Biomechanical Issues in the Aortic Arch

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by

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Aortic arch: biomechanical issues

- complex geometry of the aortic arch
- forces induced (pressure, flow)
- mechanical behavior

10% of the AA

difficult to treat
from basic models......

to real geometry......!!
• tortuous geometry to reach implantation position
  
  → *risk of injuring vessel*

• endograft undergoes deformation once implanted (torsion, flexure, compression…)

  → *specific stress in the device*

  → *geometry match is not controlled (migration..)*
Pressure forces

at implantation time

Initial configuration

balance configuration:
- graft segments still compressed
- vessel wall under tension

from diastole to systole

systole
Consequences = compromise must be found...

1. stent segments must be sufficiently compressed.....

Pressure forces

contact rupture = migration risk
2. ...but not too much  

- **issues with endograft positioning**

1. **at rest**
   - fabric is under tension

2. **once implanted**
   - radial force = possible fabric slight folding
stress in the biological tissue

stress >> 0.25 Mpa
(native tissue)
Flow forces / shearing force

\[ \tau = \frac{32 \cdot \mu \cdot Q}{\pi d^3} \]

\[ F_{\text{shearing}} = \left( \frac{32 \cdot \mu \cdot Q}{\pi d^3} \right) \times \text{Inner Surface Area} \]

…..graft migration risk
Flow forces / drag force

\[ F_x = -Q_m^2 / S [\sin \alpha_2 - \sin \alpha_1] + P_1.S.\sin \alpha_1 - P_2.S.\sin \alpha_2 \]

\[ F_y = Q_m^2 / S [\cos \alpha_2 - \cos \alpha_1] + P_1.S.\cos \alpha_1 + P_2.S.\cos \alpha_2 \]

if \( \alpha_1 = \alpha_2 \)
\[ F_x = 0 \]

…..graft migration risk

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Flow forces / pulse force

\[ P_1 = P_2 + \rho a L \]

\[ F_{\text{pulse}} = \Delta P \times \text{obstructed area} \]

acceleration

_____.. graft migration risk
what about the segments material…?

1. stress level
  ➔ traumatism level
  ➔ rigidity

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what about the segments material…?

1. stress level
   - traumatism level
   - rigidity

2. elastic deformation range
   - at implantation (no balloon)
   - compliance respect

**Stress**

**Strain**

- loading
- unloading

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what about the segments material…?

1. stress level
   ➔ traumatism level
   ➔ rigidity

2. elastic deformation range
   ➔ at implantation (no balloon)
   ➔ compliance respect

3. load / unload behavior
Conclusions

- tortuous geometry to reach implantation position
  
  *risk of injuring vessel*
  
- endograft undergoes deformation (specific flow conditions)
  
  *migration risk*
  
  *endoleak*
  
TAA Endografting = efficient technology (short term)
BUT.....
still requires to be optimized (design, materials...)
Thanks for attention