Status Of Stroke Prevention During TEVAR: What Percent Are Due To Particulate Emboli And What Percent Due To Air Emboli: Techniques To Prevent Both

Tilo Kölbl, MD, PhD
German Aortic Center Hamburg
Dept. Of Vascular Medicine
University Cardiovascular Center Hamburg

Cardiovascular Interventions

Stroke in TEVAR
- Incidence
  - In TEVAR: 4.5%
  - 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

Stroke Rate Depends on Definition

Neuro-ARC: Stroke Definition

Proposed Standardized Neurological Endpoints for Cardiovascular Clinical Trials
An Academic Research Consortium Initiative

Disclosures
- Research-grants, traveling, proctoring speaking-fees, IP, royalties with Cook.
- Consultant with Philips
- Consulting, speaking-fees with Getinge
- Shareholder Mokita Medical GmbH
- IP, Consultant with Terumo Aortic
- Medical Devices shown are partially not approved by FDA
Silent Brain Infarcts: Not So Silent!

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

Gupta et al. 2016; Stroke 47:719-25
Vermeer et al. 2007; Lancet Neurol 6:11-6

Silent Brain Infarcts in TEVAR

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

Pithers et al. 2018; Brit J Surg 105:344-78

Emboli Pathways in Cryptogenic Stroke

Conclusions: Substantial diastolic retrograde flow originating from complex plaques in the descending aorta was detected by multidirectional 3D MRI velocity mapping and constitutes a stroke mechanism.

Harloff et al. 2009; Stroke 40:1505-8

The Cause of Stroke in TEVAR

- Particle embolism during wire manipulation and graft release
- Air embolism from stent graft
- Hemodynamic stroke

Courtesy of Dr. Janosi, Essen

Elephant in the Room

Air bubbles are released by thoracic endograft deployment: An in vitro experimental study

Karanen Ingi, Giuseppe Conticelli, Valery Chekmarev, Anders Jaysson, Niklas Nilsson and Mats Fahlberg

Stroke by Air-Embolism in TEVAR

Air bubbles are released by thoracic endograft deployment: An in vitro experimental study

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Pathophysiology of Air-Embolism

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

Air-Filters Reduce MRI-Lesions

Heparin and Air Filters Reduce Embolic Events Caused by Intra-Arterial Cerebral Angiography: A Prospective, Randomized Trial

<table>
<thead>
<tr>
<th>Study</th>
<th>Results</th>
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<tbody>
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<td>Furlow et al. 1982</td>
<td>Stroke 13: 847-52</td>
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- DBT-group better in 2 neurocognitive tests
- P.o. neurocognitive impairment related to micro-embolization
- Majority of MES during CABG gaseous origin

Air-Embolism and Cognitive Function after CPB

Protecting the brain from gaseous and solid micro-emboli during coronary artery bypass grafting: a randomized controlled trial

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Air-Embolism in TEVAR

Standard tubular graft often also saline flushing
HITS Most Frequent During Deployment

- MES in Landing Zones 0-2 (Mean)
- Right side
- Left side

TCD: 90% of HITS during TEVAR are Gaseous

- Gaseous emboli counts (n=20)

MR-lesions associated with gaseous HITS

- Air Embolism in EVAR/TEVAR

- 5 days after EVAR
- 2 days after TEVAR

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
Protection Strategies

- CEP devices
  - Filter devices, e.g. Sentinel by Cleart Med.
  - Deflectors, e.g. Triguard by Keystone Heart
  - Others...
- 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

- 2014-2015: n=36
- All complex arch TEVAR:
  - Branched arch
  - Fenestrated arch
  - Ascending TEVAR
  - All zone 0-1
- Stroke: 1/36 (3%)
  - Minor non-disabling stroke

Liquid Gas Resolution

- Bench-top model
  - N=10 tubular stentgrafts
  - Group G (10): liquid gas resolution
  - Validated volume measurement:
    A: 0.79ml air after standard flushing
    B: 0.51ml gas after + CO\textsubscript{2} flushing
    C: 0.51ml gas with add. flushport
    D: 0.07ml gas with add. flushport + CO\textsubscript{2} flushing
    G: 0.004ml gas with liquid gas resolution
Conclusion

- Stroke and SBI during TEVAR is relevant and needs to be avoided.
- Silent brain infarctions (SBI) during TEVAR are a frequent finding and associated with neurologic symptoms and cognitive dysfunction.
- The source of stroke and SBI during TEVAR appears multifactorial.
- Air-embolism plays a significant role in stroke and SBI during TEVAR.
- Intravascular air release from medical devices should be avoided.