Extensibility and Distensibility of the thoracic aorta in patients with aneurysm

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Impact of TEVAR on pulsatile changes in TBAD

Conflict of interest:

None
Impact of TEVAR on pulsatile changes in TBAD

Background

- The thoracic aorta is a pulsatile environment and experiences high hemodynamic forces

ECG-Gated CTA
Impact of TEVAR on pulsatile changes in TBAD

Background

- The thoracic aorta is a pulsatile environment and experiences high hemodynamic forces
- TEVAR for TBAD is increasing rapidly\(^1\)

\(^1\)Von Allmen EJVES 2013
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Background

• But what is the impact of TEVAR on this pulsatile environment?
Background

- Distensibility (radial expansion) is 2-20% and is preserved after TEVAR


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van Prehn AVS 2009
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Background

• Besides distension, the aorta also seems to **elongate** (longitudinal expansion) during the cardiac cycle*

116,2 mm

128,8 mm

*B-lab unpublished data
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Background

• Besides distension, the aorta also seems to **elongate** (longitudinal expansion) during the cardiac cycle*

![Image showing elongation of the aorta](image)

116.2 mm  →  128.8 mm

= 10.8% elongation

*B-lab unpublished data
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Background

- A rigid thoracic stent-graft might influence the pulsatile aortic changes and increase wall stress
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• A rigid thoracic stent-graft might influence the pulsatile aortic changes and increase wall stress

• Increased wall stress might increase the risk of extension (retrograde and antegrade) dissection and SINE (Trigometric functions)³

³Riambau Vascular 2008
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Background

• A rigid thoracic stent-graft might influence the pulsatile aortic changes and increase wall stress

• Increased wall stress might increase the risk of extension (retrograde and antegrade) dissection and SINE\(^3\)

• Dissected aortas might be more of risk compared to other aortic diseases\(^4\)

\(^3\)Riambau Vascular 2008, \(^4\)Kpodonu EJCTS 2008
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**Aim**

Quantify pulsatile changes in both aortic distension and elongation during the cardiac cycle, before and after TEVAR
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**Aim**
Quantify pulsatile changes in both aortic distension and elongation during the cardiac cycle, before and after TEVAR

**Purpose**
To understand the impact of TEVAR on pulsatile aortic changes, potentially clarifying TEVAR related complications such as retrograde dissection and stent-graft induced new entry-tear
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Methods

• 2 patients with TBAD and 1 control
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Methods

Patient 1

- 53-year old female with acute TBAD → TEVAR, 2 stent-grafts (2x 200 mm)
Methods

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Patient 2
• 55-year old male with Marfan syndrome and ruptured acute TBAD
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Methods

Patient 1
• 53-year old female with acute TBAD → TEVAR, 2 stent-grafts (2x 200 mm)

Patient 2
• 55-year old male with Marfan syndrome and ruptured acute TBAD → TEVAR, 2 stent-grafts (150 + 200 mm)
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Methods

Patient 1
• 53-year old female with acute TBAD → TEVAR, 2 stent-grafts (2x 200 mm)

Patient 2
• 55-year old male with Marfan syndrome and ruptured acute TBAD → TEVAR, 2 stent-grafts (150 + 200 mm)

Patient 3
• Healthy control patient: 49-year old female with thoracic pain, on CT no vascular pathology
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## Methods

<table>
<thead>
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<th>1</th>
<th>2</th>
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</thead>
<tbody>
<tr>
<td>ECG-Gated CTA</td>
<td>8 sets of dicom files</td>
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Methods

1. ECG-Gated CT
2. ECG-Gated CTA
3. 8 sets of dicom files

Segementation
Methods

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5 anatomical levels for diameter and area
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**Methods**

4 anatomical levels for diameter and area

**Distensibility**

→ 5 anatomical levels for diameter and area

**Elongation**

→ 3 aortic segments
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Results

- **Distensibility** was significant ($p < .05$) during the cardiac cycle at each anatomical level, in each patient, both pre- and postoperatively.
Results

- **Preoperative** mean aortic diameter change was:
  - Level STJ: 8.3% (ranging from 7.4-9.1%, SD 0.9)
  - Brachiocephalic trunk: 4.1% (" " 3.5-4.8%, SD 0.6)
  - LSA: 4.3% (" " 4.2-4.4%, SD 0.1)
  - 10 cm distal LSA: 5.6% (" " 4.6-6.8%, SD 1.2)
  - 20 cm distal LSA: 7.6% (" " 2.5-14.5%, SD 6.2)
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Results

• **Preoperative** mean aortic diameter change per patient
Results

- **Preoperative** mean aortic diameter change per patient
- The highest aortic diameter changes at level 20 cm distal of the LSA might be explained by the moving dissection flap

**Preoperative Diameter Change**

Aortic levels: A, B, C, D, E

- Pt 1 TBAD
- Pt 2 TBAD + Marfan
- Pt 3 Control
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Results

• Post-TEVAR aortic diameter
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Results

• Post-TEVAR aortic diameter increased significantly at:

• Patient 1:
  - Level C (p=.000)
  - Level D (p=.000)
  - Level E (p=.000)
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Results

- **Post-TEVAR aortic diameter** increased significantly at:
  - Patient 1:
    - Level C ($p = .000$)
    - Level D ($p = .000$)
    - Level E ($p = .000$)
  - Patient 2:
    - Level A ($p = .036$)
    - Level D ($p = .007$)
    - Level E ($p = .000$)
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Results

• Post-TEVAR aortic diameter changes (distensibility):
Results

• **Post-TEVAR aortic diameter changes** (distensibility):
  
  **Preserved or increased** at the levels:
  - Level STJ: 8.3 → 8.0% (SD 0.9)
  - Brachiocephalic trunk: 4.1 → 5.7% (SD 2.9)
  - LSA: 4.3 → 6.5% (SD 2.7)
  - 10 cm distal LSA: 5.6 → 9.7% (SD 1.9)
  - 20 cm distal LSA: 7.6 → 12.4% (SD 0.9)
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Results

• Post-TEVAR aortic diameter changes (distensibility):
  Preserved or increased at the levels:
  - Level STJ: 8.3 → 8.0% (SD 0.9)
  - Brachiocephalic trunk: 4.1 → 5.7% (SD 2.9)
  - LSA: 4.3 → 6.5% (SD 2.7)
  - 10 cm distal LSA: 5.6 → 9.7% (SD 1.9)
  - 20 cm distal LSA: 7.6 → 12.4% (SD 0.9)
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Results diameter changes, patient 1

Pre-TEVAR

Level D from 0.0% to 3.5%

Post-TEVAR

From 0.0% to 11.3%

![Graph showing mean aortic diameter change (%)](attachment:graph.png)

Aortic levels with stent-graft coverage (%)

- A (0%)
- B (0%)
- C (100%)
- D (100%)
- E (0%)

- Pre
- Post
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Results diameter changes, patient 1

Pre-TEVAR

Level E from 0.0% to 2.1%

Post-TEVAR

From 0.0% to 10.0%
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Results diameter changes, patient 2

Pre-TEVAR

Level B from 0.0% to 4.0%

Post-TEVAR

From 0.0% to 7.4%
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Results diameter changes, patient 2

Pre-TEVAR

Level C from 0.0% to 2.6%

Post-TEVAR

From 0.0% to 8.5%

Aortic levels with stent-graft coverage (%)
Results

- **Pre-operative elongation**: significant elongation changes ($p < 0.05$) were observed during the cardiac cycle at each anatomical level, in each patient, both pre- and postoperatively.
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Results

- **Pre-operative elongation**: highest changes were observed in the Marfan patient, lowest in the TBAD patient

![Graph showing preoperative elongation change](image_url)
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Results

• **Pre-operative elongation:** highest changes were observed in the Marfan patient, lowest in the TBAD patient

  **Preoperative Elongation Change**

  Overall:
  - Total thoracic aorta: 2.3% (ranging from 1.4-3.2%, SD 0.9)
  - Ascending aorta: 6.6% ("   " 4.8-9.4%, SD 2.5)
  - Aortic arch: 8.8% ("   " 8.2-9.1%, SD 0.5)
  - Descending aorta: 2.8% ("   " 1.4-4.8%, SD 1.8)
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Results

• Post-TEVAR aortic Length:
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Results

- Post-TEVAR aortic Length:

Patient 1:
- Total aortic length decreased after TEVAR from 360.7 mm to 358.3 mm
  
  \(0.7\%, \ p=.01\)
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Results

• Post-TEVAR aortic Length:

Patient 1:

- Total aortic length decreased after TEVAR from 360.7 mm to 358.3 mm (0.7%, p=.01)
- Aortic arch length increased from 37.0 mm to 40.4 mm (9.2%, p=.000)
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**Results**

- **Post-TEVAR aortic Length:**
  - Patient 1:
    - Total aortic length decreased after TEVAR from 360.7 mm to 358.3 mm (0.7%, p=.01)
    - Aortic arch length increased from 37.0 mm to 40.4 mm (9.2%, p=.000)
    - Descending aorta decreased from 244.5 mm to 263.3 (7.7%, p=.000)
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Results

• Post-TEVAR aortic Length:

Patient 2:
- Aortic arch length increased from 40.7 mm to 42.4 mm (4.2%, p=.00)
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Results

• Post-TEVAR elongation changes, patient 1:
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Results

• Post-TEVAR elongation changes, patient 1:

![Graph showing mean aortic elongation change (%)]

- **Aortic segments with stent-graft coverage (%):**
  - L (49%)
  - L1 (0%)
  - L2 (64%)
  - L3 (63%)

- **Mean Aortic Elongation change (%):**
  - Pre
  - Post

- **Graph:**
  - 8.1% → 13.1%
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Results

• Post-TEVAR elongation changes, patient 2:

![Graph showing mean aortic elongation change (%) before and after TEVAR. The graph indicates a significant increase from 9.4% to 15.8% in the patient's aortic segments with stent-graft coverage.]
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Results

- Overall post-TEVAR elongation changes
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Results

- Overall post-TEVAR elongation changes

  Increased:
  - Total thoracic aorta: 1.9% $\rightarrow$ 3.0% (SD 2.0)
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Results

• Overall post-TEVAR elongation changes

  Increased:
  - Total thoracic aorta: 1.9% → 3.0% (SD 2.0)
  - Ascending aorta: 7.1% → 10.5% (SD 7.5)
  - Aortic arch: 8.7% → 11.0% (SD 3.0)
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Results

- Overall post-TEVAR elongation changes

**Increased:**
- Total thoracic aorta: 1.9% → 3.0% (SD 2.0)
- Ascending aorta: 7.1% → 10.5% (SD 7.5)
- Aortic arch: 8.7% → 11.0% (SD 3.0)

**Decreased:**
- Descending aorta from 3.1% to 2.0% (SD 0.6)

Mean Elongation Change

Aortic segment with stent-graft coverage (%)
Results

• The inter-observer variability
  All mean differences were smaller than the repeatability coefficients and linear regression analysis was non-significant.
    - Elongation change: \( p = .14 \)
    - Diameter change: \( p = .09 \)
    - Area change: \( p = .85 \)
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Limitations

• Small cohort, preliminary study

• Heterogeneity

• Segmentation of only the true lumen
Conclusions

- The thoracic aorta showed significant pulsatile aortic changes in both distensibility and elongation, most evident in the Marfan patient.
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• Distensibility was preserved after TEVAR.
Conclusions

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• Distensibility was preserved after TEVAR.

• Elongation was not preserved after TEVAR.
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Conclusions

- The thoracic aorta showed significant pulsatile aortic changes in both distensibility *and* elongation, most evident in the Marfan patient.
- Distensibility was preserved after TEVAR.
- Elongation was not preserved after TEVAR.
- TEVAR was associated with increased elongation proximally to the stent-graft.
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Conclusions

• The thoracic aorta showed significant pulsatile aortic changes in both distensibility and elongation, most evident in the Marfan patient

• Distensibility was preserved after TEVAR

• Elongation was not preserved after TEVAR

• TEVAR was associated with increased elongation proximally to the stent-graft

• Is this observation associated with stent-graft related complications, such as dissection extension and SINE?
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Conclusions

• The thoracic aorta showed significant pulsatile aortic changes in both distensibility and elongation, most evident in the Marfan patient.

• Distensibility was preserved after TEVAR.

• Elongation was not preserved after TEVAR.

• TEVAR was associated with increased elongation proximally to the stent-graft.

• Is this observation associated with stent-graft related complications, such as dissection extension and SINE?

• Further investigation is warranted to understand if these findings should have implications for patient selection and stent-graft design.
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