SURGICAL & RADIOLOGICAL ENDOVASCULAR SYMPOSIUM
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IRM de Flux 4D des Dissections Aortiques: Peut-on prévenir l'évolution à long terme?

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LadHyX

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Ecole Polytechnique de Paris: Abdul Barakat
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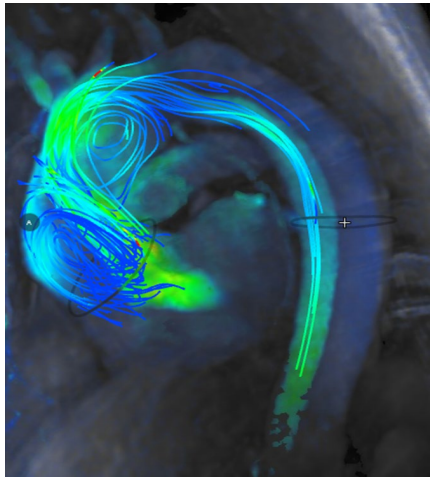
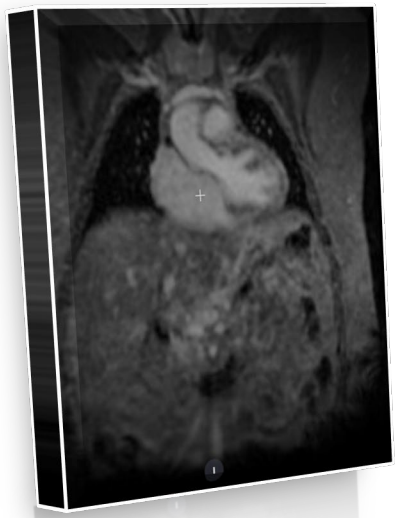
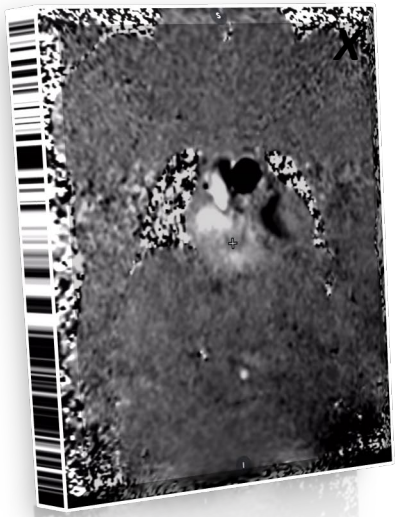


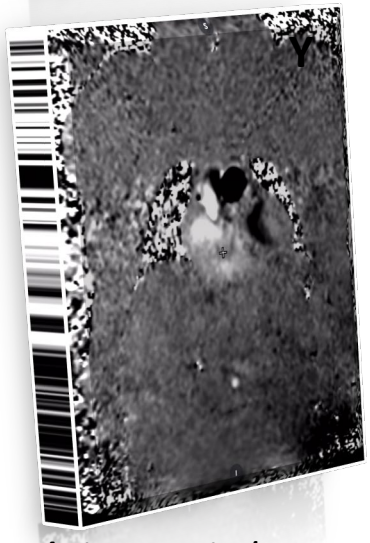
4D Flow Raw Data



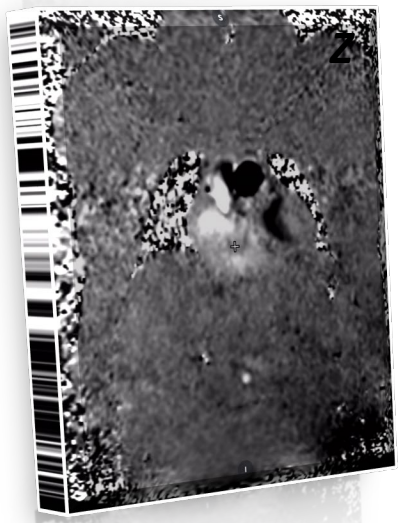
Magnitude Image



Right - Left



Antero-posterior

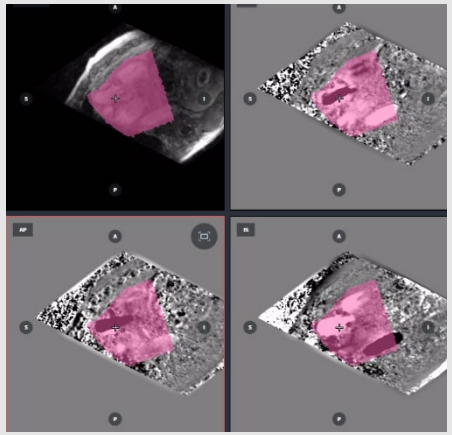


Superior-Inferior

Local Software or Cloud processing (Protected Health Information)

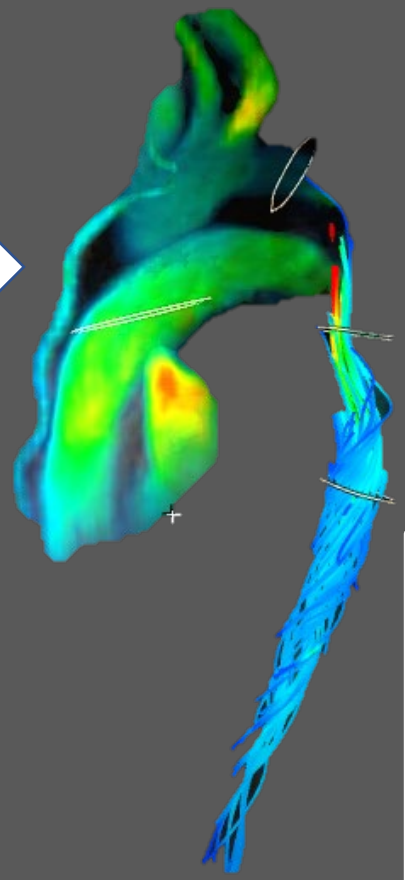
Preprocessing: Phase Offsets & Background correction +/- Helped by AI

- Eddy currents
- Noise masking
- Filtering of static tissue



Post-Processing:

Visual Flow Analysis



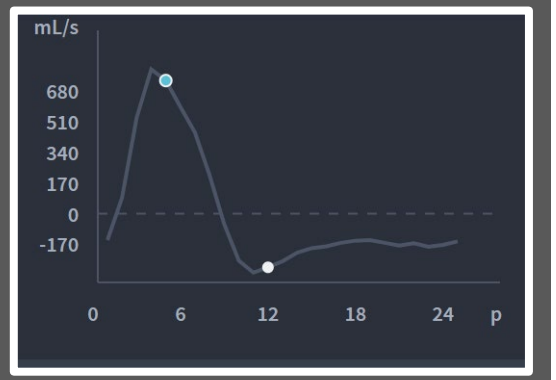
Quantitative Flow Analysis

Current trends

- Forward Flow
- Reverse Flow
- Regurgitation Fraction
- Peak Velocity

Advanced tools

- Wall Shear Stress



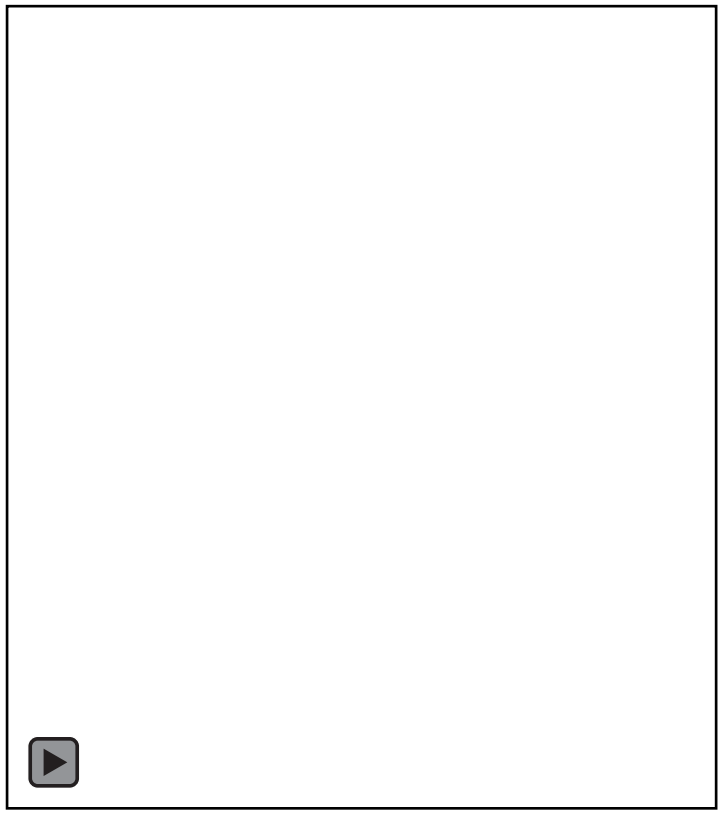
Azarine A et Al. Radiographics 2019

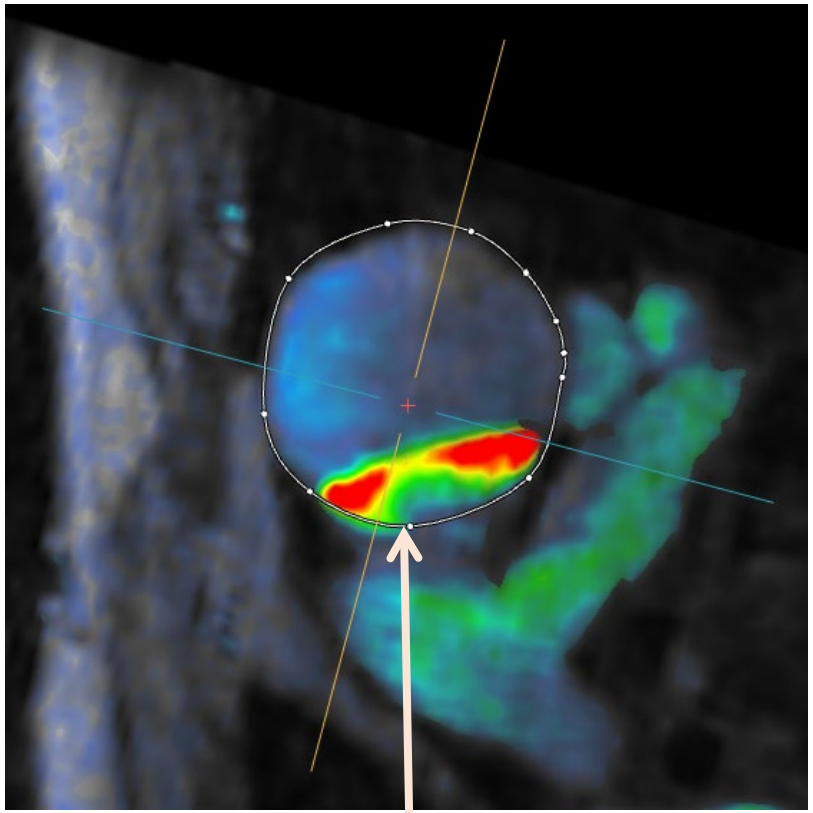
Aortic dissection in 4D Flow MRI: type A (no time for MRI!)

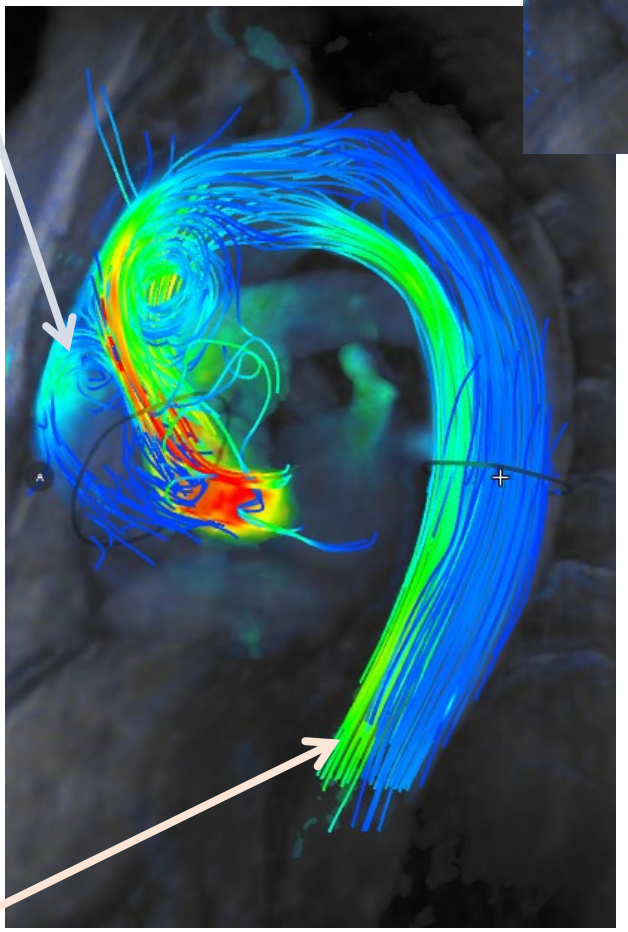
Chronic type A Dissection

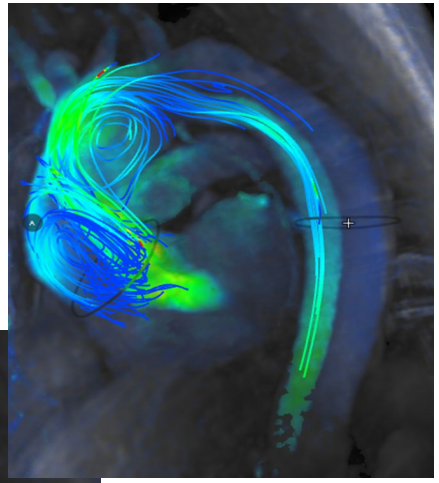
Type A dissection

Vortex in False lumen









True lumen

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Residual or Type B Dissection: MRI with 4D Flow enables Combination of Traditional Anatomic predictors and Functional Hemodynamic Biomarkers: Risk Stratification

Chronic type B survival:

- 50-80% at 5 years
- 30-60% at 10 years

Indications for Repair:

- Growth >10mm/y
- Diameter >60mm

Traditional Predictors of Aortic Dilation

Tear location and size (proximal Desc A, size>10mm/1cm^2)

Baseline Descending Aorta diameter > 40mm; >50 +++

Partial false lumen thrombosis

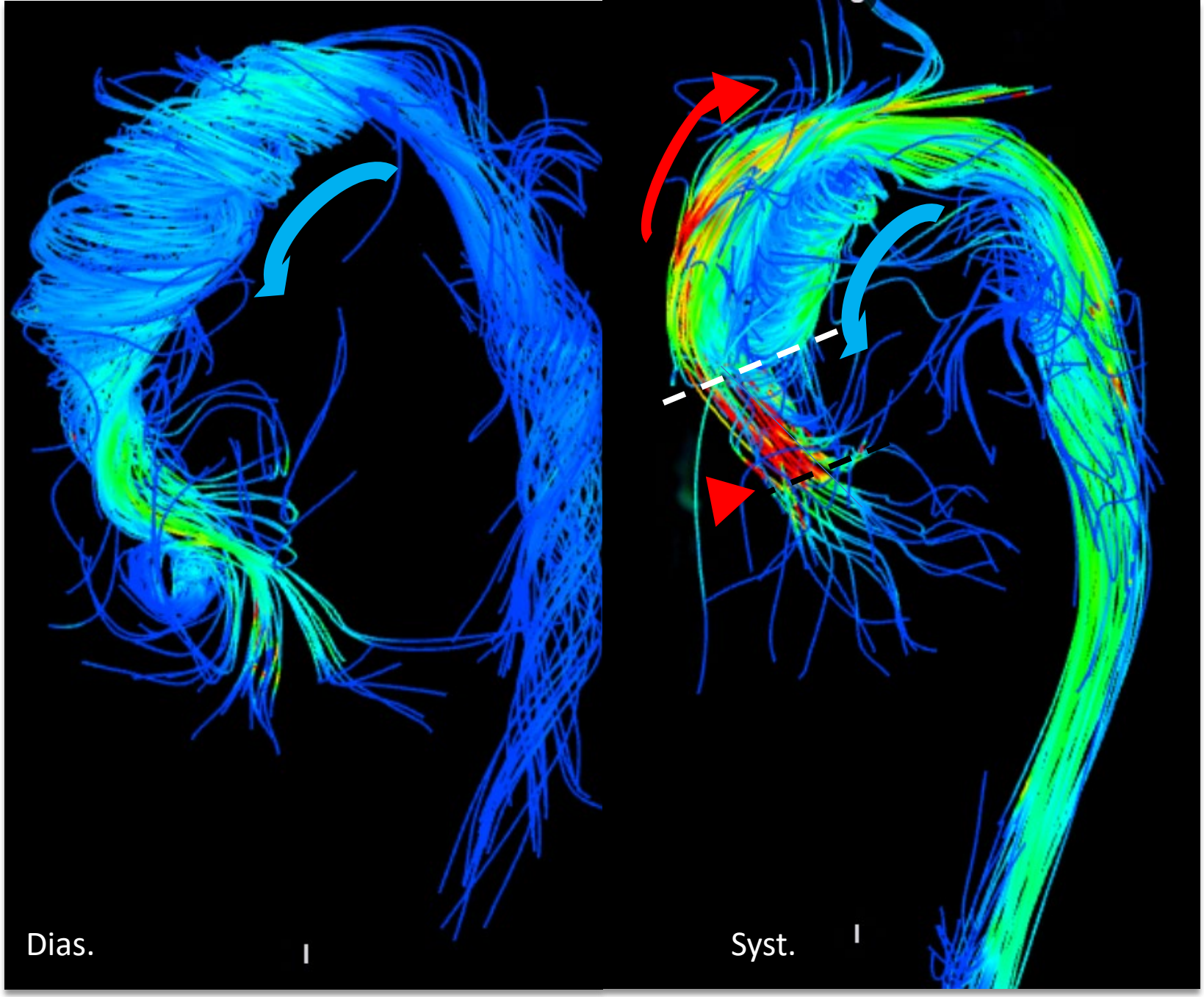
Post-Bentall

Laminar Forward Flow along the Bentall Prothesis

Vortical and recirculation flow moved to anterior aortic arch

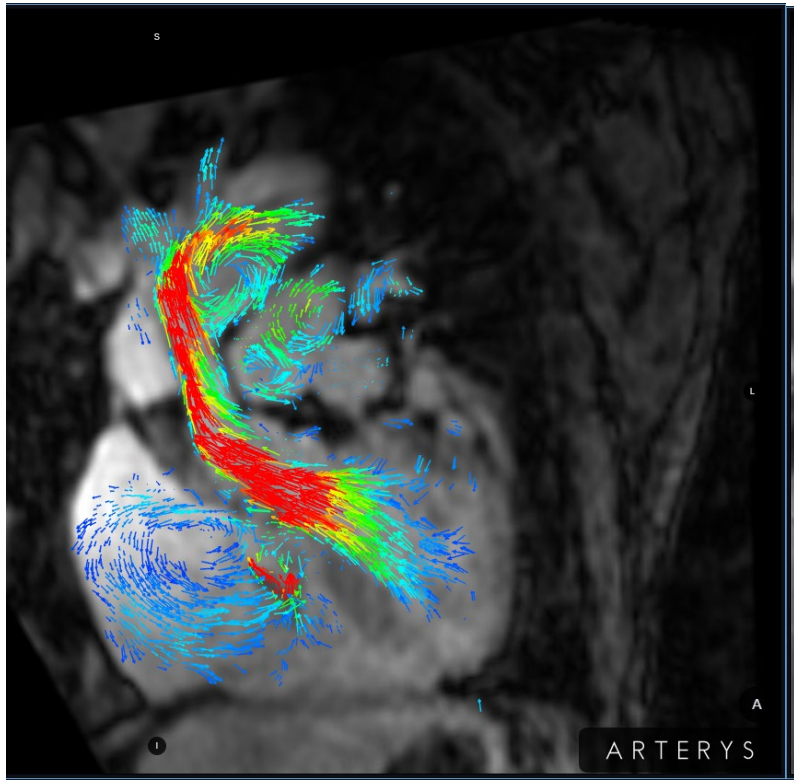
⇒Adverse flows

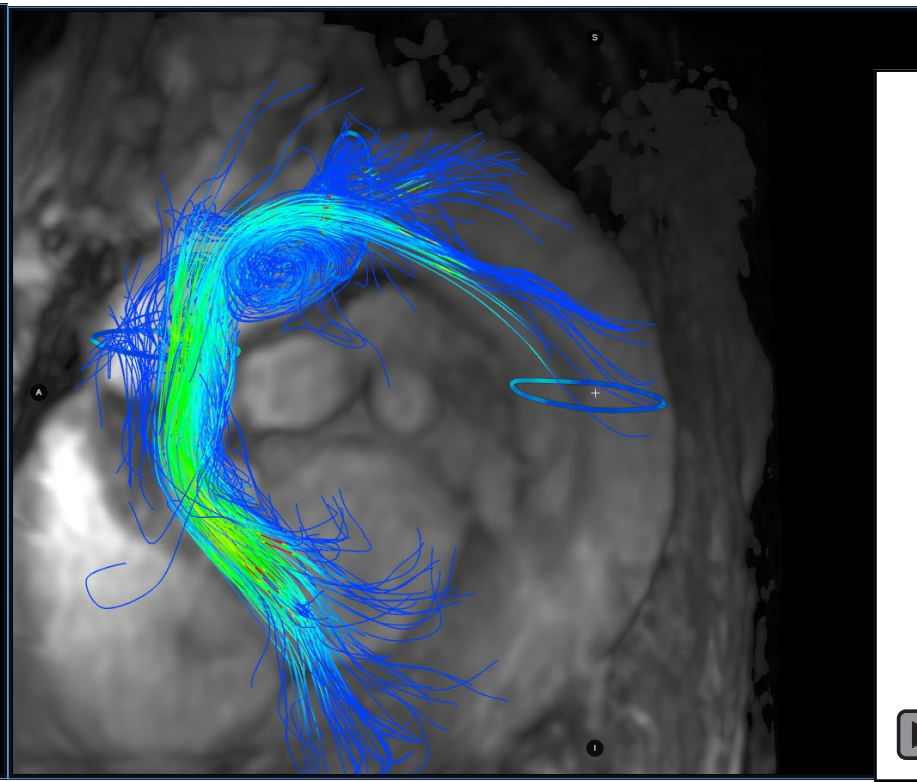
⇒ Anterior Arch dilation



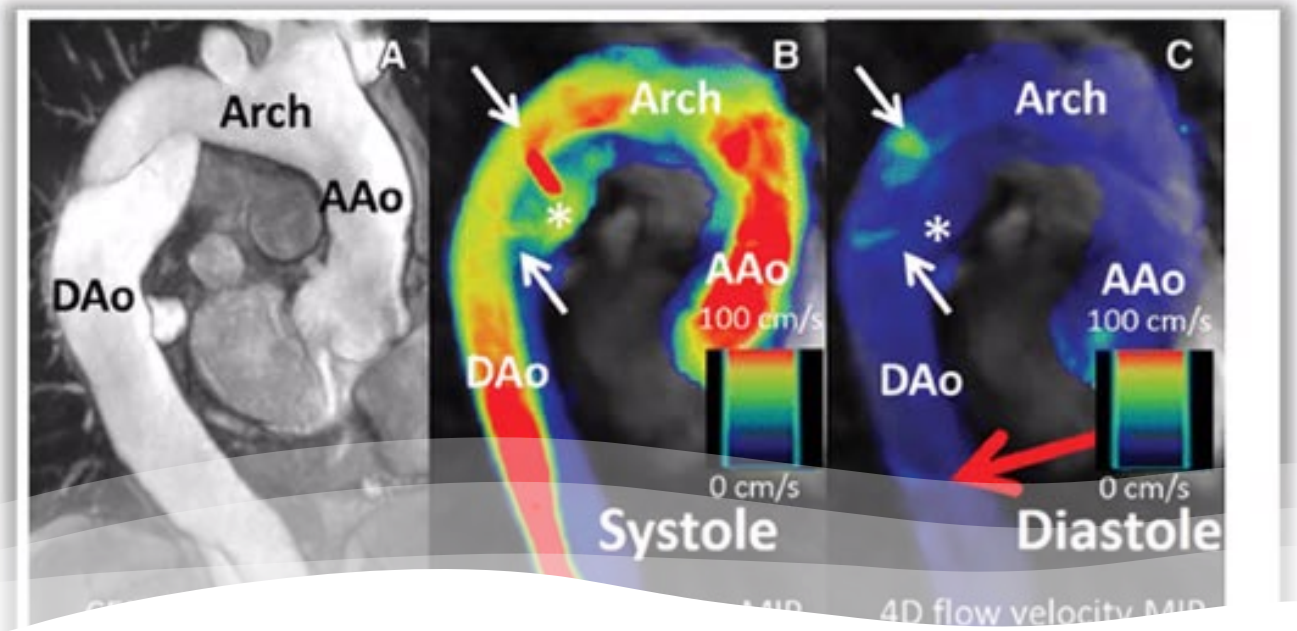
Acute Aortic Dissection :

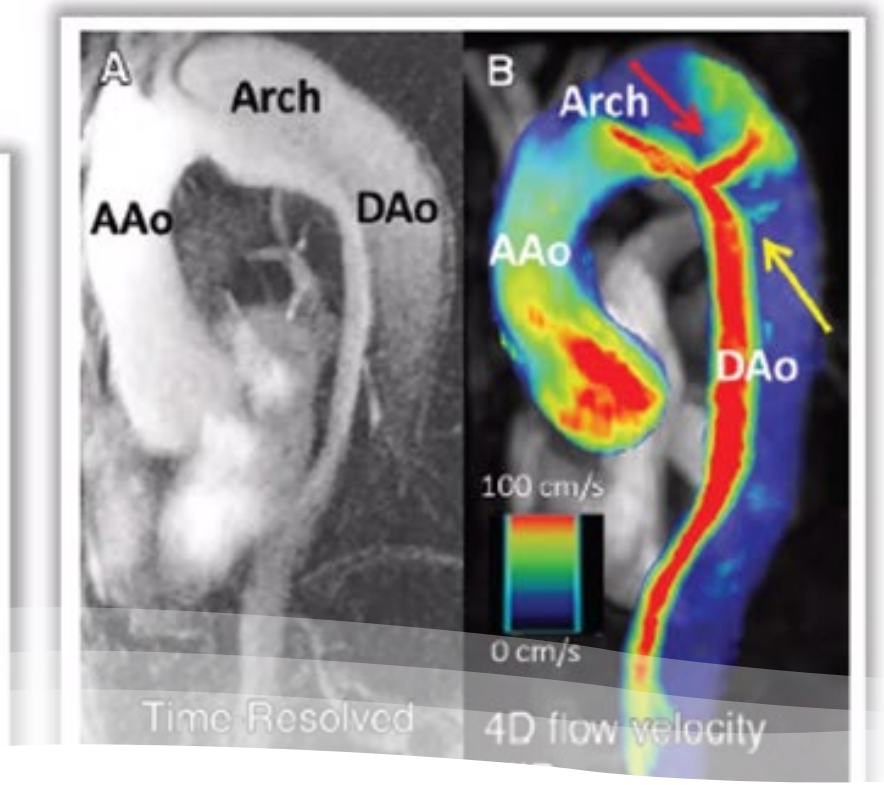
Off-Pump Wrapping
In High-Risk Patients
Comprehensive flow analysis using 4D flow

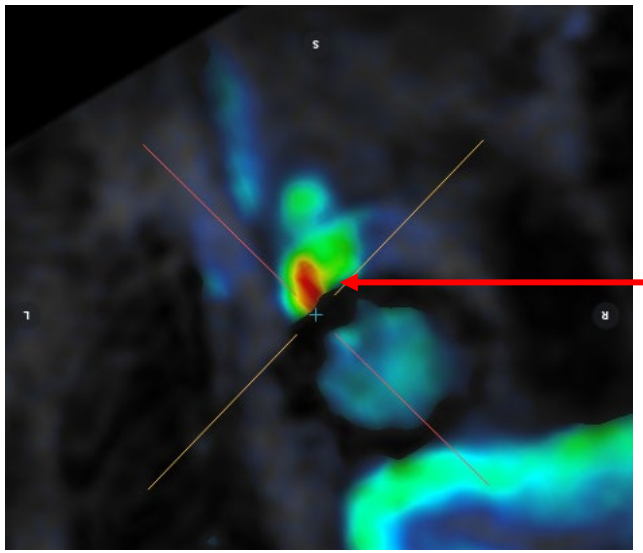




Why Aortic Hemodynamics?







Azarine A et Al. Radiographics 2019

- Flow Velocity Quantification: Stenosis? Stagnation?
- Tear hemodynamics
- TEVAR : may help for Endoleak characterization
- Adverse Flow characterization: Laminar, Turbulent, Helical or Vortical flows ?
- Potential Predictive Biomarkers: WSS, PWV, Stiffness, Regurgitant Fraction, vorticity …

Increased Wall Shear Stress (WSS) to Predict Aortic Dilation

Longitudinal Study (median 6-year follow-up [IQR 5.5-6.7 years]:

Capability of WSS to predict aortic growth

JACC: CARDIOVASCULAR IMAGING VOL. ■, NO. ■, 2021

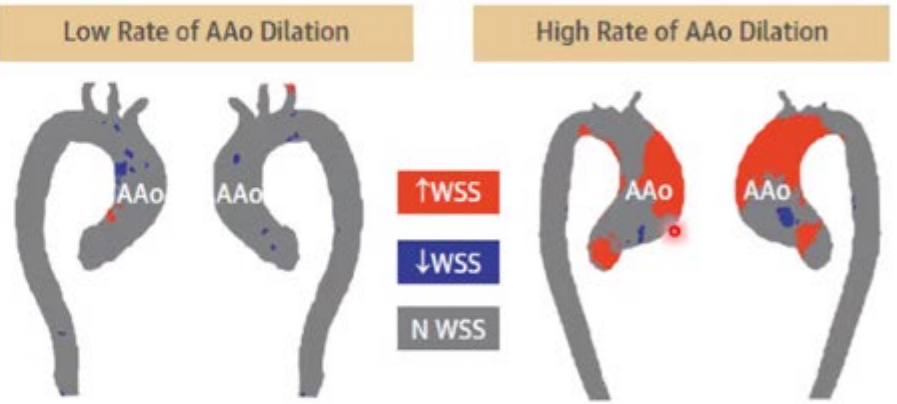
PUBLISHED BY ELSEVIER

NEW RESEARCH PAPER

Association of Regional and Progressive Ascen Dilation in Bicuspid Aor

Gilles Soulat, MD, PhD,[a,*] Michael B. Scott, PhD,[a,b,*] Bradley S. Chris Malaisrie, MD,[d] Patrick McCarthy, MD,[d] Paul W.M Michael Markl, PhD[a,b]

FIGURE 2 Regionally Elevated WSS in Patients With Fast Versus Slow Rates of Aortic Dilation



Aorta WSS heat map examples for 2 patients arranged by rate of aortic dilation (fast vs slow, defined as greater or less than 0.24 mm/y, respectively). Each panel represents right anterior and left posterior views of the patient-specific WSS heat map illustrating abnormal WSS relative to individually age- and sex-matched WSS population averages.

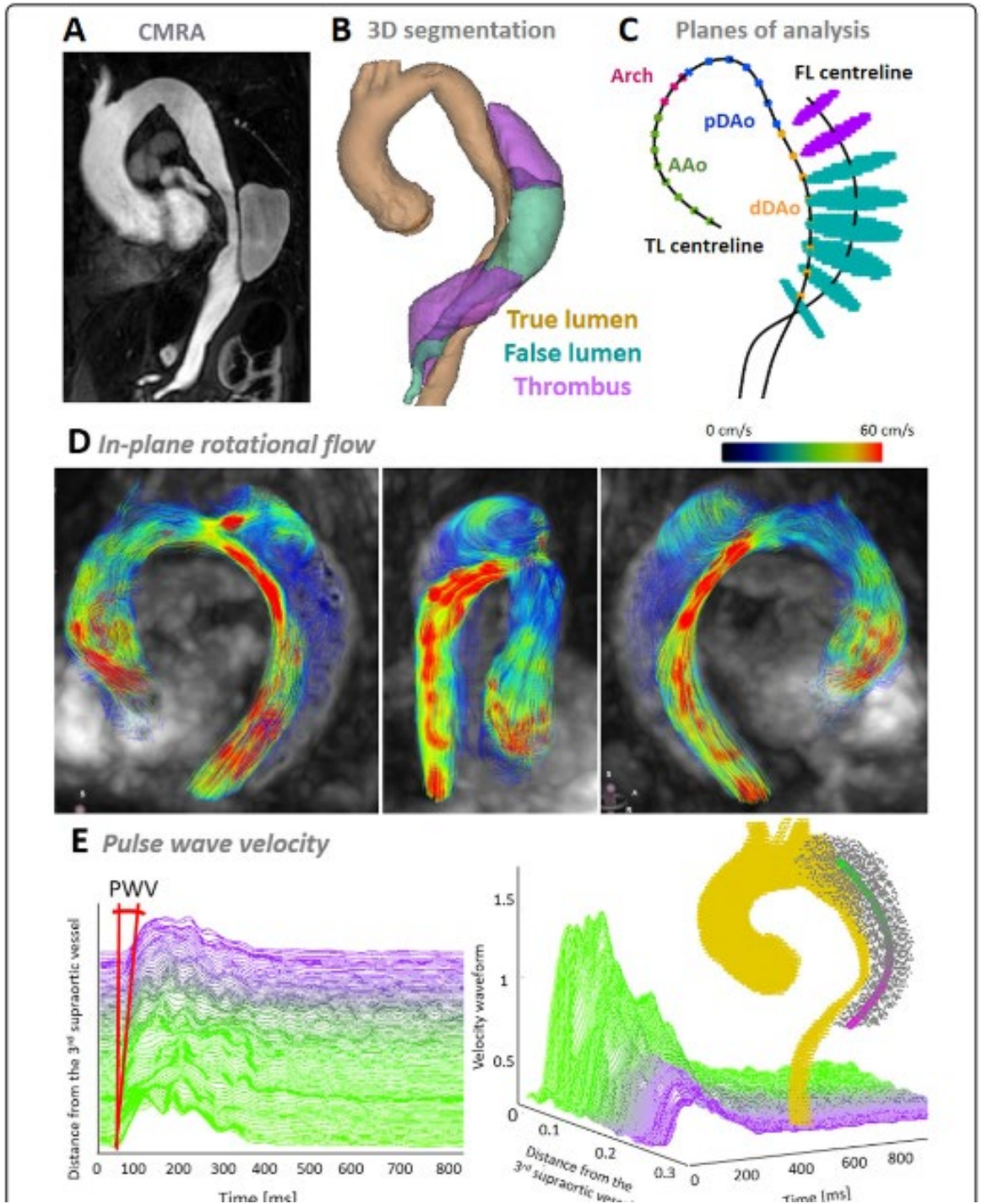
Ruiz-Munoz et al.: largest long. Study n = 54

Dynamic Markers complement Traditional Anatomical variables

No Significant role in Aortic Growth:
- Type A or B
- Flow stasis (V<5cm/s)
- WSS near significant

Key Independent Predictors of AD Growth:

- **Pulse Wave Velocity:** reflects false lumen Stiffness and predicts Growth: Stiffer the wall = increased local pressure
- **In-plane Rotational Flow (IRF) :** helical flow increases Pressurization (systole)
- **False Lumen Thrombus volume** correlated with growth
- **Entry Tear Area**



RESEARCH Open Access

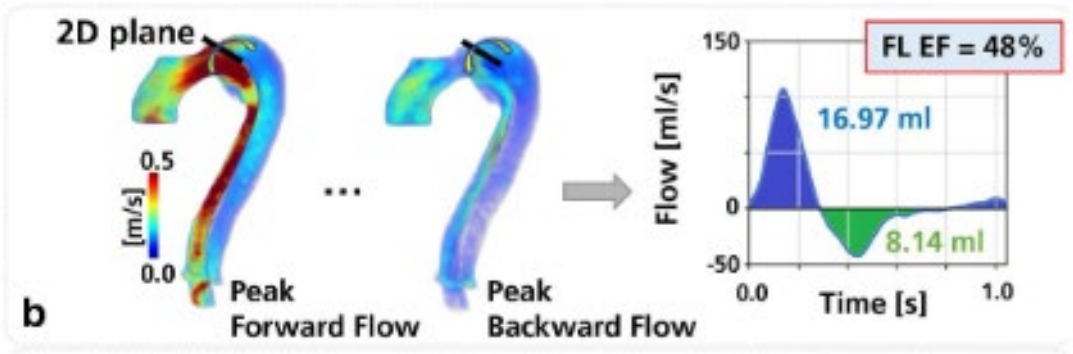
False lumen rotational flow and aortic stiffness are associated with aortic growth rate in patients with chronic aortic dissection of the descending aorta: a 4D flow cardiovascular magnetic resonance study

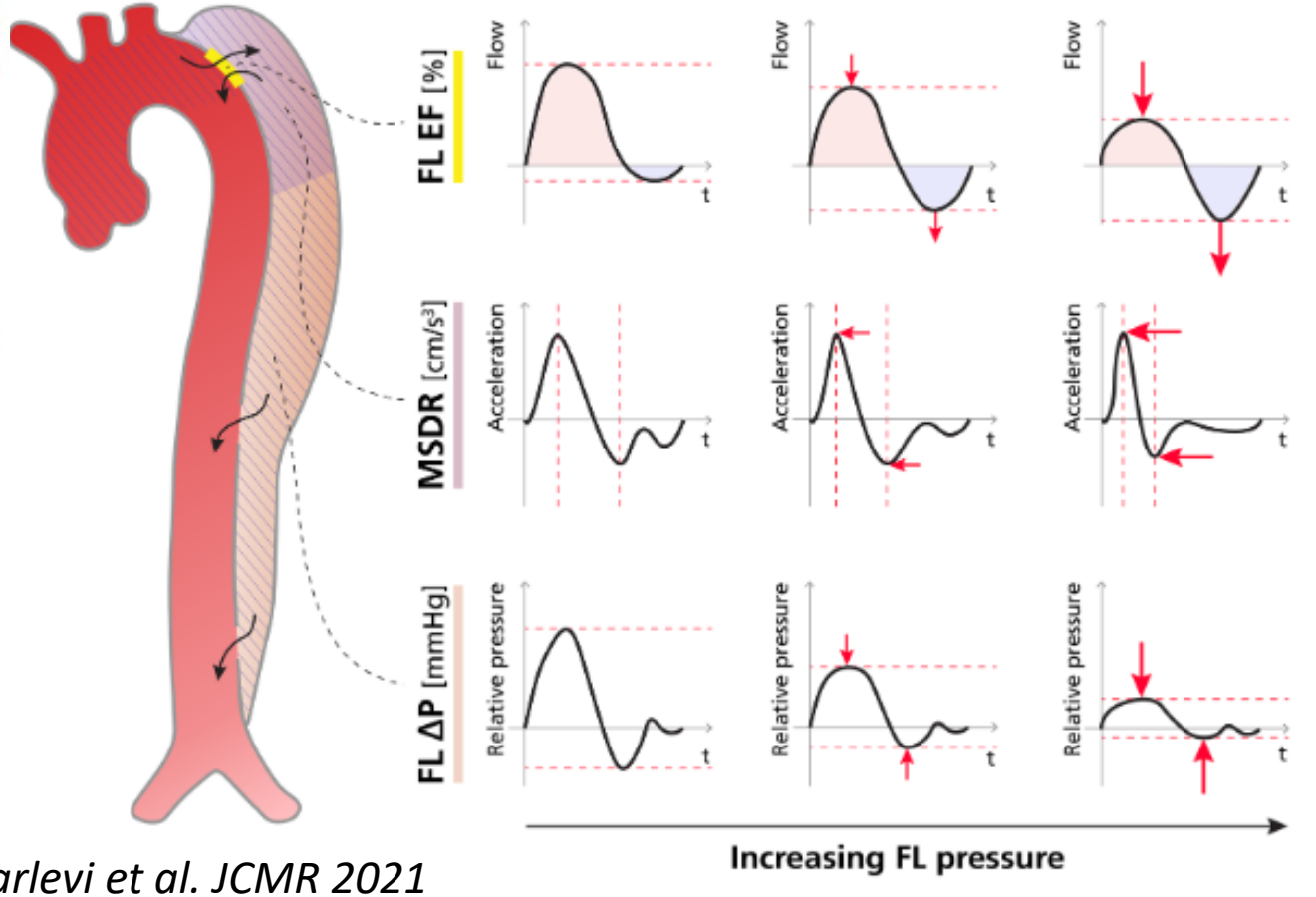
Aroa Ruiz-Muñoz[1,2,3,4†], Andrea Guala[1,2*†], Lydia Dux-Santoy[1], Gisela Teixidó-Turà[1,2,3], Maria Luz Servato[3], Filipa Valente[3], Juan Garrido-Oliver[1], Laura Galian-Gay[3], Laura Gutiérrez[3], Rubén Fernandez-Galera[3], Guillem Casas[3], Teresa González-Alujas[3], Hug Cuéllar-Calabria[1,4,6], Kevin M. Johnson[7], Oliver Wieben[7], Ignacio Ferreira-Gonzalez[1,3,4,5], Arturo Evangelista[1,2,3,4,8] and Jose Rodriguez-Palomares[1,2,3,4*]

Abstract

Background: Patency of the false lumen in chronic aortic dissection (AD) is associated with aortic dilation and long-term aortic events. However, predictors of adverse outcomes in this population are limited. The aim of this study was

4D Flow MRI Derived False Lumen (FL) metrics to predict Aortic Growth Rate: False Lumen Ejection Fraction (more pressurization in FL)





- **False Lumen Ejection Fraction : Yes**
- **FL Maximal relative Pressure: Yes**
- **Max Systolic Deceleration Rate: No**

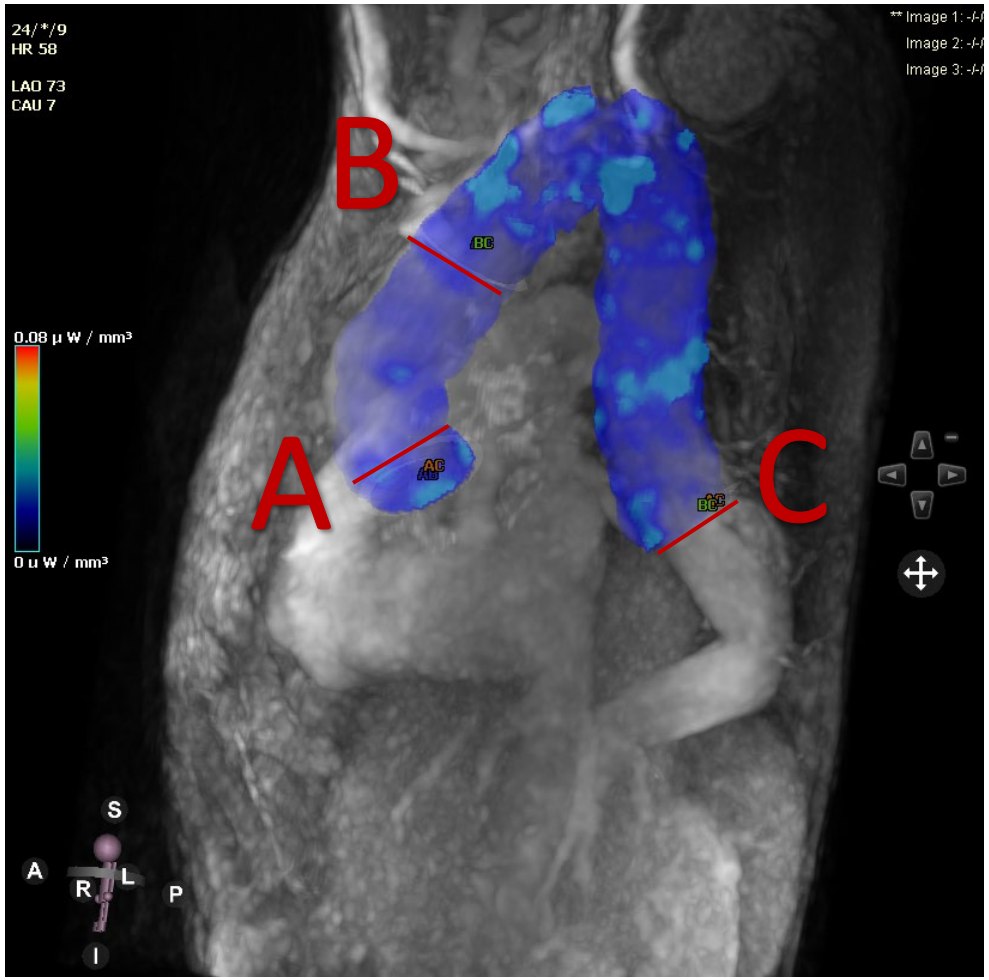
FLMRP= difference in absolute pressure between aortic root and distal FL

Marlevi et al. JCMR 2021

Multi Centric Multi vendor Prospective study to assess Aortic Dissection Flow patterns Before and After Endograft : FASCAT

ARTERYS
Medical Imaging Cloud AI

- **Positive/Negative/Net flow**
- **Fraction of reverse flow**
- **Flow eccentricity**
- **Peak speed**
- **WSS**
- **Anatomical data**



A: Sino-tubular junction
B: 1cm before TEVAR
C: 1cm after TEVAR

circle
CARDIOVASCULAR IMAGING

- **Kinetic Energy Loss**
- **Wall Shear Stress**
- **Pulse Wave Velocity**
- **LV Function & Strain**

FASCAT: 4-D Flow To Assess *Flow And Structural Changes After TEVAR*

FLOW ECCENTRICITY changes in the Ascending Aorta

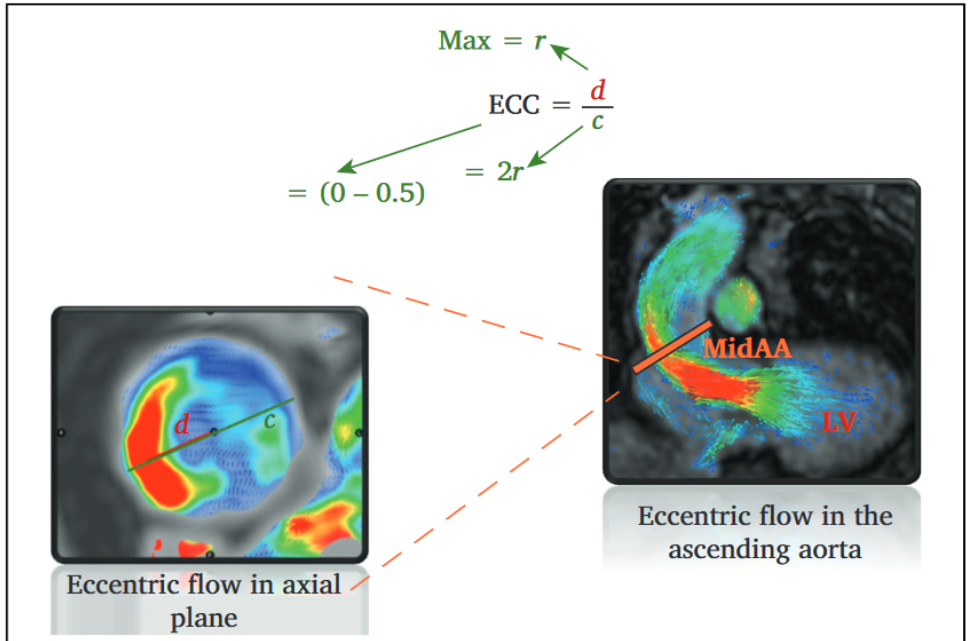
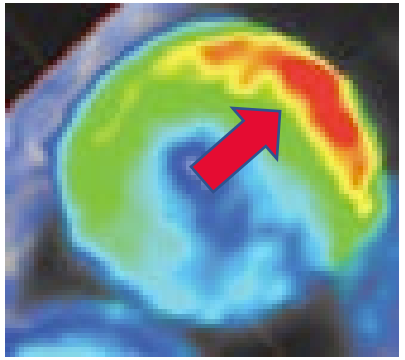
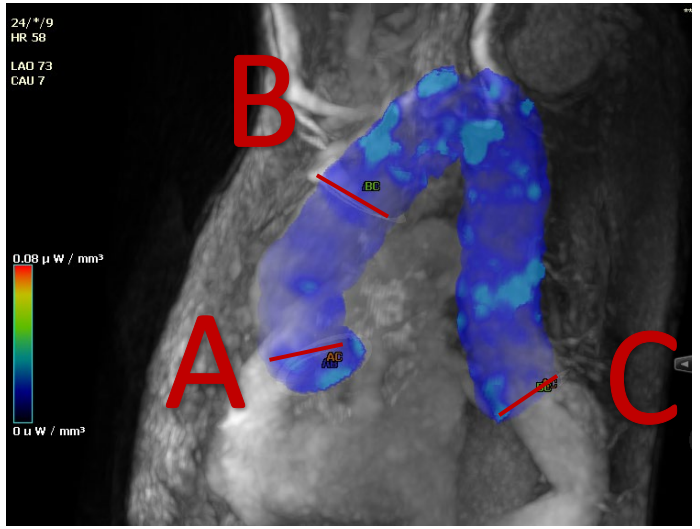
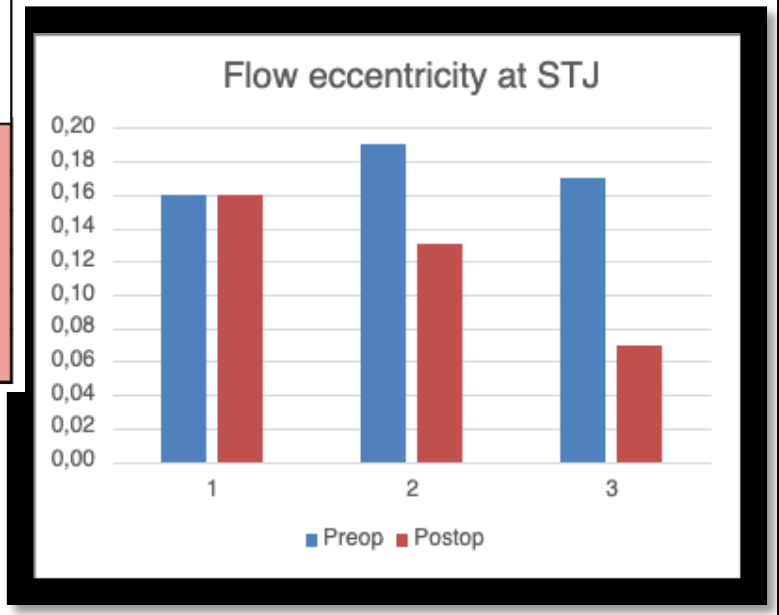
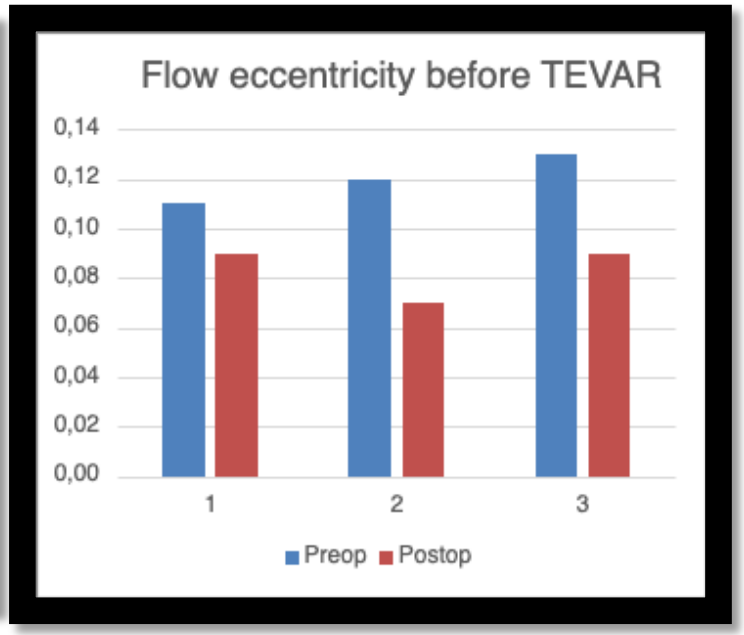


Figure 2. Diagram showing basic four dimensional flow magnetic resonance imaging (4D flow MRI) metrics extracted for all phases. ECC = flow eccentricity (with values ranging between 0 and 0.5); *d* = distance between the centre of the positive flow and centre of the contour; *c* = mean contour diameter; *r* = vessel radius; MidAA = mid ascending aorta; LV = left ventricle.





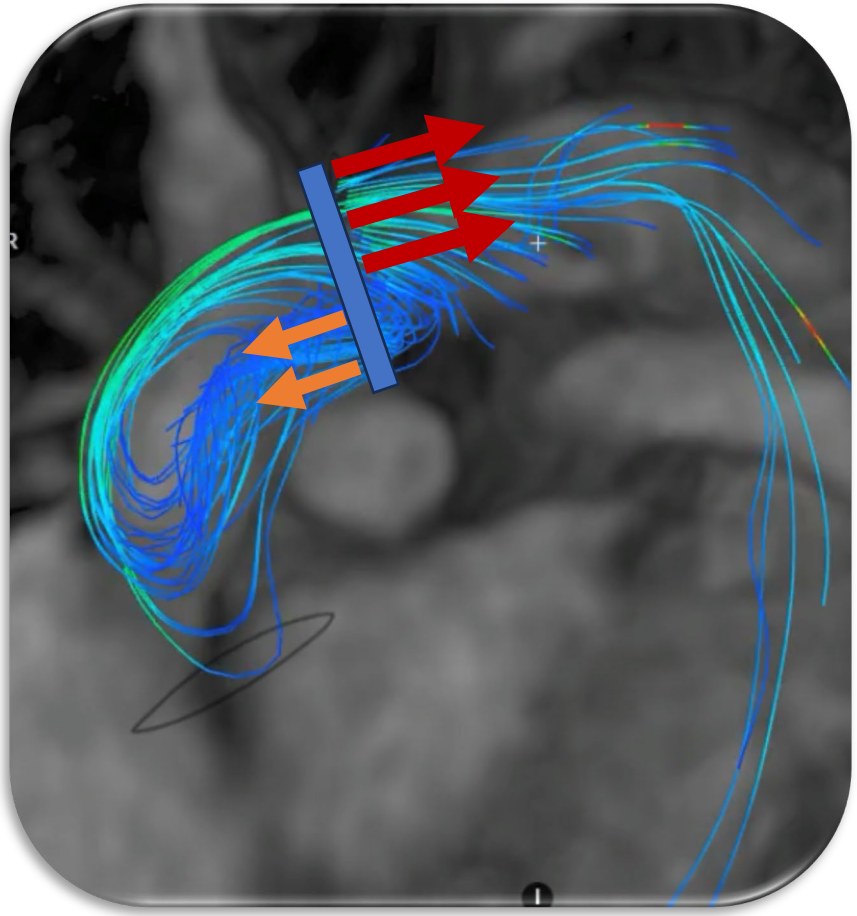


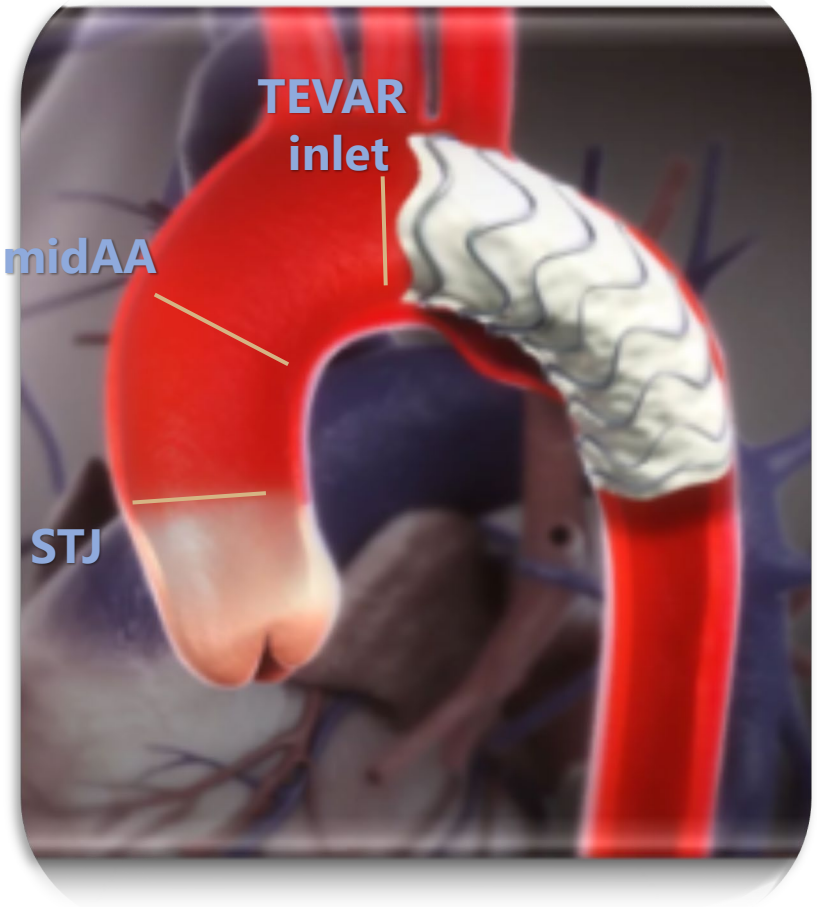


RESULTS

EFFECT OF TEVAR ON AORTIC FLOW FIELDS

Fraction of Reverse Flow



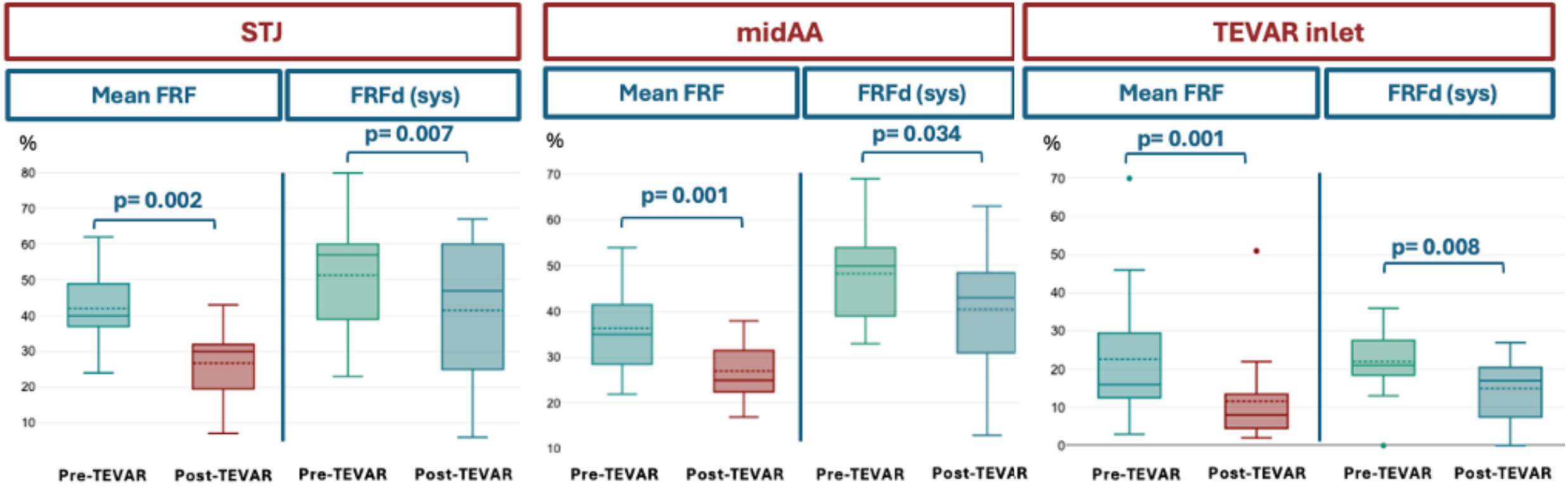


Aortic Reverse Flow (ARF)
Aortic Forward Flow (AFF)

RESULTS

EFFECT OF TEVAR ON AORTIC FLOW FIELDS

SIGNIFICANT DECREASE IN UPSTREAM RETROGRADE FLOWS



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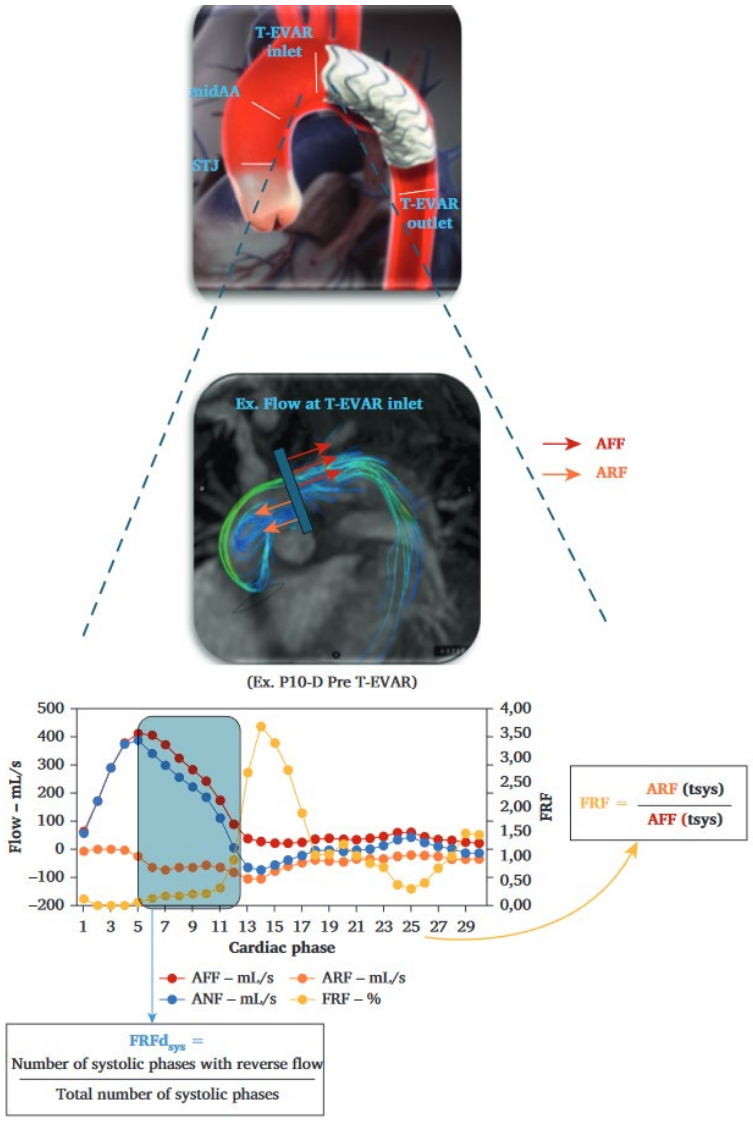
A Hauguel et al. Eur J Vasc Endovasc Surg 2025



Changes in Ascending Aortic and Aortic Arch Secondary Flow Patterns Following Endovascular Repair of the Descending Thoracic Aorta

Alexandra Hauguel [a,b], Kianosh Kasani [c], Virgile Chevance [d], Xingjian Zhang [b], Abdul I. Barakat [b], Stephan Haulon [a,*], Arshid Azarine [d]

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WHAT THIS PAPER ADDS

This pre to post thoracic endovascular aortic repair (T-EVAR) study using four dimensional flow magnetic resonance imaging (4D flow MRI) found a significantly increased aortic stiffness in the stented segment, leading to a decrease in pulse wave velocity upstream of the graft. Concurrently, a significant decrease in secondary flow upstream of the T-EVAR was observed, suggesting improved upstream aortic flow fields and blood circulation. These upstream haemodynamic improvements post T-EVAR could, to a certain extent, counteract the deleterious effects of increased aortic stiffness in the stented segment. These results strongly support the importance of aortic fluid mechanics assessment pre to post T-EVAR, in addition to changes in aortic compliance, to holistically understand the effects of aortic endografting.

After TEVAR: decrease in FRFsys and it's duration in the ascending Aorta

⇒ PWV decreased in the ascending aorta and anterior arch

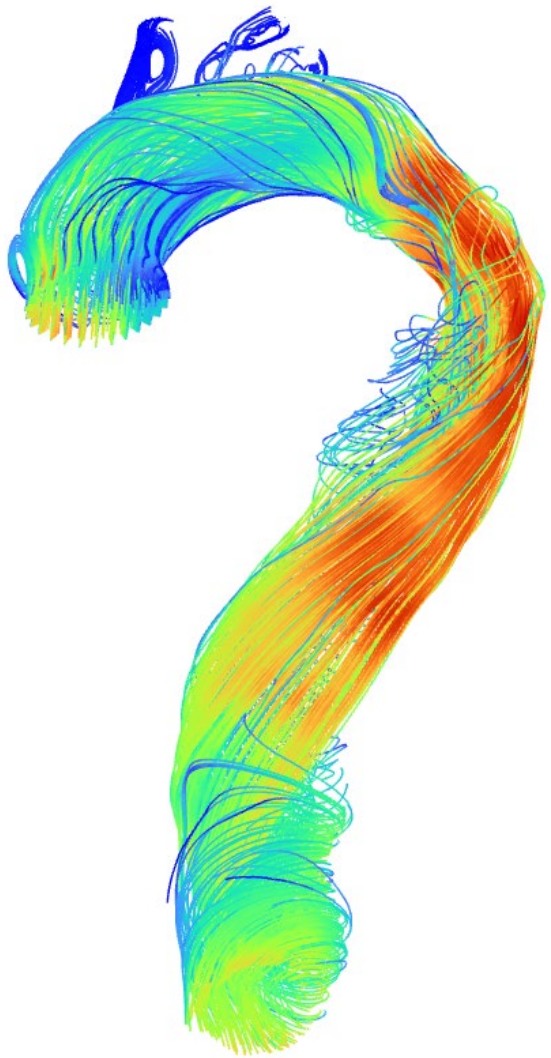
Even if stiffness is increased in the stented portion (PWV increase)

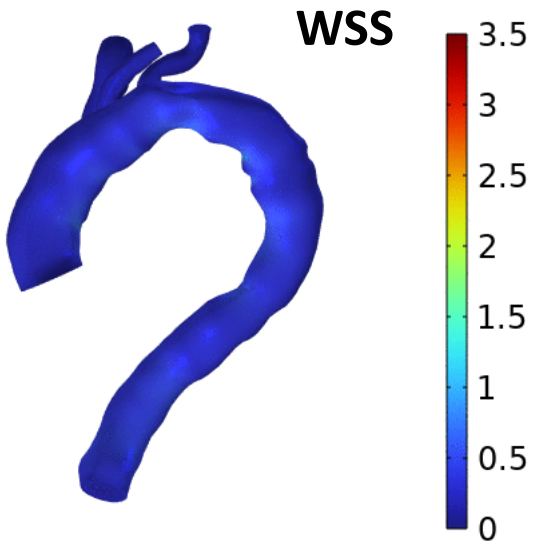
⇒ Eccentricity decreased in the proximal aorta

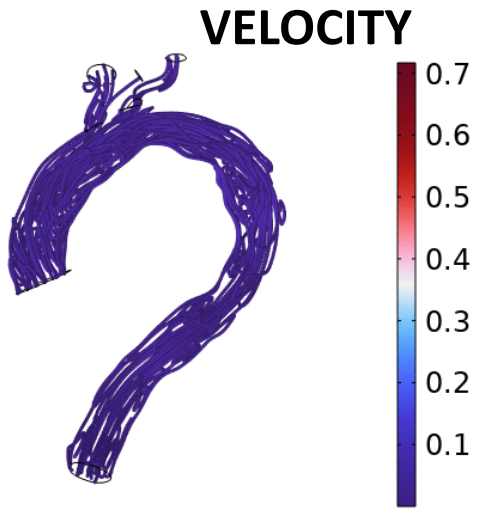
⇒ Better LV-Aortic Coupling

Perspective

EFFECT OF TEVAR ON AORTIC FLOW FIELDS





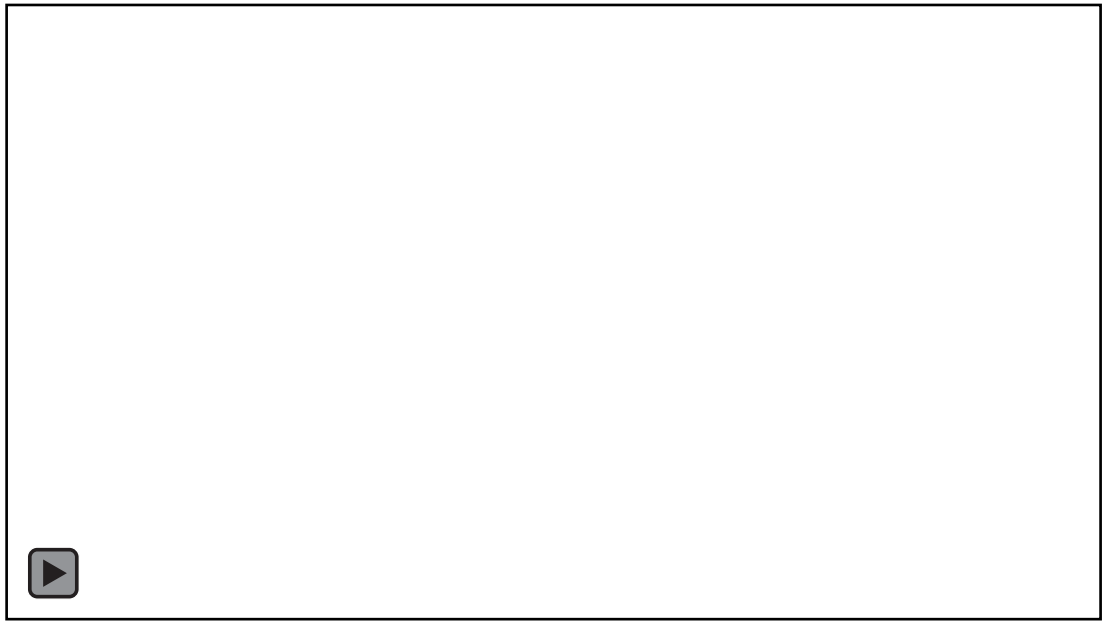


Effect on the growth at 2 years of these biomarkers, including FRF_{sys}

Larger cohorts, multi-vendor

Automatized measurement AI training

Identifying vortical flow clusters Using Q-Criterion



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CONCLUSION: 4D Flow MRI

New insights into the False and the True lumen Hemodynamics

Secondary flow patterns characterization

Possible: Post Surgery / Endograft follow-up

Many Independent predictors of Aortic Growth:

False Lumen Ejection Fraction, PWV, In plane rotational flow, Helicity… WSS?

“Research Tools”=> to be automated?

Other promising biomarkers to further validate on larger cohorts for Risk Stratification