University Heart Center Hamburg

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Air Embolism In TEVAR: Role and Prevention

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CONTROVERSES ET ACTUALITÉS EN CHIRURGIE VASCULAIRE
CONTROVERSIES & UPDATES IN VASCULAR SURGERY
JANUARY 19-21 2017
MARRIOTT RIVE GAUCHE & CONFERENCE CENTER
PARIS, FRANCE

Disclosures

- Research-grants, travelling, proctoring speaking-fees, IP, royalties with Cook.
- Consultant with Philips

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

Kamuran Inci[1], Giasemi Koutouzi[2], Valery Chernoray[3], Anders Jeppsson[4], Håkan Nilsson[3] and Mårten Falkenberg[2]

(c)

(a)

Inci et al. 2016 Sage Open Med 4:1-5

Stroke in TEVAR

- Incidence 3-11%
- Anterior/posterior circulation
- Silent undetected strokes up to 60%
- Mechanism of stroke unclear

Feezor et al. 2007; J Endovasc Ther 14:568-73

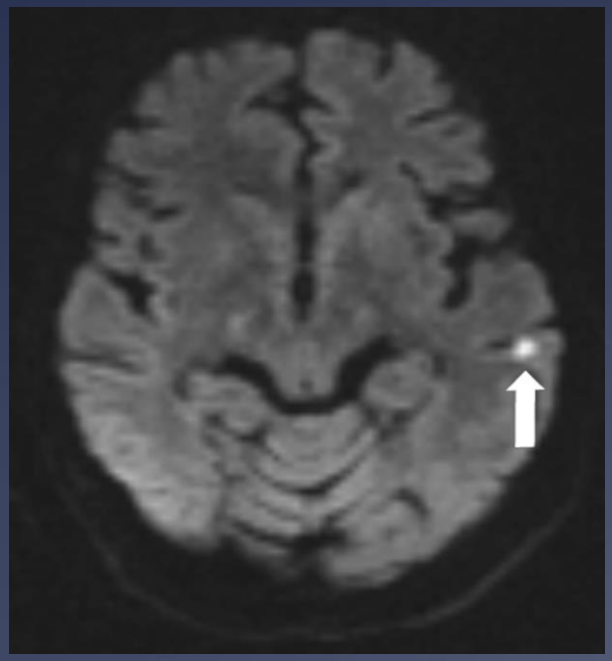
Kahlert et al. 2014; Ann Thorac Surg 98:53-8

Böckler et al. 2016; Eur J Vasc Endovasc Surg: in press

Silent Stroke in TEVAR

Silent Cerebral Ischemia After Thoracic Endovascular Aortic Repair: A Neuroimaging Study

Philipp Kahlert, MD, FESC, Holger Eggebrecht, MD, FESC, Rolf A. Jánosi, MD, Heike A. Hildebrandt, MD, Björn Plicht, MD, Konstantinos Tsagakis, MD, Christoph Moenninghoff, MD, Felix Nensa, MD, Petra Mummel, MD, Gerd Heusch, MD, FRCP, Heinz G. Jakob, MD, Michael Forsting, MD, Raimund Erbel, MD, FESC, and Marc Schlamann, MD



- Single center, n=19
- Pre- and post EVAR MR
- MRI-protocoll: DWI and FLAIR
- No clinical apparent strokes
- 12/19 (63%) new DWMRI-lesions
- Most with multiple lesions (1-6)

Kahlert et al. 2014; Ann Thorac Surg 98:53-8

Mechanism of Stroke

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

Risk Factors

Pathology/anatomy:

* Landing zone
* Arch angulation
* Atheromatous burden

Procedural:

* Emergency
* Cuff extension
* LSA-coverage
* Use of embolic protection

Comorbidities:

* History of stroke
* Chronic renal insufficiency

Feezor et al. 2007; J Endovasc Ther 14:568-73
Chung 2011; J Vasc Surg 54:979-84
Ullery et al. 2012; J Vasc Surg 56:1510-7
Kotelis et al. 2012; Lang Arch Surg 397: 1267-73
Melissano et al. 2012; Eur j Vasc Endovasc Surg 43: 269-75
Böckler et al. 2016; Eur J Vasc Endovasc Surg: in press

Stroke in TEVAR

Associations expected if particle embolism:

* Plaque burden
* Pathology:
  * More frequent in aortic aneurysm
  * Less frequent in aortic dissection

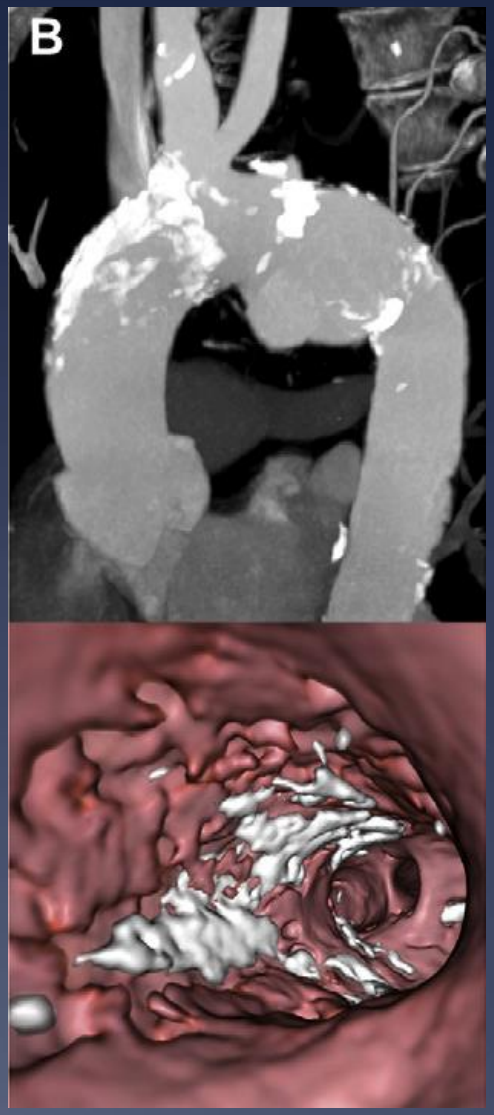


Image from Melissano et al. 2012; Eur j Vasc Endovasc Surg 43: 269-75

Stroke in TEVAR

Vascular distribution of stroke and its relationship to perioperative mortality and neurologic outcome after thoracic endovascular aortic repair

Brant W. Ullery, MD,[a] Michael McGarvey, MD,[b] Albert T. Cheung, MD,[c] Ronald M. Fairman, MD,[a] Benjamin M. Jackson, MD,[a] Edward Y. Woo, MD,[a] Nimesh D. Desai, MD,[d] and Grace J. Wang, MD,[a]
Philadelphia, Pa

Table I. Univariate analysis of demographic and perioperative characteristics for patients with and without perioperative stroke after thoracic endovascular aortic repair (TEVAR)

Variable[a]	*Stroke (n = 20)*	*No stroke (n = 510)*	P
Aortic pathology			
Thoracic aortic aneurysm	14 (70)	393 (77)	.43
Acute type B dissection	4 (20)	77 (15)	.53
PAU	1 (5)	25 (5)	>.99
Traumatic transection	1 (5)	15 (3)	.46

- Single center 2001-2010
- N=530
- Stroke 3.8%
- TAA 3.4%
- TBAD 4.9%

Ullery et al. 2012; J Vasc Surg 56:1510-7

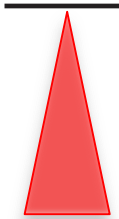
Stroke in TEVAR

Risk Factors for Perioperative Stroke During Thoracic Endovascular Aortic Repairs (TEVAR)

Robert J. Feezor, MD[1]; Tomas D. Martin, MD[2]; Philip J. Hess, MD[2]; Charles T. Klodell, MD[2]; Thomas M. Beaver, MD[2]; Thomas S. Huber, MD, PhD[1]; James M. Seeger, MD[1]; and W. Anthony Lee, MD[1]

TABLE 2
Aortic Atheroma Grade in Patients With Perioperative Stroke (CVA) Versus Those Without CVA

Atheroma Grade	No CVA (n=187)	CVA (n=9)
1	25 (13.4%)	2 (22.2%)
2	46 (24.6%)	1 (11.1%)
3	46 (24.6%)	3 (33.3%)
4	58 (31.0%)	2 (22.2%)
5	4 (2.1%)	0 (0%)
N/A	8 (4.3%)	1 (11.1%)



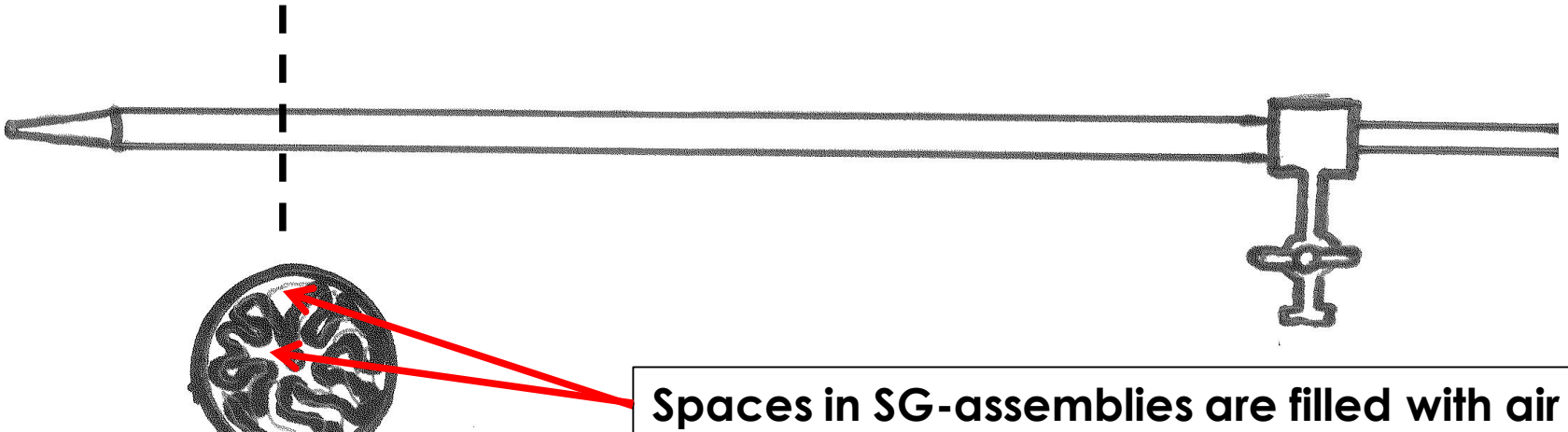
- Single center; n=196; Age 68y
- Stroke 4.6%
- Pathology: No risk factor!
- Atheroma grade: No risk factor!

Proximal Extent of Repair: only risk-factor for stroke!

Feezor et al. 2007; J Endovasc Ther 14:568-73

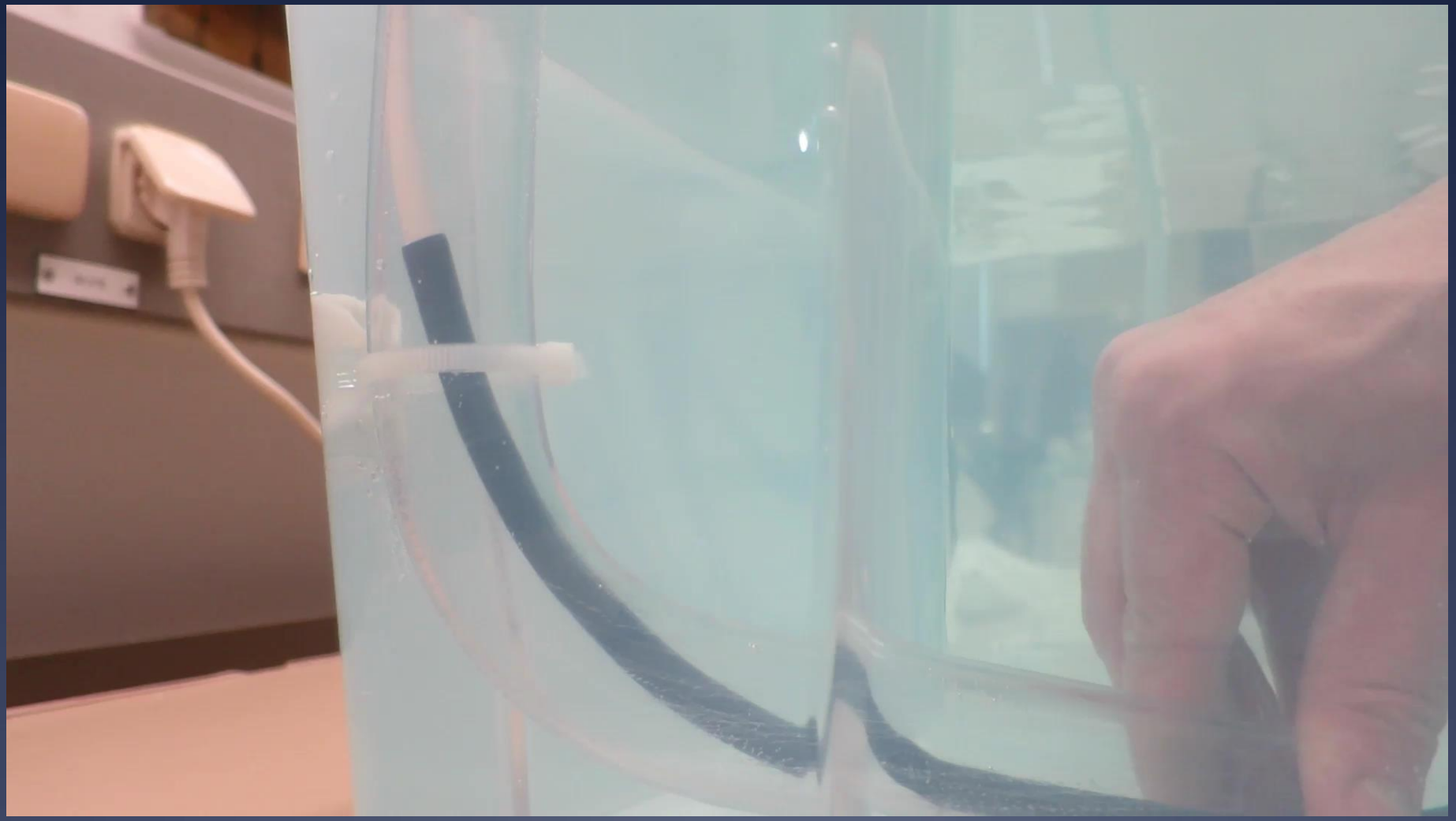
Why would air embolism play a significant role?

Air in Stentgrafts



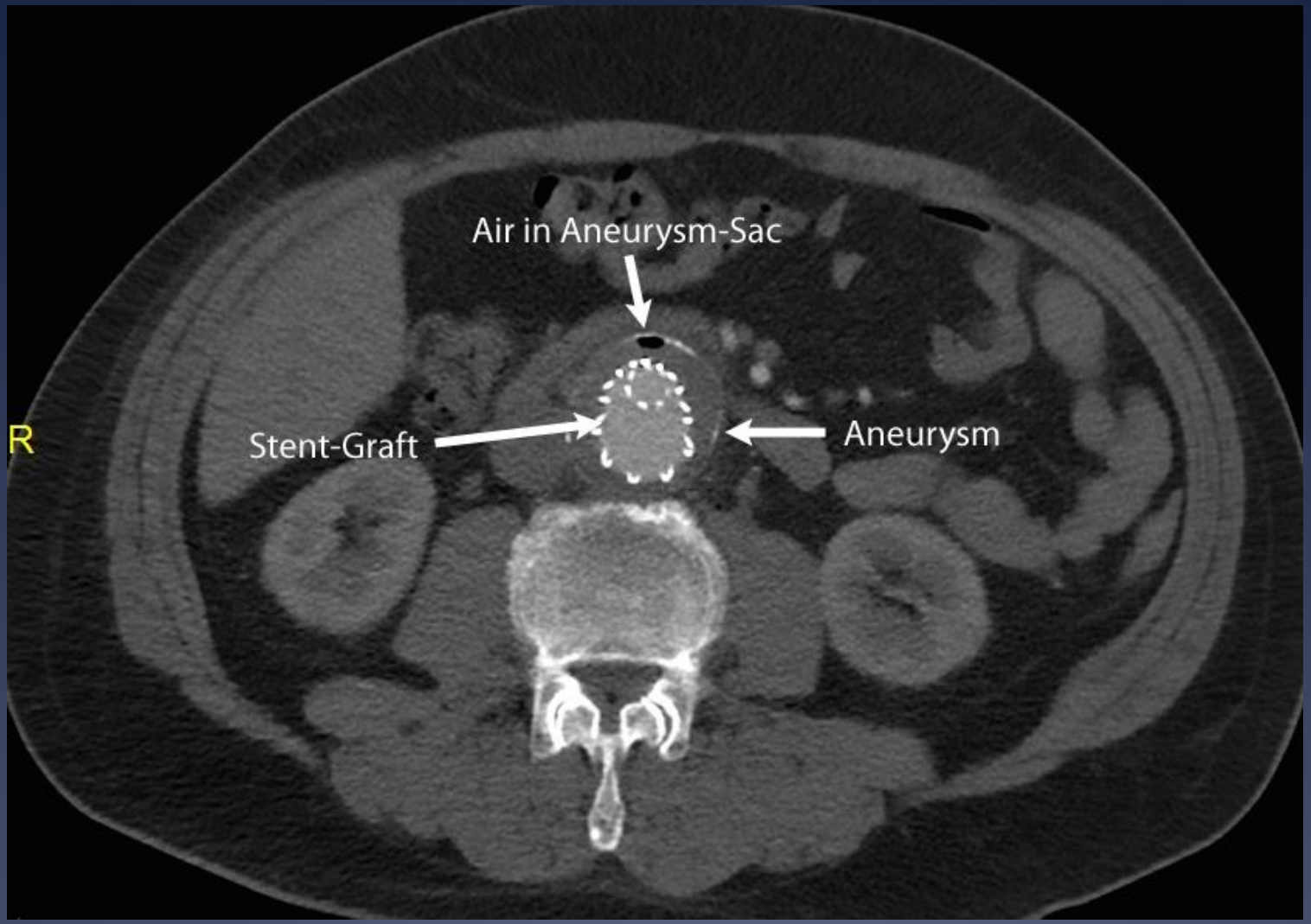
Saline-flushing insufficiently removes air from stent-grafts.

Air-Embolism in TEVAR



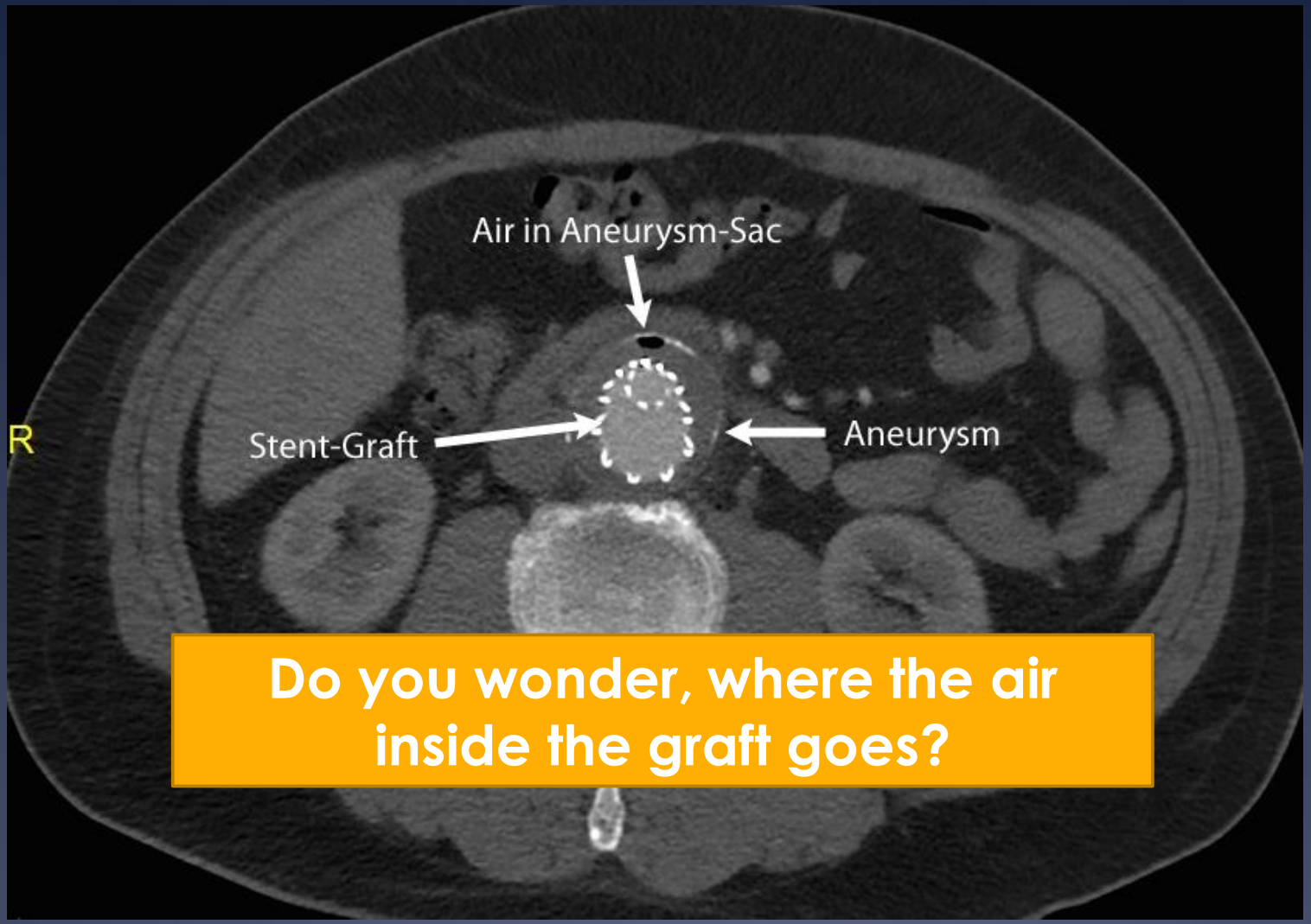
Standard tubular stent graft after 60ml saline flushing

Air Embolism in EVAR



5 days after Standard EVAR

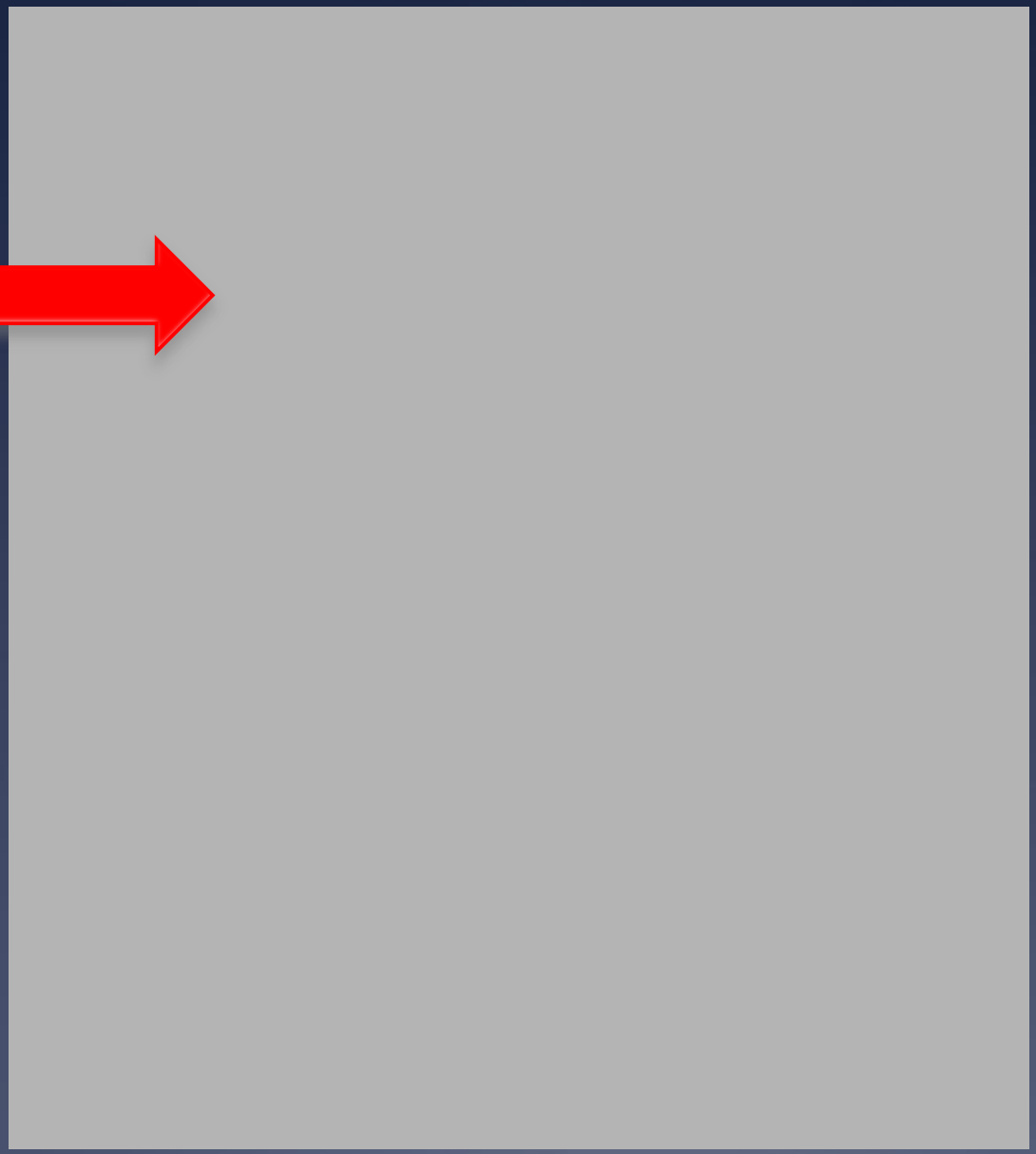
Air Embolism in EVAR



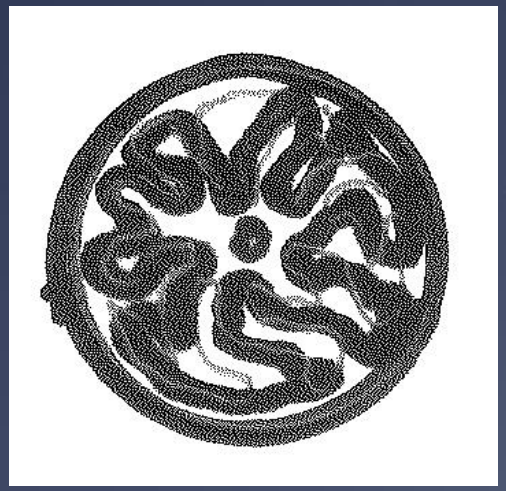
45% of EVAR for AAA !

Saleptsis et al. 2016; unpublished data

Air-Embolism in TEVAR



Air in stent-grafts should be replaced by a less harmfull gas before flushing with saline !



CO^2 - Flushing

- Introduced 2013
- In proximal TEVAR
- 1.5 bar
- 2min
- **Followed by standard flushing with 60ml saline !**

CO^2 Properties

- 22-fold more solulable in blood compared to air
- 50-60-fold more solulable in Saline compared to N^2
- 2-fold better tolerated than O^2 when injected
- 5-fold better tolerated than air when injected
- 1.5-fold heavier than air
- Used widely in cardiac surgery to prevent air-embolism

Kunkler et al. 1959; Ann Surg 149:95-9
Ng et al. 1968; Thorax 23: 194-6
Mitz et al. 1979; J Theor Biol 80:537-51
Svenarud et al. 2004; Circ 109:1127-32

CO^2 - Flushing

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

Journal of Endovascular Therapy
1–3

DOI: 10.1177/1526602816633705
www.jevt.org
SAGE

- 2014-2015: 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

Kölbel et al 2016; J Endovasc Surg 23: 393-5

Air-Embolism in TEVAR

Journal of Endovascular Therapy
1–5
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DOI: 10.1177/1526602816675621
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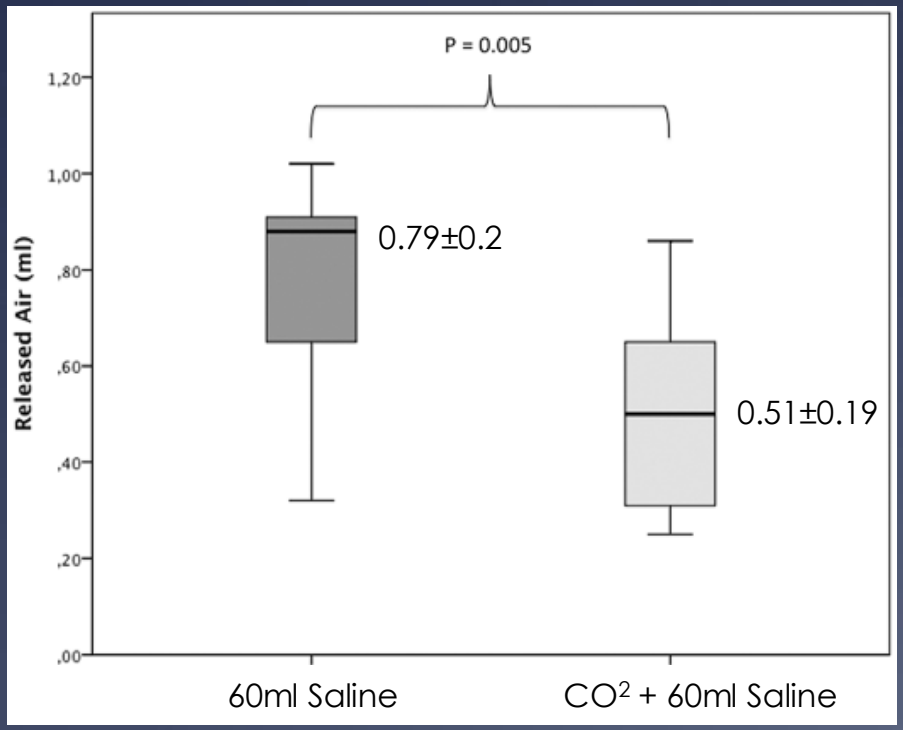
Air Embolism During TEVAR: Carbon Dioxide Flushing Decreases the Amount of Gas Released From Thoracic Stent-Grafts During Deployment

Fiona Rohlffs, MD[1], Nikolaos Tsilimparis, MD, PhD[1], Vasilis Saleptsis, MD[1], Holger Diener, MD[1], E. Sebastian Debus, MD, PhD[1], and Tilo Kölbel, MD, PhD[1]



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

Rohlffs et al. 2016, J Endovasc Ther Epub

Conclusion

- The dogma, that stroke during TEVAR is caused by particle-embolism is not proven.
- Air-embolism may play a significant role in TEVAR-related stroke.
- DW-MRI not yet sufficiently utilized to detect silent stroke during TEVAR.
- Carbondioxide flushing reduces air-embolism
- **If you use CO^2-flushing, you have to flush with saline afterwards!**

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