

Clinical Relevance of Dynamic 4-D Analysis in the Thoracic Aorta throughout the Cardiac Cycle

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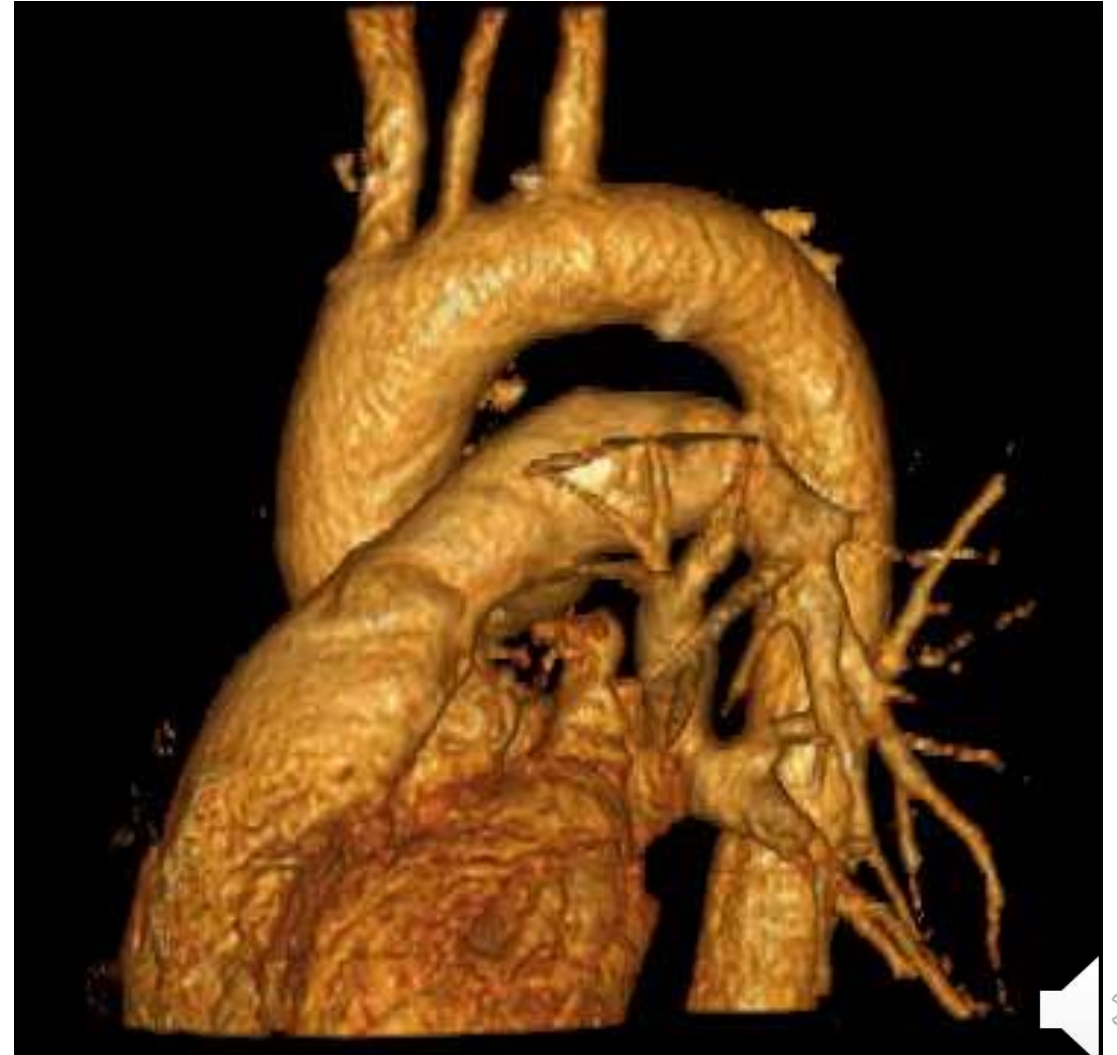


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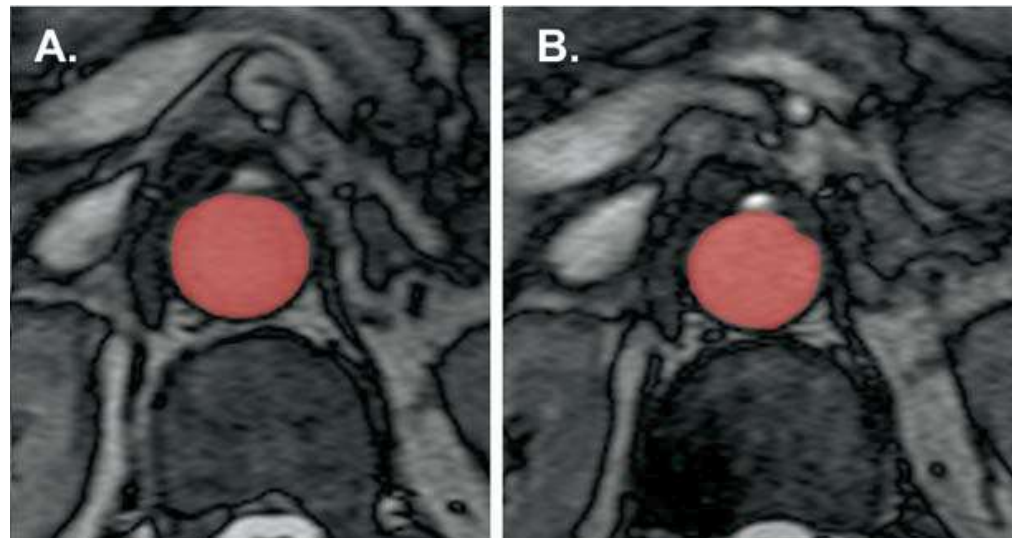
4D Animation of Aortic Arch Dynamics

Left Subclavian Artery



Background

- Dynamic analysis throughout cardiac cycle → 4th dimension
- Use of high-fidelity CT angiogram or MR
- Studies have shown significant multi-directional strain and displacement in thoracic and abdominal aorta throughout cardiac cycle^{1,2,3}
- These dynamic changes will have implications for endovascular thoracic aortic repair



1. Van Herwaarden et al., Dynamic magnetic resonance angiography of the aneurysm neck: conformational changes during the cardiac cycle with possible consequences for endograft sizing and future design, J Vasc Surg 2006

2. Mujeeb Zubair et al., Impact of cardiac cycle on thoracic aortic geometry – morphometric analysis of ecg-gated computed tomography, Ann Vasc Surg 2020

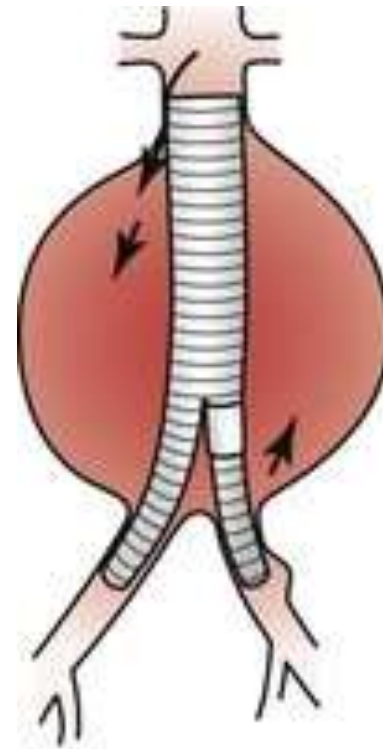
3. Nasr et al., Characterization of the physiological displacement of the aortic arch using non-rigid registration and MR imaging, Eur J Vasc Endovasc Surg 2017



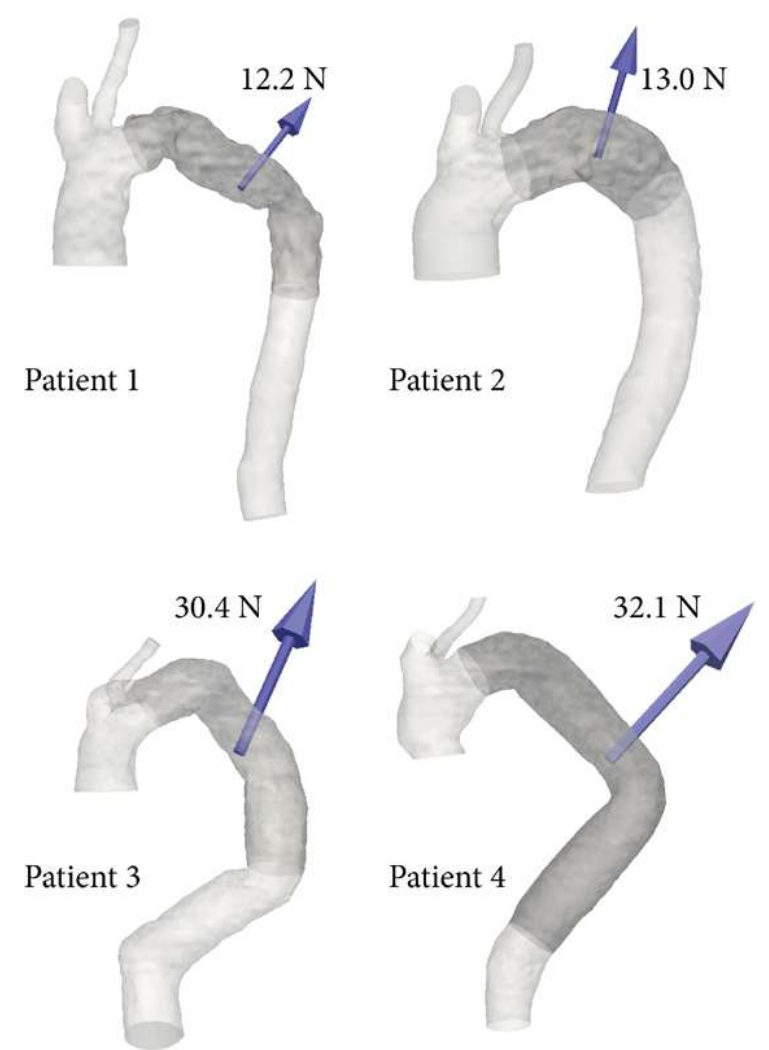
Clinical Relevance

- Stent-graft sizing mismatch could lead to complications:
 1. Type 1 endoleak
 2. Graft migration due to differential drag forces

Understanding 4D motion is key in endovascular graft design!



Type I



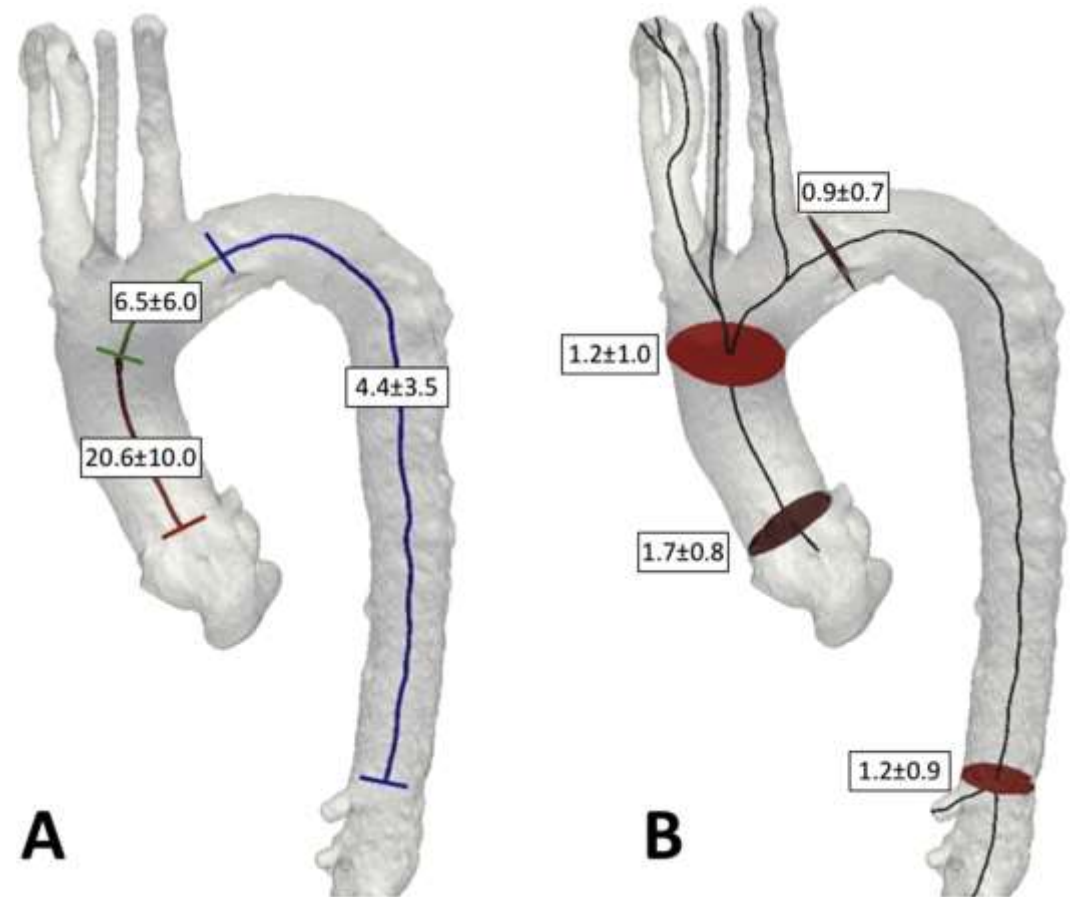
1. Belvroy et al., Type 1b endoleaks after thoracic endovascular aortic repair are inadequately reported: a systematic review, *Ann Vasc Surg* 2020
2. van Bakel et al., Blood flow after endovascular repair in the aortic arch: a computational analysis, *Aorta* 2018



Durability

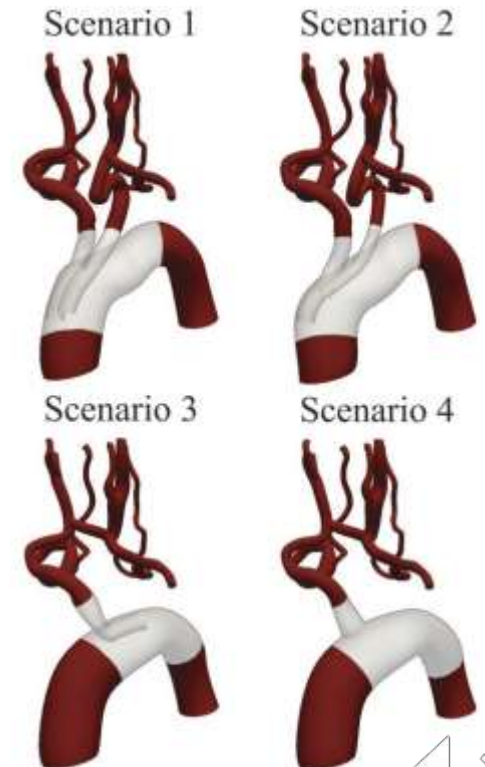
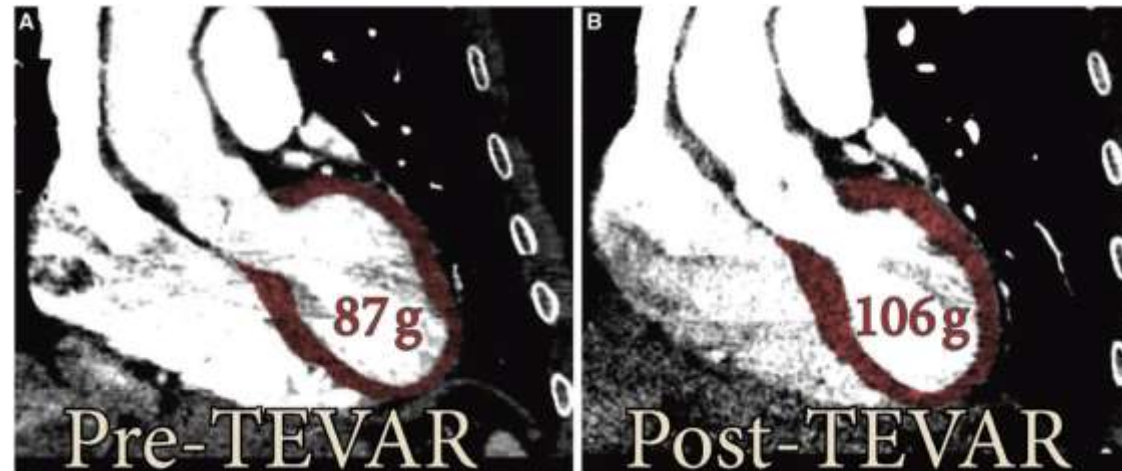
- Stent-graft 'tear and wear' due to RSI¹
- Personalized graft sizing (using pulse pressure)
- Increased conformability

→ Increased graft durability ≥ 15 years!



Considerations and Applicability

- 4-D is time consuming, need for dedicated radiologists
- Enables incorporation of CFD (computational fluid dynamics), but requires expertise^{1,2}
- CFD gives insight into clinical consequences:
 - Patient-specific stent graft design
 - Cardiac remodeling
 - End organ perfusion

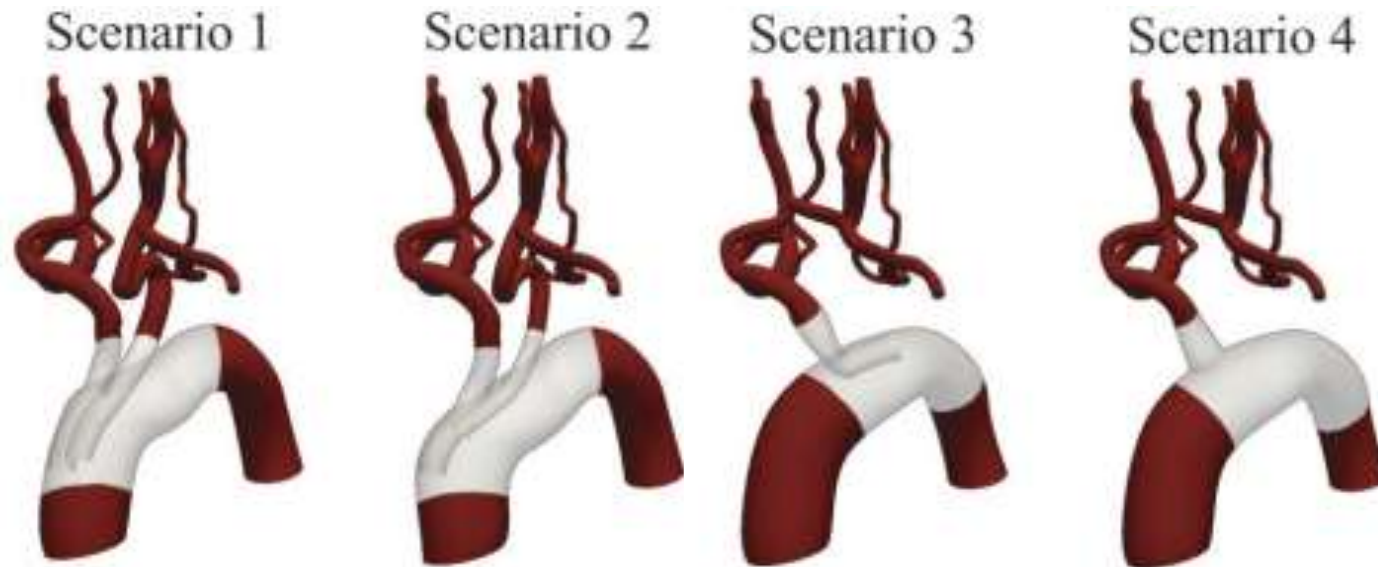


1. van Bakel et al., A computational analysis of different endograft designs for zone 0 aortic arch repair, Eur J Cardiothorac Surg 2018
2. van Bakel et al., Cardiac remodeling following thoracic aortic repair for descending aortic aneurysms, Eur J Cardiothorac Surg, 2018



Future perspectives

- Incorporation of 4D analysis into existing clinical software
- Improved endograft design → conformability is key
- Pre-operative planning for endovascular repair accounts for pulsatile motion of aorta



Take Home Message

Although we should be proud of contemporary achievements, we should not become complacent!

We still have ways to go regarding:

- Increased graft durability
- Decreased graft-related comorbidities

