Importance of Air Emboli in Causing Strokes after TEVAR: New Technology and Techniques to Prevent Air Emboli from Devices

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Stroke in TEVAR

- Incidence
  - in TEVAR: 3-11%
  - in complex TEVAR: >10%
- Anterior/posterior circulation
- Mechanism of stroke unclear
- Mortality 20%

Perera et al. 2015; Br J Surg 102: s2: 5
Feezor et al. 2007; J Endovasc Ther 14:568-73
Böckler et al. 2016; Eur J Vasc Endovasc Surg 51:791-800

Cook Zenith Branched Arch Endograft

- n = 27; Hamburg, Tokio, Lille
- 4/2013-11/2014
- Technical success 27/27
- 30d Mortality 0/27
- 1y mortality 1/27
- Stroke/TIA 3/27 (11%)

Spear et al 2016; Eur J Vasc Endovasc Surg 51: 380-5

Bolton – Relay Branched Stentgraft

European experience
- Multicenter
- n = 15, 12 male, Age 76
- All elective
- Technical success 15/15
- Mortality 1/15 (7%)
- Stroke 3/15 (20%)

Czerny, M et al. 2018; Eur J Cardio Thorac Surg 53:1007-12

Stroke Definition

Patient level pooled analysis from the TriGuard Trials (N=142)

Lansky et al. 2017; JACC; 69: 679-91
Lansky et al. 2017; Eur Heart J; 54:91
**Stroke in TEVAR**

Cerebral embolization, silent cerebral infarction and neurocognitive decline after thoracic endovascular aortic repair

- 31 TEVAR and MRI:
  - 25 MRI-lesions (81%)
  - 4 with clinical stroke (13%)
  - 21 subclinical
  - 15 Neurocognitive testing: Decline in 6/7 Domains

*Patena et al. 2018; Biol J Surg 105:366-78*

**Clinical Impact of SBI**

- Postoperative confusion
- Cognitive dysfunction
- Future stroke
- Impaired mobility
- Depression
- Dementia
- Parkinson disease
- Alzheimer disease

*Griem et al. 2016; Stroke 47:719-25
Ghanem et al. 2017, PLooC 12:e0168852
Verme et al. 2007; Lancet Neurol 6:11-9*

**Pathophysiology**

- Ischemia by arterial blockage
- Shear stress of passing bubbles
- Inflammatory response
- Brain metabolism ↓
- Nerval function ↓
- Blood-brain barrier damage
- Cerebral blood flow ↓
- Disturbance of blood distribution
- Intracranial pressure ↑

Vlaji et al. 2003; Clin Physiol Funct Imaging 23: 237-46
Furlow et al. 1982; Stroke 13: 847-52*

**Air-Embolism in TEVAR**

Air embolism during thoracic endograft deployment: An in vitro experimental study

*Kamuran Inc, Wassermi, Cherny, Anders Jepsson, Mikael Nilssen and Morten Palsberg*

*Inc et al. 2016, Surge Open Med 4:1-6*

**Cerebral Protection in TEVAR**

Cerebral embolic protection in thoracic endovascular aortic repair

- Claret’s Sentinel CEP device in TEVAR
- 10 patients
- TCD with gas/solid differentiation:
- >90% of HITs are gaseous
- Pre- and postoperative DWI/MRI

*Grover et al. J Vasc Surg 16 May 24 2018*
Air-Embolism in TEVAR

Standard tubular stent graft after 60ml saline flushing

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Elephant in the Room

Air

Air Embolism in EVAR

5 days after Standard EVAR

Protection Strategies

- Patient selection
- Minimize catheter/wire manipulation
- Temporary occlusion of carotid arteries
  - Vessel-loop
  - Balloon
  - Clamp

LSA Balloon Occlusion

Balloon protection of the left subclavian artery in debranching thoracic endovascular aortic repair

Seike et al. 2018; J Thor Cardiothor Surg; accepted

Courtesy of Prof. Matsuda, Japan
**Protection Strategies**

- CEP-devices
  - Filter devices, e.g. Sentinel by Chimed Med.
  - Deflectors, e.g. Triguard by Keystone Heart
  - Other...
- Carbon dioxide flushing
- Dead-space-reduction
- Liquid gas resolution

**CO\textsuperscript{2} - Flushing**

**Carbon Dioxide Flushing Technique to Prevent Cerebral Arterial Air Embolism and Stroke During TEVAR**

- 2014-2016: n=36
- All complex arch and ascending TEVAR:
  - Branched arch
  - Fenestrated arch
  - Ascending TEVAR
- All zone 0-1
- Stroke: 1/36 (3%)
  - minor non-disabling stroke

**Additional Flushport**

- Bench-top model
  - \(N=20\) tubular stentgrafts
  - Group A (10): 60ml saline
  - Group B (10): Carbondioxide +60ml saline
  - Validated volume measurement:
    - A: 0.79ml air after standard flushing
    - B: 0.51ml gas after + CO\textsuperscript{2}-flushing

**Perfluorcarbons (PFCs)**

- High solubility of respiratory gases
- Low vapor pressure
- Radiopacity
- High specific weight
- High stability-bioinert-no metabolisation
- High viscosity

- Blood-substitute
- Liquid breathing
- Ophthalmic surgery
- Contrast agent

**Degassed PFC**

- Bench-top model
  - \(N=10\) tubular stentgrafts
  - Group G (10): Degassed PFC+60ml saline
  - Validated volume measurement:
    - A: 0.79ml air after standard flushing
    - B: 0.51ml gas after + CO\textsuperscript{2}-flushing
    - D: 0.07ml gas after + CO\textsuperscript{2}-flushing
    - G: 0.004ml gas with degassed PFC
Stroke during TEVAR is relevant and needs to be avoided.

Silent brain infarctions (SBI) are a frequent finding (80%) after TEVAR and associated with neurologic symptoms and cognitive dysfunction.

The source of stroke and SBI during TEVAR appears multifactorial.

Air-embolism from devices plays a significant role and should be prevented.