables 6, 7 and 8, respectively.

Secondary outcome measures

Performed management subdivided in hospitals is shown in Table 9. Because of the small sample size of several management strategies (short clinical observation, discharged home with observation at home, discharged without observation at home and other management), we merged this data into one group (other management group) to compare numbers of performed management between hospitals. Variations in performed management existed between hospitals (p < 0.000). These variations seemed to be due to the higher percentage for brain CT in the University Hospital (44.1%) compared to the percentages for brain CT in the two large regional general hospitals (23.3% and 25.9%, respectively).

Dutch guideline adherence for both hospital admission and brain CT subdivided into hospitals are shown in Table 10. Guideline adherence for both hospital admission and brain CT differed between hospitals (p < 0.000). This variation seemed to be due to higher percentages for guideline adherence for both hospital admission and brain CT in the Erasmus University Hospital (64.9%) compared to percentages for guideline adherence for both hospital admission and brain CT in the Elisabeth-TweeSteden Hospital (44.0%) and Amphia Hospital (39.2%).

Performed management if the Dutch guideline was not followed as shown in Table 11. Most children in whom none adherence for brain CT and/or hospital admission occurred were admitted to the hospital (69.6%). Reasons for none adherence or explanation for management in case of none adherence were not mentioned in medical reports in most children (65.8%). Physicians did not mention in the medical reports that they were aware of nonadherence in 270 patients (95.4%).

Table 4. Dutch guideline adherence for hospital admission, brain CT and for both hospital admission and brain CT subdivided in age groups.

	<2 years (*n* = 104)			2–5 years (*n* = 177)			>6 to ≤17 years (*n* = 282)			Total (*n* = 563)		
	HA, *n* (%)	CT, *n* (%)	Both HA and CT, *n* (%)	HA, *n* (%)	CT, *n* (%)	Both HA and CT, *n* (%)	HA, *n* (%)	CT, *n* (%)	Both HA and CT, *n* (%)	HA, *n* (%)	CT, *n* (%)	Both HA and CT, *n* (%)
Adherence	45 (43.3)	42 (40.4)	38 (36.5)	105 (59.3)	105 (59.3)	94 (53.1)	188 (66.7)	169 (59.9)	148 (53.5)	338 (60.0)	316 (56.1)	280 (49.7)
Nonadherence	59 (56.7)	62 (59.6)	66 (63.5)	72 (40.7)	72 (40.7)	83 (46.9)	94 (33.3)	113 (40.1)	134 (47.5)	225 (40.0)	247 (43.9)	283 (50.3)
Overuse	52 (88.1) [a]	0 (0.0)[a]		59 (82.0)[a]	1(1.4)[a]		86 (91.5)[a]	20 (17.7)[a]		197 (87.6)[a]	21 (8.5)[a]	
	52 (50.0)[b]	0 (0)[b]		59 (33.3)[b]	1 (0.6)[b]		86 (30.5)	20 (7.1)		197 (35.0)[b]	21 (3.7)[b]	
Underuse	7 (11.9)[a]	62 (100.0)[a]		13 (18.1)[a]	71(98.6)[a]		8 (8.5)[a]	93(82.3)[a]		28 (12.4)[a]	226 (91.5)[a]	
	7 (6.7)[b]	62 (59.6)[b]		13 (7.3)[b]	71 (40.1)[b]		8 (2.8)[b]	93 (33.0)[b]		28 (5.0)[b]	226 (40.1)[b]	

n = number of patients, HA = hospital admission, CT = computed tomography, MTBI = mild traumatic brain injury.
[a]Percentages were calculated as proportion of the group management not according to the guideline for hospital admission and brain CT, respectively.
[b]Percentages were calculated as proportion of the age groups <2 years (*n* = 104), 2–5 years (*n* = 177), ≥6 to ≤17 years (*n* = 563) and all analysed patients (*n* = 563), respectively.

Possible major criteria associated with nonadherence for the Dutch Guideline for brain CT, hospital admission and both brain CT and hospital admission are shown in Table 12. Age younger than 2 years seemed to be a predictor for nonadherence compared to age of 2 years or older for both hospital admission, brain CT and adherence for hospital admission and brain CT together. In children younger than 2 years of age, overall presence of a skull haematoma is associated with nonadherence. Overall, the presence of altered behaviour and vomiting is associated with nonadherence in children 2–5 years of age.

Discussion

This multicentre study shows that often contrary to the advice given in the National Guideline MTBI, hospital admission is the most performed management in children with MTBI who presented in the ED in hospitals in the southwest region of the Netherlands. Only in approximately half of the patients the guideline for both hospital admission and brain CT was respected. Management and guideline adherence vary across hospitals. If the Dutch guideline is not followed, hospital admission is the most common management.

Management

Our findings differ from previous Dutch studies. We found higher percentages of hospital admission (49.2% vs. 8.4%) and brain CT (30.9% vs. 6.5%) in children with MTBI (37). Another Dutch study found more similar percentages for brain CT scan (20.5%) and hospital admission (68.8%; whether or not prior to a brain CT) in their group of children with MTBI (38). The wide range of published management is unexplained and supports our finding that performed management varies substantially between hospitals, and even national guidelines are put aside in favour of pressure of daily practice. A similar variation in management is shown in adults (41). The NVN assumed that the implementation of the current Dutch guideline in 2010 could reduce the number of brain CT. However, the number of brain CT (2009 2.8%, 2012 6.5%) and the number of hospital admissions (2009 4.9%, 2012 8.4%) in children with MTBI alarmingly increased after implementation of the current Dutch guideline in children, which seems not be caused by an increased number of ciTBI but possibly rather by the feeling of insecurity of the professional concerning mTBI in children (37).

Guideline adherence

A previous Dutch study showed higher percentages of guideline adherence for brain CT (97% vs. 56.1%) and for hospital admission (81.9% vs. 60%) (37) than our study. Guideline adherence also varies considerably in adults with TBI (41). Our study shows CT overuse in 21 (12%; 3.7% of all 563 analysed children) of all 174 patients who received a brain CT. Nevertheless, CT underuse represents 40.1% of all 563 analysed children. In an American study, children younger than 2 years of age who received a brain CT because of MTBI, brain CT overuse was presented in 2.6% (95% CI, 0.5–8.3%).

Table 5. Adherence Dutch MTBI guideline concerning brain CT and hospital admission (n = 563).

	Advice Dutch guideline				
Performed management	CT +/HA – *n* (%)[a]	CT + or HA + *n* (%)[a]	CT -/HA + *n* (%)[a]	CT -/HA – *n* (%)[a]	Total, *n* (%)[a]
CT +/HA –	143 (25.4) CT adherence HA adherence	10 (1.8) CT adherence HA adherence	7 (1.2) CT overuse HA underuse	14 (2.5) CT overuse HA adherence	174 (30.9)
CT -/HA +	162 (28.8) CT underuse HA overuse	80 (14.2) CT adherence HA adherence	0 (0.0) CT adherence HA adherence	35 (6.2) CT adherence HA overuse	277 (49.2)
CT -/HA –	44 (7.8) CT underuse HA adherence	20 (3.6) CT underuse HA underuse	1 (0.2) CT adherence HA underuse	47 (8.3) CT adherence HA adherence	112 (19.9)
Total	349 (62.0)	110 (19.5)	8 (1.4)	96 (17.1)	563 (100)

n = number of patients, CT = computed tomography, HA = hospital admission, MTBI = mild traumatic brain injury.
[a]Percentages were calculated as proportion off all analysed patients (*n* = 563).

Table 6. Adherence Dutch MTBI guideline concerning brain CT and hospital admission in patients <2 years (*n* = 104).

	Advice Dutch guideline			
Performed management	CT +/HA – *n* (%[a])	CT + or HA + *n* (%)[a]	CT -/HA – *n* (%)[a]	Total, *n* (%)[a]
CT +/HA –	10 (9.6) CT adherence HA adherence	1 (1.0) CT adherence HA adherence	0 (0.0) CT overuse HA adherence	11 (10.6)
CT -/HA +	48 (46.2) CT underuse HA overuse	24 (23.1) CT adherence HA adherence	4 (3.8) CT adherence HA overuse	76 (73.1)
CT -/HA –	7 (6.7) CT underuse HA adherence	7 (6.7) CT underuse HA underuse	3 (2.9) CT adherence HA adherence	17 (16.3)
Total	65 (62.5)	32 (30.8)	7 (6.7)	104 (100)

n = number of patients, CT = computed tomography, HA = hospital admission, MTBI = mild traumatic brain injury.
[a]Percentages were calculated as proportion off patients <2 years (*n* = 104).

Table 7. Adherence Dutch MTBI guideline concerning brain CT and hospital admission in patients 2–5 years (*n* = 177).

	Advice Dutch guideline			
Performed management	CT +/HA – *n* (%)[a]	CT + or HA + *n* (%)[a]	CT -/HA – *n* (%)[a]	Total, *n* (%[a])
CT +/HA –	15 (8.5) CT adherence HA adherence	9 (5.1) CT adherence HA adherence	1 (0.6) CT overuse HA adherence	25 (14.1)
CT -/HA +	48 (27.1) CT underuse HA overuse	56 (31.6) CT adherence HA adherence	11 (6.2) CT adherence HA overuse	115 (65.0)
CT -/HA –	10 (5.6) CT underuse HA adherence	13 (7.3) CT underuse HA underuse	14 (7.9) CT adherence HA adherence	37 (20.9)
Total	73 (41.2)	78 (44.1)	26 (14.7)	177 (100)

n = number of patients, CT = computed tomography, HA = hospital admission, MTBI = mild traumatic brain injury.
[a]Percentages were calculated as proportion of patients 2–5 years (*n* = 177).

In children 2–20 years of age who received a brain CT, brain CT overuse was presented in 11.5% (95% CI, 6.4–18.7%) (36). However, CT underuse was not studied (36). Until now, to the best of our knowledge, no data regarding overuse and underuse of hospital admissions were independently described in the literature. We found that age younger than 2 years, skull haematoma in patients younger than 2 years, vomiting and altered behaviour in children 2–5 years were predictive variables for non-guideline adherence for both brain CT and hospital admission. Because the majority of non-guideline adherence is due to a combination of underuse of brain CT and overuse of hospital admission, these variables seem to be predictive for underuse of brain CT and overuse of hospital admission in particular. A Scandinavian study described age <4 years (OR 25.6; 95% CI 9.1–72.0; $p < 0.001$) and medical cause of injury (OR 234.6; 95% 108.5–507.3; $p < 0.001$) as predictive variables for non-guideline adherence (30).

The aim of evidence-based clinical practice guidelines is to improve the quality of care, facilitate decision-making and reduce variations in clinical practice (42). Therefore, implementation of guidelines and a good guideline adherence is important. However, guidelines are based on the general population and cannot replace clinical experience. Hospital admission is the most frequently performed management when physicians wave the Dutch guideline in children with MTBI (69.6%). This suggests that physicians prefer to keep on the safe site and rather admit a child with MTBI to the

Table 8. Adherence Dutch guideline concerning brain CT and hospital admission in patients ≥6 to ≤17 years (n = 282).

Advice Dutch guideline				
Performed management	CT +/HA – n (%)[a]	CT -/HA + n (%)[a]	CT -/HA – n (%)[a]	Total, n (%)[a]
CT +/HA –	118 (41.8) CT adherence HA adherence	7 (2.5) CT overuse HA underuse	13 (4.6) CT overuse HA adherence	138 (48.9)
CT -/HA +	66 (23.4) CT underuse HA overuse	0 (0.0) CT adherence HA adherence	20 (7.1) CT adherence HA overuse	86 (30.5)
CT -/HA –	27 (9.6) CT underuse HA adherence	1 (0.4) CT adherence HA underuse	30 (10.6) CT adherence HA adherence	58 (20.6)
Total	211 (74.8)	8 (2.8)	63 (22.3)	282 (100)

n = number of patients, CT = computed tomography, HA = hospital admission, MTBI = mild traumatic brain injury.
[a]Percentages were calculated as proportion of patients ≥ 6 to ≤ 17 years (n = 282).

Table 9. Difference between hospitals for performed management based on chi-squared test.

	Brain CT	Hospital admission	Other	Total
Erasmus University Hospital (n, %)[a]	83 (44.1)	74 (39.4)	31 (16.5)	188 (100)
Elisabeth-TweeSteden Hospital (n, %)[a]	54 (23.3)	129 (55.6)	49 (21.1)	232 (100)
Amphia Hospital (n, %)[a]	37 (25.9)	74 (51.7)	32 (22.4)	143 (100)
Total (n, %)[a]	174 (30.9)	277 (49.2)	112 (19.9)	563 (100)
X^2 = 23.745, df = 4, p < 0.000				

n = number of patients, CT = computed tomography.
[a]Percentages were calculated as proportion of the total performed management of the hospital: Erasmus University Hospital, Elisabeth-TweeSteden Hospital and Amphia Hospital, respectively.

Table 10. Difference between hospitals for Dutch guideline adherence for hospital admission, brain CT and both (hospital admission and brain CT) based on chi-squared test.

	Guideline adherence hospital admission			Guideline adherence CT			Guideline adherence both hospital admission and CT		
	Adherence HA	Nonadherence HA	Total	Adherence CT	Nonadherence CT	Total	Adherence both HA and CT	Nonadherence both HA and CT	Total
Erasmus University Hospital (n, %)[a]	138 (73.4)	50 (26.6)	188 (100.0)	128 (68.1)	60 (31.9)	188 (100.0)	122 (64.9)	66 (35.1)	188 (100.0)
Elisabeth-TweeSteden Hospital (n, %)[a]	124 (53.4)	108 (46.6)	232 (100.0)	117 (50.4)	115 (49.6)	232 (100.0)	102 (44.0)	130 (56.0)	232 (100.0)
Amphia Hospital (n, %)[a]	76 (53.1)	67 (46.9)	143 (100.0)	71 (49.7)	72 (50.3)	143 (100.0)	56 (39.2)	87 (60.8)	143 (100.0)
Total (n, %)[b]	338 (60.0)	225 (40.0)	563 (100.0)	316 (56.1)	247 (43.9)	563 (100.0)	280 (49.7)	283 (50.3)	563 (100.0)
	X^2 = 21.028, df = 2, p < 0.000			X^2 = 16.410, df = 2, p < 0.000			X^2 = 26.765, df = 2, p < 0.000		

n = number of patients, HA = hospital admission, CT = computed tomography.
[a]Percentages were calculated as proportion of all analysed patients per hospital: Erasmus University Hospital, Elisabeth-TweeSteden Hospital and Amphia Hospital, respectively.
[b]Percentages were calculated as proportion of all 563 patients.

Table 11. Performed management if guideline was not followed.

	n (%)
Performed management	
Brain CT	21 (7.4)
Hospital admission	197 (69.6)
Short clinical observation	3 (1.1)
Discharged with observation at home	33 (11.7)
Discharged without observation at home	28 (9.9)
Other	1 (0.4)
Total	283

n = number of patients, CT = computed tomography.

hospital than perform a brain CT which may enhance the risk for future brain tumour. Hence, physicians caring for children with MTBI do not seem to agree with the management strategy advised in the guideline. The Dutch guideline is included in the local guidelines of all three hospitals and is accessible for consultation online in the hospital system 24 hours a day. The diagnostic work-up of children with TBI is included in the training of every neurological resident before working in the emergency room. Despite these

Table 12. Possible major criteria associated with none adherence Dutch guideline for brain CT, hospital admission and both brain CT and hospital admission.

	CT		HA		Both CT and HA	
	OR	95% CI	OR	95% CI	OR	95% CI
Age <2 years	2.2	1.4–3.4	2.3	1.5–3.6	1.9	1.2–3.0
<2 years of age						
Skull haematoma	13.2	4.9–35.4	4.8	2.1–11.1	9.5	3.6–25.0
Altered behaviour	2.3	0.7–7.6	1.8	0.6–5.8	1.9	0.6–6.3
2–5 years of age						
Altered behaviour	11.8	4.8–29.0	3.7	1.8–7.7	8.2	3.4–19.9
Vomiting	12.1	5.2–28.5	5.4	2.5–11.3	8.2	3.5–19.2
≥ 6 to ≤17 years of age						
Vomiting	1.4	0.8–2.4	1.1	0.6–1.9	0.9	0.5–1.6

CT = computed tomography, HA = hospital admission.

instructions, professionals apparently rather stay on the safe side. Revision of the guideline is needed and would lead to either to alternative and more accepted strategy in general practice or should lead to a thorough information campaign towards these physicians in order to obtain a more general and accepted guideline adherence. An important question in this context is, if the deviations from the guideline are harmful to children. A US study showed that hospital admission before making a decision regarding the use of computed tomography (CT) was associated with reduced CT in children with MTBI (31.1% vs. 35.0%; difference: −3.9% 95% CI: −5.3 to −2.6%) compared to children who were not admitted to hospital for observation before a decision was made regarding CT use, although the rate of ciTBI was similar in both groups (22). Hence, poor guideline adherence with hospital admission as performed management seems to not be harmful for children with MTBI because ciTBI were not missed in case of hospital admission. However, hospital admission maybe a social burden to parents and an unnecessary financial burden for the medical care system. In contrast, hospital admission could be an effective strategy to reduce CT and thus result in less ionizing radiation exposure. However, the possibilities for implementation of hospital admission may vary between countries with different health care systems. In addition, strict and better instruction of parents/caregivers of how to observe their children properly in the home situation including instruction on alarm symptoms maybe an alternative strategy.

Differences between hospitals

Percentages of brain CT vary between 23.3% and 44.1% between hospitals. In the USA, percentages of brain CT vary between 19.2% and 69.2% between hospitals. This variation is not explained by the percentages of positive brain CT's, percentages of ciTBIs or the severity of patient clinical findings (31). Regarding hospital admission, percentages vary between 39.4% and 55.6% across hospitals. No data concerning differences in hospital admission across hospitals were found in the literature. Regarding Dutch guideline adherence, percentages vary between 39.2% and 64.9% for both brain CT and hospital admission. No studies were found with which our findings could be compared. In this study, differences in guideline adherence between hospital seems to induces variation in performed management. For example, the Erasmus University Hospital shows the highest percentage for CT corresponding with the highest percentage for guideline adherence. Presumed differences in capacity for hospital admission, hospital culture, teamwork with paediatricians, guideline implementation and cost policy may explain the variation in guideline adherence between hospitals.

Limitations study

This study has some limitations. Data were collected retrospectively. Several data concerning clinical variables, which are a potential crucial part of the Dutch flowchart for management, were frequently not recorded in the medical reports. In clinical practice, if patients are presenting without some symptoms, these absent symptoms are frequently not recorded in the medical reports. Therefore, we assumed that a clinical variable was not present if this clinical variable was not mentioned in the medical reports. Of all clinical variables, 40.2% (mean) was missing. This may have induced bias and may obscure lack of examination of clinical variables according to the Dutch guideline by physicians resulting in overestimate of guideline adherence.

We only included patients who were registered by a neurologist or paediatric neurologist with DBC codes. However, children who presented at the Amphia hospital and younger than 1 year are first seen by a paediatrician and children of 1 year and older are first seen by an emergency doctor. Afterwards, a neurologist or paediatric neurologist can be consulted, so we may have missed some children.

Our data were collected from one tertiary and two large general (teaching) hospitals and may not be generalized to the management and guideline adherence in a few smaller hospitals in the Netherlands. Based on a combination of our findings and results of previous Dutch studies (37,38), the between-centre variation in performed management and guideline adherence could be larger.

Data concerning follow-up were not collected; therefore, we cannot compare management and guideline adherence with numbers of identified or missed ciTBI.

Conclusion

Hospital admission is the most performed management in children with MTBI. Guideline adherence for the management of MTBI in children is poor and varies between hospitals. In case of nonadherence, hospital admission is the most performed management. These findings suggest that physicians prefer hospital admission above CT despite the recommendations of the guideline in the Netherlands. Based on these results, the current Dutch guideline should be revised or guideline implementation instructions may be developed to improve guideline adherence.

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Declaration of Interest

The authors report no declarations of interest.

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Appendix I

Definition of clinical variables Dutch guideline flowchart for management MTBI(8): mechanism of injury, history, symptoms and physical examination findings.

GCS < 15	GCS < 15 during examination by the treating physician (including ongoing post-traumatic anterograde amnesia during examination in patients aged ≥ 6 years)
Clinically suspect for skull fracture	Palpable skull fracture, battle's sign (retro-auricular bruising), raccoon eyes (periorbital bruising) and/or cerebrospinal fluid
Post-traumatic seizure	Tonic and/or clonic jerking activity occurring after the traumatic event witnessed or suspect after the injury
Focal neurologic deficit	Any focal abnormality of the cranial nerves, motor or sensory systemor deep tendon reflexes observed by neuroloc examination.
Skull haematoma	Swelling of the skull (frontal, occipital, parietal and/or temporal) In children younger than 2 years of age, skull haematoma is an important predictor for intracranial injury. Therefore, in this study if an skull hematoma was mentioned in the medical reports, including frontal, we assumed that a brain CT would had been performed if the guideline was followed
Altered behaviour	The patient is not acting normally during examination (parental report), regardless of the GCS score
Suspect of high-impact injury	Suspect for high-impact injury; according to the physician expertise and mentioned as suspect of high-impact injury in the medical records by the physician
External haematoma parietal, temporal or occipital	Swelling of the scalp parietal, temporal or occipital
Fall > 1 m	Fall >1 m from head till ground/object, including patient's length. A fall from 5 stairs is equal to a fall from 1 m In this study, we assume that a fall from 5-stair steps is equal to a fall from 1 m, based on the NICE guideline, which is mentioned in the Dutch Guideline. Body length includes fall height
Somnolence or agitation	Parental report of somnolence or agitation
Dangerous mechanism of injury	Mechanism of injury which meets the criteria for high energetic trauma according to the Dutch guideline
Post-traumatic anterograde amnesia	Inability to create new memories after the head trauma
External head injury	Clinically laceration or abrasion of the skin or haematoma above the eyebrows