ORIGINAL ARTICLE

A meta-analysis of GCS 15 head injured patients with loss of consciousness or post-traumatic amnesia

J Batchelor, A McGuinness

Emerg Med J 2002;19:515-519

See end of article for
authors' affiliations

Correspondence to:
Mr J S Batchelor,
Department of Emergency
Medicine, Manchester
Royal Infirmary, Oxford
Road, Manchester
M13 9WL, UK;
johnbatchelor@msn.com

Accepted for publication
29 October 2001

Objectives: The classification of patients with "minor head injury" has relied largely upon the Glasgow Coma Scale (GCS). The GCS however is an insensitive way of defining this heterogeneous subgroup of patients. The aim of the study was to develop an extended GCS 15 category by meta-analysis of previously published case-control studies that have identified symptom risk factors for an abnormal head tomogram.

Methods: Eligibility for the study was defined as: (1) Full papers and not abstracts. (2) Case-control or nested case-control studies on GCS 15 patients (adults or adults plus children). Outcome variable being head tomography: normal or abnormal. (3) Documentation of one or more symptom variables such that the odds ratio could be calculated. Five symptom variables were defined for the purpose of the study: headache, nausea, vomiting, blurred vision, and dizziness.

Results: Three articles fulfilled the criteria for the study. The Mantel-Haenszel test using a pooled estimate was used to calculate the common odds ratio for an abnormal head tomogram for each of the five symptom variables. The odds ratio for the symptom variables was: dizziness 0.594 (95%CI 0.296 to 1.193), blurred vision 0.836 (95%CI 0.369 to 1.893), headache 0.909 (95% CI: 0.601 to 1.375), severe headache 3.211 (95% CI: 2.212 to 4.584), nausea 2.125 (95% CI 1.467 to 3.057), vomiting 4.398 (95% CI 2.790 to 6.932).

Conclusion: The results of this study provide a framework on which GCS category 15 patients can be stratified into four risk categories based upon their symptoms.

The Glasgow Coma Scale (GCS) was first published by Teasdale and Jennett¹ in 1974. Several years later a simple classification system to define head injury severity that was based upon the GCS was subsequently developed by Jennett and Teasdale² and by Rimel *et al.*^{3,4} Minor head injuries were defined as a GCS of 13-15 in this system. Culotta *et al.*⁵ in 1996 following a retrospective study found that patients with a GCS of 13-15 represented a heterogeneous group of patients with statistically significant different head tomography abnormality rates. Culotta *et al.*⁵ on the basis of their findings suggested separating patients with GCS 13-14 into a different category from patients with a GCS 15, thus effectively redefining minor head injury. These findings were confirmed by a similar study by Gomez *et al.*⁶ Hsiang *et al.*⁷ in 1997 on the basis of a cohort study of 1360 patients with GCS 13-15 suggested that this group of patients could also be divided into two subgroups: mild head injury and high risk mild head injury. Mild head injury being defined as GCS 15 without radiographic abnormalities. High risk mild head injury being defined as GCS 13-14, or a GCS 15 with acute radiographic abnormalities. More recently Swann and Teasdale⁸ recognising the limitation of the GCS with regard to minor head injury have suggested another subclassification. Mild head injury being defined as GCS 13-14. Minor head injury being defined as GCS 15. The authors recognised in their monograph that this is a somewhat arbitrary definition. More importantly however is that this classification system also fails to resolve the fact that GCS 15 patients also represent a heterogeneous group of patients.

The aim of the study was to determine the common odds ratio for an abnormal head tomogram in GCS 15 patients with loss of consciousness (LOC) or post-traumatic amnesia (PTA) and one of five symptom variables; headache, nausea, vomiting, blurred vision, or dizziness.

METHOD

Criteria for selecting studies

Full papers and not abstracts. Case-control or nested case-control studies on GCS 15 patients (adults or adults plus children) with LOC or PTA, all of whom underwent a head tomogram (abbreviated form CT). The indication for head tomography being LOC or PTA. Documentation of one or more symptoms such that a 2x2 contingency table could be constructed. Five symptoms were defined for the purpose of the study; (1) headache, (2) nausea, (3) vomiting, (4) blurred vision, (5) dizziness. The control group being GCS 15 with LOC/PTA but without the symptom variable.

Search strategy

The following databases were searched Medline, and PubMed, January 1990 to February 2001. The following words or phrases were used in the search: minor head injury OR mild head injury OR Glasgow Coma Scale OR traumatic brain injury. Cross referencing from relevant articles and hand searching of journals was also performed. The following journals were hand searched: *Journal of Trauma*, *Critical Care Medicine*, *Annals of Emergency Medicine*, *Emergency Medicine Journal*, *Neurosurgery*, and the *British Journal of Neurosurgery*. A more focused search was performed on the Medline database using the OVID interface; Craniocerebral trauma/cl, di, ra [Classification, Diagnosis, Radiography] LIMIT to human AND abstracts.

Review procedures

A decision to include or exclude a study was made by the author of this monograph using the inclusion criteria defined

Abbreviations: GCS, Glasgow Coma Score; LOC, loss of consciousness; PTA, post-traumatic amnesia

Table 1 Results of search strategy

Author	Study design	Size of cohort	CT abnormality rate (%)	Neurosurgical intervention rate (%)
Jeret <i>et al</i> 1993	Prospective cohort	712	9.4	0.28
Miller <i>et al</i> 1997	Prospective cohort	2143	6.4	0.2
Haydel <i>et al</i> 2000	Prospective cohort	520	6.9	0.4

above. The suitability of the papers for inclusion was also based upon whether all patients in the cohort underwent head tomography, clearly defined definitions, and the availability of data to enable the odds ratios to be calculated by the author of this monograph.

Statistical methods

A pooled estimate (random effect model) for the common odds ratio was performed using the Mantel-Haenszel test. Before calculating the common odds ratio the Breslow-Day test for homogeneity of the odds ratio was performed. The analysis was performed using SAS version 6.12 (SAS Institute, Inc, Cary, North Carolina).

RESULTS

The Medline search using the OVID interface produced 243 full papers of which two fulfilled the inclusion criteria (table 1). A third paper that fulfilled the inclusion criteria was identified by cross referencing (Jeret *et al*⁹, table 1). The study by Jeret *et al*⁹ was a cohort study of 712 consecutive patients over the age of 17 years with PTA or LOC. The study by Miller *et al*¹⁰ was a cohort study of 2143 consecutive patients of all ages

with PTA or LOC. The study by Haydel *et al*¹¹ was a cohort study of 520 consecutive patients who were at least 3 years of age with GCS 15 and LOC. The study design, the CT abnormality rate and the neurosurgical intervention rate are shown in table 1. The likelihood ratio and the post-test probability (for an abnormal head scan) for each of the symptom variables are shown in table 2. The variables available for analysis (by author) are shown in tables 3. The Breslow-Day test for homogeneity of the odds ratio (for an abnormal head scan) showed that only the headache variable had any significant discordance (table 4). This was attributable to the large difference in the odds ratio between the Miller study and the other two studies (table 5). The Breslow-Day test for the homogeneity of the odds ratio was recalculated for the Jeret and Miller studies only. This result showed no significant discordance between the odds ratios of the two studies. An odds ratio was calculated for the symptom severe headache (Miller study only) and also a common odds ratio for the symptom headache (Jeret and Miller study). Figure 1 shows that only the severe headache, nausea, and vomiting variables resulted in a statistically significant increase in the odds ratios for an abnormal head scan.

Table 2 Likelihood ratios and post-test probability for an abnormal CT scan for each symptom variable

Symptom variable	Likelihood ratio	Post-test probability
Dizziness	0.643	0.046
Blurred vision	0.85	0.06
Nausea	1.98	0.13
Vomiting	4.17	0.24
Headache	1.009	0.07
Severe headache	2.98	0.18

The common (average) pre-test probability was calculated to be 0.075.

Table 3 Symptom variables as a percentage of the dataset (by author)

Author	Headache	Vomiting	Nausea	Dizziness	Blurred vision
Jeret	58	7	15	23	13
Miller	32.3	5.7	10.2		
Haydel	24	9			

Table 4 Breslow-Day test for homogeneity of the odds ratio for an abnormal CT scan

Symptom	χ^2 Value	DF	p Value
Headache (Jeret, Miller, Haydel)	25.087	2	0.001
Headache (Jeret, Haydel)	4.188	1	0.041
Vomiting	3.371	2	0.185
Nausea	1.466	1	0.226

DISCUSSION

The three studies included in the meta-analysis showed similar neurosurgical intervention rates but some variation in the overall incidence of abnormal CT scans. Variations in thresholds for inclusion may explain some of the variation in the CT abnormality rates. For instance the Haydel study¹¹ included only patients with LOC in contrast with the Jeret⁹ and Miller¹⁰ study that included patients with both LOC and PTA. The main difference between the three studies however

Table 5 Unweighted odds ratio for an abnormal CT scan (by author), for the five symptom variables

Author	95%CI
(headache*)	
Jeret	0.675
Miller	3.211
Haydel	1.688
(nausea*)	
Jeret	1.504
Miller	2.432
(vomiting*)	
Jeret	1.898
Miller	3.384
Haydel	1.282
(dizziness*)	
Jeret	0.594
(blurred vision*)	
Jeret	0.836

*Unweighted odds ratio for an abnormal CT scan.

Figure 1 Pooled odds ratio for an abnormal CT scan by symptom.

was that the Jeret⁹ study included patients who were 18 years or over, while the Miller¹⁰ and Haydel¹¹ studies both included children.

A pooled (random effects model) rather than a fixed effect model was used to calculate the common odds ratio because the three studies were similar in size and the Breslow-Day test showed no significant discordance between the odds ratios. All studies in the meta-analysis were nested case-control type studies and in all three studies some patients had more than one symptom. A fundamental assumption being made is that the distribution of the symptom variables is the same in both groups. A true nested case-control meta-analysis (that is, patients with LOC/PTA and no symptoms (control group) compared with those with LOC/PTA and only one symptom (test group)) was not undertaken by the author because the data were not available in any of the monographs. There is no reason to believe that publication bias is likely to be a significant problem in this meta-analysis although inclusion of full articles only might have resulted in loss of some potentially useful additional data.

None of the three studies distinguished between patients with a single vomit and patients with repeated vomiting. Data from a cohort study of 10 000 head injured patients by Arienta *et al*¹² showed that patients with a single vomit had a much lower risk of an abnormal CT scan when compared with patients with repeated episodes of vomiting (3% versus 43% (χ^2 26.25, $p=0.001$, the χ^2 test was calculated by the author of this monograph).

Despite some of the limitations previously discussed the results of this study suggest that the variables severe headache, nausea, and vomiting may be important risk factors in predicting abnormal CT scan in GCS 15 patients with LOC/PTA. Several other authors have looked at the relation between head injury symptoms and abnormal CT rates. Nagy *et al*¹³ performed a prospective study of 1170 patients with GCS 15 and LOC. A comparison of patients with normal scans to those with abnormal scans showed that the abnormal group was more likely to have headache, nausea, vomiting, dizziness, or seizures (12.5% versus 2.1%; $p=0.002$; Fisher's exact χ^2 test). These four symptoms were analysed as a group rather than in isolation. Hsiang *et al*⁷ prospectively evaluated 1177 GCS 15 patients and also performed a subset analysis of patients with vomiting. Their results showed that there was no difference between the vomiting group and the non-vomiting group with regard to CT abnormality rates. Unfortunately the study was flawed because only 58% of the GCS 15 patients underwent CT. Lee *et al*¹⁴ also prospectively evaluated 1812 GCS 15 patients. A CT scan was only performed if the patient deteriorated neurologically. Lee *et al*¹⁴ found that the relative risk of neurological deterioration was 15.4 times greater in patients

with vomiting and 7.3 times greater in patients with headache.

The presence of LOC or PTA is currently used as a means of triaging GCS 15 patients either for inpatient observation or head tomography. Stein *et al*¹⁵ was one of the first authors to use LOC/PTA as a means of triaging GCS 15 patients based upon a retrospective study of 1538 patients. Miller *et al*¹⁶ performed a similar study to Stein *et al*¹⁵ and found that the overall CT abnormality rate was 6.1%, compared with 13.2% in the study by Stein *et al*¹⁵. If patients with signs or symptoms of a skull fracture were excluded the CT abnormality rate was only 3% in the Miller study. Miller *et al*¹⁶ questioned the validity of performing head tomography on all patients in category GCS 15 with only LOC/PTA because of the low rate of abnormal CT scans and zero neurosurgical intervention rate in their study. A follow up study¹⁰ on an extended version of the same dataset identified four risk factors for abnormal CT scans in GCS 15 patients. The four risk factors being severe headache, nausea, vomiting, and evidence of a depressed skull fracture on clinical examination. Using the same dataset the four risk factors resulted in a sensitivity rate of 65% and a specificity rate of 63%. Haydel *et al*¹¹ in their prospective study identified seven risk factors for predicting abnormal CT scans in GCS 15 patients (short-term memory deficit, drug, or alcohol intoxication, age >60 years, seizure, headache, vomiting, and evidence of trauma above the clavicles). These seven risk factors were applied to a second dataset of 909 GCS 15 patients. All patients with a positive CT scan ($n=57$) had a least one of the risk factors. Stiel *et al*^{17,18} have also developed a clinical decision rule for head tomography in patients with minor head injury (defined as GCS 13–15). They also identified repeated vomiting as being an important risk factor. Arienta *et al*¹² using multivariate analysis identified a variety of signs, symptoms, and conditions as risk factors for identifying abnormal CT scans in head injured patients. They proposed a new classification for head injured patients based upon the combination of identified risk factors and the GCS. Their classification system (groups α , β , γ , δ) although evidenced based does have some limitations. A GCS 15 patient with a generalised headache is not classifiable by their system. Their management strategy based upon this classification system may result in a large number of unnecessary head scans because all patients with LOC, PTA, or a single vomit, undergo head tomography.

The results of this meta-analysis and data from the Arienta study¹² provide a basic framework for stratifying GCS category 15 patients into four groups: GCS 15a, GCS 15b, GCS 15c, and GCS 15d based upon symptom variables previously analysed. The fulcrum for this stratification is based around the odds ratio for a symptom variable in GCS 15 patients with LOC/PTA. Category GCS 15a represents head injured patients who have been asymptomatic up to the time of presentation (very small risk). Head injured patients with (or who have experienced) symptoms of dizziness, blurred vision, or mild headache are classified as GCS 15b (low risk—that is, no significant increase in the odds ratio compared with the GCS 15 with LOC/PTA group). Head injured patients with LOC or PTA are classified as GCS 15c (intermediate risk). Patients with severe headache, persistent nausea, or more than one vomit are classified as GCS 15d (high risk category for abnormal head tomography; significant increase in the odds ratio for an abnormal scan).

An initial management algorithm based upon this framework has been developed (fig 2). The management algorithm also incorporates other non-symptom high risk factors. Patients with high risk factors (fig 2) automatically fall into GCS 15d category. More than one vomit was used as a "high risk factor" based upon the data from the Arienta study¹² as discussed previously. It is not clear at the present time what the relative risk (or odds ratio) is for an abnormal CT scan in patients with a single vomit. The definition of severe headache is the same one as used by Miller *et al*¹⁶—that is, defined on

†The indications for a SXR are based upon the recommended guidelines from the Institute of Neurosurgery, Queens Square, UCLH Trust, London.

- (1) Scalp swelling, bruising or laceration suggestive of an underlying fracture.
- (2) Loss of consciousness (LOC) or post-traumatic amnesia (PTA).
- (3) Violent mechanism of injury.

If clinically indicated skull radiographs should be performed early to prevent a delay in CT in those patients who are found to have a fracture on skull radiography.

Figure 2 Initial management algorithm for GCS category 15 patients.

patient questioning by comparison to a mild or moderate headache. The use of the word “high risk” is a relative one in view of the fact that less than 1% of GCS 15 patients in all three studies required neurosurgical intervention. This fact is also apparent from table 2, which shows that the post-test probability for an abnormal head CT is still low even for “high risk” symptom variables. Rimel *et al*⁹ in 1981 found from a cohort study of patients with minor head injury (defined as GCS 13–15) that 59% had memory problems three months after injury. A more recent study by Thornhill *et al*¹⁰ has also shown that a significant proportion (47%) of patients with minor head injuries (defined as GCS 13–15) had significant disability 12 months after injury.

The question of age (elderly patients) as a risk factor remains unclear. A retrospective study was performed by Nagurney *et al*²⁰ on 1649 GCS 15 patients all of whom underwent head tomography. Twenty per cent in the elderly group (> 60 years) had an abnormal CT scan compared with 13% in the non-elderly group. The difference was statistically significant. The Nagurney study²⁰ used several criteria for head tomography and so it is not possible to calculate an odds ratio for elderly patients with GCS 15 and LOC/PTA. Age has been advocated as a “triage” risk factor for head tomography in GCS 15 patients by some authors (Haydel *et al*¹¹) but not by others (Arienta *et al*¹², Miller *et al*¹⁰). The Haydel study¹¹ identified increased age as a risk factor using recursive partitioning analysis. The odds ratio from the Haydel study¹¹ for elderly patients suggests however that it may not be a statistically significant risk factor (odds ratio=2.498; 95%CI 0.972 to 6.371; authors’ calculation). Thus although there is some evidence to show that elderly patients are more likely to have abnormal head tomograms after head trauma there is no strong evidence at the present time to suggest that the threshold for head tomography should be any lower in this group of patients. Similarly coagulation problems (for example, warfarin) have also been advocated as a triage risk factor for head tomography by some authors (Arienta *et al*¹²) but not by others

(Miller *et al*,¹⁰ Haydel *et al*¹¹). Garra *et al*²¹ retrospectively reviewed 39 GCS 15 anticoagulated patients without LOC or neurological abnormalities all of whom underwent head tomography. None of the 39 patients was found to have an abnormal tomogram. Garra *et al*²¹ as a result of this study and a review of paediatric head trauma cases in haemophiliacs concluded that in the absence of LOC or neurological abnormalities head tomography is probably not warranted in this group of patients. There was no discussion however regarding patients with severe headache or vomiting. Brown *et al*²² retrospectively reviewed 124 GCS 15 anticoagulated patients without LOC all of whom underwent head tomography, 6% of the cases had positive scans. This study also failed to record the number patients with severe headache or vomiting. At the present time evidence that demonstrates the relation between head tomogram abnormality rates and patient symptoms is currently incomplete in this heterogeneous group of patients.

Although two of the studies in this meta-analysis included children the management algorithm has been developed for adults and not for children. The results of several studies^{23–27} suggest that headache, nausea, and vomiting are not predictive of intracranial abnormalities in this age group.

CONCLUSION

The common odds ratio based model for the subclassification and management of GCS 15 patients has yet to be fully evaluated. The advantage of this model over the triage risk factor model developed by Miller *et al*¹⁰ and Haydel *et al*¹¹ is that it provides a better framework for managing low and intermediate risk patients.

Contributors

Anne McGuinness discussed the core ideas and edited the final draft. The guarantors for the paper are Mr John Batchelor and Miss Anne McGuinness.

Authors’ affiliations

J Batchelor, A McGuinness, Department of Accident and Emergency Medicine, University College Hospital, London, UK

REFERENCES

- 1 Teasdale GM, Jennett B. Assessment of coma and impaired consciousness. *Lancet* 1974;ii:81–4.
- 2 Jennett B, Teasdale G. Aspects of coma after severe head injury. *Lancet* 1977;i:878–1.
- 3 Rimel RW, Giordani B, Barth JT, *et al*. Disability caused by minor head injury. *Neurosurgery* 1981;9:221–8.
- 4 Rimel RW, Giordani B, Barth JT, *et al*. Moderate head injury: completing the clinical spectrum of brain trauma. *Neurosurgery* 1982;11:344–51.
- 5 Culotta VP, Sementilli ME, Gerold K, *et al*. Clinicopathological heterogeneity in the classification of mild head injury. *Neurosurgery* 1996;38:245–50.
- 6 Gomez PA, Lobato RD, Ortega JM, *et al*. Mild head injury: differences in prognosis among patients with a Glasgow Coma Scale score of 13–15 and analysis of factors associated with abnormal CT findings. *Br J Neurosurg* 1996;10:453–60.
- 7 Hsiang JNK, Yeung T, Yu ALM, *et al*. High-risk mild head injury. *J Neurosurg* 1997;87:234–8.
- 8 Swan LJ, Teasdale GM. Current concepts in the management of patients with so-called ‘minor’ or ‘mild’ head injury. *Trauma* 1999;1:143–55.
- 9 Jeret JS, Mandell M, Anziska B, *et al*. Clinical predictors of abnormality disclosed by computed tomography after mild head trauma. *Neurosurgery* 1993;32:9–16.
- 10 Miller EC, Holmes JF, Derlet R. Utilising clinical factors to reduce head CT scan ordering for minor head trauma patients. *J Emerg Med* 1997;15:453–7.
- 11 Haydel MJ, Preston CA, Mills TJ, *et al*. Indications for computed tomography in patients with minor head injury. *N Engl J Med* 2000;343:100–5.
- 12 Arienta C, Caroli M, Balbi S. Management of head-injured patients in the emergency department: a practical protocol. *Surg Neurol* 1997;48:213–19.
- 13 Nagy KK, Joseph KT, Krosner SM, *et al*. The utility of head computed tomography after minimal head injury. *J Trauma* 1999;46:268–70.
- 14 Lee ST, Wong LCW, Yeh YS, *et al*. Relative risk of deterioration after mild closed head injury. *Acta Neurochir (Wien)* 1995;135:136–40.
- 15 Stein SC, Ross SE. Mild head injury: a plea for routine early CT scanning. *J Trauma* 1992;33:11–14.

- 16 **Miller EC**, Derlet RW, Kinser D. Minor head trauma: Is computed tomography always necessary? *Ann Emerg Med* 1993;**22**:1148–55.
- 17 **Stiel IG**, Lesiuk HJ, Vandemheen K, *et al*. A clinical decision rule for the use of CT head in patients with minor head injury. *Acad Emerg Med* 2000;**6**:370.
- 18 **Stiel IG**, Lesiuk HJ, Vandemheen K, *et al*. Revised Canadian CT head rule for patients with minor head injury. *Acad Emerg Med* 2000;**7**:564.
- 19 **Thornhill S**, Teasdale GM, Murray GD, *et al*. Disability in young people and adults one year after head injury: prospective cohort study. *BMJ* 2000;**320**:1631–5.
- 20 **Nagurney JT**, Borczuk P, Thomas SH. Elder patients with closed head trauma: a comparison with nonelder patients. *Acad Emerg Med* 1998;**5**:678–84.
- 21 **Garra G**, Nashed AH, Capobianco L. Minor head trauma in anticoagulated patients. *Acad Emerg Med* 1999;**6**:121–4.
- 22 **Brown J**, Li J, Levine M, Rosen M. Do anticoagulated patients with minor head trauma need head CT? Results from the COSH Phase 1 Trial. *Acad Emerg Med* 2000;**7**: 495.
- 23 **Dietrich AM**, Bowman MJ, Ginn-Pease ME, *et al*. Paediatric head injuries: can clinical factors reliably predict an abnormality on computed tomography? *Ann Emerg Med* 1993;**22**:1535–40.
- 24 **Quayle KS**, Jaffe DM, Kuppermann N, *et al*. Diagnostic testing for acute head injury in children: when are head computed tomography and skull radiographs indicated? *Paediatrics* 1997;**99**:E11.
- 25 **Gruskin KD**, Schutzman SA. Head trauma in children younger than 2 years: are there predictors for complications? *Arch Pediatr Adolesc Med* 1999;**153**:15–20.
- 26 **Greenes DS**, Schutzman SA. Clinical indicators of intracranial injury in head-injured infants. *Paediatrics* 1999;**104** (4 pt 1):861–7.
- 27 **Brown FD**, Brown J, Beattie TF. Why do children vomit after minor head injury? *J Accid Emerg Med* 2000;**17**:268–71.