ECOCARDIOCHIRURGIA.it

Milano, 16 Ottobre 2012

L'ecografia intraoperatoria negli interventi cardiochirurgici di emergenza.

Cerchiamo di prevenire il danno neurologico.

Emanuele Catena

Direttore SC Anestesia e Rianimazione

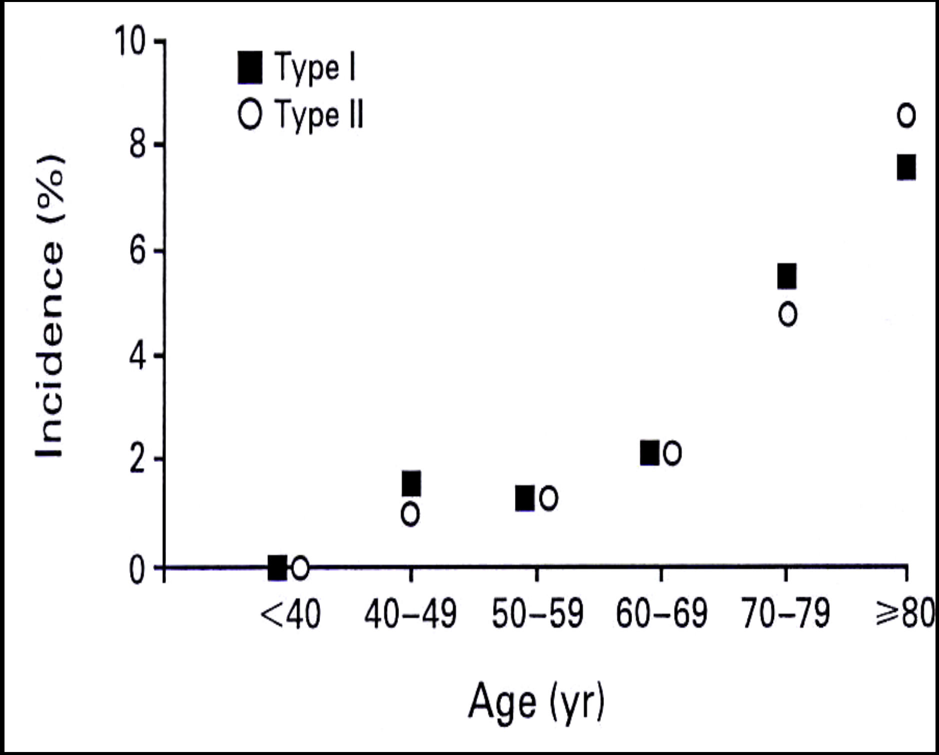
AZIENDA OSPEDALIERA CARLO POMA

The New England Journal of Medicine

VOLUME 335 DECEMBER 19, 1996 NUMBER 25

ADVERSE CEREBRAL OUTCOMES AFTER CORONARY BYPASS SURGERY

GARY W. ROACH, M.D., MARC KANCHUGER, M.D., CHRISTINA MORA MANGANO, M.D., MARK NEWMAN, M.D., NANCY NUSSMEIER, M.D., RICHARD WOLMAN, M.D., ANIL AGGARWAL, M.D., KATHERINE MARSCHALL, M.D., STEVEN H. GRAHAM, M.D., PH.D., CATHERINE LEY, PH.D., GERARD OZANNE, M.D., AND DENNIS T. MANGANO, PH.D., M.D., FOR THE MULTICENTER STUDY OF PERIOPERATIVE ISCHEMIA RESEARCH GROUP AND THE ISCHEMIA RESEARCH AND EDUCATION FOUNDATION INVESTIGATORS*



Type I: fatal cerebral injury and nonfatal strokes

Type II: new deterioration in intellectual function, memory deficit, new onset of seizures

Risk factors for adverse cerebral outcome:

TYPE I

- Proximal aortic atherosclerosis
- History of neurologic disease
- Use of IABP
- Diabetes mellitus
- History of hypertension
- History of pulmonary disease
- History of unstable angina
- age

TYPE II

- Age
- Systolic blood pressure > 180 mmHg
- History of alcohol consumption
- History of CABG
- Dysrhythmia on day of surgery
- Antihtpertensive therapy

Adverse cerebral outcomes occurred in 129 /2108 patients (6.1%)

- **3.1 % had type I** (8 died if cerebral injury, 55 had nonfatal strokes, 2 TIA, 1 stupor)
- **3.0% had type II** (55 deterioration intellectual function, 8 seizures)

Roach et al., NEJM 1996

PostOperative Cognitive Dysfunction (POCD)

impairment of memory, concentration, language, comprehension, and social integration

- 53% (N. 261) at hospital discharge
- 36% after six weeks
- 24 % six months postoperatively

after cardiac surgery

Newman et al., NEJM 2001

The incidence of early POCD: 60% Slater et al., Ann Thorac Surg 2009;87:36-45.

Post-Operative Cognitive Dysfunction (POCD)

after cardiac surgery

- 37% (N. 551, CABG surgery) had POCD at ***one year***. A substantial association was found between POCD and changes in QoL.

- 42% experienced decline in cognitive function after ***five years***. Only 5.2% reported a poor general health status based on QoL measures.

Philips-Bute B, et al. Psychosom Med 2006;68:369-75.

Limitations:

- Cognitive tests used
- Timing of testing
- Definition of cognitive decline

62 studies identified assessing POCD after cardiac surgery

Consensus Statement Guidelines (1995) are not widely accepted or applied: most batteries covered the domains of attention and memory, less frequently motor function

Heterogeneity limits the ability to compare POCD among studies

Rudolph JL et al. Acta Anaesthesiol Scand 2010;54:663-677

Risk-factors for POCD

- **Age:** associated to atherosclerosis, alterations in the vasculature and auto-regulation of cerebral blood flow
- **Education** increases the synaptic density in the neocortex, neuronal communication
- **Previous diseases**: diabetes mellitus, systemic arterial hypertension, chronic renal failure

Gao L et al. CHEST 2005

Funder KS et al Minerva Anest 2009

- **Alcohol dependence**

Hudetz JA, et al. Int J Environ Res Public Health 2009;6:2725-2739

Etiology of cerebral injuries associated with POCD

- **Cerebral microemboli** (air, opening of heart chambers, cooling process, fat, …)
- **Cerebral macroemboli** (atheroma of the aortic wall, clamp. aorta, cannulation)
- **Global cerebral hypoperfusion** ⇐

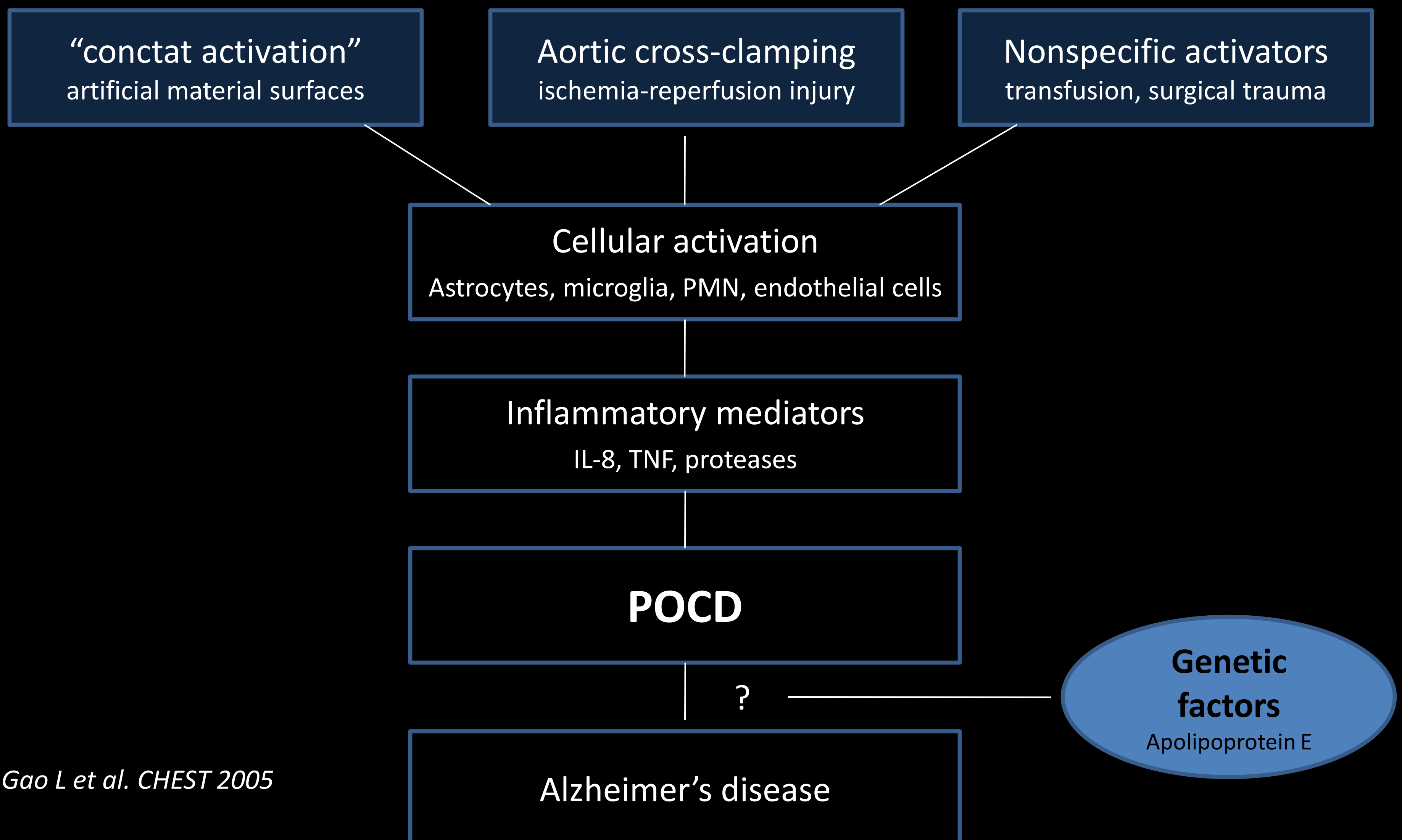
Duration and type of surgical procedure --> prolonged CPB, surfaces of circuit

Hyperthermia during and after CPB --> toxic neurotransmitters, free radicals
--> barrier permeability --> emergy consumption

Aggressive rewarming process --> the speed is directly related to jugular desaturation --> altered cognitive performance

Hyperglycemia (> 200 mg/dL) --> lactate --> acidosis --> excitatory aminoacids

Etiology of cerebral injuries associated with POCD: ***inflammation***



Gao L et al. CHEST 2005

Cognitive dysfunction after non-cardiac surgery

An incidence of 25.8% after 1 week and 9.9% at 3 months postoperatively

- 60 years or more
- Major vascular procedures
- Atherosclerosis, cerebrovascular disease, hypertension, diabetes

Funder KS, et al. Minerva Anestesiol 2009;75:329-32

The importance of intraoperative management

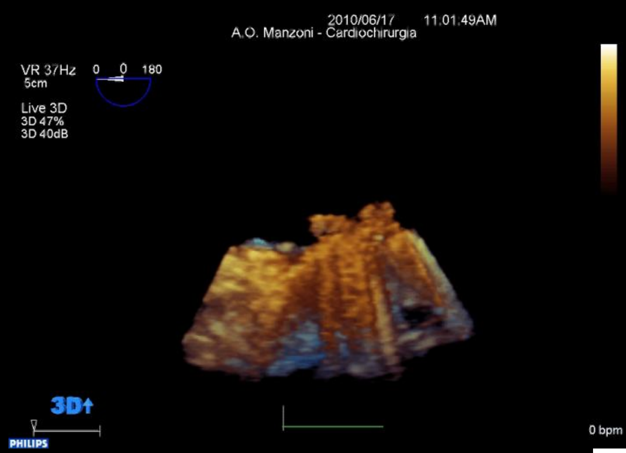
HEMODYNAMIC STABILITY

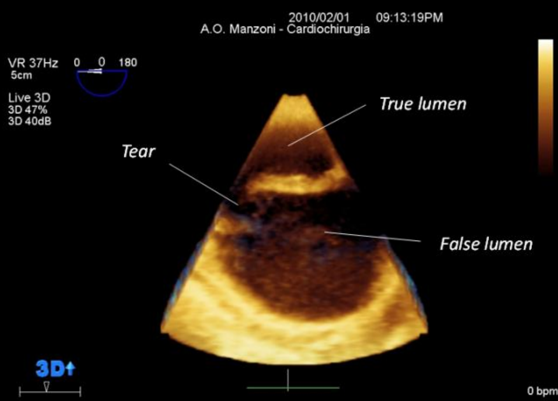
A drop in Mean Arterial Pressure from a preoperative baseline may put patients at risk for early POCD after coronary artery bypass graft operation

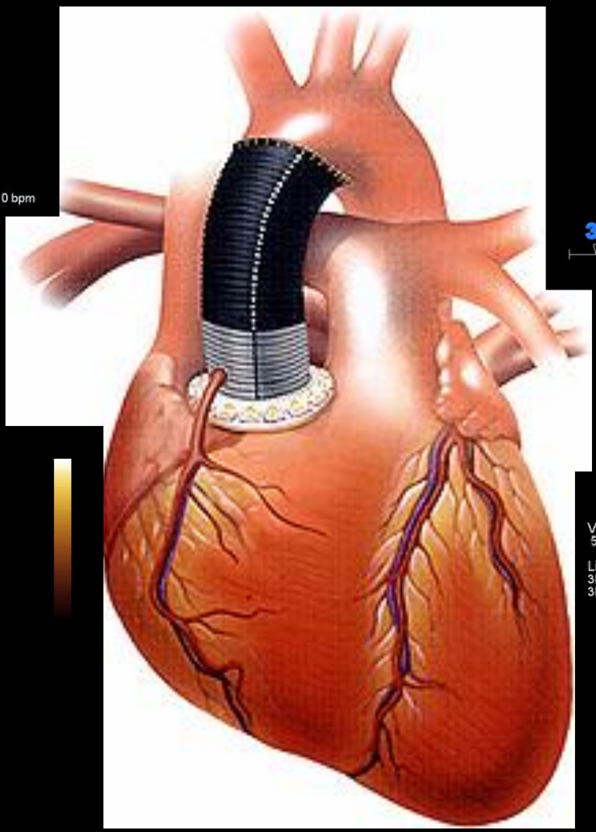
Arch Neurol 2007;64(8):1111-1114

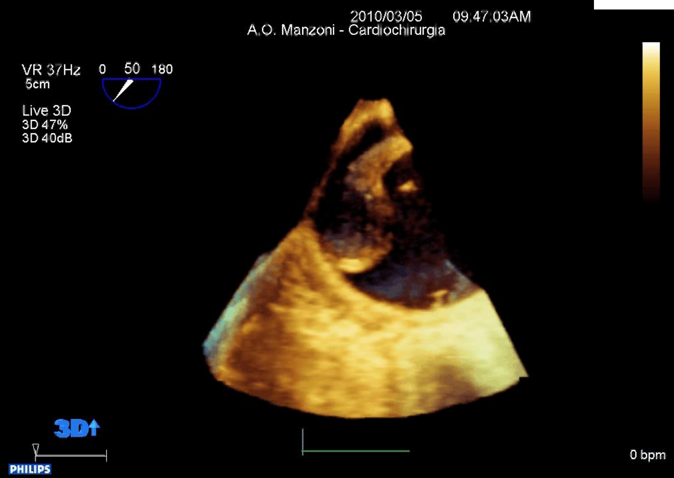
Aortic arch surgery

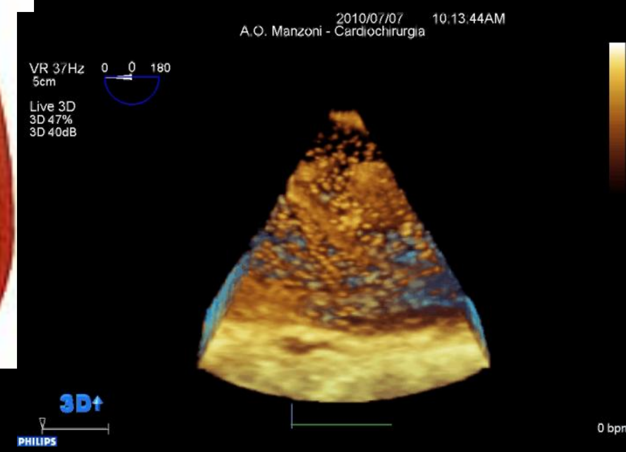
Cerebral protection











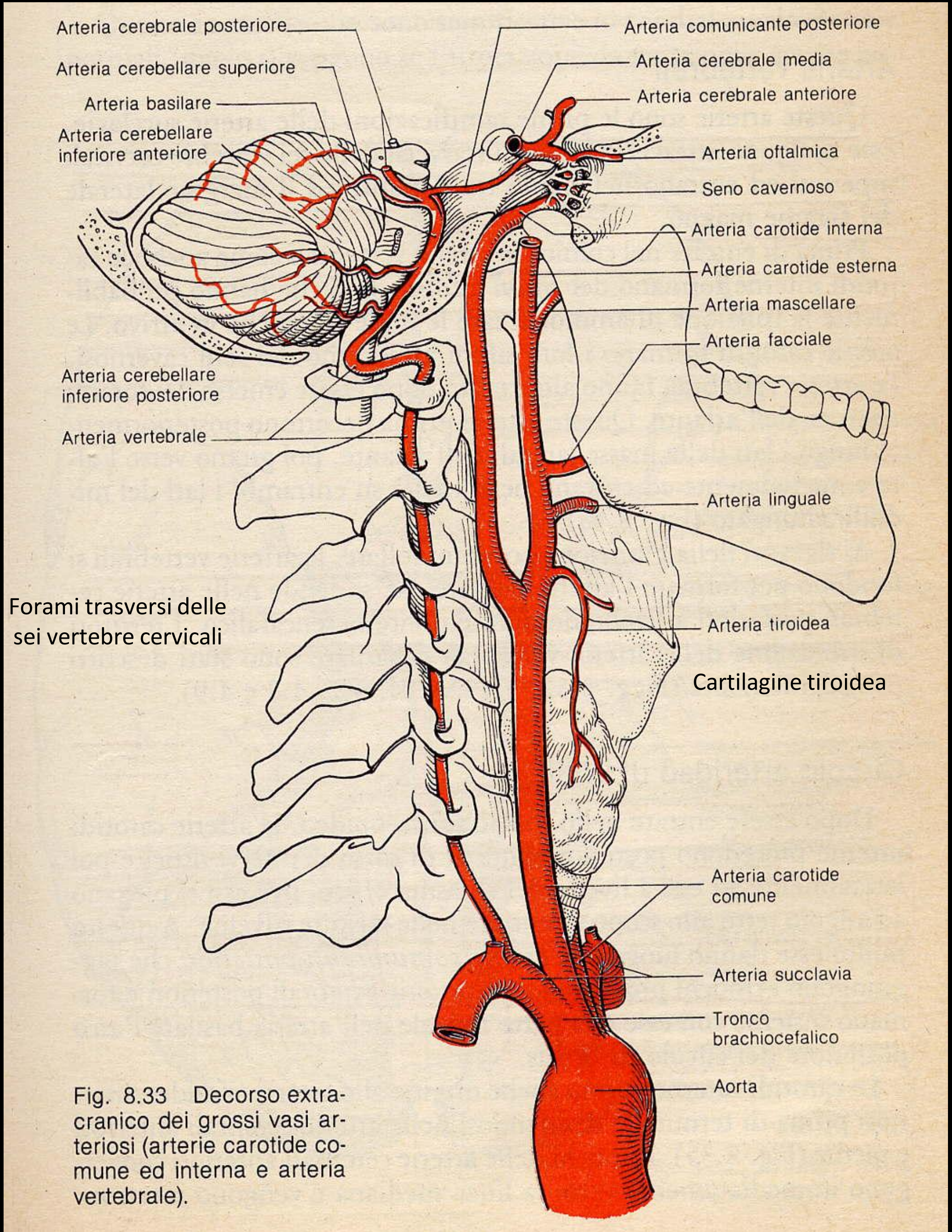


Fig. 8.33 Decorso extracranico dei grossi vasi arteriosi (arterie carotide comune ed interna e arteria vertebrale).

Le a. carotidi interne e le vertebrali sono indipendenti fino a quando entrano nel cranio dove sono interconnesse da un sistema anastomotico di sicurezza:
il circolo di Willis e l’arteria basilare

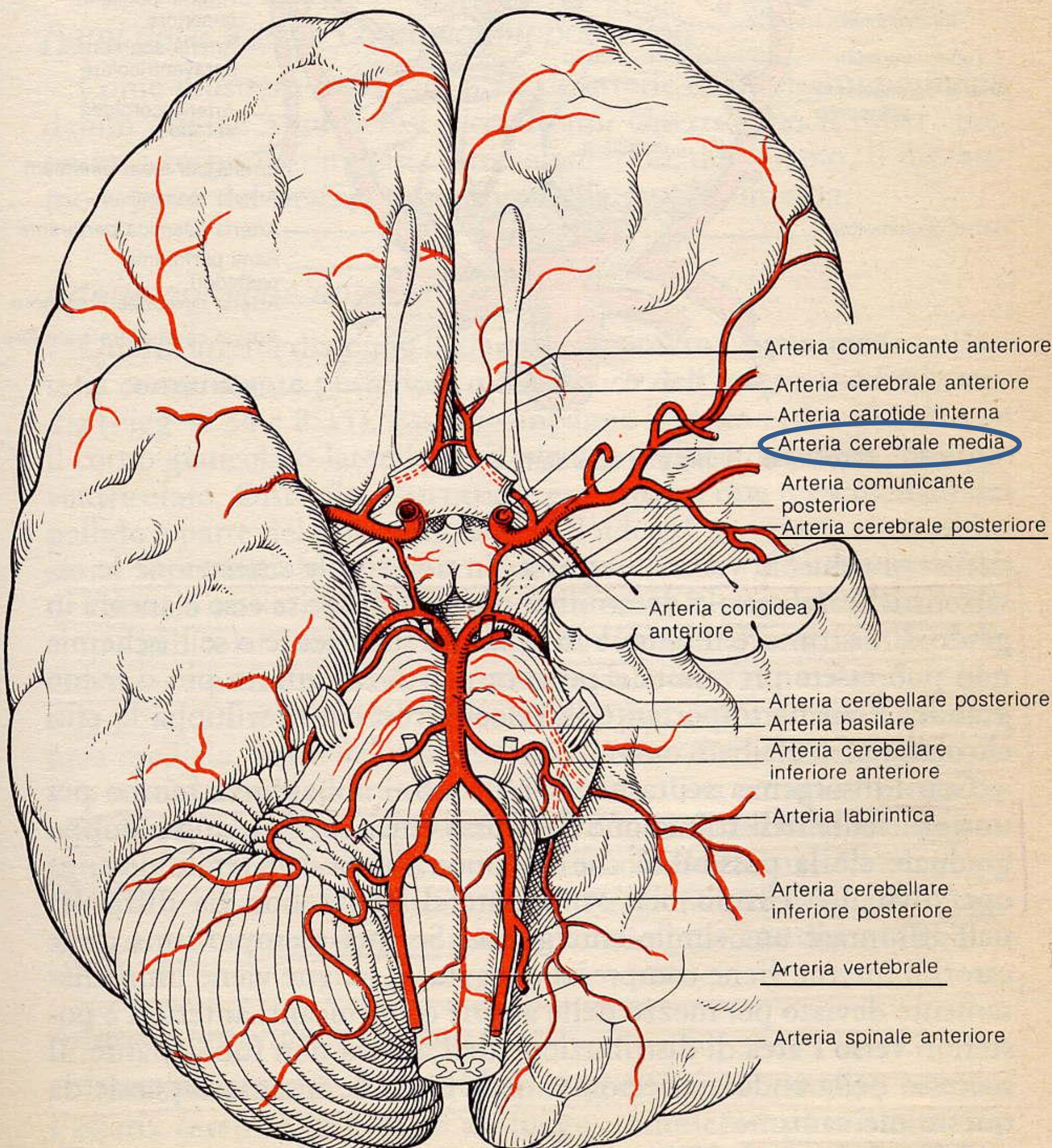


Fig. 8.34 Arterie della base cerebrale.

Se una delle a. carotidi interne viene compressa il sangue viene deviato per mezzo delle ARTERIE COMUNICANTI verso l'area di distribuzione dell'arteria non funzionante

Un circolo di Willis normale esiste in non più della metà di tutte le persone. In alcuni casi una o entrambe le arterie comunicanti posteriori possono mancare

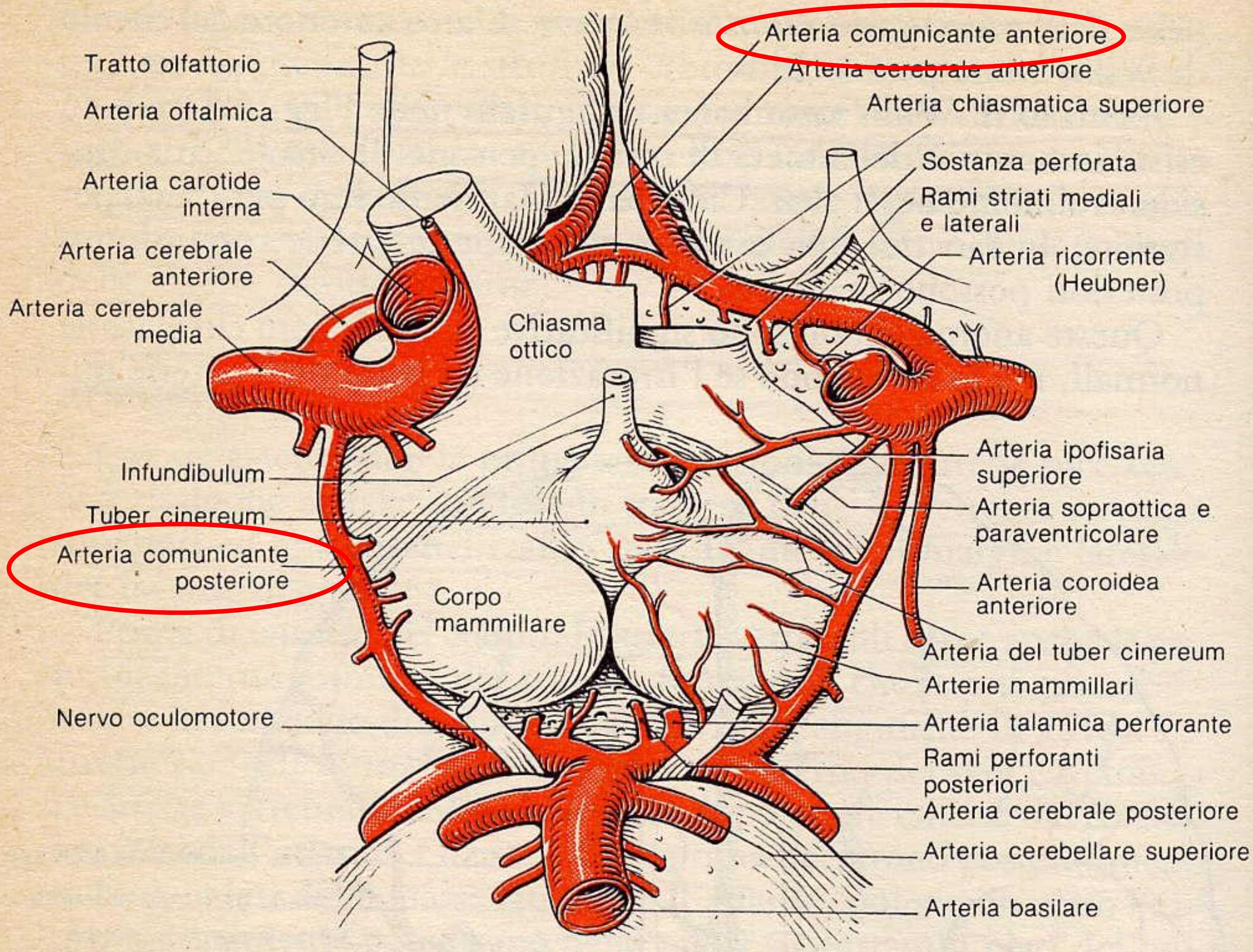


Fig. 8.35 Circolo di Willis ed i suoi rami.

Cerebral damage during aortic arch surgery occurs primarily due to 2 mechanisms:

1) ***Global injury*** secondary to inadequate protection of the brain during interruptions of normal cerebral perfusion
2) ***Focal defects*** resulting from embolization of atheroma and surgical debris into the cerebral vessels.

Cerebral protection during surgery

1) suppressing the metabolic demand:

Hypothermia:

At 37°C: O_2 consumption 2.9 ml/g/min
At 25°C: O_2 consumption 0.9 ml/g/min
At 20°C: O_2 consumption 0.5 ml/g/min

Anesthetic drugs: pentobarbital

(N-methil-D aspartate receptor antagonist, steroids, mannitol)

2) maintaining the metabolic supply

At 37°C CBF 55 ml/min/100 g brain tissue
At 37°C CBF < 18/ml/100g: ischemic phenomena

3 techniques for brain preservation during aortic surgery:

1) deep hypothermic circulatory arrest (DHCA)

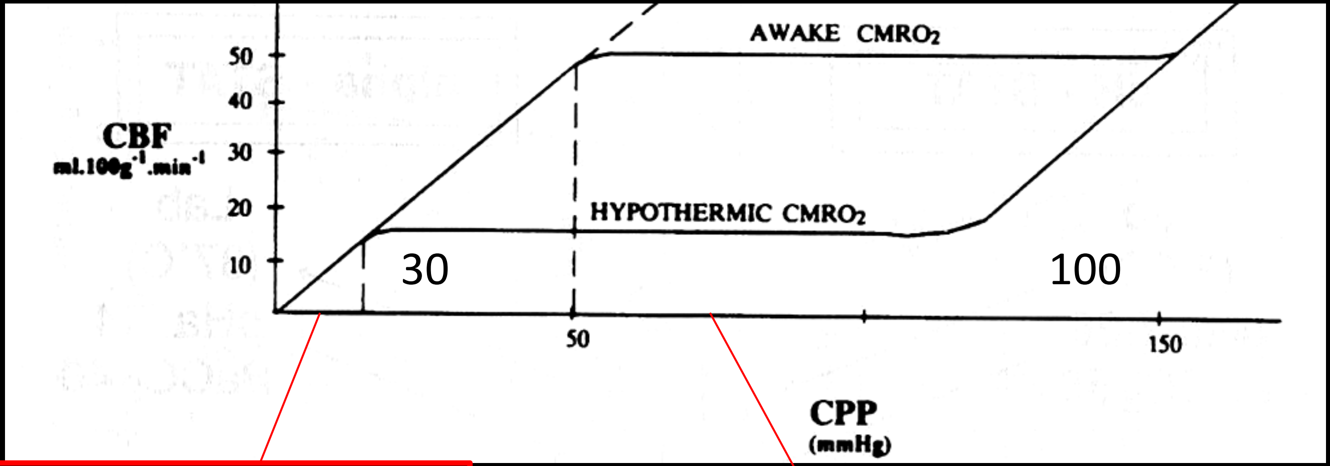
2) retrograde cerebral perfusion

3) anterograde cerebral perfusion

Hypothermia

- reduces the release of cytotoxic excitatory neurotransmitters
- preserves adenosine triphosphate
- Reduces production of O2 free radicals during reperfusion

At 37°C autoregulation of CBF is maintained for a wide spectrum of mean arterial pressures



Direct relation between flow and perfusion pressures

In deep hypothermic situations (20°C) autoregulation is maintained for perfusion pressures ranging from 30 to 100 mmHg

1) deep hypothermic circulatory arrest (DHCA) 18-19 °C

Cerebral ischemia at normothermia can be tolerated without injury for 5 minutes

DHCA at 18° C is theoretically safe for only 25 minutes

DHCA at 18° C > 30 minutes: cerebral injury

- Quick and simple technique, especially in urgent situations
- Bloodless and motionless
- Surgical field without any mechanical encumbrances and clamps: no extra cannulas or tubings are required
- No dangers inherent in the cerebral perfusion techniques: *flowing too slow risks hypoperfusion and flowing too fast risks cerebral edema*

1) deep hypothermic circulatory arrest (DHCA) at 18-19 °C results in:

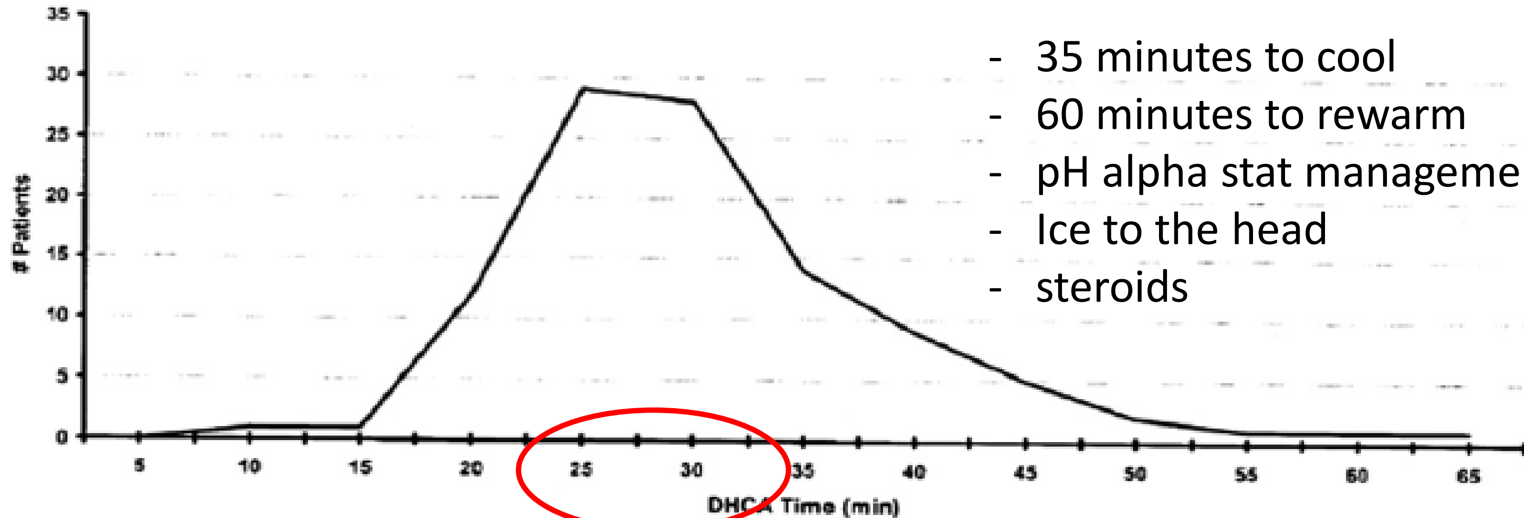
- Prolonged CPB: long period of cooling and rewarming

→ High incidence of temporary and permanent neurologic dysfunction (10-25%)

→ Adverse effects in multiple organ systems: coagulopathy (strong risk factor for bleeding requiring reexploration) and renal failure

endothelial dysfunction, neuronal apoptosis, haemoconcentration, increased blood viscosity, thrombocytopaenia, reduced systemic vascular resistances, severe veno-constriction

1) deep hypothermic circulatory arrest (DHCA) 18-19 °C



- 35 minutes to cool
- 60 minutes to rewarm
- pH alpha stat management
- Ice to the head
- steroids

Fig. 1. Distribution of deep hypothermic circulatory arrest (DHCA) time. Total time in minutes that each patient was exposed to straight DHCA at our institution (mean, 31 minutes; range, 10–61 minutes). (*From* Gega A, Rizzo JA, Johnson MH, et al. Straight deep hypothermic arrest: experience in 394 patients supports its effectiveness as a sole means of brain preservation. Ann Thorac Surg 2007;84(3):759–66; with permission.)

Total mortality 2.2%
Re-exploration for bleeding 4.5%
Stroke rate 2.3%

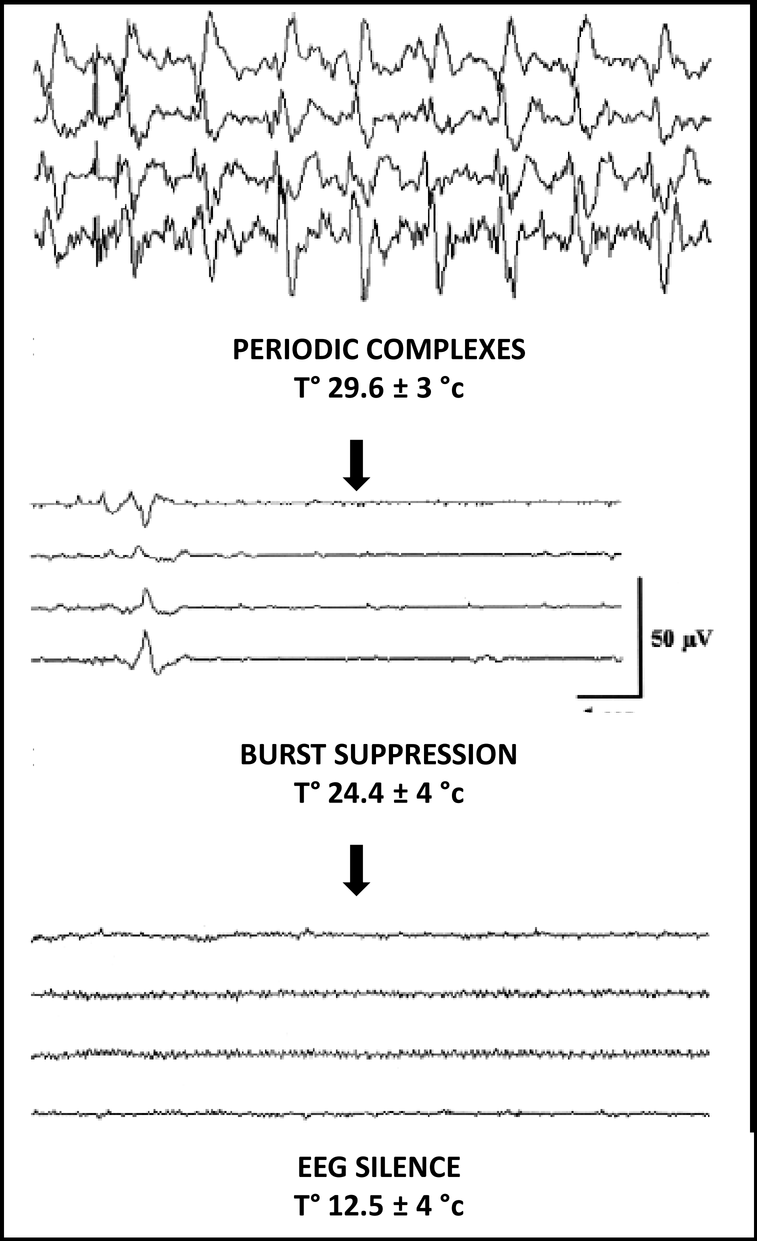
In the 61 patients in whom circulatory arrest time > 40 min stroke rate was 13%

1) deep hypothermic circulatory arrest (DHCA) 18-19 °C

Protection measures:

- The temperature needs to be reduced slowly (>30 min) to achieve uniform cooling of the brain
- **EEG** electrical silence before circulatory arrest
- **SjO2**>95% to ensure adequate suppression of cerebral metabolic activity
- Haemodiluition (Hmt 20%)
- Strict control of blood glucose to avoid intracellular acidosis

DHCA and EEG



Only 60% of patients shows EEG silence by either a nasoph T of 18°C or a cooling > 50 min

The only absolute predictors of EEG silence were nasoph T < 12.5 °C and cooling > 50 min

Is there a "best temperature" for circulatort arrest?

Should all patients be cooled to 12°C?

Circulatory arrest 36.6 ± 12 min: neurologically normal patients
Circulatory arrest 51.6 ± 21 min: postoperative neurologic impairment

Stecker MM, Ann Thorac Surg 2001;71:14-21.

2) retrograde cerebral perfusion (RCP) through superior vena cava at deep hypotermia

- In 1980 Mills and Ochsner used RCP to treat accidental air embolism during cardiopulmonary bypass: RCP potentially reduces the risk of stroke related to embolic materials.

- Retrograde perfusion is possible because there are no valves in the cerebral veins. In this technique the brain is perfused by via the superior vena cava at a flow rate of 0.3-0.5 l/min, maintaining a jugular bulb pressure of less than 25 mmHg

Ueda Y, J Cardiovasc Surg 1990; 31:553-558.
Ueda Y, Cardiol Clin 2010;28:371-379.

Ascending and Transverse Aortic Arch Repair
The Impact of Retrograde Cerebral Perfusion

Anthony L. Estrera, MD; Charles C. Miller, III, PhD; Taek-Yeon Lee, MD;
Pallav Shah, MD; Hazim J. Safi, MD

1107 repairs of the ascending and trasverse aortic arch (1991-2007).

RCP used in 82% (907 patients)

- Mortality 30 days 10.4%
- **Stroke 2.8%**
- TND 15%

The use of RCP + DHCA was associated with a reduction in mortality and ***stroke***

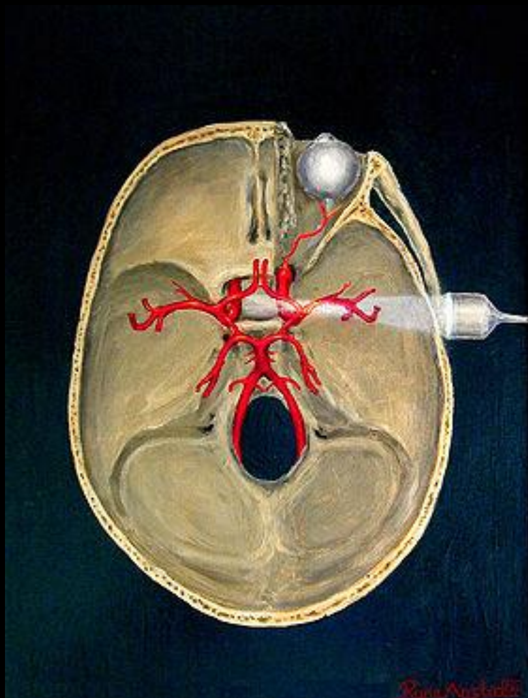
Mean RCP time was 26 min and only 22% of patients underwent circulatory arrest time > 40 min

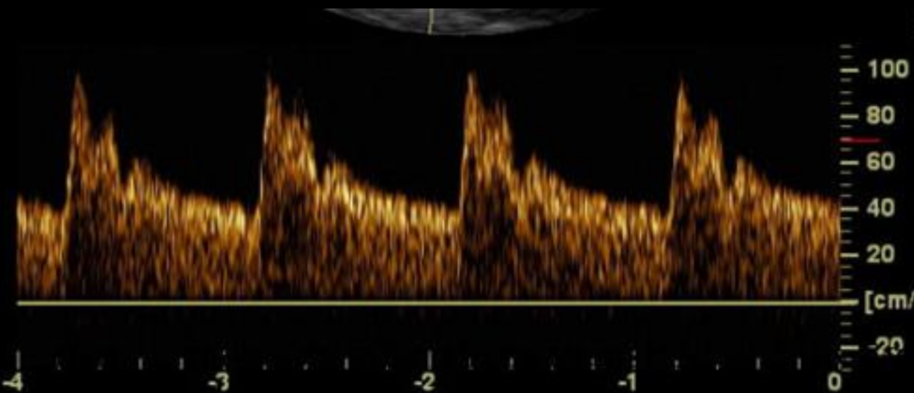
Adequacy of RCP flow was determined by the presence of reversed blood flow in the middle cerebral arteries by transcranial Doppler ultrasound

Because cerebral venous capacitance, vessels may require a higher pressure to establish retrograde cerebral flow; nonguided RCP may not achieve adequate cerebral protection.

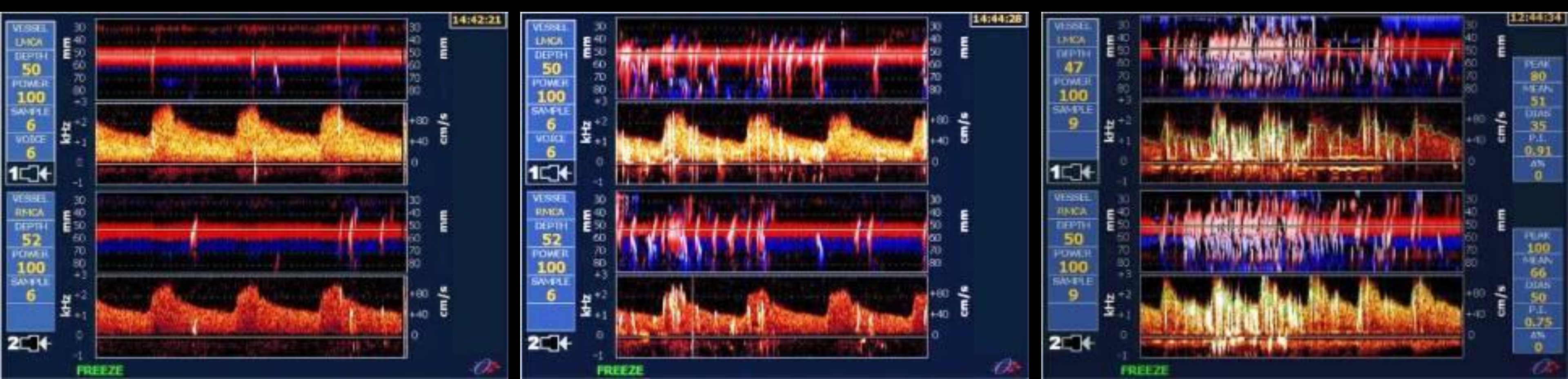
Estrera AL, Circulation 2008;118:160-166

Transcranial Doppler



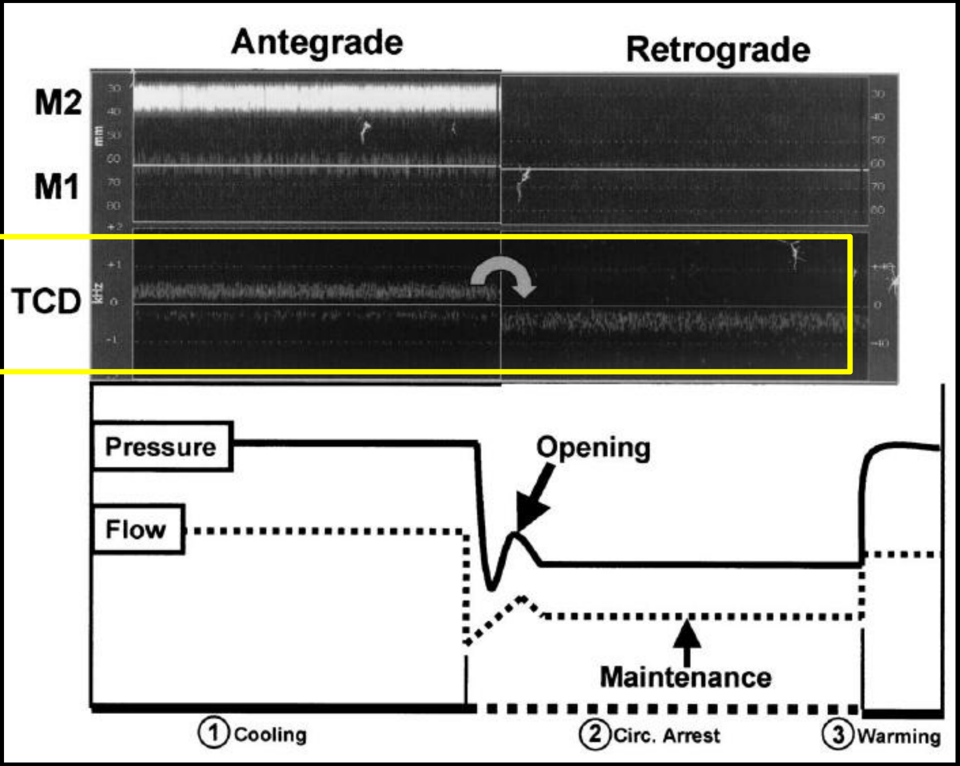


Mean cerebral artery



M-mode transcranial Doppler

Monitoring for 40 ascending and trasferse aortic arch repair during RCP + DHCA



A higher RCP pressure was required to immediately identify reversed cerebral blood flow (“opening pressure”)

Once identified RCP pump flow could be decreased to a maintenance level (0.5 L/min and 25 mmHg)

Estrera AL, Ann Thorac Surg 2003;76:704-10

With RCP pressure limited to < 20 mmHg, reversed cerebral blood flow was observed in only 3 of 15 patients.

Tanoue Y Ann Thorac Surg 1999;67:672-5

Retrograde cerebral perfusion

Without "opening pressure"

- Only 3% to 5% of the oxygenated perfusate flowing through the superior vena cava reappears as a backflow through carotid and subclavian arteries

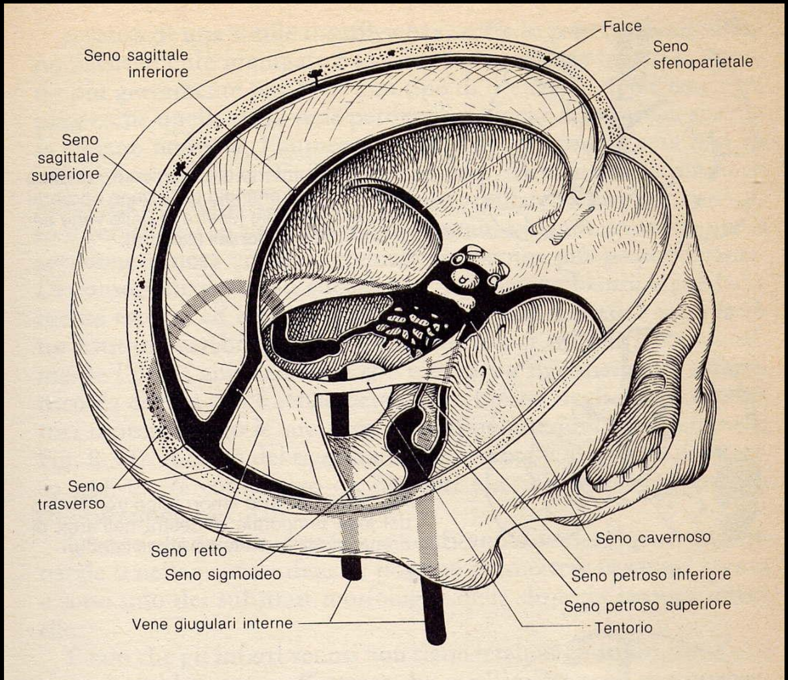


Fig. 8.53 Seni della dura madre.

Most of the fluid retrogradely perfused irrigates the perivertebral venous system through the azygos vein.

Vena cava sup

Vene brachiocefaliche (anonime)

Vene giugulari

Grandi Seni

3) Anterograde selective cerebral perfusion

(DeBakey, 1957)

- **GUILMET technique *(1986)***: cold blood cerebroplegia maintaining the patient's core temperature at moderate hypotermia

- **KAZUI technique *(1992)***: brain perfusion and CPB performed at the same level of moderate hypotermia

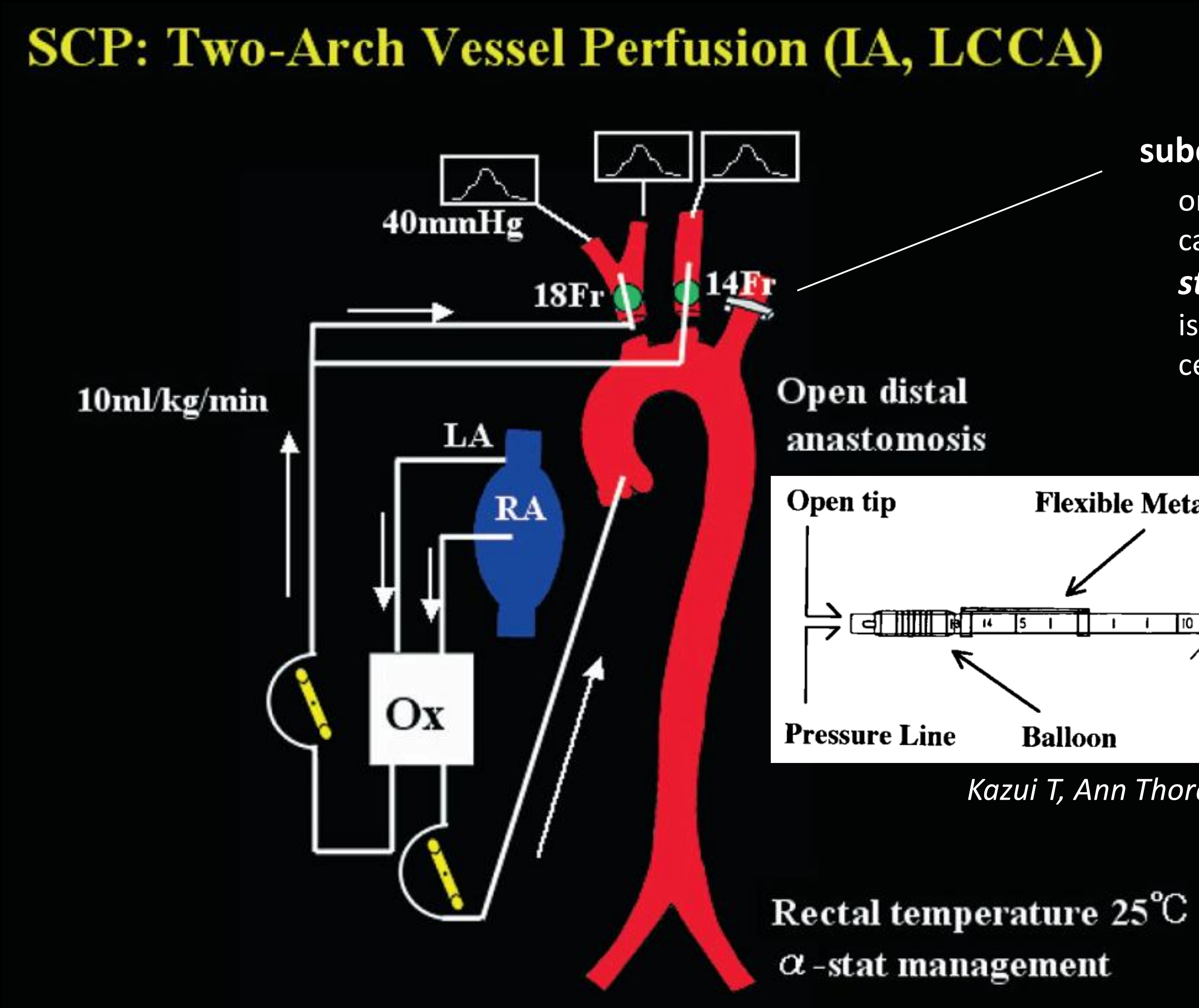
Jean Bachet, Cardiol Clin 2010;28:389-401.

KAZUI technique

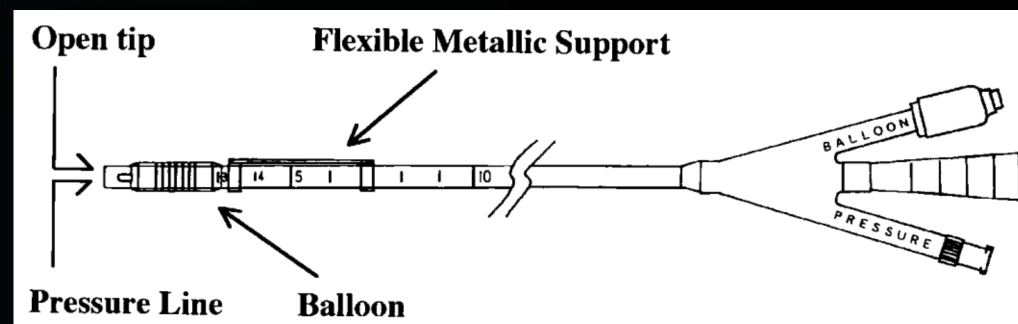
- the core temperature (nasopharyngeal) of the patient is lowered to 25°C which corresponds to a rectal temperature of 28°C
- CPB is discontinued
- Aortic arch is opened; cannulas are inserted into the ostia of the innominate and left common carotid arteries
- A total flow of 10 ml/Kg/min is pefused through both cannulas. The pressure in the carotid arteries sets generally between 50 and 70 mmHg.

Kazui T, Ann Thorac Cardiovasc Surg 2001; 7:186-8

KAZUI technique



subclavian artery cross clamped or occluded by a small Foley catheter to avoid any possible ***steal syndrome*** and consequent ischemia of the posterior cerebrum



Kazui T, Ann Thorac Cardiovasc Surg 2001; 7:186-8

Advantages of anterograde SCP

- It can extend the safe duration of cerebral protection up to 90 minutes
- It obviates the need of deep hypothermia thus reducing the pump time, and risk of hypothermia-related complications (pulmonary insufficiency, coagulopathy)
- It is more effective in supplying oxygenated blood to the brain thus ensuring a more physiologic brain energy metabolism

472 aortic arch replacement using anterograde SCP (1986-2006).

- In-hospital Mortality: 9.3% 4.1%
- **PND 3.2%**
- TND 4.7%

Mean SCP time 88.2 minutes

Kazui T, Ann Thorac Surg 2007;83:796-8.

Retrograde and Antegrade Cerebral Perfusion: Results in Short Elective Arch Reconstructive Times

Rita Karianna Milewski, MD, PhD, Davide Pacini, MD, G. William Moser, RN, Patrick Moeller, MS, Doreen Cowie, CCP, Wilson Y. Szeto, MD, Y. Joseph Woo, MD, Nimesh Desai, MD, PhD, Luca Di Marco, MD, Alberto Pochettino, MD, Roberto Di Bartolomeo, MD, and Joseph E. Bavaria, MD

Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania; and University of Bologna, Bologna, Italy

There was no significant difference in permanent neurologic deficit, temporary neurologic dysfunction, or renal failure, between 682 patients RCP/DHCA and 94 ACP/ MHCA

ACP/MCHA: nasopharingeal temperature 26 °C, Kazui technique
RCP/DHCA: systemic cooling until EEG was isoelectric, perfusion 10°C

…for aortic reconstruction times less than 45 minutes

Ann Thorac Surg 2010;89:1448-57

Prevention of brain injury

Epiaortic and transesophageal echocardiography

- *Ozatik et al. J Card Surg 2005*

  Introduction of **epiaortic scanning** reduced the prevalence of stroke from 1.2% to 0.7% in the retrospective review of 8.547patients.

- *Zingone et al. Eur J Cardiothorac Surg 2006*

  Epiaortic scanning was associated with a several fold reduction in the early postoperative stroke in 2.172 patients particularly in patients with significant aortic pathology

Scanning on the ascending aorta to select the site for cannulation.
RAxA cannulation if the ascending aorta is not suitable for cannulation

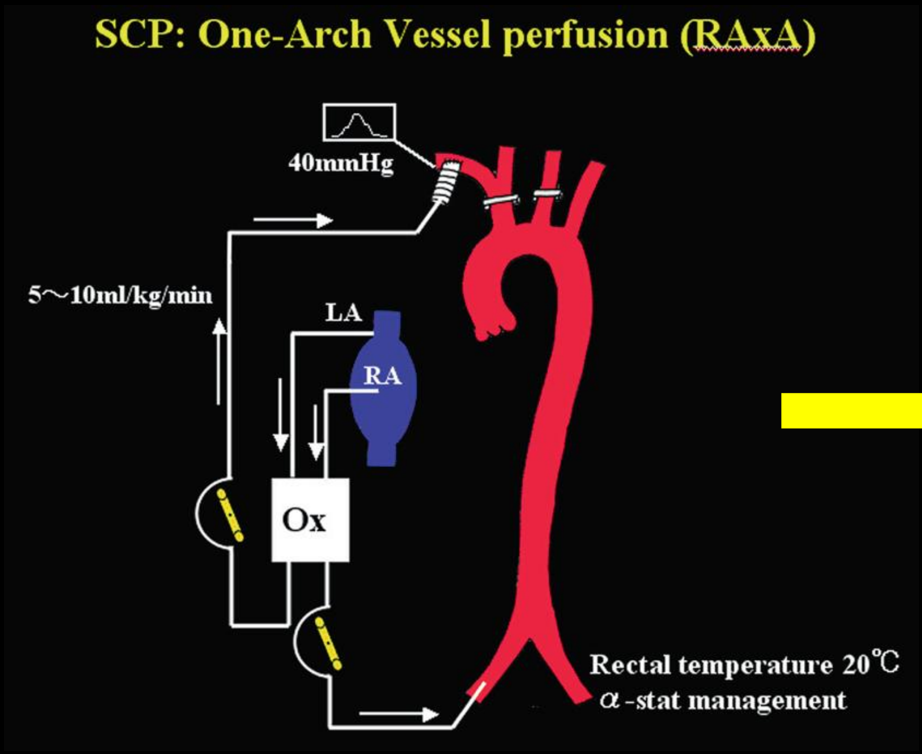
Is ***unilateral anterograde cerebral perfusion*** equivalent to bilateral cerebral perfusion?

At least 10-15% of human beings have anatomic abnormalities of the Circle of Willis and therefore incomplete connections between the cerebral hemispheres or between the anterior and posterior structures of the brain.

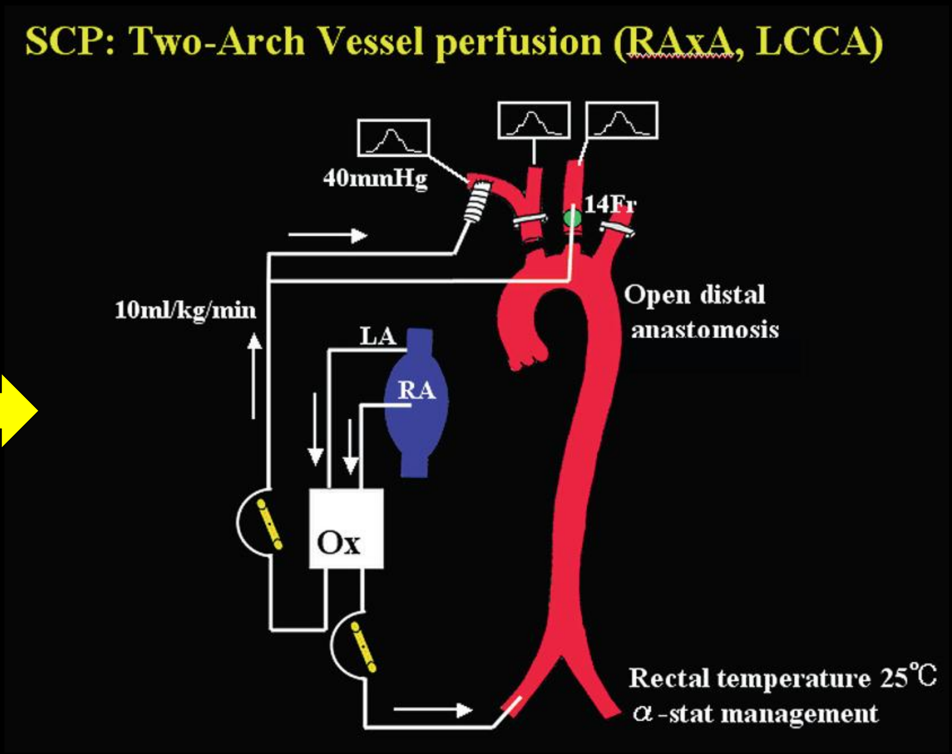
The Circle of Willis is nor the only pathway for cerebral-cross perfusion, but the extracranial collateral circulation plays a maningful role, especially in patients with an incomplete circle of Willis.

Urbanski PP, Eur J Cardiothorac Surg 2008;33:402-8.

Unilateral cerebral perfusion



Bilateral cerebral perfusion



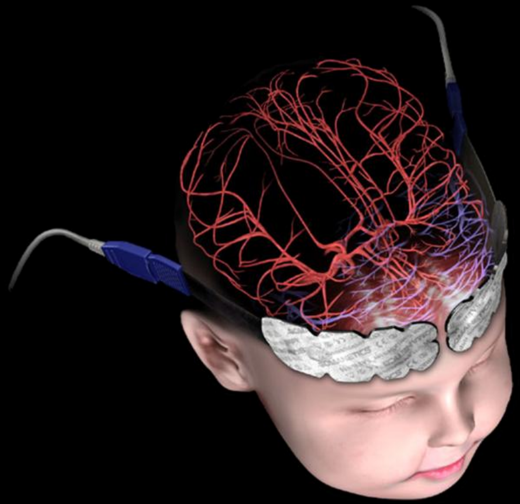
Cannulation of right axillary artery (RAxA) is useful in acute aortic dissection type A and aortic re-do.

- Contraindicated when artery is involved in the dissection process
- Obesity makes the exposure difficult
- It's better to attach a side-graft to avoid the cannulation-related complications.

Saturazione cerebrale: rSO2

- Il primo sistema di gestione paziente, *approvato FDA*, che permette un monitoraggio DELLA SATURAZIONE DI OSSIGENO REGIONALE CEREBRALE E/O SOMATICA :

- NON INVASIVO
- DIRETTO
- CONTINUO E MULTICANALE
- SEMPLICE DA USARE E INTERPRETARE

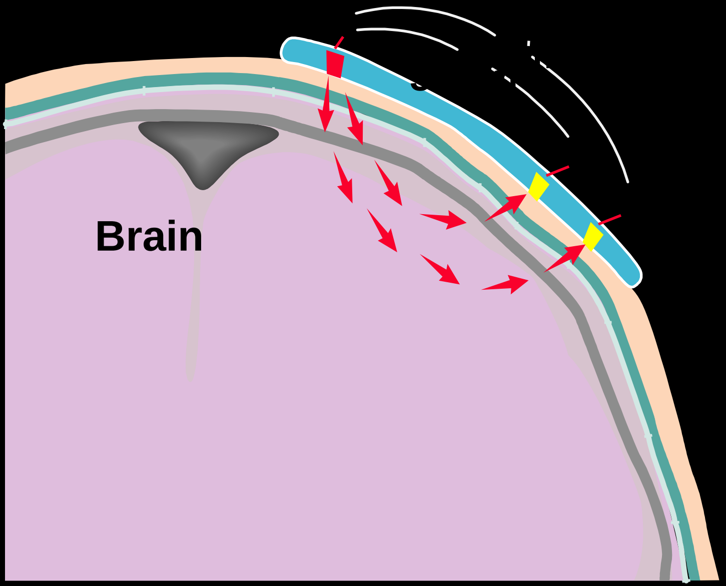


Il parametro rSO2

- **Specifica saturazione regionale a livello tessutale (*Artero-Venosa*)**
- rSO2 è il risultato di una misurazione di una somma della saturazione dell’ossigenazione arteriosa, venosa e capillare nelle seguenti proporzioni:
  - 75% sangue venoso
  - 20% sangue arterioso
  - 5% sangue capillare

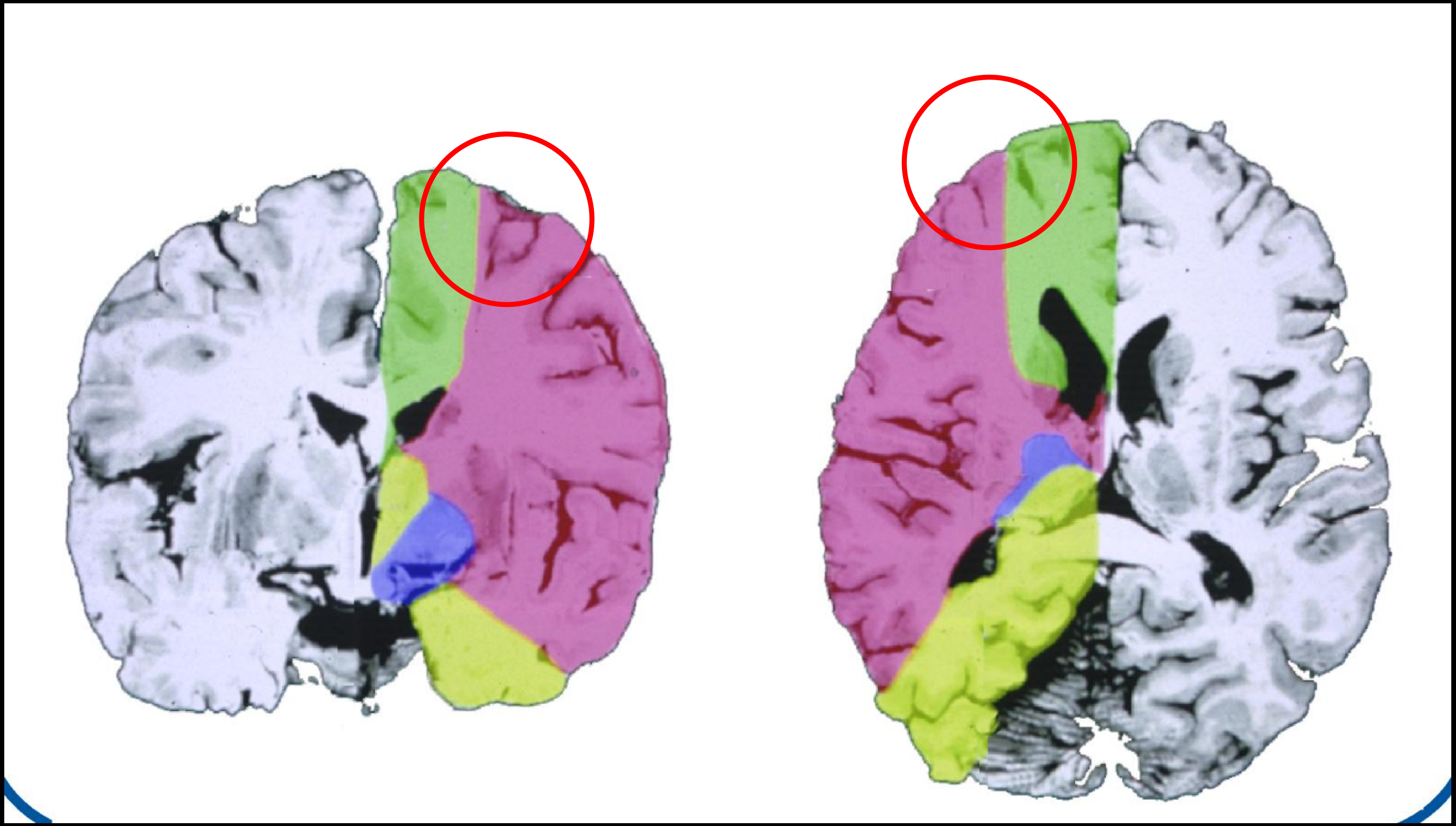
Il parametro rSO2

- Sfrutta il principio della spettroscopia a infrarosso
- Non ha bisogno di un segnale pulsante per fornire una misurazione
- Il sensore funge da emettitore e rilevatore di luce infrarossa a opportune lunghezze d’onda specificamente assorbite dall’emoglobina ossigenata e non ossigenata.
- In tal modo è possibile la misurazione dell’emoglobina legata all’ossigeno; l’algoritmo genera un numero che rappresenta la saturazione regionale d’ossigeno (cerebrale o somatica).

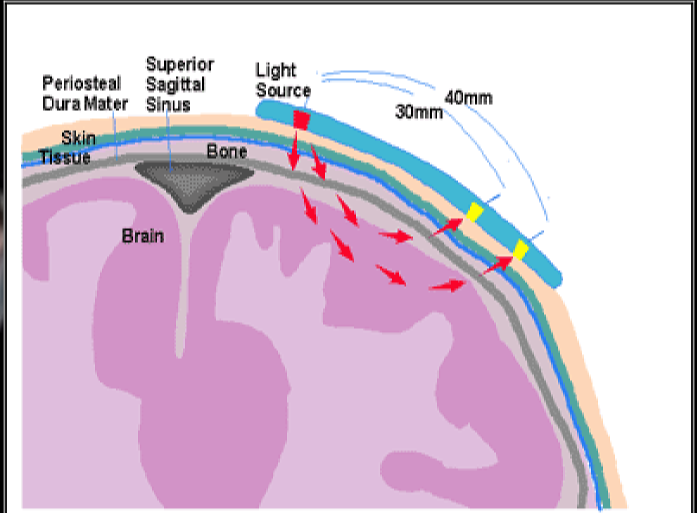


$$SO_2 = \frac{HbO_2}{HbO_2 + Hb} \times 100\%$$

rSO2: zone interessate alla misurazione



Near-Infrared Spectroscopy (NIRS)



The mean photon path in tissue is a "banana" shape.

Regional O2 saturation is monitored in the bilateral frontal lobes.

Each sensor consists of one silicon diode which receives the signals and 3 LEDs which emit near-infrared light of wavelengths 750, 850, 810 nm, respectively, for measurement of deoxy-Hb, oxy-Hb, and Hb level

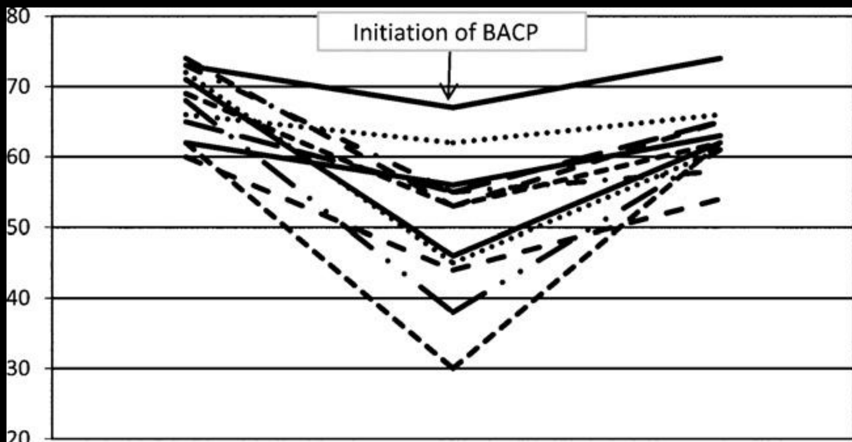
$$rSO2= (oxy – Hb)/(oxy – Hb + deoxy – Hb) \times 100$$

Aortic arch surgery using bilateral antegrade selective cerebral perfusion in combination with near-infrared spectroscopy☆

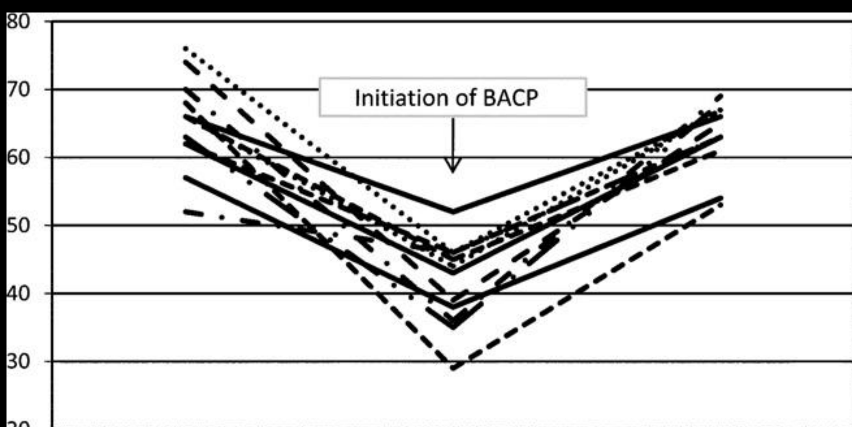
Marieluise Harrer*, Ferdinand Rudolf Waldenberger, Gabriel Weiss, Sandra Folkmann, Michael Gorlitzer, Reinhard Moidl, Martin Grabenwoeger

Heart Center Hietzing, General Hospital Hietzing, Vienna, Austria

Cerebral O2 saturation at right cerebral cortex:

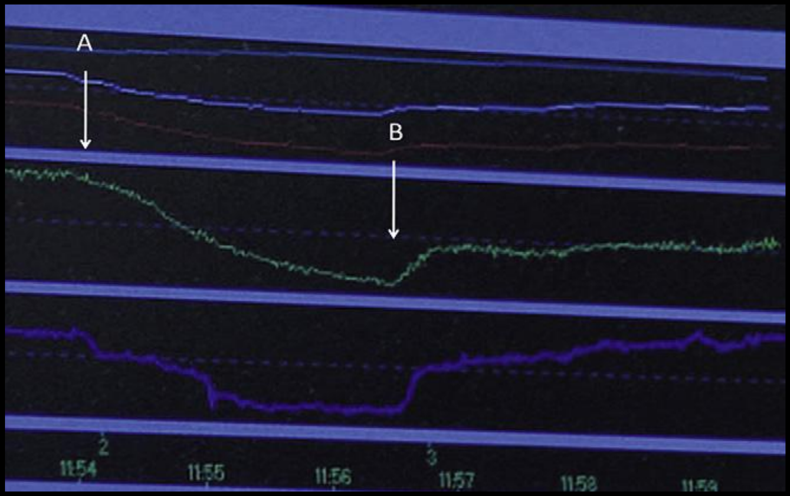


Cerebral O2 saturation at left cerebral cortex:



After initiation of circulatory arrest and clamping of the brachio-cephalic trunk, unilateral anterograde cerebral perfusion was started.

After 2 min a drop in cerebral O2 sat from 63±5% to 44±7.9% was observed over the left frontal cortex in 12 of 13 patients



Eur J Cardiothorac Surg 2010 "in press"

Near-Infrared Spectroscopy (NIRS)

rSO2 of 67 ± 10 has been reported in conscious adult health volunteers

Right versus left differences of > 10% occurred in <5% of the individuals

A low or asymmetric rSO2 baseline usually represents the consequences of cerebral vascular disease, BPCO, congestive HF, chronic hypertension, diabetes, sickle cells disease

Brain damage is related to both the extent and the duration of the drop in rSO2:

an increase of neurologic events when rSO2 drops below 55% for longer than 5 min.

A potential interaction exists between PND and TND: prolonged ischemic periods may aggravate the size of and embolic defect causing clinical neurological symptoms

Orihashi K, Eur J Cardiothorac Surg 2004;26:907-911

Near-Infrared Spectroscopy (NIRS)

- rSO2 is a measure of local microcirculatory O2 supply-demand balance (no brain tissue viability). It provides an alert that cerebral ischemia is likely to be present at a given moment.

- NIRS is unlikely to be capable of differentiating the causes of the rSO2 drop: air, atheroma, malperfusion (reduced SpO2, low Hb, reduced cardiac output, increased O2 consumption, venous congestion).

- rSO2 can remain unchanged when the emboli cause cerebral ischemia at a site other than the NIRS sampling site
- NIRS is limited for detecting embolic events or hypoperfusion in the basilar region.

Harrer M, Eur J Cardiothorac Surg 2010 "in press"

Edmonds HL, J Cardiothorac Vasc Anesth 2006;20:445-449

DHCA: SjO2 and NIRS

- Is an *invasive procedure*
- *Migration of catheter* is a problem: sample blood may be proximal to opening of the facial vein into the internal giugular vein with false high values of SjvO2
- *Extracerebral contribution* to jugular venous blood
- *Rate of aspiration* of the blood sample may affect readings
- Is a monitor of *global oxygenation.* There may be focal areas of ischemia not detected

Leyvi G, J Cardioth Vasc Anesth 2006;20:826-833.

- Is an *non-invasive method*
- Allows measurement of cerebral oxygenation during the arrest period
- NIRS data decrease during *hemodiluition*, whereas SjO2 remain unchanged
- rSO2 < SjO2 at *lower temperatures* (different effects on the distribution of blood in the venous and arterial circulations with age)
- NIRS evaluates *only a part of the region* of the anterior cerebral artery distribution
- NIRS increases more during deep cooling with *Ph-stat* compared with alpha-stat management: the effects of vasodilatation associated with pH stat strategy are potentially beneficial to offset the vasoconstrictive effect of cooling

Usefulness of transcranial color Doppler ultrasonography in aortic arch surgery

Emanuele Catena, MD*, Giordano Tasca, MD**, Giulia Fracasso, MD*, Antonio Toscano, MD*, Maria Bonacina, MD*, Tulika Narang, MD*, Andrea Galanti, MD**, Michele Triggiani, MD**, Giovanni Lorenzi, MD***, Amando Gamba, MD**

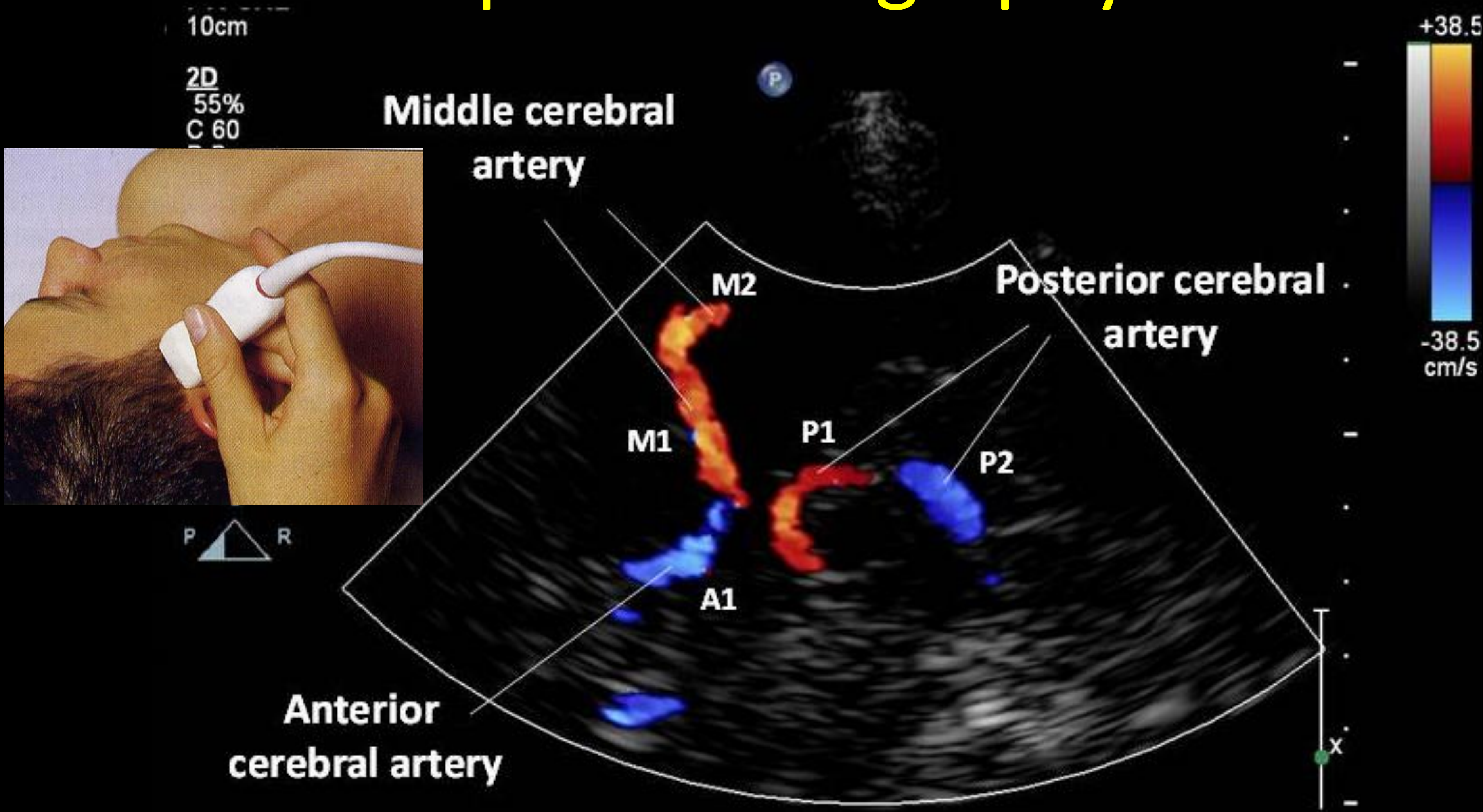
* Cardiovascular Anesthesia and Intensive Care, "Alessandro Manzoni" Hospital of Lecco, Italy

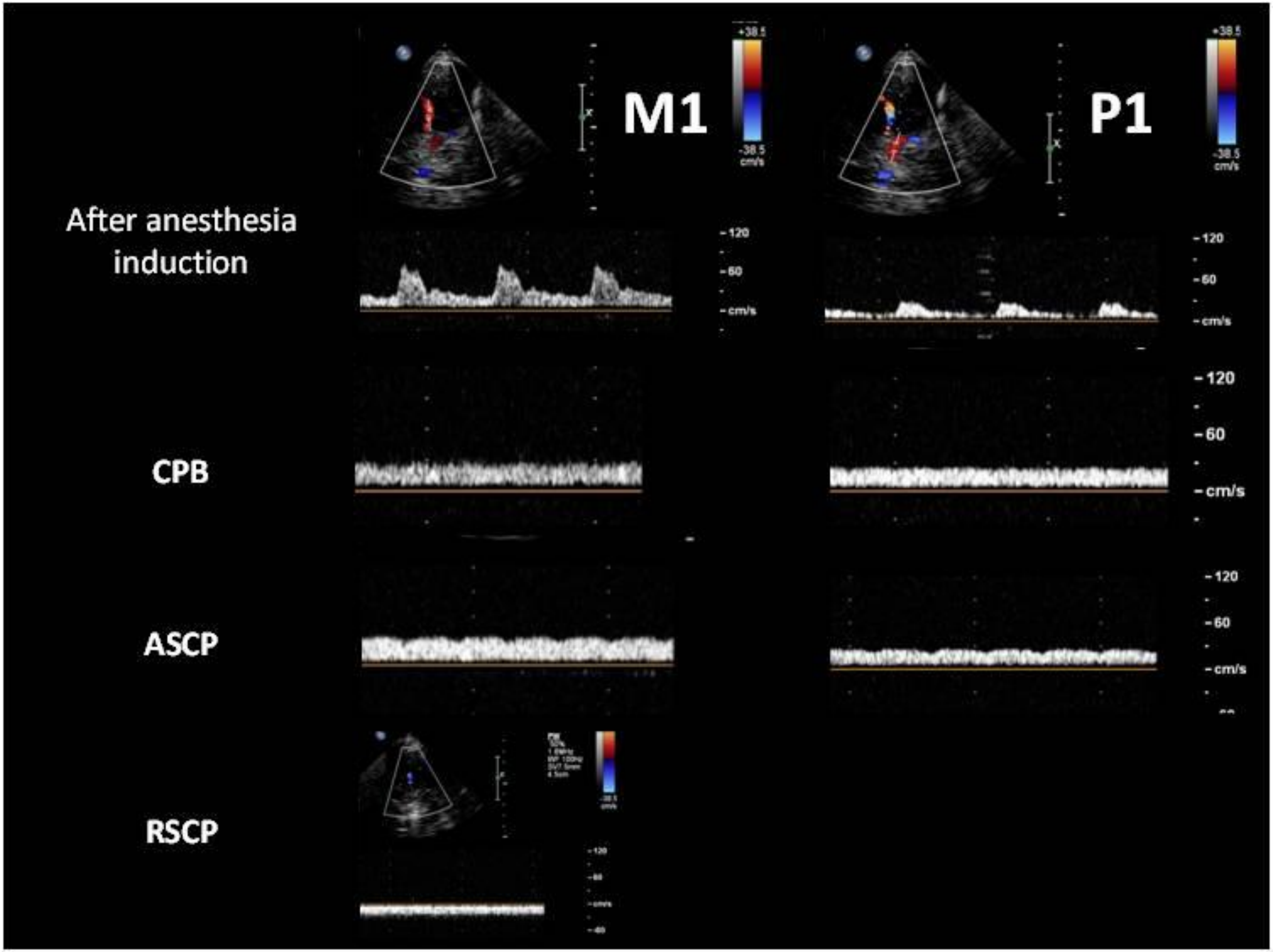
** Cardiac Surgery, "Alessandro Manzoni" Hospital of Lecco, Italy

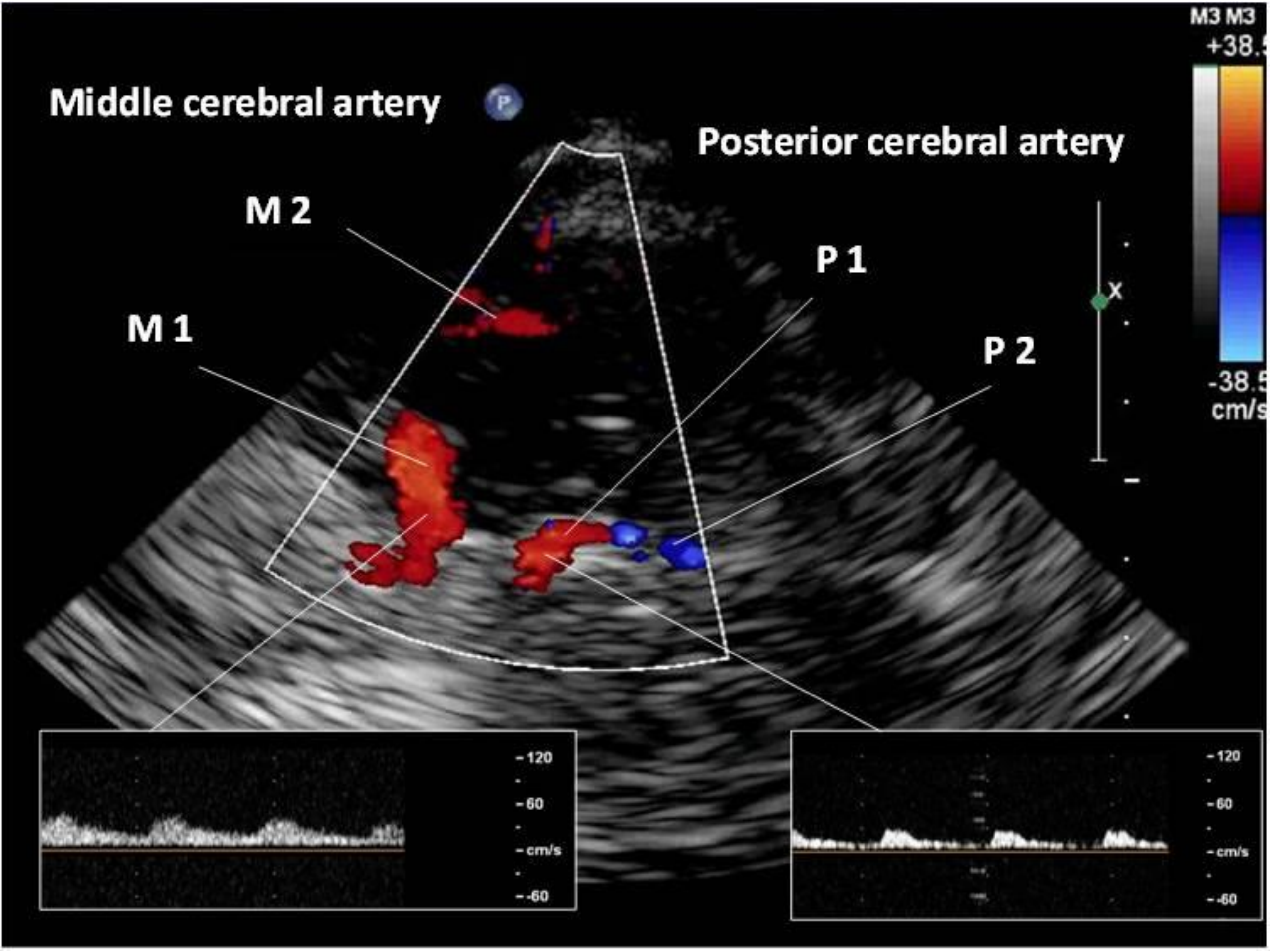
*** Vascular Surgery, "Alessandro Manzoni" Hospital of Lecco, Italy

J Cardiovasc Med 2012 Jul 12.

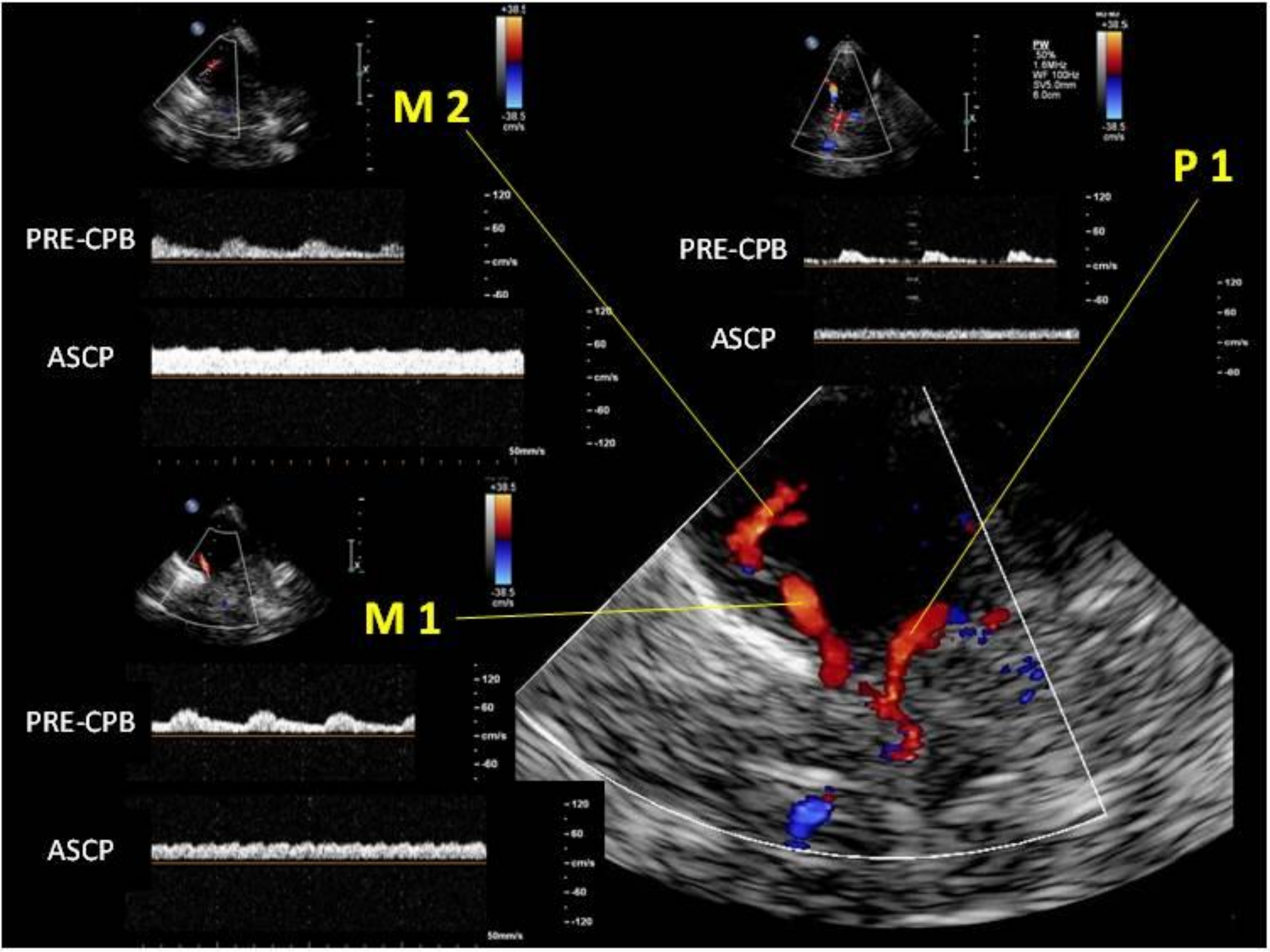
Trans-temporal echography




M1
P1
After anesthesia induction
CPB
ASCP
RSCP
+38.5
-38.5 cm/s
-120
-60
-cm/s

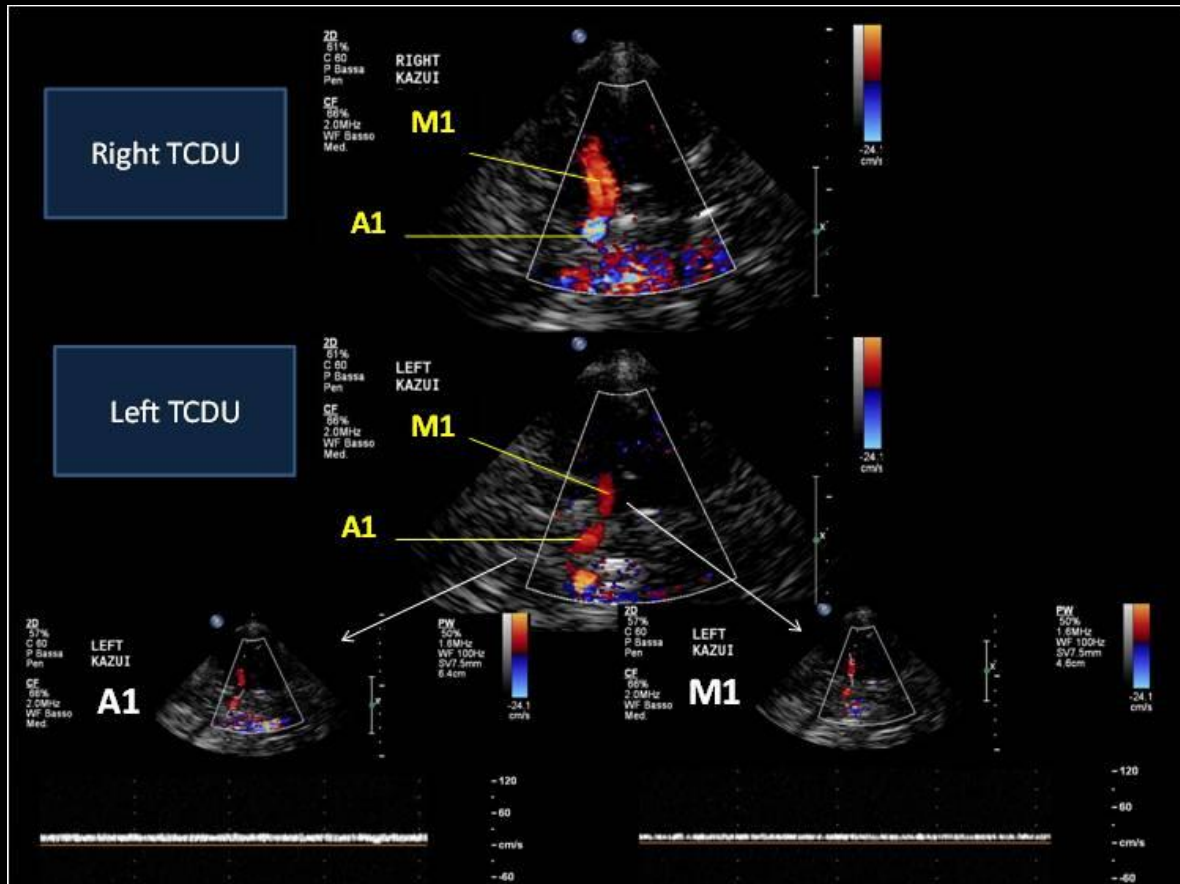


Middle cerebral artery
Posterior cerebral artery
M 2
M 1
P 1
P 2
M3 M3
+38.5
-38.5
cm/s
120
60
cm/s
-60
120
60
cm/s
-60



M 2
P 1
M 1
PRE-CPB
ASCP
PRE-CPB
ASCP
PRE-CPB
ASCP
PRE-CPB
ASCP
+38.5
-38.5
cm/s
120
60
cm/s
-60
-120
50mm/s
PW
50%
1.6MHz
WF 100Hz
SV5.0mm
6.0cm

Patient undergoing brain protection using **unilateral cerebral perfusion** via right axillary artery:



On the ***right side*** TCDU shows a normal color Doppler velocity pattern of the segments M1 (red) and A1 (blue).

On the ***left side*** TCDU shows a reversed blood flow (red) in the segment A1 of the anterior cerebral artery due to the activation of collateral flow through the anterior part of the circle of Willis.

Case	Age	sex	diagnosis	operations	CPB (min)	CLAMP (min)	ASCP (min)	RSCP (min)	CA (min)	complications	prognosis
1	69										Alive
2	71										Alive
3	70										Alive
4	75										Alive
5	87										alive
6	69										Alive
7	77	F	An asc aorta An arch	Sleeve operation Asc aorta R Arch R	109	79	9	4	20	–	Alive
8	67	M	An asc aorta An arch	Asc aorta R Arch R	186	135	65	3	70	–	Alive
9											alive
10											alive
11											Alive
12											Alive
13											Alive
14											Alive
15											Alive
16											Alive
17											Alive
18											Alive
19											death
20	67	F	Diss type A	Asc aorta R Emi-arch R	250	78	22	–	29	Cerebral infarction	alive
21	61	M									alive
22	40	M									alive
23	61	F									alive
24	54	M									Death
25	77	F									alive
26	79	F		CABG							alive
27	69	F	Diss type A	Asc aorta R	97	82		4	27		alive
28	69	M	Diss type A	Asc aorta R	237	43					death
29	80	F	An asc aorta	Asc aorta R Emiarch R	47	31	10	–	13	–	alive

Between 1 January 2010 and 31 December 2011,
29 consecutive patients underwent to TCDU monitoring during hypothermic circulatory arrest.

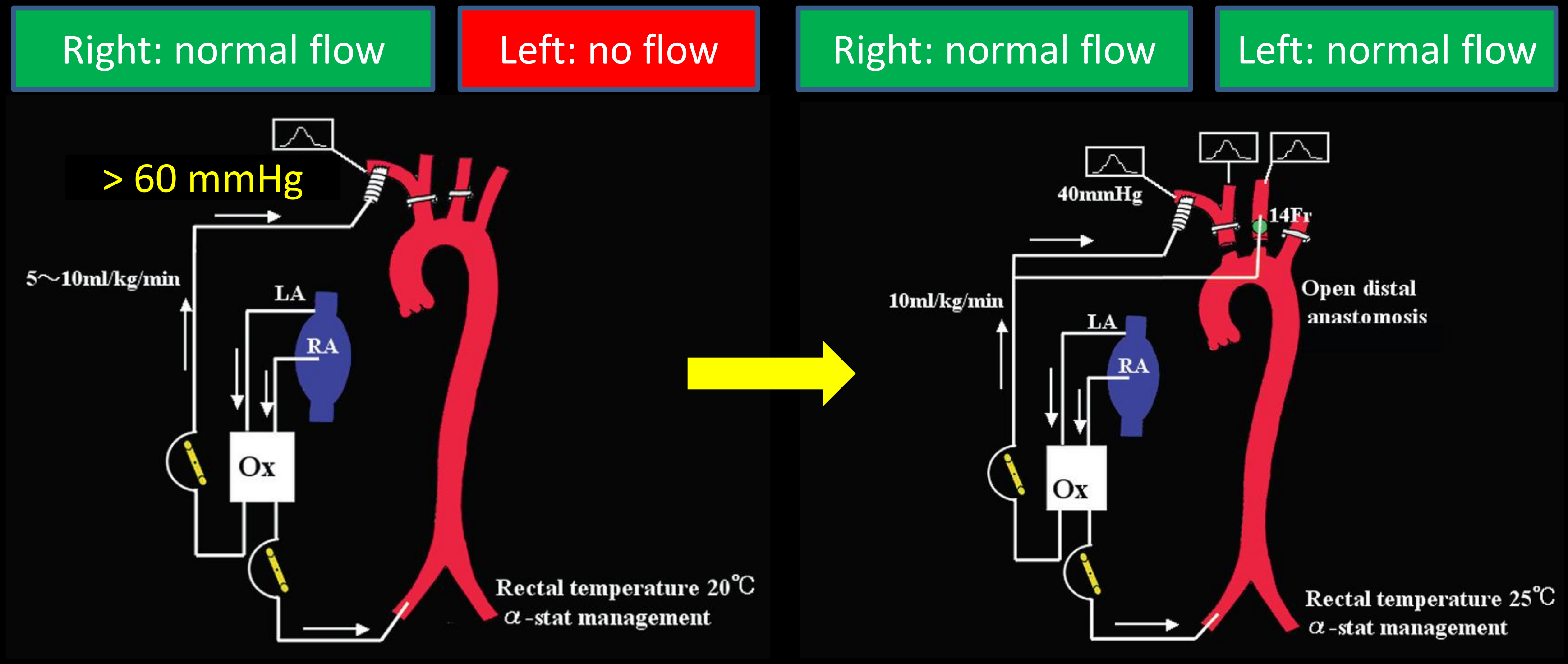
In 28/29 cases (96.5%) trans-temporal TCDU was successfully performed:

M1 segment of the MCA was visualized in all 28 cases (100%)
M2 in 22 patients (78.5 %)
P1 segment of PCA in 26 patients (92.8 %)
P2 in 19 patients (67.8%)

There was 3/29 (10.3 %) of perioperative mortality:
cardiac failure in one patient
multi-organ failure in two patients.

J Cardiovasc Med 2012 Jul 12.

Cases 5 and 6 were 87- and 69-year old male patients who underwent ascending aorta and total arch replacement.



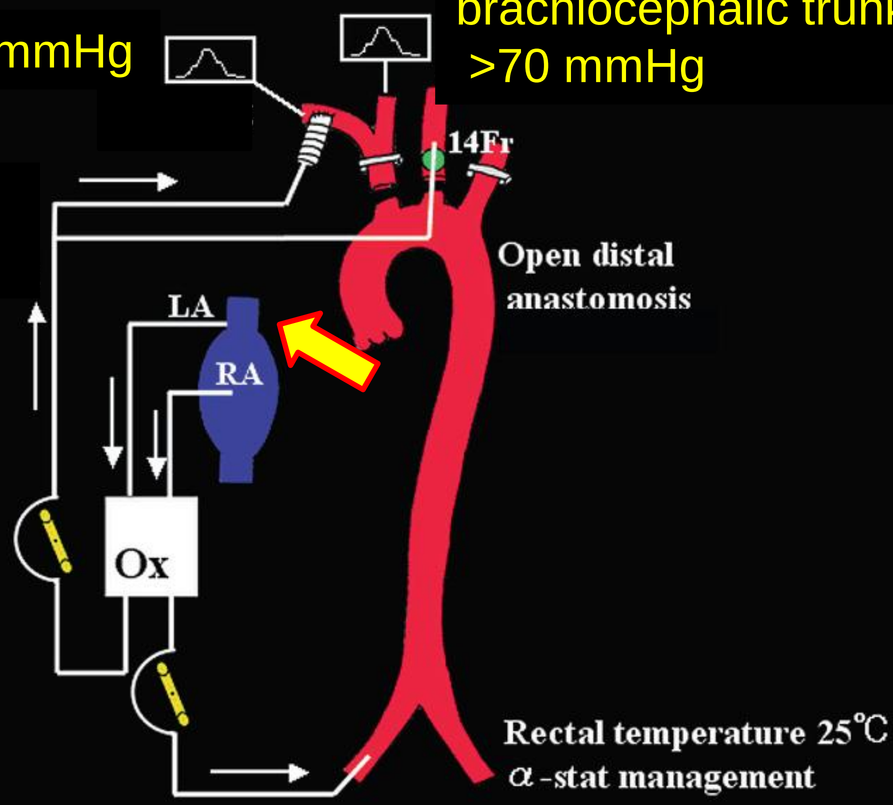
After the first two minutes of circulatory arrest, unilateral anterograde cerebral perfusion through the brachio-cephalic trunk was started.

Case 16 was a 62 year old male patient who underwent ascending aorta replacement. Three minutes after ASCP was started, blood flow resulted bilaterally undetectable by TCDU despite:

radial artery pressure >50 mmHg

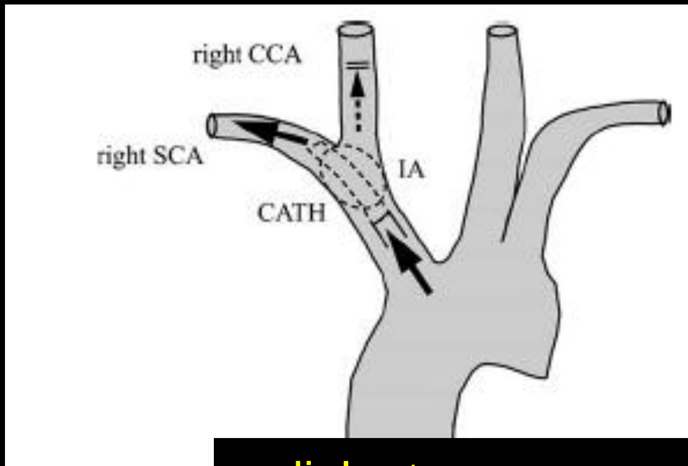
brachiocephalic trunk pressure >70 mmHg

high cerebral perfusion rate: 12-14 ml/Kg/min

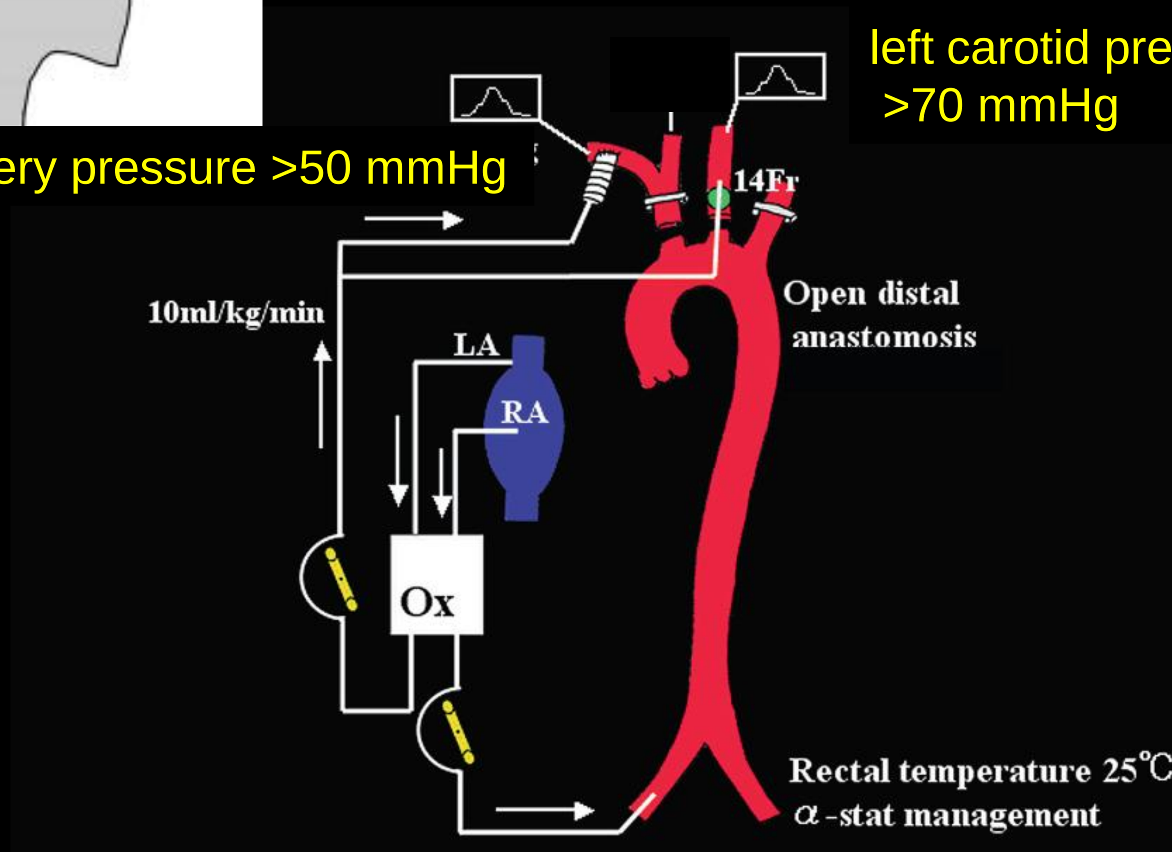


Surgeon checked the ASCP circuit: an accidental occlusion of the venous cannula inserted into superior vena cava was detected.

As the obstruction was released, blood flow became detectable bilaterally.



Case 17 was a 59 year old male patient who underwent ascending aorta replacement. After ASCP was started, TCDU showed a severely reduced blood flow in the right middle and posterior cerebral arteries despite:

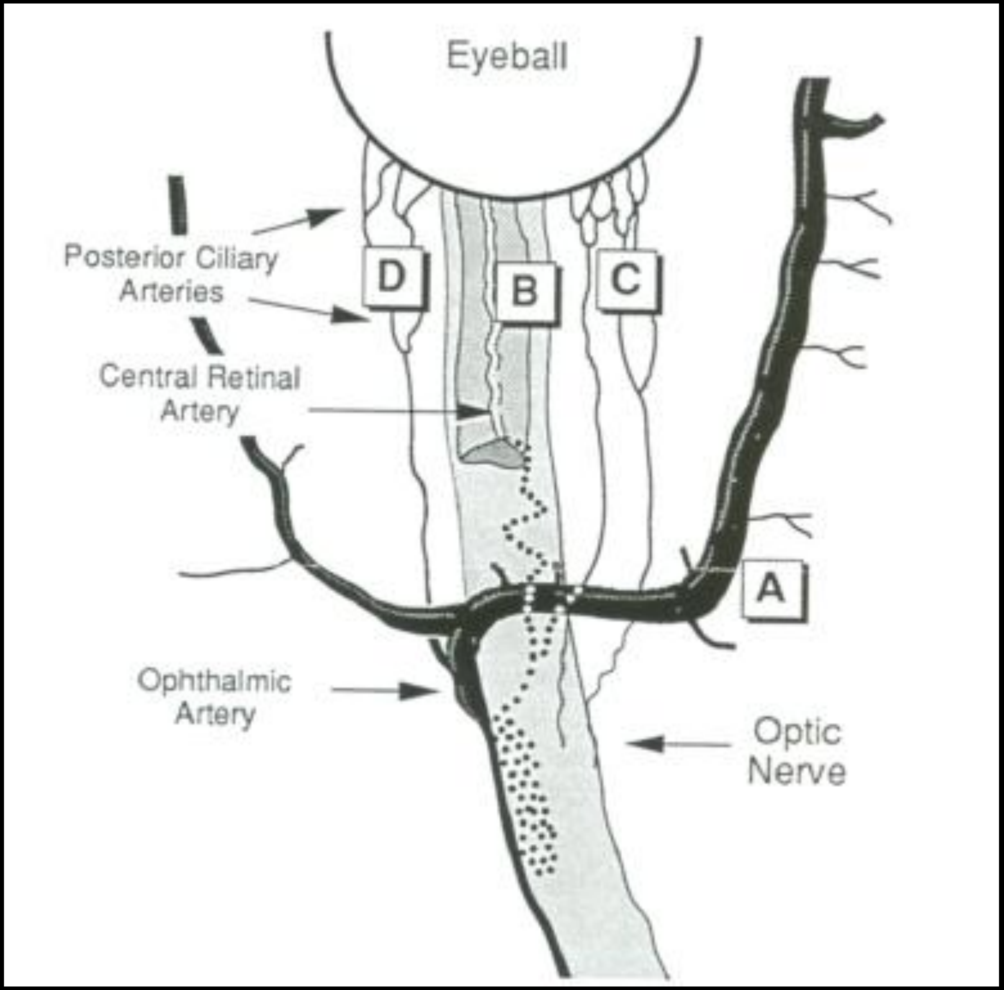


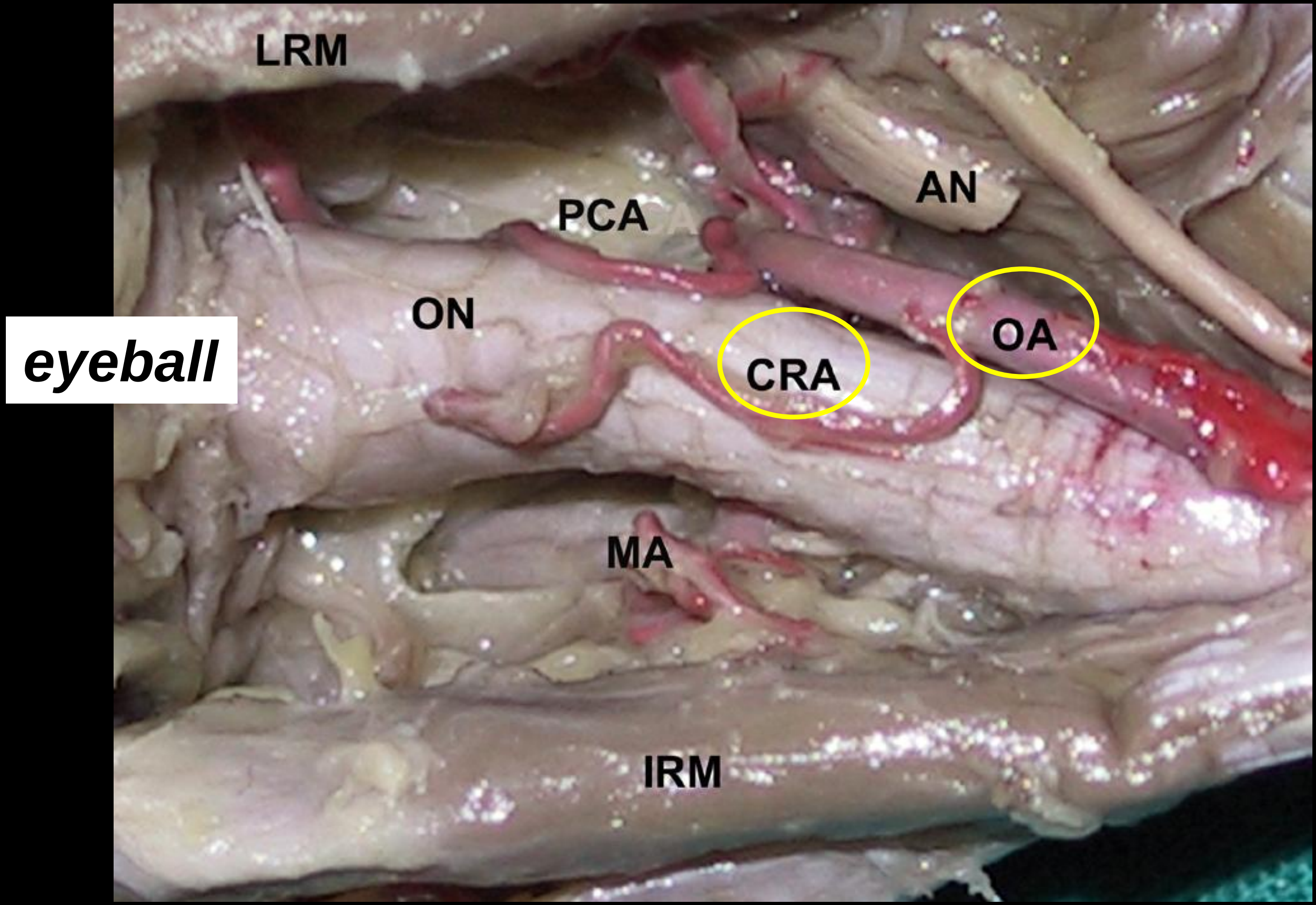
left carotid pressure >70 mmHg

radial artery pressure >50 mmHg

The surgeon withdrew the catheter by a few centimeters into the brachiocephalic trunk and TCDU showed immediate normalization of cerebral blood flow.

Trans-orbital echography



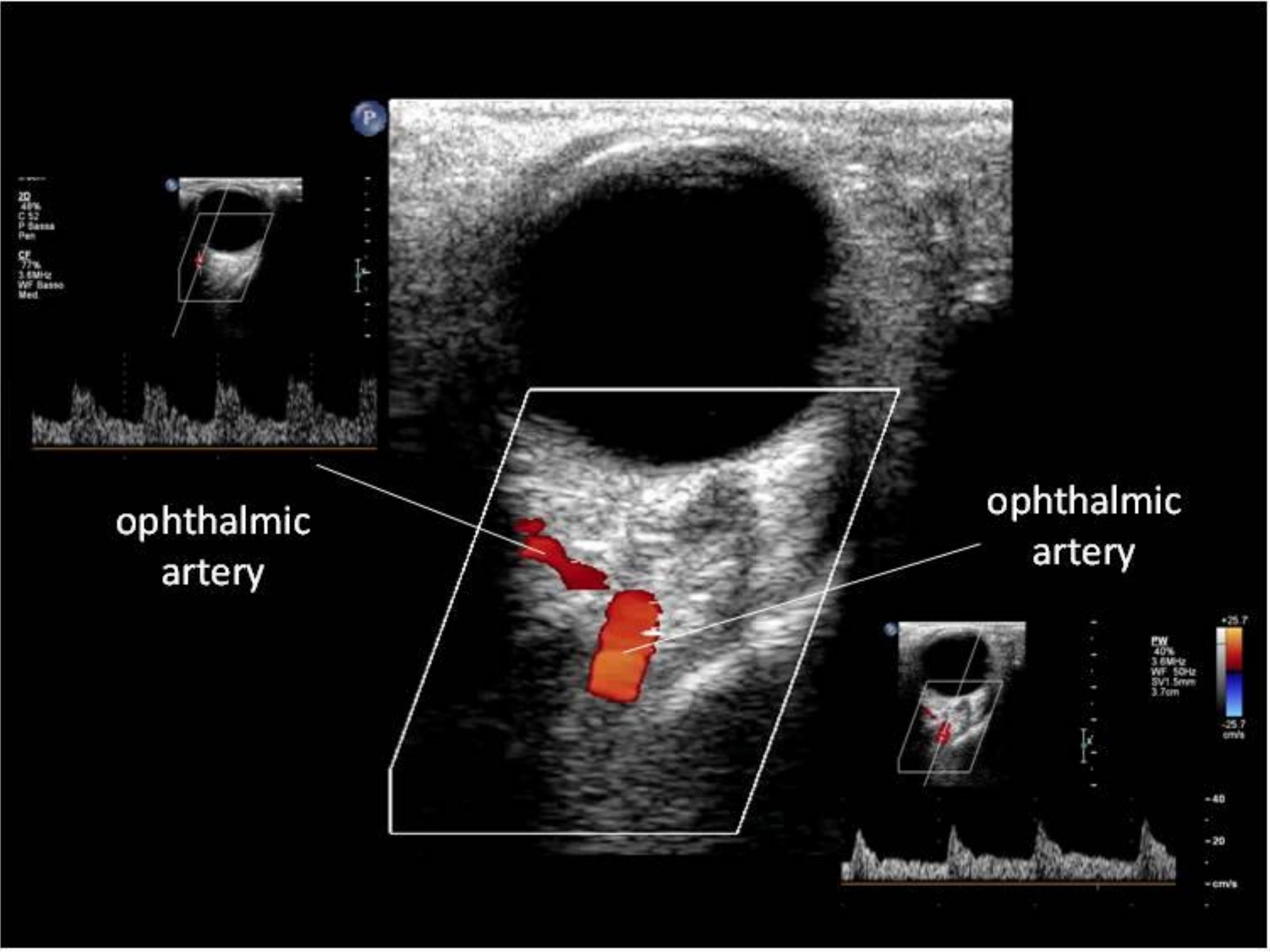


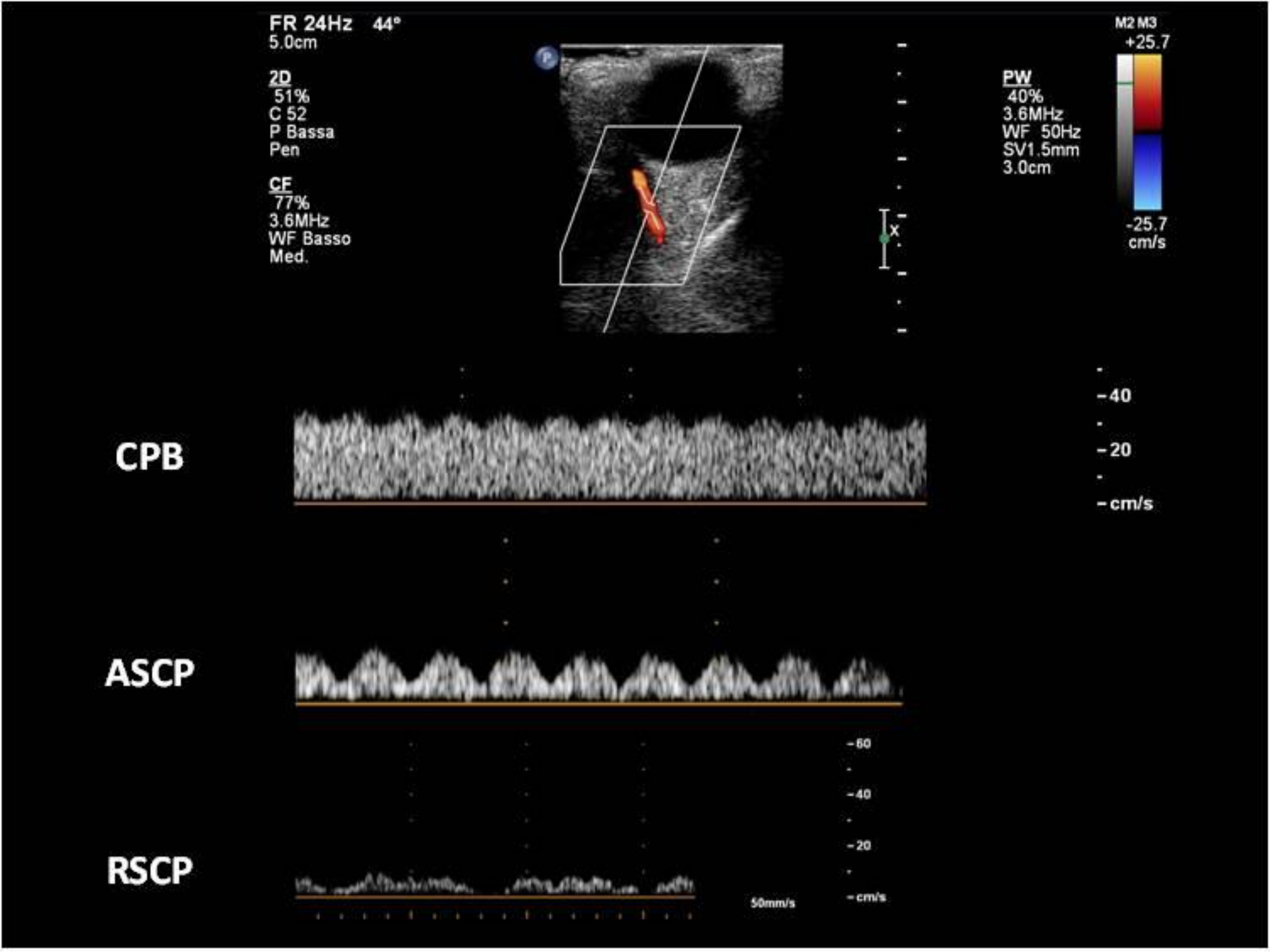
Course of the intra-orbital part of central retinal artery

OA: *ophthalmic artery;* ***CRA:*** *central retinal artery;*

ON: *optic nerve;* ***AN:*** *abducens nerve;* ***LRM:*** *lateral rectus muscle;* ***IRM:*** *inferior rectus muscle;*

MA: *muscular arteries;* ***PCA:****posterior ciliary artery;* ***E:*** *eyeball*


ophthalmic artery
ophthalmic artery
+25.7
-25.7
cm/s
40
20
cm/s


FR 24Hz 44°
5.0cm
2D
51%
C 52
P Bassa
Pen
CF
77%
3.6MHz
WF Basso
Med.
PW
40%
3.6MHz
WF 50Hz
SV1.5mm
3.0cm
M2 M3
+25.7
-25.7
cm/s
CPB
40
20
cm/s
ASCP
RSCP
60
40
20
cm/s
50mm/s

TCDU advantages in aortic surgery

- it was applied easily in all patients
- it was applied without adjunctive costs. TCDU examinations were performed by using a “cardiologic” probe, widely available on all current ultrasound equipment
- it allowed to obtain early detection of perfusion abnormalities, preventing neurological consequences
- allows to assess, in case of the unilateral cerebral perfusion is adopted, the proper blood flow to the contra-lateral hemisphere
- it allowed to optimize cerebral perfusion rate, avoiding “hyper-perfusion” phenomenon and consequent brain damage
- it was an essential tool to guide RSCP perfusion rate.

Thank you for
your attention

Conclusions

Different types of cerebral perfusions protect the brain during circulatory arrest

- **Different techniques may be performed according to the complexity of the procedure** and the expected duration of the circulatory arrest:
  - circulatory arrest not longer than 15-20 min: deep hypothermia
  - prolonged circulatory arrest: selective anterograde cerebral perfusion (Kazui) provides the same brain perfusion as a standard CPB, maintaining an adequate cerebral blood supply at moderate hypothermia.
  - acute aortic dissection type A and aortic re-do: cannulation of right axillary artery (+ left carotid artery)

→ Monitoring with both NIRS and transcranic echo color Doppler

Conclusions (2)

- **PND** occurs secondary to embolic pheomena, adverse sequelae of atherosclerotic aortic pathology. A positive relationship between TCD-detected cerebral emboli and the atheromatous burden of the ascending aorta and aortic arch.
- A potential interaction exists between PND and TND: prolonged ischemic periods may aggravate the size of an embolic defect ("ischemic penumbra") causing clinical neurological symptoms

→ Monitoring with both NIRS and transcranic echo color Doppler

- There is a correlation between **TND** and duration of cerebral perfusion technique
- There is a correlation between **TND** and age
- If changes in cognitive function occur, they are dependent on CP duration, microemboli, CPB itself (inflammatory response, SIRS), patient characteristics

Type A aortic dissection

Age (years, means ± SD, range)	66.2 ± 9.37, range 40-87
Sex (m/f)	19/9
Hypertension %	24 (68.5%)
CAD %	4 (11.4%)
Preoperative ischemic brain damage %	1 (2.8%)
COPD %	7 (20%)
Diabetes mellitus %	3 (8.5%)
Smoking %	15 (42.8%)

Operative procedures	
Ascending aorta with hemi-arch %	14 (%)
Arch replacement %	4 (%)
Ascending aorta replacement %	10 (%)
Associated procedures	
Aortic valve replacement %	1 (%)
Aortic root %	3 (%)

Four different phases of the operation for TCDU application

1) The First control is made before going on extracorporeal circulation (ECC) to seek the spot with the best window and familiarize with the patient vascular anatomy
2) The Second control is made at full flow on ECC to evaluate whether or not the cerebral arteries are adequately perfused either by the true or false aortic lumen.
3) The Third control is made, once reached the target temperature and the selective cerebral perfusion is started, to optimize the cerebral flow.
4) Fourth and last control in made once the anterograde flow of the ECC is restarted for the whole body rewarming.

ELSEVIER

European Journal of Cardio-thoracic Surgery 36 (2009) 943–945
www.elsevier.com/locate/ejcts

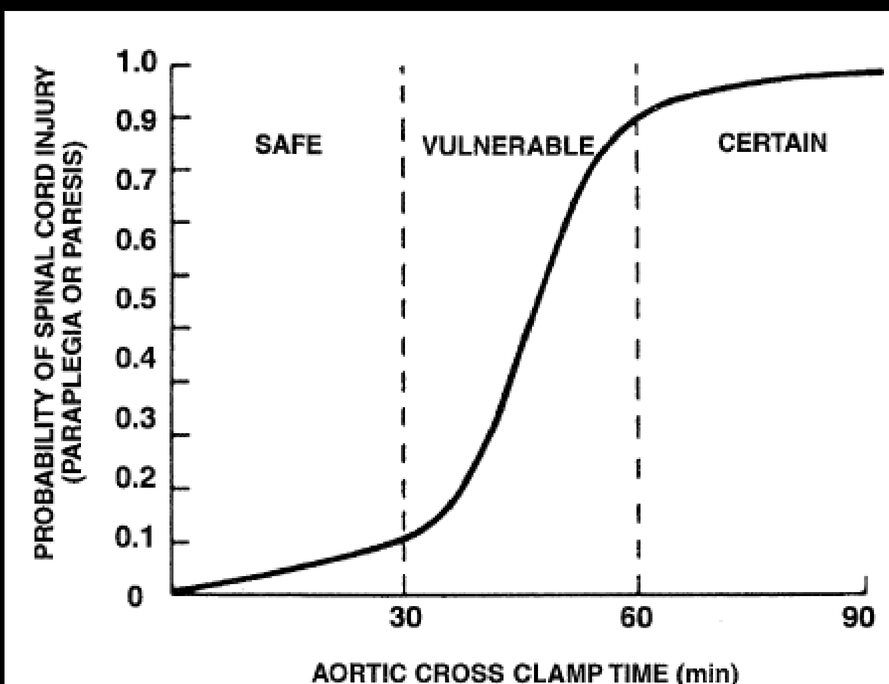
Editorial

The brain, the spinal cord, selective antegrade cerebral perfusion and corporeal arrest temperature — are we reducing the margin of patient safety in aortic arch surgery?

AM Ranasinghe, Birmingham, UK

Spinal cord injury

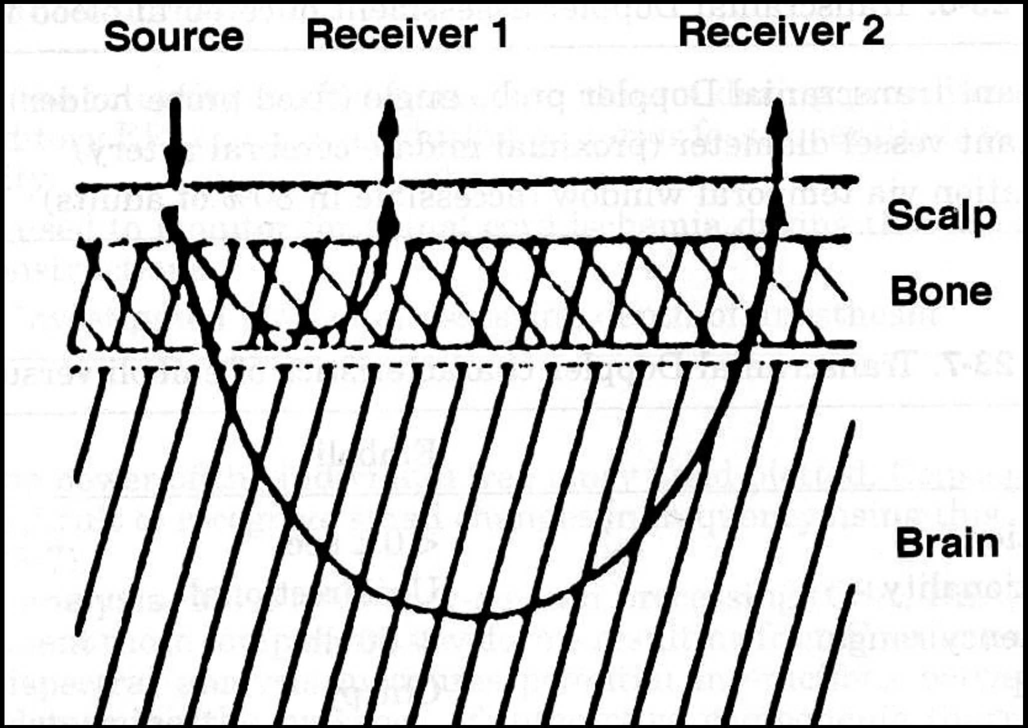
Descending aorta cross-clamping



Short or small anterior spinal artery
→ importance of intercostal arteries and Adamkeivitz
→ open back-bleeding intercostal arteries create a steal phenomenon as blood is shunted from spinal arteries to intercostals.

- Intraoperative hypotension
- Thromboembolic occlusion
- Reperfusion injury and edema

Near-Infrared Spectroscopy (NIRS)



Total cortical O2 saturation (venous, capillary, and arteriolar) is represented by the intensity difference between the superficial and deep sensors.

Intraoperative cerebral oxygen desaturation is significantly associated with an increased risk of cognitive decline and prolonged hospital stay after CABG

Slater et al., Ann Thorac Surg 2009;87:36-45.

INTERVENTIONS:

Increasing $PaCO_2$, increasing systemic arterial blood pressure, adjusting pump flow rate or anesthetic depth, reduction of temperature, blood trasfusion.

Cardiac surgery in octogenarians

Peri-operative outcome and long-term results

P. Kolh[1], A. Kerzmann[1], L. Lahaye[1], P. Gerard[2] and R. Limet[1]

Eur Heart J 2001;22:1235-1243.

Table 2 Operative results

Variable	AVR (n=100)* No. of patients	CABG (n=70) No. of patients (%)	MVR (n=12) No. of patients (%)
Deaths	14	[redacted]	[redacted]
Cerebrovascular accident	2	[redacted]	[redacted]
Myocardial infarction	7	[redacted]	[redacted]
Pneumonia	15	[redacted]	[redacted]
Prolonged mechanical ventilation (>48 h)	24	[redacted]	[redacted]
Permanent pacing	5	—	2 (16)
Dialysis	4	2 (3)	3 (25)
Arrhythmias	24	17 (24)	3 (25)
Reoperation for bleeding	5	2 (3)	—
Reoperation for sternal instability	1	2 (3)	—
Pericardial drainage	4	—	—
Hospital stay (days)	19·6 ± 11·4	17·8 ± 10·5	16·6 ± 8·9
Prolonged hospital stay (>14 days)	46	41 (58)	5 (42)
ICU stay (days)	7·8 ± 9·5	5·8 ± 5·2	7·6 ± 9·8

Abbreviations as for Table 1.
*In the aortic valve replacement group, n=100 (obtained by adding 70 patients with aortic valve replacement alone and 30 patients with aortic valve replacement+CABG). Therefore, all absolute numbers are also percentages.

2.8%

Ascending aortic atheromatous disease was predictive of stroke

Pre-operative risk factors associated with operative mortality were NYHA functional class IV, prolonged CBP time, and urgent procedure

Moderate Hypothermia and Unilateral Selective Antegrade Cerebral Perfusion: A Contemporary Cerebral Protection Strategy for Aortic Arch Surgery

Bradley G. Leshnower, MD, Richard J. Myung, MD, Patrick D. Kilgo, MS, Thomas A. Vassiliades, MD, J. David Vega, MD, Vinod H. Thourani, MD, John D. Puskas, MD, Robert A. Guyton, MD, and Edward P. Chen, MD

Clinical Research Unit, Division of Cardiothoracic Surgery, Joseph B. Whitehead Department of Surgery, and Rollins School of Public Health, Emory University School of Medicine, Atlanta, Georgia

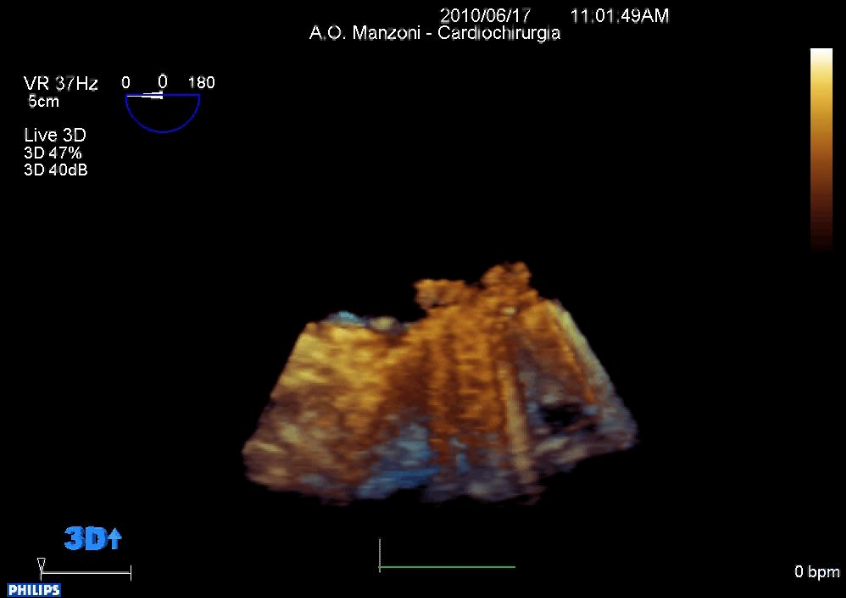
Table 3. Perioperative Data and Outcomes

Variable/Outcome	Number (%) or Mean ± SD (n = 412)
Temperature: HCA (°C)	25.7 ± 2.8
Cardiopulmonary bypass time (minutes)	193 ± 64
Cross-clamp time (minutes)	150 ± 60
Circulatory arrest time (minutes)	30 ± 15
Mortality	29 (7.0)
PND	15 (3.6)
TND	21 (5.1)
Renal failure-dialysis	19 (4.6)
Hospital LOS (days)	10.3 ± 7.5

HCA = hypothermic circulatory arrest; LOS = length of stay; PND = permanent neurologic dysfunction; TND = temporary neurologic dysfunction.

PND is the result of embolic phenomena, directly related to the site of arterial cannulation into the innominate and left common arteries (Kazui method), especially in patients with atheromatous aortic disease.

The method of cerebral perfusion has no effect on the incidence of PND, but significantly impacts the incidence of TND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5cm
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Live 3D
3D 47%
3D 40dB
3D
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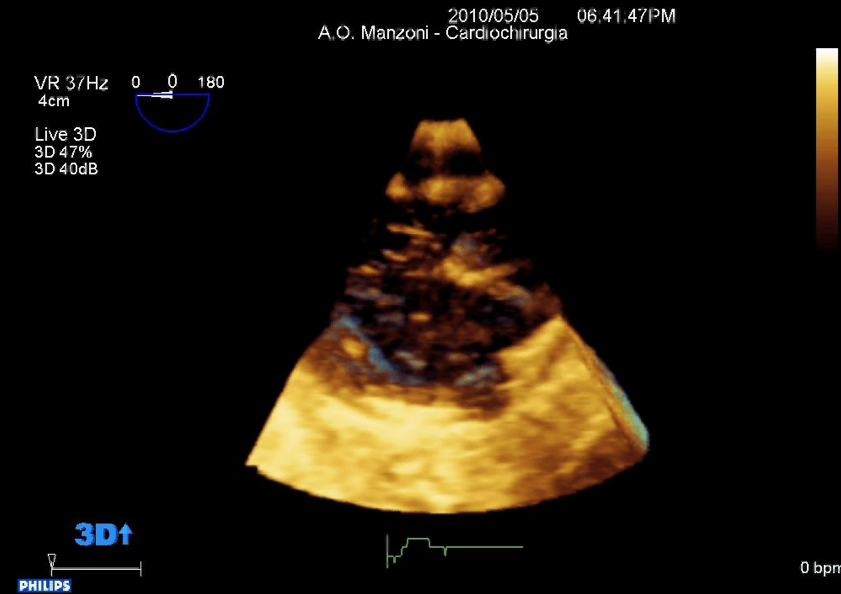
2010/05/05 06.41.47PM
A.O. Manzoni - Cardiochirurgia
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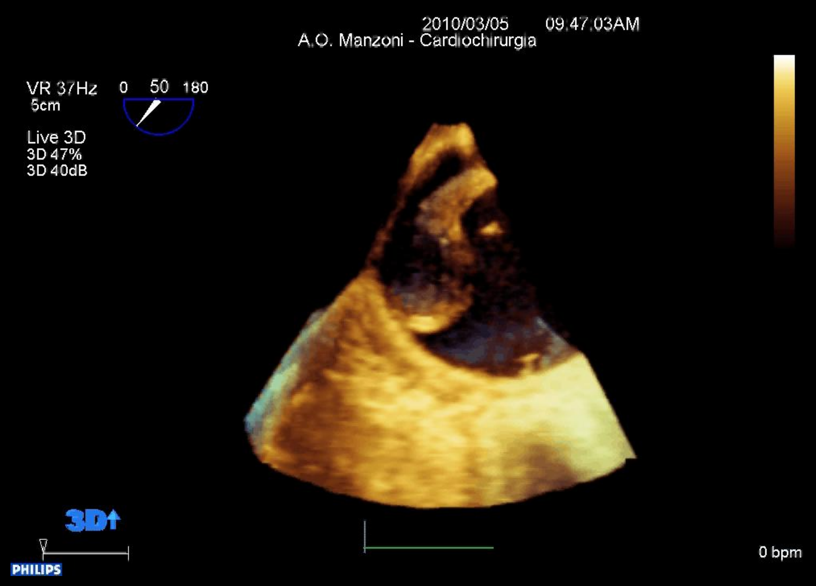
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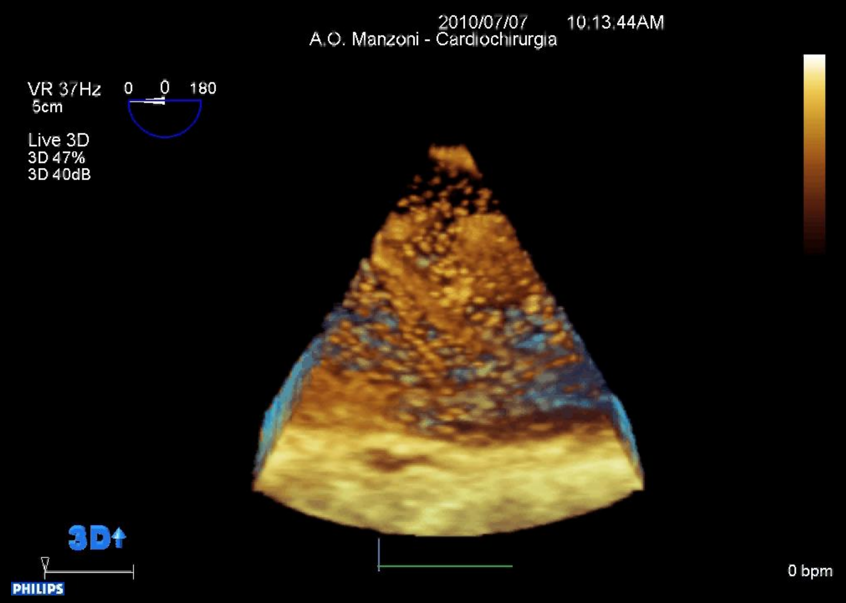
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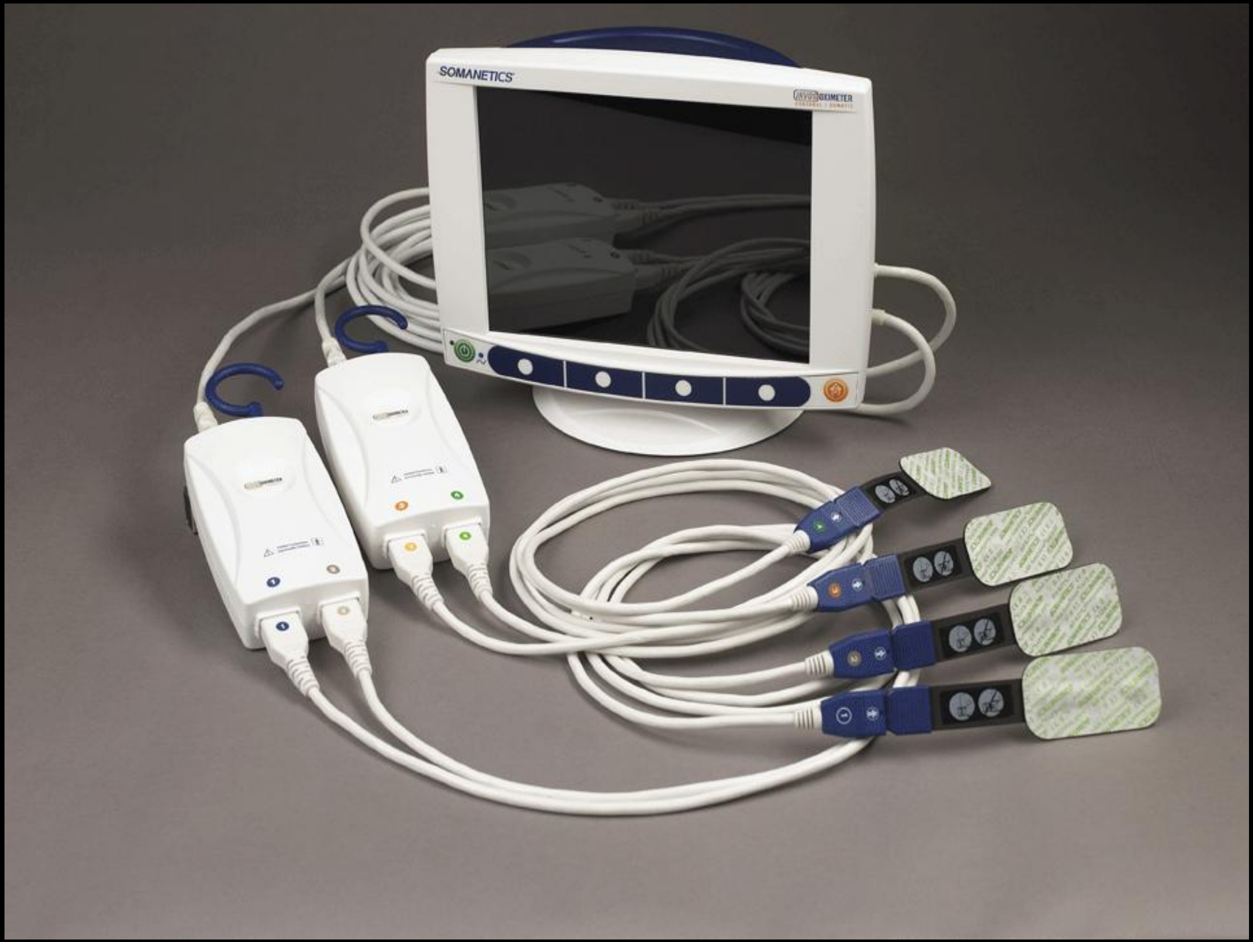


Interactive CardioVascular and Thoracic Surgery 10 (2010) 948-952
www.icvts.o

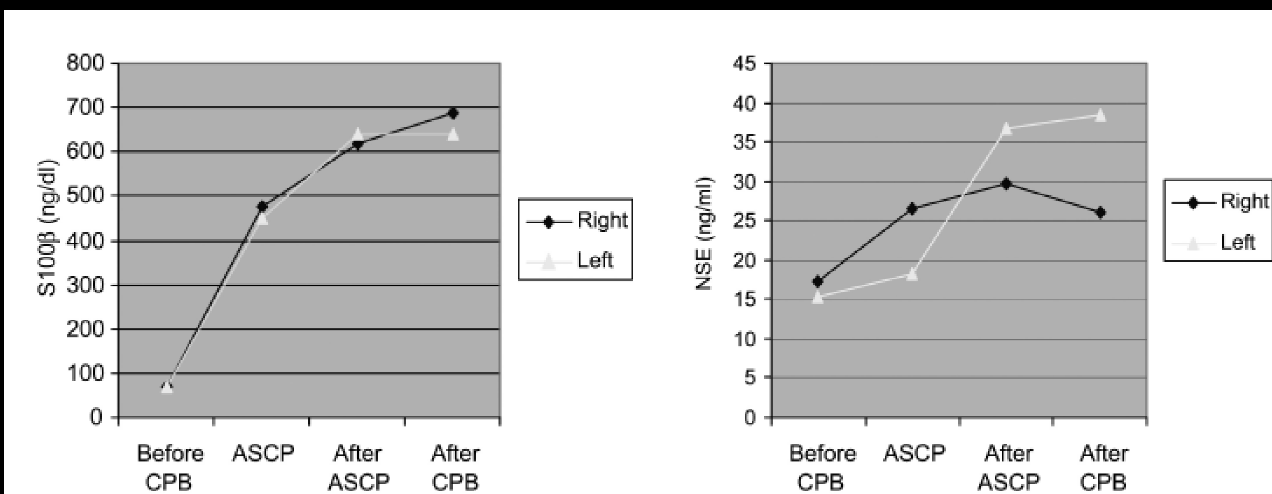
Institutional report - Vascular thoracic

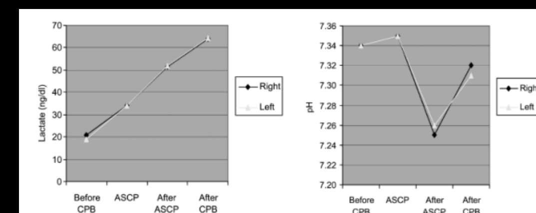
Neurochemical markers during selective cerebral perfusion via the right brachial artery

Mehmet Ali Özatik*, Sabit Kocabeyoglu, Seref A. Küçüker, Ahmet Saritas, Garip Altintas, Ümit Kervan, Soner Yavas, Mustafa Paç

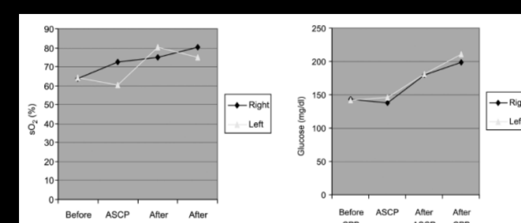
Cardiovascular Surgery Clinic, Türkiye Yüksek Ihtisas Education and Research Hospital, 06100 Sihhiye, Ankara, Turkey

At the initiation of anterograde perfusion, visual assessment of the returning blood through left common carotid and subclavian arteries has been one of the valuable proofs of contra-lateral hemispheric perfusion



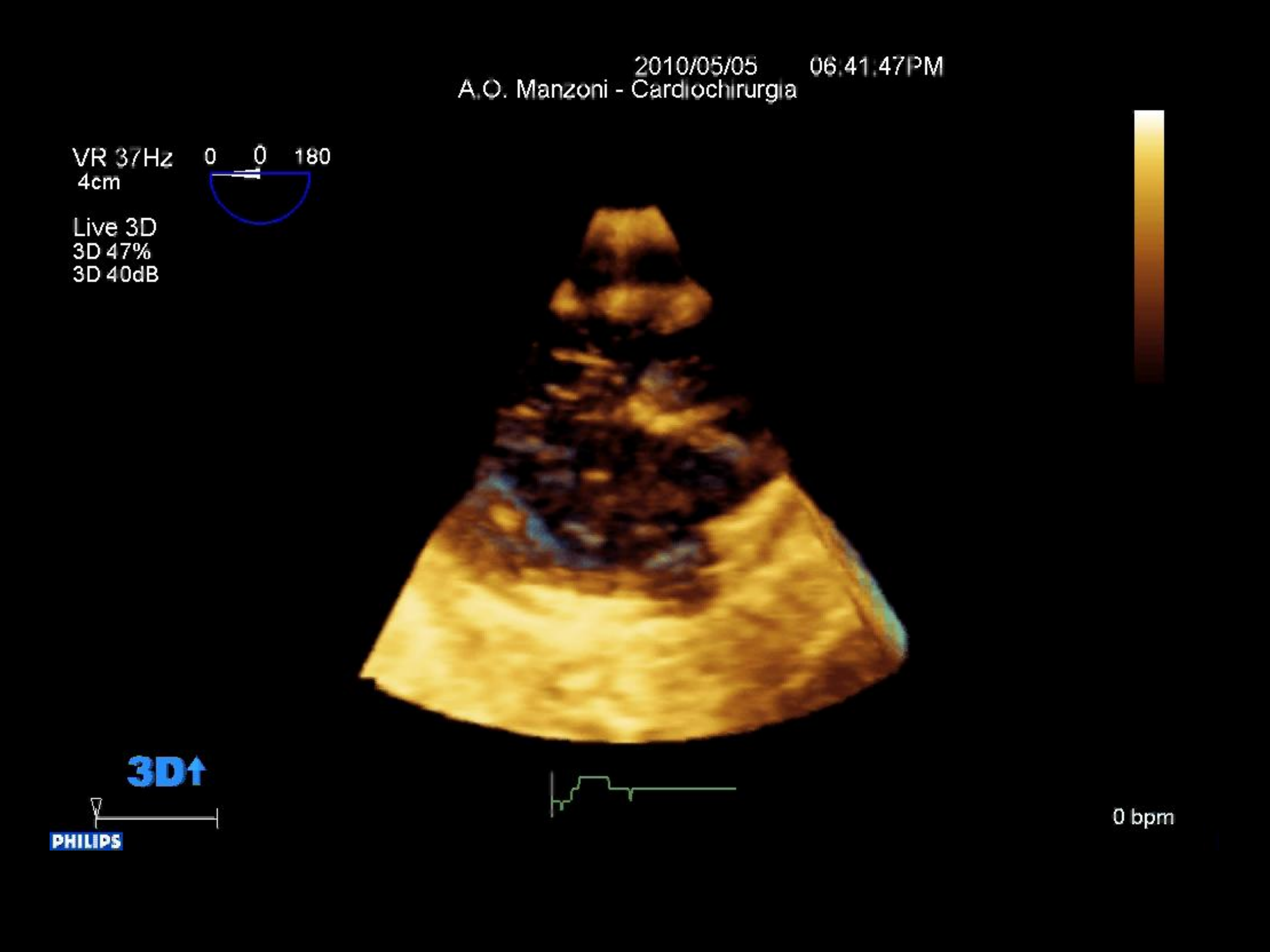


Lactate PH



sO2 Glucose

Markers of damage to neuronal (NSE) and glial (S 100 ß) brain tissue are significantly associated with early neuropsychological outcome of cardiac surgery with CPB



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A.O. Manzoni - Cardiochirurgia
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4cm
0 0 180
Live 3D
3D 47%
3D 40dB
3D
PHILIPS
0 bpm

Cerebral functions and metabolism after antegrade selective cerebral perfusion in aortic arch surgery[☆]

Davide Pacini[a,*], Luca Di Marco[a], Alessandro Leone[a], Caterina Tonon[b], Cinzia Pettinato[c], Cristina Fonti[d], David N. Manners[b], Roberto Di Bartolomeo[a]

[a] *Department of Cardiac Surgery, S. Orsola-Malpighi Hospital, University of Bologna, Bologna, Italy*

17 patients aortic arch surgery using Kazui procedure at 26° C

15 patients elective on-pump CABG

cerebral positron emission tomography (PET)

Mean ASCP time
85.7 min

- No evidence of ischemic brain injury after ACP; only some degree of reversible brain edema secondary to CPB (increased permeability of the blood-brain barrier due to inflammatory response)
- Cognitive outcomes comparable to patients undergoing coronary artery bypass
- The lack of the left subclavian artery perfusion during cerebral perfusion leads to temporary glucose hypometabolism in the occipital lobes without neuronal injury

Antegrade selective cerebral perfusion in thoracic aorta surgery: safety of moderate hypothermia☆

Davide Pacini[a,*], Alessandro Leone[a], Luca Di Marco[a], Daniele Marsilli[b], Fedaa Sobaih[b], Simone Turci[a], Valeria Masieri[a], Roberto Di Bartolomeo[a]

[a] Department of Cardiac Surgery, S. Orsola-Malpighi Hospital, University of Bologna, Bologna, Italy
[b] Department of Cardiac Anesthesiology, S. Orsola-Malpighi Hospital, University of Bologna, Bologna, Italy

Group A (189 patients): T nasoph ≥ 25° C

Group B (116 patients): T nasoph < 25° C

In both groups there was no statistically significant difference in:

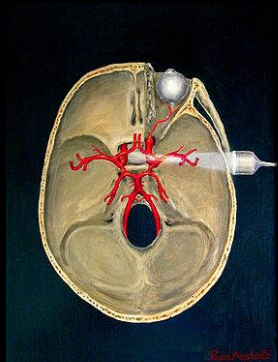
Variables	Group A (n = 189)	Group B (n = 116)	p
In-hospital mortality (%)			
Overall patients	24 (12.7)	16 (13.8)	0.862
Urgent/emergent surgery	9/61 (14.8)	10/48 (20.8)	0.656
Permanent neurologic deficit	6 (3.1)	2 (1.7)	0.715
Transient neurologic deficit	15 (7.9)	10 (8.6)	0.833
Pulmonary complications	28 (14.8)	15 (12.9)	0.736
Renal failure (dialysis)	9 (4.8)	9 (7.8)	0.203
Myocardial infarction	7 (3.7)	2 (1.7)	0.491
Bleeding (rethoracotomy)	16 (8.5)	11 (9.5)	0.836

Variables	Group A (n = 189)	Group B (n = 116)	p
CBP time (min, mean ± SD)	193.6 ± 59.4	189 ± 65.9	0.526
Myocardial ischemic time (min, mean ± SD)	131.1 ± 45	119.8 ± 49.9	0.041
ASCP time (min, mean ± SD)	63 ± 37.7	58.6 ± 35.6	0.314
Nasopharingeal temperature (°C, mean ± SD)	25.8 ± 0.8	21.9 ± 1.9	<0.001

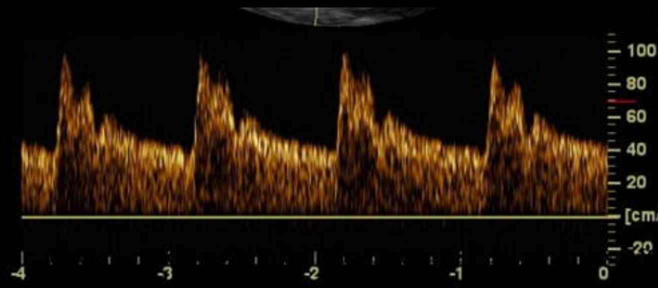
RISK FACTOR ANALYSIS:

Multivariate risk factor analysis for in-hospital mortality, permanent neurologic deficit, and transient neurologic deficit

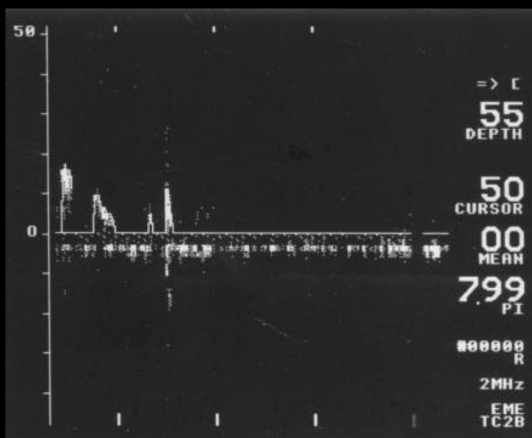
	Odds ratio	95% CI	p
In-hospital mortality			
Chronic aortic dissection	3.88	1.01–14.77	0.046
CPB time	1.01/min	1.00–1.01	0.002
Permanent neurologic deficit			
CPB time	1.01/min	1.00–1.02	0.006
Transient neurologic deficit			
Age	1.12/year	1.07–1.24	<0.001
Female gender	3.4	1.11–10.64	0.032
Acute dissection	4.8	1.82–12.84	0.001
AVR	3.4	1.32–8.88	0.011



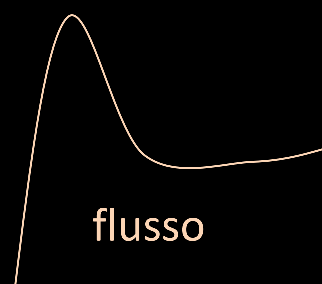
Transcranial Doppler

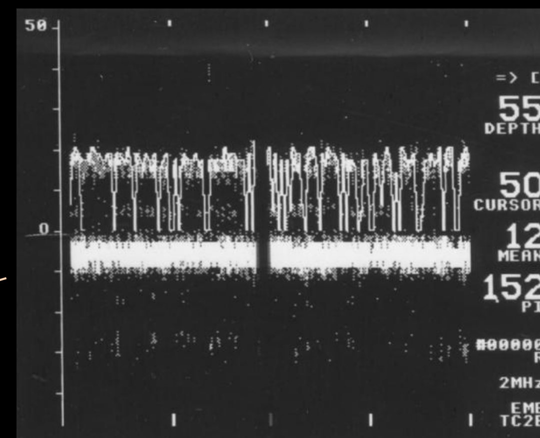


Left middle cerebral artery during SACP:



Perfusion of 300 ml/min
No flow is present



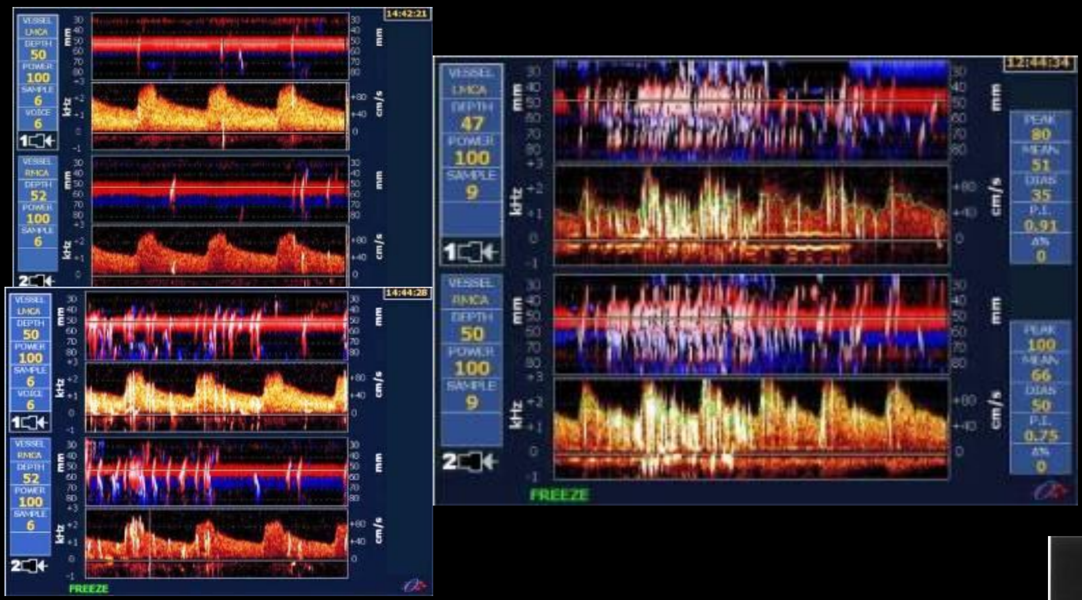


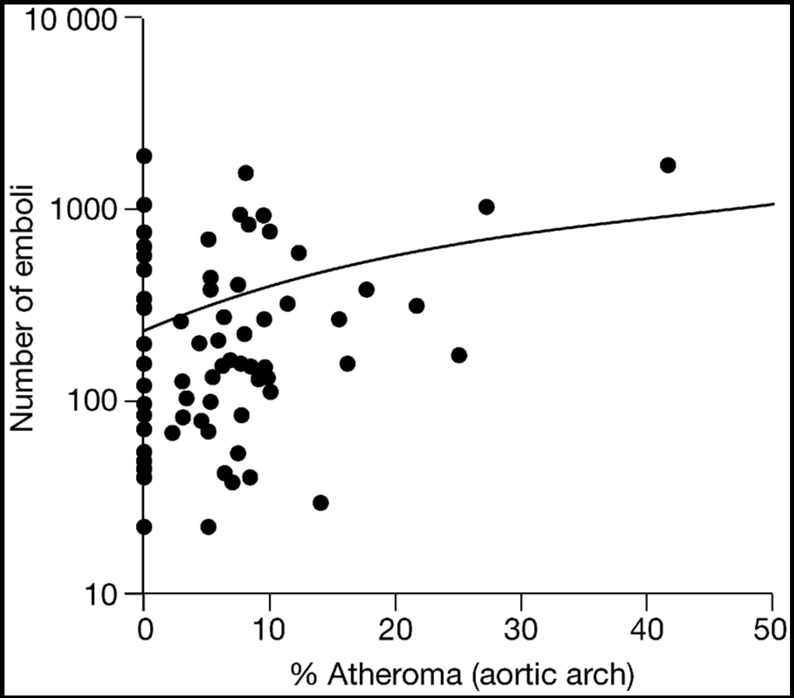
Perfusion of 550 ml/min
A mean flow of 12 cm/s is seen

A certain resistance in the brain has to be overcome and adequate cerebral blood flow has to be optimized in the individual patient

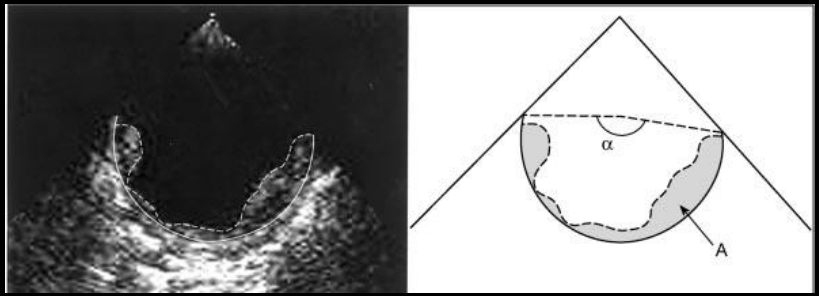
De Vries AJ, Anesth Analg 1999;89:1588

A positive relationship between TCD-detected cerebral emboli and the atheromatous burden of the ascending aorta and aortic arch.





Mackensen GB, Br J Anaesth 2003;91:656-61

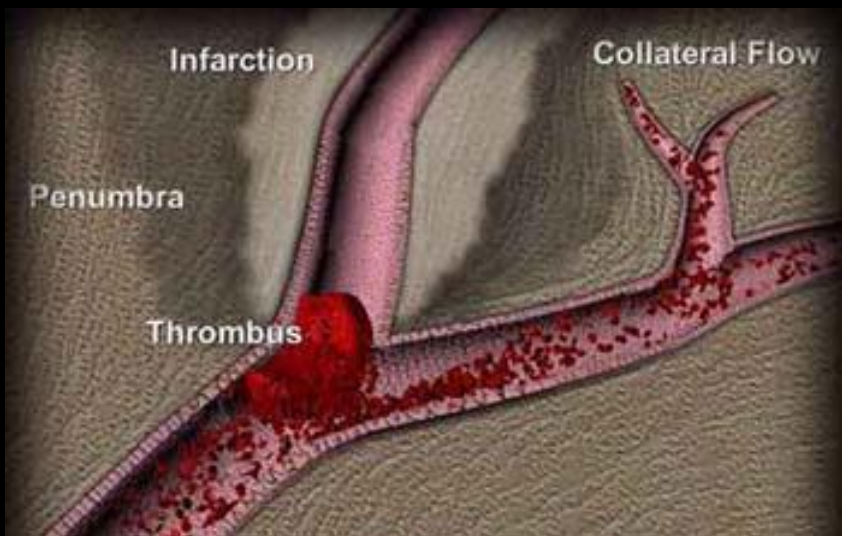


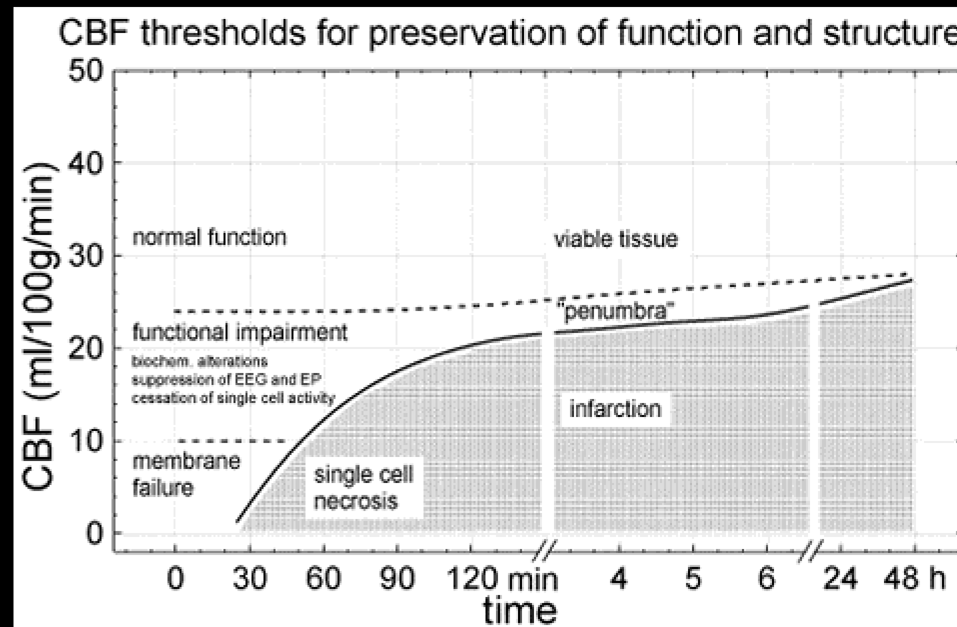
The atheroma burden in each aortic segment was determined as the ratio of the atheroma area (A) to the total area of the aortic segment visualized.

For the descending aorta, where the entire circumference could not always be visualized, the area of the visualized segment was adjusted according the angle (a) subtended by that segment.

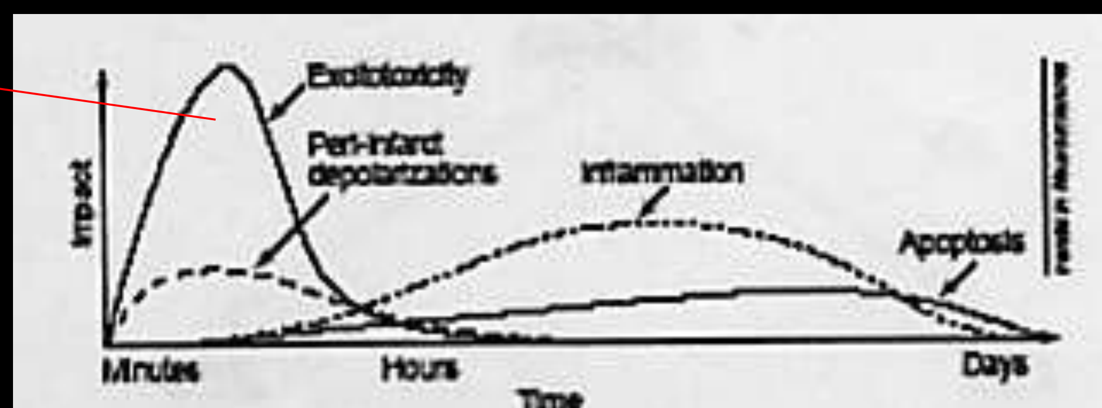
The ischemic "penumbra"

tessuto ischemico potenzialmente recuperabile



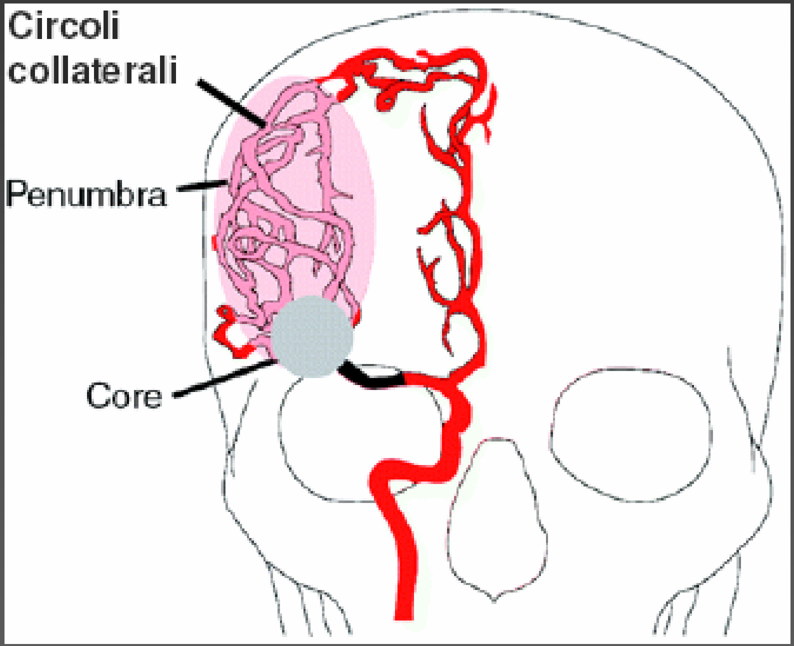


EXCITOTOXICITY:
excitatory amino-acid (EAA, glutamate and aspartate) release



"emboli clearance"

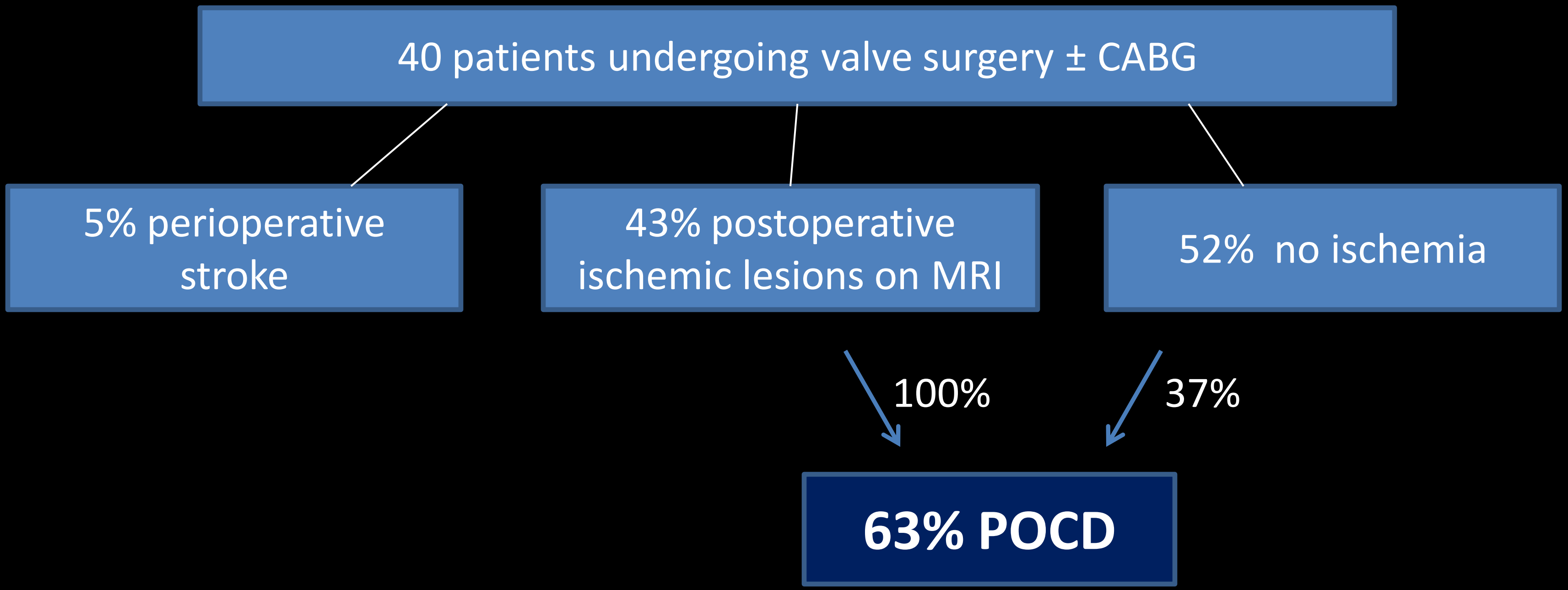
La penombra ischemica è un'area di tessuto cerebrale che si forma durante la fase acuta dell'ictus ischemico alla periferia del core ischemico ed appare:



- severamente ipoperfusa
- danneggiata in modo reversibile perché funzionalmente compromessa, ma strutturalmente ancora integra grazie alla vasodilatazione prodotta dalla apertura di circoli collaterali di compenso
- ancora vitale e potenzialmente recuperabile in caso di riperfusione
- a rischio di infarto verso il quale evolve progressivamente in circa 8-10 ore se non viene riperfusa ("time is brain")

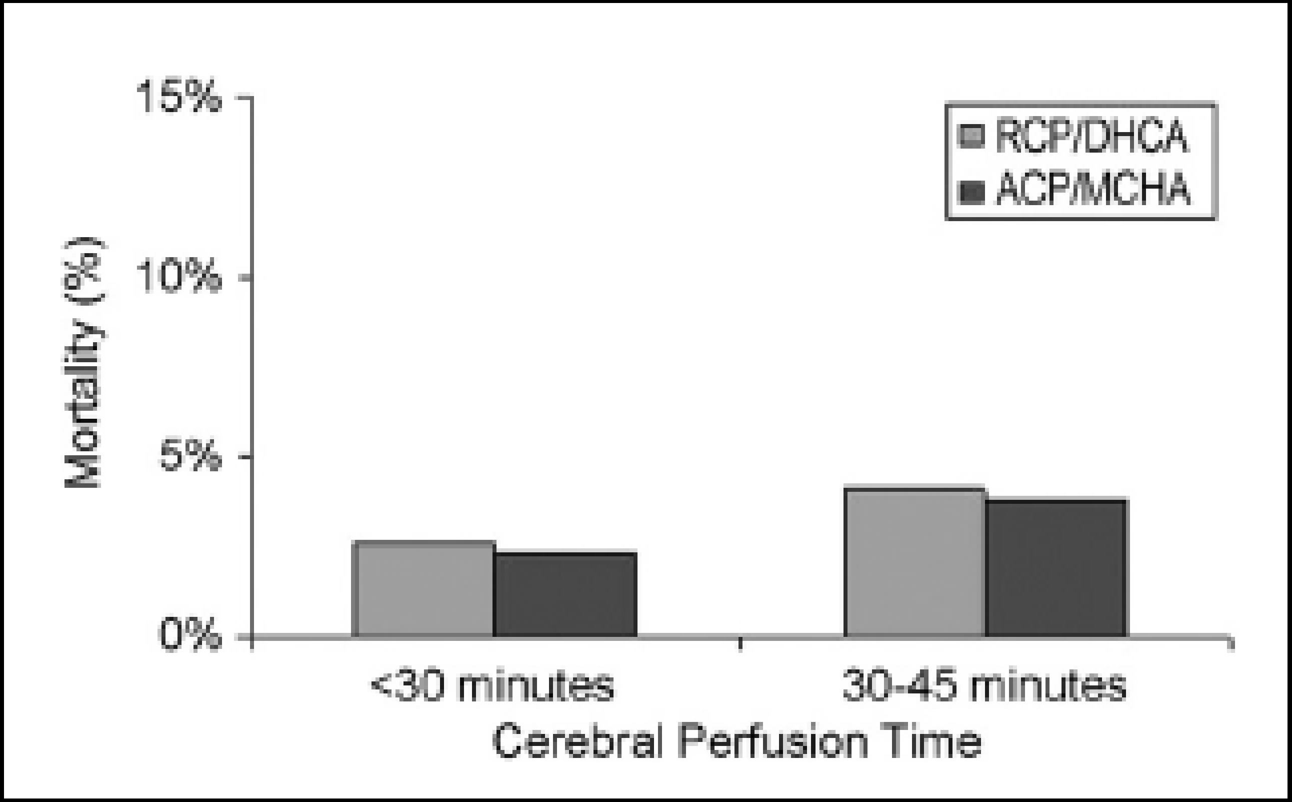
Cerebral Ischemic Lesions on Diffusion-Weighted Imaging Are Associated With Neurocognitive Decline After Cardiac Surgery

Stroke 2008;39:14



POCD is associated with perioperative ischemia and is more severe with greater ischemic load

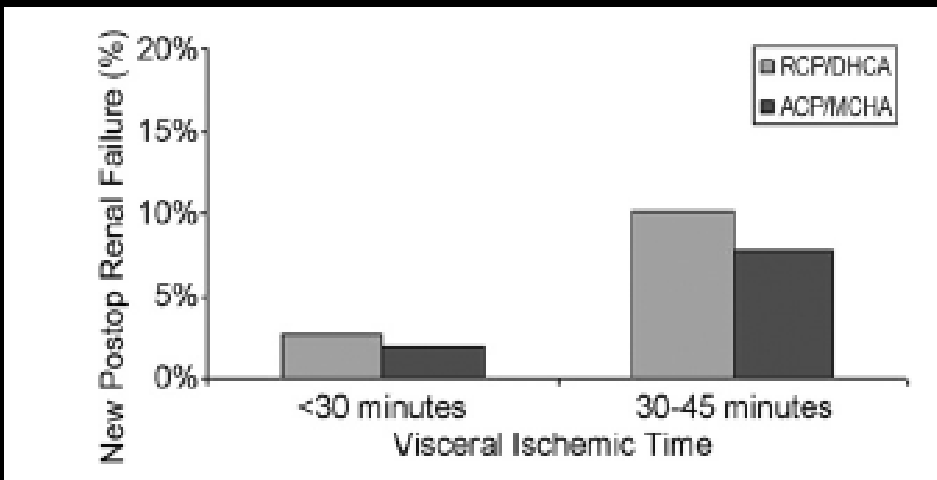
There is no significant difference in the incidence of in-hospital **mortality** between RCP/DHCA and ACP/MCHA



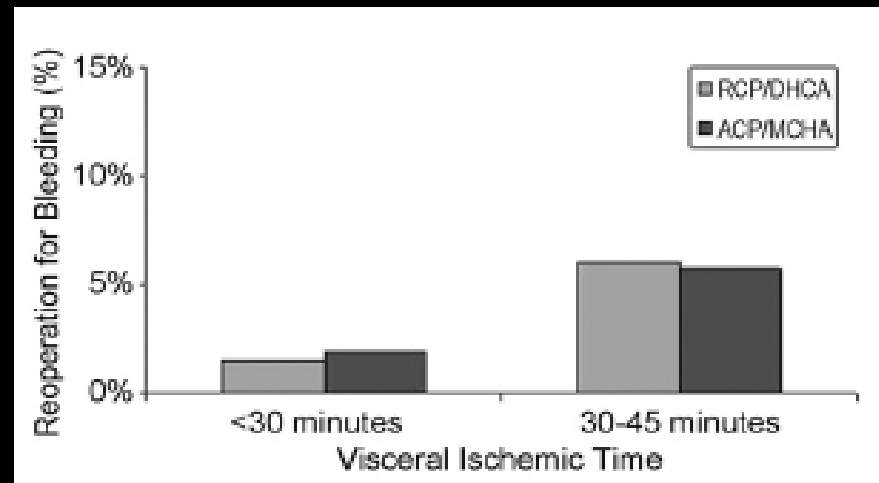
Milewski, Ann Thorac Surg 2010;89:1448-57

No significant difference between RCP/DHCA and ACP/MCHA

New Postoperative Renal failure



Reoperation for Bleeding



…for aortic reconstruction times less than 45 minutes!

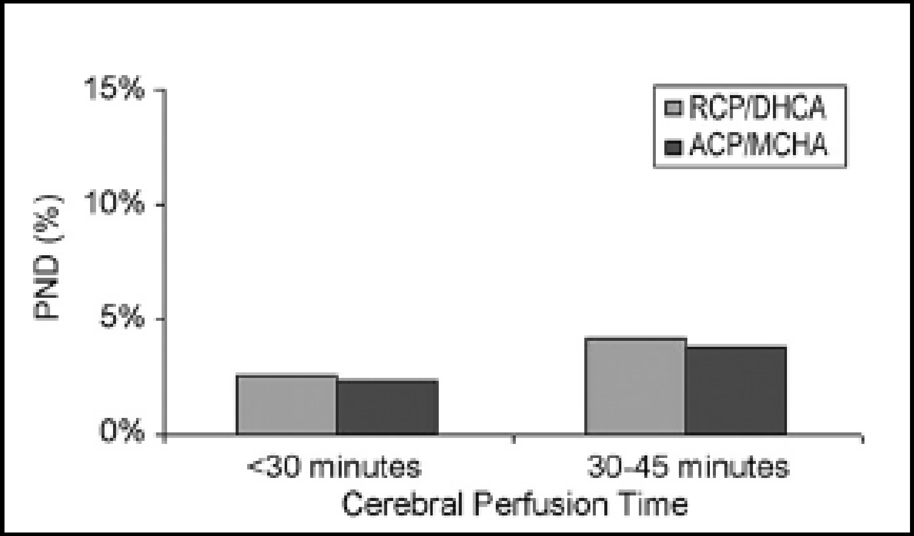
Increasing visceral ischemic time can be associated with adverse “visceral” outcomes independent of techique

For arrest times > 60 min, ACP/DHCA is recommended to protect the **spinal cord** and visceral organs.

?

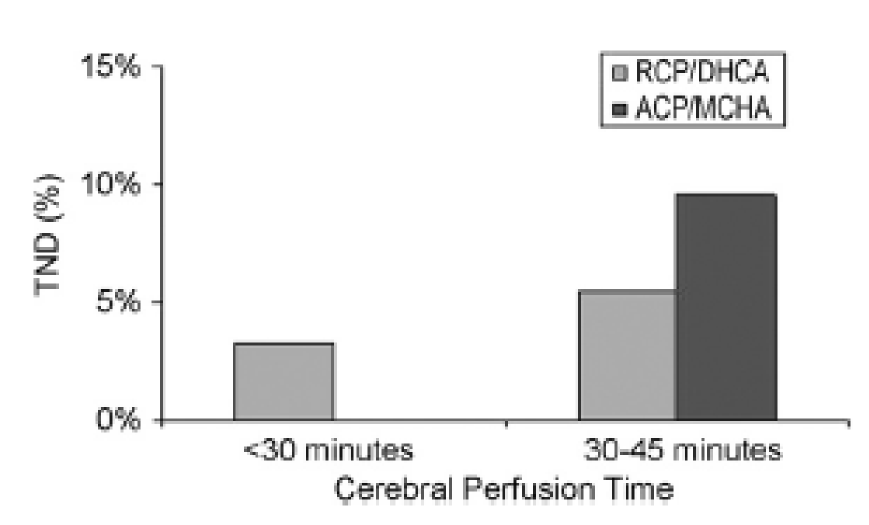
Milewski, Ann Thorac Surg 2010;89:1448-57

PND occurs secondary to embolic pheomena, not a result of global ischemia and is less dependent on the cerebral perfusion duration:



Permanent neurologic deficit

There is a correlation between **TND** and duration of cerebral perfusion technique:

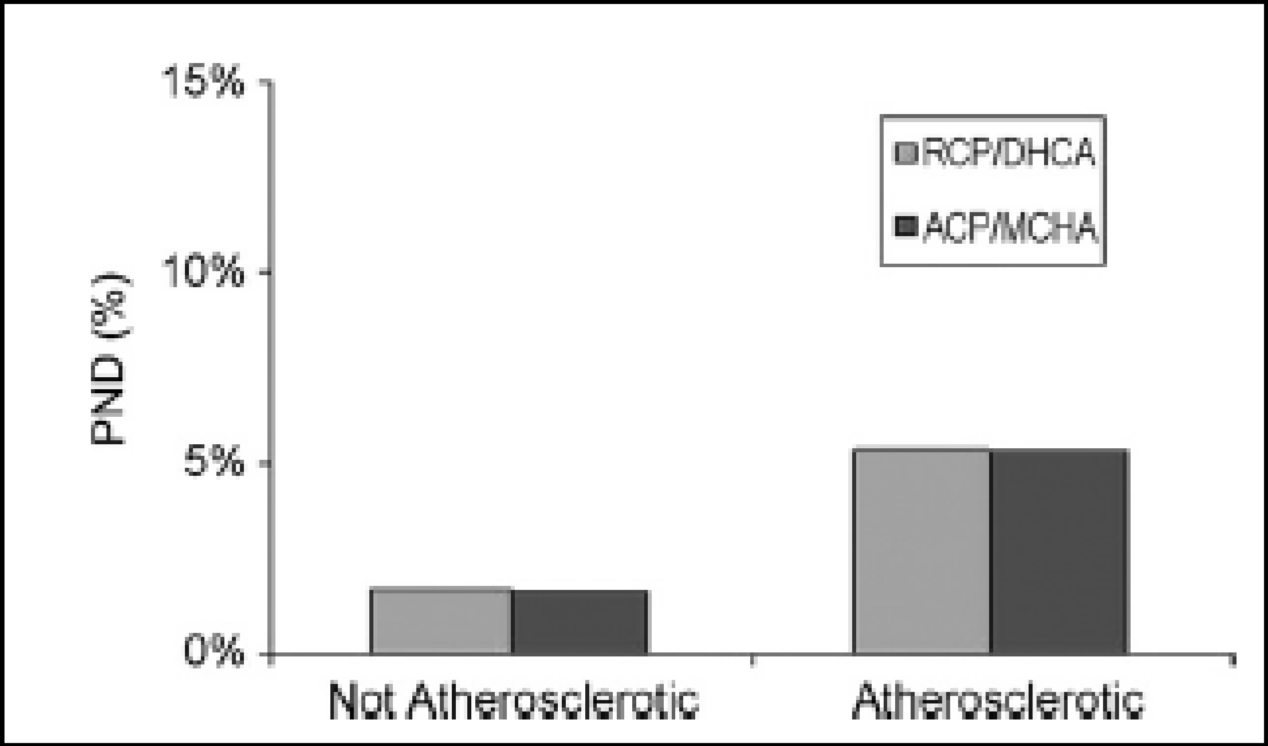


Transient neurologic dysfunction

ACP/MCHA: nasopharingeal temperature 26 °C, Kazui technique
RCP/DHCA: systemic cooling until EEG was isoelectric, perfusion 10°C

Milewski, Ann Thorac Surg 2010;89:1448-57

The risk of permanent neurologic deficit increases significantly with atherosclerotic versus nonatherosclerotic aortic aneurysm



PND correlates with the adverse sequelae of atherosclerotic aortic pathology

Milewski, Ann Thorac Surg 2010;89:1448-57