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CPB AND AORTIC SURGERY

The State of the Art

From a Theoretical to a Practical Approach

M-G LAGNY ECCP University of Liege Hospital (ULg CHU)

SUMMARY

- Introduction
- Ascending aortic surgery
- Descending aortic surgery
- Coagulation management
- Blood management
- Conclusions

INTRODUCTION

- Prevention

Michel JB, et al.
Novel aspects of the pathogenesis of aneurysms oh the abdominal aorta in humans. Cardiovasc Res. 2011 Aprl 1;90(1):18-27
Golledge J, Norman PE,

- Medical treatment

Current status of medical management for abdominal aortic aneurysm.Atherosclerosis, 2011. 217 (1):p.57-63.

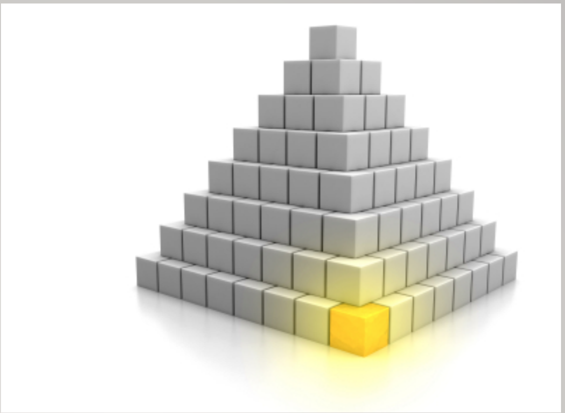
- Endovascular aortic repair

Nienaber CA, et al.
Randomized comparison of strategies for type B aortic dissection: the INvestigation of STEnt Grafts in Aortic Dissection (INSTEAD) trial. Circulation, 2009. 120(25):p.2519-28.

Hao Z, et al.
Endovascular stent-graft placement or open surgery for the treatment of acute type B aortic dissection: a meta-analysis. Ann Vasc Surg, 2012. 26(4):p.454-61.

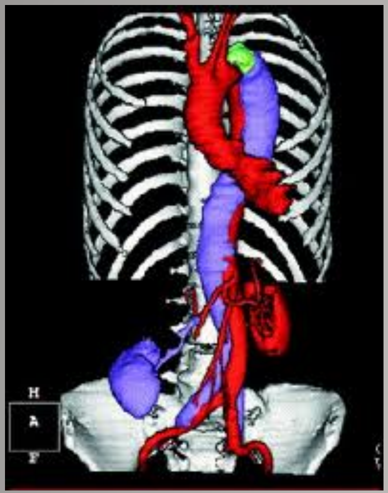
AIM OF THE TOPIC

CPB for aortic surgery: state of the art



- Knowledge
- Anatomical and pathophysiological pre-requisite
- Flexibility
- Equipment

Ascending aortic surgery and arterial cannulation:



Surgical repairment

- Ascending aorta
- Left subclavian/ axillary
- Femoral
- Other

The arterial cannulation

Cannulation site	Advantages	Disadvantages
Femoral artery	Ease of access Size Adequate flow rates	Retrograde flow Proximal embolization
Axillary/subclavian artery	Reports of redu… mortality and st…	
Aortic cannulation Ventricular apex Direct	Speed of cannulation Adequacy of flow Antegrade flow Direct cannulation of true lumen	Identification of true lumen

eTable 3: The potential advantages and disadvantages of the different cannulation sites utilized in acute type A aortic dissection

Malperfusion

Arm numbness

Embolic event

Bonser RS, et al. *Acute Aortic Dissection. JAAC Vol. 58, No. 24, 2011.*

Arterial cannulation complication and perfusion: local dissection

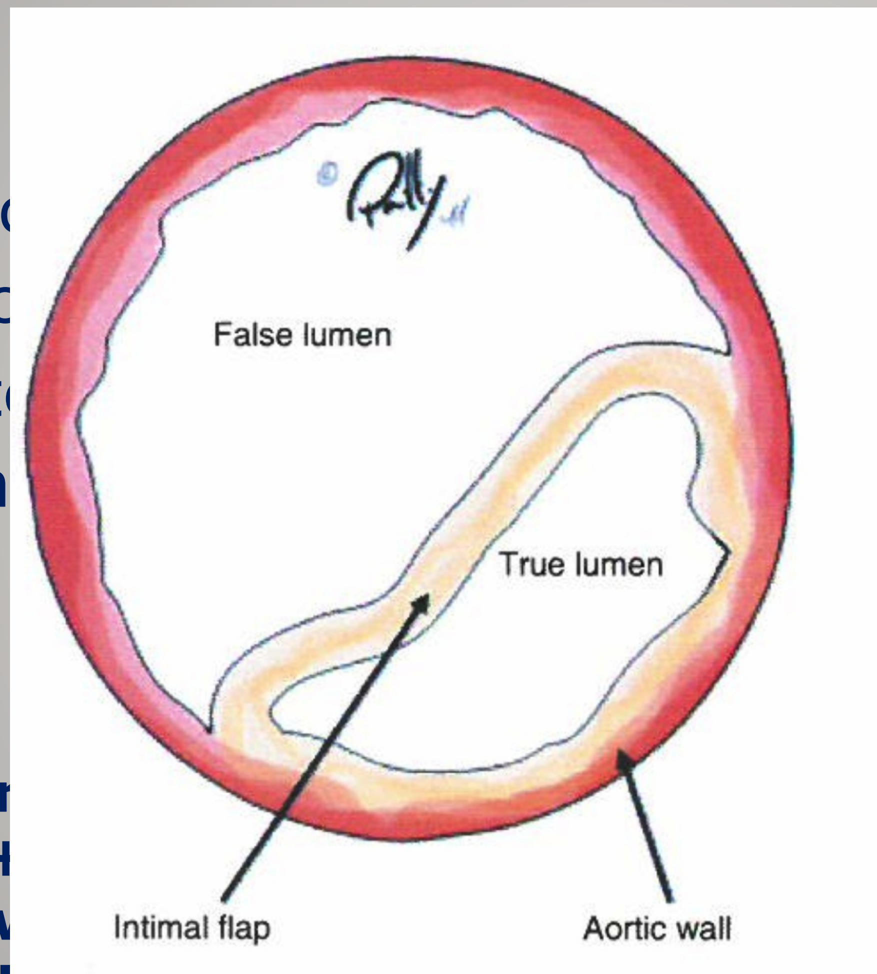
- Pressure monitoring

SWITCH TO ANOTHER CANNULATION SITE

Anticipation: Y Line

Arterial cannulation complication and perfusion: malperfusion (FLAP)

- Sudden inc … ure
- Inequate c … TCD
- Inadequat … P)
- Late diagn
- Left radial

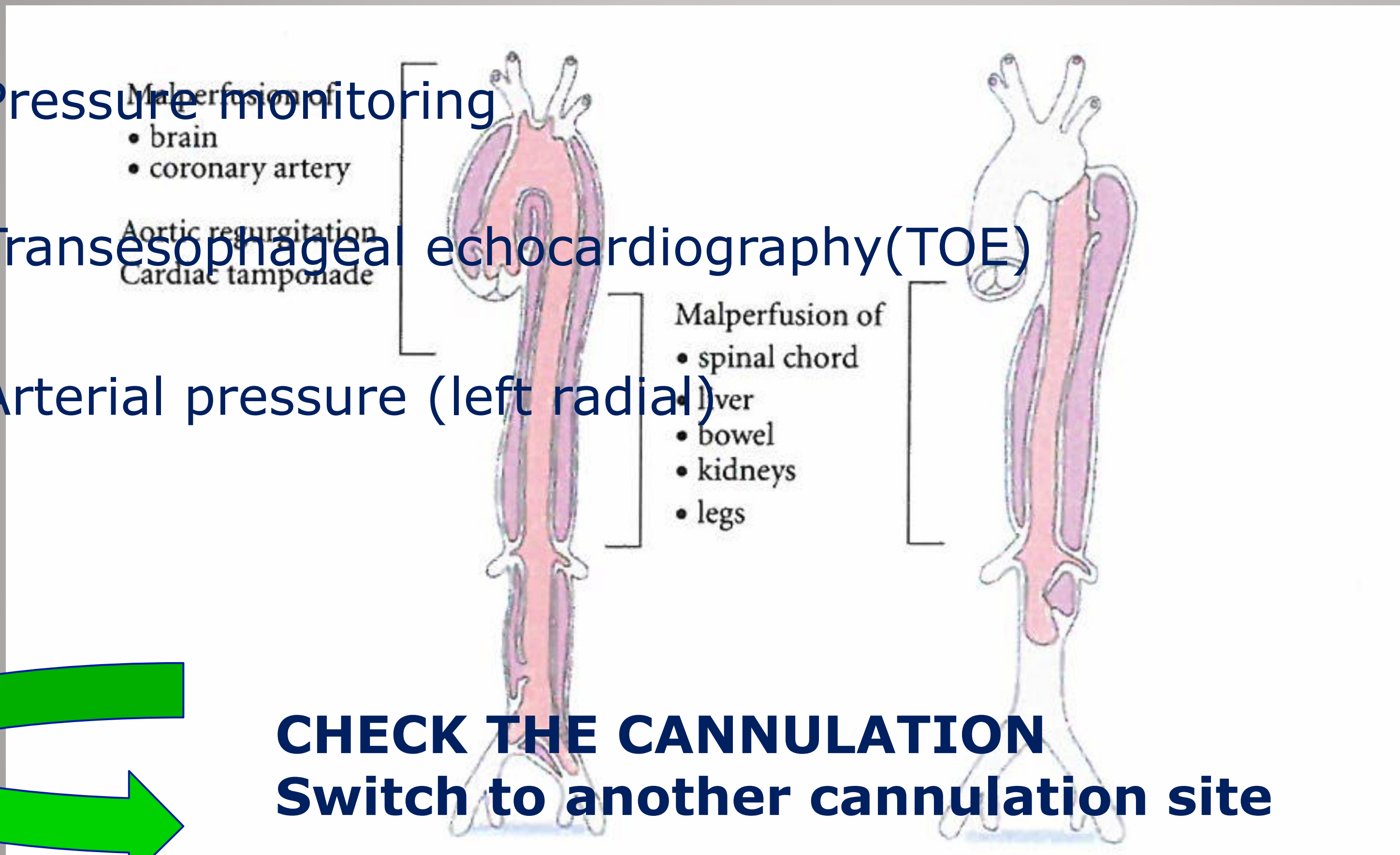


Pr
(+
Sv … ite
RE-INSTORE ANTEGRADE FLOW

Krüger T, et al. *British Journal of Surgery 2012; 99:1331-1344*

Arterial femoral cannulation complication and perfusion: false lumen

- Pressure monitoring
- Transesophageal echocardiography(TOE)
- Arterial pressure (left radial)



CHECK THE CANNULATION
Switch to another cannulation site

Bonser RS, et al. *Evidence, lack of evidence, controversy and debate in the provision and performancde of the Surgery of acute type A aortic dissection. JAAC Vol. 58, No. 24, 2011 December 6, 2011:2455-74.*

Arterial cannulation complication and perfusion: embolic event

- Doppler
- Specific cannula

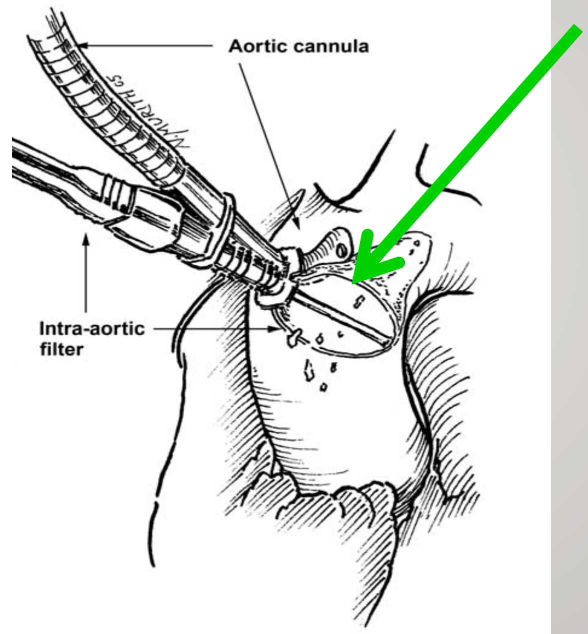


Fig. 1 Schematic drawing shows the deployment and location of the intra-aortic filter.

Christenson JT, et al. *Tex Heart Inst J. 2005;32(4):515-21.*

Cerebral protection

Protecting the brain during aortic surgery: an enduring debate with unanswered questions.

Stein LH, Elefteriades JA,
Section of Cardiothoracic Surgery, Yale University School of Medicine, New Haven, CT 06510, USA.
Cardiothorac Vasc Anesth. 2010 Apr;24(2):316-21. Epub 2009 Jul 30.

Cerebral protection and hypothermia

Hypothermia: reduction of metabolic demand

Temperature (°C)	Cerebral Metabolic Rate (% of baseline)	Safe Duration of HCA (min)
37	100	5
30	56 (52–60)	9 (8–10)
25	37 (33–42)	14 (12–15)
20	24 (21–29)	21 (17–24)
15	16 (13–20)	31 (25–38)
10	11 (8–14)	45 (36–62)

Calculations based on assumption that there is a 5-min tolerance for circulatory arrest at 37°C. Values in parenthesis are 95% confidence intervals. HCA = hypothermic circulatory arrest.

Mc Cullough JN, et all. *Ann Thorac Surg 1999;67:1895-9.*

Deep hypothermia circulatory arrest: Cooling period

- Respect of temperatures gradients (6-10°C max)
- Hct level versus viscosity (25% Hct max)
- Homogenization of temperatures (cerebral and systemic)
- Hardware:

  Heater cooler device

  Efficient heat exchanger

  Cooling helmet

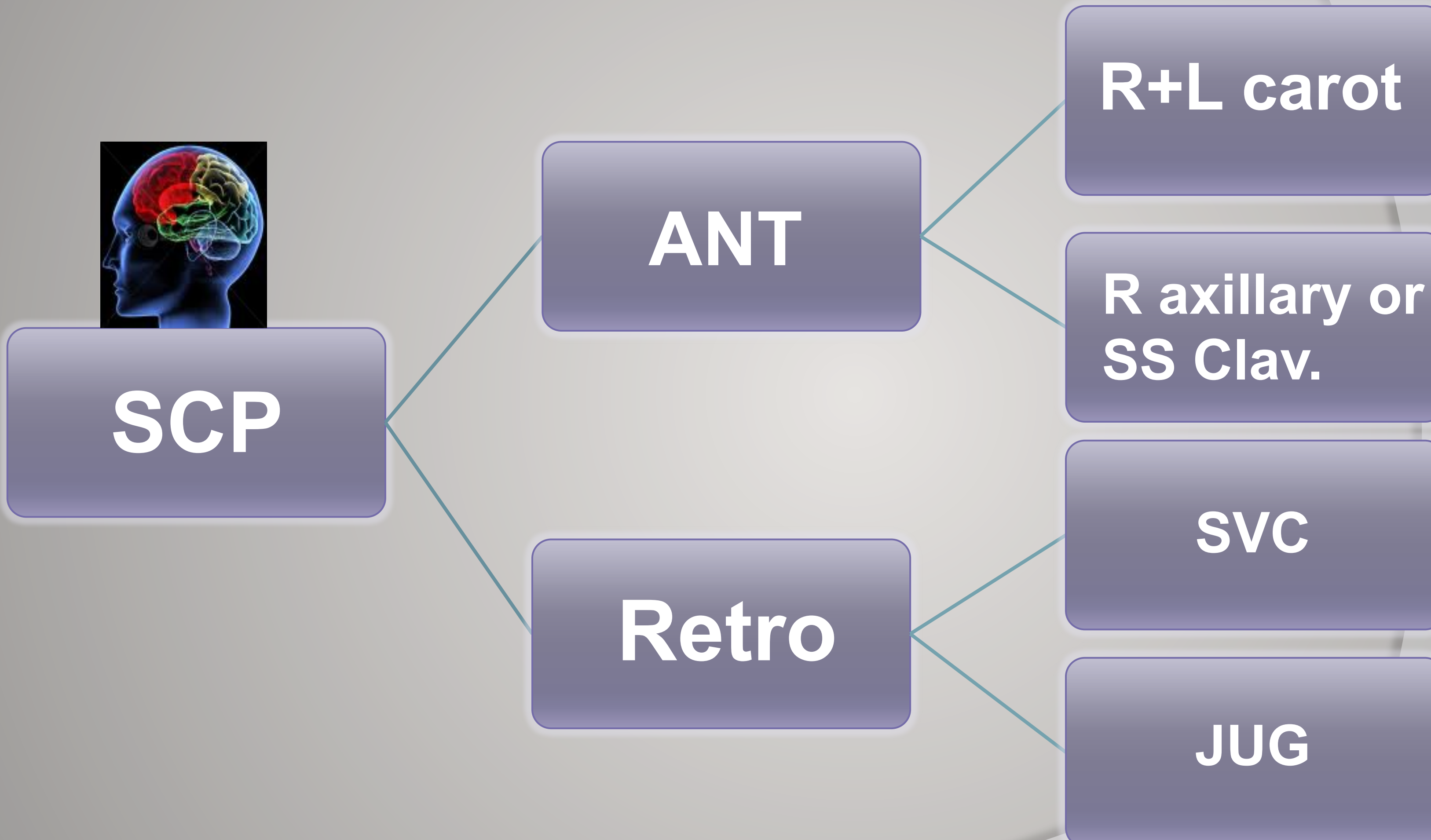
  Blanket

Surgery on the ascending aorta and the arch cerebral protection

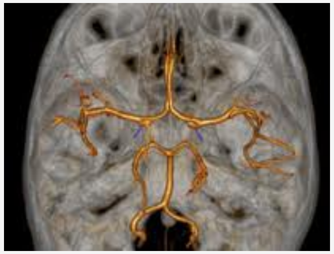
Surgery

- DHCA
- DHCA+SCP
- MHCA+SCP

Selective cerebral perfusion:

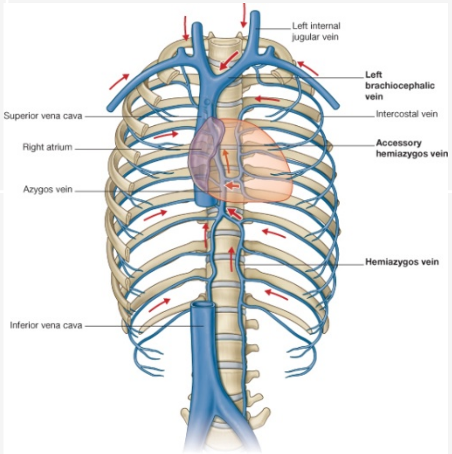


Antegrade selective cerebral perfusion: Complications and monitoring

Pro	Cons	Monitoring
Control of flow delivery	Local dissection Downstream dissection	Pression NIRS, Doppler
	Embolic load	Doppler
	Cerebral oedema in case of overflow and or over pressure	Flow and pressure control
	Integrity of the circle of Willis? in case of single carotid perfusion	NIRS, transcranial doppler, Left radial arterial pressure (60mmHg) (JbSVO_2) (S100 protein; NSE)

Retrograde cerebral perfusion: complications and monitoring

Pro	Cons	monitoring
Easy of access	Poor control of flow delivery, Dispersion of the flow through the Azygos vein	NIRS, transcranial doppler
Retrograde flush of the carotids	Cerebral oedema in case of overflow and/or overpressure	Flow control and venous pressure (30 mmHg)



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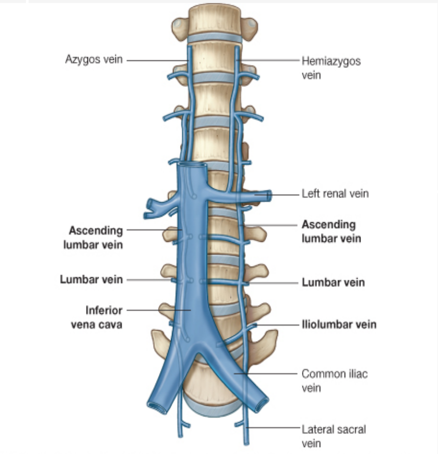

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Hypothermia and blood gases management

	Pro	Cons
alpha-Stat:	Natural status Autoregulation CBF Preservation of intracellular pH and enzyme activity	Less efficient and homogeneous cooling Less reduction of O_2 consumption
pH-Stat:	Increased CBF More homogeneous cooling Greater reduction of O_2 consumption Increased tissue oxygenation	Loss of autoregulation CBF « Luxurious » CBF, vol Increased risk of microembolism

Duebener LF, et al. *Effects of pH management during deep hypothermic bypass on cerebral microcirculation: alpha-stat versus pH-stat. Circulation 2002;106[suppl I]:I-103-I-108.*

Hypothermia and blood gases management

An evidence-based review of the practice of cardiopulmonary bypass in adults: A focus on neurologic injury, glycemic control, hemodilution, and the inflammatory response

Kenneth G. Shann, CCP,[a] Donald S. Likosky, PhD,[b] John M. Murkin, MD,[c] Robert A. Baker, PhD CCP(Aust),[d] Yvon R. Baribeau, MD,[e] Gordon R. DeFoe, CCP,[b] Timothy A. Dickinson, MS,[f] Timothy J. Gardner, MD,[g] Hilary P. Grocott, MD,[h] Gerald T. O'Connor, PhD, DSc,[b] David J. Rosinski, CCP,[i] Frank W. Sellke, MD,[j] and Timothy W. Willcox, CCP(Aust)[k]

Circulation 2002;106[suppl I]:I-103-I-108.

Anesth., vol 11 num4, Dec 2007.

pH Management

The clinical team should manage adult patients undergoing moderate hypothermic CPB with alpha-stat pH management. (Class I, Level A)

J Thorac Cardiovasc Surg 2003; 125:625-32

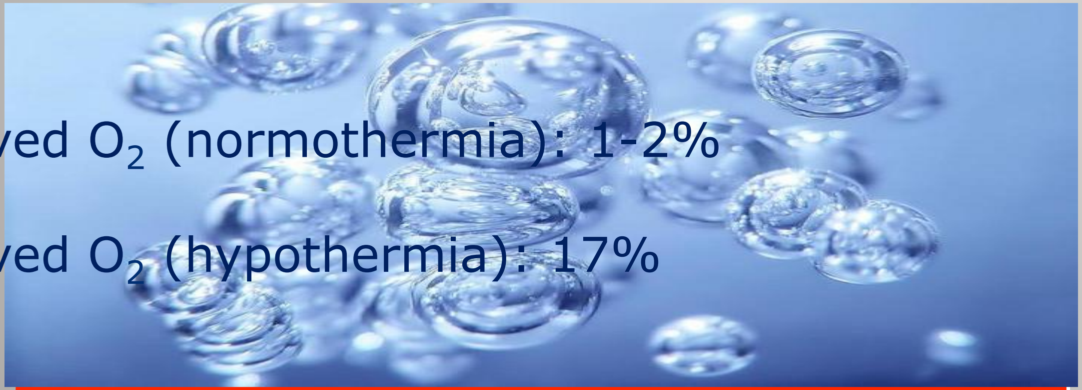
Hypothermia and blood gases management

The Brain Uses Mostly Dissolved Oxygen During Profoundly Hypothermic Cardiopulmonary Bypass

Franklin Dexter, MD, PhD, Frank H. Kern, MD, Bradley J. Hindman, MD, and William J. Greeley, MD

Department of Anesthesia, University of Iowa, Iowa City, Iowa

Ann Thorac Surg 1997;63:1725-9



- Dissolved O_2 (normothermia): 1-2%
- Dissolved O_2 (hypothermia): 17%

Fig 2). Maintaining the P_aO_2 at high levels (ie, >400 mm Hg), to maximize dissolved C_aO_2, can support the brain's oxygen requirements.

Deep hypothermia circulatory arrest euglycemia

Avoiding Stroke During Cardiac Surgery

Seminars in Cardiothoracic and Vascular Anesthesia
14(2) 95–101

DOI: 10.1177/1089253210370902
http://scv.sagepub.com
SAGE

Kristine Kellermann, DVM[1], and Bettina Jungwirth, MD[1]

Abstract

The life saving benefits of cardiac surgery are frequently accompanied by negative side effects such as stroke, that occurs with an incidence of 2%-13% dependent to type of surgery. The etiology is most likely multifactorial with embolic events considered as main contributor. Although stroke presents a common complication, no guidelines for any routine use of pharmacological substances or non-pharmacological strategies exist to date.

Non-pharmacological strategies include monitoring of brain oxygenation and perfusion with devices such as near infrared spectroscopy and Transcranial Doppler help. Epiaortic and transesophageal echocardiography visualize aorta pathology, enabling the surgeon to sidestep atheromatous segments. Additionally can the use of specially designed aortic cannulae and filters help to reduce embolization. Brain perfusion can be improved by using antero- or retrograde cerebral perfusion during deep hypothermic circulatory arrest, by tightly monitoring mean arterial blood pressure and hemodilution. Controlling perioperative temperature and glucose levels may additionally help to ameliorate secondary damage.

Many pharmacological compounds have been shown to be neuroprotective in preclinical models, but clinical studies failed to confirm these results so far.

Remacemide, an NMDA-receptor-antagonist showed a significant drug-based neuroprotection during cardiac surgery. Other substances currently assessed in clinical trials whose results are still pending are acadesine, an adenosine-regulating substance, the free radical scavenger edaravone and the local anesthetic lidocaine.

Stroke remains as significant complication after cardiac surgery. Non-pharmacological strategies allow perioperative caregivers to detect injurious events and to ameliorate stroke and its sequelae. Considering the multi-factorial etiology though, stroke prevention will likely have to be addressed with an individualistic combination of different strategies and substances.

Deep hypothermia circulatory arrest and reperfusion injury

- Reperfusion at temperature: 1 minute
- Low pressure
- Normoxia
- Respect of temperatures gradients (6-10°C max)
- Reperfusion solution?

Deep hypothermic circulatory arrest and global reperfusion injury: Avoidance by making a pump prime reperfusate—A new concept

Bradley S. Allen, MD

J Thorac Cardiovasc Surg 2003; 125:625-32

- Hyperkaliemia (?) ➔ hemodiafiltration

Deep hypothermia circulatory arrest: Rewarming period

- 2 sites of temperature: nasopharyngeal and arterial flow
- Time
- Temperature of blood: 37°C maximum (arterial line)

Grocott HP. *PRO: Temperature Regimens and Neuroprotection During Cardioplumonary Bypass: does rewarming rate matter? Anesthesia and analgesia.* 2009 Dec; 109 (6):1738-40.

McCullough JN, and all. *Cerebral metabolic suppression during hypothermic circulatory arrest in humans. Ann Thorac Surg.* 1999;67:1895-9.

Avoidance of Hyperthermia

Limiting arterial line temperature to 37°C might be useful for avoiding cerebral hyperthermia. (Class IIa, Level B)

"Coupled temperature" ports for all oxygenators should be checked for accuracy and calibrated.

Shann KG, et al. *An evidence-based review of the practice of cardiopulmonary bypass in adults. J Thorac Cardiovasc Surg 2006; 132-283-90.*

Ascending aortic surgery and monitoring:

Recommendations for Haemodynamic and Neurological Monitoring in Repair of Acute Type A Aortic Dissection

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[3] *Department of Card... UK*

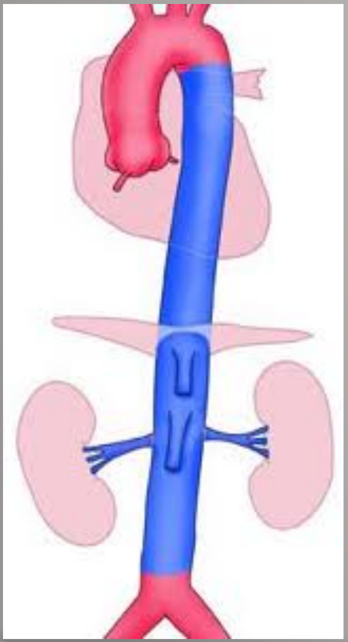
Correspondence sho...

Table 1: Essential and desirable monitoring techniques for use in repair of acute type A aortic dissection.

Essential monitoring
Electrocardiogram
Arterial oxygen saturations
Peripheral and core temperatures
Central venous pressure
Pre- and postarch arterial lines
Transoesophageal echocardiogram
Desirable monitoring
Pulmonary artery flotation catheter
Continuous intra-arterial blood gas monitor
Near infrared spectroscopy (cerebral and peripheral)
Jugular venous oxygen saturations
Transcranial Doppler
Electroencephalography

Anesthesiology Research and Practice Volume 2011, Article ID949034.

Descending aortic surgery



- Surgical repair
  - Left-left Bypass
  - Right-left Bypass
  - Conventional CPB
  - None

Descending aortic surgery

Evolution of Risk for Neurologic Deficit After Descending and Thoracoabdominal Aortic Repair

Hazim J. Safi, MD, Anthony L. Estrera, MD, Charles C. Miller, PhD,
Ta… Jer…
Dep… Hos… …nn

Background. Cross-clamp time has been reported to correlate with risk of neurologic deficit after thoracoabdominal aortic aneurysm repair. Introduction of cerebrospinal fluid drainage and distal aortic perfusion (adjunct) has greatly reduced the incidence of neurologic deficit. We reevaluated the effect of cross-clamp time before and after introduction of adjunct during a 13-year period.

Methods. Between 1991 and 2004, we repaired 1,106 thoracic and thoracoabdominal aortic aneurysms. Four hundred one patients were female and 705 were male (median age, 67 years). Selective use of adjunct was begun in late 1992, with its routine use by 1993.

Results. Aortic cross-clamp times have increased significantly (34 seconds/year; $p < 0.0001$) since 1991. Despite this increase in cross-clamp time, neurologic deficit rates have declined from the first to the fourth quartile ($p < 0.02$). This decrease in neurologic deficit is most pronounced with the extent II thoracoabdominal aortic aneurysms (21.1% to 3.3%). The use of the adjunct increased the cross-clamp time by a mean of 12 minutes ($p < 0.0001$), but was associated with a significant protective effect against neurologic deficit (odds ratio = 0.4; $p < 0.0002$). Although other previously established risk factors remained significantly associated with neurologic deficit, cross-clamp time is no longer significant.

Conclusions. Adjunct significantly reduced the risk of neurologic deficit, despite increasing cross-clamp time. The use of the adjunct appears to blunt the effect of the cross-clamp time and may provide the surgeon the ability to operate without being hurried. Because cross-clamp time has been effectively eliminated as a risk factor with the use of the adjunct, using this variable to construct risk models becomes irrelevant in our experience.

(Ann Thorac Surg 2005;80:2173–9)

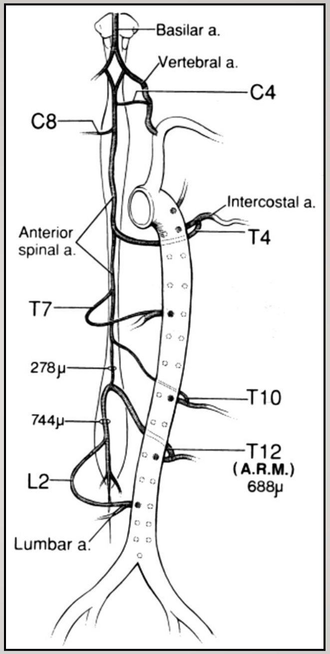
Ann Thorac Surg 2005:80-2173-9.

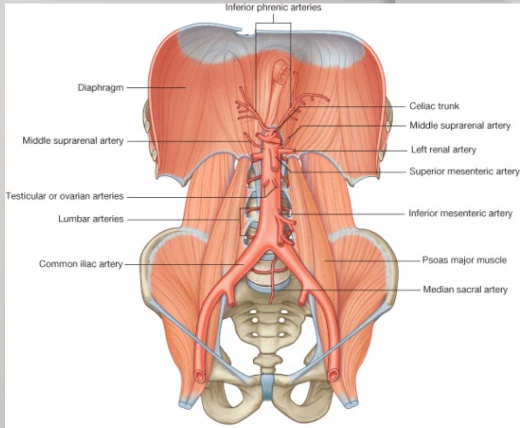
Descending aortic surgery: CPB circuit

Left-left bypass Right-left bypass	Conventional miniaturizated CPB
Left atrium - distal aorta Right atrium - distal aorta	Right atrium (femoral access) – distal aorta
Centrifugal pump Autoregulation of the volemia	Centrifugal or roller pump
	Heat exchanger + oxygenator
Low heparin level	Full heparinized
	Easy shunt for selective perfusion
	Quick response to acute hemorrhagic event

Surgery on the descending aorta medullar and splanchnic selective perfusion

- Perfusion
- Local hypothermia
- Systemic mild hypothermia (32°C)





Medullar and splanchnic perfusion: complications and monitoring

Complications	monitoring
Local dissection	Q-Pressure
Oedema in case of overflow and or over pressure or brain herniation	CSF pressure
Malperfusion Upstream embolism	Flow, regional pressure (60mmHg), Doppler flowmetry MEP (motor evoquated potential). Mucosal pH tonometry NIRS ?

Surgery on the descending aorta: medullar protection

Thoracoabdominal Aortic Aneurysm Repair: Results of Conventional Open Surgery

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Department of Cardio-thoracic Surgery, St. Antonius Hospital, Nieuwegein, The Netherlands

- Cerebral Spinal drainage

Effect of Extended Cross-Clamp Time During Thoracoabdominal Aortic Aneurysm Repair

Hazim J. Safi, MD, Anders Winnerkvist, MD, Charles C. Miller III, PhD, Dimitrios C. Iliopoulos, MD, Michael J. Reardon, MD, Rafael Espada, MD, and John C. Baldwin, MD

Department of Surgery, Baylor College of Medicine and The Methodist Hospital, Houston, Texas

Coagulation management

Artificial Organs
24(1):49–56, Blackwell Science, Inc.

Maintenance of Blood Heparin Concentration Rather than Activated Clotting Time Better Preserves the Coagulation System in Hypothermic Cardiopulmonary Bypass

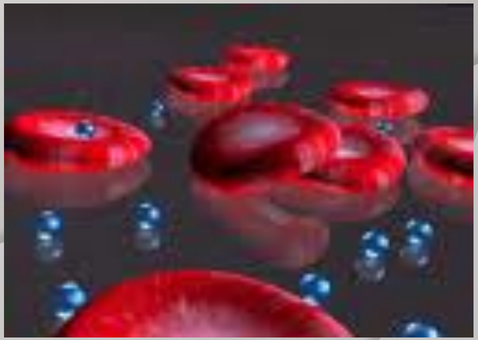
Kazuaki Shirota, Takashi Watanabe, Yasushi Takagi, Yasuhisa Ohara, Akihiko Usui, and Kenzou Yasuura

Department of Thoracic Surgery, Nagoya University School of Medicine, Nagoya, Japan

G I G A

Blood management

- Selective suction blood management
- Specific filtration
- Cell saving process
- Selective allogenic blood component transfusion



Conclusions

- Aorta surgery is a team work
- Multiple modal approaches
- Engineering developments
- EBM and EBP

ACKNOWLEDGEMENT

Surgical team
Anaesthesiology team
Scrub nurses

F BLAFFART
D HELLA
MP FISSETTE
T AMAND
M ERPICUM
JN KOCH
D BERTRAND

THANK YOU

GIGA

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CHU de Liège