Techniques and Complications of Aortic Surgery

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SMC TS

Arch Aneurysm

- Open surgery
  - Still demanding procedure
  - Recent progress in technique & materials

    Axillary cannulation

    Selective cerebral perfusion

    Epiaortic US

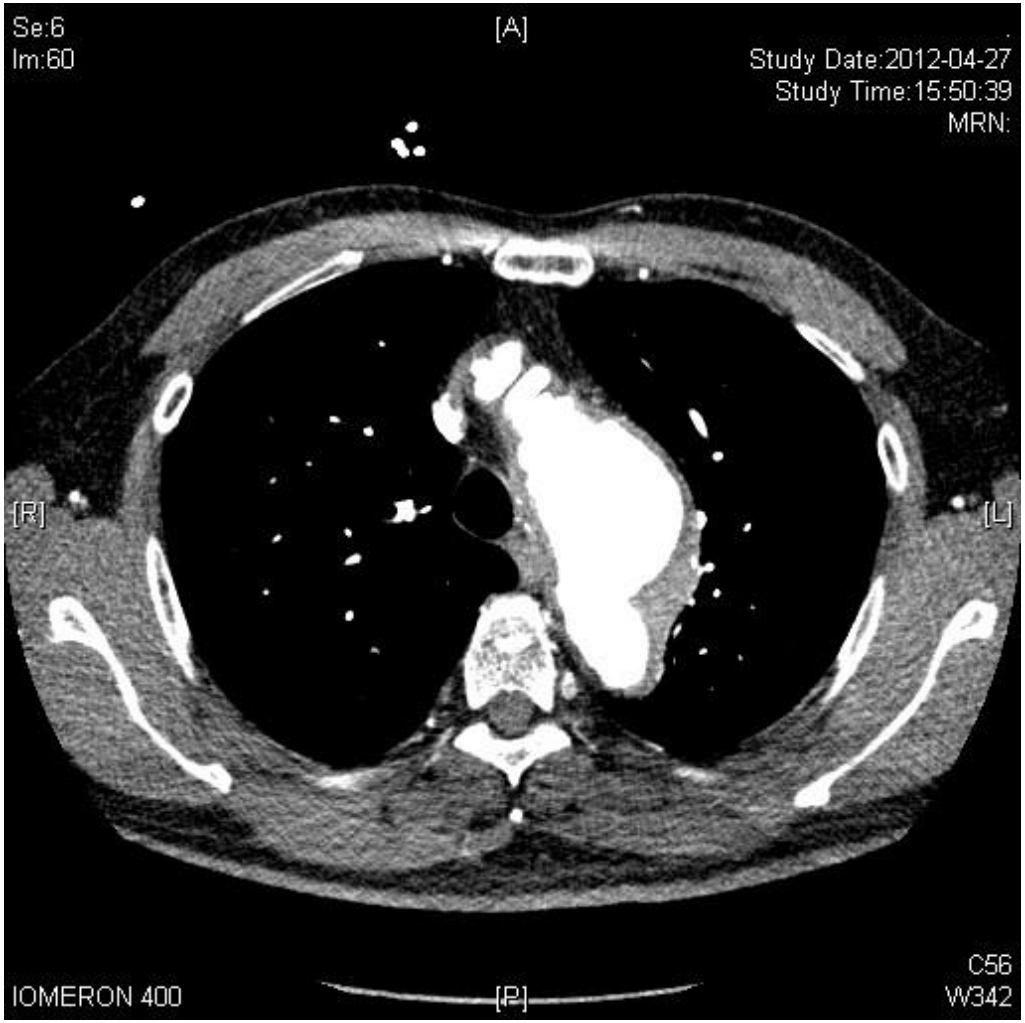
    Neurologic monitoring

    Graft materials, glues, etc
- Endovascular & Hybrid treatment
  - Recently rapidly expansion
  - Relatively good early results in selected patients

Open Repair Strategy

- Incision:
  - Median sternotomy, Clamshell, Lt thoracotomy
- Cannulation site
  - Ascending aorta, Axillary artery, Femoral artery
- Temperature
  - Deep or Moderate hypothermia
- Brain perfusion or protection
- Anastomotic order
  - Arch first
  - Distal first
  - Proximal first

Atheroma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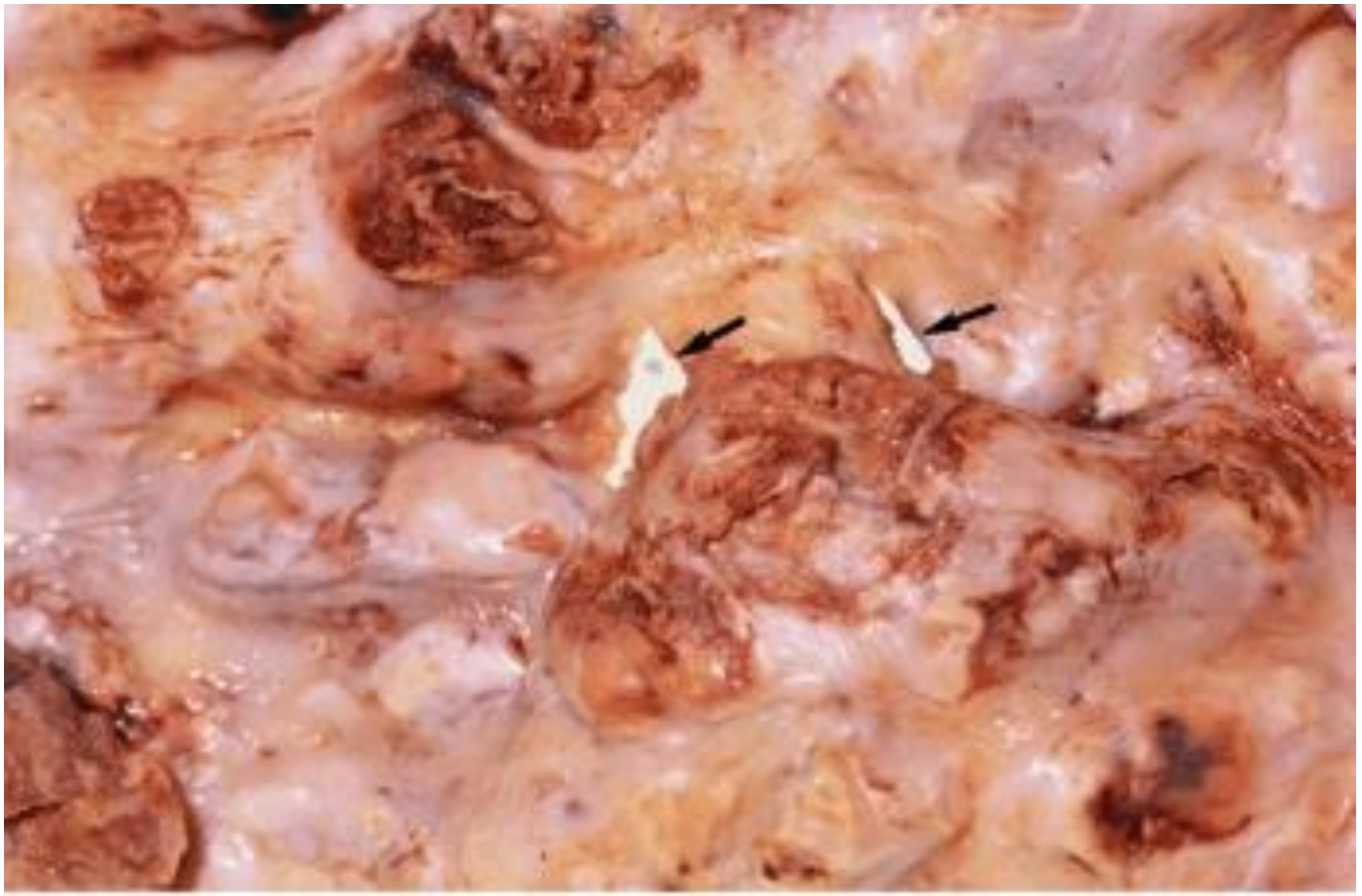
Shaggy aorta



(JACC 1988;32:83-9)

Prevention of Atheroma

- Macroembolism
- Intraoperative identification
  - Aortic cannulation site
  - ACC site
  - Proximal anastomosis of CABG
- Alternative cannulation
- Specially designed cannulae

Identification of atheroma

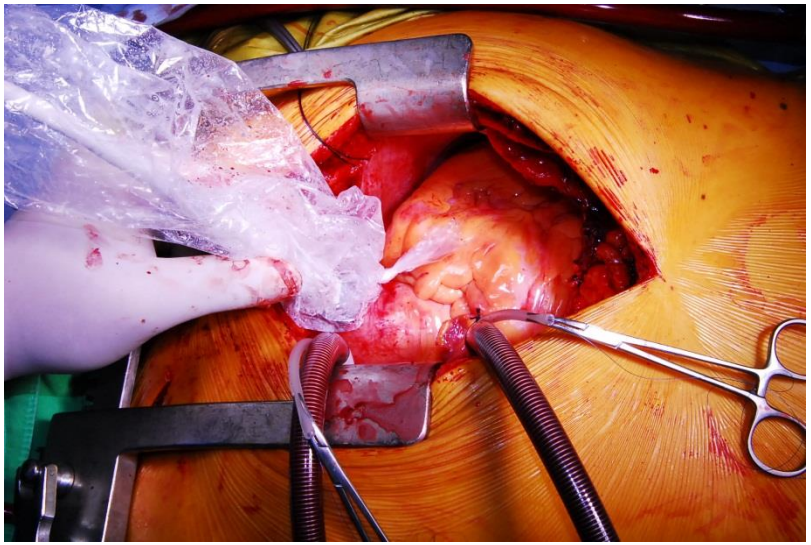
- Soft >> hard

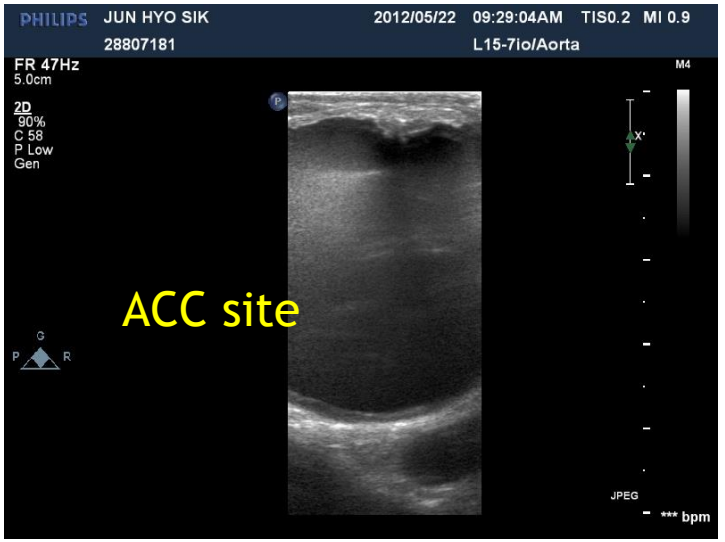
  Mobile >> non-mobile
- Method
  - Digital palpation
    - Do not detect more dangerous soft plaque
  - TEE
    - Limited view (esp, distal ascending aorta)
  - Epiaortic ultrasonography

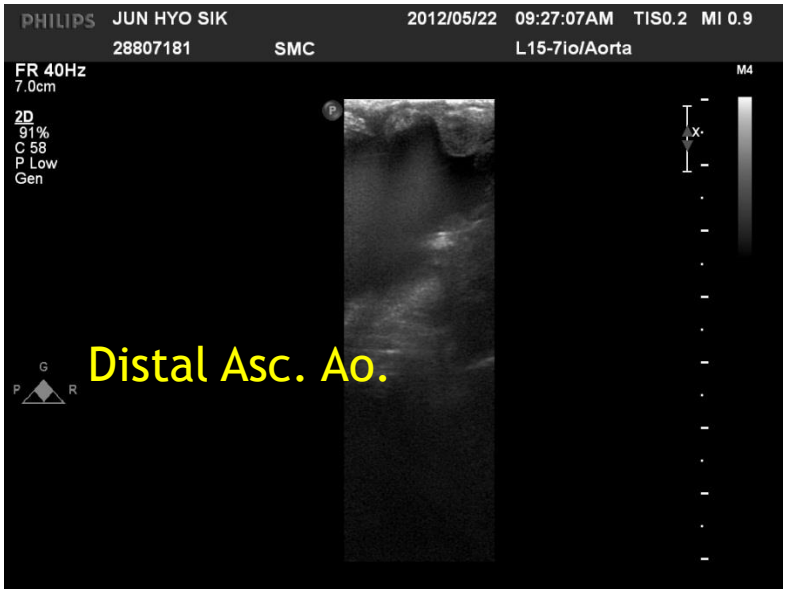
TEE

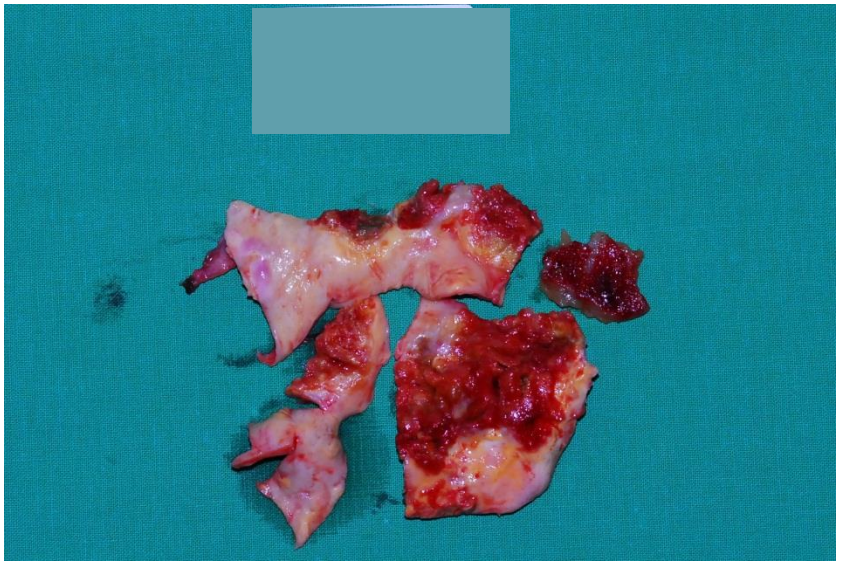
- Limited view (esp, distal ascending aorta)

Epiaortic Ultrasonography









DP vs TEE vs EAU

An Intraoperative Assessment of the Ascending Aorta: A Comparison of Digital Palpation, Transesophageal Echocardiography, and Epiaortic Ultrasonography

Sujeeth Suvarna, FRCSI,* Andrew Smith, FRCA,† Jan Stygall, MSc,‡§ Shyam Kolvecar, MS, FRCS(CTh),*
Robin Walesby, FRCS,* Michael Harrison, FRCP,‡
and Stanton Newman, DPhil, Dip Psych, AFBPS, MRCP(Hon)‡

Objectives: **There are a number of techniques available to assess the aorta for atheromatous disea… ative period. This study compared the … the findings of digital palpation (DP), tra… cardiography (TEE), and epiaortic ultra… detection of atheroma in the ascending…**

Design: **A prospective, observational …**

Setting: **A single-institution, cardiothe… pital.**

Participants: **One hundred fifty-four p… elective cardiac surgery.**

Interventions: **The ascending aorta of … elective coronary artery bypass surger… atheroma by means of the 3 techniqu… scored as present or absent. The sensitiv… the techniques were compared.**

Measurements and Main Results: **Assuming EAU provides … " the sensitivity of both TEE and DP were …on identified only 20 patients (12%); TEE …nd, in contrast, EAU detected atheroma …). There were 3 and 6 false-positives by …tively.**

…ming EAU as the "gold standard" to de- … study has shown that when assessing …a neither DP nor TEE appear sensitive. … the proposal that detection of atheroma …ed by EAU.

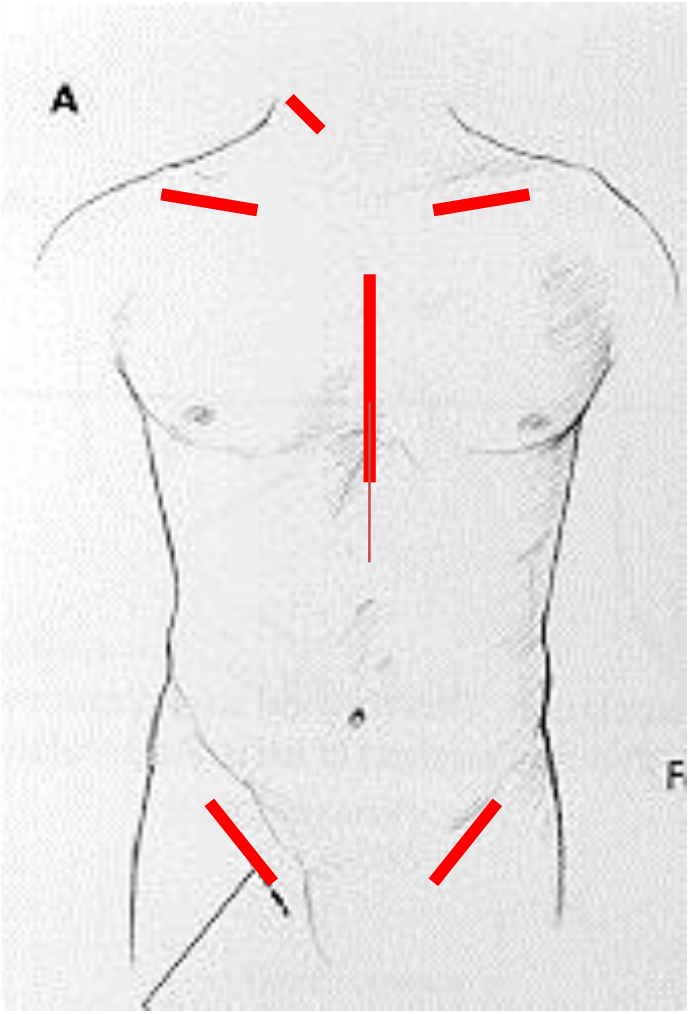
…ning, digital palpation, transesophageal …epiaortic scanning

Sensitivity:
DP (12%),
TEE (20%),
EAU (53%)

False positive:
DP (3/154),
TEE (6/154),
EAU (none)

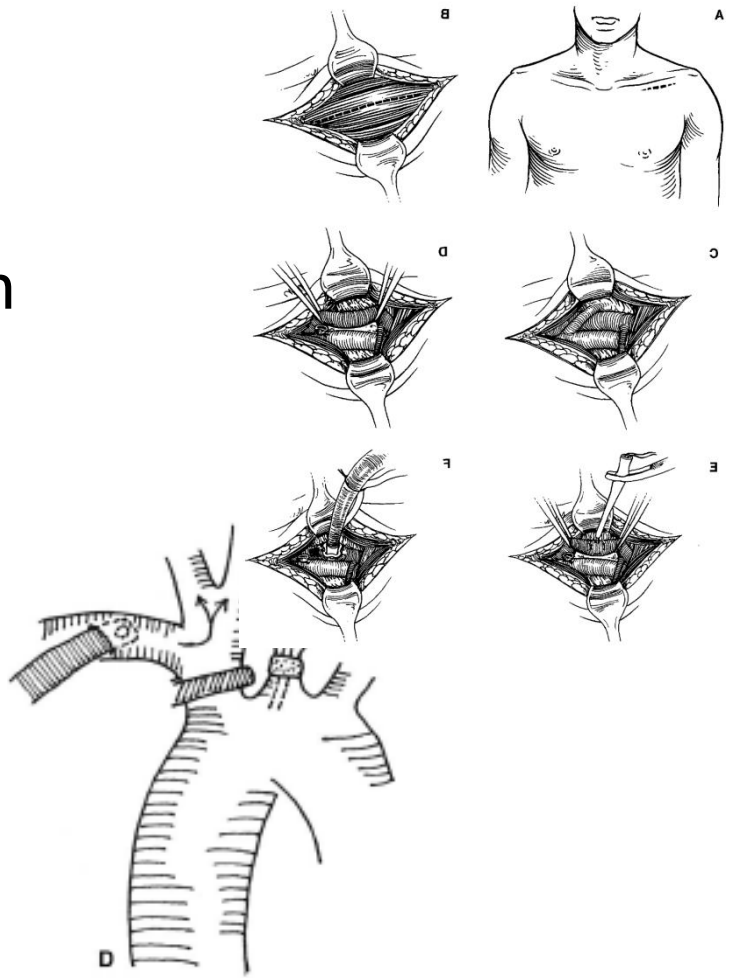
Alternative Cannulation

- Distal arch >> ascending aorta
- Axillary artery
- Femoral artery
- Brachial artery
- Carotid artery
- LV apex

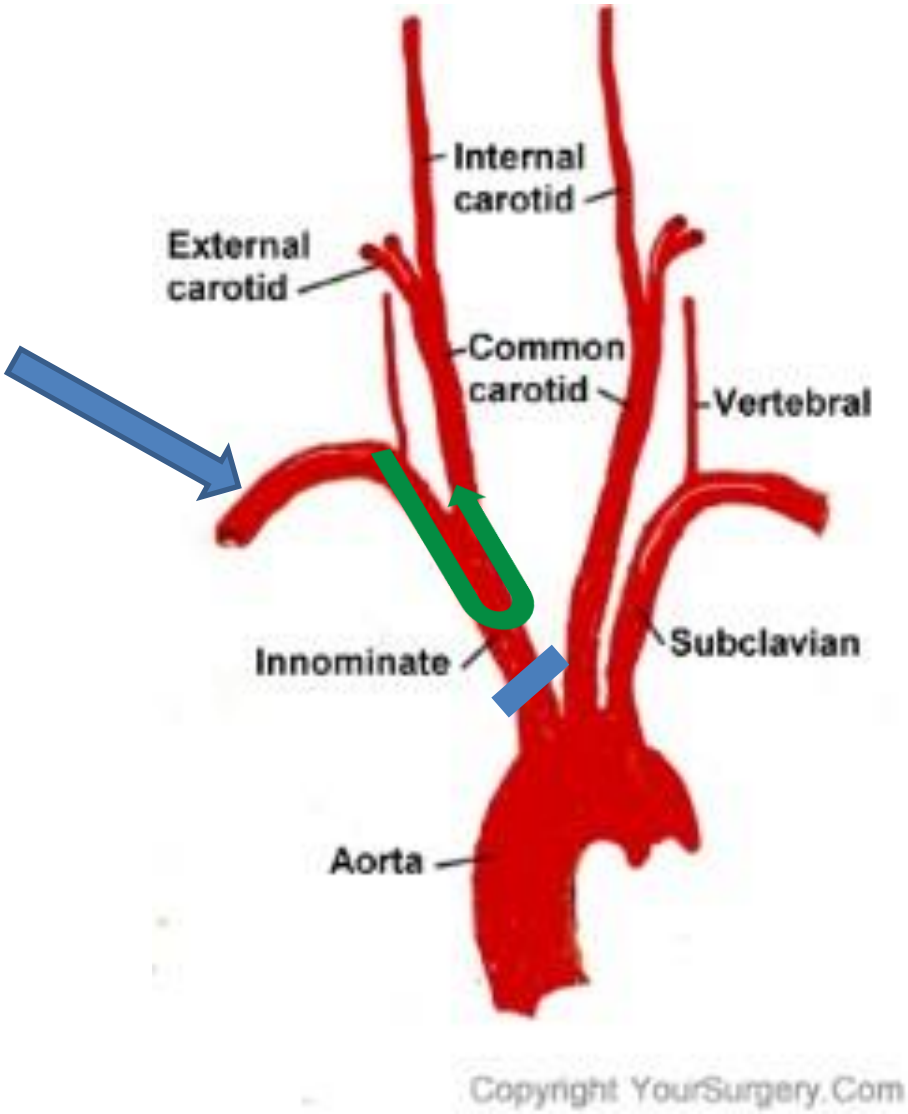


Axillary Artery Cannulation

- Sabik JF et al. (JTCS 1995;109:885-91)
- Advantages
  - Easily exposed
  - Less atherosclerosis
  - Antegrade selective perfusion
- Disadvantages
  - Time consuming
  - Axillary artery dissection
  - Small axillary artery



Cerebrovascular Anatomy

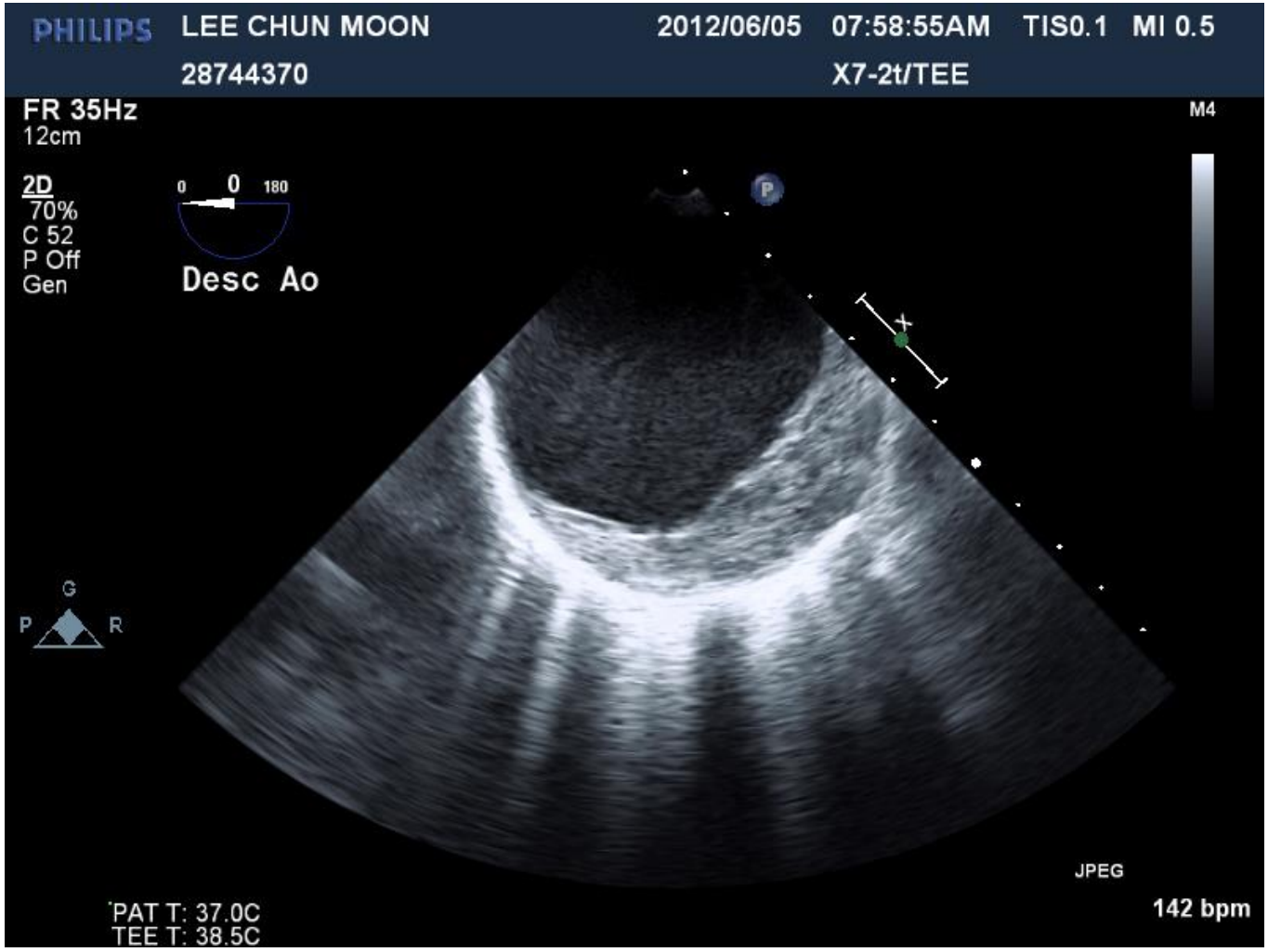


Femoral Artery Cannulation

- 1950 ~
- Usually used for thoracic aortic surgery
- Advantages
  - Easy to access & repair
  - Emergency bypass
- Disadvantages
  - Retrograde perfusion of emboli
  - Malperfusion during Type A acute AD surgery
  - Ilio-femoral artery disease

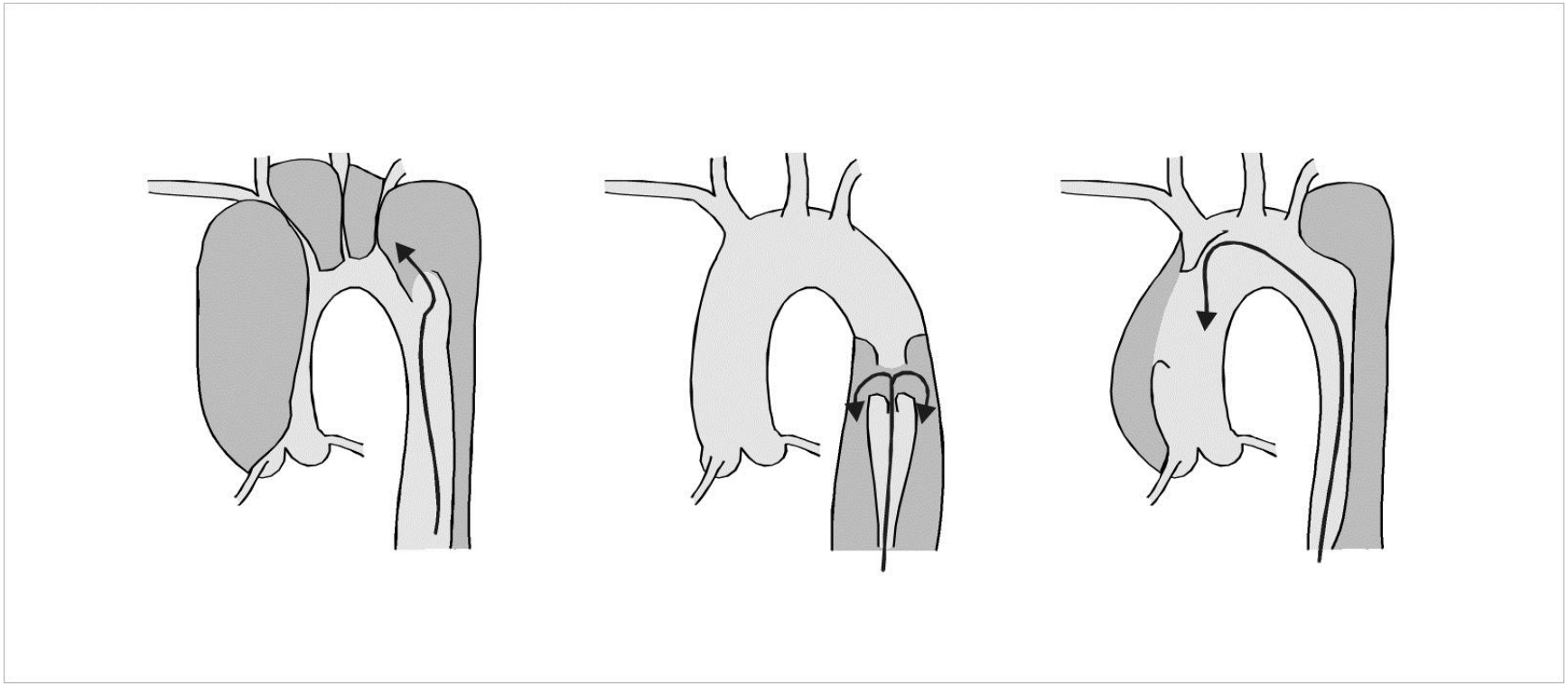
Descending Aorta Mobile Thrombus

- Intraop TEE



Malperfusion During Acute type A AD

- ~ 13%
- Radial artery pressure monitoring
- Re-entry tear: patent false lumen



2. Prevention of Microemboli

- Associated with cognitive dysfunction
- Origin
  - Gas
  - Fat from mediastinal suction fluid
  - Silicon from CPB circuit
- associate with systemic inflammatory response
- Arterial filter (25 > 40μm) is helpful
  - Can reduce microemboli, but not all

Protective Mechanisms

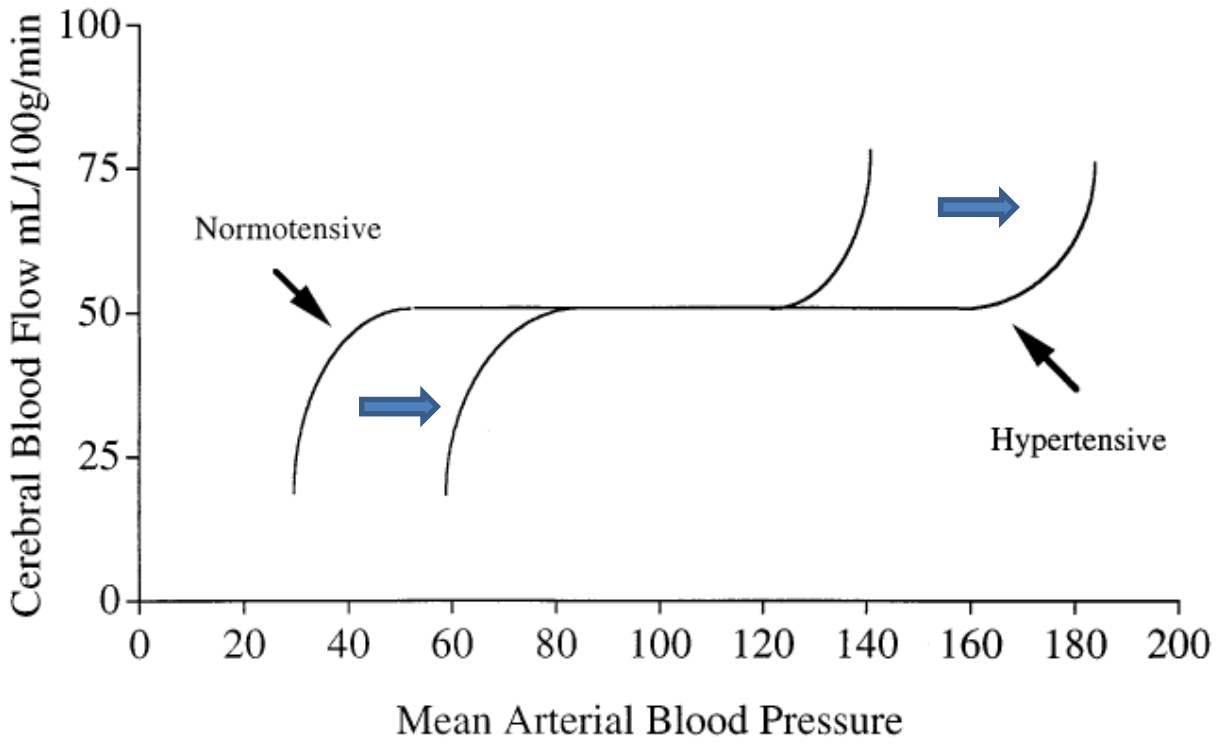
- Air embolism
  - CO_2 flushing (more soluble)
  - Avoid too low venous reservoir level
  - Closed systems
  - Dynamic bubble trap
  - Avoid injection of air
- Fat embolism
  - Using a cell saver
  - Arterial & fat filter

3. Prevention of Hypoperfusion

- Brain metabolism
- Autoregulation
- Optimal MAP?
- Optimal Hct?
- Monitoring modalities

Autoregulation of CBF

- CBF maintained constant independent of BP
- MAP: 50 ~ 120 mmHg



Optimal MAP?

- High risk patients needed higher MAP
  - Hypertension
  - Diabetes
  - Old age
  - CVA Hx.
  - Carotid disease
- More trauma to blood

  Needed larger cannulae

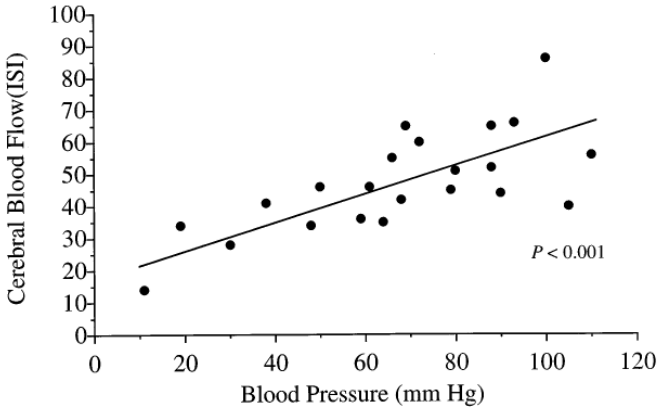
  Increase embolic load

Alpha vs pH stat

- Hypothermia
  - CO_2 content ↓, pH ↑

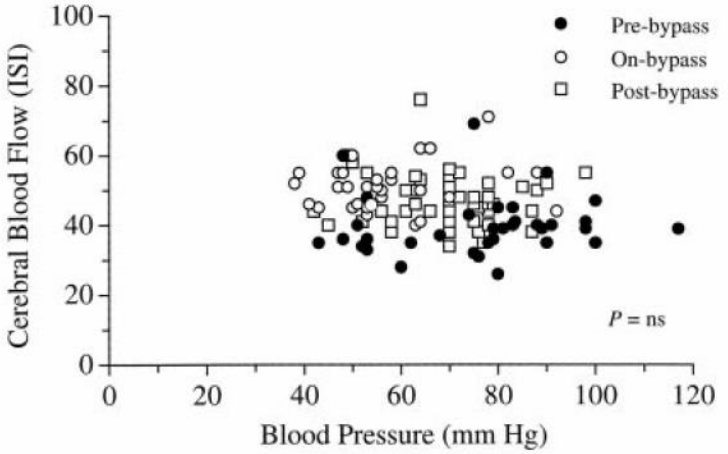
pH stat

- Add CO_2 to correct pH
- CBP ↑
- Embolic event ↑
- Neonate surgery



Alpha stat

- Maintain CO_2 constant
- Maintain autoregulation
- Adult surgery



Hypothermia

- Decrease brain metabolism
- Oxygen consumption: 3 mL/100g/min
- Flow/metabolism ratio
  - 37^{o}C - 15:1
  - At 28^{o}C

    alpha stat - 30:1

    pH stat – 60:1

Normal CBF: 40 ~ 60 mL/100g/min

- pH stat can cause unnecessary high flow & high incidence of embolism in adult

Hypothermic Circulation Arrest

- Brain metabolism: 23% at 20°C, 17% at 15°C
- Reactive hyperemia → oxygen debt
- > 25 min: risk of transient neurologic deficit

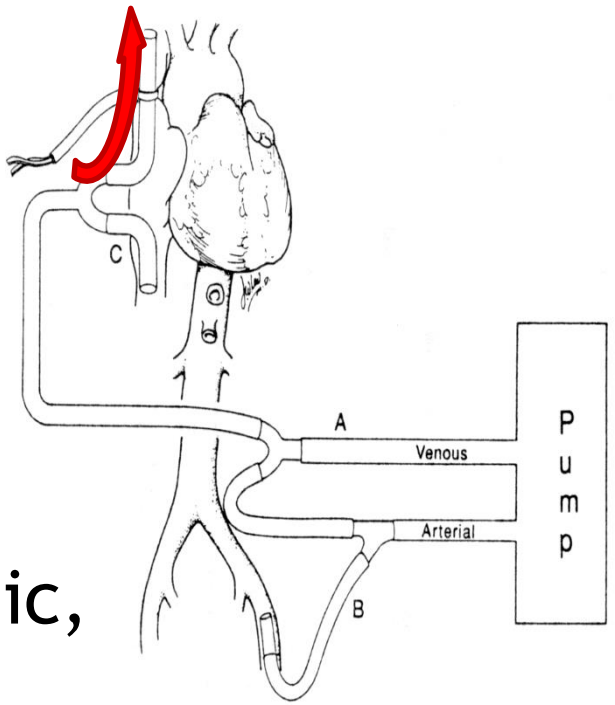
  > 40 min: risk of stroke

  > 1 hr: mortality increase
- Long bypass time and bleeding

(ATS 2007;83:s799-804)

Retrograde Cerebral Perfusion

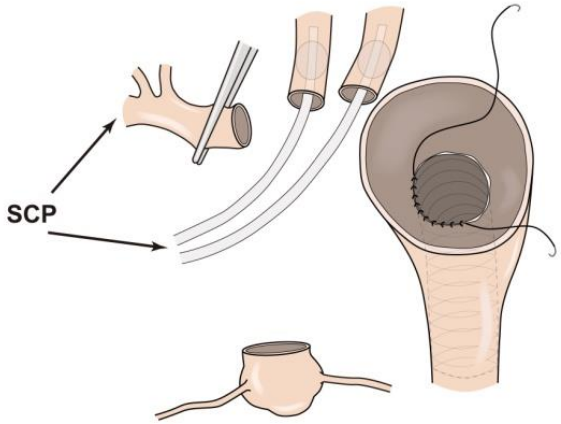
- < 25 ~ 30mmHg of CVP
- Flush out embolic debris
- Brain cooling
- No evidence of cerebral metabolic, neurologic or neuropsychological benefit
- Cerebral edema



(ATS 2007;83:s799-804)

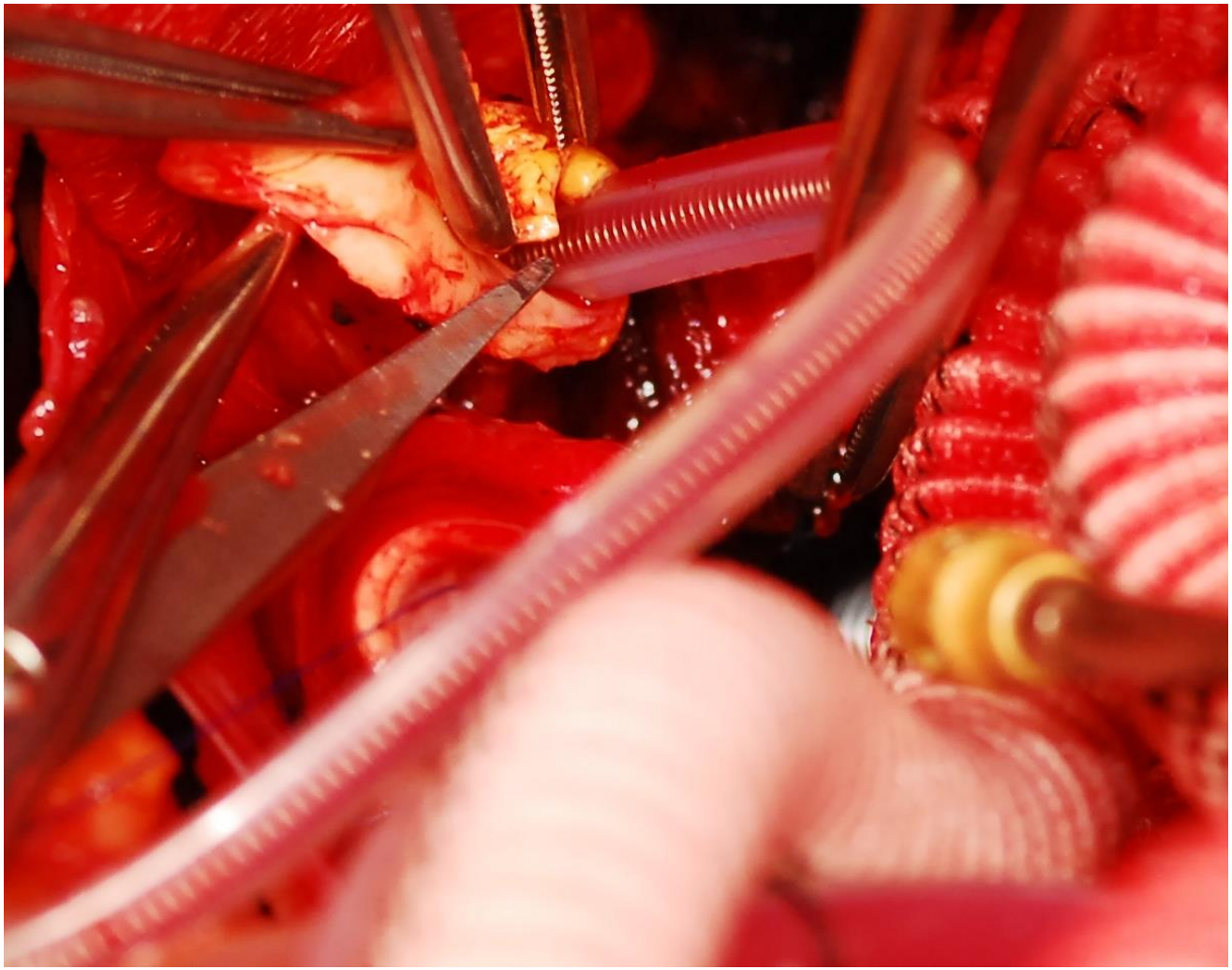
Antegrade Selective Cerebral Perfusion

- Physiologic
- Low rates of morality & neurologic morbidity (short CPB time, bleeding risk ↓)
- Methods
  - Unilateral
  - Bilateral
  - Three branches
- Clamping, balloon catheter, snaring
- Complicated arch surgery
- Embolic & Malperfusion risk
- Caution of branch vessel atheroma



(ATS 2007;83:s799-804)

Atheroma of LCC

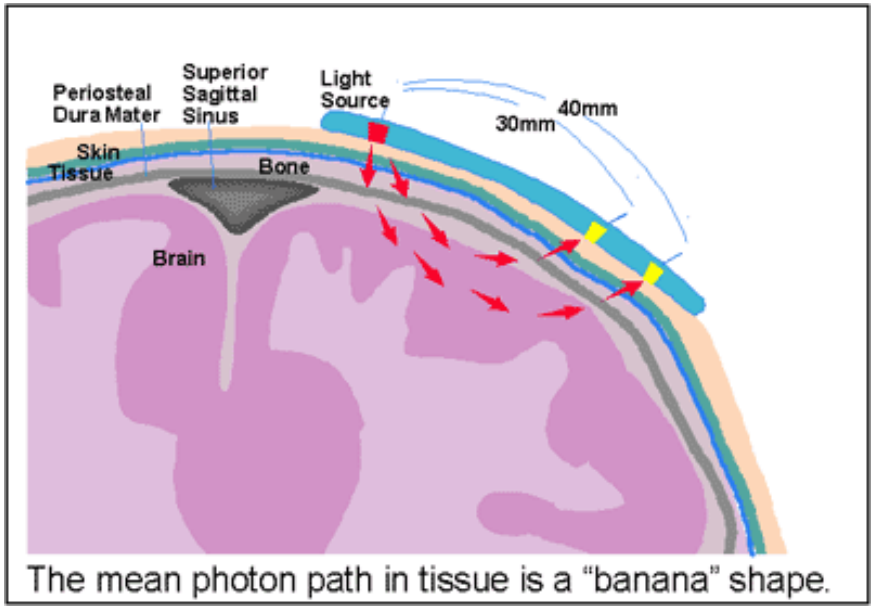


Optimal Flow of Selective Perfusion

- Depend on hypothermia
- Pressure monitoring
  - Radial artery pressure may not be accurate
- Flow
  - Approximately 10 ml/kg/min
  - Cerebral oxymeter may be helpful

Neurologic Monitoring

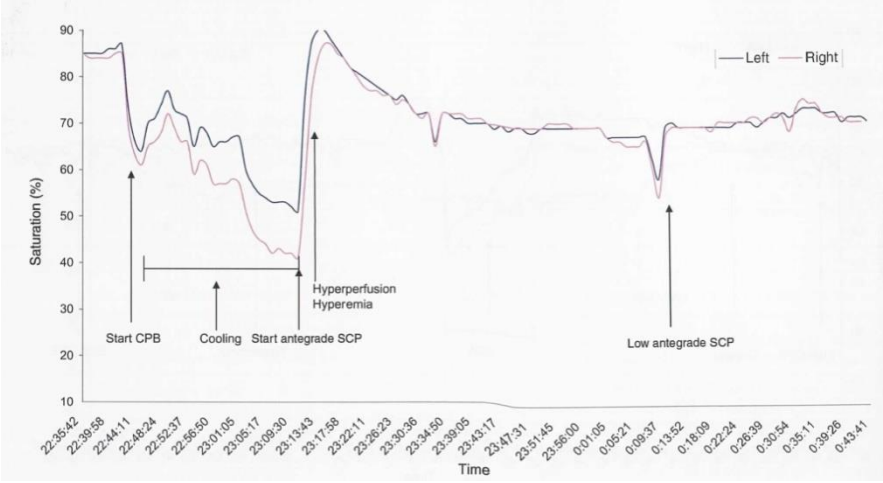
- Near-infrared spectroscopy (cerebral oxymeter)

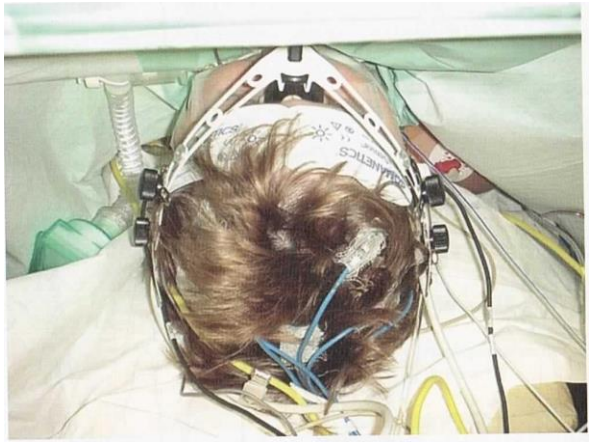


- Transcranial Doppler
- EEG
- Jugular venous oxygen saturation

Near-infrared Spectroscopy

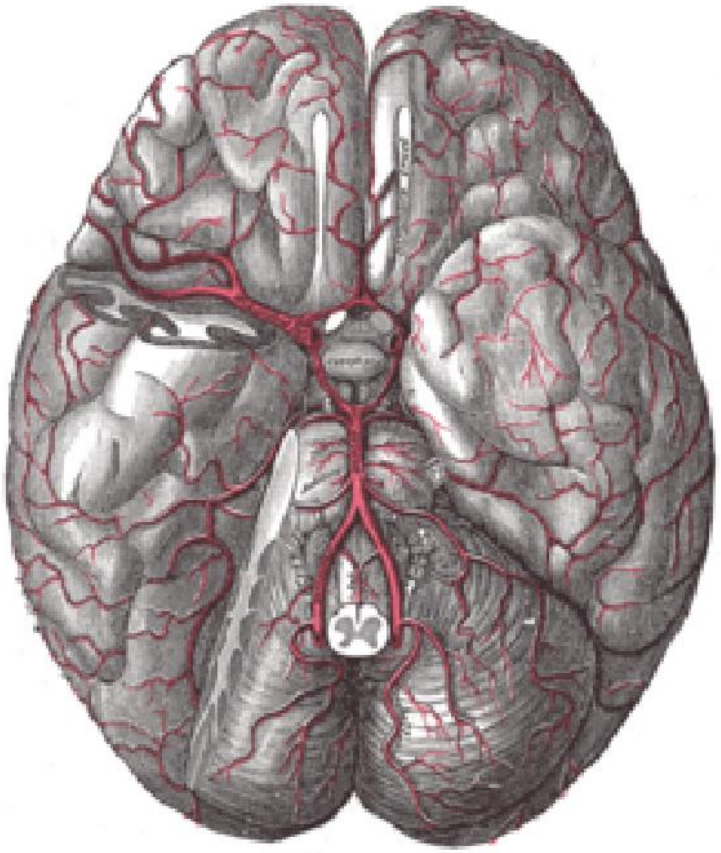
- Merits
  - Non-invasive
  - Continuous, real-time
  - Safe
  - Portable
  - Easy to interpret
- Drawbacks
  - Cannot monitor entire brain
  - Cannot differentiate causes
  - Bilirubin
  - Normal in dead brain

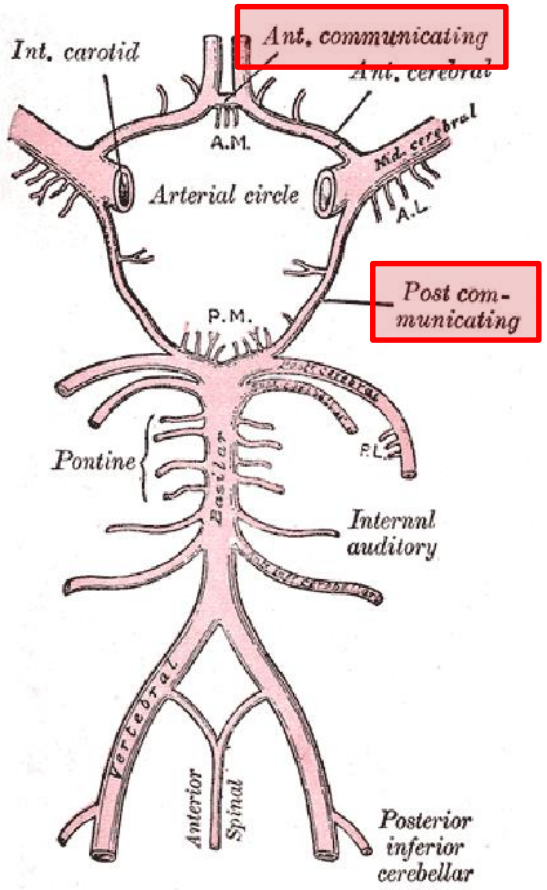




Circle of Willis

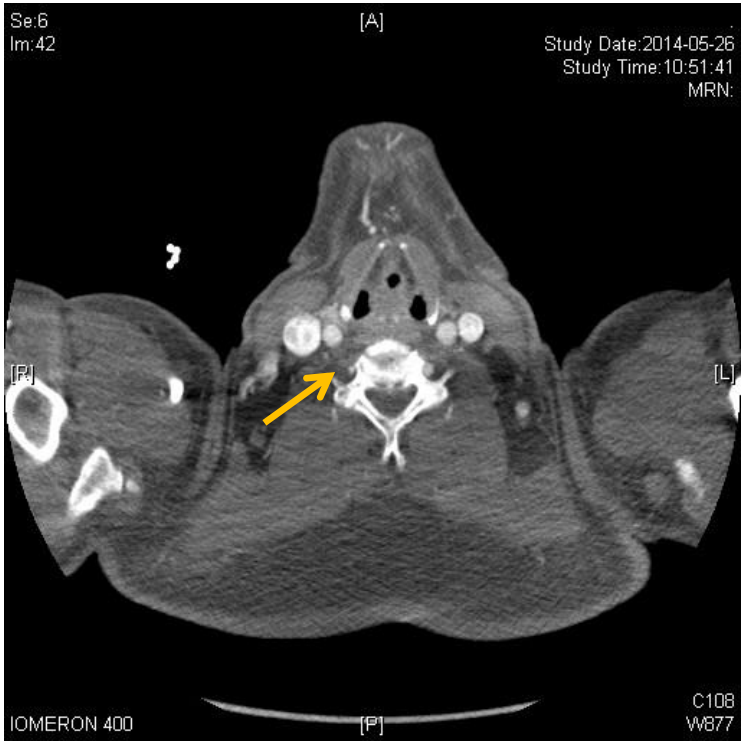
- Not intact: ~15%
- Cerebral oxymeter: usually frontal area





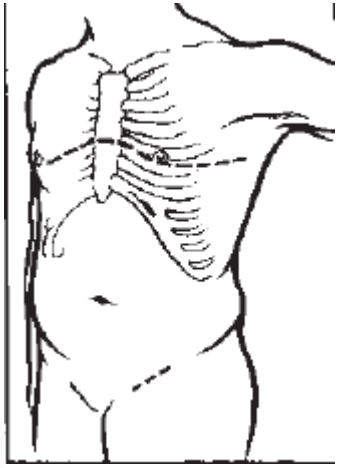
Variation of Circle of Willis

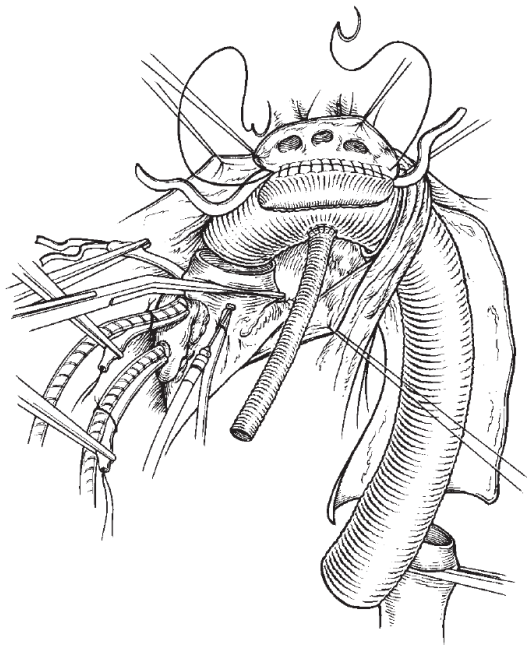
- Not uncommon
- Cerebral oxymetry: not helpful
- 3-vessel perfusion

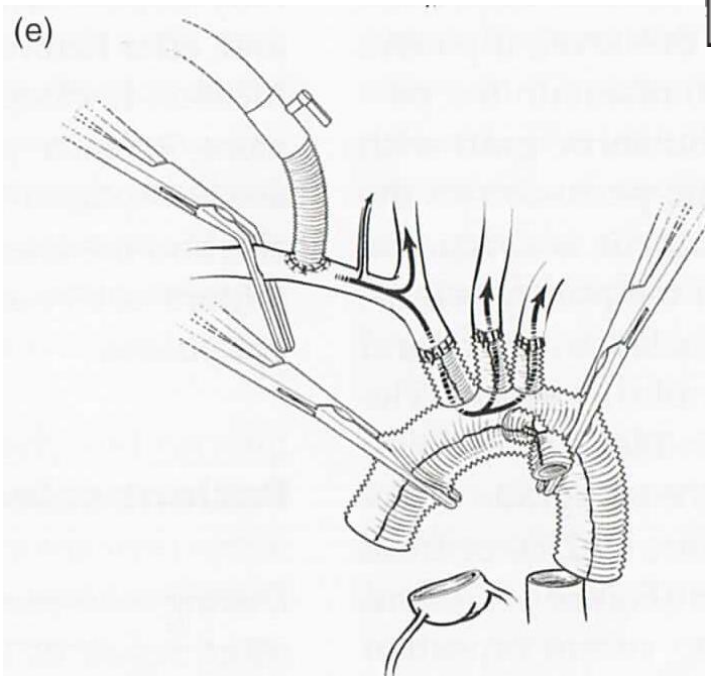


Arch-first Technique (I)

- Kouchoukos NT et al (ATS 2007)
- Extensive arch aneurysm
- Clamshell incision
- En bloc or branched graft technique







Arch-first Technique (II)

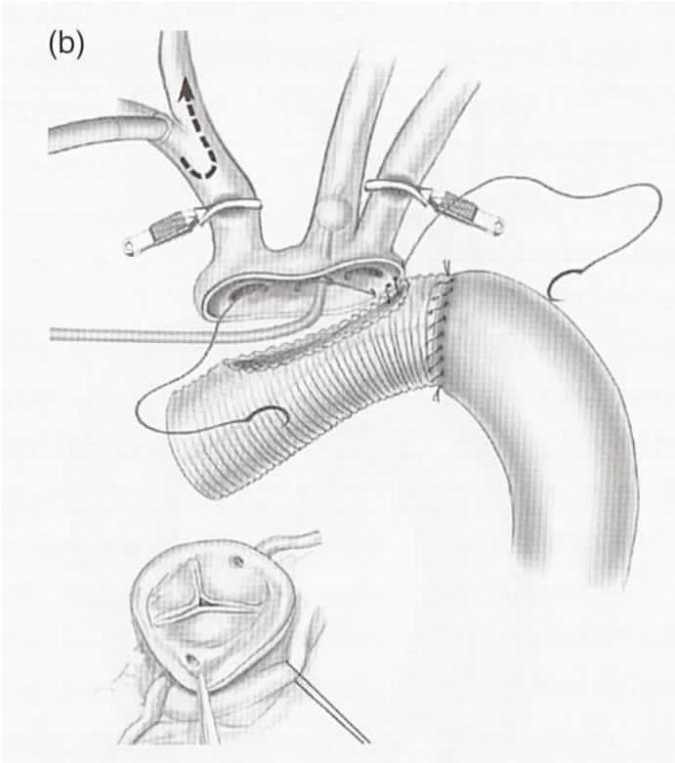
- N = 69
- Brief period circulatory arrest (≠ 10 min)
- Hospital mortality: 7.2%
- Bleeding: 13%

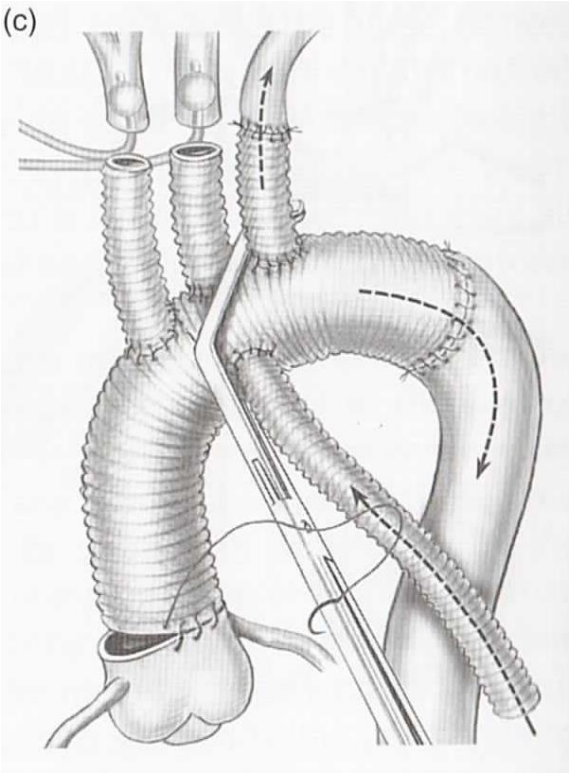
  Tracheostomy: 13%

  No permanent CVA

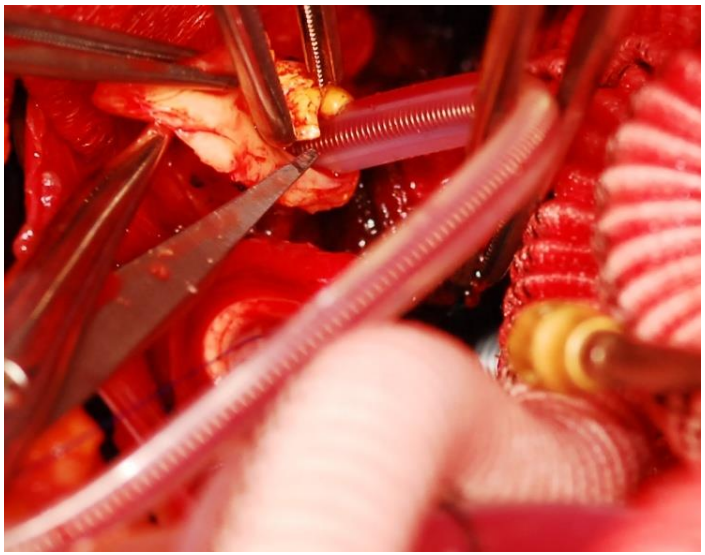
Distal-first Technique (I)

- En bloc or separate graft implantation
  - Antegrade selective cerebral perfusion
  - Moderate hypothermia





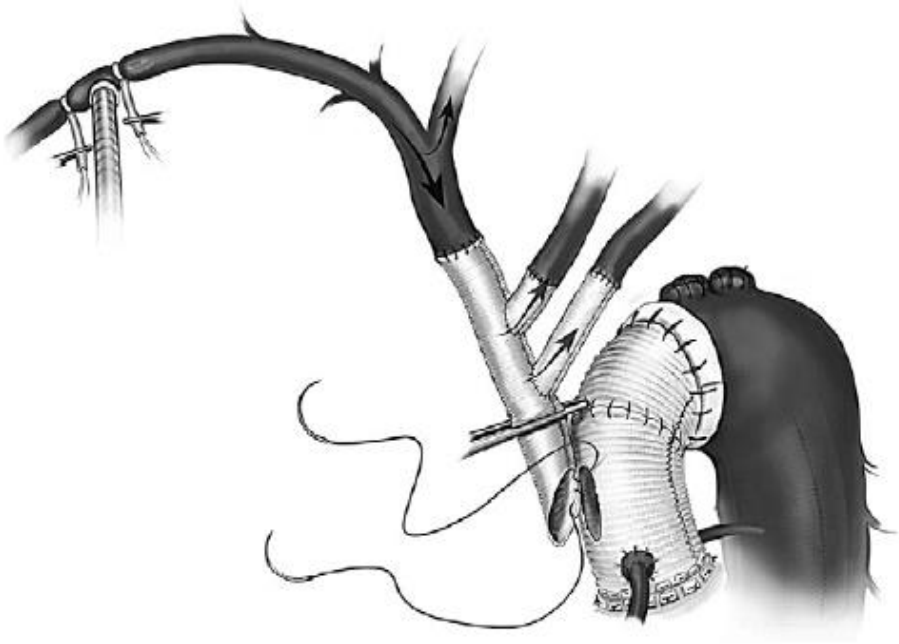
Distal-first Technique (II)



- Separate graft technique
- Kazui T et al (ATS 2007)
  - N = 472
  - In-hospital mortality: 9.3%
    (4.1% in recent 266)
  - Permanent neurologic dysfunction: 3.2%
- Sasaki H et al (ATS 2007)
  - N = 305 elective operation
  - Early mortality: 2.3%
  - Permanent neurologic dysfunction: 1.6%

Trifucated Graft Technique

- Spielvogel D. et al (ATS 2007;83:S791-5)
- Axillary a. cannulation
- DHCA & SCP
- Hospital death: 4.7%
- Permanent CVA: 4.1%



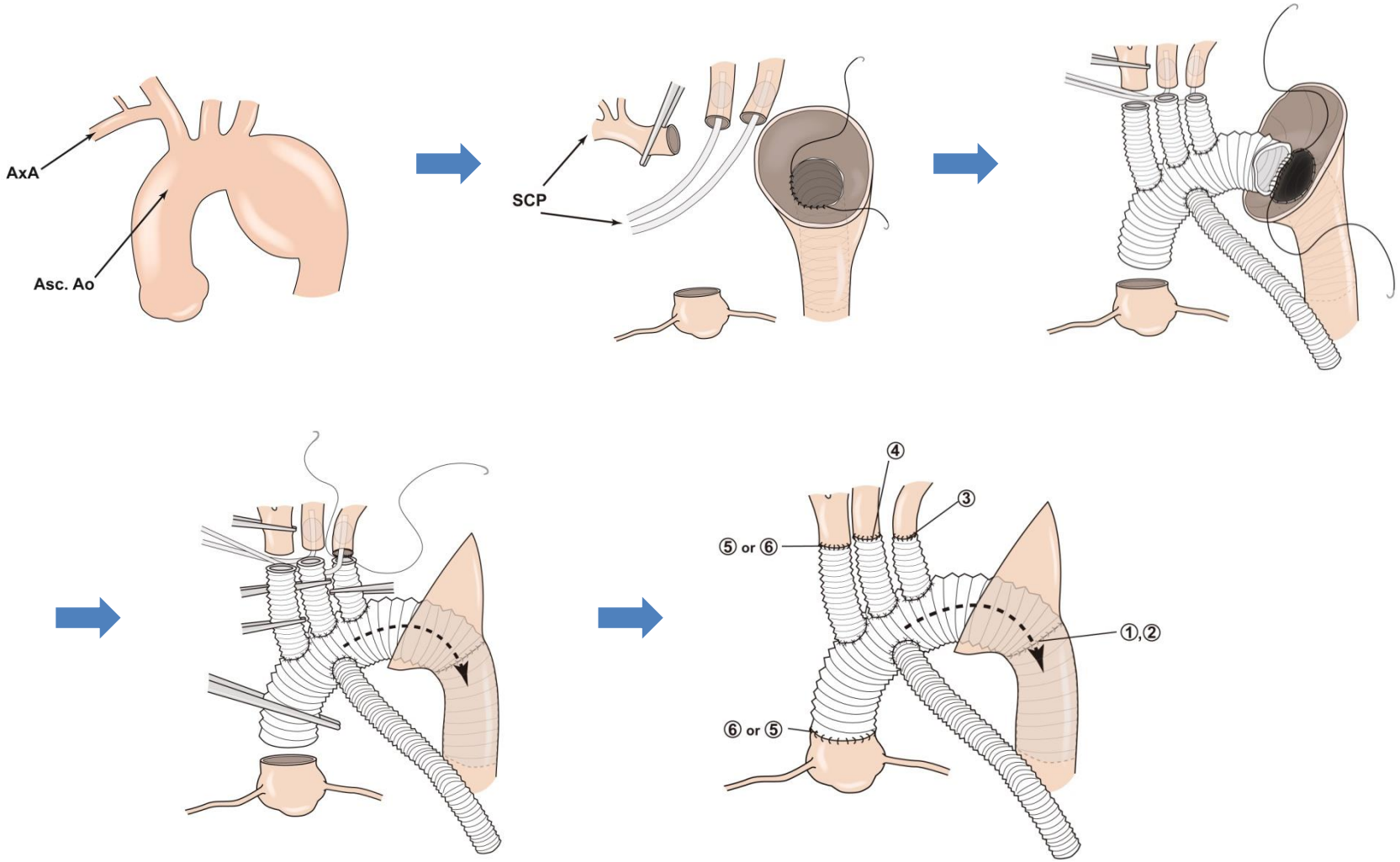
SMC Strategy for Total Arch Replacement

- Epiaortic US
- Axillary cannulation

  (ascending aorta cannulation if no atheroma)
- Moderate to deep (cooling to ≈ 25 ~ 27°C) hypothemia
- Selective cerebral perfusion
  - Innominate a. clamping or cannulation
  - Lt. CCA & Lt. Subclavian a. direct balloon cannulae
- Near-infrared spectroscopy
- Distal first technique using separate graft
- Rewarming during arch vessel anastomosis

SMC Technique

- Short segment insertion using separate graft



Thoracoabdominal Aortic Aneurysm

- Most challenging procedure

- High operative morbidity & mortality
  - Pulmonary complication
  - Paraplegia
  - ARF
  - Cerebral complication
  - Etc

OSR Current Results

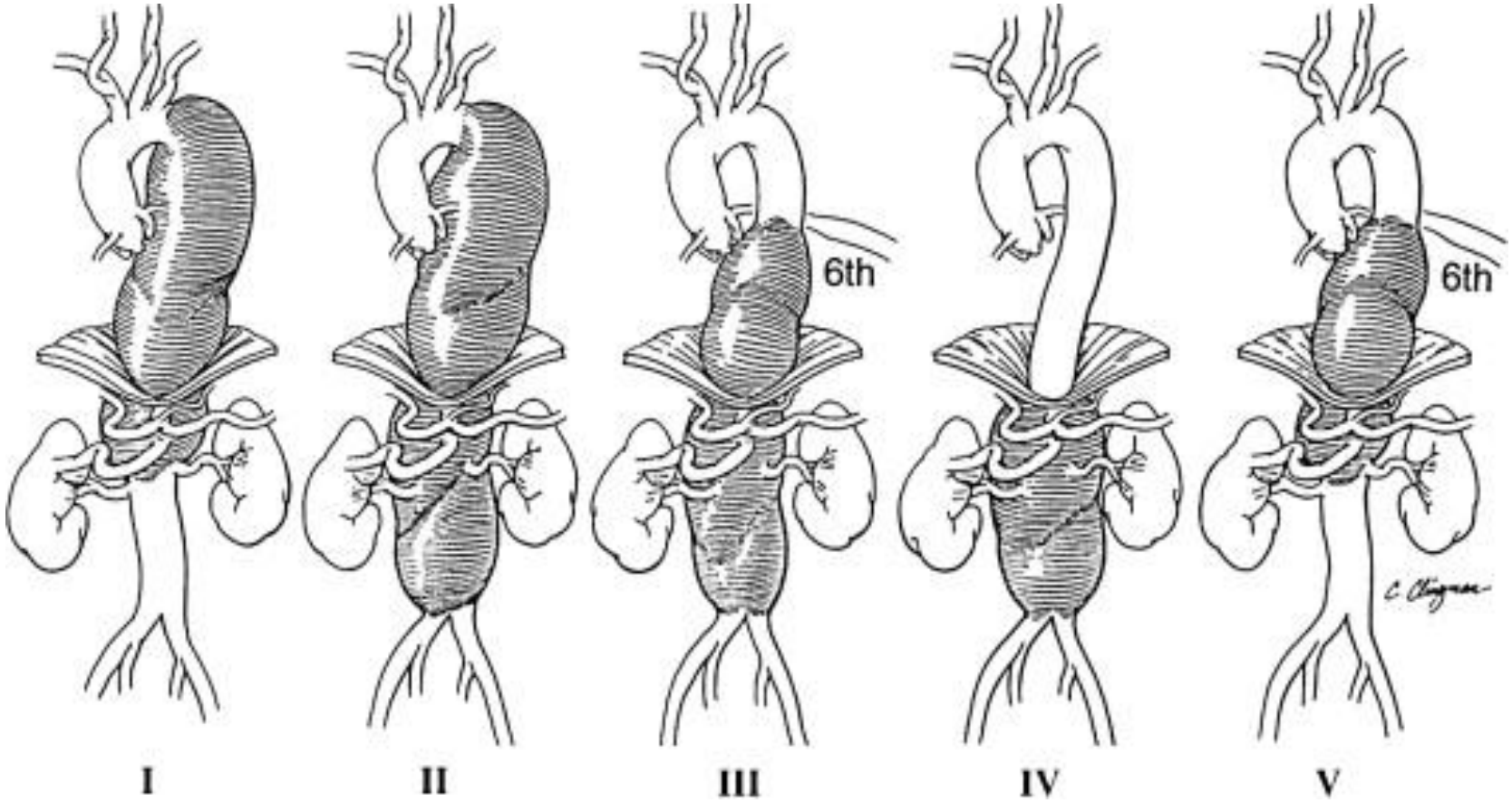
Table 4 Summary of clinical outcomes of open surgery for chronic type B aortic dissection

	First author	30-day mortality [%]	Stroke [%]	Spinal cord ischemia [%]	Renal ischemia [%]	Reoperation for bleeding [%]	Late reintervention [%]	Hospital stay (days)
Historic series	Reul	7 [17]	NR	NR	NR	NR	5 [12]	NR
	Jex	5 [14]	1 [3]	1 [3]	5 [14]	5 [14]	NR	NR
	Gandjbakhch	4 [33]	NR	NR	NR	NR	NR	NR
	Glower	2 [9]	NR	NR	NR	NR	5 [23]	NR
	Kawashima	7 [25]	NR	0	3 [11]	NR	NR	NR
	Fann	5 [15]	0	NR	NR	4 [12]	9 [26]	NR
	Safi	9 [10]	8 [9]	NR	NR	NR	NR	NR
	Okita	12 [15]	2 [3]	5 [6]	12 [15]	8 [10]	12 [15]	NR
	Zanetti	3 [15]	NR	1 [5]	3 [15]	NR	NR	NR
	Miyamoto	0	2 [5]	0	0	2 [5]	4 [10]	NR
Contemporary series	Nienaber	1 [8]	3 [25]	2 [17]	3 [25]	NR	NR	40
	Goksel	2 [13]	NR	0	NR	NR	3 [20]	NR
	Takagi	1 [3]	2 [5]	NR	4 [10]	1 [3]	2 [5]	NR
	Zoli	10 [10]	6 [6]	5 [5]	5 [5]	4 [4]	15 [14]	18.3
	Mutsuga	0	2 [6]	3 [9]	1 [3]	2 [6]	NR	NR
	Pujara	14 [8]	8 [5]	4 [2]	18 [11]	23 [14]	23 [14]	11[M]
	Corvera	2 [2]	1 [1]	3 [3]	1 [1]	4 [4]	8 [9]	NR
	Nozdrzykowski	2 [13]	2 [13]	2 [13]	5 [33]	5 [33]	0	24
	Conway	5 [6]	2 [2]	2 [2]	2 [2]	NR	6 [7]	13.5[M]
Mean	Historic series	15.2	5.3	4.6	13.5	NC	16.8	NC
	Contemporary series	7.5	5.9	5.1	8.1	8.1	11.3	NC
	Overall [range]	11.1 [0-33]	5.6 [0-13]	4.9 [0-13]	11.9 [0-33]	9.9 [0-33]	13.3 [0-23]	NC

(Ann Cardithorac Surg 2014;3:340-50)

Classification

- Crawford type



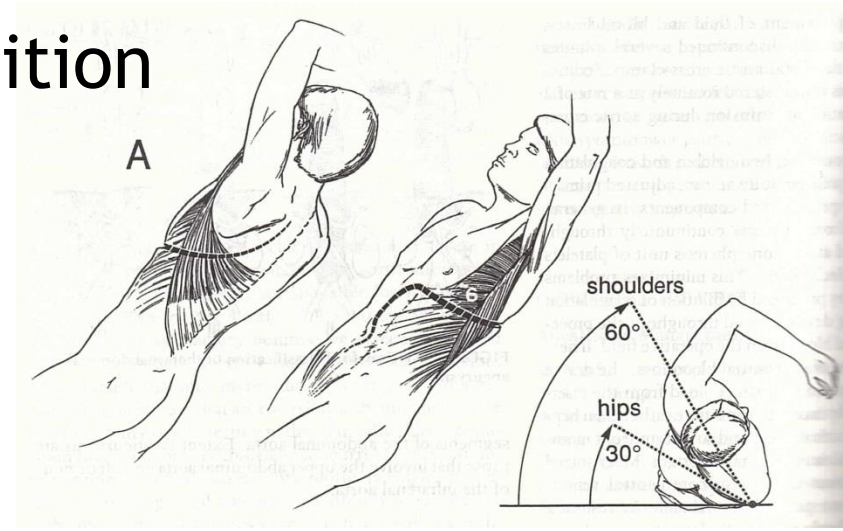
Anesthetic Preparations

- Double lumen E-tube
  - Not necessary lower thoracic aorta involvement only
- A-line
  - Radial artery (Rt >> Lt)
  - Femoral artery (Rt >> Lt), especially distal perfusion
- Large-bore peripheral IV line
- Central line & Swan-Ganz catheter
- Cerebral monitoring
  - Cerebral oxymeter, EEG, etc
- TEE
- Others

Exposure

- Bean bag, semi-lateral position
- Thoracoabdominal incision
- Intercostals
  - Type I & II: 6th ICS
  - Type III & IV: 7th ~ 9th ICS

  : if necessary, rib cutting or resection



- Abdomen
  - Midline vs pararectal incision
  - Transperitoneal vs retroperitoneal
- Diaphragm
  - Circumferential vs radial incision

Surgical Strategies

- To prevent complications
  - Brain injury, Organ ischemia & paraplegia, Pulmonary complications, Bleeding complications, etc
- Without extracorporeal circulation
  - Clamp-and-go technique without bypass
  - Passive shunt
- With extracorporeal circulation
  - LA-femoral without oxygenator
  - Femoro-femoral bypass with oxygenator
    - Mild hypothermia
    - Deep hypothermic circulatory arrest

Clamp-and-Go Technique

- Proximal clamping & hemodynamic disturbances
  - – Peripheral vascular resistance & afterload ↑ ↑
  - → proximal hypertension
    ventricular stain & stroke work ↑
    pulmonary congestion ↑
    CSF pressure ↑
  - → Epi & NE, lactate, renin ↑
  - → ischemic injury
- Release of aortic clamp
  - – Preload & afterload ↓ ↓
    reperfusion injury, washout metabolites, shock

Clamp-and-Go Technique

- Slow clamp apply & pharmacological mx.
- Tolerable ischemic time: less than 30 (35~45)min
- Merits
  - No anticoagulation
  - Simple
- Limited to simple cases in experienced centers

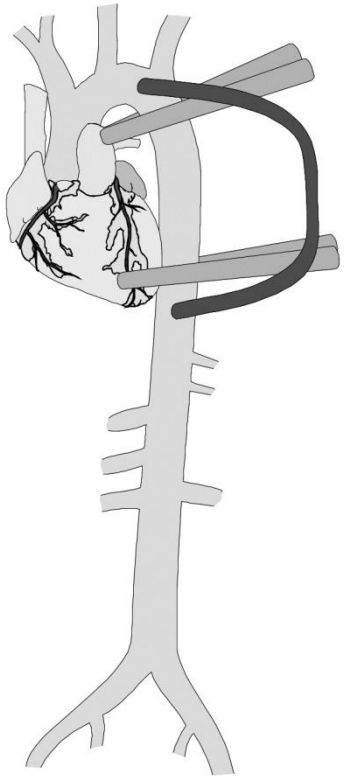
Table 2. Incidence of p/p Following TAAA Repair in Comparative Studies Evaluating LHB

	Extent I			*Extent II*		
Author	*No. Without LHB (%)*	*Total No. of Patients With LHB (%)*	*P Value*	*No. Without LHB (%)*	*Total No. of Patients With LHB (%)*	*P Value*
Bavaria et al[5]*	3/11 (27.3)	0/14	0.072	2/5 (40.0)	2/12 (16.7)	0.330
Safi et al[4]*	2/30 (6.7)	1/56 (1.8)	0.278	9/22 (40.9)	11/85 (12.9)	0.003
Coselli series	13/320 (4.2)	9/290 (3.1)	0.866	29/259 (11.2)	17/375 (4.8)	0.019

(Semin Thorac Cardiovasc Surg 2003)

Passive Shunt

- Gott shunt
  - 1955 Etheredge et al, type IV(?)
  - 1956 DeBakey et al, TAA
- Axillo-femoral bypass
  - 1955 Comerota et al,
  - 1977 Taylor et al,

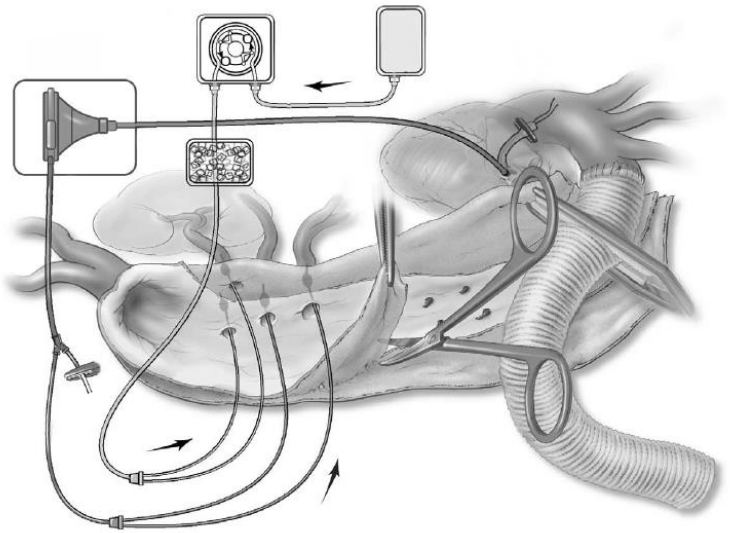


- No systemic anticoagulation
- Can not regulate pressure & flow actively
- Atherosclerotic aorta partial clamping
- No direct visceral perfusion

LA-Femoral (des. aorta) Bypass

- Coselli, Safi, Svensson et al
- Centrifugal pump

  No oxygenator
- Reduced heparinization
- No suction or reservoir



Variable	Extent I			Extent II		
	Without LHB (n = 325)	With LHB (n = 290)	P Value	Without LHB (n = 259)	With LHB (n = 376)	P Value
Mean intraoperative ischemic times (min):						
Total aortic clamp	31.8	46.3	<0.0001	51.6	68.8	0.0001
Intercostal ischemic	31.9	34.5	0.016	36.3	31.5	0.0939
Renal ischemic	31.6	45.8	<0.0001	42.5	57.0	0.0001
Perioperative complications:						
Mortality						
No. of intraoperative (%)	5 (1.5)	0	0.437	0	1 (0.3)	0.572
No. of 30-d (%)	25 (7.7)	5 (4.1)	0.739	15 (5.8)	28 (7.4)	0.270
No. of in-hospital (%)	31 (9.5)	7 (5.7)	0.108	19 (7.3)	35 (9.3)	0.857
No. of p/p†‡ (%)	13 (4.2)	9 (3.1)	0.866	29 (11.2)	17 (4.5)	0.019
No. of acute renal failures‡ (%)	18 (7.1)	5 (4.1)	0.538	26 (10.0)	30 (8.0)	0.896
No. of bleeding complications (%)	5 (1.5)	3 (1.0)	1.000	10 (3.9)	11 (2.9)	0.972
No. of strokes‡ (%)	10 (3.1)	6 (2.1)	0.707	4 (2.8)	1 (0.5)	0.764
No. of cardiac complications (%)	26 (8.0)	26 (9.0)	0.936	24 (9.3)	33 (8.8)	0.719
No. of pulmonary complications‡ (%)	128 (40.0)	93 (32.1)	0.151	97 (37.5)	119 (31.7)	0.278
No. of wound dehiscence‡ (%)	13 (4.1)	10 (3.4)	0.959	9 (3.5)	25 (6.7)	0.298

Total CPB with TCA

- Kouchoukos, Griepp, Fehrenbacher, etc
- Minimal dissection
- No need for proximal & sequential ACC
- No need for selective renal & visceral perfusion
- Easy access to proximal arch & ascending aorta
- Bloodless field
- Return of the majority of shed blood
- Protection of the brain, spine, kidney, visceral
- Excessive blood loss
- Mortality & morbidity (pulmonary cx.) ↑

(Semin Thorac Cardiovasc Surg 2003)

Hypothermic Cardiopulmonary Bypass and Circulatory Arrest for Operations on the Descending Thoracic and Thoracoabdominal Aorta

Nicholas T. Kouchoukos, MD, Paolo Masetti, MD, Chris K. Rokkas, MD, and

N = 192, TAAA (114)
Circulatory arrest time: 38min
No other adjuncts for spinal cord protection
Results:
30-day mortality: 6.8% (15% in type II)
emergent (40%): elective (2.9%)
Paraplegia (2.7%), Renal failure (2.2%),
tracheostomy (9%), CVA (2%), bleeding (5%)
Conclusion
DHCA provides safe and substantial protection against end organs.
Limits
Long cardiopulmonary bypass time
Bleeding & adverse outcome ?

Background. Hy
with circulatory arr
ations on the distal
and the thoracoabd
of this technique w
simple aortic clamp
regional hypotherm
Methods. One hu
range, 20 to 83 year
coabdominal aortic
placement of the in
thermic cardiopul
circulatory arrest (n
used when the locat
placement of clamp
or (in 161 patient
thoracoabdominal
the risk for develop
was judged to be i
bar arteries were at
101 of the 161 patients (63%) who had extensive aortic
replacement. No other adjuncts for spinal cord protection
were used.

Results. The 30-day mortality was 6.8% (13 patients). It
was 40% (8 of 20) for patients having emergent opera-

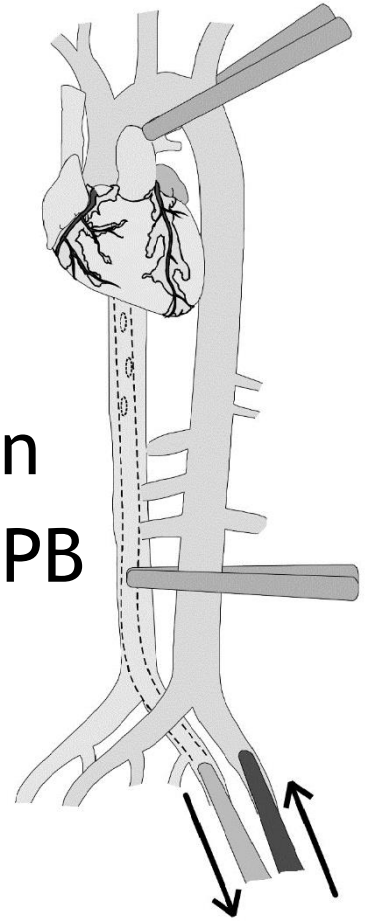
rupture) and 2.9% (5 of
he 90-day mortality was
curred in 4 and parapa-
186 operative survivors
d be assessed postoper-
rvivors with thoracoab-
aplegia occurred in 1 of
2 with extent II, and 2 of
patient (extent II) devel-
stoperative day after a
e 47 patients with aortic
Among the 186 operative
required in 4 patients
ort in 18 (10%), reopera-
anical ventilation (≥ 48
stomy in 17 (9%). Four

rdiopulmonary bypass
s safe and substantial
renal, cardiac, and vis-
ceral organ system failure that equals or exceeds that of
other currently used techniques but without the need of
other adjuncts.

(Ann Thorac Surg 2002;74:S1885–7)

Femoro-Femoral Partial Bypass

- Stanford university
- Improved exposure & adjunctive equip.
- Enhanced oxygenation
- Myocardial protection
- Systemic hypothermia & organ protection
- Versatility to allow conversion to total CPB
- Versatility in arterial cannulation
- Individually perfuse branch
- Systemic anticoagulation
- Inflammatory responses



(Semin Thorac Cardiovasc Surg 2003)

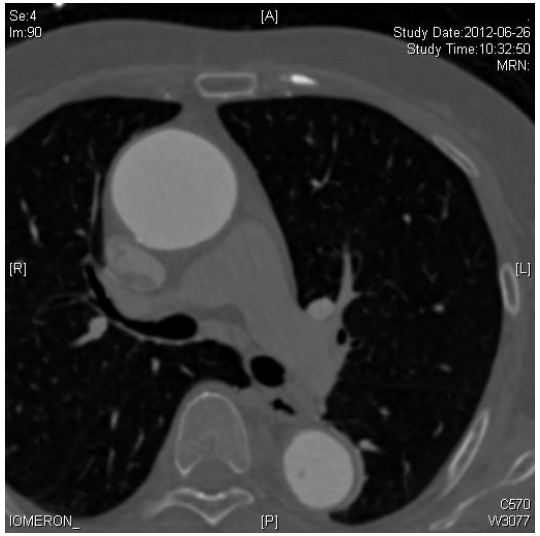
PVD

- Atherosclerotic iliac or femoral arteries
- Not uncommon

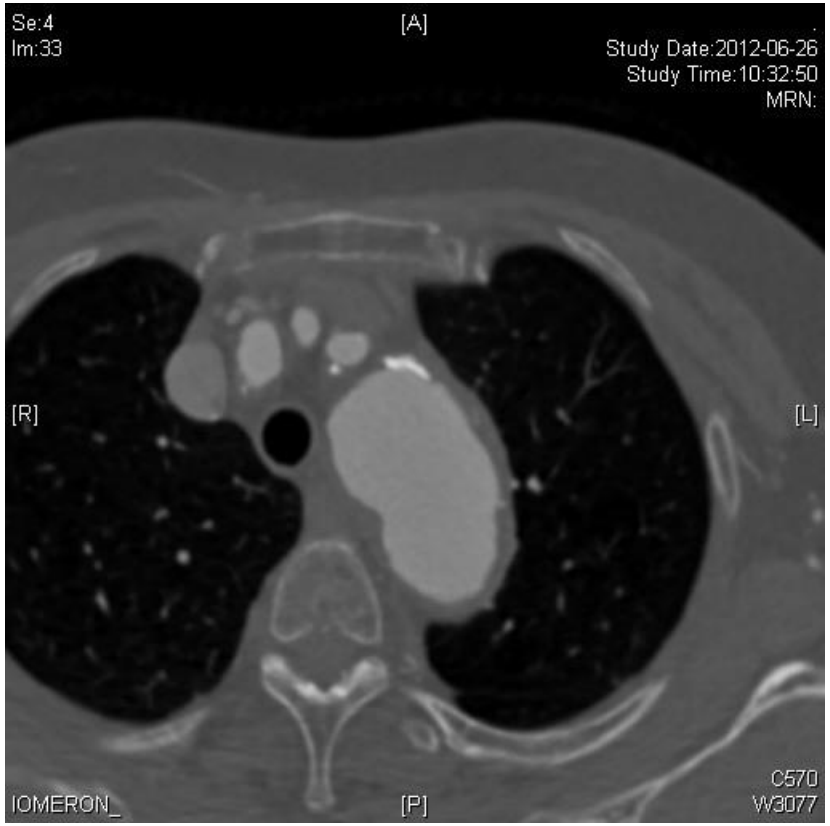
- Preop. evaluation
- Rt. Femoral pr. Monitoring
- Descend. aortic cannulation

Hostile Aorta

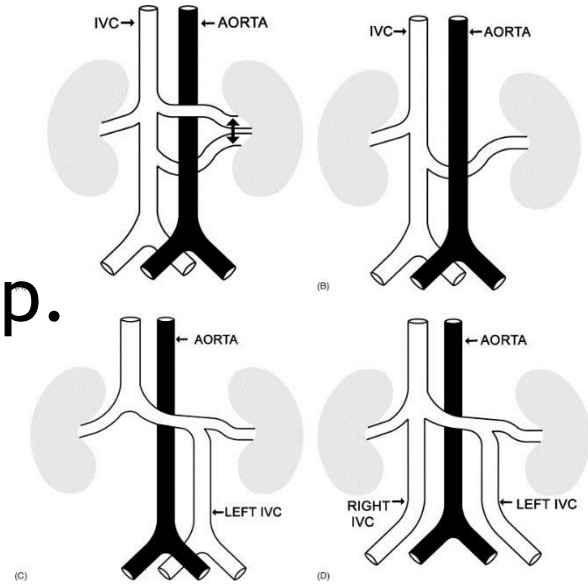
- ACC site calcification or atheroma
  → embolic complications



- Preop. evaluation
- Digital palpation
- Epi-aortic probe
- ACC at safe area
  or Total circulatory arrest

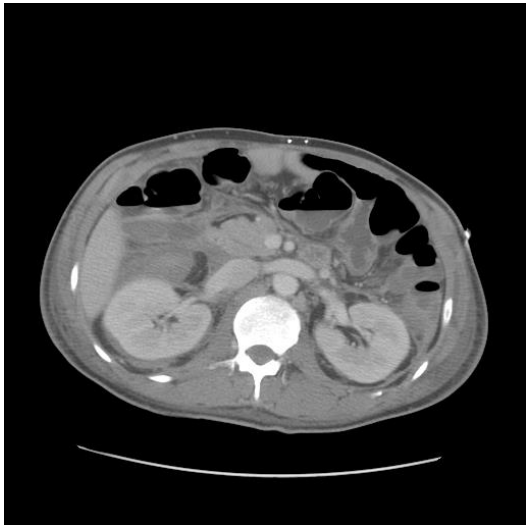


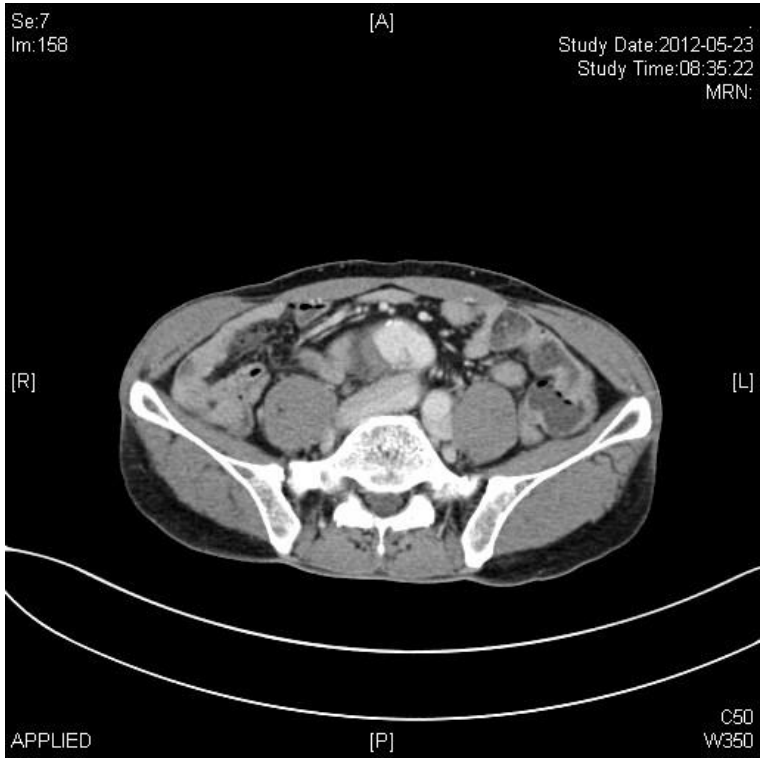
IVC Injury



- IVC anomaly: 6.65% in aortoiliac op.
- Occasionally occur in normal IVC

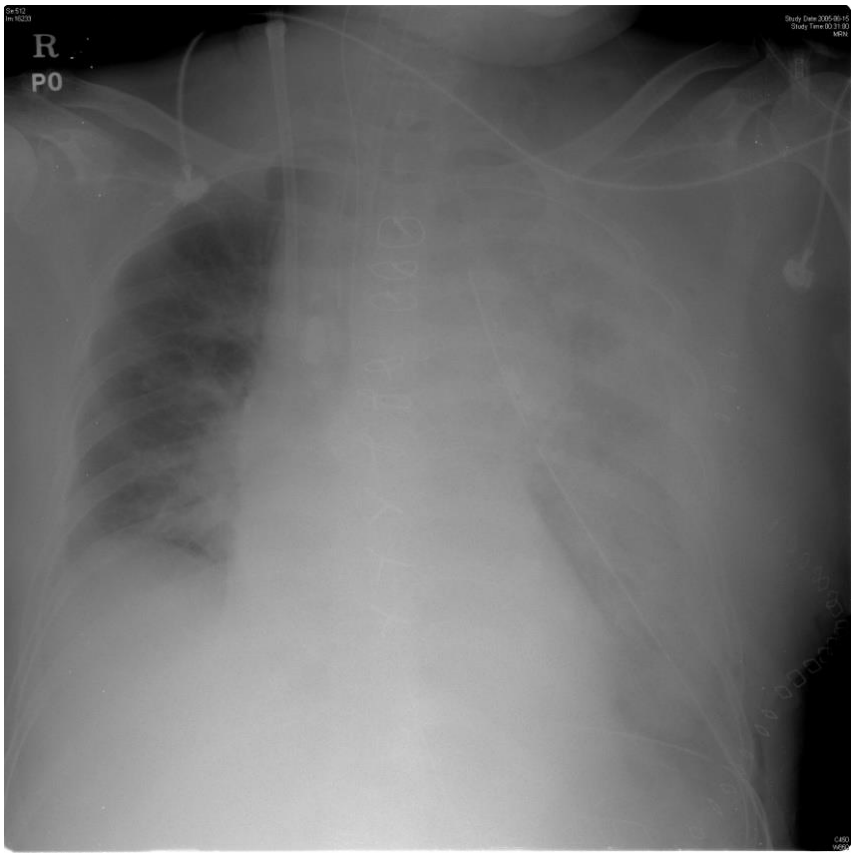
- Preop. evaluation
- Gentle catheter procedure
- TEE monitoring





Pulmonary Injury

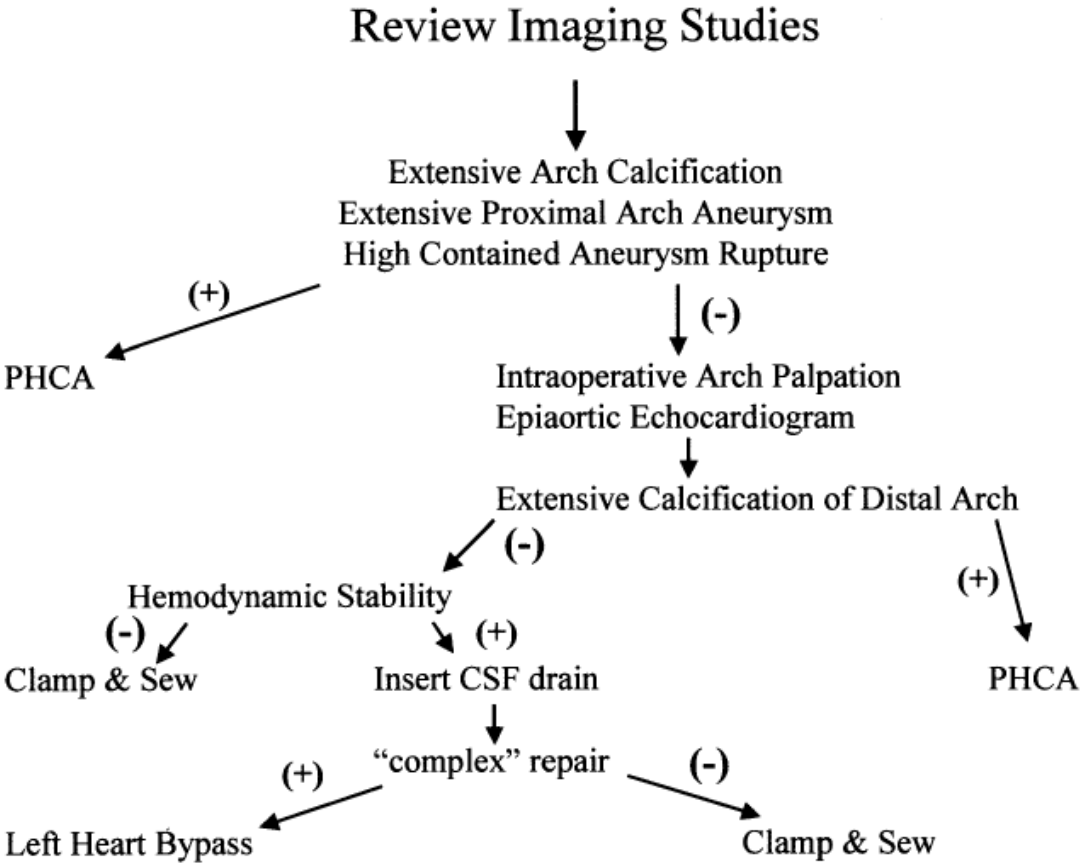
- Underlying lung problems
- Lung adhesion (ex, redo-aortic surgery)
- Lung injury during dissection
  + CPB with heparin



- Gentle dissection
- Staged operation
  (Elephant trunk, etc)

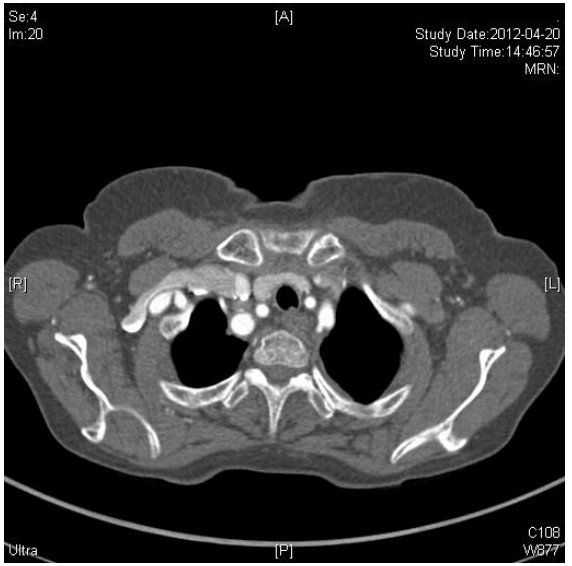
Integrated Approach ?

- Cornell university
- Complex:
  - Extent II
  - ACC > 30 min
  - LV function ↓
  - Dissection (+)

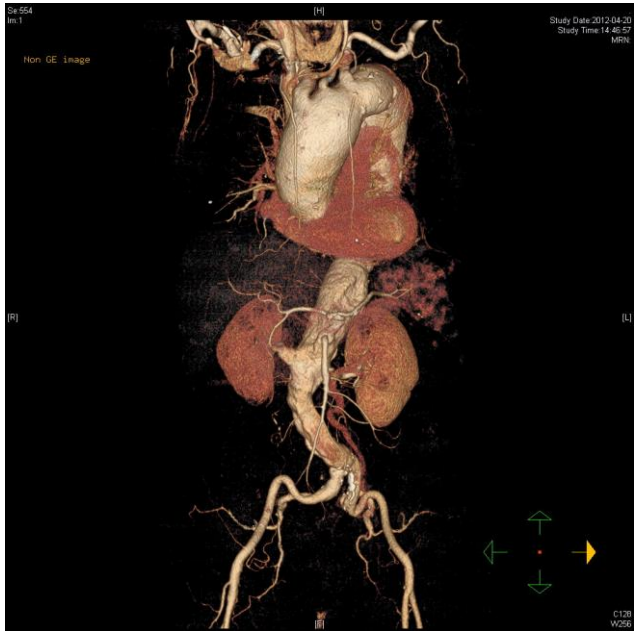


(Ann Thorac Surg 2005)

Mega Aorta



- F/77
- PMHx: HT (+), hysterectomy (5YA)
- PI: incidentally founded aortic aneurysm during work-up for R/O asthma
- General condition: not too bad
- Cardiac Echo: TR (+)
- CAG: minimal change
- FEV_1/FVC=1.27/2.15 L

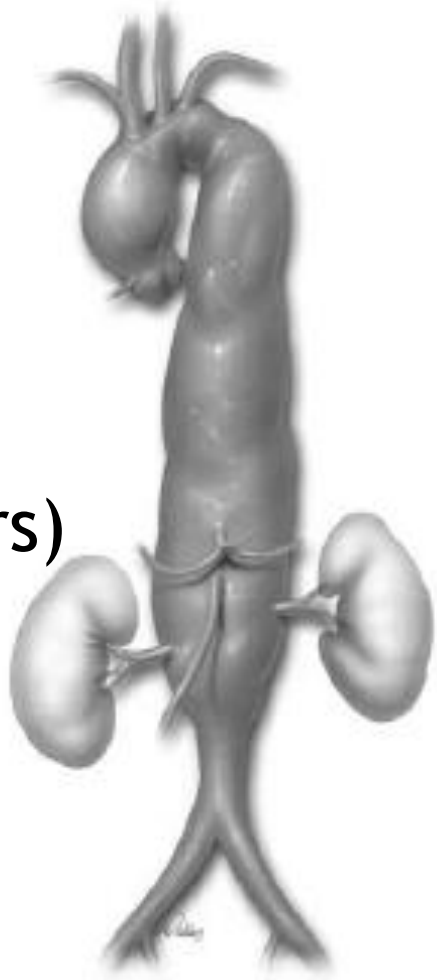


Plan?

- Medication only?
- Intervention?
- Operation?
  - Conventional? Or hybrid?
  - One stage? or 2nd or 3rd stage
  - Single admission or multiple admissions?
  - Interval?
- Present courses
  - ‘12. 6. 5: Ascend. & total arch repl. + elephant trunk
  - ‘12. 6.25: Descend. thoracic aorta repl.
  - ‘12. 7.14: discharge
  - Present: OPD f/u

Mega Aorta Syndrome

- A rare condition
- Multilevel aneurysmal change
- Sometimes, the whole aorta,
  from the coronary ostia to the iliac
- Disease progression is slow (over years)
- Mostly symptomatic before
  catastrophic presentation



Treatment Strategy

- Open one-stage total
- Open staged operation with elephant trunk
- Hybrid procedure
  - 1st total arch replacement + 2nd endovascular
  - 1st debranching + 2nd endovascular
- Frozen elephant trunk
  - 1st total arch replacement
  - 1st debranching
- Others

Extended replacement of the thoracic aorta†

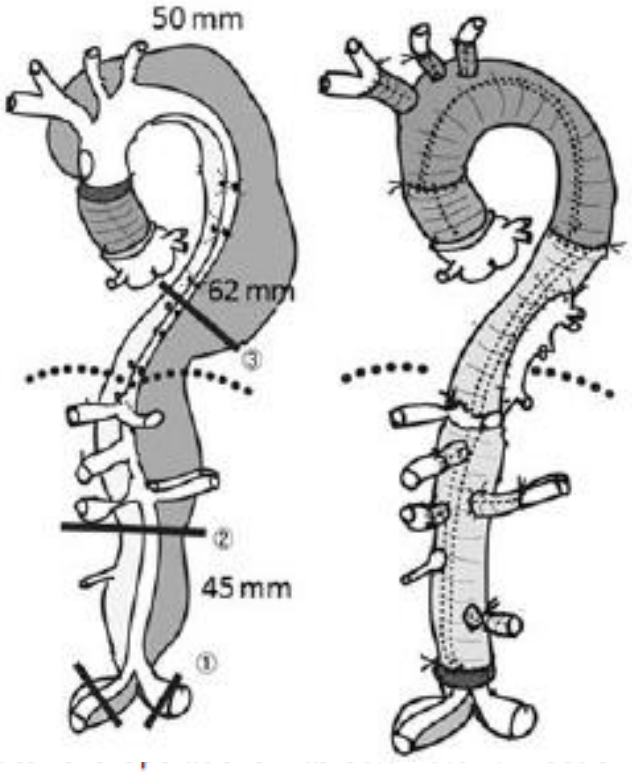
Yutaka Hino, Kenji Okada, Takanori Oka, Takeshi Inoue, Akiko Tanaka, Atsushi Omura, Hiroya Kano and Yutaka Okita*

OBJECTIVES: We present our experience of total aortic arch replacement.

METHODS: Twenty-nine patients (21 males and 8 females; mean age 63.3 ± 13.3 yea … went graft replacement. The pathology of the diseased aorta was non-dissecting a … aortic dissection in 18 patients (acute type A: one, chronic type A: 11, chronic type … prev … men … post … seve … cisio … asce … diop … dom … atriu …

N = 21 (ascending ~ abdominal arota: 8)
Age: 63.3 ± 13.3
Various incision & cannulation techniques
30-day mortality: 2 (6.6%)

Actual survival at 5 Yr: 80.6 ± 9.0%
Freedom from aortic event at 5 Yr: 96.0 3.9%
Conclusion
Satisfactory results using specific strategies and appropriate organ protection.



RESU … (rupt … rupt … the subsequent aortic events was 96.0 ± 3.9% at 5 years.

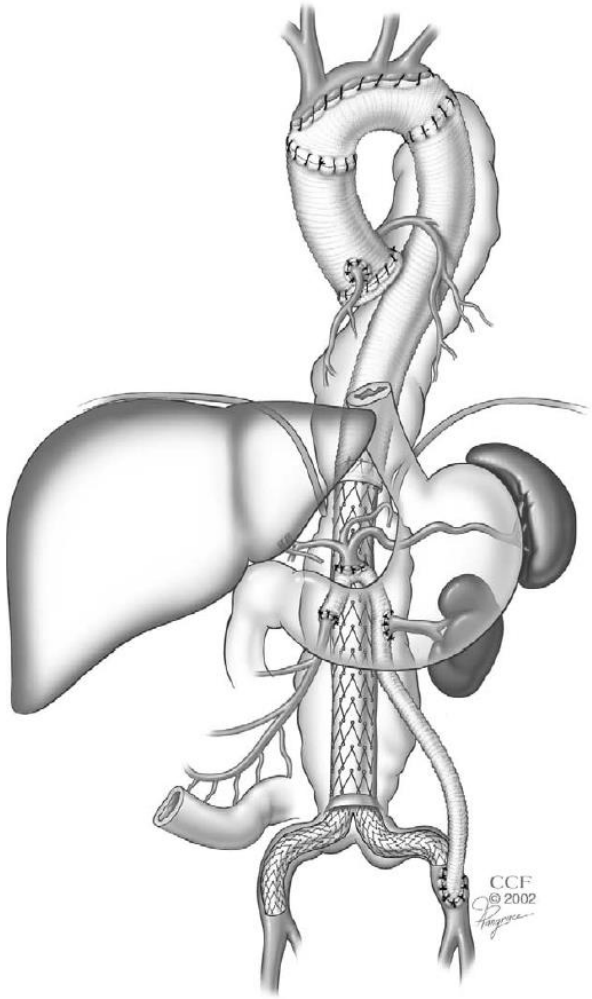
CONCLUSIONS: Our treatment method for extensive thoracic aneurysms achieved satisfactory results using specific strategies and appropriate organ protection according to the aneurysm extension in the selected patients.

Elephant Trunk Procedure: Newer Indications and Uses

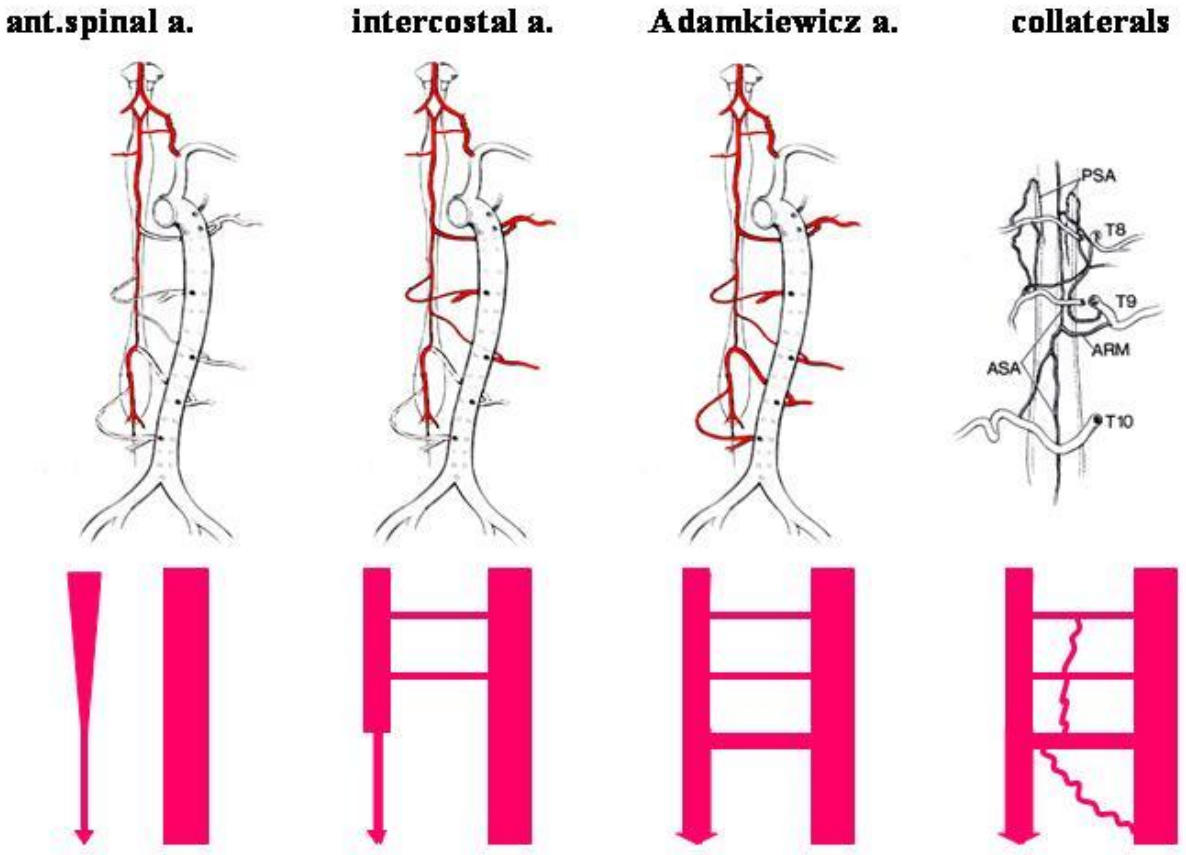
Lars G. Svensson, MD, PhD, Kyung-Hwan Kim, MD, Eugene H. Blackstone, MD,
Joan M. Alster, MS, Patrick M. McCarthy, MD
Joseph F. Sabik, MD, Richard S. D'Agostino, M
Delos M. Cosgrove, MD

Background. The elephant trunk procedure is used for valve
extensive aortic aneurysms. We evaluated its safety,
newer ind
tion on su
Method
patients (a
procedure
The trunk
ing aorta a
arch graft
left subcl
dissection
syndrome
reoperatio
was adjur
In 15 pati
the left subclavian and common carotid arteries. Coro-
nary artery bypass was performed in 36 (38.4%) and aortic

N = 93
1st stage 30-day mortality: 2 (2.2%)
Death during interval: 11 (12.1%)
2nd stage op. : 47 (57%)
Open thoracotomy (40)
Stent graft (7)
Early death: 4 (8.5%)
Conclusion
It is safe and should be used more with initial cardiac surgery.



Spinal Cord Protection during TAAA



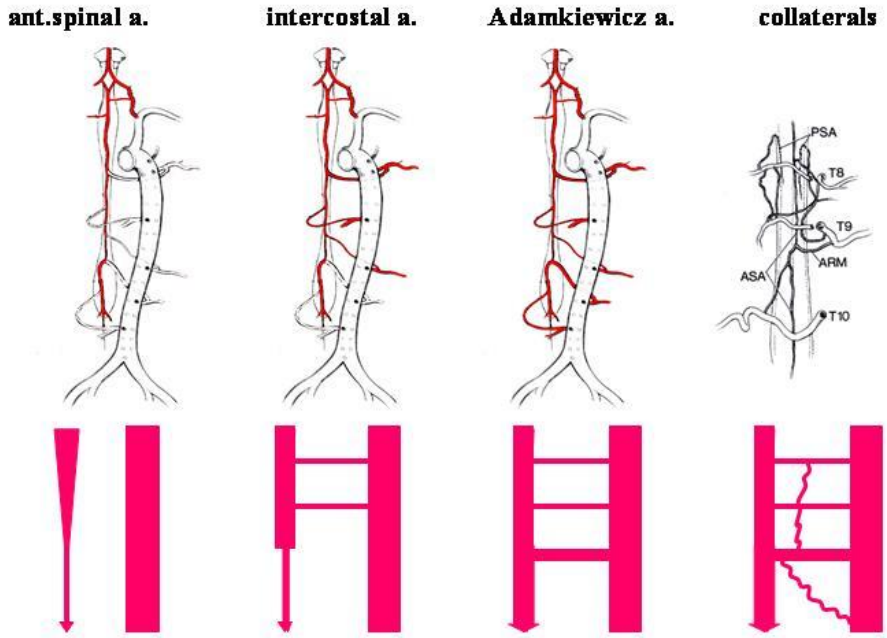
Risk Factors

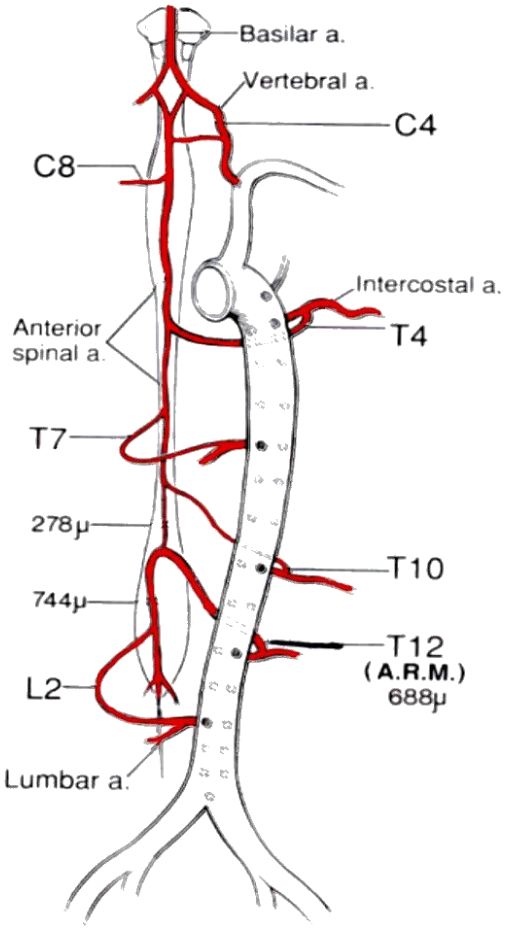
- Extent or coverage of aorta
- Lower thoracic & upper lumbar
- Abdominal aortic pathology or surgery
- Subclavian a. or hypogastric a.
- Old age
- Emergent procedure
- Renal failure
- Bleeding
- Hypotension
- etc

(Semin Vasc Surg 2009;22:187-92)

Blood Supply of Spinal Cord

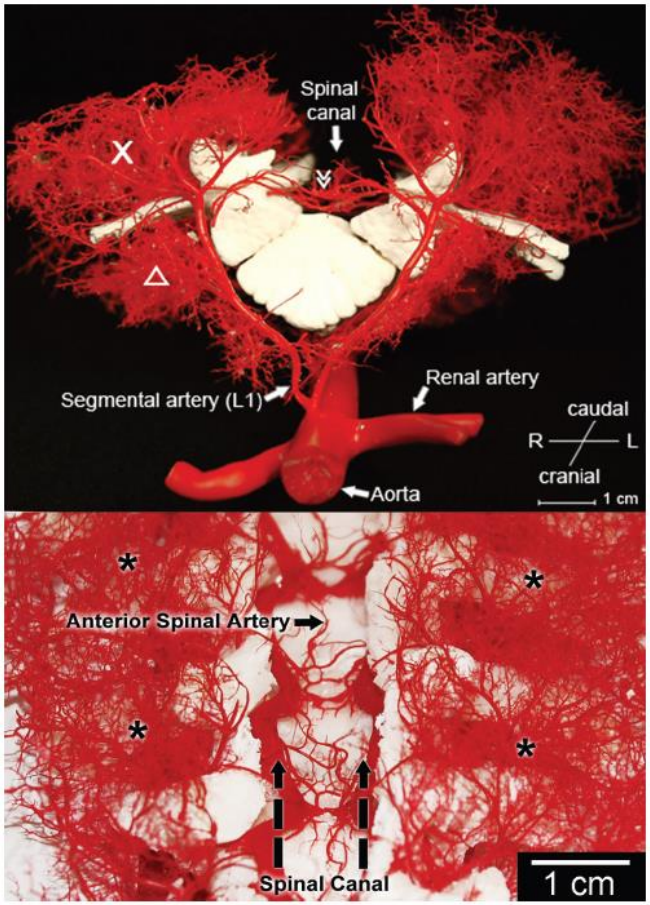
- Anterior spinal artery
- Intercostal arteries
- Adamkiewicz artery
- Collateral network

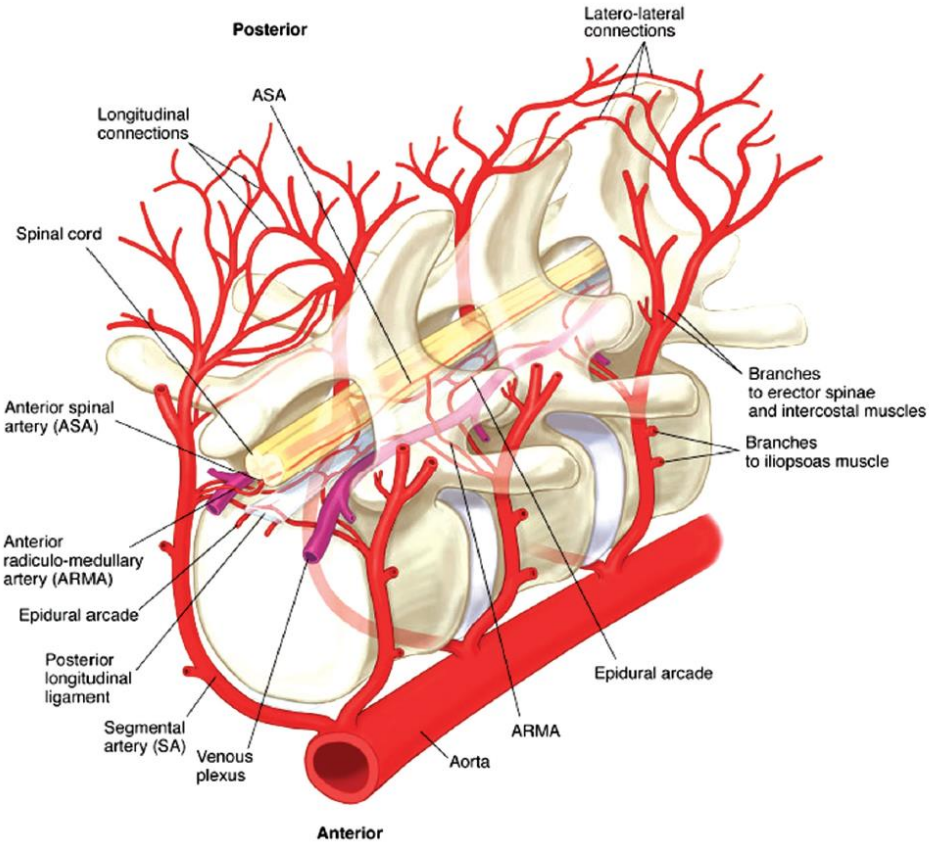




Collateral Network Concept

- Epidural arterial arcades
- Extraspinal network: paraspinal m.

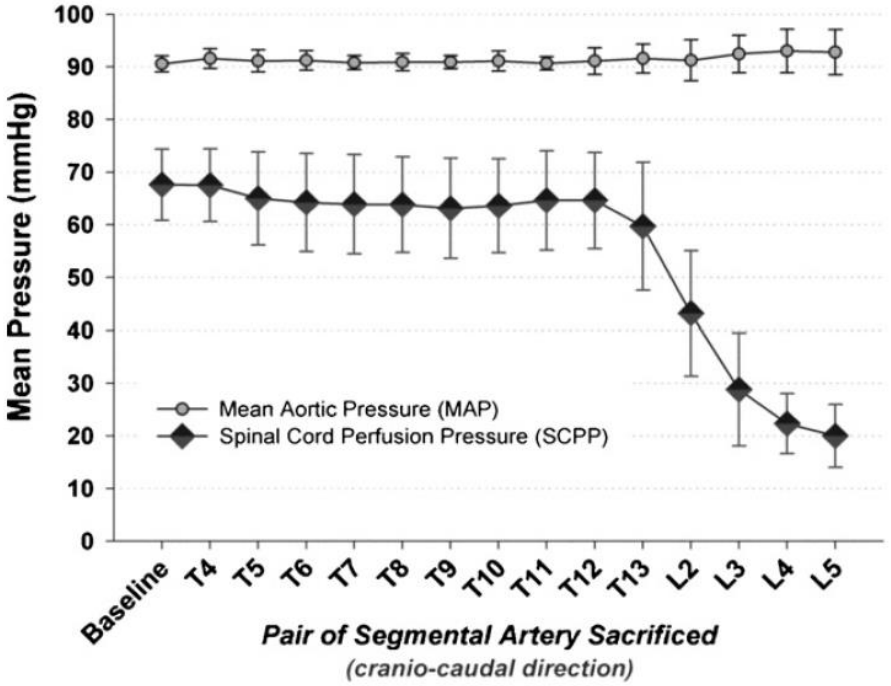


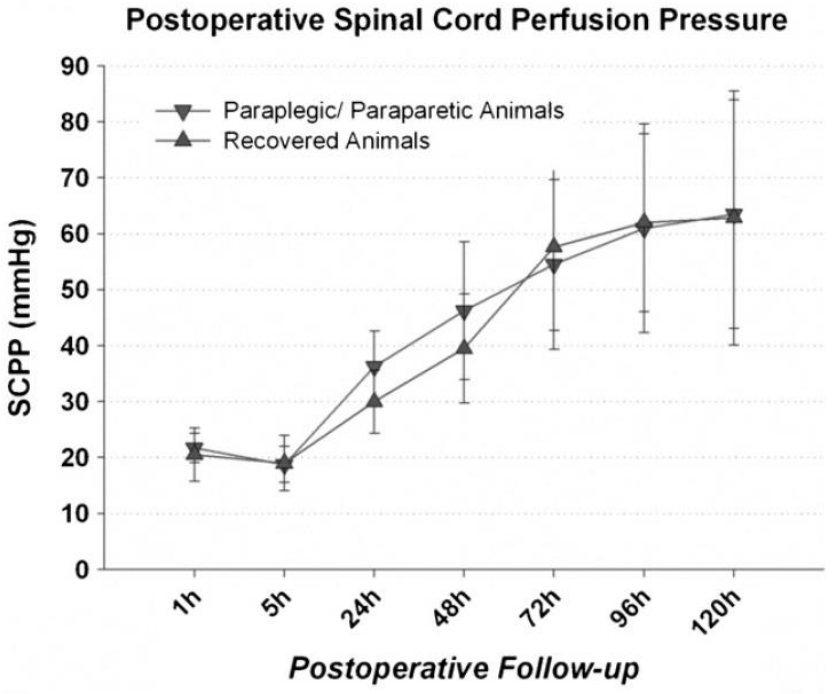


(Perspect Vasc Surg Endovasc Ther 2011;23:214-22)

Spinal Cord Perfusion Pressure

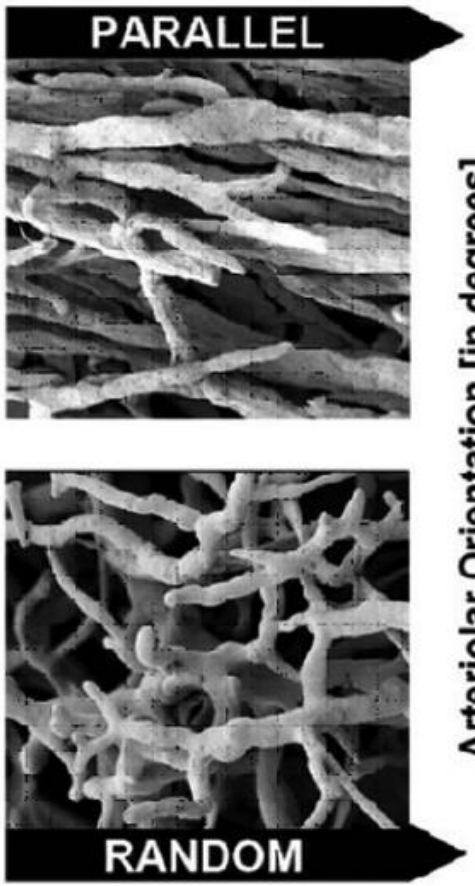
- Lumbar artery cannulation
- Segmental a. clamping in a craniocaudal direction

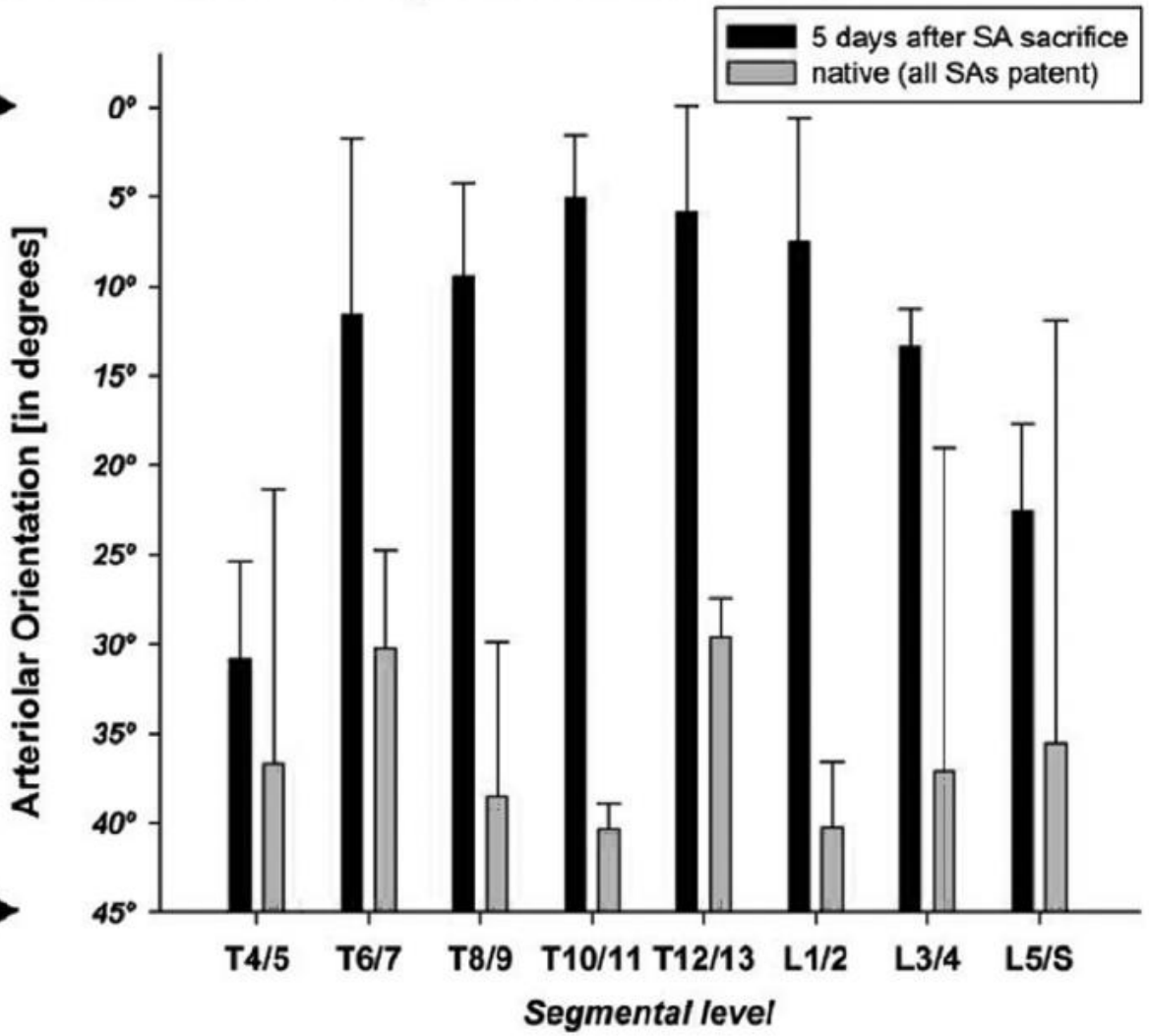




(Eur J Cardiothorac Surg 2011;23:214-22)

Orientation of Collateral Network

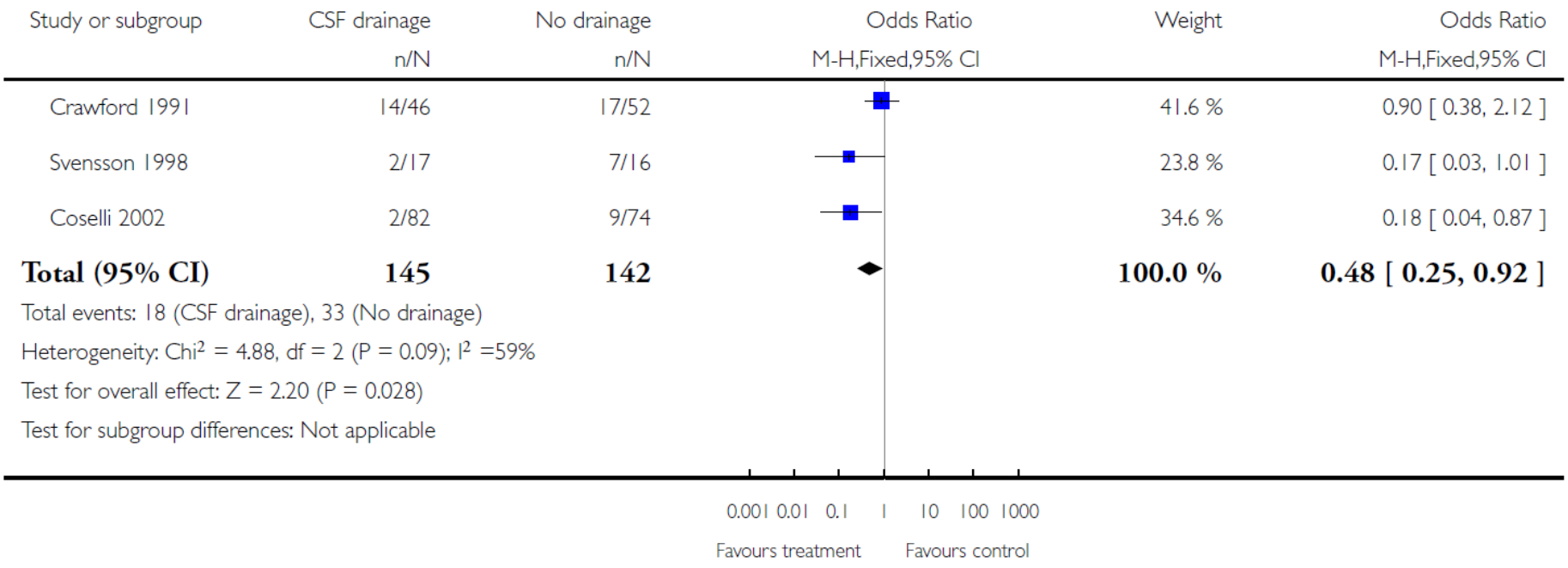




(Perspect Vasc Surg Endovasc Ther 2011;23:214-22)

CSF Drainage

- SCPP = MAP (CNP) – CSF pr.
- Complications (1.5%): SDH, headache, etc

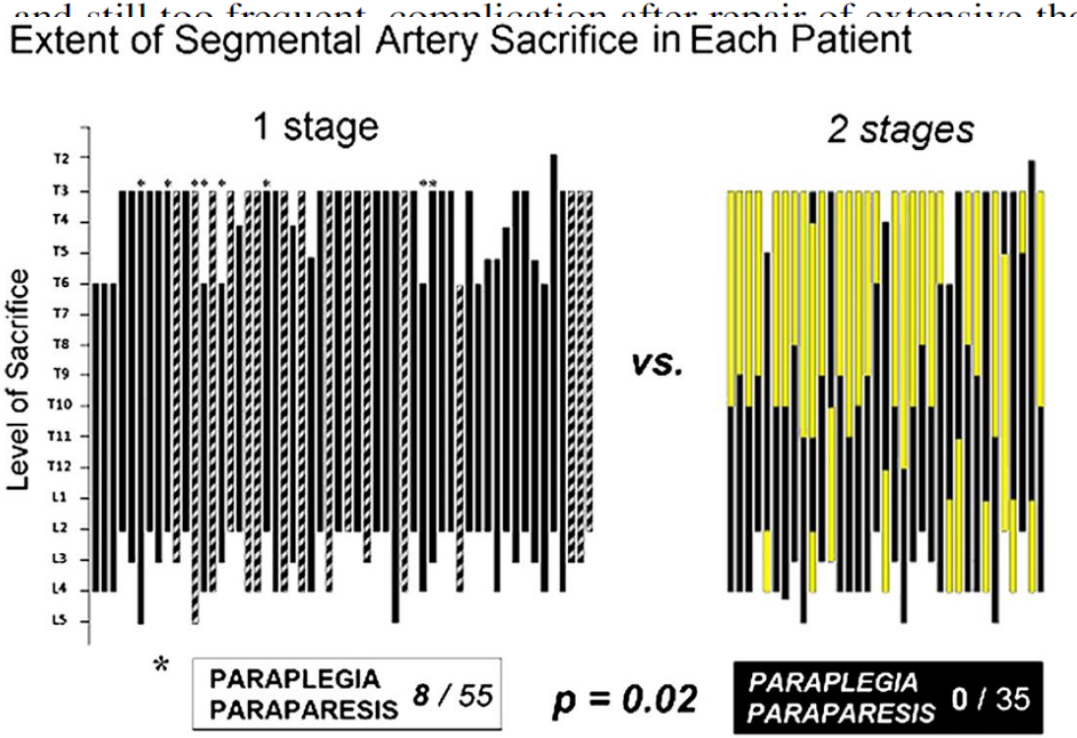


(Cochrane Database Syst Rev 2012;10)

Staged repair significantly reduces paraplegia rate after extensive thoracoabdominal aortic aneurysm repair

Objective: Paraplegia remains a devastating and still too frequent complication after repair of extensive thoracoabdominal aortic aneurysms. Strategies to reduce the risk of spinal cord ischemia, by limiting segmental artery sacrifice—or occlusion, essential for en

Methods: Ninety patients who underwent e open surgical repair from June 1994 to Dece age, 65 ± 12 years; 49% were male), most v had a single procedure (single-stage group). procedures (2-stage group), usually Crawfor thoracic aneurysm. The median interval betw were no significant differences between the sion, chronic obstructive pulmonary disease cerebrospinal fluid drainage. In single-stage tients, left-sided heart bypass was used in 40



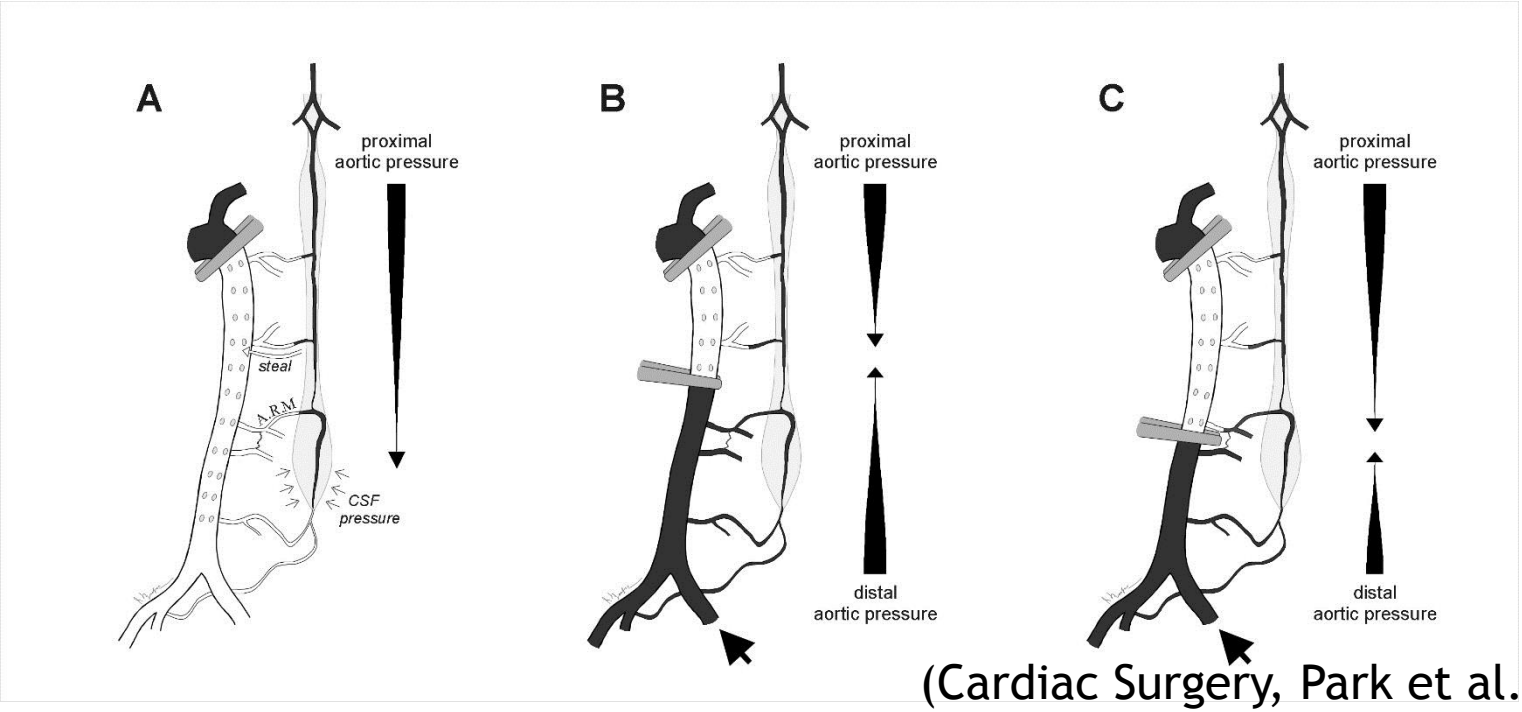
1994 ~ 2007
55 single-stage : 35 two-stage
Results:
No difference in mortality & other morbidities
Spinal cord injury
15% in single-stage : none in two-stage
Conclusion
A staged approach may reduce the incidence of spinal cord injury.

differences in mortality, stroke, post- etween the groups. However, 15% versus none in the 2-stage group 2-stage group occurred despite a sig- dian of 14 (11–15) versus 12 (9–15)

ysm repair may reduce the incidence s involving hybrid or entirely endo-

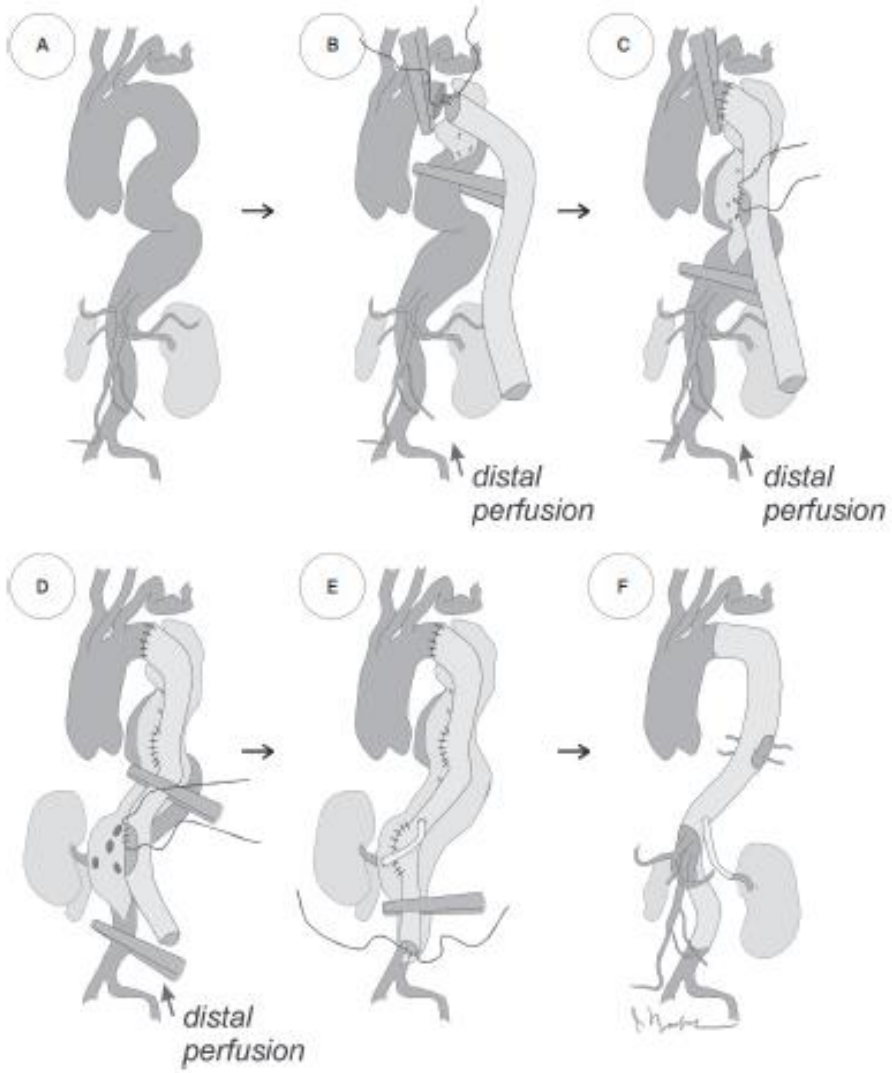
Distal Perfusion & Sequential Clamping

- Proximal clamping
  - Distal ischemia
  - CSF pressure ↑
- Mild hypothermia



(Cardiac Surgery, Park et al.)

Sequential Clamping & Distal Perfusion



Simultaneous Evaluation of the Whole Aorta and Artery of Adamkiewicz by MDCT

Recent technical advancement has allowed simultaneous visualization of the artery of Adamkiewicz and whole aorta by multidetector-row-CT (MDCT). Although we could visualize the artery of Adamkiewicz in a high percentage of patients with thoracoabdominal aortic diseases, CT scanning with an adequate protocol and careful post-processing are necessary for accurate evaluation. Noninvasive evaluation of the artery of Adamkiewicz is useful in planning surgery. Preoperative evaluation of the intercostal arterial level from which the artery of Adamkiewicz originates is reportedly important for preventing postoperative spinal cord ischemia. Although, the usefulness of preoperative information on the artery of Adamkiewicz is still controversial, preoperative identification of the artery of Adamkiewicz by imaging has gradually spread since our first report, and has been included in preoperative evaluation items at many institutions, revealing its contribution to improvement in surgical results. (*English Translation of J Jpn Coll Angiol, 2004, 44: 693-699.)

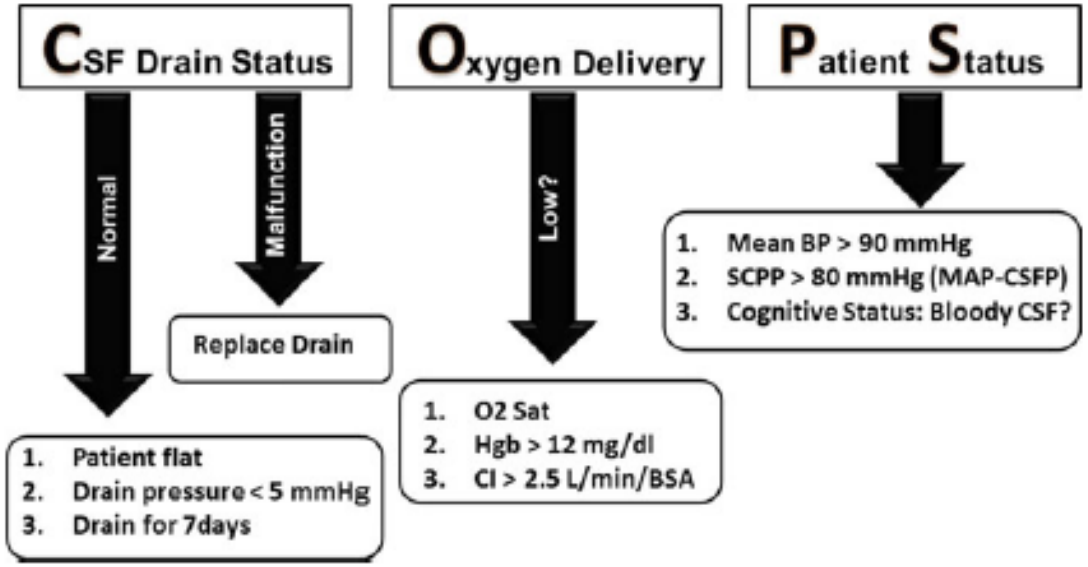
Prevention of Paraplegia During Open Surgery

- Reimplantation of critical segmental arteries
  - Preoperative identification (CT or MRI)
  - MEP or SSEP monitoring
- Maintenance of perfusion pressure
  - Avoidance of proximal hypotension
  - Distal aortic perfusion (LA-femoral or femoro-femoral bypass)
- Minimize ACC or ischemic time
  - Sequential clamping
- Enhancement of cord perfusion
  - CSF drain
  - Avoidance of blood flow steal
  - Intrathecal papaverine ?
- Tolerance to ischemia and reperfusion injury
  - Hypothermia (deep or mild hypothermia)
  - Epidural cooling
  - Pharmacological adjuncts ?

(Cardiac Surgery, Park et al.)

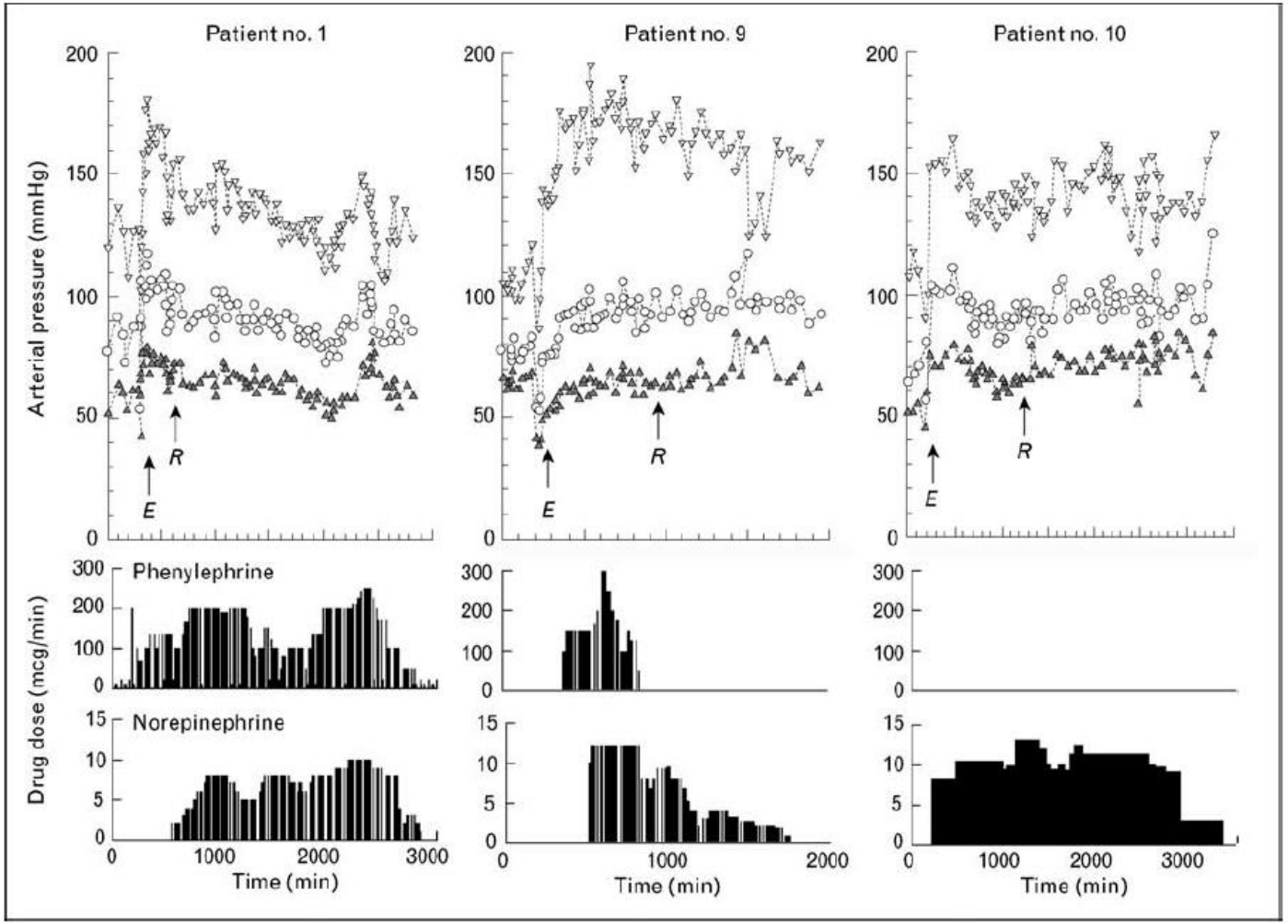
Delayed Paraplegia

- More often than immediate onset
- Mechanism:
  - Apoptosis
  - Hypotension, systemic inflammatory response syndrome, sepsis, diminished oxygen delivery, etc



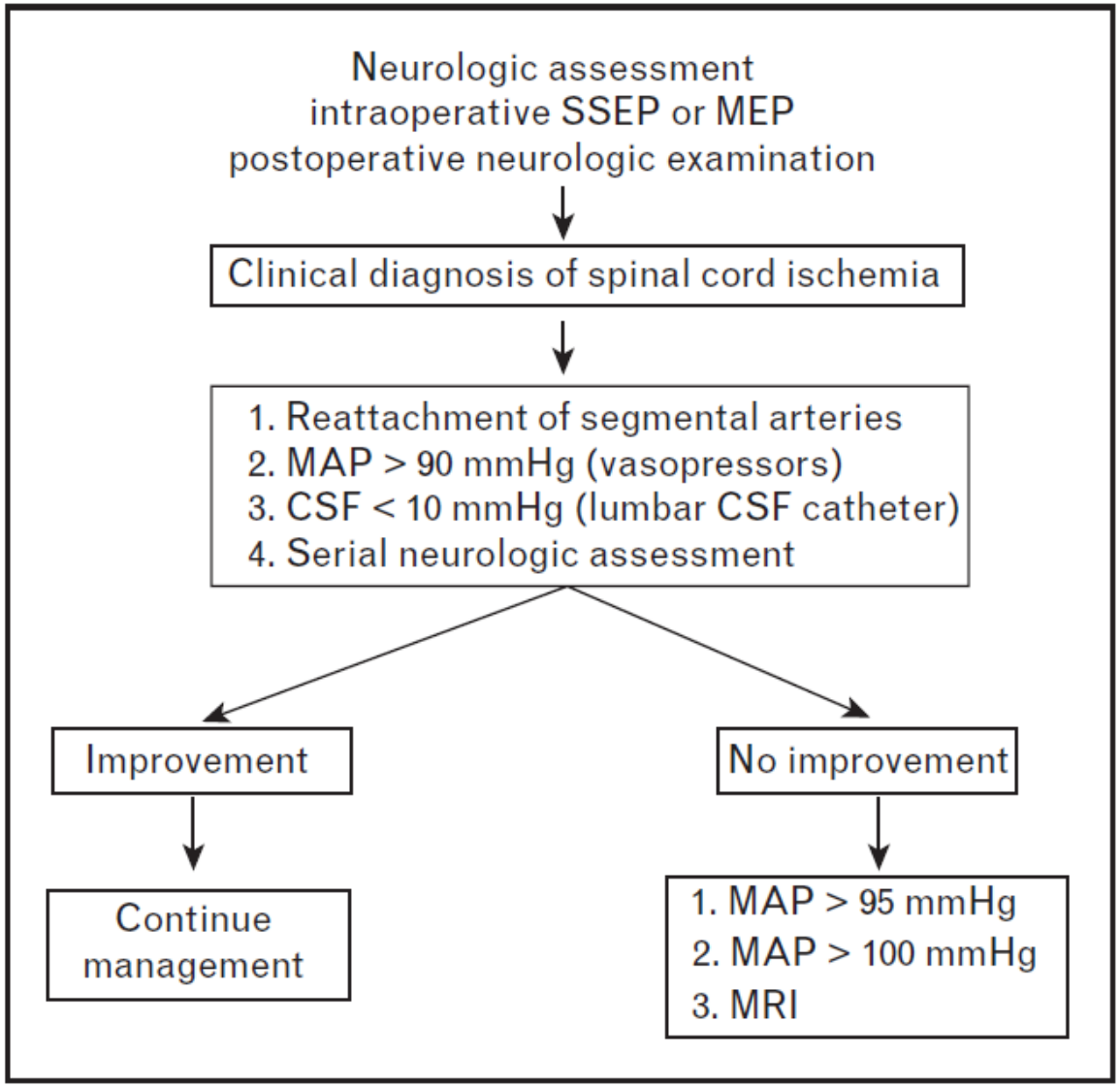
(J Anesth 2013)

High Blood Pressure



(Curr Opin Anaesthesiol 2010;23:95-102)

Algorithm for Detection & Treatment



(Curr Opin Anaesthesiol 2010;23:95-102)

Operative Strategy in SMC

- Thoracoabdominal aortic aneurysm (TAAA)
  high risk descending thoracic aortic aneurysm (TA)
- CSF drainage
- MEP & SSEP monitoring (since 2006)
- Moderate hypothermia
- Femoro-femoral partial bypass if ACC possible
- Sequential clamping
- Minimize back bleeding
- Intercostal a. reimplantation (2~3 pairs)
- Perioperative high blood pressure

Trend of Pump Time by Cases