Hemodynamic physiology during perioperative intracranial hypertension
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Summary
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This thesis describes the influence of perioperative intracranial hypertension on the cerebral perfusion, oxygenation and homeostasis in different surgical conditions. The main approach through this work is firstly to create a meticulous description of the intracranial physiopathological alterations due to different surgical interventions. Secondly, a study on the optimization of the monitoring is performed and several therapeutic implication are recommended.

Chapter 0 provides a general introduction on the cerebral anatomy, physiology and different autoregulation mechanisms. Also the physiopathology of the Cushing reflex is elucidated, and more specifically the first effects of hyperacute intracranial hypertension, as is seen in surgical interventions. The basic principles of the used monitoring systems are explained and some specificities of endoscopic neurosurgery.

In chapter 1, we investigated the haemodynamic effects of increased intracranial pressure (ICP) in a prospective observational study in patients during endoscopic neurosurgical procedures. As a precise description of the haemodynamic changes in relation to the ICP during neuroendoscopy was still lacking in the literature, the aim of this study was to offer a high resolution description of this phenomenon. Additionally, we investigated the most suitable parameters to detect increased ICP timely to prevent deleterious brain ischaemia, together with possible strategies to keep the cerebral perfusion at a safe level. The main message of this study is that – contrary to the conventional view of the Cushing reflex being a combination of hypertension and bradycardia – the initial phase of the Cushing reflex in hyperacute intracranial hypertension consists of a combination of hypertension and tachycardia.

Based on Doppler-measurements during a neuro-endoscopic procedure we show in chapter 2 the exact sequence of events after a complete stop of the cerebral blood flow and the value of the Cushing reflex for its fast detection.

In chapter 3, in a rat model of endoscopic neurosurgery we confirm our clinical findings that the first sign of acute intracranial hypertension is a concurrent arterial hypertension and tachycardia. Secondly, we show that at high rinsing pressures, important translocation of rinsing solution to the vascular compartment occurs, with significant lowering of haematocrit levels. Histological analysis of the rat brains elucidates that a clinically normal postoperative behavior does not exclude important neurological damage. Thirdly, uncontrolled excessive intracranial hypertension, even without complete brain ischaemia can induce fatality due to pulmonary edema.

Because the optimal location and methodology to determine the ICP during neuroendoscopic procedures was not yet determined, in chapter 4 we investigated different approaches and propose a transendoscopic monitoring system. This noninvasive technique increases the accuracy considerably compared to current practices.
The occurrence of the Cushing reflex is an indispensable diagnostic tool to detect intracranial hypertension. Presently, timely detection of this reflex is only possible using invasive arterial blood pressure monitoring. Therefore, in chapter 5 we investigated the possibilities and limitations of non-invasive continuous arterial blood pressure monitoring in these neurosurgical procedures.

In chapter 6, the impact of hour-long positioning in steep Trendelenburg position for robotic endoscopic surgery is examined. This promising surgical technique can only be performed safely with adequate knowledge of its influence on the human physiological homeostasis. Since this was never thoroughly clarified, we investigated its influence on the cardiopulmonary system, and on cerebral perfusion and oxygenation.

In chapter 7, a more fundamental physiological analysis of the cerebral microcirculatory physiology was performed by synchronous computerized waveform analysis of the arterial invasive blood pressure and transcranial Doppler signal. This analysis has demonstrated that this hour-long steep Trendelenburg position has no clinically significant effect on the cerebral vascular resistance parameters. In addition, we identified a simple formula to determine the zero-flow pressure based on discrete blood-pressure values without the need for complex regression analysis.

In conclusion, as discussed in chapter 8, minimally invasive techniques offer improved treatment options for several medical conditions. These novel therapies have an important surgical advantage of limiting tissue damage, which is of specific importance in neurosurgery. Besides being minimally invasive, robotic surgery – being pioneered in urological procedures – has the additional advantage of providing superior visualization and movement control, permitting reduced nerve damage and blood loss, and improved oncological outcome. However it is of capital interest that there is a profound understanding of the anaesthesiological consequences of these minimal invasive manipulations to provide an optimal protection of the human physiology during the surgical procedure. Even more, only a concerted effort between the anaesthesiological management and the surgical intervention will permit optimal implementation of the technological merits provided by the advances in optical and robotical technology. Specifically in neurosurgical endoscopy, the conflicting interest of the surgical and anaesthesiological control of the intracranial pressure requires optimal monitoring and comprehension to combine physiological security with surgery perfection. Likewise, proper anaesthesiological management of the extreme patient positioning required for urological endoscopical surgery is essential to safely navigate the patient through this highly unphysiological condition.