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# Current practice in neurocritical care of patients with subarachnoid haemorrhage and severe traumatic brain injury

## Results of the Austrian Neurosurvey Study

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**Summary**
*Objectives* The task force Neuroanaesthesia of the Austrian Society of Anaesthesiology, Resuscitation and Intensive Care Medicine (ÖGARI) is aiming to develop and provide recommendations in order to improve neurocritical care in Austria. Thus, a survey on neurocritical care concepts in Austria regarding intensive care of subarachnoid haemorrhage (SAH) and severe traumatic brain injury (TBI) was performed to assess the current status.
*Methods* An online internet questionnaire comprising 59 items on current concepts of SAH and TBI critical care was sent to 117 anaesthesiology departments.
*Results* The survey was answered by 30 (25.6 %) of the hospitals, 24 (80 %) of them treating patients with SAH and/or TBI. Data from ten SAH centres reveal that definitive care was achieved within 24 h in all hospitals; a case load >50 per year is noted in 70 % of intensive care units (ICU). In all, 50 % of departments employ written protocols for treatment. Regarding the treatment of TBI patients, 14 answers were received, indicating that 42.9 % of departments provide care for >50 patients per year. Time between arrival and CT scan is <30 min in all hospitals, and 28.6 % of departments rely on written protocols. Only 14.3 % of hospitals report about routine morbidity and mortality rounds. While the neurologic status is assessed at discharge from the ICU, there is no evaluation of 1-year outcome.
*Conclusions* Definitive care of SAH and TBI patients is achieved timely in Austria. When compared with SAH, more hospitals with lower case loads take care of TBI patients. Written guidelines and protocols at institutional level are often missing. Since routine morbidity and mortality conferences are sparse, and long-term outcome is not assessed, there is room for improvement.

**Keywords** Survey study · Neurocritical care · Current practice · Aneurysmal subarachnoid hemorrhage · Traumatic brain injury

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## Introduction

The development of neurocritical care in Austria has been significant during the last years. This is true for centralisation, specialisation and, in part, harmonisation of treatment strategies. In this regard, international guidelines and recommendations aim to translate scientific evidence into clinical practice. Aneurysmal subarachnoid haemorrhage and severe traumatic brain injury are frequent entities in neurocritical care. Currently accepted best clinical practice

in management of SAH patients is provided by an international, multidisciplinary consensus conference organized by the Neurocritical Care Society and by the European Stroke Organization [1, 2]. Key recommendations include early aneurysm repair by either endovascular or microsurgical techniques in order to prevent re-bleeding. Antifibrinolytic therapy prior to early aneurysm repair should be considered. Routine use of anticonvulsant prophylaxis with phenytoin is not recommended after SAH; other anticonvulsants may be considered for routine prophylaxis. Management of intravascular volume status should target normovolemia instead of hypervolemia. In case of suspected delayed cerebral ischemia (DCI), arterial hypertension should be induced. Oral administration of nimodipine (60 mg every 4 h) is recommended for a period of 21 days after aneurysmal SAH. If nimodipine causes hypotension, lower doses in shorter intervals are preferable. Inducing hypermagnesaemia for prevention of vasospasm and DCI after SAH is not recommended, but hypomagnesaemia should be avoided. Administration of statins should be continued, and initiation of statin therapy is an option. For effective prevention of deep venous thrombosis sequential compression devices should be routinely used in all SAH patients. According to Neurocritical Care Society recommendations, the use of low molecular weight heparin or unfractionated heparin should be withheld in patients with unprotected aneurysms as well as 24 h before and after intracranial procedures [1]. Finally the consensus conference advised treatment of SAH patients in high volume centres.

In the field of severe traumatic brain injury, management guidelines of the Brain Trauma Foundation (BTF) [3] are still of utmost importance. Key recommendations apply to blood pressure and oxygenation. Thus avoidance of hypotension with a systolic blood pressure less than 90 mmHg, and hypoxia with arterial oxygen partial pressure less than 60 mmHg or oxygen saturation less than 90 % is key. According to BTF guidelines intracranial pressure (ICP) should be monitored in all salvageable patients with a severe traumatic brain injury and abnormal computer tomographic (CT) findings. In special circumstances (age over 40 years, unilateral or bilateral motor posturing, or systolic blood pressure less than 90 mmHg at admission) ICP monitoring is also indicated in patients with severe TBI and normal CT scan. Treatment should be initiated when the ICP exceeds 20 mmHg. For hyperosmolar therapy, mannitol at doses of 0.25–1 g/kg body weight is recommended. Cerebral perfusion pressure (CPP) equals the difference between mean arterial pressure and ICP. CPP target value should be within the range of 50–70 mmHg. Prophylactic use of phenytoin or valproate is not recommended for preventing late posttraumatic seizures, but anticonvulsants are indicated to decrease the incidence of early posttraumatic seizures within 7 days of injury. Prophylactic hyperventilation, prophylactic administration of barbiturates to induce burst suppression electroencephalogram or the use of steroids are not recommended in the management of severe traumatic brain injury [4]. Issues which are not addressed by BTF guidelines are the use of hypertonic saline, targets for sodium serum concentration and arterial partial pressure of carbon dioxide. There is increasing evidence that hypertonic saline is more effective for control of raised ICP when compared with mannitol [5, 6]. Induction of systemic hypothermia causes reduction of brain metabolism and cerebral blood flow, and subsequently also decreases ICP. However high-quality evidence for improvement of neurologic outcome after severe traumatic brain injury by therapeutic hypothermia is still lacking. In the Eurotherm trial outcome in the hypothermia group was even worse than in the control group [7]. Neuroprotective agents are intended for preventing secondary brain injury after trauma. Still, none of the tested substances i. e. progesterone [8, 9] was able to show efficacy in terms of improving clinical outcome in randomized controlled trials.

The primary goal of this survey was to assess the current status of neurocritical care in Austria focusing with a specific focus on two tracer diagnoses, namely SAH and TBI. Neurocritical care in Austria is typically provided by intensive care units (ICUs), which are either run by anaesthesiologists, neurologists or neurosurgeons. The chosen entities, i. e. aneurysmal SAH and TBI, frequently require a combined neuroanaesthesiological/neurosurgical/neurointerventional management not only in ICU, but also in the operating theatre or during radiological assessment in a time-critical manner while maintaining continuity of care.

Neurocritical care can be differentiated as neuroanaesthesiological or neurological critical care. Neurologic critical care is typically handling disorders which rarely need surgical intervention, such as inflammatory or infectious diseases of the central nervous system or status epilepticus. Undoubtedly, the two sections are overlapping. Our survey focuses on the first-mentioned area of neurocritical care which is provided by 11 hospitals in Austria with a dedicated neurosurgery department and 7 dedicated trauma centres run by the Allgemeine Unfallversicherungsanstalt (AUVA, Austrian Workers' Compensation Board). Either neurosurgeons or trauma surgeons do surgical management in this context.

The task force Neuroanaesthesia was founded in 2012 as one of the working groups of the Austrian Society of Anaesthesiology, Resuscitation and Intensive Care Medicine (ÖGARI). Basically, the objective of this working group is to assist neuro-intensivists by developing and providing recommendations for critical care—especially in fields where scientific data is incomplete, or guidelines are missing. The ÖGARI task force includes mainly anaesthesiologists and is supported by neurosurgeons in specific issues. There

**Table 1** Participating centres

| SAH | TBI |
|---|---|
| LKH Feldkirch | LKH Feldkirch |
| LKH – Univ. Klinikum Graz | LKH – Univ. Klinikum Graz |
| Univ. Klinik Innsbruck | UKH Graz |
| Klinikum Klagenfurt | Univ. Klinik Innsbruck |
| Landes-Nervenklinik Wagner-Jauregg Linz | Klinikum Klagenfurt |
| CDK Salzburg | Landes-Nervenklinik Wagner-Jauregg Linz |
| LK St. Pölten | UKH Meidling |
| AKH Wien | CDK Salzburg |
| Krankenanstalt Rudolfstiftung Wien | UKH Salzburg |
| LK Wiener Neustadt | LK St. Pölten |
| | AKH Wien |
| | Krankenanstalt Rudolfstiftung Wien |
| | UKH Lorenz Böhler Wien |
| | LK Wiener Neustadt |

*SAH* Subarachnoid Haemorrhage, *TBI* Traumatic Brain Injury, *LKH* Landeskrankenhaus (state hospital), *CDK* Christian Doppler Klinik (Christian Doppler clinical center), *LK* Landesklinikum (state hospital), *AKH* Allgemeines Krankenhaus (general hospital), *UKH* Unfallkrankenhaus (trauma hospital), *Univ.* Klinikum Universitätskrankenhaus (University hospital)

is no board specification in Neuro-Intensive Care in Austria so far.

## Methods

An online questionnaire comprising 59 items on current concepts of SAH and TBI critical care was developed by the ÖGARI task force Neuroanaesthesia and sent to 117 Anaesthesiology Departments all over Austria in 2013; head of departments were asked to respond. The questionnaire was distributed via Internet employing SurveyMonkey® (Palo Alto, CA USA). Data were further processed with Microsoft Excel (MS Office 2010®).

The questionnaire was structured as follows:

*Section 1*: Statistical data: hospital size and structure; availability of neurosurgery; number of ICU beds; number of patients with SAH and TBI admitted per year.

*Section 2:* Care of SAH patients. Questions addressed availability, time frame and number of therapeutic interventions (i.e. endovascular vs. neurosurgical); existence and employment of written institutional guidelines defining subsequent and on-going intensive care. Furthermore, specific medication such as type of vasopressor drugs, drugs for coagulation disorders, thromboprophylactic medication, anticonvulsive drugs and steroids were evaluated. In addition, strategies for treatment of vasospasms were elaborated. Finally, management of ventriculostomy and cerebrospinal fluid (CSF) drainage with respect to duration, monitoring of possible infection and administration of antibiotics was assessed.

*Section 3:* Care of TBI patients. Assessment of time intervals between admission and brain CT ccan, evaluation of biomarkers indicative of brain injury, subsequent consequences such as intracerebral pressure monitoring and existence of institutional guidelines. Further questions addressing goal-directed therapeutic interventions for management of intracranial pressure, plasma sodium concentration and arterial carbon dioxide concentration; use of barbiturates and therapeutic hypothermia as well as medication for thromboembolic protection. Finally, departments were asked to describe their concept how to detect and treat blunt injuries of extra-cerebral vessels, i. e. carotid and vertebral arteries.

*Section 4:* Quality and outcome assessment. Centres were questioned whether routine morbidity and mortality rounds are established and one-year neurologic outcome is assessed in all patients.

A print-out version of the complete survey is available as a supplement to this paper.

## Results

A dense network of 177 hospitals ensures public health care in Austria. Based on the ÖGARI registry, the online questionnaire was sent to all 117 Anaesthesiology departments. Data were obtained from 30 hospitals (26 %). When hospitals were further evaluated according to the scope of service provided and the focus of interest, i. e. institutions with special expertise in SAH or TBI management, numbers were as follows. Neurosurgery was permanently available in 11 hospitals, thus qualifying for SAH treatment. From all but one, a completed questionnaire was received. 14 hospitals assigned to level I trauma care responded to questions addressing TBI management comprising 10 hospitals with neurosurgery departments and 4 dedicated AUVA trauma centres (Table 1). Hospitals participating in the study differed in size defined by the number of beds between 130–140 (AUVA Trauma centres) and 1900 (university hospital). Data are presented in Tables 2–9 in an anonymised random order.

### *Centres participating in SAH care*

The annual number of patients, availability of microsurgery and endovascular therapeutic options, and availability of written treatment protocols are outlined in Table 2. All hospitals are able to ensure the appropriate level of care within 24 h after admittance, although 20 % of centres must transfer patients scheduled for endovascular intervention (coiling) to another hospital. 60 % of centres provide all services including endovascular interventions even during night shifts. Thus 80 % of hospitals are eligible for comprehensive SAH care, and 70 % treat >50 patients per year.

For subsequent intensive care, written guidelines and protocols are available in 50 % of anaesthesiology departments; one was in the development process.

**Table 2** Number of SAH patients per year, available interventions, time until definitive care and availability of institutional guidelines

| *n* = 10 | Interventions | | | | Options | | | Time to definitive care | | | | Institutional guidelines | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Center | <10 | 10–35 | 35–50 | >50 | Clipping | Coiling | Both | Immediate | ≤24 h | ≤48 h | ≤72 h | Available | None | In preparation |
| 1 | | | | X | | | X | X | | | | X | | |
| 2 | | | | X | | | X | | X | | | | X | |
| 3 | | | | X | | | X | X | | | | X | | |
| 4 | | | | X | | | X | X | | | | | X | |
| 5 | | | X | | X | | | | X | | | X | | |
| 6 | | | | X | | | X | X | | | | X | | |
| 7 | | | | X | | | X | | X | | | | | X |
| 8 | | | X | | | | X | X | | | | X | | |
| 9 | | | | X | | | X | | X | | | | X | |
| 10 | | X | | | X | | | X | | | | | X | |
| [%] | | 10 | 20 | 70 | 20 | | 80 | 60 | 40 | | | 50 | 40 | 10 |

*SAH* Subarachnoid Haemorrhage

**Table 3** ICU medication

| *n* = 10 | Antifibrinolytics | | Steroids | | Anticonvulsive medication | | | Medication against vasospasm | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Centre | Yes | No | Yes | No | Prophylactic | In case of seizures | No | Nimodipine | Nicardipine | Statins | Mg |
| 1 | | X | | X | | X | | X | | X | X |
| 2 | | X | | X | | | X | X | | X | X |
| 3 | X | | | X | | X | | X | | | X |
| 4 | | X | | X | X | | | X | | | |
| 5 | X | | X | | | X | | X | | | |
| 6 | | X | | X | | X | | X | | | |
| 7 | | X | | X | | X | | X | | | X |
| 8 | | X | | X | | | X | X | | | |
| 9 | | X | | X | | | X | X | | | |
| 10 | | X | | X | | X | | X | | X | X |
| [%] | 20 | 80 | 10 | 90 | 10 | 60 | 30 | 100 | | 30 | 50 |

*Mg* Magnesium

When vasopressor drugs are needed to correct hypotension, norepinephrine is the first line drug in 70 % of departments, in 20 % of ICUs phenylephrine is employed and dopamine is administered as an add on drug to norepinephrine in 10 % of ICUs. Other drugs such as antifibrinolytics, anticonvulsants and steroids are outlined in Table 3. With respect to anticonvulsants, levetiracetam is the predominantly used drug (80 %), followed by a combination of levetiracetam and carbamazepine (10 %) and phenytoin (10 %).

In order to prevent cerebral vasospasms, nimodipine is employed in all ICUs. Administration is predominantly intravenous (60 %) followed by the enteral route as soon as possible, whereas 40 % of departments choose enteral application only. In 50 % magnesium is employed, and 30 % also administer statins. When hypotension is noted during nimodipine administration, dosage is adjusted (90 %), whereas infusion is terminated in rare occasions when hypoxemia due to intrapulmonary shunting is observed (70 %); a phenomenon which is not observed by 30 % of ICUs. Vasospasmolytic therapy is typically driven by transcranial Doppler ultrasonography, provided by neurosurgeons (50 %), anaesthesiologists (30 %) or neurologists (20 %). In 70 % of centres endovascular balloon angioplasty is performed if needed, and intra-arterial infusion of vasodilators is provided in 80 % of departments.

Besides the attempt to achieve cerebrovascular vasodilation as described above, arterial hypertension is induced in all ICUs when needed in order to counteract vasospasms. Hypervolemia either alone or in combination with haemodilution is considered appropriate in 20 vs. 40 % of ICUs, respectively. In order to increase cardiac index, dobutamine is administered in 80 % of departments.

Interestingly, target mean blood pressure for patients with proven vasospasm differs between critical care units: 100 mmHg (50 %) vs. 90 mmHg (10 %) vs. 110–120 (20 %) vs. an individualized threshold (20 %). For prophylaxis of vasospasm, target mean blood pressure is considered appropriate when 90 mmHg

**Table 4** Thromboembolic prophylaxis in SAH: interventions and timing of low molecular weight heparin

| *n* = 10 | Measures | | | | | Low molecular weight heparin | | | |
|---|---|---|---|---|---|---|---|---|---|
| Centre | LMWH | UFH | Compression stockings | Pneumatic compression stockings | Colloids | Immediately | ≥24 h | ≥48 h | ≥72 h |
| 1 | X | | | | | | X | | |
| 2 | X | | | | | | X | | |
| 3 | X | | X | X | | | X | | |
| 4 | X | | X | X | | | | | X |
| 5 | X | | X | X | | | X | | |
| 6 | X | | X | X | X | X | | | |
| 7 | X | | | X | | | X | | |
| 8 | X | | | | | | X | | |
| 9 | X | | | | | | X | | |
| 10 | X | | | X | | | X | | |
| [%] | 100 | | 40 | 60 | 10 | 10 | 80 | | 10 |

*SAH* Subarachnoid Haemorrhage, *LMWH* low molecular weight heparin, *UFH* unfractionated heparin

**Table 5** Management of ventriculostomy

| *n* = 10 | Routine change | | Monitoring of CSF infections | | | | Parameters considered indicative for infection: | | | | Exchange of the ventriculostomy | | Antibiotics via ventriculostomy | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Centre | No | Every 8 days | Cell count | Microbiology | PCR | PCT/IL-6 | General signs of inflammation; cell count in CSF | Microbiologic findings in CSF | Septifast of CSF | PCT oder IL-6 in CSF | Increase in systemic inflammation parameters | Only in case of findings in CSF | Yes | No |
| 1 | | X | X | X | | | X | X | | | | X | | X |
| 2 | X | | X | X | | | X | X | | | | X | X | |
| 3 | X | | X | X | | | | | X | X | | X | | X |
| 4 | X | | X | X | | | X | X | X | X | | X | X | |
| 5 | X | | X | X | X | X | X | X | X | X | | X | X | |
| 6 | X | | X | | | | X | X | | | | X | X | |
| 7 | X | | X | X | | X | X | X | | | X | | X | |
| 8 | X | | X | X | | | X | X | | | | X | X | |
| 9 | X | | X | X | | | X | X | | | | X | X | |
| 10 | X | | X | X | | X | X | X | | X | | X | X | |
| [%] | 90 | 10 | 100 | 90 | 10 | 30 | 90 | 90 | 30 | 40 | 10 | 90 | 80 | 20 |

*CSF* cerebrospinal fluid, *PCR* polymerase chain reaction, *PCT* procalcitonin, *Il-6* interleukin 6

are maintained (60 %) vs. 100 mmHg (20 %). Medication to prevent thromboembolic complications is depicted in Table 4, and management of ventriculostomy and CSF drainage in Table 5. Drainage is not exchanged based on predefined time intervals in 90 % of centres, and antibiotics are administered in case of suspicious infection via the drain in 80 % of ICUs.

### *Centres participating in TBI care*

The annual number of patients admitted, time intervals between admission and CT scan, availability of biomarkers for TBI assessment and advanced cerebral monitoring techniques are presented in Table 6.

Interestingly, biomarkers are considered important by the majority of TBI centres for guidance of radiologic assessment (57.1 %); for weaning from the ventilator only few rely on biomarkers (14.3 %). Biomarkers are deemed suitable and valuable by 57.1 % of ICUs when estimating the prognosis, although elevated biomarkers alone do not trigger intracranial pressure monitoring. Despite data supporting the use of advanced cerebral monitoring in TBI patients such as assessment of intraparenchymal oxygen partial pressure or microdialysis [10], both techniques are rarely employed (35.7 % vs. 21.4 %, respectively).

In 28.6 % of centres, written treatment protocols comprising target values for cerebral perfusion pressure, blood sodium level and arterial carbon dioxide pressure are established (Table 7). Employment of burst suppression barbiturate coma and therapeutic hypothermia as well as current medication for prevention of thromboembolic complications are outlined in Table 8. The latter issue is also addressed by use of

**Table 6** TBI patients per year, time between admission and CT scan, assessment of biomarkers and TBI monitoring

| *n* = 14 | TBI per year | | | | Emergency CT scan | | | Biomarker | | Biomarkers employed | | Monitoring | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Centre | <10 | 10–35 | 35–50 | >50 | <10 min | 10–30 min | >30 min | Yes | No | NSE | S100B | ptiO2 | NIRS | MD | BIS | EEG | EP |
| 1 | | | X | | | X | | | X | | | | X | | X | X | X |
| 2 | | X | | | | X | | | X | | | | | | X | | |
| 3 | | | | X | | X | | | X | | | X | | X | | | X |
| 4 | | | | X | X | | | X | | | X | | | | | X | X |
| 5 | | | | X | X | | | X | | X | X | | X | | X | X | X |
| 6 | | | | X | X | | | X | | X | X | X | X | X | X | X | X |
| 7 | | | | X | | X | | X | | X | X | X | X | | X | | X |
| 8 | | | | X | | X | | | X | | | | X | | X | | X |
| 9 | | X | | | X | | | | X | | | X | | X | | X | X |
| 10 | | X | | | X | | | X | | | X | X | | | X | | |
| 11 | | X | | | X | | | X | | | X | | | | X | X | X |
| 12 | X | | | | | X | | | X | | | | | | X | X | X |
| 13 | | X | | | X | | | X | | | X | | | | X | | X |
| 14 | | | X | | | X | | | X | | | | | | | X | |
| [%] | 7.1 | 35.7 | 14.3 | 42.9 | 50.0 | 50.0 | | 50.0 | 50.0 | 21.,4 | 50.0 | 35.7 | 35.7 | 21.4 | 71.4 | 57.1 | 78.6 |

*TBI* traumatic brain injury, *NSE* neuronspecific enolase, *ptiO2* tissue oxygen pressure, *NIRS* near infrared spectroscopy, *MD* cerebral microdialysis, *BIS* bispectral index, *EEG* electroencephalography, *EP* evoked potentials

pneumatic compression stockings (71.4 %) and regular administration of colloids (7.1 %).

### *Blunt cerebrovascular injuries (BCVI)*

Predefined screening guidelines for detection of blunt injury of extracerebral vessels are reported by 35.7 % of centres, subsequent treatment protocols for BCVI are available in 14.3 % of hospitals and one additional institution was preparing guidelines during the study phase. Unfractionated vs. low molecular weight heparin was the drug of choice in case of blunt BCVI in 35.7 vs. 42.9 % of centres, while acetylsalicylic acid was chosen in 14.3 % of hospitals. For prolonged treatment exceeding the intensive care phase, low molecular weight heparin and oral anticoagulant medication have been reported as standard therapies by 42.9 vs. 28.6 % of institutions; acetylsalicylic acid was prescribed by 42.9 % of departments; 7.1 % reported clopidogrel as an alternative to acetylsalicylic acid.

Information about the frequency of interdisciplinary morbidity and mortality conferences and assessment of long-term outcome after TBI is presented in Table 9.

## Discussion

Our survey sheds light on the current status of neurocritical care in Austria. The number of institutions responding to the Internet-based online questionnaire was representative since all but one major centre participated. The average caseload of patients suffering from aneurysmal SAH was reported to be >50 per year by the majority of hospitals participating in the survey. Based on these numbers and recommendations from current literature, we suggest that hospitals involved in neurointensive care of SAH do have significant experience and competence in this field [11–13]. Furthermore, 80 % of hospitals are able to offer both microsurgery for aneurysm clipping and endovascular interventions. Time to definite care after hospital admission is likewise appropriate and consistent with current guidelines [1, 2]. This is also the case in terms of nimodipine use in general, transcranial Doppler ultrasonography, medication to prevent thromboembolic events or the nonroutine change of ventriculostomy catheters. The degree of uncertainty seems to be low in these issues and therefore guideline adherence is high, constituting the cornerstone of neurocritical care in Austria. [1, 2]. On the other hand there are questions of daily practice which are not adequately addressed by international guidelines. As an example, nimodipine administration after aneurysmal SAH is recommended by the Neurocritical Care Society Consensus Conference orally every 4 h for 21 subsequent days [1]. However, oral administration can be impossible in intubated and sedated patients with prolonged gastric emptying and reflux via the nasogastric tube. This issue has been addressed by the European Stroke Organization Guidelines [2] recommending intravenous application when oral administration might fail, but intravenous dosage is not provided. Moreover, the aforementioned guidelines do not discuss appropriate therapy in case of nimodipine-induced hypotension. In this situation institutional treatment protocols have to close the gap between international guidelines and challenges

**Table 7** Availability of institutional guidelines and target CPP pressures, plasma sodium concentration and paCO2

| *n* = 14 | TBI SOP | | | CPP | | | | Sodium levels | | | | paCO2 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Centre | Yes | No | In preparation | 50–60 mmHg | 60–65 mmHg | 65–70 mmHg | >70 mmHg | 135–140 mmol/l | 140–145 mmol/l | 145–150 mmol/l | 150–155 mmol/l | 30–35 mmHg | 35–40 mmHg | 40–45 mmHg |
| 1 | X | | | | | X | | | X | | | | X | |
| 2 | | X | | | | X | | | X | | | | X | |
| 3 | | X | | | | X | | | | | X | | X | |
| 4 | | X | | | X | | | X | | | | | X | |
| 5 | | | X | | | | X | X | | | | X | | |
| 6 | | X | | | | X | | | X | | | | X | |
| 7 | X | | | | X | | | | | X | | | X | |
| 8 | | X | | | X | | | | X | | | | X | |
| 9 | X | | | | X | | | | X | | | | X | |
| 10 | | X | | | X | | | | | X | | | X | |
| 11 | | | X | | X | | | | | X | | | X | |
| 12 | | X | | | X | | | | | X | | | X | |
| 13 | | X | | | | X | | | X | | | X | | |
| 14 | X | | | | X | | | | | X | | | X | |
| [%] | 28.6 | 57.1 | 14.3 | | 57.1 | 35.7 | 7.1 | 14.3 | 42.9 | 35.7 | 7.1 | 14.3 | 85.7 | |

*TBI* Traumatic Brain Injury, *SOP* Standard Operating Procedure, *CPP* Cerebral Perfusion Pressure, *paCO2* arterial carbon dioxide pressure

**Table 8** Burst suppression barbiturate coma; therapeutic hypothermia; timing of thromboembolic prophylaxis

| *n* = 14 | Barbiturate coma | | If answered as yes | | | Therapeutic hypothermia | | | Low weight molecular heparin | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Centre | No | Yes | Routine | Rare | Last resort | Routine | Rare | Very rare | Never | Immediately | 24 h | 48 h | 72 h | Later |
| 1 | | X | | | X | | X | | | | X | | | |
| 2 | | X | | X | | | | | X | | | | X | |
| 3 | X | | | | X | | X | | | | X | | | |
| 4 | | X | | | X | X | | | | | | | | X |
| 5 | | X | | X | | | X | | | X | | | | |
| 6 | | X | X | | | | X | | | | | | X | |
| 7 | | X | | | X | | X | | | | | X | | |
| 8 | | X | | | X | | X | | | X | | | | |
| 9 | | X | X | | | | | X | | | X | | | |
| 10 | | X | X | | | X | | | | | | | | X |
| 11 | X | | | | | X | | | | | | X | | |
| 12 | | X | X | | | X | | | | | | X | | |
| 13 | | X | | X | | | X | | | X | | | | |
| 14 | | X | | | X | | | | X | | X | | | |
| [%] | 14.3 | 85.7 | 28.6 | 21.4 | 42.9 | 28.6 | 50.0 | 7.1 | 14.3 | 21.4 | 28.6 | 21.4 | 14.3 | 14.3 |

of daily routine. Interestingly, written institutional treatment protocols are not established in 40 % of all centres taking care of SAH patients, and missing in 57 % of the TBI trauma centres. This finding of our survey clearly suggests potential improvement for neurocritical care in Austria and thus provides a field for action to the task force Neuroanaesthesia. By assisting local institutions in adopting and tailoring key recommendations as appropriate, adherence with the international guidelines could be even increased. Moreover, in a rapidly changing world, recommendations and established therapies must be kept up to date. We observed one institution still relying on steroids for SAH patients, despite the fact that this medication has been eliminated from the international guidelines. After discussing this particular finding with the task force Neuroanaesthesia of the Austrian Society of Anaesthesiology, Resuscitation and Intensive Care Medicine, the local algorithm was corrected.

When compared with SAH, patients suffering from severe TBI are managed in more hospitals (14 vs. 10). As a consequence, the average caseload is lower (70 vs. 43 % for centres with >50 SAH vs. TBI patients per year, respectively). Based on the statistical data available from the public health care system in 2013 (Leistungsorientierte Krankenanstaltenfinanzierung, LKF), a total of 2989 hospital admissions due to aneurys-

**Table 9** Morbidity and mortality (*M&M*) conferences; outcome assessment

| *n* = 14 | M&M conferences | | | Outcome assessment | | In case outcome assessment is performed – point of time | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Centre | Routine | Occasionally | Never | No | Yes | Discharge | 30 days | 90 days | 180 days | 360 days |
| 1 | | X | | X | | | | | | |
| 2 | | | X | | X | X | | | | |
| 3 | | X | | | X | X | | | | |
| 4 | | X | | | X | X | | | | |
| 5 | X | | | | X | X | | | | |
| 6 | | X | | X | | X [sic] | | | | |
| 7 | | | X | | X | | | X | X | |
| 8 | | | X | | X | X | | | | |
| 9 | | | X | | X | X | X | X | | |
| 10 | | | X | | X | X | | | X | |
| 11 | | X | | | X | X | X | | X | |
| 12 | | X | | X | | | | | | |
| 13 | X | | | | X | X | | | | |
| 14 | | X | | X | | | | | | |
| [%] | 14.3 | 50.0 | 35.7 | 28.6 | 71.4 | 71.4 | 14.3 | 14.3 | 21.4 | |

mal SAH vs. 1875 TBI grade II and III, 17,700 TBI grade I and 1595 skull fractures are noted [14]. Thus, the number of patients with TBI is significantly higher when compared with SAH, but the actual number of TBI patients at need for neurocritical care cannot be extrapolated from the data mentioned before. However, it is obvious that more hospitals are involved in neurotraumatology.

Our survey further confirmed that one key recommendation of the Neuroanaesthesia task force, namely minimizing the time interval between hospital admission and CT scan to values <30 min in severe TBI patients, is achieved by all trauma centres [15].

Based on the current literature, the likelihood of blunt injury of extra cerebral vessels (internal carotid artery, vertebral artery) is approximately 1 % [16]. Interestingly, the majority of hospitals do not have a defined screening protocol or treatment algorithms after positive testing. Again there is a field for action in implementing existing scientific evidence into clinical practice.

With regard to structural changes in order to improve neurocritical care in Austria, we suggest the implementation of interdisciplinary morbidity and mortality conferences, and a structured assessment of long-term neurologic outcome. While only 14.3 % of centres report about routine conferences, none of the hospitals reported a systematic follow-up after discharge from the ICU. Continuity of care between emergency department, ICU and operating theatre under time-critical conditions is of utmost importance for patients with brain lesions. Therefore we introduced the term "continuous track anaesthesia" for this form of close interaction and cooperation between the two locations in 2010 [17]. Continuous track anaesthesia is characterized by continuity in therapeutic strategies, monitoring and documentation and forms an integral part of neuroanaesthesiological critical care.

This survey focused on institutions with special expertise in SAH and/or TBI management to assess the current status of neurocritical care in Austria. There is increasing evidence that specialized neurocritical care is associated with improvement in outcome for patients with brain injuries. Reduced in-hospital mortality [18] and an increase in favourable outcomes as assessed by Glasgow Outcome Scale [19] are the key benefits from treatment of patients with brain lesions in neurocritical care units. Moreover, a shorter length of stay in ICU and hospital [18, 20] and more patients being likely to return to employed status are further valuable effects of specialized care. These findings do have implications for health care policy and health economics; they also justify interhospital transfers of patients to centres and adequate funding, staffing and equipping of these institutions. Moreover presentation of neurocritical care to the general population as well as to the professional audience is compulsory. Cooperation of centres in working groups seems to be essential for further development of this meanwhile mature discipline.

**Conflict of interest** G. Herzer, U. Illievich, W.G. Voelckel and H. Trimmel declare that they have no competing interests.

## References

1. Diringer MN, Bleck TP, Hemphill JC, et al. Critical care management of patients following aneurysmal subarachnoid haemorrhage: recommendations from the neurocritical care society's multidisciplinary consensus conference. Neurocrit Care. 2011;15:211–40.
2. Steiner T, Juvela S, Unterberg A, et al. European Stroke Organization Guidelines for the management of intracranial aneurysms and subarachnoid haemorrhage. Cerebrovasc Dis. 2013;35:93–112.

3. Brain Trauma Foundation. Guidelines for the management of severe traumatic brain injury. J Neurotrauma. 2007;24(Suppl 1):S1–106.
4. CRASH Trial Collaborators. Effect of intravenous corticosteroids on death within 14 days in 1008 adults with clinically significant head injury (MRC CRASH trial): randomised placebo-controlled trial. Lancet. 2004;364(9942):1321–8.
5. Li M, Chen T, Chen SD, et al. Comparison of equimolar doses of mannitol and hypertonic saline for the treatment of elevated intracranial pressure after traumatic brain injury: a systematic review and meta-analysis. Medicine (Baltimore). 2015;94(17):e736.
6. Haddad SH, Arabi YM. Critical care management of severe traumatic brain injury in adults. Scand J Trauma Resusc Emerg Med. 2012;20:12.
7. Andrews PJD, Sinclair HL, Rodriguez A, et al. Hypothermia for intracranial hypertension after traumatic brain injury. N Engl J Med. 2015;373:2403–12.
8. Skolnick BE, Maas AI, Narayan RK, et al. A clinical trial of progesterone for severe traumatic brain injury. N Engl J Med. 2014;371(26):2467–76.
9. Kabadi SV, Faden AI. Neuroprotective strategies for traumatic brain injury: improving clinical translation. Int J Mol Sci. 2014;15(1):1216–36.
10. Menon DK, Citerio G, Vespa P, et al. Consensus summary statement of the international multidisciplinary consensus conference on multimodality monitoring in neurocritical care. A statement for healthcare professionals from the Neurocritical Care Society and the European Society of Intensive Care Medicine. Intensive Care Med. 2014;40:1189–209.
11. Boogarts HD, van Amerongen MJ, de Vries J, et al. Caseload as a factor for outcome in aneurysmal subarachnoid haemorrhage: a systematic review and meta-analysis. J Neurosurg. 2014;120(3):605–11.
12. Leake CB, Brinjikji W, Kallmes DF, et al. Increasing treatment of ruptured cerebral aneurysms at high-volume centers in the United States. J Neurosurg. 2011;115(6):1179–83.
13. McNeill L, English SW, Borg N, et al. Effects of institutional caseload of subarachnoid haemorrhage on mortality: a secondary analysis of administrative data. Stroke. 2013;44(3):647–52.
14. Bundesministerium für Gesundheit. Krankenanstalten in Zahlen. Überregionale Auswertung der Dokumentation der landesgesundheitsfondsfinanzierten Krankenanstalten 2014. http://www.kaz.bmg.gv.at/fileadmin/user_upload/Publikationen/uereg_oesterreich_2013.pdf. Accessed 2015 Jun 14.
15. Arbeitsgruppe zur Optimierung der Erstversorgung von Patienten mit SHT. Empfehlungen zur Erstversorgung von Patienten mit Schädel-Hirn-Trauma 2013. http://www.oegari.at/web_files/dateiarchiv/editor/empfehlung__zu_erstversorgung_sht_2013.pdf. Accessed 2015 Jun 02.
16. Bromberg WJ, Collier BC, Diebel LN, et al. Blunt cerebrovascular injury practice management guidelines: the Eastern Association for the Surgery of Trauma. J Trauma. 2010;68(2):471–7.
17. Herzer G, Trimmel H. Neuroanaesthesia. Principles of optimized perioperative management. Anaesthesist. 2010;59(4):371–82.
18. Suarez J, Zaidat OO, Suri MF, et al. Length of stay and mortality in neurocritically ill patients: impact of a specialized neurocritical care team. Crit Care Med. 2004;32(11):2311–7.
19. Egawa S, Hifumi T, Kawakita K, et al. Impact of neurointensivist-managed intensive care unit implementation on patient outcomes after aneurysmal subarachnoid haemorrhage. J Crit Care. 2016;32:52–5.
20. Josephson SA, Douglas VC, Lawton MT, et al. Improvement in intensive care unit outcomes in patients with subarachnoid haemorrhage after initiation of neurointensivist co-management. J Neurosurg. 2010;112(3):626–30.