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Role of Robotic Transcranial Doppler in Aortic Arch Surgery

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Disclosure

- Terumo Aortic – Consultant, Research and Educational Grants
- Artivion – Consultant, Research and Educational Grants

Timeline of Major Milestones in Aortic Arch Surgery (1950–Present)

1950 – Wilfred Gordon Bigelow: Experimental hypothermia and circulatory arrest (Toronto)

1952 – F. John Lewis: First intracardiac repair under hypothermic circulatory arrest (Minnesota)

1953 – John H. Gibbon: First successful cardiopulmonary bypass operation

1950s–60s – Michael E. DeBakey: Development of aortic graft replacement techniques

1975 – Randall B. Griepp: Total aortic arch replacement using deep hypothermic circulatory arrest

1983 – Hans G. Borst: Introduction of the elephant trunk technique

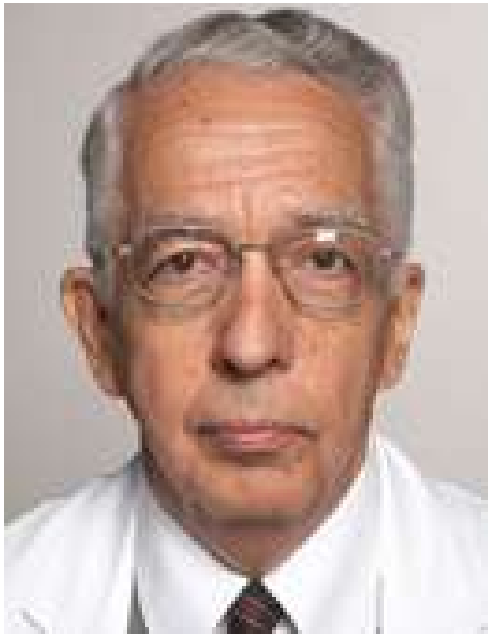
Late 1980s–1990s – Tirone E. David / Nicholas T. Kouchoukos: Retrograde cerebral perfusion

1990s – Teruhisa Kazui: Selective antegrade cerebral perfusion

2000s – Frozen elephant trunk (Karck, Schäfers, Shrestha and others)

Modern era – Moderate hypothermia with selective cerebral perfusion for complex arch repair

Hypothermic Circulatory Arrest



In 1975, Griepp's study reporting the initial use of profound hypothermic circulatory arrest (PHCA) for transverse arch repairs to achieve the goal of reducing neurologic complications.

Griepp R.B., Stinson E.B., Hollingsworth J.F., Buehler D.Prosthetic replacement of the aortic arch. J Thorac Cardiovasc Surg 1975;70:1051-1063.

Safe Period in Hypothermic Circulatory Arrest

Cerebral Metabolic Suppression During Hypothermic Circulatory Arrest in Humans

Jock N. McCullough, MD, Ning Zhang, MD, David L. Reich, MD, Tatu S. Juvonen, MD, PhD, James J. Klein, MD, David Spielvogel, MD, M. Arisan Ergin, MD, PhD, and Randall B. Griepp, MD

Department of Cardiothoracic Surgery, Mount Sinai Medical Center, New York, New York

Table 4. Calculated Safe Duration of Hypothermic Circulatory Arrest

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.

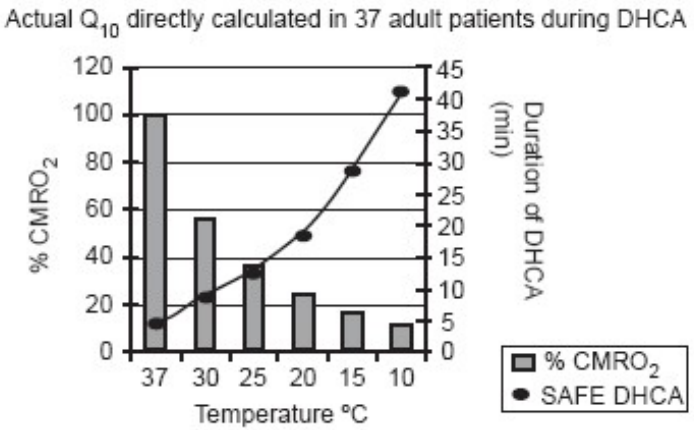
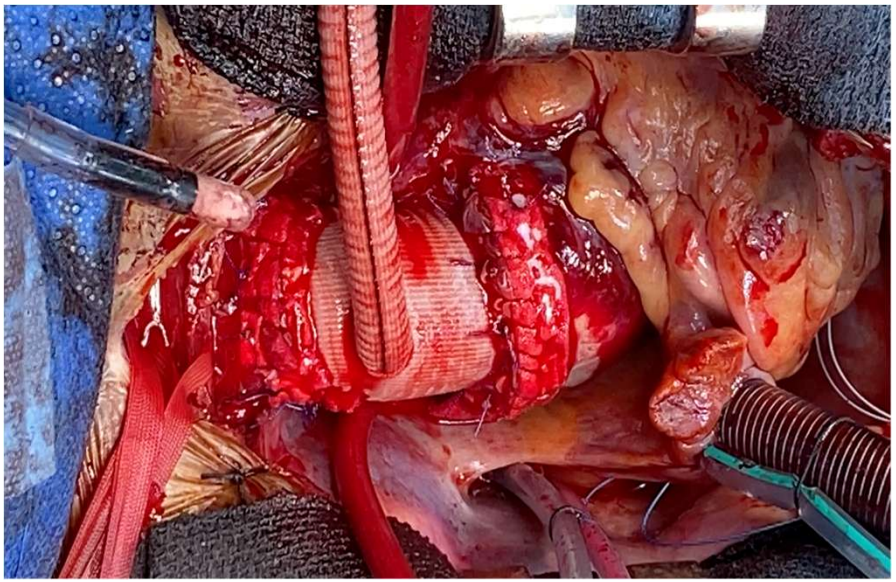
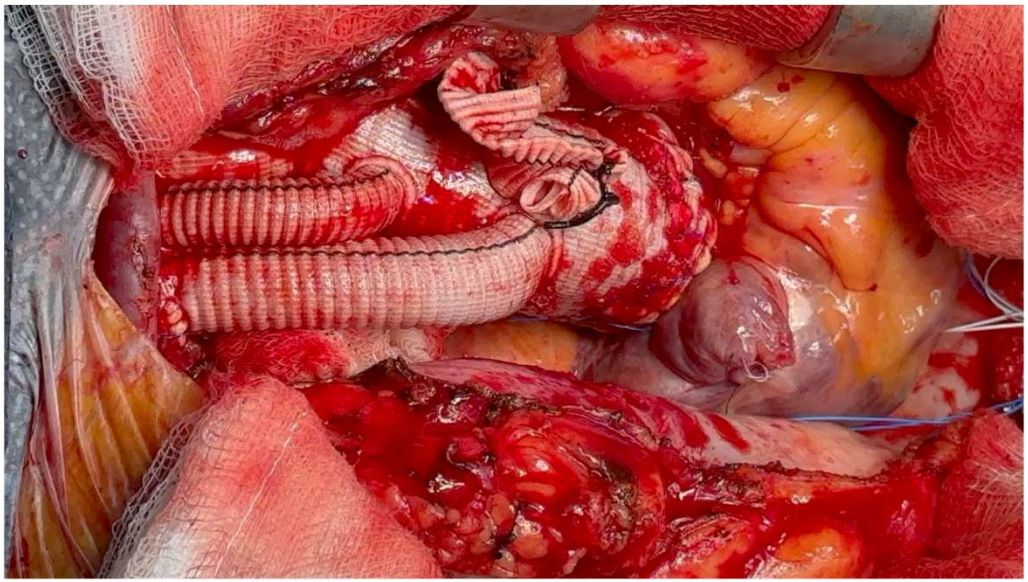


FIGURE 31-4. Limits of "safe" duration of circulatory arrest. Q_{10} for the adult brain is calculated from direct measurement of $CMRO_2$ in 37 adult patients undergoing thoracic aortic operations with DHCA. The temperature-related reduction in the metabolic rate and the calculated "safe periods of arrest" are shown. $CMRO_2$ = cerebral metabolic rate for oxygen; DHCA = deep hypothermic circulatory arrest. Data from McCullough JN et al.[25]

Interposition Graft vs Total Arch + FET

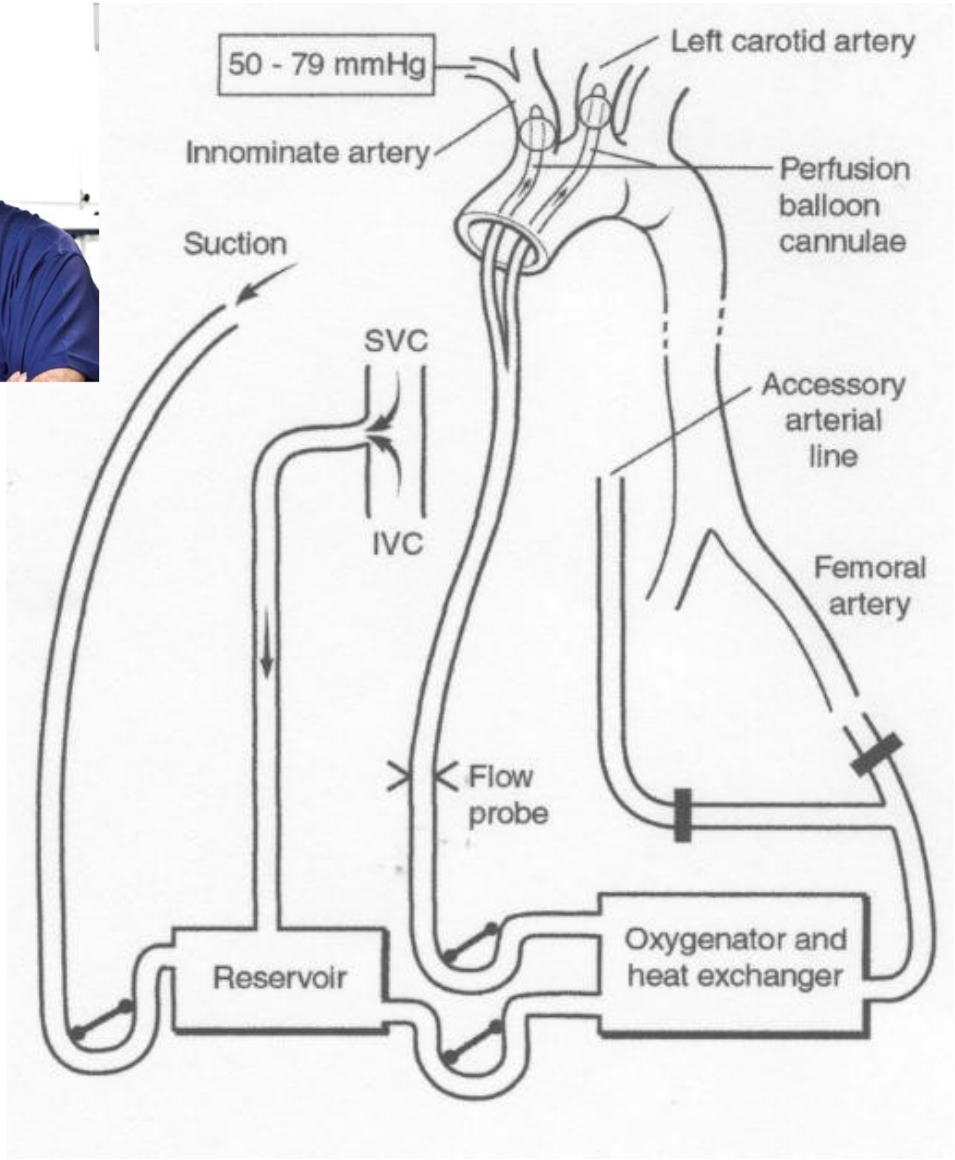




Common Cause of CVA in Arch Surgery

- Manipulation of diseased ascending and arch with consequent athero-embolisation is the main cause of CVA in elective surgery

- Cerebral malperfusion is the significant cause of CVA in surgery for Acute Dissection



Selective antegrade cerebral perfusion

- **Continued cerebral metabolic support**
- **Antegrade flow more physiological**
- **May allow longer arrest times**
- **May not require profound hypothermia**

Bonser, in Operative Cardiac Surgery 2004

Techniques of Selective Antegrade Cerebral perfusion

- Concept has sound physiological basis
- Takes advantage of autoregulation of cerebral blood flow targeted at perfusion pressure rather than fixed flow
- Addition of hypothermia makes method safer with reduced flow and pressure requirements
- Gives “luxury of time “ to allow repair of pathology
- Disadvantages: Cluttered operative field, embolization due to cannulated vessels manipulation

Techniques of Selective Antegrade Cerebral perfusion

- Variations of inflow cannulations
- Right axillary/Subclavian artery
- Innominate and left common carotid arteries
- Multi limb branched graft
- Flow rate adjusted to right radial artery pressure of 50 mm Hg (usually 10 to 20 ml/kg/min)

How do you know your protection is adequate?

- Direct intra-operative checks – amount and colour of blood backflow from cross circulation
- Arterial blood pressure monitoring – Rt RA +/- Lt RA
- NIRS – cerebral
- TCD – flow in bilateral middle cerebral arteries

Proximal and distal arterial pressure monitoring

Monitoring (NIRS)

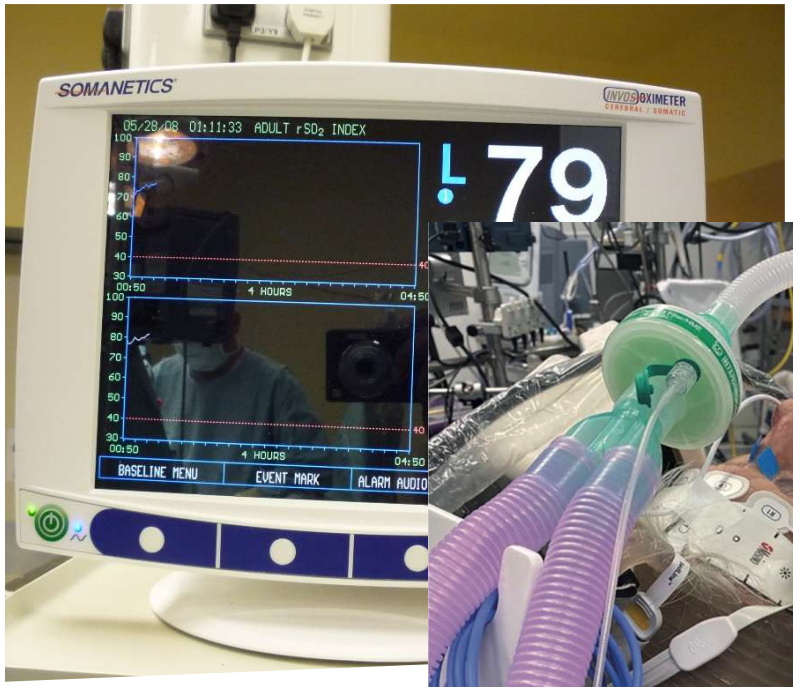
Brain

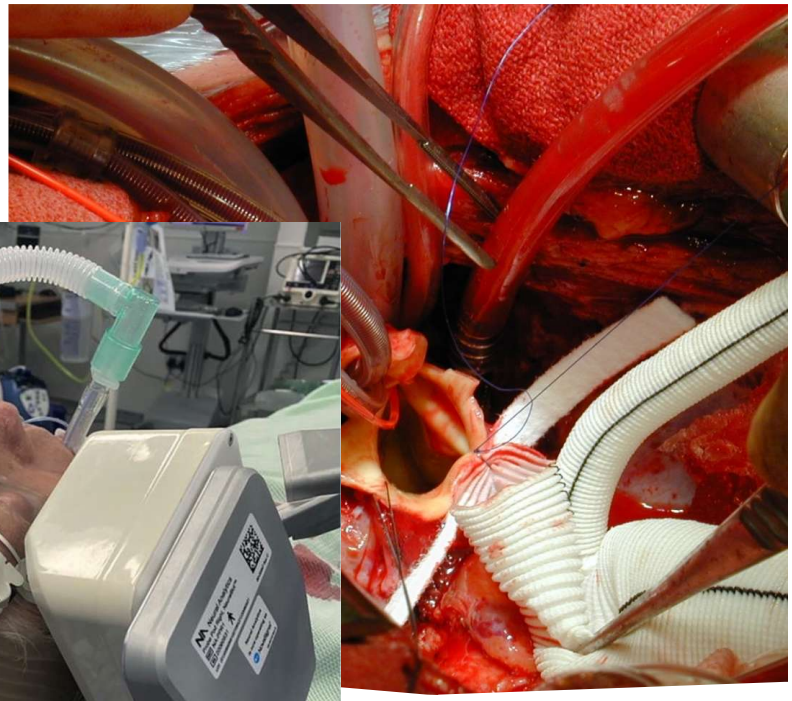
Spinal and lower limbs

Case Report: First Fully Autonomous Transcranial Doppler Robotic System During Carotid Stenting

Zsolt Garami[1], Alan Lumsden[1], Robert Hamilton[2]
[1]Methodist DeBakey Heart and Vascular Center, Houston, USA; [2]Neural Analytics, Inc. Los Angeles, USA

Transcranial Doppler mainly used in vascular surgery and neurological intervention


SOMANETICS
INVOS OXIMETER
CEREBRAL / SOMATIC
05/28/08 01:11:33 ADULT rSO2 INDEX
79
4 HOURS
BASELINE MENU
EVENT MARK
ALARM AUDIO



Scalp Cooling Cap

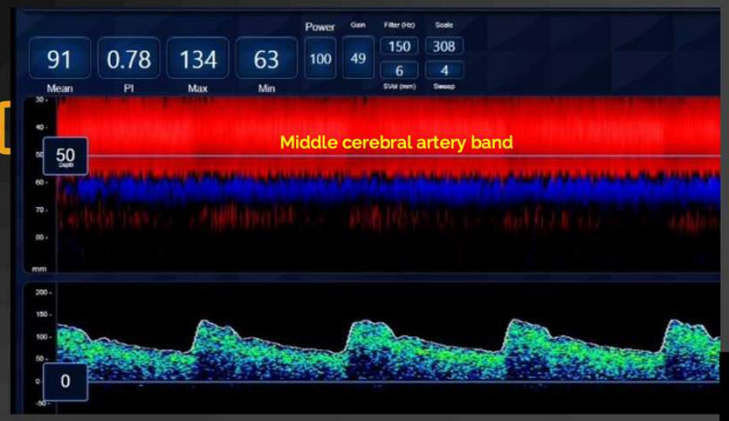
Robotic TCD Trial

- February 2022 – March 2022
- Bart's aortic service with institutional review approval
- Patients underwent aortic arch surgery with HCA

Middle Cerebral Artery

Depth	Velocity	Direction
30-60mm	55±12 cm/s	Toward

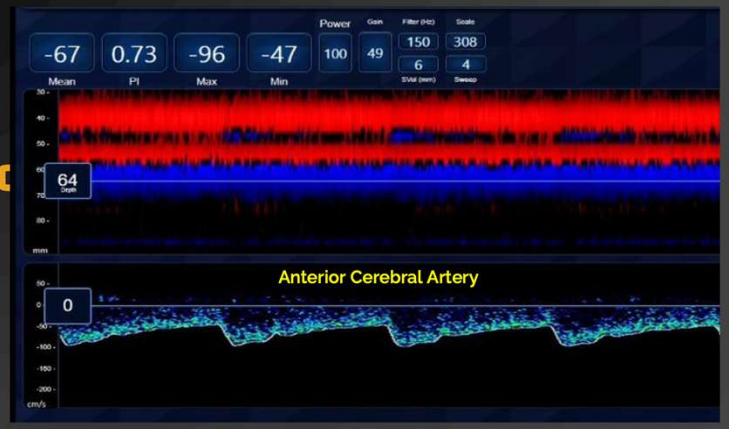
Must have flow below 50mm



Anterior Cerebral Artery (ACA1 & ACA2)

Depth	Velocity	Direction
60-75mm	55±11 cm/s	Away

Blue band attached to MCA

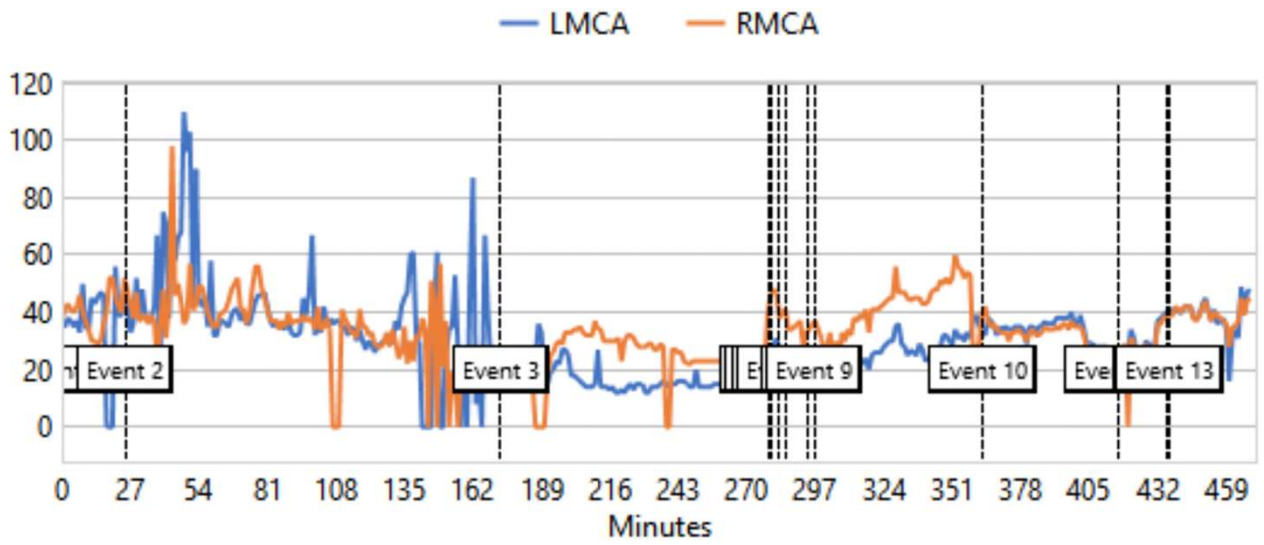


Right Sided cannulation only

Bilateral Cannulation

Case 1

- Redo Arch + FET



Pre- CPB


Gary Ephraim
LMCA
RMCA
22/02/2022 10:06:31 AM
200 -
150 -
100 -
50 -
0 -
-50 -
cm/s
0
37
Mean (cm/s)
67
Max (cm/s)
24
Min (cm/s)
1.16
PI
30 -
40 -
50 -
60 -
70 -
80 -
mm
47
Depth
60
Power (%)
50
Gain
300
Filter (Hz)
10
SVol (mm)
NovaSignal
0
40
Mean (cm/s)
71
Max (cm/s)
25
Min (cm/s)
1.17
PI
57
Depth
60
Power (%)
50
Gain
300
Filter (Hz)
10
SVol (mm)
NovaSignal

CPB


Gary Ephraim
LMCA
RMCA
22/02/2022 11:19:58 AM
200 -
150 -
100 -
50 -
0 -
-50 -
cm/s
0
46
Mean (cm/s)
61
Max (cm/s)
31
Min (cm/s)
0.66
PI
30 -
40 -
50 -
60 -
70 -
80 -
mm
50
Depth
60
Power (%)
50
Gain
400
Filter (Hz)
10
SVol (mm)
NovaSignal
48
Mean (cm/s)
70
Max (cm/s)
32
Min (cm/s)
0.81
PI
59
Depth

Initial Cooling

During Cooling

Pre-HCA


Gary Ephraim
LMCA
60 -
45 -
30 -
15 -
0
-15 -
cm/s
0
17
Mean (cm/s)
18
Max (cm/s)
16
Min (cm/s)
0.10
PI
30 -
40 -
50
60 -
70 -
80 -
mm
50
Depth
60
Power (%)
53
Gain
125
Filter (Hz)
10
SVol (mm)
NovaSignal
RMCA
22/02/2022 12:59:28 PM
45 -
30 -
15 -
0
-15 -
-30 -
cm/s
0
18
Mean (cm/s)
19
Max (cm/s)
17
Min (cm/s)
0.07
PI
30 -
40 -
50
60
70 -
80 -
mm
52
Depth
60
Power (%)
50
Gain
125
Filter (Hz)
10
SVol (mm)
NovaSignal

Bilateral ACP

After Distal Flow Recommenced

After LCC Reimplantation

After Reimplantation of Innominate

Rewarming on CPB

End of Procedure

Patients

MRN	Date	Age	Sex	Elect/urgent	Procedure
Pt 1	22/02/2022	31	M	Elective	Arch/FET
Pt 2	24/02/2022	67	M	Elective	AVR(t) FET
Pt 3	25/02/2022	77	M	Elective	Root/AA/Arch/fet/extra an subclavian
Pt 4	04/03/2022	63	M	Urgent	AA/Hemiarch
Pt 5	17/03/2022	54	M	Elective	Redo avr/AA/conven ET
Pt 6	18/03/2022	69	F	Elective	Root/AA/he i arch/salvage cabg/iabp
Pt 7	21/03/2022	83	F	Urgent	AA/De-branching neck vessels+endovascular sub stent
Pt 8	24/03/2022	84	F	elective	AA/Arch/FET

Baseline Pre-CBP

L NIRS% Baseline (mean)	**68**
R NIRS% (Baseline (mean)	67
LMCA Vel PreCPB cm/s (mean)	32.14
RMCA Vel PreCPB cm/s (mean)	32.1
MAP mmHg PreCPB (mean)	68.2

CPB start

L NIRS% CPB Start(mean)	**68**
R NIRS% CPB Start (mean)	67
LMCA Vel CPB start cm/s (mean)	32.14
RMCA Vel CPB start cm/s (mean)	32.1
MAP mmHg CPB start (mean)	68.2
Nasopharyngeal T CPB Start	34.3
Bladder T CBP Start	34.5
Venous ret T CBP Start	33.8

Values @ Target Temperature

L NIRS% Target T(mean)	**67.2**
R NIRS% Target T (mean)	65.2
LMCA Vel Target T (MTTF) (mean)	19.2
RMCA Vel Target T (MTTF) (mean)	19
MAP mmHg Target T (mean)	65.5
Nasopharyngeal T Target T	21.6
Bladder T Target T	22.5
Venous ret T Target T	21.2
pSI target t (median) IQR	0
%SR Target T (median) IQR	100 (98.7-100)

Values at Minimum Target Velocity

Flow ml/min MTT vel achieved Mean/ Median (IQR)	**437.5/450 (387.5-500)**
Flow ml/min/kg MTT vel achieved Mean/ Median (IQR)	5.62/5.1(4.82-5.9)
L NIRS% at MTT vel Mean/Median (IQR)	62.3/65(57.5-68.5)
L NIRS% at MTT vel Mean/Median (IQR)	64.3/65(61.5-67.5)

DHCA Patients (7)

Number of patients	7
Age (mean)/years	63.7
Male/Female	5(71.4%)/28.6%
Weight(mean)/kg	73
Previous CVA	1(14%)
Elective/urgent	6(86%)/1(14%)
CPB (Mean) mins	330
DHCA (Mean)mins	73
Mortality	1 (14%)
LOA ICU days mean/median (IQR)	5.8/5(4-6)
LOA Hosp days (mean)	9.8/8(7-12)
New CVA clinical	0
Post op CT Brain	0

Conclusion

- Robotic transcranial doppler is a potential additional tool in monitoring and guiding cerebral perfusion during aortic surgery with hypothermic circulatory arrest

- In combination with NIRS and cooling, robotic transcranial doppler guided management of cerebral perfusion during aortic arch surgery may lead to improved clinical outcomes

Thank you

William Harvey Heart Centre