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Practices in Neurosurgical Anesthesia – A Survey among Austrian Centers

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Abstract

Introduction: The discipline of neuroanesthesia provides vital services to facilitate neurosurgery and postoperative intensive care, and is a main contributor to patient outcomes. Even though individual anesthetic interventions are regularly subject to scientific scrutiny, no exhaustive systemic overview of adopted methods in different Austrian neurosurgical centers has been delivered to date. In order to establish a cross-sectional overview of practice among eleven Austrian neurosurgical centers, we conducted a digital survey, which included 72 questions in four sections, namely general features of participating centers, characteristics of neuroanesthesia for cranial as well as spinal surgery, and peculiarities of neurosurgical intensive care.

Methods: We carried out a 72-item, cross-sectional online questionnaire which allowed for different types of answers upon invitation *via* e-mail. After conclusion of the survey and screening of given answers, we applied descriptive statistics in order to present our dataset in tabular and free-text form.

Results: At 100% response rate, we were able to compile an exhaustive overview of neuroanesthesia among all Austrian neurosurgical centers.

Conclusion: We demonstrate and discuss specific areas of interest, especially in areas in which conclusive scientific evidence has not been delivered to date. Commonalities and differences of standard neuroanesthetic practice, available diagnostic and therapeutic resources and organizational specifics across our sample were identified.

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Introduction

Diligent anesthesiologic care plays a vital role for patients in neurosurgical procedures with regard to patient safety, enhancement of surgical conditions and facilitation of surgical methods, and therefore, optimum patient outcome. As anesthesiologic methods have been proven time and again to significantly determine the success of said procedures, a variety of challenges present themselves to the anesthesiologist in clinical practice. First, these encompass routine tasks such as induction and maintenance of as well as emergence from anesthesia, monitoring vital parameters and preserving vital functions, and planning postoperative care. Second, operative procedures in neurosurgery pose certain extraordinary procedural and patient-related challenges to the anesthesiologist, such as complex patient positioning, strictly timed awake procedures and specific physiologic and pharmacologic considerations. The wide spectrum of neurosurgery primarily consists of cranial and spinal column interventions but also includes a degree of peripheral nerve surgery. Even though individual anesthetic interventions are regularly subject to scientific scrutiny, no exhaustive systemic overview of adopted methods in different Austrian neurosurgical centers has been delivered to date. We set out to investigate standard practices across these centers and present our findings.

Material and Methods

Our study was conceived as a cross-sectional questionnaire survey in the German language, and approved by the Research Ethics Committee at the Medical University of Innsbruck. We performed an electronic questionnaire among consultants of eleven different neurosurgical centers across

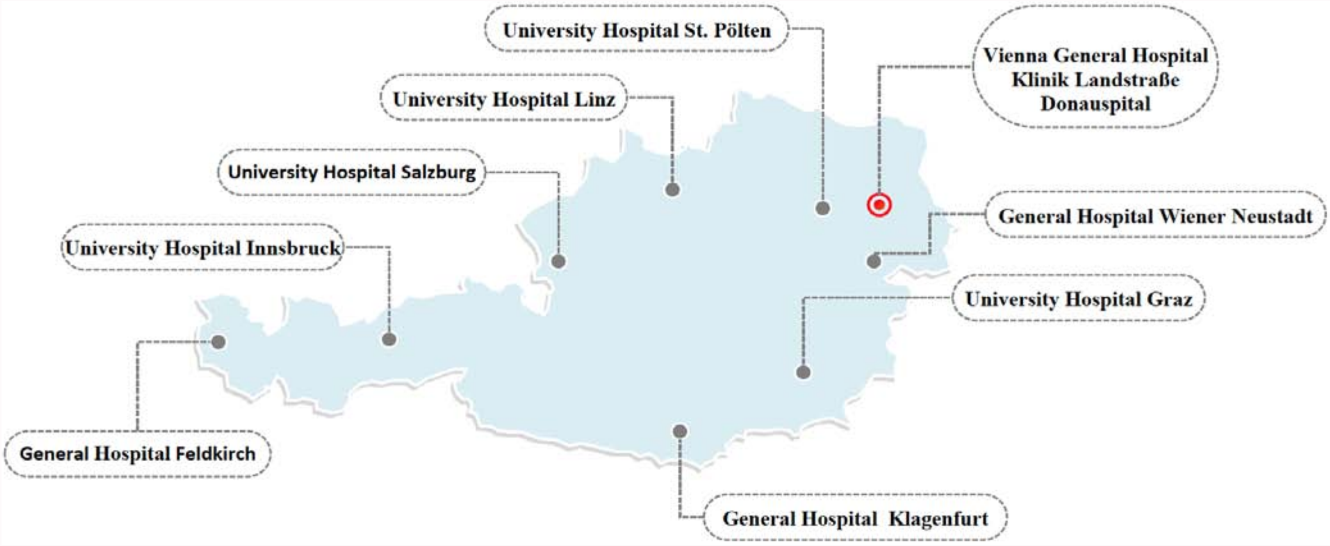

Figure 1: Neurosurgical centers in Austria.

Austria, in which between 900 and 4,200 neurosurgical procedures are performed yearly (Figure 1).

This selection comprises any institutional caregiver performing both cranial and spinal neurosurgical procedures in Austria. Four weeks before deployment of our survey, heads of neurosurgical anesthesiology were contacted *via* e-mail and informed about the impending survey. The initial provisioning of the electronic survey was communicated *via* e-mail, and idle participants were remembered *via* e-mail again three weeks after initial deployment. Therefore, responses were submitted between 12/2019 and 03/2020. We included 72 questions, which allowed for either free-form, single- or multiple-choice answers depending on the respective issue, as well as additional comments in free-form text fields. These questions were divided into four sections, namely general questions (n=20), specific questions regarding cranial (n=43) and spinal (n=3) procedures, and questions regarding the neurosurgical Intensive Care Unit (ICU, n=5). We utilized the online survey tool LimeSurvey, which allowed for the submission of individual surveys only after completion of all the above questions. Where admissible, our forms allowed for options best translated as “none”, “none of the above”, “not applicable” or otherwise unspecified. One final free-form text field was provided to allow for further comments or elucidations regarding the discussed issues if the respondent deemed such additions necessary.

After completion, survey data points were exported in a Microsoft Excel data format (see supplementary materials for raw data). To ensure validity, response times were screened, of which all appeared appropriate (Median 1681,5 s; IQR 1005,7 s). Additionally, all instances of free-form answers were reviewed. Where applicable, these responses were rationally allocated to existing items, or added separately as novel items in order to provide concise data. Then, Microsoft Excel was utilized to apply descriptive statistics. For whenever single answers were omitted (e.g., “n/a”), the number of valid answers were used as denominator and reported separately. Data are provided as median values and interquartile ranges or minimum-maximum values, if not indicated otherwise. We present an excerpt of our dataset, with the full dataset being available as supplementary material.

Results and Discussion

All neurosurgical centers responded, resulting in a 100% response rate, and all questionnaires were completed and valid. The following tables (Tables 1-4) give a comprehensive overview of our survey, some areas of interest are highlighted in text.

Although two respondents did not specify cases, more than 18,000 neurosurgical procedures are performed yearly across all responding institutions (Median 1800 [900-4200], IQR 1400). As far as cranial procedures are considered, all centers perform tumor, vascular, pituitary gland and shunt surgery as well as surgery for intracranial hematoma and traumatic brain injury. Stereotactic biopsies (10/11, 91%), stereotactic surgery for Parkinson’s disease (5/11, 45%) and epilepsy surgery (6/11, 55%) are of limited scope within our sample. With respect to spinal surgery, neurosurgical departments treat spinal column and spinal cord tumors, disc herniations, and cervical and lumbar stenoses. Except for one center, neurosurgical department also routinely perform vertebral fusion surgery (10/11, 91%), whereas spinal column deformity correction surgery (3/11, 27%) and spinal cord injury (4/11, 36%) broadly remains a domain of orthopedics and/or traumatology departments. As far as miscellaneous peripheral nerve surgery is concerned, our sample paints a heterogenous picture. While trigeminal nerve (Janetta procedures, 10/11, 91%) and peripheral nerve decompressions (9/11, 82%) are performed in a majority of centers, peripheral nerve reconstructive surgery (3/11, 27%), ablation of the trigeminal ganglion (5/11, 45%) and facet joints (4/11, 36%) are restricted to a minority of centers.

While we have found the results of our survey to be revealing in several areas, we commence by discussing its limitations prior to highlighting some areas of special interest. To compensate for local specifics, we allowed for both the omission of single answers and free-form comments to complement given answers. This added some complexity to the description of the dataset, which resulted, most prominently, in n<11 for specific questions. Also, our data is limited by the fact that individual procedures (esp. DSA coiling, catheter-directed thrombolysis and thrombectomy) might be performed by different departments and medical specialties across centers. Additionally, individual questions were dropped from

Table 1: General neuroanaesthetic features of participating centers (n=11 unless specified otherwise, data are given as n [%] or median value [min…max]).

No. of neurosurgical centers surveyed	11
Responding centers	11 (100%)
No. of neurosurgical procedures performed annually, *n=9*	1800 (900…4200)
No. of centers performing Cranial surgery, *thereof*	11 (100%)
Tumor, vascular, pituitary gland, ventriculoperitoneal shunt, intracranial hematoma and traumatic brain injury surgery	11 (100%)
Stereotactic biopsies	10 (91%)
Sterotactic surgery (Parkinson's disease)	5 (45%)
Epilepsy surgery	6 (55%)
Other (not specified)	3 (27%)
No. of neurosurgical centers performing spinal surgery, *thereof*	11 (100%)
Spinal column/spinal cord tumors, disc herniations, cervical/ lumbar stenosis	11 (100%)
Vertebral fusion surgery	10 (91%)
Deformity correction	3 (27%)
Spinal cord injury	4 (36%)
Miscellaneous surgeries	
Trigeminal nerve decompression (Janetta procedure)	10 (91%)
Peripheral nerve decompression	9 (82%)
Peripheral nerve reconstructive surgery	3 (27%)
Trigeminal ganglion ablation	5 (45%)
Facet joint ablation	4 (36 %)
Other (not specified)	1 (9%)
No. of centers performing pediatric neurosurgery (age < 6a)	8 (73%)
Availability of standard operating procedures (SOPs)	9 (82%)
Anesthesiologic modalities, *availibility of*	
Continuous autotransfusion / blood salvage	10 (91%)
Rotation thromboelastometry (ROTEM, TEG)	11 (100%)
Depth of anesthesia monitoring	10 (91%)
Anesthesiologic modalities, *routine use*	
Continuous relaxometry	8 (73%)
Depth of anesthesia monitoring	10 (91%)
Near infrared spectroscopy, *n=10*	2 (20%)
Measures for surgery in prone position, *n=10*	
Routine use of glycopyrrolate for reducing salivation	2 (20%)
Routine use of Woodbridge spiral tube	7 (70%)
Routine evaluation of patient blood management	3 (27%)
Specialties in charge of advanced monitoring, e.g., evoked potentials (SSEP, MEP) or Electromyography (EMG)	
Neurosurgeons	5 (45%)
Medical Technologists/Assistants	6 (55%)
Routine choice of premedication agent	
Midazolam	5 (45%)
Pregabalin	2 (18%)
Lorazepam	1 (9%)
Midazolam/Oxazepam	1 (9%)
None	2 (18%)
Intraoperatively available radiodiagnostic modalities	
X-Ray	10 (91%)
Computed Tomography (CT)	3 (27%)
Magnet Resonance Imaging (MRI)	3 (27%)
Computer-assisted surgery for surgical navigation	11 (100%)
Angiography	6 (54%)

As shown above, Austrian neurosurgical centers offer a broad variety of both spinal and cranial surgery. Standard operating procedures, which are one of the pillars of the survey at hand, are available in a majority of centers (82%). Continuous autotransfusion (91%) and thromboelastometry (100%) are both widely available, and modalities such as continuous relaxometry (73%) and, notably, depth of anesthesia monitoring (91%) are routinely employed.

this publication solely due to questionable validity of the set of given answers. From a conceptual perspective, our results do rely on the existence of department-wide, streamlined standards, and an interpretation of such results includes the assumption of broad caregiver adherence within individual departments. We are confident that this precondition is widely met due to an 82% prevalence of SOPs across our sample, which indicates a demand for the streamlining of patient care and optimization of outcomes. On the contrary, we expected greater differences in areas in which extensive or decisive research is scarce or in which national or international guidelines are not yet available, which has been true to some extent.

For craniotomy, 91% of centers across our sample reported to routinely opt for TIVA over balanced anesthesia. We attribute this choice to the fact that a series of evidence has been presented in support of beneficial effects of Propofol over inhalative anesthetics with regard to increased CPP, reduced ICP and reduced cerebral swelling, which produce improved surgical conditions [1]. This approach is in line with available international guidelines, which imply the use of TIVA and specify ultra-short acting opioids as first-line choice [2]. This requirement is unequivocally met by Austrian neurosurgical centers, which specified Propofol/Remifentanil as their drugs of choice for TIVA. The Royal College of Anesthetists guidelines also call for cell salvage systems and depth of anesthesia monitoring, which, across our sample, are widely available and in broad routine use, respectively. Consistent with available evidence, which implies possible underestimation of Propofol plasma concentrations through Target-Controlled Infusion (TCI) devices and therefore probable undersedation, just 18% of respondents made routine use of such systems [2,3].

In sitting patient positioning, Venous Air Embolism (VAE) due to negative pressures in elevated venous vessels are of concern due to incidence rates of up to 40%, but severe perioperative morbidity is generally rare [4,5]. Higher PEEP (>10 cmH_2O) has been shown not to decrease the rate of venous air embolism in patients undergoing neurosurgery in the sitting position, but a combination of a lower PEEP and/or other measures such as lesser degree of elevation ("semi-sitting") or the use of anti-shock trousers might reduce the incidence of VAE [6-8]. Accordingly, our sample revealed that of 73% of centers employing seated positions, only one center applies PEEP of >10 mbar routinely, while the remaining centers routinely opt for values between 5 mbar to 10 mbar. Some evidence suggests that supine positioning, which bears very little risk for VAE, might be a feasible alternative to sitting positioning for some procedures, but only a minority of centers (27%) adopted this concept throughout our sample. Placement of CVC for cranial surgery in sitting position to achieve an aspiration line for the event of venous air embolism might be warranted by *in vitro* research, which allowed for the recovery of up to 86% of infused air, but case series show that the omission

Table 2: Characteristics of neuroanesthesia for intracranial surgery in participating centers (n=11 unless otherwise specified, data are given as n [%] or median value [min…max]).

Preferred site for Central Venous Catheters (CVC) placement	
Subclavian vein	7 (64%)
Internal jugular vein	3 (27%)
Subclavian and femoral vein	1 (9%)
Availability of ultrasound devices for central venous access	11 (100%)
Patient positioning for CVC placement (ICP normal)	
Supine position	9 (82%)
Trendelenburg positioning	2 (18%)
Patient positioning for CVC placement (ICP elevated), *n=10*	
Supine position	1 (10%)
Trendelenburg positioning	1 (10%)
Reverse Trendelenburg positioning	8 (80%)
Patient positioning for CVC placement (ICP elevated and monitored), *n=10*	
Supine position	5 (50%)
Reverse Trendelenburg positioning	5 (50%)
CVC placement as standard procedure for craniotomies	6 (54%)
Routine application of positive end-expiratory pressure (PEEP) in mechanical ventilation	11 (100%)
Routine PEEP (non-obese, no prior pulmonary condition) [mbar]	
ICP normal	5 (5…7)
ICP elevated	5 (5…7)
Preferred automated mode of ventilation	
Pressure-controlled (PCV)	6 (54%)
Volume-controlled (VCV)	2 (18%)
Individually decided	3 (27%)
Preferred mode of general anesthesia	
Total Intravenous Anesthesia (TIVA)	10 (91%)
Balanced anesthesia with volatile hypnotic agent	1 (9%)
Agents routinely used in TIVA	
Propofol	11 (100%)
Remifentanil	11 (100%)
Fentanyl	2 (18%)
Other agents (Sufentanil, Ketamine, Midazolam)	0
Opiates in routine use during general anesthesia	
Remifentanil	10 (91%)
Fentanyl	9 (82%)
Piritramide	5 (45%)
Sufentanil	2 (18%)
Morphine, alfentanil	0
Other agents	1 (9%)
Routine use of Target Controlled Infusion (TCI) systems	2 (18%)
Muscle relaxants in routine use	
Rocuronium	11 (100%)
Cisatracurium	4 (36%)
Other agents (atracurium, mivacurium, vecuronium, pancuronium, or succinylcholine)	0
Inhalative agents in routine use for balanced anesthesia	
Sevoflurane	10 (91%)
Desflurane	5 (45%)
Other agents (N_2O, Isoflurane, Xenon)	0
None	1 (9%)
Target mean arterial pressure (MAP) in otherwise normotensive patients [mmHg]	
Subarachnoid hemorrhage (SAH), *n=7*	70 (65…90)
Cerebral vasospasm, *n=6*	85 (65…100)
Traumatic brain injury (TBI), *n=6*	75 (65…90)
Availability of SOPs for treatment of increased ICP	9 (82%)
Routine measures for treatment of increased ICP, *n=7*	
Reverse Trendelenburg positioning	6 (86%)
Optimization of head-neck axis	5 (71%)
Deepening of anesthesia	6 (86%)
Mild hyperventilation ($PaCO_2$ 30-40 mmHg)	4 (57%)
Barbiturate administration	5 (71%)
Mannitol administration	6 (86%)
Sorbitol administration	1 (14%)
Hypertonic saline administration	3 (43%)
TRIS-Puffer administration	3 (43%)
Hypothermia (32°C to 34°C)	2 (29%)
Switch from inhalative to intravenous narcotic agent	1 (14%)
Other measures (PEEP <5 mbar, Trendelenburg and supine positioning)	0
Induction of barbiturate coma for treatment of increased ICP	8 (73%)
Permissive hypotension in cerebrovascular surgery	
As a routine measure	1 (9%)
When requested by surgeon	5 (45%)
None	5 (45%)
Adenosine for induced cardiac arrest in cerebral aneurysm clipping	
Routine administration	0
When requested by surgeon	2 (18%)
Never	9 (82%)
Rapid ventricular pacing for flow reduction to optimize surgical conditions	0
Administration of 1.0 FiO_2 before cerebral aneurysm clipping, *n=10*	
Routine administration	4 (40%)
When requested by surgeon	1 (10%)
Never	5 (50%)
Intraoperative prevention of vasospasm, *n=10*	
Routinely	4 (40%)
When requested by surgeon	4 (40%)
Never	1 (10%)
Applied techniques for the prevention of vasospasm, *n=9*	
Induced normotension (MAP > 90 mmHg)	2 (18%)
Administration of intravenous calcium channel blockers	4 (36%)
Both	3 (27%)
Anesthetic induction of EEG-guided burst suppression (when indicated)	7 (64%)
Sitting patient positioning for distinct procedures, *thereof*	8 (73%)
Posterior fossa surgery	8 (100%)
Craniocervical junction surgery	7 (88%)

Upper cervical spine surgery with dorsal surgical access	3 (38%)
Routine patent foramen ovale (PFO) screening for sitting positioning, *n=8*	7 (88%)
Employed screening modalities for PFO, *n=8*	
Transthoracic echocardiogram (TTE)	6 (75%)
Transesophageal echocardiogram (TEE)	3 (38%)
Contrast-enhanced doppler sonography (cTDC)	2 (25%)
Routine PEEP for sitting positioning (non-obese, no prior pulmonary condition), *n=8* [mbar]	
<5	0
5-1-	7 (88%)
11-15	1 (13%)
>15	0
Allocation of a free CVC lumen (‘aspiration line’) for the detection and treatment of air embolism, *n=10*	8 (80%)
Occurrence of clinically significant air embolism which required anesthesiologic intervention within the previous five years	5 (45%)
Neurosurgical departments routinely performing awake craniotomies*, thereof*	8 (73%)
More than five per year (> 5/a)	6 (75%)
Less than five (< 5/a)	2 (25%)
Standard mode of anesthesia for trepanation of chronic subdural hematoma (SDH), *n=10*	
General anesthesia	7 (70%)
Local anesthesia	1 (10%)
Combined general and local anesthesia	2 (20%)
Standard mode of anesthesia for stereotactic surgery, *n=10*	
General anesthesia	7 (70%)
Sedoanalgesia	2 (20%)
Local anesthesia	1 (10%)

Some notable particularities were observed regarding intracranial procedures. CVC placement is a routine measure for craniotomies in just above half of centers (54%), and primary CVC insertion sites differ, but air aspiration lines are commonly allocated (80%). Maintenance of anesthesia is largely achieved by TIVA (91%) with Propofol and Remifentanil as respective narcotic and analgetic agents (both 100%). Yet, target-controlled infusion systems are not routinely employed (18%). All centers aim to keep PEEP at 5 mbar or above, including in cases of elevated ICP and in sitting patients, and none opt for zero-PEEP. Notably, one center opts for PEEP >11 mmHg for patients in the sitting position. In cerebrovascular surgery, permissive hypotension (routinely: 9%, on surgeon request: 45%), induced cardiac standstill via adenosine (on surgeon request: 18%) or rapid ventricular pacing (0%), and 100% FiO_2 application prior to aneurysm clipping (routinely: 40%, on surgeon request: 10%) are applied rather infrequently. Prevention of cerebral vasospasm via calcium channel inhibition (36%), MAP >90 mmHg (18%), or both (27%), is widely addressed either as a routine measure (40%) or at the surgeons’ request (40%). Most centers have SOPs for elevated ICP in place, which include a variety of measures; most commonly reverse Trendelenburg positioning (86%), increase of anesthetic depth (86%), administration of barbiturates (71%) and mannitol (86%), and optimization of the head-neck axis (71%). Sitting patient positioning is practiced in eight neurosurgical departments, thereof primarily for posterior fossa (100%) and craniocervical junction surgery (88%).

Table 3: Characteristics of neuroanesthesia for spinal surgery in participating centers (n=11 unless specified otherwise, data are given as n [%] or median value [min…max]).

Preferred mode of general anesthesia, *n=10*	
Total intravenous anesthesia (TIVA)	5 (50%)
Balanced anesthesia with volatile hypnotic agent	3 (30%)
No preference	2 (20%)
Opiates in routine use during general anesthesia	
Remifentanil	11 (100%)
Fentanyl	10 (91%)
Piritramide	5 (45%)
Sufentanil	2 (18%)
Morphine, alfentanil, or other agents	0

Regarding spinal surgery, maintenance of anesthesia becomes differently nuanced – most notably, the distinct preference for TIVA in cerebral surgery (100%) shifts towards a balanced (30%) or indifferent (20%) approach in some centers.

Table 4: Characteristics of intensive care for neurosurgical patients in participating centers (n=11 unless specified otherwise, data are given as n [%] or median value [min…max]).

Available ICU beds for neurosurgical patient care, *n=9*	10 (8…22)
Variable number of available ICU beds for neurosurgical patient care	2 (18%)
Medical disciplines in charge of neurosurgical post-operative ICUs	
Anesthesiology	5 (45%)
Neurosurgery	2 (18%)
Multidisciplinary	4 (36%)
Availability of cerebral microdialysis	3 (27%)
Routine PEEP for invasively ventilated post-craniotomy patients (non-obese, no prior pulmonary condition) [mbar]	
0–5 mbar	3 (27%)
>5 mbar	8 (73%)
Routine delay of extubation to the ICU following uneventful intracranial surgery	5 (45%)

Post-neurosurgical intensive care units are not homogenously staffed by one medical specialty across our sample. Although intensive care units are predominantly staffed by anesthesiologists (45%), whose Austrian board certification encompasses intensive care medicine, some centers have multidisciplinary teams (36%) or neurosurgeons (18%) provide intensive care for neurosurgical patients.

of aspiration lines is not necessarily accompanied by increased perioperative morbidity [9-11].

Evidence to prove a benefit in hyperventilation to mitigate elevated ICP and enhance surgical conditions is inconclusive, as a reduction in ICP has been commonly proven, but might be counteracted by a simultaneous reduction in cerebral blood flow [12,13]. This ambiguity is reflected by our sample, in which just more than half of respondents hyperventilate patients suffering from increased ICP. Likewise, no center reported to use PEEP <5 mbar for the reduction of total airway pressure and concomitant decrease in ICP. Although these consequences have been conclusively proven in literature, their effects on patient outcomes are currently unpredictable, and therefore individual monitoring and titration is warranted [14]. Although monitoring modalities such as depth of anesthesia monitoring and neuromuscular monitoring have been widely adopted across our sample, Near-Infrared-Spectroscopy (NIRS) is only available in one of five centers, but could prove a valuable tool for the guidance of both hyperventilation and airway pressures to regulate ICP [15,16]. Apart from routine measures, some respondents mentioned that direct ICP monitoring, which allows for the most precise regulation of Cerebral Perfusion Pressure (CPP), is utilized when feasible.

When correlating some answers by department size, i.e., the annual number of neurosurgical procedures performed, some obvious coherences can be observed. Unsurprisingly, a small number of neurosurgical procedures are almost exclusively confined to large centers, most notably stereotactic surgery for Parkinson’s disease, epilepsy surgery, and spinal column deformity correction surgery. Conversely, the use and availability of the most advanced anesthetic modalities are not tied to department size. Like NIRS, which is disposable at one large and one smaller center, neuromuscular and depth of anesthesia monitoring as well as Thromboelastometry (TEG/TEM) are available at centers of all sizes. Point-of-care TEG/TEM, on the other hand, is available in smaller centers, whereas larger centers can make use of laboratories to deliver real-time results around the clock.

In conclusion, we deliver an all-around view of available resources and routine procedures among neuroanesthetic departments among Austrian neurosurgical centers. Our survey reveals broad compliance with evidence-based principles of modern neuroanesthesia and a generally favorable set of available methods, devices and modalities across neurosurgical centers in Austria.

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