Original Article

Wien Klin Wochenschr (2007) 119/1–2: 56–63
DOI 10.1007/s00508-006-0764-1

WIENER KLINISCHE WOCHENSCHRIFT
The Middle European Journal of Medicine
Printed in Austria

Severe Traumatic Brain Injury in Austria V: CT findings and surgical management

Johannes Leitgeb[1], Katharina Erb[2], Walter Mauritz[3], Ivan Janciak[2], Ingrid Wilbacher[2], and Martin Rusnak[2] for the Austrian Severe TBI Study Investigators

[1] University Department of Trauma Surgery, General Hospital Vienna, Vienna, Austria
[2] INRO (International Neurotrauma Research Organisation), Vienna, Austria
[3] Department of Anaesthesia and Critical Care Medicine, Trauma Hospital "Lorenz Boehler"; INRO Medical Advisory Board, Vienna, Austria

Austrian Severe TBI Study Investigators

Local study coordinators: Florin Botha (Linz), Franz Chmeliczek (Salzburg), Georg Clarici (Graz), Hilda-Dietlinde Gulle (Klagenfurt), Walter Moser (Klagenfurt), Ernst Trampitsch, (Klagenfurt)

INRO team: Alexandra Brazinova, Katharina Erb, Johannes Leitgeb, Lucia Lenartova, Annalisa Rosso

Schweres Schädelhirntrauma in Österreich V: CT-Befunde und chirurgische Aspekte

Zusammenfassung. *Ziel:* Das Ziel dieser Arbeit ist es, CT-Befunde und chirurgisches Management von Patienten mit schwerem Schädel-Hirn-Trauma (SHT) in Österreich darzustellen.

Patienten und Methoden: Es standen Datensätze von 415 Patienten zur Verfügung, die von 5 österreichischen Zentren in die Studie inkludiert worden waren. Analysiert wurden Inzidenz, chirurgisches Management und Behandlungsergebnis unterschiedlicher intrakranieller Läsionen, sowie das Behandlungsergebnis von Patienten mit/ohne chirurgischer Intervention und mit/ohne Hirndruckmessung. Für die erste Analyse wurde die Patienten je nach dem CT-Befund insgesamt 16 Gruppen zugeordnet. Für die zweite Fragestellung wurden die Patienten in 4 Gruppen (mit/ohne Operation jeweils mit/ohne Hirndruckmessung) eingeteilt.

Results: Das mittlere Alter betrug 48,9 Jahre; das Verhältnis von Männern zu Frauen betrug 299:116. Die häufigsten isolierten Läsionen waren Kontusionen (CONT) und diffuses Ödem. Kombinierte Läsionen waren viel häufiger; die häufigsten Kombinationen waren CONT plus Subarachnoidalblutung (SAH) mit und ohne Subduralhämatom (SDH). 276 (66,5%) Patienten wurden operativ behandelt. Osteoplastistische Operationen (OPS; n = 221) wurden häufiger durchgeführt als osteoklastische (OCS; n = 91) und dekompressive Eingriffe (DEC; n = 15). Die Intensivstations(ICU)-Mortalität betrug 29,7% für operativ versorgte Patienten; bei konservativ behandelten Patienten lag diese etwas höher (33,1%). Die ICU-Mortalität von Patienten mit SDH war nach OCS niedriger (18,8%) als nach OPS (36,0%). Patienten die eine Hirndruckmessung erhielten, jedoch keine sonstige chirurgische Therapie benötigten, hatten die niedrigste 90-Tage Mortalität (17,5%).

Schlussfolgerungen: Hirndruckmessung scheint sowohl chirurgisch versorgten wie auch konservativ behandelten Patienten Vorteile zu bringen. Bei Patienten mit SDH, die operativ versorgt wurden, fand sich ein signifikant besseres Ergebnis. Bei Patienten mit SDH war das Ergebnis nach osteoklastischer Operation signifikant besser als nach osteoplastischer Operation.

Summary. *Objectives:* The aim of this paper is to describe CT findings and surgical management of patients with severe traumatic brain injury (TBI) in Austria.

Patients and methods: Data sets from 415 patients treated by 5 Austrian hospitals were available. The analysis focused on incidence, surgical management, and outcome of different types of intracranial lesions, and outcome of surgical interventions with and without monitoring of intracranial pressure (ICP). For the first analysis we assigned the patients to 16 groups based on the type of lesion as evaluated by CT scan. For the second analysis we created 4 groups based on surgical treatment (yes/no) and ICP monitoring (yes/no).

Results: The mean age was 48.9 years with a male to female ratio of 299:116. The most frequent single lesions were contusions (CONT) and diffuse brain edema. Combined lesions were far more common than single lesions; the most frequently observed combinations included CONT and subarachnoid hemorrhage (SAH) with or without subdural hematoma (SDH). Surgery was done in 276 (66.5%) patients. Osteoplastic surgery (OPS; n = 221) was the most common method followed by osteoclastic surgery (OCS; n = 91) and decompressive craniectomy (DEC; n = 15). ICU mortality was 29.7% for all patients who had any kind of surgery, which was lower than that of patients who were treated non-operatively (33.1%). The ICU mortality of patients with SDH was lower with OCS (18.8%) than with OPS (36.0%). Patients who received ICP monitoring but did not require surgery had the lowest 90 day mortality (17.5%).

Conclusions: ICP monitoring seems to be beneficial in both operatively and non-operatively treated patients with severe TBI. Patients with SDH who were operated on had significantly better outcomes. In patients with SDH, their outcome after osteoclastic surgery was significantly better than after osteoplastic procedures.

Key words: Brain injury, traumatic, hematoma, epidural, subdural, intracerebral, hemorrhage, subarachnoid, surgery, osteoplastic, osteclastic, decompressive, outcome.

Introduction

The Austrian Severe Traumatic Brain Injury (TBI) Study was done in five participating Austrian hospitals and enrolled a total of 492 patients with severe TBI. Detailed information regarding background, goals, and methods of the study has been published in a previous paper [1]. The goal of this paper is to describe CT findings and surgical management of these patients.

Patients and methods

The methods of the Austrian Severe TBI Study have previously been described in detail [1]. Briefly, data on accident, prehospital treatment, hospital treatment, and patient status were collected using internet-based databases [2]. All patients admitted to the participating hospitals were included if they fulfilled the criteria for severe brain trauma [3]. Patients who died at the scene, during transport to the hospital, or immediately after admission to the emergency room were excluded. For this paper, only data sets that included the relevant surgical data as well as CT scan evaluations were used. Data from 415 patients was extracted into Microsoft Excel files for analysis. The analysis focused on:

- Incidence and outcome of different intracranial lesions;
- Surgical management of different intracranial lesions;
- Outcome after surgical or non-surgical management with and without ICP monitoring.

Correlations between CT findings or treatment options and ICU outcome (survival or death), 90-day outcome (survival or death) and final outcome (based on the last available Glasgow Outcome Score, see [1]) were computed. Final outcome is reported as "favorable" (good recovery, moderate disability) or "unfavorable" (severe disability, vegetative state, death). The mortality prediction made possible by the Trauma and Injury Severity Score (TRISS; [4]) was used to calculate the Observed vs. Expected mortality ratio (O/E mortality ratio) at day 90; a detailed discussion is provided in the first paper of this series [1].

The XLSTAT add in for Microsoft Excel [5] was used for statistical processing of the data. The analyses were done using standard descriptive statistics and univariate correlation, and the significances of differences between treatment options were tested by means of the Chi²-test for nominal variables, and t-test as well as one- way ANOVA for numeric variables. Logistic regression was used to perform analysis of multiple variables, and to correct for age, injury severity score (ISS), and first Glasgow Coma Scale (GCS) score whenever groups were compared with regard to outcomes. A $p < 0.05$ was considered significant.

Results

Data sets of 415 patients from the 5 participating centres were available for analysis. In total, 3258 treatment days were analyzed. The majority of patients were male (299; 72%), mean age was 48.9 ± 21 years, mean ISS was 27.2 ± 12.9 points, mean first GCS was 5.7 ± 2.9 points, and expected hospital survival was 63 ± 29%. Overall ICU mortality was 30.8% (128/415), and 90-day mortality was 35.7% (148/415). Final outcome was "favorable" in 33% of cases (good recovery in 23%, moderate disability in 10%), "unfavorable" in 51% (severe disability in 8%, persistent vegetative state in 6%, and death in 38%); and in 16% final outcome was unknown.

Frequency and outcome of different intracranial lesions

All patients had a CT-scan on admission to the hospital, and at least one type of lesion was found in all patients: epidural hematoma (EDH), subdural hematoma (SDH), subarachnoid hemorrhage (SAH), or parenchymal lesions (CONT). According to the type of lesion or the combination of lesions found on the CT-scan the patients were classified into 16 diagnostic groups. The frequencies of the different types of lesions are shown in Fig. 1. Combined lesions were more common than single lesions; the most frequently observed combinations included CONT and SAH with or without SDH. The most common single lesions were CONT and diffuse brain edema. Age, ISS, and outcomes of patients with the different types of lesions are given in Table 1. ICU and 90-day mortality were found to be significantly higher in lesions involving SDH alone and in combination with SAH ($p < 0.05$) than in the other groups. These groups also had the highest O/E ratios. Logistic regression showed that age, ISS and first GCS associated with the diagnoses "SDH" and "SAH"

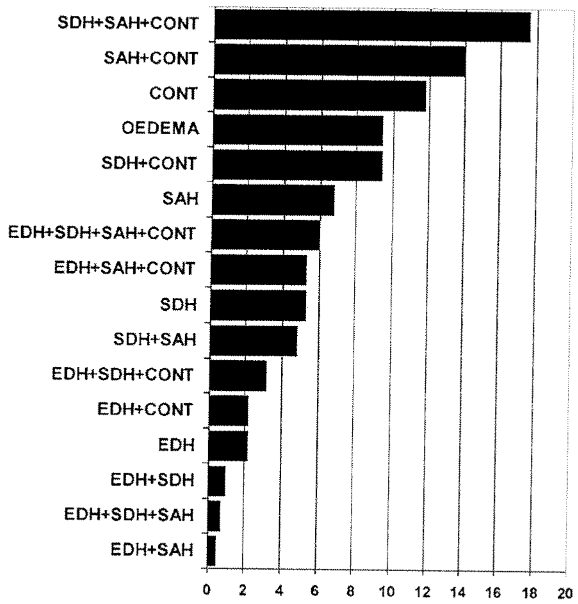

Fig. 1. Frequency of different intracranial lesions and their combinations. Bars represent percentage of 415 patients

Table 1. Intracranial lesions: frequency, age (years), injury severity, predicted survival (%), outcome, and O/E ratio for different lesions and their combinations. Abbreviations: see text. Significant differences between groups are marked **bold**. Confidence intervals (95%) of mean values are set in parenthesis

Type of laesion	n	%	Age mean	ISS mean	TRISS mean (%)	Dead at ICU (%)	Dead at 90 days (%)	O/E ratio
EDH	9	2.2	49 (32; 66)	23.2 (18.3; 28.1)	71.0 (53.0; 89.0)	22.2	22.2	0.8
SDH	22	5.3	56 (46; 65)	22.3 (18.9; 25.6)	59.9 (47.4; 72.4)	**54.6**	**54.6**	1.4
SAH	28	6.8	55 (46; 63)	30.1 (26.4; 33.8)	61.8 (49.0; 74.7)	25.0	28.6	0.7
CONT	49	11.8	38 (32; 43)	24.7 (21.8; 27.5)	72.4 (64.5; 80.3)	20.4	24.5	0.9
EDH+SDH	4	1.0	30 (20; 40)	29.5 (18.4; 40.6)	89.8 (79.1; 100.4)	0.0	0.0	0.0
EDH+SAH	2	0.5	26 (−19; 71)	30.0 (−5.9; 65.9)	85.5 (27.1; 143.9)	0.0	0.0	0.0
EDH+CONT	9	2.2	34 (26; 42)	28.8 (18.9; 38.7)	76.7 (58.6; 94.7)	22.2	22.2	1.0
SDH+SAH	20	4.8	55 (44; 65)	28.8 (22.2; 35.4)	53.4 (38.6; 68.2)	**45.0**	**55.0**	1.2
SDH+CONT	39	9.4	56 (50; 62)	21.2 (18.8; 23.5)	69.0 (61.2; 76.7)	23.1	33.3	1.1
SAH+CONT	58	14.0	47 (41; 52)	30.6 (26.9; 34.3)	56.7 (48.2; 65.2)	32.8	36.2	0.8
EDH+SDH+SAH	3	0.7	71 (38; 104)	22.0 (11.5; 32.5)	46.0 (5.3; 86.7)	**66.7**	**100**	1.9
EDH+SDH+CONT	13	3.1	52 (29; 64)	21.9 (17.9; 25.9)	75.2 (64.8; 85.5)	15.4	30.8	1.2
EDH+SAH+CONT	22	5.3	43 (36; 51)	31.0 (25.0; 36.9)	63.1 (50.2; 76.1)	31.8	31.8	0.9
SDH+SAH+CONT	73	17.6	56 (52; 61)	25.3 (22.5; 28.1)	62.3 (55.2; 69.4)	38.4	43.8	1.2
EDH+SDH+SAH+CONT	25	6.0	51 (44; 58)	32.9 (24.8; 41.0)	54.8 (41.1; 68.4)	44.0	44.0	1.0
OEDEMA	39	9.4	40 (34; 46)	31.4 (26.5; 36.9)	56.5 (46.1; 67.0)	25.6	30.8	0.7
Total	**415**	**100**	**48.9 (46.9; 50.9)**	**27.2 (26.0; 28.5)**	**63.1 (60.2; 60.0)**	**31.3**	**36.1**	**1.1**

play a significant role: after controlling for these parameters, the differences in mortality were no longer significant. There were no statistically significant associations between the various types of lesions and parameters of intensive care: mean hours of elevated ICP and impaired CPP were not different, and days of analgesia, sedation, and ventilation were fairly equal.

Surgical management of different intracranial lesions

For this evaluation placement of an ICP monitoring device was not counted as "neurosurgery". Two thirds of the patients (n = 276; 66.5%) underwent neurosurgery, and one third (n = 139; 33.5%) were treated non-surgically. An overview is given in Table 2. Surgical procedures were done most frequently in patients with a diagnosis (single or combined) of EDH (84%), followed by SDH (77%), CONT (74%), and SAH (70%). Surgery was done in all patients of group EDH+CONT (100%) followed by group EDH+SAH+CONT where 91% had surgery, while only 15% of the patients with diffuse brain edema were operated upon.

Osteoplastic surgery (OPS; craniotomy where the bone flap was replaced) was the most common operation (n = 221; 67.6%). Osteoclastic surgery (OCS; craniotomy where the bone flap was removed) was less frequently done (n = 91; 27.8%). Decompressive craniectomy (DEC; bilateral craniotomy where large bone flaps were removed) was done in few patients only (n = 15; 4.6%). The total number of surgical procedures was 362 because 52 patients (12.5%) were operated on twice, and 13 patients (3.1%) were operated on three or more times. OPS was done most frequently in patients with EDH (single or combined) (67%), followed by patients with CONT (60%), SDH (58%), and SAH (55%). OCS was also done most frequently in patients with EDH (single or combined) (34%), followed by SDH (31%), CONT (26%) and SAH

Table 2. Surgical procedures. Number of patients (total, operated on), percentage of operated patients, numbers of different procedures, outcome, and O/E ratio for different intracranial lesions and their combinations. Abbreviations: see text. Significant differences between groups are marked **bold**. Confidence intervals (95%) of mean values are set in parenthesis

Type of laesion	Total number of patients	Number of patients with surgery	Percentage of patients with surgery	Number of osteo-plastic procedures	Number of osteo-clastic procedures	Number of decom-pressive craniecto-mies	Dead at ICU (%); surgical patients	Dead at 90 days (%); surgical patients	O/E ratio; surgical patients
EDH	9	7	77.8	6	1	0	28.6	28.6	1.0
SDH	22	18	81.8	17	2	0	**55.6**	**55.6**	1.6
SAH	28	15	53.6	12	2	1	26.7	26.7	0.8
CONT	49	27	55.1	25	4	0	18.5	22.2	0.7
EDH+SDH	4	3	75.0	2	1	0	0.0	0.0	0.0
EDH+SAH	2	1	50.0	1	0	0	0.0	0.0	0.0
EDH+CONT	9	9	100	7	4	0	22.2	22.2	1.0
SDH+SAH	20	11	55.0	8	5	1	36.4	**54.6**	1.3
SDH+CONT	39	34	87.2	25	13	1	23.5	32.4	1.0
SAH+CONT	58	38	65.5	34	8	3	31.6	34.2	0.8
EDH+SDH+SAH	3	2	66.7	0	2	1	50.0	**100.0**	2.4
EDH+SDH+CONT	13	11	84.6	10	3	0	9.1	18.2	0.7
EDH+SAH+CONT	22	20	90.9	18	7	0	35.0	35.0	0.9
SDH+SAH+CONT	73	54	74.0	39	25	7	31.5	38.9	1.1
EDH+SDH+SAH+CONT	25	20	80.0	14	11	1	30.0	30.0	0.8
OEDEMA	39	6	15.4	3	3	0	50.0	50.0	0.9
Total	**415**	**276**	**66.5**	**221**	**91**	**15**	**29.7**	**34.4**	**1.0**

(26%). DEC was performed most frequently in patients with SDH+SAH+CONT. More than half of the patients (57.8%) with SDH were treated with OPS, followed by OCS (31.2%), and DEC (5.5%). Of the 15 patients who had DEC, 11 had a diagnosis of SDH (73.3%). ICU mortality was 29.7% for all patients who had any kind of surgery, which was lower than that of patients who were treated non-operatively (33.1 %). Mortality was significantly higher in patients with SDH alone or in combination with SAH (55.6%; Chi²-test: $p < 0.05$). These patients had the highest O/E ratios.

To correlate outcome to surgical method, death rates were calculated for patients who were treated with one surgical method only (OPS: n = 179; OCS: n = 48 and DEC: n = 4). An overview is given in Table 3, and mortality is shown in Fig. 2. ICU mortality was 31.3% for pa-

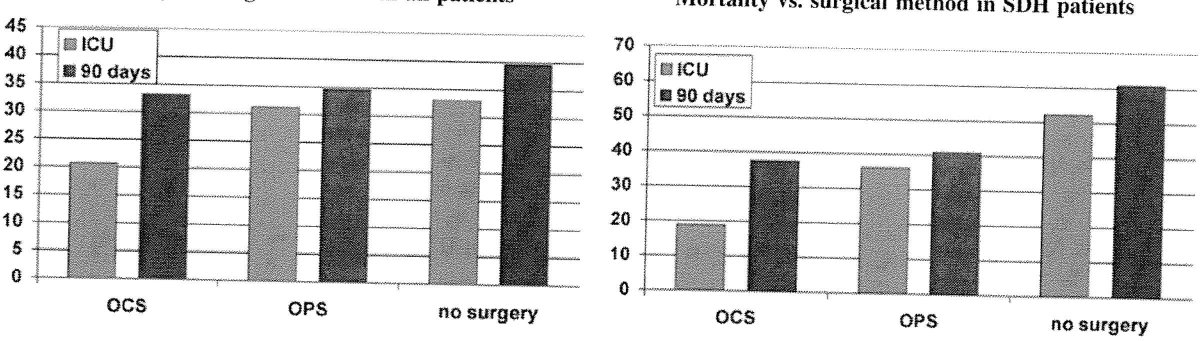

Fig. 2. Outcome of different surgical methods in all patients and in patients with SDH. Bars represent percentage of patients who died

Table 3. Surgical procedures in all patients and in patients with SDH. Number and percentage of patients, age, injury severity, first GCS, predicted survival (%), outcome, and O/E ratio for different surgical procedures. Abbreviations: see text. Significant differences between groups are marked **bold**. Confidence intervals (95%) of mean values are set in parenthesis

	Osteoplastic surgery	Osteoclastic sugery	Decompressive surgery	No surgery
All patients				
Patients (n)	179	48	4	139
Patients (%)	43.1	11.6	1.0	33.5
Age mean	49.4 (46.4; 52.4)	52.2 (46.4; 58.0)	52.3 (22.8; 81.7)	49.2 (45.5; 53.0)
ISS mean	24.7 (23.1; 26.3)	27.1 (23.4; 30.7)	27.0 (21.5; 32.5)	29.8 (27.3; 32.4)
TRISS mean (%)	66.0 (61.9; 70.1)	64.4 (55.8; 73.0)	54.0 (24.0; 84.0)	59.8 (54.2; 65.4)
GCS (first) mean	5.8 (5.3; 6.2)	6.2 (5.2; 7.1)	5.5 (–0.5; 11.5)	5.8 (5.3; 6.2)
Dead at ICU (%)	**31.3**	**20.8**	**50.0**	**33.1**
Dead at 90 days (%)	**34.6**	**33.3**	**75.0**	**39.6**
O/E ratio	1.0	1.0	0.9	1.6
SDH patients				
Patients (n)	86	32	3	46
Patients (%)	43.2	16.1	1.5	23.1
Age mean	56.2 (52.0; 60.3)	59.0 (52.9; 65.0)	53.7 (1.1; 106.3)	54.8 (48.3; 61.2)
ISS mean	21.2 (19.4; 22.9)	25.9 (21.3; 30.6)	27.7 (18.3; 37.0)	31.1 (25.9; 36.3)
TRISS mean (%)	69.9 (64.4; 75.4)	60.4 (49.9; 70.8)	53.7 (–0.4; 107.7)	52.0 (42.0; 61.9)
GCS (first) mean	6.0 (5.3; 6.7)	5.8 (4.8; 6.7)	6.3 (–3.7; 16.3)	5.3 (4.5; 6.0)
Dead at ICU (%)	**36.6**	**18.8**	**33.3**	**52.2**
Dead at 90 days (%)	**40.7**	**37.5**	**66.7**	**60.9**
O/E ratio	1.4	0.9	1.4	1.3

tients who had OPS, 20.8% for patients who had OCS, and 50.0% for those with DEC. Patients who had more than one neurosurgical operation (n = 65) had an ICU mortality of 24.6% and a 90 day mortality of 30.8%. As SDH was one of the main reasons for surgery, we analyzed this subgroup of patients (Table 3). Patients with SDH had a significantly better outcome when treated surgically: ICU mortality was 30.7% vs. 52.2% ($p < 0.01$), and 90-day mortality was 37.9% vs. 60.9%, ($p < 0.05$). ICU mortality of SDH patients was significantly lower with OCS (18.8%) than with OPS (36.0%). After controlling for age, ISS, and first GCS by logistic regression, this difference was still significant. The 90 day mortality was 37.9% for those patients with SDH who were treated surgically, while it was 60.9% for patients who were treated non-operatively ($p < 0.05$). After correcting for risk factors with logistic regression this difference was not significant. The lowest O/E ratio was found in patients who underwent OCS (0.9), while it was 1.4 for OPS and DEC patients, and 1.3 in patients who were treated non-surgically.

Outcome after surgical vs. non-surgical management, with and without ICP monitoring

For this analysis, the 415 patients were assigned to one of 4 groups:

- no ICP monitoring, no surgery ("NONE"),
- ICP monitoring, no surgery ("ICP"),
- Surgery, no ICP monitoring ("SURG"),
- Surgery and ICP monitoring ("BOTH").

The results of this analysis are given in Table 4. Almost one quarter of the patients had neither ICP monitoring nor surgery (group "NONE"). One third of these patients had SDH. This group included the most seriously injured patients as they had the highest ISS, the lowest TRISS, and the highest mortality of all 4 groups. In some of these patients treatment was probably limited to ventilation and sedation because of the obviously poor prognosis. This group, however, also included some of the patients who had no major intracranial lesions, and recov-

Table 4. Surgical vs. non-surgical management with and without ICP monitoring. Number and percentage of patients, age, injury severity, first GCS, predicted survival (%), outcome, and O/E ratio for different treatment options. Abbreviations: see text. Significant differences between groups are marked **bold**. Confidence intervals (95%) of mean values are set in parenthesis

	NONE	ICP	SURG	BOTH
Patients (n)	99	40	52	224
Patients (%)	23.9	9.6	12.5	54.0
Age mean	51.9 (47.6; 56.2)	42.5 (35.2; 49.7)	**56.2 (49.9; 62.5)**	47.0 (44.5; 49.6)
ISS mean	30.3 (27.0; 33.7)	28.6 (25.0; 32.3)	22.8 (19.8; 25.8)	26.6 (25.1; 28.1)
TRISS mean (%)	59.4 (52.6; 66.2)	60.9 (50.7; 71.1)	61.7 (53.7; 69.7)	65.4 (61.7; 69.1)
GCS (first) mean	5.9 (5.4; 6.4)	5.5 (4.5; 6.5)	5.5 (4.6; 6.3)	5.8 (5.4; 6.2)
ICU mortality	40.4	15.0	**25.0**	**30.8**
90-day mortality	**48.5**	**17.5**	**30.8**	**35.3**
O/E ratio	1.2	0.5	0.8	1.0
Good recovery (GOS 5)	n = 23; 23.2%	n = 11; 27.5%	n = 5; 9.6%	n = 55; 24.6%
Moderate dis. (GOS 4)	n = 11; 11.1%	n = 4; 10.0%	n = 4; 7.7%	n = 22; 9.8%
Severe dis. (GOS 3)	n = 2; 2.0%	n = 3; 7.5%	n = 5; 9.6%	n = 23; 10.3%
Vegetative st. (GOS 2)	n = 1; 1.0%	n = 2; 5.0%	n = 4; 7.7%	n = 17; 7.6%
Death (GOS 1)	n = 49; 49.5%	n = 7; 17.5%	n = 18; 34.6%	n = 82; 36.6%
Favourable	n = **34; 34.3%**	n = **15; 37.5%**	n = **9; 17.3%**	n = **77; 34.4%**
Unfavourable	n = 52; 52.5%	n = 12; 30.0%	n = 27; 51.9%	n = 122; 54.5%

ered without major interventions. Patients in this group had the highest 90 day mortality (48.5%); this was probably due to age and trauma severity as logistic regression did not show a significant difference.

In about 10% of the patients (group "ICP"), no surgery was required, but ICP monitoring devices were placed. The durations of elevated ICP and decreased CPP were slightly, but not significantly, shorter than those in patients of group "BOTH". As in group "NONE", about one third of the patients had a diagnosis of SDH. Despite high ISS and low TRISS, group "ICP" outcomes were better than in all other groups: the patients in this group had the lowest 90 day mortality (17.5%); after controlling for confounding variables with logistic regression this difference was significant.

Surgery without postoperative ICP monitoring was done on 12.5% of the patients (group "SURG"). This group had the highest mean age (56.2 vs. 47.8; $p < 0.001$) and the lowest ISS (22.8 vs. 27.8; $p < 0.001$); 34/52 patients (66%) had a diagnosis of SDH. In this group, OPS (n = 29; 49%) was done less frequently than in group "BOTH", and more patients had OCS (n = 26; 44%) and DEC (n = 4; 7%). The decision not to place an ICP monitoring device was probably based on the high rate of OCS, as well as on the results of the CT-scans: most of the patients showed open basal cisterns on midbrain level (73.1% vs. 66.1% of "BOTH"). ICU (25.0%) as well as 90 day mortality (30.8%) were lower than that of group "BOTH" (n.s.). A favorable outcome was achieved in only 17.3% of the cases, but the O/E ratio was 0.8.

More than half of all patients had surgery and ICP monitoring (group "BOTH"). OPS was done most frequently (n = 192; 72%), while OCS (n = 65; 24%) and DEC (n = 11; 4%) were done less frequently than in group "SURG". More than half of the patients (119/224; 53%) had a diagnosis of SDH. Durations of elevated ICP and decreased CPP were higher than in group "ICP" (n.s.), and the longest durations were observed in patients who underwent DEC ($p < 0.001$ for both ICP and CPP vs. group "ICP"). Despite a higher ISS, this group had the best TRISS, but outcomes were worse than in group "SURG" as 90 day mortality was 35.3% (n.s.). A favorable outcome was achieved in 34.4% (n.s.) of the cases, and the O/E ratio was 1.0.

Discussion

The goal of this paper was to describe the surgical management of patients with severe TBI in Austria. The results have to be interpreted with caution because they are based on registry data rather than data from a randomized study. It has to be considered that for most interventions there were differences between patients who were treated and those who were not treated. To correct for that all outcome data has been corrected for age, ISS, and first GCS, and O/E ratios have been reported together with mortality. Some key aspects will be discussed below.

A new aspect of our study is the classification of different types of cranial lesions; most other studies deal with single types of lesions only. The incidence of EDH (single and combined) in our study was 21%, very similar to that reported in a German study (22%) [6], while EDH was less frequently observed in a Spanish study (14%) [7] and a US study (9%) [8]. All of those studies report hospital based incidence data. Incidence of SDH (single and combined) was 48% in our study, again comparable to the German data [6] (41%), and much higher than the rates reported in the Spanish (20%) [7] and the US studies (29%) [8]. In our study 56% of the patients had SAH (single and combined), regarding this kind of lesion no comparable studies were found. Contusion incidence was 69%, about twice the rates reported by the German (37%) [6] and the Spanish studies (31%) [7]. With regard to the combination of lesions, we again found only few studies for comparisons: A study from Turkey [9] reported the incidence of a combination of EDH + SDH in 16/113 patients (14%); no other associated intracerebral lesions were mentioned. In our study patients with EDH + SDH represent only 1% (4/415) of the whole study group. Münch et al. [6] reported an incidence of 6% for the combination of EDH+SDH+CONT which is comparable to the 3% (13/415) in our study. The lower incidences reported in the Spanish [7] and the US [8] studies are difficult to explain. Neither the Spanish nor the US study included penetrating brain injuries, therefore a possible explanation for the lower incidence might be the fact that the studies were done in the early 80s: it seems possible that fewer severe cases reached the Emergency room or the OR.

Mortality of patients with EDH was 30% (ICU) and 33% (90 day) in our study. Both Lobato et al. [7] and Gennarelli et al. [8] reported 21% mortality for patients with EDH after 3 [8] and 6 months [7], respectively. A possible explanation for this difference might be the fact that these studies included only patients where EDH was the predominant injury whereas in our study most patients with EDH had additional intracranial lesions that might have influenced outcome. Another German study (Regel et al.) [10] stated that mortality of EDH was commonly 0–40%, and Servadei [11], summarizing other studies from various authors, reported a rate between 9% and 59%. All of these studies deal with operatively and non-operatively treated cases. The mortality of our patients with SDH was 36% (ICU) and 43% (90 day), and was much lower than that published by other authors. Lobato et al. [7] reported a mortality of 63%, Koc at al. [9] reported 60%, Regel et al. [10] cited a common mortality of SDH from 50% to 90%, and Servadei [12] stated that mortality of patients with SDH was between 36% and 79%. Gennarelli et al. [8], however, found a mortality of 19% in patients with SDH. Regarding mortality of patients with SAH, we were unable to find any studies for comparisons. The mortality of our patients with CONT was 31% (ICU) and 35% (90 day) while Lobato et al. [7] reported 45% mortality for these patients.

In our study OPS was performed on 53% of all patients, OCS on 22%, and DEC on 3.6%. The rate of OCS seems to be rather low as other authors [13] reported that OCS was done more frequently than OPS (44% vs. 43%). In our study only one third of operatively treated patients with SDH had OCS. This might be due to a new trend in surgery for SDH: Ruchholtz et al. [14] reported that OPS is more frequently used today. Decompressive craniectomy was done most frequently on patients with SDH+SAH+INT, and these patients had a mortality of 54%. Earlier studies [15] confirm that DEC may decrease ICP in patients with SDH, but does not improve outcome (mortality 67%), and other authors [9, 16] report a mortality of 100% for patients with SDH and DEC. Many studies assess the effects of DEC as a "second line" therapy for lowering ICP or/and mortality [6, 17–19]. To date, there is still not enough evidence to recommend DEC for these indications. In our study the best outcome after surgery was found in patients with EDH (90 day mortality 33%). The mortality of patients with SDH was lower for operatively treated patients (45% vs. 50%), and patients treated by OCS had a significantly better outcome than those who had OPS. This is confirmed by other studies: Koc. et al. [9] reported lower mortality (35%) for craniotomy without vs. craniotomy with dural grafting (55% mortality). Ruchholtz et al. [14] recommend OPS for treatment of EDH, and OCS for treatment of SDH. The reason for this recommendation is that brain edema and/or recurrence of hematoma are better tolerated after OCS, and deleterious increases in ICP may be avoided. Other authors [20, 21] argue that OPS may less frequently lead to recurrence of hematoma, and may therefore be beneficial.

Monitoring of ICP is an important treatment option for patients with severe TBI. ICP monitoring is recommended by all available guidelines for management of severe TBI [22–24]. In our study the patients of the group "ICP" had the lowest mortality (statistically significant), and the patients of group "NONE" had the highest mortality. This raises the question why the patients of the group "NONE" did not receive ICP monitoring. In some patients this might be explained by an obviously hopeless situation, but many patients had GCS, ISS and CT findings comparable to those who were monitored. They were, however, significantly older. It is unclear whether age was the reason why no ICP monitoring was done in these patients. Regarding operatively treated patients, those from group "SURG" had a lower mortality than those from group "BOTH" (n.s.). This may be explained by the fact that the patients of group "SURG" had slightly better TRISS and GCS (n.s.). There is not a single study which analyses the outcome of patients who were treated operatively but without ICP monitoring. There is no obvious reason why these patients did not receive ICP monitoring. Contrary to expectations, however, this management did not impair outcome.

In conclusion, our study showed that patients who do not require surgical treatment, but have ICP monitoring have the best outcome. This is true for all kinds of intracranial lesions, with the notable exception of SDH where operatively treated patients have significantly better outcomes. In these patients the method of choice seems to be osteoclastic trepanation. We recommend that all patients with severe TBI should have ICP monitoring.

Acknowledgements

We have to thank Prim. Dr. Walter Löffler (Linz), Prim. Prof. Dr. Gernot Pauser (Salzburg), Prim. Dr. Volker Schalk (Klagenfurt) and Prof. Dr. Hans Tritthart (Graz), for their active support of the study in their departments.

Funding: The study was supported by a grant from the Jubiläumsfonds of the Österreichische Nationalbank (grant reference Jubiläumsfonds-Projekt Nr. 8987) which covered the costs of the meeting, the development, programming, distribution, and maintenance of the ITCP database, and fees for researchers. An additional grant was received from the Allgemeine Unfallversicherungsanstalt (AUVA), which covered the costs of the participation of Trauma Hospital "Lorenz Boehler". Prof. Dr. Rusnak's salary as study manager was paid partly by a grant from Mrs. Ala Auersperg-Isham and Mr. Ralph Isham. The costs of translating, printing, and distributing the guidelines were supported by a grant from Fresenius Kabi Ges.m.b.H.

References

1. Rusnak M, Janciak I, Majdan M, Wilbacher I, Mauritz W; for the Austrian Severe TBI Study Investigators (2007) Severe traumatic brain injury in Austria I: introduction to the study. Wien Klin Wochenschr 119: 23–28
2. Mauritz W, Rusnak M, Janciak I (2003) Implementing scientific evidence-based guidelines: case study of severe traumatic brain injuries. Clinical Research and Regulatory Affairs 20: 81–87
3. Marshall LF, Becker DP, Bowers SA, et al (1983) The National Traumatic Coma Data Bank. Part 1: design, purpose, goals, and results. J Neurosurg 59: 276–284
4. Boyd CR, Tolson MA, Copes WS (1987) Evaluating trauma care: the TRISS method. Trauma Score and the Injury Severity Score. J Trauma 27: 370–378
5. Downloaded from: www.xlstat.com/
6. Munch E, Horn P, Schurer L, Piepgras A, Paul T, Schmiedek P (2000) Management of severe traumatic brain injury by decompressive craniectomy. Neurosurgery 47: 315–323
7. Lobato RD, Cordobes F, Rivas JJ, de la Fuente M, Montero A, Barcena A, Perez C, Cabrera A, Lamas E (1983) Outcome from severe head injury related to the type of intracranial lesion. A computerized tomography study. J Neurosurg 59: 762–774
8. Gennarelli TA, Spielman GM, Langfitt TW, Gildenberg PL, Harrington T, Jane JA, Marshall LF, Miller JD, Pitts LH (1982) Influence of the type of intracranial lesion on outcome from severe head injury. J Neurosurg 56: 26–32
9. Koc RK, Akdemir H, Oktem IS, Meral M, Menku A (1997) Acute subdural hematoma: outcome and outcome prediction. Neurosurg Rev 20: 239–244
10. Regel JP, Sandalcioglu IE, Schoch B, Stolke D, Ruchholtz S (2005) Epidural haematoma after operative evacuation of an acute subdural haematoma. Discussion of primary treatment illustrated by an unusual case. Unfallchirurg 108: 246–249
11. Servadei F (1997) Prognostic factors in severely head injured adult patients with epidural haematoma's. Acta Neurochir (Wien) 139: 273–278
12. Servadei F (1997) Prognostic factors in severely head injured adult patients with acute subdural haematoma's. Acta Neurochir (Wien) 139: 279–285
13. Parzhuber A, Wiedemann E, Richter-Turtur M, Waldner H, Schweiberer L (1994) The contribution of the general and trauma surgeon in neurotraumatology: experiences and results of 10 years. Unfallchirurg 97: 615–618
14. Ruchholtz S, Nast-Kolb D (2003) Craniocerebral trauma. Unfallchirurg 106: 839–853
15. Shigemori M, Syojima K, Nakayama K, Kojima T, Ogata T, Watanabe M, Kuramoto S (1980) The outcome from acute subdural haematoma following decompressive hemicraniectomy. Acta Neurochir (Wien) 54: 61–69
16. Hatashita S, Koga N, Hosaka Y, Takagi S (1993) Acute subdural hematoma: severity of injury, surgical intervention, and mortality. Neurol Med Chir (Tokyo) 33: 13–18
17. Sahuquillo J, Arikan F (2006) Decompressive craniectomy for the treatment of refractory high intracranial pressure in traumatic brain injury. Cochrane Database Syst Rev 25: CD003983
18. Jiang JY, Xu W, Li WP, Xu WH, Zhang J, Bao YH, Ying YH, Luo QZ (2005) Efficacy of standard trauma craniectomy for refractory intracranial hypertension with severe traumatic brain injury: a multicenter, prospective, randomized controlled study. J Neurotrauma 22: 623–628
19. Coplin WM (2001) Intracranial pressure and surgical decompression for traumatic brain injury: biological rationale and protocol for a randomized clinical trial. Neurol Res 23: 277–290
20. Koumtchev Y (1993) Our experience in diagnosing and surgical treatment of traumatic intracranial hematomas. Analysis of 610 patients. Folia Med (Plovdiv) 35: 55–59
21. Koumtchev Y (1994) Analysis of three methods of surgical intervention in the management of traumatic intracranial hematomas. Folia Med (Plovdiv) 36: 49–52
22. American Association for the Surgery of Trauma; Child Neurology Society; International Society for Pediatric Neurosurgery; International Trauma Anesthesia and Critical Care Society; Society of Critical Care Medicine; World Federation of Pediatric Intensive and Critical Care Societies; National Center for Medical Rehabilitation Research; National Institute of Child Health and Human Development; National Institute of Neurological Disorders and Stroke; Synthes USA; International Brain Injury Association (2003) Guidelines for the acute medical management of severe traumatic brain injury in infants, children, and adolescents. J Trauma 54 [6 Suppl]: S235–310
23. The Brain Trauma Foundation. The American Association of Neurological Surgeons. The Joint Section on Neurotrauma and Critical Care (2000) Guidelines for the management of severe brain trauma. J Neurotrauma 17: 457–627
24. Procaccio F, Stocchetti N, Citerio G, Berardino M, Beretta L, Della Corte F, D'Avella D, Brambilla GL, Delfini R, Servadei F, Tomei G (2000) Guidelines for the treatment of adults with severe head trauma (part I). Initial assessment; evaluation and pre-hospital treatment; current criteria for hospital admission; systemic and cerebral monitoring. J Neurosurg Sci 44: 1–10

Correspondence: Prof. Walter Mauritz, INRO, Mölkergasse 4/3, 1080 Vienna, Austria,
E-mail: walter.mauritz@igeh.org