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# Anaesthetic Management of Patients Undergoing Intraventricular Neuro-Endoscopic Procedures

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## 1. Introduction

Endoscopic neurosurgery has a long history of solid progression of over a century (Enchev et al., 2008). In this period, several neuroendoscopic procedures were described, but although steady technical improvements increased the endoscopic functionality and indications, poor magnification and illumination kept neuroendoscopy difficult and unreliable, keeping it out of routine practice until the end of the 1980's. Only after the invention of new lenses, electronics and fiberoptics allowed for the manufacturing of a new generation of endoscopes granting brighter illumination and improved resolution, neuroendoscopy came forward as routine treatment in neurosurgery (Li et al., 2005). Initially, neuroendoscopy was almost exclusively performed for endoscopic third ventriculostomy (ETV) for the treatment of obstructive hydrocephalus, and still the majority of neuroendoscopies is performed for ETV. Recently however, it is increasingly used for the management of all types of neurosurgically treatable disorders (Enchev & Oi, 2008), either as a primary surgical approach or as an adjunct, such that endoscopic procedures are common in most neurosurgical departments. A continued evolution of technological advances, introduction of robotic technology, steerable endoscopes and novel neurosurgical techniques are expected to increase its applications even further. These newly implemented surgical practices offer improved treatment options, commonly referred to as 'minimally invasive' in many clinical conditions. Since endoscopic techniques allow for intracranial interventions with minimal damage to healthy brain tissue, these advances are obviously a major benefit. Additionally, some interventions have a better outcome when performed endoscopically. However, in several of these interventions, direct surgical manipulation of cerebral structures and particularities of the endoscopic techniques are a constant hazard since they can severely disturb intracranial pressure, cerebral perfusion and oxygenation. This perturbation of cerebral homeostasis may imply important risks for irreversible brain damage, and severe haemodynamical effects which, if not taken proper care of, make these surgical improvements much less minimal invasive than previously supposed. A proper understanding of the physiological changes induced by and during these procedures is essential for optimal patient care. Neuroendoscopy has been successfully used for third

ventriculostomy, tumor biopsy or resection, cyst fenestration or removal, evacuation of intraventricular haemorrhage and plexus coagulation. The technique has had its greatest application in the treatment of noncommunicating hydrocephalus by third ventriculostomy (Shubert et al., 2006). The surgeon establishes a connection between the third ventricle and the prepontine subarachnoid space by endoscopically fenestrating the floor of the third ventricle to allow the cerebrospinal fluid to flow directly from the third ventricle to the basal subarachnoid spaces, thus bypassing the aqueduct and the CSF pathways of the posterior fossa.

## 2. Key steps of the procedure

In most cases patients are positioned in the supine or semisitting position with the head flexed, so that the burr hole is located at the apex. This helps to minimize loss of CSF and air entrapment into the ventricles or the subdural space (Amini & Schmidt, 2005). During neuroendoscopy, the endoscope is operated carefully in order to minimize brain tissue damage and to allow precise manipulation of the working instruments. The presence of the shaft through the brain tissue mandates absolute immobility of the patient during the procedure. To ensure this precondition, the patient's head is fixated with neurological head pins in most cases. After infiltration with a local anaesthetic, a burr hole is made at an appropriate location for access to the intended trajectory. For endoscopic third ventriculostomy, this is mostly a right precoronal burr hole, 2-3 cm lateral to the midline. In most cases, this will provide a direct trajectory from the entry site through the foramen of Monro into the third ventricle. Then preferably a rigid endoscope is introduced through the frontal cortex into the lateral ventricle (Caemaert et al., 1992), the mandrins of the irrigation channel(s) and of the working channel are retracted. Then the endoscope is advanced into the lateral ventricle and through the foramen of Monro into the third ventricle. A connection between the third ventricle and the subarachnoid space is established by endoscopically fenestrating the floor of the third ventricle. The floor of the third ventricle is perforated bluntly, often using the tip of a Fogarty balloon catheter or coagulation probe. The initial fenestration is then enlarged to approximately a 4-mm opening by inflating the Fogarty catheter. After fenestration, the cerebrospinal fluid can drain into the basal cistern, bypassing the aqueductal stenosis. If an imperforate membrane of Liliequist is present beneath the floor of the third ventricle, which would obstruct CSF outflow, it can be opened under direct vision with a glass fiber or balloon catheter (Amini & Schmidt, 2005). During fenestration of the ventricle, there is a risk of injury to the basilar artery, which can result in fatal haemorrhage or brainstem infarction. Adequate visualization often requires continuous irrigation of the ventricles with warmed normal saline or preferably lactated ringers accompanied by drainage of cerebrospinal fluid and irrigating fluid through the scope or the burr hole. Therefore, the inlet irrigation tubes are connected to the rinsing fluid bags, either with or without pressurising equipment for active rinsing. If any significant haemorrhage occurs in the ventricle as a result of the procedure, copious irrigation must be possible until the haemorrhage is cleared. The unrestrained efflux of rinsing fluid needs to be assured in order to prevent uncontrolled intracranial hypertension during heavy rinsing. In order to prevent increased hydrostatic pressure caused by the shaft of the endoscope, an outflow tube is often connected to the outlet of the endoscope and its distal end is fixed at the same level as the burr hole, so that there is no siphoning effect or raised ICP.

### 3. State of the art anaesthesia

The anaesthetic goals should center on intraoperative immobilization, cardiovascular stability, and rapid emergence for early neurologic examination. Sharp increases in intracranial pressure must be detected and treated immediately. In this view, adequate monitoring and good communication with the neurosurgeons is essential.

#### 3.1 Preoperative planning

Patients presenting for ventriculostomy may have prior shunt placements with existing shunt tubing routed from the cranium to peritoneal, pleural (rarely), or central vascular locations. Patients may present with symptoms of elevated intracranial pressure (ICP) such as vomiting, headache, confusion or obtundation. Prolonged nausea and vomiting may have caused dehydration or electrolyte abnormalities requiring correction prior to surgery. The patient's neurologic status and examination should be documented prior to induction (Shubert et al., 2006). Hydrocephalus is often part of multisystem congenital syndromes, with associated risks such as higher risk for urinary tract infections or impaired renal function. Premedication with anxiolytics or narcotics should be titrated very carefully, since the procedures are usually very short and fast postoperative neurologic assessment is desirable. Therefore, benzodiazepines or other agents that may contribute to prolonged postoperative sedation are preferably avoided (Fàbregas & Craen, 2010).

#### 3.2 Anaesthetic technique

Intravenous and volatile hypnotics are both routinely used for neurosurgery. However, in published studies inhalation anaesthesia was the predominant technique of choice. Nitrous oxide should not be used in order to avoid elevations in ICP (Derbent et al., 2006), because of the additional risk with venous air embolism (Ganjoo et al., 2010) and the risk of diffusion into and expansion of ventricular air bubbles (Shubert et al., 2006). Mild hyperventilation can be performed in order to decrease intracranial brain volume. Because rapid emergence is of prime concern, we would recommend the use of remifentanyl during the procedure, combined with either intravenous or volatile hypnotics. Adequate care for thermoregulation must be taken since patients – especially small children – are at risk for hypothermia during neuroendoscopy, mainly because of large exchanges of irrigating fluid and ventricular CSF and by the wetting of drapes (Ambesh & Kumar, 2000). Prophylaxis against postoperative nausea and vomiting is advisable because the elevated ICP is often associated with increased gastric acid secretion, and may additionally increase the risk of vomiting. Prophylactic analgesics should be given before emergence of narcosis. A combination of a low dose of opiates (such as morphine 0.03mg/kg) and paracetamol in most cases provides adequate analgesic effect without compromising neurologic evaluation. Non-steroidal anti-inflammatory drugs are generally discouraged because of haemostatic concerns.

#### 3.3 Intraoperative monitoring

Most authors recommend invasive blood pressure monitoring by an indwelling arterial catheter in all patients, including children. We would also strongly suggest continuous measurement of the ICP and CPP. Active rinsing of the ventricles can unexpectedly increase the ICP very severely. The principal reasons for induced intracranial hypertension are high

flow rinsing (used to improve visibility during bleeding or to maintain access in collapsing ventricles) and obstruction of the outflow channel by tissue debris, blood clots or kinking of outflow tubes. These increases in ICP must be detected as soon as possible to prevent severe complications such as cardiovascular instability (Fabregas et al., 2002, Handler et al., 1994), herniation syndromes, retinal bleeding (Boogaarts et al., 2008; Hoving et al., 2009) and excessive fluid resorption (Kalmar et al., 2009). Aside from these unambiguous complications animal research showed that awakening without apparent neurological deficit does not preclude histological damage (Kalmar et al. 2009). It is possible that the same could apply for humans. Beat-to-beat monitoring of the arterial blood pressure offers the most reliable warning sign for a developing Cushing reflex, which is a sign of decreased CPP (Kalmar et al., 2005a). This CPP should at all time be maintained above 40mmHg. Transcranial doppler is the fastest and most reliable method to show abrupt decreases in cerebral blood flow due to increased ICP (Kalmar et al., 2005b). Because of its high sensitivity to impaired cerebral blood flow, it may be considered as basic monitoring, although practical objections limit its routine use during neuroendoscopy.

### 3.4 Active rinsing and Intracranial hypertension

Two strategies to ensure sufficient efflux of rinsing fluid are commonly used. The first option is to use a peel-away sheath with a diameter just slightly larger than the endoscope to provide a working porthole into the anatomy. Aside from allowing easy insertion and reduced tissue damage during endoscope manipulation, it allows for egress of irrigation fluid (Amini & Schmidt, 2005). Most surgeons however do not use an extra sheath. Effusion capacity of the rinsing fluid is consequently largely restricted to the outflow channel of the endoscope, in which case substantial intracranial pressure can emerge, mandating adequate ICP monitoring (Fabregas et al., 2001; Kalmar et al., 2005a). The manipulation of intraventricular fluid volume and pressure by controlling the rinsing inflow and outflow is sometimes advocated as a particular advantage. A surgical skill consists of deliberately increasing the intracranial pressure as a surgical intervention to expand collapsed ventricles. It is also proposed as an instrument to control haemorrhage. In the latter case, controlled increase of the intracranial pressure at least above the venous pressure, and even higher are advocated as a tool to tamponade venous or maybe even arteriolar bleeding. This allows for more delicate procedures to be performed endoscopically. Especially during complex operations, such as tumour resections characterized by frequent bleedings with each „bite“ during the piece-by-piece removal, it allows to quickly regain visibility. An increase in ICP can be tolerated up to a certain level, and it is often inevitable while providing adequate rinsing to improve visibility. However, the rinsing activity and ICP increases have to be performed in a controlled manner. Particularly in these situations, meticulous ICP monitoring, monitoring of the haemodynamical status and optimal communication between the anaesthetist and neurosurgeon are critical (Kalmar et al., 2005a). Although the technique of “pressure feeding” the rinsing fluid (i.e. using pressurised rinsing fluid) is preferred by many surgeons to provide sufficient rinsing capacity, others prefer to perform the endoscopic procedure with a steady state inflow pressure using “gravity feed” (i.e. only using gravity as a driving pressure of the rinsing fluid) to avoid barotrauma to the brain ventricles. However, even in case of “gravity feed”, a rinsing fluid bag at a level of 100 cm above the head still could cause an ICP of ~76mmHg in case of completely obstructed outflow. In case of a sudden severe increase of intracranial pressure, the surgeon should



immediately stop the rinsing and remove any instrument out of the working channel. This mostly wide channel is an additional way out for the accumulated rinsing fluid.

### 3.5 Intracranial pressure and the Cushing reflex

Endoscopic third ventriculostomy is associated with a wide range of haemodynamic effects caused by direct stimulation of brain structures, and by changes in intracranial pressure. Several mechanisms have been postulated to elucidate the neurological origin of these changes, but no indiscriminate anatomical source of the reflexes has yet been determined (Fàbregas et al., 2010). The manifestation of haemodynamical reflexes during endoscopic neurosurgery described in literature differs between authors. Historically, the “Cushing reflex” was first described by Harvey Cushing in 1901 as a simultaneous occurrence of hypertension, bradycardia and apnoea following intracranial hypertension (Cushing 1901). This observation however, was based on his experiences as a neurosurgeon, where he treated patients that were referred some time after an intracranial bleeding or with longer lasting intracranial hypertension (hydrocephalus, tumors). Although Heymans showed in 1928 in animal research that there is an initial short-lasting tachycardia before the onset of bradycardia (Heymans 1928), it is only since the introduction of neuro-endoscopy, this has become of clinical relevance. Relying on the experience in relatively slow-evolving processes like a chronic subdural hematoma, hydrocephalus or cerebral tumors, many clinicians still consider bradycardia and hypertension as the first hemodynamic sign of hyperacute intracranial hypertension. In the literature describing the “Cushing reflex” during neuro-endoscopy, the observation of hypertension is ubiquitous. However, several groups observed mostly hypertension and bradycardia as a predominant sign (El-Dawlatly 2008, Fàbregas 2001), while others (Van Aken 2003, Kalmar 2005a) systematically observed hypertension combined with an initial tachycardia, which only occasionally evolves into bradycardia. It is very conceivable that the differences in these observations are a result of variations in surgical practice. Additionally, direct pressure on certain anatomical regions seems mainly to provoke bradycardia (Baykan et al., 2005), while isolated intracranial hypertension seems rather to induce tachycardia (Kalmar et al., 2009). Al-Dawlatly suggests that the possible absence of tachycardia found in many studies may be due to the protocol that allows the irrigation fluid to vent out during the procedure without noticeable accumulation in the third ventricle. (Al-Dawlatly et al., 2008). In our experience, we frequently observe bradycardia at the moment of balloon inflation close to the brainstem. In order to prevent this, we retract the balloon somewhat into the third ventricle during dilatation of the bottom of the third ventricle. In an analysis focusing on the incidence of bradycardia, Al-Dawlatly postulated that bradycardia recorded in a small series was due to direct stimulation of the floor of the third ventricle (Al-Dawlatly et al., 1999). The most notable difference in surgical method is that for instance in the department of Van Aken & Kalmar, high-pressure rinsing is preferred as a surgical technique for rinsing, bleeding control and ventricular dilatation. Therefore, more swift and higher increases in intracranial pressure may occur which may explain the differences in clinical observations. In several neurosurgical centers however, gravitational flow, without the use of pressure bags, is preferred as a method to prevent very high ICP values. In our personal experience however, while endoscopic third ventriculostomy procedures can in most cases be performed with free flow gravitational rinsing, since bleeding is unusual and rather limited, procedures like

tumor resection or biopsies are much more at risk for severe bleeding and therefore mandate higher rinsing flows requiring high-pressure rinsing. During such events, it is useful for the surgeon to be attentive to the beeps of the anaesthesia monitor. Changes in heart rate during neuroendoscopy are very informative for acknowledgement of the consequences of increased ICP or direct stimulation of brain structures, in which case immediate action can prevent serious complications. Typical hemodynamic reflexes such as bradycardia, tachycardia or hypertension associated with ETV are transient and will respond to simple surgical manoeuvres such as reducing or stopping the inflow and retraction of the working instrument to allow egress of irrigant fluids through the working channel (Fàbregas et al., 2010). Since extensive manipulation of cerebral structures during difficult surgical procedures often coincides with higher rinsing flows, it is impossible to clearly differentiate the cause of these haemodynamic changes between direct stimulation of the brainstem and a genuine Cushing reflex. In an animal model of sudden increases in ICP devoid of any direct stimulation of brain structures severe bradycardia was never observed in the initial hypertensive phase. The haemodynamic reflex induced by isolated intracranial hypertension always consisted of hypertension, and the absence of bradycardia did not even exclude a CPP of zero. In many cases, a severe tachycardia is the only and very distinct constituent of the induced Cushing reflex (Kalmar 2009). Moreover, in this animal model, significant rinsing fluid resorption was observed at high rinsing pressures, resulting in considerable decrease in hematocrit. Many of the animals succumbed from pulmonary edema. However, these observations of exceptional fluid resorption or pulmonary complications were never reported in human cases. Interestingly, although cerebral ischaemia was present for several minutes, many of the animals recovered without any apparent clinical signs of cerebral insult while histological analysis showed signs of ischaemic injury with an increased number of pinocytic neurons in the hippocampus. This indicates that a normal awakening of the patient after an apparently uneventful narcosis may not exclude important CPP suppression and even ischaemic injury.

### 3.6 ICP monitoring

Several strategies to measure ICP are recommended in the literature. ICP measurements with an ICP tip sensor through the working channel have been used, but this may interfere with the surgical procedure (Vassilyadi & Ventureyra, 2002). An intraparenchymal ICP tip sensor will provide reliable measurements, but it is invasive and therefore less acceptable as a routine practice (Prabhakar et al., 2007). An epidurally placed ICP tip sensor is a less invasive, but a less reliable method. Although considered the gold standard, pressure measurement via a separately inserted ventricular catheter is generally unfeasible and difficult to justify. Alternatively, an ICP Tipsensor can be advanced with the endoscope into the ventricles. This provides reliable ICP-readings but bears an additional risk of tissue damage and is quite expensive. Fàbregas proposed measuring the ICP by means of a fluid-filled catheter connected to a stopcock connected to the irrigation lumen of the neuroendoscope (inflow channel) and attached to a pressure transducer zeroed at the skull base (Fàbregas et al, 2000). This "Pressure Inside the Neuroendoscope" correlates with the epidural pressure (Salvador et al., 2010) and with manifestations of the Cushing reflex (Fàbregas et al., 2010 ; Kalmar et al., 2005a). Alternatively, the outlet of the endoscope-flushing system can be connected by a long pressure tube to a pressure transducer for

continuous monitoring of the ICP (Kalmar et al., 2005a). The level of foramen of Monro was used as the zero reference point. A major pitfall in using the outflow channel to measure the ICP, is that blockage in the outflow lumen results in a severe underestimation of the true intracranial pressure. Measuring the ICP via the rinsing channels of the endoscope is preferred in literature, although it is not convincingly determined whether the inflow or outflow point is the most appropriate location. ICP monitoring is thus important, but the optimal location of monitoring is controversial. Since fluids flow down pressure gradients, and flowing fluids generate dynamic resistances, measurement at the rinsing inlet and outlet may at higher rinsing speeds correlate poorly with ventricular measurements. An In-vitro study comparing “ventricular” pressure with pressure at the rinsing inlet and outlet shows very significant respective over- and underestimations of the true “intracranial pressure” of up to 50mmHg at high rinsing flows (Dewaele et al., 2011). Measurement via a capillary tube or electronic tip sensor advanced through the rinsing inlet channel of the endoscope provides reliable ICP measurements and may – based on these in vitro observations – be proposed as best practice. Still, in order to minimally hinder rinsing capacity, only very thin catheters can be advanced through the rinsing channel. However convincing, no human studies have presently been published to confirm these in-vitro findings in clinical practice.

### 3.7 Irrigation fluid

Lactated Ringer solution at body temperature is the most frequently used irrigation fluid (Fábregas & Craen; 2010). A few studies suggest a significant disturbance of the CSF composition when using saline as rinsing fluid, especially after long procedures. To avoid intraoperative and postoperative complications arising from the use of irrigating fluids, some surgeons take care to limit the loss of CSF and to use irrigation only when necessary (Cinalli et al., 2006).

## 4. Complications

The incidence of complications can vary widely depending on the procedure. For endoscopic third ventriculostomy, an incidence of 0 to 31.2% is reported with a mortality rate of 1%. The most frequent intraoperative complications are haemostatic problems and infection. However, injury of the basilar artery complex is the most feared intraoperative complication and can cause massive intraventricular and subarchnoid hemorrhage, hemiparesis and midbrain damage (Jones & Kwok, 1994). Meningeal irritation, headache and high fever from an inflammatory response to irrigating fluid can occur (Oka et al., 1996). Uncontrolled intracranial pressure can cause retinal bleeding, resulting in Terson syndrome (Boogaarts et al., 2008; Hoving et al., 2009). Neurological morbidity can be very diverse, and can often be explained by the approach and technique, although a specific incident that is responsible for the postoperative defect is mostly unappreciated. For example, although gaze palsy is reported as a complication in 0.60% of patients, in no case was injury of the oculomotor nerve described as an intraoperative incident (Boeras & Sgouros, 2011). Many studies report transient neurological dysfunctions, which can be explained by the mechanics of the operation, such as short memory disturbances caused by irritation of the fornix by scratching of the endoscope to the wall of the lateral ventricle at the level of the foramen of Monro.



## 5. Postoperative care and longterm outcome

Transient neurologic deficits such as delayed emergence, confusion, memory loss, transient papillary dysfunction or transient hemiplegia - are the most common postoperative complication occurring in 8–38% of patients (Fàbregas et al., 2000). In an extensive meta-analysis of 2985 cases of ETV, Bouras & Sqouros described that in the immediate postoperative period after ETV, CNS infections (meningitis, ventriculitis) are recorded in 1.81% of the patients. In 2 cases, a CSF infection is reported to have evolved to sepsis. Cerebrospinal fluid leaks are recorded in 1.61% of cases. Postoperative hemorrhagic complications are reported in 0.81% of the patients. These consist of subdural hematoma, intraventricular hemorrhage, intracerebral hematoma and epidural hematoma. Subdural hygromas were recorded in 0.27% of the patients. The rate of systemic complications was 2.34%. Among them, hyponatremia, systemic infections, and deep vein thrombosis were the most frequent (Bouras & Sqouros, 2011). Particularly, hypothalamic or pituitary stalk injury can occur, resulting in diabetes insipidus or the syndrome of inappropriate secretion of antidiuretic hormone (SIADH) (Grant & Mclone, 1997). These cases are often not permanent, but in case of doubt, plasma and urine electrolytes should be observed. In case of diabetes insipidus, desmopressin 1-4µg IV (adult dose) can be administered. In case of postoperative polyuria, appropriate diagnostic measures must be performed accordingly. Patients can develop transient fever due to aseptic irritation of the ependyma or to manipulation of the hypothalamus. Convulsions have been reported by several authors, with one case resulting from pneumoencephalus. Persisting high ICP can occur postoperatively, requiring additional diagnostic measures. Respiratory arrest has been reported in infants during the first hours after neuroendoscopy, necessitating the use of apnea monitors (Shubert et al., 2006). Preferably, patients are kept in the neurosurgical care unit overnight for close surveillance of vital signs, level of consciousness, change of papillary size, polyuria or other complications.

In a review of Bouras & Sqouros, overall permanent morbidity of ETV was calculated to be 2.38%. Neurological morbidity (1.44%) includes gaze palsy (0.60%), decreased consciousness (0.34%), hemiparesis (0.34%), and memory disorders (0.17%). Hormonal morbidity (0.94%) comprised diabetes insipidus (0.64%), weight gain (0.27%), and precocious puberty (0.04%).

The overall mortality rate was 0.28%, all of them in the postoperative period because of sepsis or hemorrhagic incidents. Global good long-term outcome after ETV is between 70-80% in most series (Gangemi et al., 2007)

## 6. Explicative cases

In 2003, a 56 year old woman presenting with a subependymal tumour in the right lateral ventricle, was being operated on for an endoscopical biopsy and resection. Haemodynamic monitoring consisted of invasive arterial blood pressure (IABP), NIBP, ECG, pulse oximetry, and ICP-monitoring at the outflow-channel of the endoscope. After an uneventful induction and maintenance of narcosis with propofol, remifentanil and cisatracurium, classical patient positioning and introduction of the endoscope, the surgical procedure for tumour removal was performed.

Because of minor bleeding from the tumour surface, rinsing was performed more elaborately than usual. The heart rate and IABP revealed stable haemodynamics but without any other warning signs, an isolated increase in blood pressure of 30 mmHg was observed within less than ten seconds, followed by the onset of distinct tachycardia from 65 up to 105 bpm and a further increase of the systolic blood pressure to 180mmHg within a few seconds. Although monitoring showed a low ICP-level, the surgeon was informed of a high probability of severe intracranial hypertension, who instantly removed an instrument from the working channel in order to provide an additional outflow channel. Immediately, a flood of rinsing fluid gushed out of the working channel of the endoscope. Within fifteen seconds, the heart rate and IABP were stabilizing and after two minutes they had returned to normal levels. The procedure was resumed and completed without further events and the patient recovered without complications.

Interestingly, the collected rinsing fluid showed a lot of tumour debris floating, which probably had obstructed the outflow channel of the endoscope. This explains the inaccurately low ICP-level on the monitor.

This case shows the importance of adequate haemodynamic monitoring and comprehension of the Cushing reflex during neuroendoscopy. If in such a case the haemodynamic changes are perceived as a sign of arousal, pain or idiopathic hypertension, the patient would be treated incorrectly, while the intracranial pressure would covertly increase to deleterious levels. On the other hand, swift adequate action may have prevented severe complications. Both for the anaesthetist and the neurosurgeon, it is important to be constantly aware of sudden changes in heart rate and blood pressure. Therefore, the sound level of the monitor should be adequately high. During active rinsing, especially with presence of tissue debris in the rinsing fluid, the surgeon should be particularly attentive to such changes and act accordingly.

## 7. Expert suggestion

For stable anaesthesia and fast recovery in optimal conditions, we rely on balanced total intravenous anaesthesia with propofol TCI 2-5 µg/ml and remifentanyl TCI 2-6 ng/ml. As a rinsing fluid, Ringer's lactate solution at body temperature is favourable in order to maximally preserve electrolyte homeostasis. Monitoring of the intracranial pressure is currently performed at either the inflow or outflow channel of the endoscope with both having their drawbacks. Optimal pressure monitoring will likely progress towards noninvasive transendoscopic ICP measurement but this remains to be investigated more thoroughly. We expect most accurate ICP measurement via a capillary through the rinsing inlet channel. Studies on this topic are being performed currently. As emphasized many times, it is imperative to have beat-to-beat information on changes in blood-pressure and heart rate whenever sudden increases in ICP are possible. Since even gravitational rinsing with the rinsing fluid positioned at only 1 meter above the patient can cause an ICP of 76mmHg, every endoscopy holds such a risk. Therefore we always use invasive blood pressure monitoring, but advanced noninvasive alternatives for beat-to-beat haemodynamic monitoring may become a fine alternative.

In the postoperative period, short term memory can be disturbed due to tissue damage and irritation of the fornix at the level of the foramen of Monro, caused by friction of the

endoscopic shaft. In order to limit this complication, we favour using an endoscope with a diameter of 6mm.

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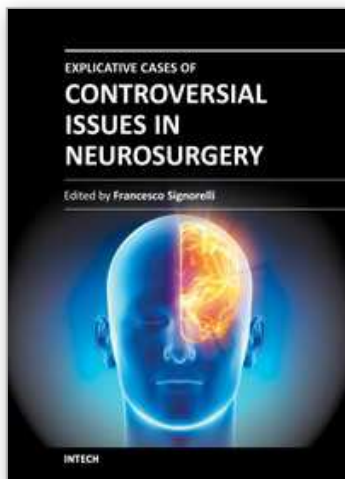
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