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Review Article

Prevention of Intraoperative Cerebral Ischemia during Neurosurgical Operations

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Abstract

Brain surgery carries the risk of intraoperative ischemic damage to the healthy tissues, which may result in significant neurological deficit in the postoperative period and worsen the clinical outcome. Recent advances in neuroimaging, intraoperative neurophysiological monitoring and surgical technique help to reduce the risk of ischemia and allow for a more aggressive approach for pathologies considered inoperable in the past.

Neurosurgical interventions on the brain carry the risk of intraoperative tissue ischemia and damage with resultant serious neurological deficit in the postoperative period. Adequate maintenance of cerebral perfusion pressure (CPP) and oxygen delivery along with timely identification and correction of focal ischemia and direct mechanical injury are the prerequisites for surgical success. Tissue dysfunction may take place whenever there is a mismatch between the cerebral blood flow (CBF) and metabolic requirements, both globally and at the focal level. Normally, the brain receives approximately 15% of cardiac output to supply its high demand for oxygen and nutrients [1]. On average, cerebral metabolic rates for O_2 and glucose are 3.5 ml/100 g/min and 5.5 mg/100 g/ min, correspondingly [2]. About 60% of O_2 is used to cover the basic metabolic demands and the remainder is utilized to serve the functional requirements [1]. The non-fasting brain relies mostly on continuous intake of glucose and oxygen to produce ATP, as it lacks significant sources of stored high-energy molecules. Due to autoregulation and neurovascular coupling involving neurogenic, neuroglial and vasogenic mechanisms, the CBF is maintained stable during fluctuations of the systemic arterial pressure within the physiological range and sufficient to satisfy the focal metabolic requirements [3,4]. However, surgical manipulations including brain retraction, ultrasonic aspiration, temporary vascular clipping, electrical coagulation, as well as systemic factors like significant arterial hypotension, anemia, hypocapnia, and others may contribute to development of intraoperative ischemia.

Brain tumor surgery is associated with a risk of trauma and vasospasm to the arteries supplying the surrounding healthy tissue, and the risk is higher for giant meningiomas and basal tumors [5,6]. Ulmer and colleagues (2006) analyzed the immediate and follow-up MRI data in 50 patients who underwent glioblastoma resection [7]. In 70% of patients, they revealed areas of restricted diffusion along the surgical margins, and in 91% of cases the changes were associated with formation of cystic encephalomalacia on the follow-up images. The authors explained the ischemic changes by intraoperative disruption of transcortical and medullary arteries causing infarction foci. It was suggested that subpial resection along the margins of gyri adjacent to the tumor might reduce the extent of perifocal ischemia during tumor removal.

With development of image-guided neurosurgery, pre- and intraoperative brain mapping, multimodal neurophysiological monitoring, and awake craniotomy, a more aggressive approach can be adopted in surgery of tumors located in highly eloquent cortical areas representing the language and motor control zones [8]. Using the above described techniques, Krieg et al. (2013) were able to successfully perform supratentorial glioma resections in 47 out of 51 patients, who were considered inoperable previously [8]. The gross total resection rate was 74%, and only 8.5% of patients developed additional permanent neurological deficit after surgery.

Another challenging area in neurosurgery is the brainstem surgery, which is associated with significant risk to the vital structures, increased morbidity and mortality. This is explained by concentration of numerous vital centers, nuclei and pathways within a small space, making surgery in vicinity of these structures extremely challenging. Cranial nerve stimulation, rhomboid fossa mapping, monitoring of sensory and motor evoked potentials (EP) help to identify the safety margins for tumor resection and reduce the extent of postoperative neurological deficit [9].

Cerebrovascular interventions including carotid endarterectomy and stenting, aneurysm clipping and endovascular coiling, AVM resection or endovascular embolization are associated with a cognate risk of brain ischemic damage due to intraoperative embolism, inadvertent vascular occlusion or disruption, and development of the hyperperfusion syndrome. Modern approaches to reduce these risks include application of microsurgical technique, intra- and postoperative pharmacologic and hypothermic protection, multimodal neurophysiological monitoring with registration of electroencephalography, EP, cerebral oximetry and other methods. Intraoperative indocyanine green videoangiography and computed tomographic angiography have been suggested as valuable methods to diagnose inadvertent vascular occlusions following aneurysm clipping [10].

Development of minimally invasive neurosurgical technique is a significant step toward safer surgery. Endoscopic approach is being increasingly used for surgery on cranial base, 3rd ventricle, and cerebellopontine angle. EP monitoring during endoscopic procedures allows for timely detection and correction of impending ischemia to the brainstem structures [11].

CONCLUSION

Advancements in neuroimaging, neuromonitoring and surgical technique have revolutionized the field of neurosurgery significantly decreasing the risk of intraoperative ischemic damage to brain structures.

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