SPINAL CORD PROTECTION DURING THORACIC & THORACOABDOMINAL AORTIC ANEURYSM REPAIR SURGERY

An Essay

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Presented by

Haitham Mohy El-Den Mahmoud Othman

M.B.B.Ch.

Faculty of Medicine – Ain Shams University

Under Supervision of

Prof. Alaa Eid Mohamed Hassan

Professor of Anesthesiology, Intensive Care & Pain Management

Faculty of Medicine – AinShamsUniversity

Dr. Ibrahim Mamdouh Esmat

Lecturer of Anesthesiology, Intensive Care & Pain Management

Faculty of Medicine - Ain Shams University

Dr. Mohammed Mahmoud Maarouf

Lecturer of Anesthesiology, Intensive Care & Pain Management

Faculty of Medicine - Ain Shams University

Faculty of Medicine

AinShams University

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AAA:	Abdominal aortic aneurysms
ASA:	Anterior spinal artery
ASIA:	American Spinal Injury Association
ARM:	Artery of Adamkiewicz
BAV:	Bicuspid aortic valve
CAD:	Coronary artery disease
COPD:	Chronic obstructive pulmonary disease
CPB:	Cardiopulmonary bypass
CSF:	Cerebrospinal fluid
CSFP:	cerebrospinal fluid pressure
CT:	Computed tomography
CTA:	Computerized tomographic angiography
CVP:	Central venous pressure
DHCA:	Deep hypothermic circulatory arrest
DLT:	Double-lumen endobronchial tube
GRA:	Great radicular artery of Adamkiewicz
HCTD:	Hereditary connective tissue disease

ICH:	Intracranial hemorrhage
ISNCSCI:	International Standards for Neurological Classification of Spinal Cord Injury
LAFB:	Left atrial-femoral bypass
LDS:	Loeys–Dietz syndrome
MAP:	Mean arterial pressure
MEP:	Motor evoked potentials
MFS:	Marfan syndrome
MRA:	Magnetic Resonance Angiography
MRI:	Magnetic resonance imaging
PAC:	Pulmonary artery catheter
PLHB:	Partial left heart bypass
PSAs:	Posterior spinal arteries
SAs:	Spinal arteries
SCBF:	Spinal cord blood flow

SCI:	Spinal cord ischemia
SCPP:	spinal cord perfusion pressure
SSEP:	somatosensory evoked potentials
TAAA:	Thoracoabdominal aortic aneurysm
TEE:	Transesophageal echocardiography
TEVAR:	Thoracic EndoVascular Aortic Repair
TGFBR1:	Transforming growth factor β receptor I
TGFBR2:	Transforming growth factor β receptor II

Introduction

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The mortality and morbidity of extensive thoracoabdominal aorta replacement has improved markedly in recent years. However, postoperative paraplegia from spinal cord infarction remains the most devastating complication that faces patients undergoing surgery on the thoracoabdominal aorta because loss of lowerlimb function imposes severe constraints on the quality of life. Additionally, paraplegia is associated with higher post-operative mortality and morbidity. Despite advances in spinal cord protection, the risk of spinal cord ischemia or infarction as a consequence of open surgical repair of thoracoabdominal aortic aneurysms (TAAAs) remains within the range of 8-28% **(Greenberg et al., 2008).**

There are two major events during which injury to the spinal cord can occur. Firstly, spinal cord injury happens depending on the duration and degree of ischemia during cross-clamping .The surgeon must temporarily interrupt aortic blood flow to the lower body, which renders the distal organs (including the spinal cord) ischemic, in order to resect the aneurysm. Secondly, damage may occur from the loss of blood flow to the spinal cord after the period of aortic cross-clamping because of failure to reattach the intercostal and lumbar arteries that are critical to the spinal cord blood supply **(Eide et al., 2005).**

Risk factors for spinal cord ischemia include extensive aortic repair, spinal cord malperfusion on clinical presentation, systemic hypotension, acute anemia, prolonged aortic clamping, prior thoraco- abdominal aortic segment repair, extent of preservation of spinal segmental arterial supply and systemic vasodilation with vascular steal **(Augoustides et al., 2014).**

Strategies to prevent and treat spinal cord ischemia after thoracic aortic operations primarily involve techniques to make the spinal cord less susceptible to infarction, minimize the duration of cord ischemia during operation, augment spinal cord blood flow hemodynamics and early detection of spinal cord ischemia to permit immediate intervention. Interventions such as deliberate hypothermia, spinal cerebrospinal fluid drainage, increasing mean arterial pressure, epidural cooling and minimizing arterial steal were effective for preventing paraplegia **(Acher & Wynn, 2009).**

Aim of the Work

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The goal of this essay is to study spinal cord ischemia due to thoracic or thoracoabdominal aortic aneurysm repair and to discuss the strategies employed to prevent or reduce spinal cord ischemia, as well as methods of monitoring of motor function during surgery.

Anatomy & Blood supply of the spinal cord

Spinal cord Anatomy:

The spinal cord is a cylindrical structure, slightly flattened dorsoventrally and located in the spinal canal of the vertebral column. Protection for the cord is provided not only by the vertebrae and their ligaments but also by the meninges and a cushion of cerebrospinal fluid (CSF) ***(Kiernan & Rajakumar, 2013)*****.**

The spinal cord is continuous with the brainstem proximally and terminates distally in the conus medullaris as the filum terminale (fibrous extension) and the cauda equina (neural extension). This distal termination varies from L3 in infants to the lower border of L1 in adults because of differential growth rates between the bony vertebral canal and the central nervous system. The spinal nerve contains motor and sensory nerve fibers to and from all parts of the body ***(Kiernan & Rajakumar, 2013)*****.**

The spinal cord is enlarged in two regions for innervations of the limbs. The cervical enlargement includes segments C5 to T1, with most of the corresponding spinal nerves forming the brachial plexuses for the nerve supply of the upper limbs. Segments L2 to S3 are included in the lumbosacral enlargement and the corresponding nerves constitute most of the lumbar and sacral plexuses (L1-S4) for the innervation of the lower limbs ***(Moore et al., 2007)*****.**

There are 31 spinal cord segments, each with a pair of ventral (anterior) and dorsal (posterior) spinal nerve roots, which mediate motor and sensory function, respectively. The ventral and dorsal nerve roots combine on each side to form the spinal nerves as they exit from the vertebral column through the neuroforamina. Each spinal cord segment innervates a dermatome ***(Moore et al., 2007)*****.**

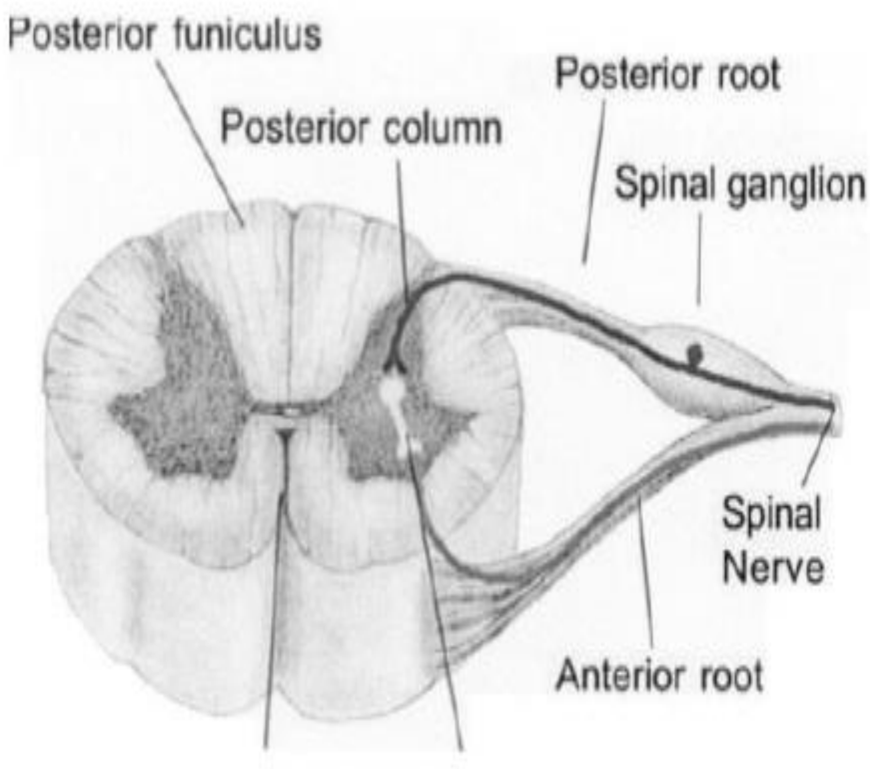

Fig .1 The posterior and anterior roots in relation to the gray and white matter of the spinal cord ***(Jacobson & Marcus, 2011)***.