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ORIGINAL  
RESEARCH

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## Outcome after Complicated Minor Head Injury

**BACKGROUND AND PURPOSE:** Functional outcome in patients with minor head injury with neurocranial traumatic findings on CT is largely unknown. We hypothesized that certain CT findings may be predictive of poor functional outcome.

**MATERIALS AND METHODS:** All patients from the CT in Head Injury Patients (CHIP) study with neurocranial traumatic CT findings were included. The CHIP study is a prospective, multicenter study of consecutive patients,  $\geq 16$  years of age, presenting within 24 hours of blunt head injury, with a Glasgow Coma Scale (GCS) score of 13–14 or a GCS score of 15 and a risk factor. Primary outcome was functional outcome according to the Glasgow Outcome Scale (GOS). Other outcome measures were the modified Rankin Scale (mRS), the Barthel Index (BI), and number and severity of postconcussive symptoms. The association between CT findings and outcome was assessed by using univariable and multivariable regression analysis.

**RESULTS:** GOS was assessed in 237/312 patients (76%) at an average of 15 months after injury. There was full recovery in 150 patients (63%), moderate disability in 70 (30%), severe disability in 7 (3.0%), and death in 10 (4.2%). Outcome according to the mRS and BI was also favorable in most patients, but 82% of patients had postconcussive symptoms. Evidence of parenchymal damage was the only independent predictor of poor functional outcome (odds ratio = 1.89,  $P = .022$ ).

**CONCLUSION:** Patients with neurocranial complications after minor head injury generally make a good functional recovery, but postconcussive symptoms may persist. Evidence of parenchymal damage on CT was predictive of poor functional outcome.

Head injury is one of the main causes of disability, especially in the younger population. In patients with severe head injury, long-term outcome in terms of disability has been studied extensively and is consequently well documented.<sup>1–4</sup> In clinical practice, however, most patients with head injury presenting to emergency departments have sustained minor head injury, which is commonly defined as a presenting Glasgow Coma Scale (GCS) score of 13–15, with or without a brief history of loss of consciousness (maximum of 15 minutes) or posttraumatic amnesia (maximum of 60 minutes) after blunt trauma to the head.<sup>5</sup> Generally, these patients make a full functional recovery, though it is not uncommon to see patients with minor head injury with long-term sequelae after the injury.<sup>6–12</sup>

With the advent of routine head CT scanning of virtually all patients with head injury, it has become clear that a substantial number (6%–10%) of patients with minor head injury have evidence of neurocranial traumatic complications.<sup>13–18</sup> Func-

tional outcome in these patients with so-called “complicated” minor head injury has been shown to be significantly poorer than that in patients without neurocranial traumatic complications after minor head injury.<sup>19,20</sup> Long-term outcome in terms of functional disability or postconcussive symptoms in patients with complicated minor head injury specifically, however, is still largely unknown.<sup>12,20</sup> Also, outcome may not be the same for different traumatic CT findings. Traumatic findings may range from an isolated linear skull fracture, which is commonly considered to be clinically insignificant and would thus be expected to be associated with favorable functional outcome, to acute extra-axial hematoma requiring neurosurgical intervention, possibly associated with poorer functional outcome and an increased prevalence of posttraumatic complaints.<sup>18,21</sup>

The purpose of our study was to assess functional outcome in terms of disability and postconcussive symptoms in patients with neurocranial complications as established with CT after minor head injury. We hypothesized that certain CT findings may be predictive of poor long-term outcome in these patients with complicated minor head injury.

### Methods

#### Study Population

This follow-up study was an extension of the CT in Head Injury Patients (CHIP) study, in which data were prospectively collected in 4 Dutch university hospitals on 3364 consecutively included patients between February 11, 2002, and August 31, 2004 (Fig 1).<sup>22</sup> Inclusion criteria for the CHIP study were the following: presentation within 24 hours of blunt head injury, 16 years of age or older, a GCS score of 13 or 14 on presentation or a GCS score of 15 and a minimum of 1 risk factor. Risk factors were a history of loss of consciousness, short-term memory deficit, amnesia for the traumatic event, posttraumatic seizure, vomiting, headache, clinical evidence of intoxication with alco-

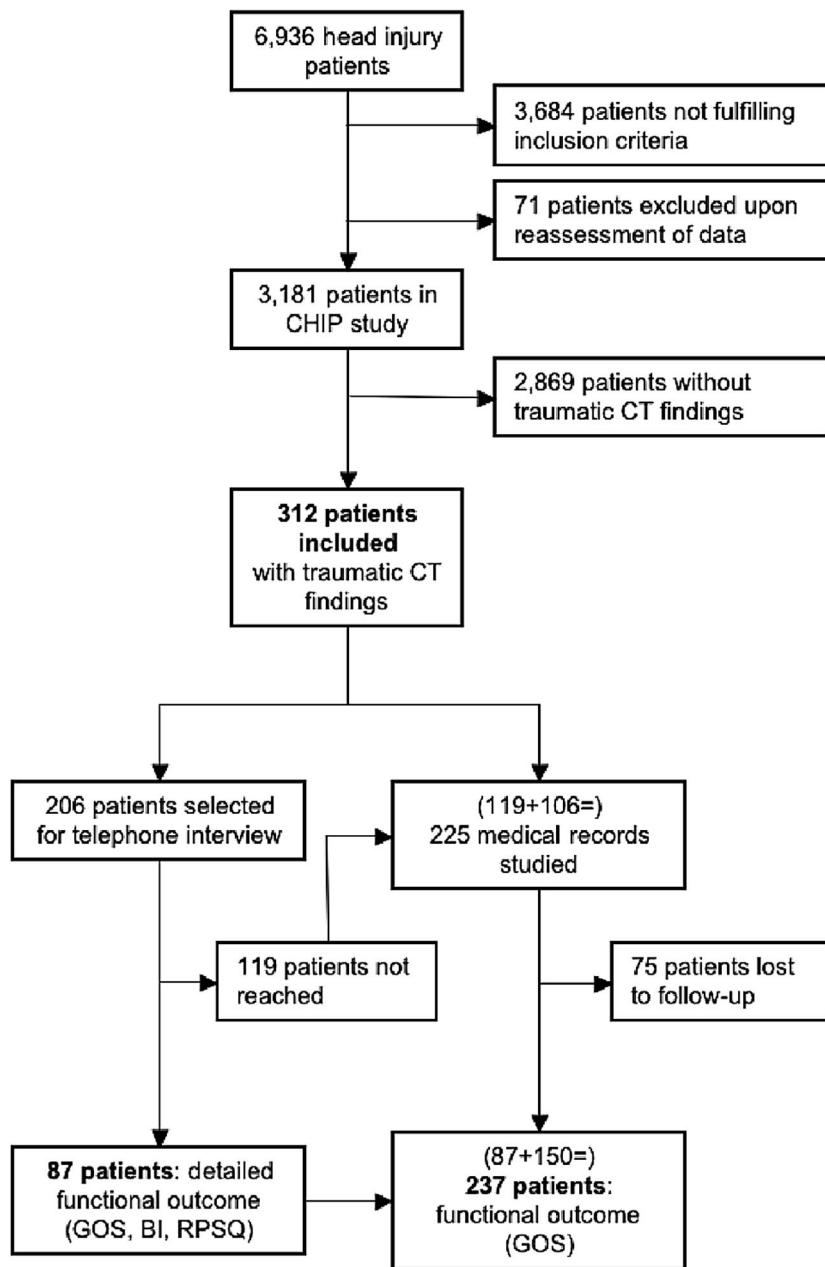
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**Fig 1.** The number of patients presenting with head injury (6936) is an estimate based on the proportion of patients included out of the total number of patients with trauma seen by a neurologist or neurologist-in-training in the emergency department of the participating center that included most patients. Of the 3181 patients included in the CHIP study, 2869 did not have any evidence of a neurocranial traumatic findings on CT, leaving 312 patients eligible for inclusion in the current follow-up study.

### Assessment Procedure

A detailed assessment of outcome was performed by telephone interview in a large sample of patients (subpopulation) from our study population. This sample consisted of all included patients in the center in which most patients had been included. In all patients who had been included in the remaining 3 participating centers, as well as in patients who could not be reached for telephone interview, global functional outcome was assessed by careful review of the patients' medical records.<sup>27</sup> Every attempt was made to reach all surviving patients from the subpopulation and to obtain their current addresses and telephone numbers from the hospital information system, patients' family doctors, telephone registry, and the local citizens' registry. Patients willing to participate were contacted by telephone, and a structured interview was conducted by a single trained researcher (D.A.v.R.). In patients who were unable to answer the questionnaire, the interview was performed with the patient's relative or caregiver as a proxy.

### Mortality

We evaluated all-cause 30-day and disease-specific 1-year mortality in all patients, to avoid errors due to adjudication, which is consistent with the cardiologic and surgical literature. In patients who had died within 1 year, patient records were reviewed to establish whether death was related to the head injury, including remote mortality. In patients who

had died of a cause unrelated to head injury, and in patients who had died more than 1 year after the head injury, death was considered not to be related to the head injury. In these patients, functional outcome from before death was derived from the patients' medical records.

hol or drugs, anticoagulant treatment or history of coagulopathy, external evidence of injury above the clavicles, or neurologic deficit. Exclusion criteria were contraindications for CT scanning or concurrent injuries precluding head CT within 24 hours of injury. After assessment by a neurologist or by a neurologist-in-training under supervision of a neurologist, all patients underwent head CT in accordance with local hospital policies and the guidelines set out by the Dutch Neurologic Society and the European Federation of Neurologic Societies.<sup>23,24</sup> Non-contrast-enhanced head CTs were performed in all included patients, by using a maximal section thickness of 5 mm infra- and 8 mm supratentorially.<sup>25,26</sup> All CT scans were evaluated by a trauma radiologist or neuroradiologist.

For the current follow-up study, all patients with neurocranial traumatic findings on CT were included (Fig 1). The study protocol was approved by the Internal Review Board, and written informed consent was obtained from all patients participating in the assessment of outcome by telephone interview.

had died of a cause unrelated to head injury, and in patients who had died more than 1 year after the head injury, death was considered not to be related to the head injury. In these patients, functional outcome from before death was derived from the patients' medical records.

### Outcome Measures

Primary outcome measure was the Glasgow Outcome Scale (GOS), which was assessed in all patients reached for telephone interview or was derived from the patients' medical records. The GOS is a 5-point scale to assess disability after head injury or other neurologic events.<sup>27</sup> The clearly defined categories are as follows: 5, full recovery (ie, the resumption of normal life even though there may be minor neurologic or psychological deficits); 4, moderate disability (ie, disabled, but independent in daily life); 3, severe disability (ie, conscious but disabled with the patient being dependent for daily support [for >8 hours per day] due to mental or physical disability); 2, vegetative state (ie, the patient being unresponsive and speechless for weeks or

months after the injury); and 1, dead, which included 30-day all-cause mortality and 1-year disease-specific mortality. Although the categories of disability are rather crude and may therefore not be very sensitive to subtle differences or changes in disability, it is the most widely used scale to assess functional outcome after head injury. It has been extensively validated and has been shown to correlate well with other measures of disability.<sup>2,28-30</sup>

In patients reached for telephone interview, a more detailed assessment of functional outcome was made according to the modified Rankin scale (mRS), the Barthel Index (BI), and the Rivermead Postconcussion Symptoms Questionnaire (RPSQ).

The mRS is a 7-point scale that is also used to assess functional disability after neurologic events such as head injury or stroke. It is more sensitive than the GOS for subtle differences in outcome, and ranges from zero (no symptoms) to 6 (death, all-cause 30-day and disease-specific 1-year mortality).<sup>31,32</sup>

The BI is a 10-item questionnaire of daily functioning, assessing the patient's independence or dependence for each item on a scale from zero (fully dependent) to 2, 3, or 4 (fully independent, maximal score varies per item).<sup>33</sup> It covers the following items: eating, getting dressed, transferring from bed to chair, ambulating, negotiating stairs, managing personal care, bathing, toileting, and controlling bowel and bladder. A maximal score (score = 20) indicates full independence for all items, whereas a minimal score (score = 0) indicates that the patient is fully dependent for all items.

The RPSQ is a 5-point scale of 16 commonly reported symptoms after head injury, with a high test-retest and inter-rater agreement for the assessment of the presence and severity of postconcussive symptoms.<sup>34</sup> Patients are asked to rate the severity for each symptom in comparison with preinjury levels on a scale from zero (no symptoms) to 4 (severe symptoms). Additional symptoms resulting from the head injury may also be recorded and rated. The higher the sum score, the more (severely) symptoms are present after the injury.

### Definitions

Neurocranial complications as identified on CT included all traumatic findings of the neurocranium. Intracranial lesions included all neurocranial complications except for isolated linear skull or skull base fractures. Traumatic subarachnoid hemorrhage and epidural and subdural hematomas were recorded as present or absent. Intraparenchymatous contusions included both hemorrhagic and non-hemorrhagic lesions. Diffuse axonal injury was defined as multiple small focal traumatic lesions in the typical locations of shearing injury. Depressed fractures included all fractures of the skull vault in which inward displacement of at least 1 of the bone fragments was seen. Linear skull fractures included all fractures of the skull vault, with no evidence of displacement of bone fragments. Skull base fractures included all fractures of the skull base. If multiple findings were present, the number of findings was recorded. Bilaterally occurring lesions were counted as 2 separate lesions. Diffuse axonal injury was counted as 1 finding. Each intraparenchymatous contusion was counted as 1 finding.

### Data Analysis

We assessed our study population for patient and clinical characteristics, including the presence of risk factors and findings on physical and neurologic examination, as well as neurocranial traumatic CT findings. We tested differences between the entire study population and the subpopulation for significance ( $P < .05$ ) with respect to patient and clinical characteristics as well as CT findings, by using the

independent samples 2-tailed  $t$  test for continuous, the Pearson  $\chi^2$  test for nominal, and the Mann-Whitney  $U$  test for ordinal variables. Similarly, we tested for significant differences ( $P < .05$ ) between the patients who had been reached for the telephone interview and those who could not be reached within the subpopulation. We also assessed potential differences in the distribution of the GOS obtained by telephone interview and the GOS derived from the patients' medical records, with the Mann-Whitney  $U$  test ( $P < .05$  for significance). All analyses, by using complete cases only, were performed with the Statistical Package for the Social Sciences (Version 12.0; SPSS, Chicago, Ill).

The distribution of functional disability according to the GOS, mRS, and BI was assessed, and the number and severity of postconcussive symptoms according to the RPSQ was recorded. We tested the association of each of the neurocranial traumatic CT findings with disability and symptoms for significance by using the Mann-Whitney  $U$  test for ordinal variables (GOS, mRS, and BI) and the independent samples  $t$  test for continuous variables (RPSQ). We assessed the association between the number of neurocranial traumatic findings and outcome by using linear regression analysis. A  $P$  value  $< .05$  was used as a threshold for statistical significance. Results not reaching this level of significance but with a  $P$  value  $< .10$  were considered near-significant.

To assess whether any of the neurocranial traumatic CT findings were independently predictive of long-term outcome according to the primary outcome measure, we performed multivariable logistic regression analysis after dichotomizing GOS into good (GOS = 5) and poor (GOS = 1–4) outcome.<sup>35</sup> We used a stepwise backward procedure by using the likelihood ratio criterion with  $P < .05$  for inclusion and  $P > .10$  for removal of variables. To reduce the number of variables,<sup>36</sup> we grouped variables that were similar as follows: Epi- and subdural hematoma were combined as extra-axial hematoma; intraparenchymatous contusions and diffuse axonal injury, as parenchymal damage; and linear and skull base fractures, as nondepressed skull fracture. The other variables entered into the model were traumatic subarachnoid hemorrhage and depressed skull fracture.

## Results

### Study Population

Of the 3181 patients originally included in the CHIP study, 312 had at least 1 neurocranial traumatic finding on CT and were thus included in the current follow-up study (Fig 1).

The subpopulation selected for telephone interview consisted of 206 (66%) patients. There were no significant differences ( $P < .05$ ) between the subpopulation and the entire study population with respect to patient and clinical characteristics or neurocranial traumatic findings on CT. Telephone interview was successfully performed in 87 (42%) patients at a mean of 2.8 years after the injury (range, 1.7–4.3 years). No telephone interview was performed in 119 patients for the following reasons: They died ( $n = 14$ ), lived abroad ( $n = 8$ ), were homeless or had no permanent address ( $n = 7$ ), moved without a forwarding address ( $n = 16$ ), did not speak Dutch ( $n = 5$ ), refused to participate ( $n = 23$ ), or had no telephone number available ( $n = 46$ ). In these 119 patients, as well as in the 106 patients not selected for telephone interview, medical records were reviewed ( $n = 225$ ) to assess functional outcome according to the GOS (Fig 1).

Patient characteristics are shown in Table 1. Within the

**Table 1: Patient characteristics and CT findings in the entire study population and in the subpopulation selected for telephone interview**

Findings	Entire Population* (n = 312)		Subpopulation (n = 206)				P Value†
	No.	%	Reached (n = 87)		Not reached (n = 119)		
	No.	%	No.	%	No.	%	
<b>Patient</b>							
Mean age‡ (range)	47.2 (17.0–93.3)		50.5 (17.5–86.6)		45.1 (17.7–93.3)		.043
Male sex	238	76	59	68	106	89	.000
Died	22	7.1	0	0	14	12	.001
Intoxication	118	38	33	38	57	48	.154
<b>Clinical</b>							
GCS score = 15	185	59	49	56	71	60	.631
GCS score = 14	90	29	27	31	33	28	.606
GCS score = 13	37	12	11	13	15	13	.993
LOC	227	73	60	69	89	75	.356
PTA	239	77	66	76	90	76	.969
Persistent amnesia	83	27	24	28	26	22	.343
Seizure§	6	1.9	0	0	3	2.5	.136
Headache	212	68	67	77	87	73	.524
Vomiting	69	22	23	26	24	20	.290
Neurologic deficit	48	15	14	16	21	18	.769
Infraclavicular injury	121	23	19	22	27	23	.885
<b>CT</b>							
Intracranial lesions	243	78	63	72	92	77	.421
Linear fracture	114	37	41	47	44	37	.144
Skull base fracture	82	26	29	33	26	22	.066
Depressed fracture	19	6.1	3	3.4	14	12	.032
Subdural hematoma							.033
Mild	58	19	23	26	16	14	
Severe	9	2.9	2	2.3	3	2.6	
Epidural hematoma							.332
Mild	31	9.9	8	9.2	14	12	
Severe	4	1.3	0	0.0	2	1.7	
SAH	86	28	30	34	30	25	.148
Contusion	142	46	28	32	51	43	.120
Diffuse axonal injury	14	4.5	2	2.3	7	5.9	.214

**Note:**—LOC indicates loss of consciousness; PTA, posttraumatic amnesia; SAH, traumatic subarachnoid hemorrhage.

\* Multiple symptoms and clinical and CT findings may be present in 1 patient.

† P values <.05 indicate differences between patients who were reached compared with those who were not reached for telephone interview (independent samples *t* test for continuous, Pearson  $\chi^2$  test for nominal, and Mann-Whitney *U* test for ordinal variables).

‡ Age in years.

§ Post-traumatic seizure.

subpopulation, patients who were reached for telephone interview were older than those who were not reached and were more commonly female (Table 1). Of the neurocranial traumatic findings on CT, depressed fracture was seen less and subdural hematoma more frequently in patients who were reached for telephone interview than those who were not reached (Table 1). Overall, there were no differences in the frequency of intracranial traumatic complications on CT. Multiple findings on CT were present in 198 patients (67%; range, 2–16).

### Mortality

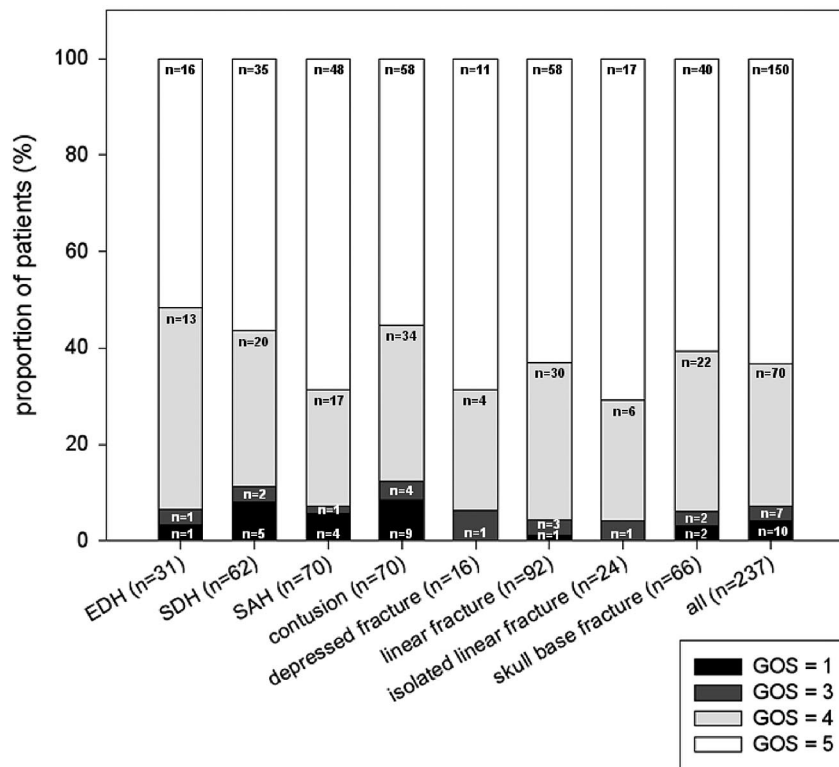
Twenty-two patients died (7.1%) at an average of 199 days (median, 78 days; range, 0–702 days). All-cause 30-day mortality was 2.9% (*n* = 9). A further 7 patients died within 1 year of injury, resulting in an all-cause 1-year mortality of 5.1%. In 1 of these patients, death was determined by the investigators to be secondary to complications from the head injury. One-year disease-specific mortality was thus 3.2% (*n* = 10). The remaining 6 patients died more than 1 year after the head injury.

### Functional Outcome

GOS data were obtained in 237 of 312 (76%) patients. There was no difference in the distribution of GOS obtained from telephone interview (87 patients, 37%) and GOS derived from medical records (Mann-Whitney *U* test, *P* = .173). Mean duration between the latest available follow-up data and time of injury was 15.1 months (median, 3.6 months; range, 0–56 months). Most patients had a good functional outcome (Fig 2), 150 (63%) patients having made full recovery. Seventy patients (30%) had minor disability. Severe disability was present in 7 (3.0%) patients, and 10 (4.2%) patients died as a consequence of head injury (9 patients within 30 days and 1 patient within 1 year of head injury).

In the subpopulation, data on mRS were available on 87 surviving patients as well as 3 patients who had died as a result of head injury (all within 30 days of injury). Most patients had no (*n* = 16, 18%) or minor (*n* = 43, 48%) symptoms. Minor disability was present in 15 (17%) patients, moderate disability in 10 (11%), and moderately severe disability in 3 (3.3%).

BI could be assessed in 87 patients. Most patients were independent for all activities (*n* = 73, 84%). All patients



**Fig 2.** Distribution (percentage) of the GOS in patients with epidural hematoma (EDH), subdural hematoma (SDH), traumatic subarachnoid hemorrhage (SAH), intraparenchymatous contusion, depressed fracture, linear fracture isolated, linear fracture, skull base fracture, and in all patients ( $n = 233$ ). GOS = 1 indicates dead; GOS = 2, vegetative state; GOS = 3, severe disability; GOS = 4, moderate disability; GOS = 5, full recovery.

**Table 2: Postconcussive symptoms as assessed with the RPSQ in 87 patients**

Symptom	No or No More (%)	Mild (%)	Moderate (%)	Severe (%)
Headache	68 (78)	2 (2.3)	4 (4.6)	13 (15)
Dizziness	61 (70)	7 (8.0)	6 (6.9)	13 (15)
Nausea	82 (94)	1 (1.1)	1 (1.1)	3 (3.4)
Noise hypersensitivity	80 (92)	2 (2.3)	1 (1.1)	4 (4.6)
Sleep disturbance	65 (75)	6 (6.9)	8 (9.2)	8 (9.2)
Fatigue	52 (60)	8 (9.2)	4 (4.6)	23 (26)
Irritability	63 (72)	7 (8.0)	9 (10)	8 (9.2)
Depression	61 (70)	7 (8.0)	9 (10)	10 (11)
Frustration	66 (76)	6 (6.9)	7 (8.0)	8 (9.2)
Poor memory	54 (62)	7 (8.0)	6 (6.9)	20 (23)
Poor concentration	59 (68)	4 (4.6)	6 (6.9)	18 (21)
Slow thinking	63 (72)	7 (8.0)	5 (5.7)	12 (14)
Blurred vision	72 (83)	5 (5.7)	7 (8.0)	3 (3.4)
Light hypersensitivity	82 (94)	2 (2.3)	1 (1.1)	2 (2.3)
Double vision	79 (91)	5 (5.7)	0 (0.0)	3 (3.4)
Restlessness	79 (91)	3 (3.4)	2 (2.3)	3 (3.4)

**Note:**—RPSQ scores of 0 and 1 indicate no or no more complaints; 2, mild; 3, moderate; 4, severe postconcussive symptoms.

were independent with respect to self-care. Dependency was highest for walking stairs, with 4 (4.6%) patients not being able to walk stairs and another 4 (4.6%) needing assistance.

RPSQ data were available on 87 patients (Table 2). Seventy-one (82%) patients had at least 1 postconcussive symptom. If present, symptoms were more frequently moderate to severe than mild. Most frequently reported symptoms were fatigue (40%), depression (30%), dizziness (30%), irritability (28%), sleep disturbances (25%), and cognitive symptoms such as poor memory (38%) and concentration (32%) and slowness of thinking (28%).

### Association between Neurocranial Traumatic CT Findings and Functional Outcome

Patients with diffuse axonal injury had a significantly or near significantly poorer outcome on all functional outcome measures than those without diffuse axonal injury (BI,  $P = .000$ ; mRS,  $P = .018$ ; GOS,  $P = .096$ ; Table 3). Patients with intraparenchymatous lesions had a significantly poorer GOS outcome ( $P = .008$ , Table 3), and patients with subdural hematoma had a significantly poorer BI outcome ( $P = .050$ , Table 3). Patients with epidural hematoma had near significantly more or more severe symptoms than those without epidural hematoma (mean RPSQ score, 23 versus 13, respectively;  $P = .054$ ; Table 3), as did patients with a skull base fracture (mean RPSQ score 18 versus 12,  $P = .070$ ; Table 3). No association with outcome was found in patients with traumatic subarachnoid hemorrhage, isolated linear or linear skull fracture, or depressed skull fracture. The number of neurocranial traumatic findings on CT was significantly associated with poorer functional outcome ( $P = .001$ ) according to GOS and near significantly associated with more or more severe symptoms ( $P = .069$ ) according to RPSQ.

Multivariable logistic regression analysis to predict outcome in terms of GOS was performed with the independent variables of extra-axial hematoma, parenchymal damage, traumatic subarachnoid hemorrhage, and depressed and non-depressed skull fracture. Evidence of parenchymal damage on CT (which included diffuse axonal injury or intraparenchymatous contusions) was the only independent predictor of poor functional outcome (odds ratio = 1.86; 95% confidence interval, 1.09–3.18;  $P = .022$ ).

### Discussion

In this follow-up study of patients with evidence on CT of neurocranial traumatic complications after minor head in-

**Table 3: Mean scores and SDs on the GOS, BI, mRS, and RPSQ\***

Traumatic CT Finding	GOS		BI		mRS		RPSQ	
	Score (SD)	P Value	Score (SD)	P Value	Score (SD)	P Value	Score (SD)	P Value
Linear fracture		.820		.433		.419		.619
Absent	4.4 (1.0)		20 (1.2)		1.3 (1.1)		13 (15)	
Present	4.6 (0.7)		19 (2.0)		1.4 (0.9)		15 (12)	
Skull base fracture		.690		.602		.105		.070
Absent	4.5 (0.9)		19 (1.9)		1.2 (1.0)		12 (12)	
Present	4.5 (0.8)		20 (0.6)		1.6 (1.0)		18 (15)	
Depressed fracture		.633		.445		.230		.302
Absent	4.5 (0.9)		19 (1.6)		1.4 (1.0)		14 (13)	
Present	4.6 (0.6)		20 (0.0)		0.7 (1.2)		6 (10)	
Subdural hematoma		.137		.050		.573		.552
Absent	4.5 (0.8)		20 (1.6)		1.3 (1.0)		13 (13)	
Present	4.3 (1.1)		19 (1.5)		1.4 (1.0)		15 (13)	
Epidural hematoma		.200		.705		.313		.054
Absent	4.5 (0.9)		19 (1.7)		1.3 (1.0)		13 (13)	
Present	4.4 (0.8)		20 (0.4)		1.6 (0.9)		23 (16)	
SAH		.330		.238		.502		.681
Absent	4.5 (0.9)		19 (1.9)		1.4 (1.1)		14 (14)	
Present	4.5 (1.0)		20 (0.8)		1.2 (0.7)		13 (12)	
Contusion		.008		.140		.449		.643
Absent	4.7 (0.6)		20 (1.6)		1.3 (1.1)		13 (14)	
Present	4.3 (1.1)		19 (1.5)		1.4 (0.9)		15 (11)	
Diffuse axonal injury		.096		.000		.018		.803
Absent	4.5 (0.9)		20 (1.5)		1.3 (1.0)		14 (13)	
Present	3.8 (1.5)		16 (2.1)		3.5 (0.7)		12 (16)	

**Note:**—SAH indicates traumatic subarachnoid hemorrhage.

\* Higher scores on the GOS and BI indicate more favorable outcome, whereas higher scores on mRS and RPSQ indicate poorer outcome and more severe postconcussive complaints, respectively.

jury, we found that most patients made a good functional recovery on long-term assessment. Evidence of parenchymal damage was the only independent factor significantly predictive of poor functional outcome. Despite generally good functional recovery, most of the patients we interviewed had 1 or more postconcussive symptoms.

A limitation of our study was the fact that a substantial number of patients were lost to follow-up. This limitation is inherent to the patient population we studied and the fact that we assessed outcome several years (2–4 years) after the injury had occurred. Patients with trauma tend to be a young actively employed population that often moves, is difficult to reach, and is less willing to participate than older patients. In our study, most patients who could not be reached had moved without forwarding addresses or had changed telephone numbers. Patients who had been reached were somewhat older and more frequently female, suggesting possible selection bias. Although these differences were statistically significant, patients from both groups were within the same middle-aged range, and in both groups male patients formed the majority. We expect that this difference in demographic characteristics will only have a very small effect on our results. More important, however, the overall frequency of intracranial traumatic findings between the 2 groups was not significantly different, suggesting that the injury severity was comparable for patients who were reached versus those who could not be reached.

A further limitation may be that we included only patients with neurocranial complications and not patients with uncomplicated minor head injury. This makes it impossible to establish whether complicated minor head injury has a poorer outcome than uncomplicated head injury. This question,

however, has already been addressed in other studies.<sup>19,20</sup> Outcome in patients with minor head injury without neurocranial complications is generally known to be good,<sup>37</sup> and the additional effort involved in following up these patients in our study would not have been justifiable. Another limitation is that we did not evaluate the effect on outcome of potentially confounding factors, such as multiple injuries due to the injury, premonitory disability, chronic pain, or litigation. Although it would be interesting to include these potential confounders in the outcome assessment, it would still be difficult to disentangle the effect on outcome of neurocranial complications and those of confounders.

Finally, the fact that some of the data in our study were obtained retrospectively may be considered another limitation. Because there were no differences between the entire study population and the subpopulation or between patients in whom outcome was assessed prospectively or retrospectively, we believe that no significant bias has been introduced by this study design. Because follow-up rates in patients with trauma tend to be low,<sup>6,10,20</sup> studies with prospectively included patients but retrospectively collected outcome data may be very valuable for these patient populations and may actually introduce less bias than an entirely prospective study with high rates of loss to follow-up.<sup>38</sup>

Follow-up studies of patients with traumatic neurocranial complications after minor head injury are in fact scarce. In a recent study by de Andrade et al,<sup>39</sup> 266 selected patients' medical records were reviewed to assess GOS after minor head injury in the presence of neurocranial traumatic CT findings. Williams et al<sup>19</sup> prospectively assessed GOS at 6 months after minor head injury in 74 patients with radiographic evidence of

neurocranial traumatic complications. In both studies, most patients had made a good functional recovery but outcome was significantly poorer than that in patients without radiographic evidence of neurocranial traumatic complications. In a third study, Fabbri et al<sup>40</sup> reported favorable outcome in most (89%) of 491 patients with minor head injury with neurocranial traumatic CT findings, but not all patients included in their study had undergone CT. Because we assessed outcome in patients with neurocranial traumatic complications from a large cohort of unselected patients with minor head injury who had all undergone CT, our findings are a good reflection of outcome in the general population of patients with complicated minor head injury. Our study confirms these previous findings of a generally favorable functional outcome after complicated minor head injury.

Diffuse axonal injury was significantly associated with higher grades of functional disability on all outcome scales, whereas intraparenchymatous contusions and subdural hematoma were associated with poor outcome according to GOS and BI, respectively. There was also a significant association between the number of neurocranial traumatic finding on CT and poor functional outcome according to the GOS. None of the CT findings were significantly associated with postconcussive symptoms, though a near significant association was found for epidural hematoma and skull base fracture and with the number of neurocranial traumatic findings on CT. Evidence of parenchymal damage (diffuse axonal injury or intraparenchymatous contusions) was found to be the only independent predictor of poor functional outcome, with an odds ratio of 1.9. Most interesting, none of the neurocranial traumatic findings were significantly associated with a better outcome, suggesting that good outcome even for so-called clinically nonsignificant lesions may not be certain. One could argue that the CT imaging protocol we used for this study was relatively insensitive for the detection of small lesions, such as small intraparenchymatous contusions or small amounts of subarachnoid hemorrhage; this insensitivity may have influenced our findings. Potentially, sensitivity could be increased with the acquisition of thinner sections as is now common practice with the advent of multidetector CT scanners, though we are not aware of any published studies formally comparing head CTs of varying section thicknesses in a trauma setting. Even assuming that thinner sections increase the detection of small intraparenchymatous injury, it is unclear whether this would affect the ability to predict outcome.

Thus far, the relationship between traumatic findings on CT and functional outcome has only been assessed in severely head-injured patients and not as yet in patients with complicated minor head injury. Only in 2 studies were less severely injured patients also included, but no distinction was made between patients with moderate and those with minor head injury.<sup>41,42</sup> In line with our findings, intracranial hematoma and contusions were among the CT findings that were identified as independent predictors of poor outcome in their and previous studies of severely injured patients.<sup>41,43,44</sup> We dichotomized the GOS classification specifically for our patient population into good (GOS = 5) and poor (GOS < 4) outcome, whereas in many studies, good functional outcome also included GOS of 4 (moderate disability).<sup>28</sup> This dichotomization is indeed appropriate for the more severely injured pa-

tients, but after minor head injury, patients generally recover fully, and moderate disability would not qualify as a good functional outcome.<sup>35</sup>

We used several outcome measures to assess the patients' outcomes. Our primary outcome measure, the GOS, is often criticized for being too crude a measure of functional outcome, in particular for patients with minor head injury. As reported previously and confirmed in the present study, most patients with minor head injury were classified according to the GOS as having made a full recovery, which does not seem to reflect the high rate of symptoms many of these patients still experience. In the subpopulation of patients whom we interviewed, we used the mRS as a more sensitive measure of outcome and were indeed able to distinguish between patients who had fully recovered and those who still had symptoms, though without any disability. The low rate of disability and the high rate of postconcussive symptoms, as assessed by the BI and the RPSQ respectively, support these findings. Although the mRS thus seems to better reflect functional outcome, the absence of disability would generally be considered good functional outcome, with or without the presence of symptoms. The GOS, with its high test-retest and interobserver agreement,<sup>2,28,29</sup> shows consistent relations with other outcome measures<sup>30</sup> and is also more suitable for reliable outcome assessment in retrospective studies because medical records often do not contain sufficient detail for classification according to the mRS.

In the present follow-up study, we found a very high rate of postconcussive symptoms. Postconcussive symptoms are very common after head injury, especially in the first weeks to months after the injury.<sup>6,7,11,12,45-48</sup> Because many of the reported symptoms, such as headache and fatigue, have a high base rate in the general population, patients with postconcussive symptoms are often considered malingerers, especially when no objective or imaging abnormalities can be found or, as in our study, no relationship between specific imaging findings and postconcussive symptoms can be determined. In a case-control study by Masson et al<sup>11</sup> of patients with head injury versus those with lower limb injury, postconcussive symptoms, except for fatigue, were significantly more often present in patients with the head injury than in those with the lower limb injury. By using the RPSQ, we attempted to control for premorbid levels of symptoms. However, because the injury had occurred on average several years previously, some degree of recall bias was unavoidable. Despite the high reported rates, symptoms generally disappear in most patients after 3–6 months, persisting only in a minority of patients.<sup>7,49</sup> To the best of our knowledge, we are the first to report postconcussive symptoms in patients with neurocranial traumatic complications after minor head injury. The high rate of symptoms in our patient population suggests that patients with minor head injury with neurocranial complications are at high risk of persistence of symptoms for years after the injury.

## Conclusion

Patients with neurocranial traumatic complications after minor head injury generally make a good functional recovery, though postconcussive symptoms may persist for many years after the injury. Evidence of parenchymal damage on CT was predictive of poor functional outcome.



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