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NEUROLOGICAL COMPLICATIONS AFTER CARDIAC SURGERY

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Abstract

Neurological complications represent a significant issue following cardiac surgery and are associated with elevated morbidity, mortality, and healthcare costs. Conditions such as stroke, cognitive dysfunction, and delirium are common after procedures like coronary artery bypass grafting (CABG) and heart valve repairs. The mechanisms of brain injury in these patients are multifactorial, primarily involving embolism, hypoperfusion, inflammation, and metabolic disturbances. Advances in diagnostic tools such as Near-Infrared Spectroscopy (NIRS), Transcranial Doppler Ultrasound (TCD), and Electroencephalography (EEG) offer valuable insights into cerebral perfusion and metabolic and electric brain activity, enabling real-time monitoring and early detection of brain injury. Prevention and management strategies include tailored preoperative assessments, optimized blood pressure management during surgery, temperature regulation, and the use of neuroprotective measures.

KEYWORDS: cardiac surgical procedures, cerebrovascular circulation, cognition disorders, intraoperative monitoring, neuroprotection, postoperative complications

INTRODUCTION

Cerebral injury is a prevalent complication of cardiac surgery, associated with elevated mortality, morbidity, and hospital costs.[1] It also correlates with a higher likelihood of post-discharge admission to a secondary care facility and a decline in quality of life.[2,3] Global or focal brain ischemia related to embolism or hypoperfusion predominates, while breakthrough cerebral hemorrhage and infection can complicate the surgery and its outcome.[4] Furthermore, neurological complications after cardiac surgery prolong hospitalization and increase mortality even in patients without radiologic evidence of stroke.[5] With the growing use of open-heart procedures, including coronary artery bypass grafting (CABG), heart valve repair, aneurysm repair, congenital heart defect repair or heart transplantation, there is a continuing need to recognize the potential threat of brain damage and to consider the factors which determine the outcome.[6]

MECHANISMS OF PERIOPERATIVE BRAIN INJURY

Neurological injury following cardiac surgery results from a complex interplay of factors, primarily involving embolism, hypoperfusion, inflammation, and metabolic disturbances.[3]

Both micro- and macroemboli can originate from atherosclerotic debris, fat, surgical particles or air introduced during cardiopulmonary bypass (CPB).[3,7] Microemboli, whether gaseous or particulate, are believed to contribute significantly to encephalopathy and neurocognitive dysfunction, with sources including air entrained into the bypass circuit or from open cardiac chambers.[3,7] Evidence supporting this includes findings from retinal angiography, autopsies, and animal studies.[3] Additionally, lipid emboli, known as small capillary arteriolar dilations (SCADs), have been found on postmortem examination and are thought to originate from blood aspirated from the pericardial cavity.[4] Although SCADs may play a role, they do not fully account for the range of neurological complications seen postoperatively.[4] Macroemboli, typically larger in size, are frequently implicated in perioperative strokes. Imaging studies suggest that 30–50% of these emboli originate from the ascending aorta, particularly in the presence of atherosclerosis.[8,9] In fact, intraoperative detection of aortic plaque is an established risk factor for stroke and cognitive decline.[3,10] Tools like epiaortic ultrasound improve visualization of the aorta and allow for surgical adjustments to minimize embolic risk.[3,10] Other sources of emboli include atrial fibrillation, which affects over 30% of patients post-CABG and promotes thrombus formation, as well as infective endocarditis, which may lead to septic emboli, mycotic aneurysms or brain infections, particularly in patients with replaced heart valves.[4,6] Additionally, neuroinflammation, an immune-mediated response involving microglial activation and cytokine release, can occur after cardiac surgery and further exacerbate neuronal damage by amplifying injury to already vulnerable brain tissue.[11]

Blood pressure instability during surgery, often due to arrhythmias, reduced cardiac output or vasodilation, can lead to cerebral hypoperfusion.[9,12] Hypoperfusion may cause direct injury or worsen embolic damage by limiting

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clearance and impairing perfusion to at-risk brain regions, such as the ischemic penumbra.[6,12] This mechanism is of growing concern in the aging surgical population.[6,12] Lastly, perioperative hyperglycemia, common even in non-diabetics due to surgical stress and hypothermia, may contribute to brain injury through oxidative stress, acidosis, blood–brain barrier disruption, and cerebral edema.[7,13] These metabolic and hemodynamic disturbances, alongside embolic and inflammatory processes, underscore the multifactorial nature of cerebral injury during cardiac surgery.[3,7,12]

RISK FACTORS AND PATIENT VULNERABILITY

Understanding these risk factors is crucial for preoperative assessment and for developing strategies to mitigate the risk of cerebral injury during cardiac procedures. Type of surgery, symptomatic cerebrovascular disease, advanced age, diabetes mellitus, and aortic atheroma represent the most important risk factors for neurological complications.[14] Single valve-replacement surgery carries a higher percentage of postoperative neurological damage compared to CABG, while multi-valve replacement procedures carry the highest risk of brain injury.[5,14] Furthermore, bilateral internal carotid artery stenosis and reoperative cardiac surgeries are particularly linked to an elevated risk of postoperative neurological complications. Patients with bilateral carotid stenosis or those undergoing repeat cardiac surgeries had notably higher rates of such issues.[5,6]

THE SPECTRUM OF NEUROLOGIC OUTCOMES

Neurologic complications following cardiac surgery contribute to increased morbidity and mortality, with stroke occurring in 2% to 4% of patients, particularly in those with a prior stroke history.[5,6,8] While short-term cognitive deficits typically resolve within one to three months, the long-term risks remain uncertain.[7] Postoperative seizures, caused by factors which may result from ischemia, hypoperfusion, emboli or metabolic issues, are also a concern.[6,15] Some anticonvulsant drugs, such as levetiracetam and lacosamide provide additional management options for prevention and therapy of postoperative seizures.[15] For over 50 years, neurocognitive dysfunction in older adults after cardiac surgery has been acknowledged, though accurately describing the condition remains difficult.[1,7] Terms such as encephalopathy, pump-head, and postoperative cognitive dysfunction (POCD) are often used.[7] These issues are especially concerning in cardiac surgery due to factors like cardiopulmonary bypass, median sternotomy, embolic load, and prolonged surgical duration.[3,6] Studies consistently identify advanced age, preoperative cognitive impairment, heart failure, and prolonged cardiopulmonary bypass as significant risk factors for neurological complications.[5,6,8,9] Techniques like Near-Infrared Spectroscopy and Transcranial Doppler help assess cerebral perfusion and predict cognitive dysfunction post-surgery.[10] Neuroprotection strategies, including pharmacological and non-pharmacological approaches, are key to reducing brain injury.[11,13,16] However, more research is needed to refine these methods and improve patient outcomes.

DIAGNOSTIC TOOLS AND MONITORING TECHNIQUES

Neurologic complications following cardiac surgery are a significant concern, making effective monitoring crucial for improving patient outcomes.[11,16] Techniques like Near-Infrared Spectroscopy (NIRS) allow real-time monitoring of cerebral oxygenation, providing vital information on brain perfusion during surgery.[3,10] Transcranial Doppler Ultrasound (TCD) is used to assess cerebral blood flow velocity, helping detect ischemia, embolic events, and potential hypoperfusion in the brain.[10,13] Electroencephalography (EEG) monitors brain activity during surgery and can help detect early signs of cognitive dysfunction and neurological complications.[10] Multimodal neuromonitoring, which combines NIRS, TCD, and EEG, offers a more comprehensive understanding of cerebral hemodynamics, optimizing cerebral perfusion and enhancing early detection of ischemia.[11,13] Furthermore, some non-invasive devices and methods can also monitor intracranial pressure waves and provide real-time insights into cerebrovascular autoregulation.[10] These devices, enhanced by artificial intelligence (AI), can help predict cognitive decline and improve patient care by enabling earlier interventions.[13] The ARCHIMEDES system (Advanced Cerebrovascular Hemodynamic Monitoring and Evaluation System) is a sophisticated platform designed for continuous, real-time assessment of cerebrovascular autoregulation, particularly in critical care and postoperative settings.[10] By detecting subtle changes in real time, it supports precision medicine by providing patient-specific cerebral perfusion goals.[13]

PREVENTION STRATEGIES AND POSTOPERATIVE MANAGEMENT

Neurological complications after cardiac surgery, including stroke and cognitive dysfunction, are significant concerns that require effective prevention and management strategies.[5,6,8] Preoperative risk assessments, including cognitive screening and evaluation of atherosclerosis, help identify high-risk patients, guiding tailored care.[5,8] Blood pressure management during cardiopulmonary bypass (CPB) is crucial, with higher mean arterial pressure (MAP) targets reducing stroke incidence.[3,6] Temperature regulation to avoid hyperthermia and neuromonitoring tools like NIRS and TCD are essential for detecting ischemia and embolism.[10,13] Postoperative management involves controlling hyperglycemia, managing arrhythmias like postoperative atrial fibrillation, and optimizing blood pressure to support brain perfusion.[3,6,8] Early neuroimaging, such as diffusion-weighted MRI, aids in identifying ischemic brain lesions for timely intervention.[5] While pharmacological agents like corticosteroids and aprotinin have been considered for neuroprotection, their efficacy remains inconclusive.[11,13] Overall, a multidisciplinary, evidence-based approach to prevention and postoperative care is vital to reduce neurological risks and improve patient outcomes.[11,13,16,17]

CONCLUSION

Neurological complications following cardiac surgery remain a critical concern, necessitating ongoing advancements in both diagnostic and management strategies. Multimodal neuromonitoring techniques, along with careful regulation of blood pressure, temperature, and glucose levels, are essential for minimizing the incidence and severity of brain injury. Although progress has been made in detecting and predicting neurological events, further research is needed to refine these strategies and improve their clinical application. By addressing both preventive and postoperative factors, healthcare providers can enhance patient outcomes, reduce morbidity and mortality, and ultimately improve the quality of life for individuals undergoing cardiac surgery.

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NEUROLOŠKE KOMPLIKACIJE NAKON KARDIOKIRURŠKIH ZAHVATA

Sažetak

Neurološke komplikacije predstavljaju značajan problem nakon kardiokirurškog zahvata jer su povezane s povišenim morbiditetom, mortalitetom i troškovima zdravstvene skrbi. Stanja kao što su moždani udar, kognitivna disfunkcija i delirij uobičajena su nakon postupaka poput premosne operacije koronarne arterije i operacije srčanih zalistaka. Mehanizmi ozljede mozga u ovih bolesnika su višestruki, a prvenstveno uključuju emboliju, hipoperfuziju, upalu i metaboličke poremećaje. Napredak u dijagnostičkim alatima kao što su bliska infracrvena spektroskopija (NIRS), transkranijalni Doppler ultrazvuk (TCD) i elektroencefalografija (EEG) olakšavaju uvid u cerebralnu perfuziju i metaboličku i električnu aktivnost mozga, omogućujući praćenje u stvarnom vremenu i rano otkrivanje moždanog oštećenja. Strategije prevencije i upravljanja uključuju prilagođene prijeoperativne procjene, optimizirano upravljanje krvnim tlakom tijekom operacije, regulaciju temperature i korištenje raznih neuroprotektivnih mjera.

KLJUČNE RIJEČI: cerebrovaskularna cirkulacija, intraoperativno praćenje, kirurški zahvati na srcu, kognitivni poremećaji, neuroprotekcija, postoperativne komplikacije