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ORIGINAL RESEARCH

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Management of traumatic brain injury in adult—A cross-sectional national study

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Abstract

Background: Mild traumatic brain injury (mTBI) is a common cause for seeking care. Previous studies have shown considerable variations in TBI management. New guidelines may have influenced management routines.

Methods: This is a descriptive cross-sectional study, collecting data through structured questionnaires. All Swedish emergency hospitals that manage and treat adult patients with mTBI (Reaction Level Scale [RLS] 1–3, Glasgow Coma Scale [GCS] 13–15, age > 18 years) for the initial 24 h after injury were included in this study.

Results: The response rate among hospitals fulfilling the study criteria's was 61/67 (91%). We observed a distinct predominance of nonspecialists being responsible for the initial management of these patients, with general surgeons and ED-physicians being the dominating specialties. A total of 45/61 (74%) of the hospitals use a guideline when managing TBI, with 12 hospitals (20%) stating that no guideline was used.

Conclusion: In general, established guidelines are used for the management of TBI in Sweden. However, some of these are outdated and several hospitals used local guidelines not based upon reliable evidence-based methodology. Most patients with TBI are managed by nonspecialist doctors, stressing the need of a reliable guideline.

KEYWORDS

emergency medicine, critical care medicine, health economics and evaluation, radiology & imaging

1 | BACKGROUND

Sweden is a relatively large and sparsely populated country, consisting of 21 autonomous healthcare regions, with a varying degree of university hospitals, regional hospitals, and smaller district hospitals. There are concerns regarding how Swedish healthcare regions manage their assignment due to factors such as geography, demography and access to healthcare personnel. Emergency departments need a broad spectrum of competence 24 h a day, with variations regarding clinical experience among Swedish doctors.[1] Under optimal circumstances, emergency departments (EDs) should be staffed by the highest competence available but, in reality, there is a wide variation of clinical experience among doctors. Despite these variations, Swedish health care is globally considered to be on a high level.[2]

Traumatic brain injury (TBI) is a common cause for seeking ED care. There are difficulties of determining the incidence of head trauma globally due to a broad spectrum of studies with various definitions of TBI. A common incidence is 600/100,000 inhabitants and approximately 100–300/100,000 of these need hospital

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admittance.[3] A total of 70%–90% of all TBI are graded as minimal, mild (mTBI), or moderate, and men are overrepresented.[3]

A study conducted in the Nordic countries between 1987 and 2000 showed a median TBI mortality of 12.6/100,000 inhabitants.[4] During this period one could also discern a noticeable decline in mortality rate in Scandinavia. Traffic accidents, physical abuse and fall, often under the influence of alcohol, are considered the most common causes.[4]

In a minority of patients with minimal and mTBI, life-threatening intracranial bleeding may occur. Identifying and managing this category of patient is considered a clinical challenge. Adequate management is important; neither to under-triage serious pathology but at the same time avoiding over-triage and unnecessary radiation from computed tomography (CT) scans.

The first evidence-based Scandinavian guideline for the management of TBI, the Scandinavian Neurotrauma Committee guideline 2000 (SNC-00), developed by the Scandinavian Neurotrauma Committee, was published more than 20 years ago.[5] Loss of consciousness (LOC) and/or amnesia and decreased level of consciousness at admittance were considered the most important predictors of intracranial pathology. Anticoagulant treatment, signs of skull base/skull fracture, shunt-treated hydrocephalus, and seizures were considered as significant risk factors.

In the years after the introduction of SNC-00, the potential unjustified use of CT was a concern. A report from the Nordic radiation protection authorities in 2012 indicated that 20%–75% of completed CT scans may be considered unnecessary. The number of CT scans/1000 inhabitants increased almost linearly between 1993 and 2010 in Sweden.[6] A review article also suggested a 12–20-fold increase in the use of CT in the United States and the United Kingdom.[7] The correlation between radiation dose and the potentially increased risk of malignancy do not seem to be fully appreciated.[8] Several reports indicate an increased risk of cerebral malignancy related to ionizing radiation exposure.[9–11] One study indicated an increased risk of glioma in adults with previous exposure to CT radiation to the head/neck, indicating an increased risk if more than three such examinations were performed.[12]

The Nordic authorities advocate increased knowledge regarding radiation risks from both the remittent and the radiologist, that radiation of asymptomatic patients is unjustified, and finally, that more frequent reviews regarding the effectiveness of conducted CT scans should be made.[6] A retrospective study from the Swedish Radiation Protection Authority in 2009 found that 20% of all radiation to the head through CT modality may lack medical justification.[13]

In 2013, revised evidence-based guidelines for emergency care of TBI were published, SNC-13[14] (Figure 1). This guideline is currently being validated through an ongoing prospective study in the Nordic countries. According to SNC-13, the biomarker S100B can

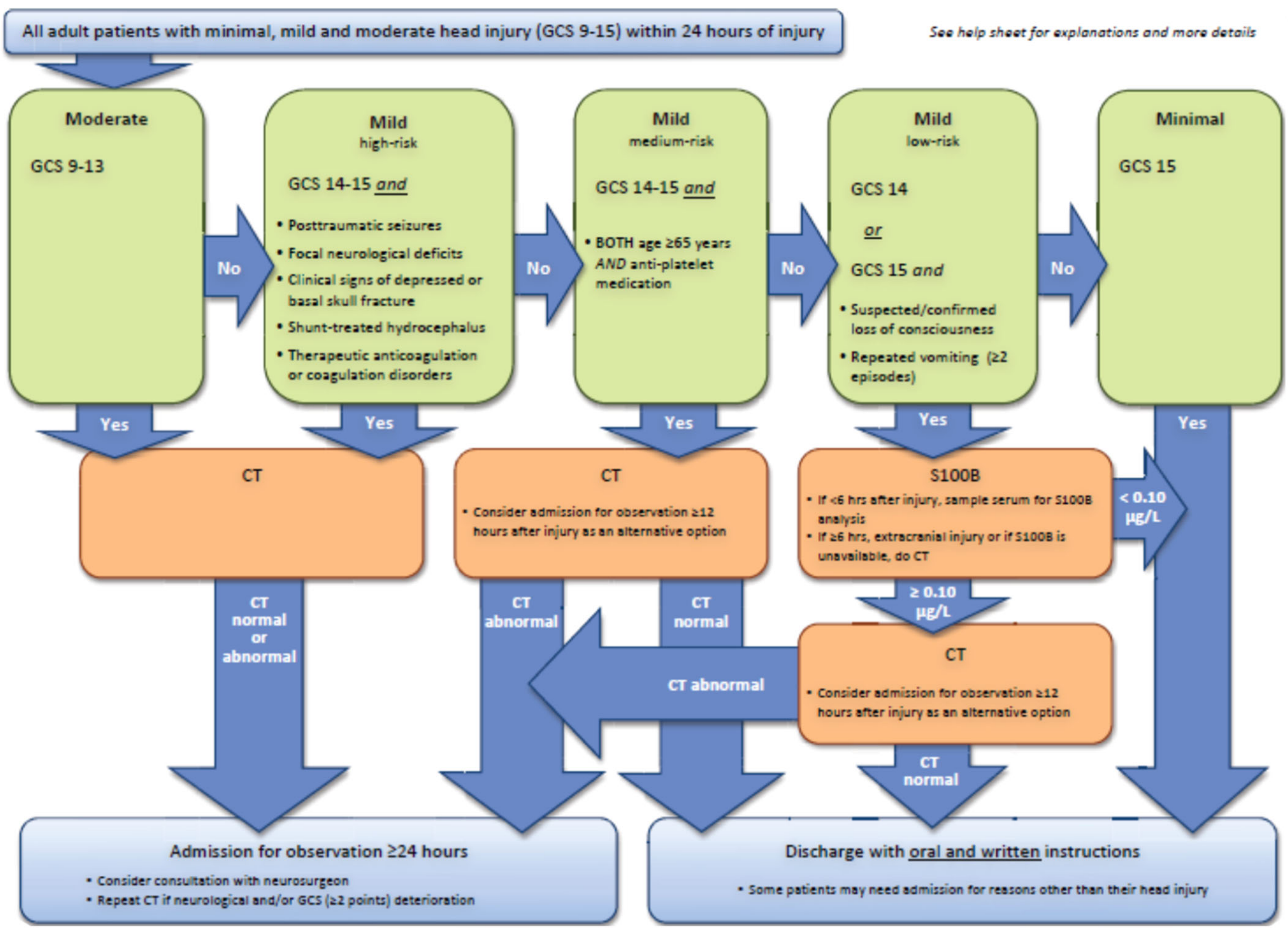

FIGURE 1 The SNC-13 guideline.

serve as a complement to clinical assessment for discharge, without needing a CT scan, in low-risk patients. The benefit of S100B as a screening marker has been validated.[15,16] S100B has a reported sensitivity of 95% and specificity of 31%, with a cut-off set to < 0.1 µg/L.[16] No statistical difference was seen in the level of S100B between intoxicated/nonintoxicated patients, but a slight decrease of specificity among patients > 65 years was noticed.[17]

Two cross-sectional studies from Norway and Sweden, respectively, showed large variations in the management of TBI, with a lack of both guidelines and admittance/observation criteria.[18,19] Management and treatment were largely performed by inexperienced doctors and by departments of various specialties.[20]

Considering the ongoing national validation efforts of various guidelines, an updated assessment concerning the current management of mTBI in Sweden is necessary. Such results may facilitate later guideline implementation.

2 | AIM

The purpose of this survey is to study how adult patients with TBI are currently being managed in Swedish emergency departments and to examine the dynamics of this management over time.

3 | METHODS

This is a descriptive cross-sectional study. Data were collected through questionnaires. All Swedish emergency hospitals that manage and treat adult patients with mTBI (Reaction Level Scale [RLS] 1–3, Glasgow Coma Scale [GCS] 13–15, age > 18 years) for the first 24 h met the criteria to be included in this study.

The questionnaire was designed in the web-based program esMaker and was sent by e-mail to each hospital in May 2020–January 2021. Reminders were sent by email and then by phone call. The intended respondents were doctors with solid knowledge of the management of TBI in their own hospital. The goal was to achieve a response rate of > 90%.

The questionnaire was structured to reflect different aspects of management:

- General information about the hospital and its structure.
- Initial care in the ED.
- Further management and diagnostic tools.
- Admittance criteria's and observation routines.
- Discharge criteria's and follow ups.

The survey contained multiple-choice questions, see Supporting Information: Material. Respondents had several opportunities to share their own thoughts of TBI management, both in general and specific terms. In addition, an extra questionnaire was sent to respondents, addressing attitudes toward the use of S100B.

Experience level of doctors was categorized to specialist (categories “attending” and “specialist” were merged), resident/preresident level (categories “assistant physician, dependent,” “assistant physician, independent” and “intern” were merged). Respondents were asked to rate how frequent (on a five-grade scale, always; often; sometimes; rarely; never) each of the categories manages adults with TBI at their emergency department. Grades “always” and “often” were merged and presented for respective hospital size. The question did not compare the frequency between different specialties in one hospital. Responders were able to choose the same answer in every category.

In a similar way, clinical specialties were categorized with respect to hospital type. For the respective type of clinical speciality, respondents were asked to rate how frequent (on a 5-grade scale, always; often; sometimes; rarely; never) each of the specialities manages adults with head trauma at their emergency department. Grades “always” and “often” were merged and presented for respective hospital size.

A comparison with a similar study from 1999 regarding guidelines use, experience level of doctors, and discharge criteria was conducted.

3.1 | Statistics

Descriptive quantitative statistics were applied to compile the results. A cross-comparison was performed between three categories depending on the size of the hospital; district, regional, and university hospitals. Fisher's exact tests were used to statistically compare small (local and district) and large (university) hospitals. A p-value of <0.05 was considered significant.

4 | RESULTS

The response rate among hospitals fulfilling the study criteria's was 61/67 (91%).

4.1 | General information about the hospital and its structure

4.1.1 | Responding hospitals

A total of 10/11 (90.9%) of the university hospitals, 19/22 (86.4%) of the regional hospitals and 32/34 (94.1%) of the district hospitals responded.

Attending physicians (51.7%), specialists (28.3%), and resident physicians (16.7%) most frequently responded. In addition, these respondents had several other key roles such as head of unit, lead author of a local TBI protocol, or a member of a trauma group. Two nurses with solid knowledge regarding the management of TBI at their hospital also responded (3.3%).

Fifty-one out of sixty-one hospitals manage both adults and children (78.5%).

4.1.2 | Anesthesiologic, neurosurgical, and radiological accessibility

A total of 60 hospitals (98.4%) always have access to an anesthesiologist around the clock.

Six hospitals (9.8%) have access to a neurosurgeon at their location. In remaining hospitals, the transportation time to the nearest neurosurgical department varied. Nine hospitals (14.8%) have transportation time exceeding 2 h (as can be noted in Figure 2).

Accessibility to CT was high, with 58 hospitals (95.1%) having access to CT 24 h a day. The few remaining hospitals, exclusively district hospitals, have access to CT at specific times, mostly during office hours. Accessibility to MRI was low, with only six hospitals having access to MRI 24 h a day. The remaining hospitals had access at specific times, mostly during office hours.

4.2 | Initial care in the ED

4.2.1 | Clinical seniority and speciality

The level of clinical seniority when managing TBI varied, with a distinct predominance of nonspecialists managing these patients (Table 1). There was no significant difference between smaller and larger hospitals regarding the presence of specialists ($p = 0.08$). While residents and preresidents are a dominating category in the initial management of TBI, specialists are more frequently involved than in 1999 ($p < 0.00001$).

General surgeons and ED-physicians were the dominating specialties managing TBI (Table 2). Neurosurgeons and neurologists are rarely involved. University hospitals had a significantly higher presence of other departments than ED doctors and surgeons managing TBI in adults compared with smaller hospitals. ($p = 0.025$). While surgeons still are a dominating specialty managing TBI, they are significantly less common in this study than in 1999 ($p < 0.00001$).

Thirteen hospitals (21.3%) state that a nurse in some cases independently assesses and discharge patients in the ED after TBI. No statistical difference ($p = 0.204$) was found when comparing local/regional and university hospitals. Seven hospitals (53.8%) have a written protocol regarding this assessment.

4.3 | Guideline use

A total of 45/61 of the hospitals use a guideline (74%). Twelve hospitals (20%) did not use a guideline and three respondents (5%) did not consequently use a guideline (Table 3). There was no statistically significant difference between smaller hospitals (local and regional) and university hospitals ($p = 0.0997$).

As can be noted in Table 4:

TABLE 1 Level of experience of responsible clinician.

	District hospitals *n* (%)	Regional hospitals *n* (%)	University hospitals *n* (%)	Total *n* (%)
Preresidents	38 (118)	27 (142)	8 (80)	73 (120)
Residents	18 (56)	17 (89)	7 (70)	43 (70)
Specialist	9 (28)	4 (21)	6 (60)	19 (31)

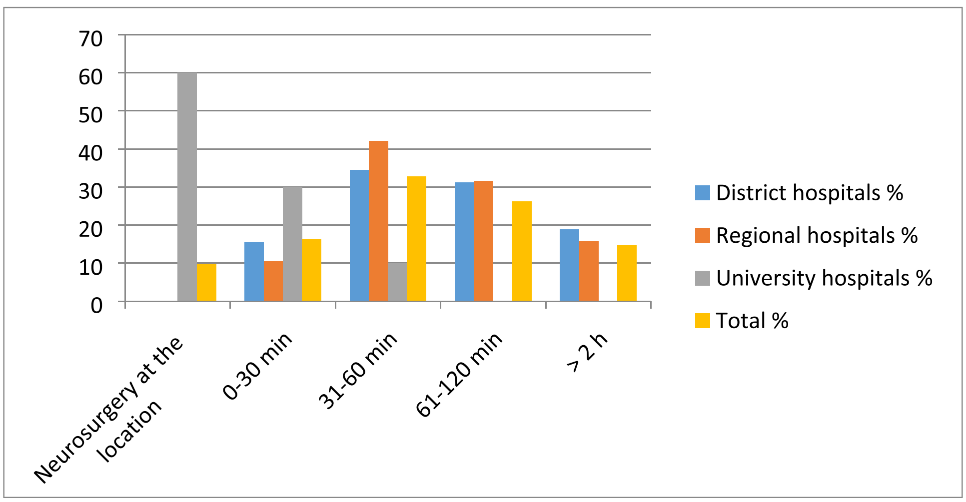

FIGURE 2 Transportation time to the nearest neurosurgical clinic. Response rate 61/61 (100%).

TABLE 2 Responsible speciality.

	District hospitals *n* (%)	Regional hospitals *n* (%)	University hospitals *n* (%)	Total *n* (%)
Surgeons	23 (72)	17 (89)	4 (40)	44 (72)
ED	11 (34)	7 (37)	7 (70)	25 (41)
Neuro	0 (0)	0 (0)	1 (10)	1 (2)
Others	5 (16)	0 (0)	4 (40)	9 (15)

Abbreviation: ED, emergency department.

TABLE 3 "Do you apply a guideline"?

	District hospitals *n* (%)	Regional hospitals *n* (%)	University hospitals *n* (%)	Total *n* (%)
Yes	23 (71.9)	12 (66.7)	10 (100)	45 (75)
No	7 (21.9)	5 (27.8)	0 (0)	12 (20)
Unsure	2 (6.2)	1 (5.6)	0 (0)	3 (5)

Note: Response rate 60/61 (98.4%).

TABLE 4 Choice of guideline.

	District hospitals *n* (%)	Regional hospitals *n* (%)	University hospitals *n* (%)	Total *n* (%)
SNC-13	6 (26.1)	7 (63.6)	7 (70)	20 (45.5)
Locally constructed guideline/ routine	9 (39.1)	3 (27.3)	4 (40)	16 (36.4)
Another guideline	8 (34.8)	1 (9.1)	1 (70)	10 (22.7)
Guideline based on expert opinion	6 (26.1)	1 (9.1)	2 (20)	9 (20.5)
Canadian Head CT rule	3 (13)	3 (27.3)	3 (30)	9 (20.5)
Nexus II	1 (4.3)	1 (9.1)	1 (10)	3 (6.8)
SNC-00	1 (4.3)	0 (0)	0 (0)	1 (2.3)
New Orleans-criteria (NOC)	0 (0)	0 (0)	0 (0)	0 (0)
ACEP Clinical Policy	0 (0)	0 (0)	0 (0)	0 (0)

Note: Response rate 44/45 (97.8%).

- Twenty hospitals used the SNC-13 guideline (45.5% of hospitals applying a guideline and 32.8% of all hospitals in this study).
- Nine hospitals used the Canadian Head CT Rule (20.5% of hospitals applying a guide line and 14.8% of all hospitals in this study).
- Nine hospitals (20.5% of hospitals applying a guideline and 14.8% of all hospitals in this study) used a locally constructed guideline, often based upon expert opinion within the hospital rather than an evidence-based guideline.
- Three hospitals applied Nexus II (6.8% of hospitals applying a guideline and 5% of all hospitals in this study).
- One hospital applied SNC-00 (2.3% of hospitals applying a guideline and 1.6% of all hospitals in this study).
- Sixteen hospitals (36.4% of hospitals applying a guideline and 26.2% of all hospitals in this study) used a local modification of a pre-existing validated guideline.
- None used New Orleans criteria's or the ACEP Clinical Policy.

4.4 | Further management and diagnostic tools

The most frequently used scales of consciousness were RLS (78.3%) and GCS (56.7%), applied individually or in combination. Three hospitals use the AVPU-scale.

CT is the radiological modality ($n = 61$) used by every responding hospital in the initial diagnostic stage, when available. Thirty-two hospitals address the occurrence of sedating adult patients with TBI prior or during CT (53.3%, response rate 98.4%).

Routines regarding the need for blood sample analyses vary. Twenty-two hospitals (32.7%) analyze blood samples from all adult patients with TBI on a routine basis. Thirty-eight hospitals (63%) take blood samples depending on the condition of the patient.

Twenty-two hospitals could potentially analyze S100B (53%, response rate 67.2%), 21 of these hospitals use the SNC-13 guideline. However, only eight of these hospitals (38.1%) routinely used S100B. Some positive response, but mostly skepticism toward S100B was brought up by the responders.

4.5 | Admission criteria and observation routines

A total of 53/61 hospitals (86.9%) have the possibility to admit patients for observation at their own hospital, including the ED. Most districts hospitals ($n = 25$, 78%) have this possibility, with the remaining hospitals admitting patients to another, larger hospital.

Patients are most often observed in an emergency ward (39.6%) or a general ward (37.7%) (see Figure 3). Level of consciousness, trauma mechanism, CT results, clinical status, and presence of intoxication were described as factors decisive for the choice of ward.

Level of consciousness (100%), pupil reaction (96.2%), pulse/ blood pressure (94.3%), and neurological status (71.7%) are the most frequently reported observation parameters monitored during admission (see Figure 4). The frequency and duration of monitoring during observation were often decided by a doctor or according to a local routine (Table 5).

4.6 | Discharge criteria and follow-up

Among hospitals with the possibility for observation, 15 hospitals (28.9%) applied criteria that need to be fulfilled before patients could be discharged (Table 6).

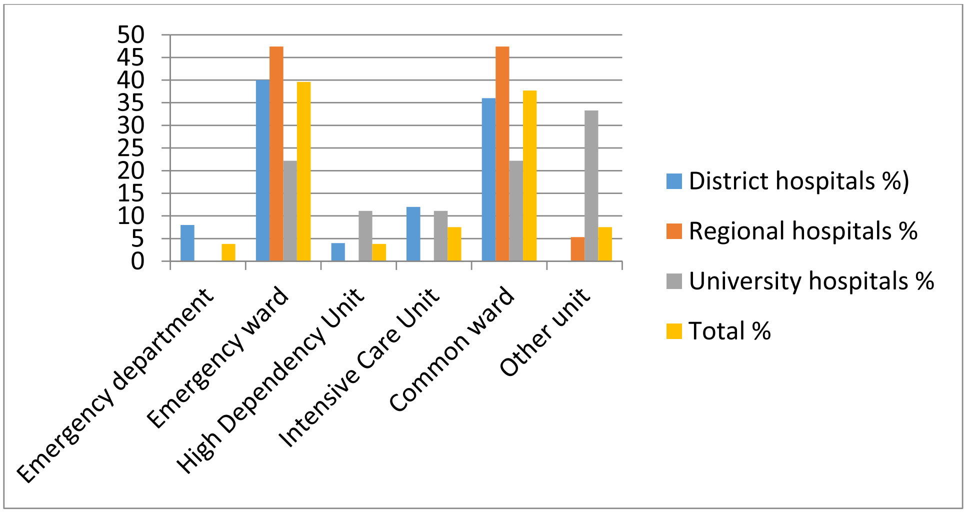

FIGURE 3 Primary choice of ward. Response rate 53/53 (100%).

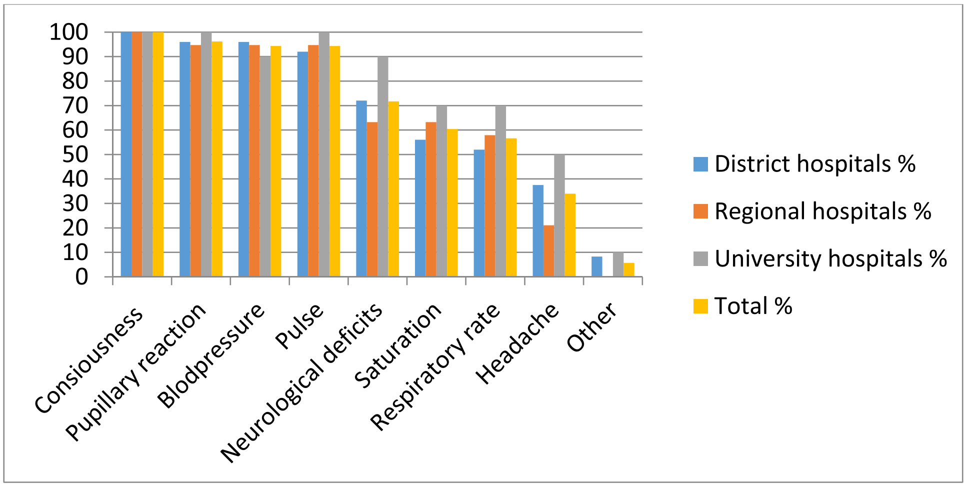

FIGURE 4 Parameters evaluated during in-hospital observation due to head trauma. Response rate 53/53 (100%).

TABLE 5 Factors for how often and for how long controls are performed during the observation period.

	District hospitals *n* (%)	Regional hospitals *n* (%)	University hospitals *n* (%)	Total *n* (%)
"Doctors choice"	11 (47.8)	13 (68.4)	2 (22.2)	26 (51)
Locally produced guideline	8 (34.8)	6 (31.6)	3 (33.3)	17 (33.3)
SNC 2013 guideline	6 (26.1)	2 (10.5)	5 (55.5)	13 (25.5)
Other	1 (4.3)	2 (10.5)	0 (0)	3 (5.9)
Unsure	1 (4.3)	0 (0)	1 (11.1)	2 (3.9)
No routine available	0 (0)	0 (0)	0 (0)	0 (0)

Note: Response rate 51/53 (96.2%).

TABLE 6 Discharge criteria.

	District hospitals *n* (%)	Regional hospitals *n* (%)	University hospitals *n* (%)	Total *n* (%)
Yes	5 (20.8)	6 (31,6)	4 (44.4)	15 (28.8)
No	19 (79.2)	13 (68.4)	5 (55.6)	57 (71.2)

Note: Response rate 52/53 (98.1%).

Twenty-nine hospitals (47.5%) occasionally provided follow-up after TBI but none did this on a routine basis (Table 7). There was no statistical difference between large and small hospitals ($p = 0.262$). There was an even spread between telephone calls (34.5%), revisit to an outpatient clinic (55.2%), or referral to another clinic (55.2%). In 25 hospitals (41%), follow-up is never done.

TABLE 7 "Are adults with head trauma followed up after being discharged by you or another healthcare institution?"

	District hospitals *n* (%)	Regional hospitals *n* (%)	University hospitals *n* (%)	Total *n* (%)
Yes, always	0 (0)	0 (0)	0 (0)	0 (0)
Yes, occasionally	15 (46.9)	8 (42.1)	6 (60)	29 (47.5)
No	13 (40.6)	10 (52.6)	2 (20)	25 (41)
Unsure	4 (12.5)	1 (5.3)	2 (20)	7 (11.5)

Note: Response rate 61/61 (100%).

TABLE 8 "Is information given to the patient regarding concussion/head injuries when he or she leaves the hospital?"

	District hospitals *n* (%)	Regional hospitals *n* (%)	University hospitals *n* (%)	Total *n* (%)
Yes—orally	3 (9.4%)	3 (15.8)	2 (20)	8 (13.1)
Yes—written	5 (15.6)	5 (26.3)	1 (10)	11 (18)
Yes—orally and written	21 (65.6)	11 (57.9)	6 (60)	38 (62.3)
No	1 (3.1)	0 (0)	0 (0)	1 (1.6)
Unsure	2 (6.3)	0 (0)	1 (10)	3 (4.9)

Note: Response rate 61/61 (100%).

Fifty-seven hospitals (93.4%) provided information to patients before discharge (Table 8). Information was provided orally (13.1%), written (18%), or combined (62.3%). For example, information regarding diagnosis, expected recovery time and instructions regarding escalation of activity level are given. A smaller number of hospitals apply discharge criteria in this study compared with 1999 ($p < 0.00001$).

5 | DISCUSSION

Seven years after the introduction of SNC-13, there are still considerable variations in the management of TBI in Swedish hospitals. There does not seem to be any broad nationwide consensus regarding initial management, use of guideline/-s or follow-up. However, only one significant difference was noticed when comparing local, district, and university hospitals through the collected data. This seems to indicate an acceptable level of equality in TBI care within the Swedish health care system, at least when having hospital size and its resources in mind.

More hospitals use a guideline when compared with earlier studies.[19] However, one out of five hospitals in this study still did not use a guideline and only 45% of hospitals applying a guideline use the updated Scandinavian guideline, SNC-13. Although there is no evidence to support one guideline over another in Sweden, the fact that some hospitals do not use a guideline at all is worrying, as the use of TBI guideline increases patient safety.[21,22]

Ideally, relevant clinical guidelines should be validated side-by-side in a prospective, national, and representative cohort before any can be fully recommended. These results will also likely improve compliance and enhance standardization of management. Such an effort is underway in Sweden.

These patients are almost exclusively managed by only two specialities in Sweden; general surgery and emergency medicine. The gradual introduction and growth of emergency medicine as a speciality in Sweden is reasonably the reason for the decrease in general surgery management. As previous studies have shown, TBI is initially still managed by nonspecialist doctors and often interns. This fact stresses the need of a reliable and robust guideline, as most of these doctors will lack sufficient clinical experience to safely and efficiently manage these patients.

There is a high availability to both CT scanning and anesthesiology competence around the clock. The availability to neurosurgical competence varies due to geographical aspects. The use of S100B has not been widely introduced in daily practice, despite being included as an option in the SNC-13 guidelines and there seems to be skepticism toward the use of this biomarker. The main reason for this seems to be the insufficient specificity of the biomarker in this clinical setting.[23] To improve the management of mTBI, a novel predictive tool is needed. As for all other organ systems, it is reasonable that a reliable biomarker will be very useful for clinical guidance. S100B is safe and cost-effective,[24–27] but the low specificity seems to limit practical use. Newer biomarkers with higher specificity may, together with S100B, effectively reduce CT scanning in lower risk patients.[28] Also, efforts concerning barriers and facilitators regarding biomarkers (and other aspects of compliance) in this patient group need to be studied and such an effort is currently underway.

More than 40% of the hospitals do not perform follow-ups of adult patients with TBI. However, 93% of the hospitals provide some kind of information during discharge, 13% only provide it orally. As only a subset of patients have issues with postconcussion syndrome (PCS), predictive scores may be useful to identify which patients may benefit from a structured follow-up.[29,30] One study indicated that PCS may decrease quality of life, especially in the elderly; frequently reported symptoms over time were dizziness, sleep disturbances, fatigue, and forgetfulness.[31]

The strengths of the study include the high response rate and overall completeness of data. A potential weakness may be that many of the respondents are ED doctors and may lack complete knowledge regarding observation routines and follow-up. However, we stressed in the survey that the respondent should seek out the required information in their respective hospital. Misinterpretation of some questions may have occurred.

6 | CONCLUSION

Management of head injuries in Sweden is generally performed using established guidelines or decision rules and this practice has increased over time. However, some of these guidelines are outdated and several hospitals used local guidelines not based upon a satisfactory evidence base. Most patients with TBI are managed by nonspecialist doctors, stressing the need of a robust guideline. Despite good evidence and guideline support, many hospitals still admit patients for observation instead of using CT.

AUTHOR CONTRIBUTIONS

Albert Modin: Writing—original draft. **Fredrik Wickbom**: Resources; Software; review and editing. **Christian Kamis**: Resources. **Johan Undén**: Resources; Supervision; writing—review & editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request. These datasets would be anonymized as this was a condition for the survey protocol.

ETHICS STATEMENT

All methods were carried out in accordance with relevant guidelines and regulations. No information was obtained from patient journals during the course of this study and no individual patient data is used. Questions concerning the management of TBI through general terms are obtained by a questionnaire. The national Ethics Review Board approved the study in the form of expert opinion, record number 2020-02693. Only for identifying information/images of patients or participants; otherwise NA.

TRANSPARENCY STATEMENT

The lead author Albert Modin affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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REFERENCES

1. En akut bild av Sverige. Kartläggning av akutsjukvårdens organisation och arbetsfördelning - Myndigheten för vård- och omsorgsanalys (2018).
2. Health at a Glance 2019 - OECD Indicators.
3. Cassidy JD, Carroll L, Peloso P, et al. Incidence, risk factors and prevention of mild traumatic brain injury results of the WHO collaborating centre task force on mild traumatic brain injury. *J Rehabil Med*. 2004;36(43 suppl):28-60.
4. Sundstrøm T, Sollid S, Wester K. Deaths from traumatic brain injury in the Nordic countries, 1987-2000. *Tidsskr Nor Laegeforen*. 2005;125(10):1310-1312.
5. Ingebrigtsen T, Romner B, Kock-Jensen C. Scandinavian guidelines for initial management of minimal, mild, and moderate head injuries. *J Trauma*. 2000;48(4):760-766.
6. Statement concerning the increased use of computed tomography in the nordic countries—The Nordic Radiation Protection co-operation. Accessed 30 August, 2021. http://nordicxray.gr.is/PublishedFiles/2012%20Statement%20concerning%20the%20increased%20use%20of%20computed%20tomography.pdf
7. Hall EJ, Brenner DJ. Cancer risks from diagnostic radiology. *Br J Radiol*. 2008;81(965):362-378.
8. Brenner DJ, Hall EJ. Computed tomography—an increasing source of radiation exposure. *N Engl J Med*. 2007;357:2277-2284.
9. Sadetzki S, Chetrit A, Freedman L, Stovall M, Modan B, Novikov I. Long-term follow-up for brain tumor development after childhood exposure to ionizing radiation for tinea capitis. *Radiat Res*. 2005;163(4):424-432.
10. Preston DL. Tumors of the nervous system and pituitary gland associated with atomic bomb radiation exposure. *CancerSpectrum Knowledge Environment*. 2002;94(20):1555-1563.
11. Bondy ML, Scheurer ME, Malmer B, et al. Brain tumor epidemiology: consensus from the brain tumor epidemiology consortium. *Cancer*. 2008;113(7 suppl):1953-1968.
12. Davis F, Il'yasova D, Rankin K. Medical diagnostic radiation exposures and risk of gliomas. *Radiat Res*. 2011;175(6):790-796.
13. Almén Anja, Leitz Wolfram, Richter Sven. National survey on justification of CT-examinations in Sweden. Report number: 2009:03.
14. Undén J, Ingebrigtsen T, Romner B. Scandinavian guidelines for initial management of minimal, mild and moderate head injuries in adults an evidence and consensus-based update. *BMC Med*. 2013;11:50.
15. Undén J, Romner B. A new objective method for CT triage after minor head injury–serum S100B. *Scand J Clin Lab Invest*. 2009;69(1):13-17.
16. Müller K, Townend W, Biasca N, et al. S100B serum level predicts computed tomography findings after minor head injury. *J Trauma*. 2007;62(6):1452-1456.
17. Calcagnile Olga, Holmén Anders. Michelle chew and Johan undén. S100B levels are affected by older age but not by alcohol intoxication following mild traumatic brain injury. *Scand J Trauma Resusc Emerg Med Actions*. 2013;21:52.
18. Ingebrigtsen T, Romner B. Management of minor head injuries in hospitals in Norway. *Acta Neurol Scand*. 1997;95(1):51-55.
19. Bellner J, Ingebrigtsen T, Romner B. Survey of the management of patients with minor head injuries in hospitals in Sweden. *Acta Neurol Scand*. 1999;100(6):355-359.
20. Bellner J, Ingebrigtsen T, Romner B. Routines required for management of minor head injuries. *Lakartidningen*. 1999;96(47):5196-5198.
21. Elmoheen A, Salem W, Bashir K. Reducing unnecessary CT scan of the head for minor paediatric head injuries at the emergency department. *BMJ Open Qual*. 2021;10(1):e000973. doi:10.1136/bmjoq-000973
22. Kuppermann N, Holmes JF, Dayan PS, et al. Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study. *Lancet*. 2009;374(9696):1160-1170.
23. Undén J, Bellner J, Eneroth M, Alling C, Ingebrigtsen T, Raised BR. serum S100B levels after acute bone fractures without cerebral injury. *J Trauma*. 2005;58(1):59-61.

24. Undén L, Calcagnile O, Undén J, Reinstrup P, Bazarian J. Validation of the scandinavian guidelines for initial management of minimal, mild and moderate traumatic brain injury in adults. *BMC Med*. 2015;13:292.
25. Calcagnile O, Anell A, Undén J. The addition of S100B to guidelines for management of mild head injury is potentially cost saving. *BMC Neurol*. 2016;16(1):200.
26. Seidenfaden SC, Kjerulff JL, Juul N, et al. Diagnostic accuracy of prehospital serum S100B and GFAP in patients with mild traumatic brain injury: a prospective observational multicenter cohort study—"the PreTBI I study". *Scand J Trauma Resusc Emerg Med*. 2021;29(1):75.
27. Rogan A, O'sullivan MB, Holley A, McQuade D, Larsen P. Can serum biomarkers be used to rule out significant intracranial pathology in emergency department patients with mild traumatic brain injury? A systemic review & meta-analysis. *Injury*. 2022;53(2):259-271.
28. Amoo M, Henry J, O'Halloran PJ, et al. S100B, GFAP, UCH-L1 and NSE as predictors of abnormalities on CT imaging following mild traumatic brain injury: a systematic review and meta-analysis of diagnostic test accuracy. *Neurosurg Rev*. 2022;45(2):1171-1193.
29. Hou R, Moss-Morris R, Peveler R, Mogg K, Bradley BP, Belli A. When a minor head injury results in enduring symptoms: a prospective investigation of risk factors for postconcussional syndrome after mild traumatic brain injury. *J Neurol Neurosurg Psychiatry*. 2012;83(2):217-223.
30. Skandsen T, Stenberg J, Follestad T, et al. Personal factors associated with postconcussion symptoms 3 months after mild traumatic brain injury. *Arch Phys Med Rehabil*. 2021;102(6):1102-1112.
31. Jia-Wei Chung, Doresses Liu, Li Wei, et al. Postconcussion symptoms after an uncomplicated mild traumatic brain injury in older adults: frequency, risk factors, and impact on quality of life. *J Head Trauma Rehab*. 2022;37(5):278-284.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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