Real time evaluation of flow patterns of AAA depending on intramural thrombosis using AneurysmFlow.

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Disclosure

Speaker name:

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☐ I have the following potential conflicts of interest to report:

☐ Consulting

☐ Employment in industry

☐ Stockholder of a healthcare company

☐ Owner of a healthcare company

☐ Other(s)

☑ I do not have any potential conflict of interest
AAA Rupture Risk Prediction

- AAA size
- AAA expansion rate
- Only 25% of AAAs rupture in a patient’s lifetime.

- New tools for AAA rupture risk evaluation
  - AAA wall shear stress
  - Vessel asymmetry
  - FEARI (Finite element analysis rupture index)
  - RPI (Rupture potential index)
  - SP (Severity parameter)
  - Growth of intraluminal thrombus
  - Method of determining AAA growth and rupture based on math models

Darling RC, Circulation. 1977
Association of Hemodynamic Characteristics and Cerebral Aneurysm Rupture

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Abstract

Background and purpose—Hemodynamic factors are thought to play an important role in the initiation, growth, and rupture of cerebral aneurysms. This report describes a study of the associations between qualitative intra-aneurysmal hemodynamics and the rupture of cerebral aneurysms.

Methods—210 consecutive aneurysms were analyzed using patient-specific CFD simulations under pulsatile flow conditions. The aneurysms were classified into categories depending on the complexity and stability of the flow pattern, size of the impingement region, and inflow concentration by two blinded observers. A statistical analysis was then performed with respect to history of previous rupture. Inter-observer variability analysis was performed.

Results—Ruptured aneurysms were more likely to have complex flow patterns (83%, p<0.001), stable flow patterns (75%, p=0.0018), 66% concentrated inflow (66%, p<0.0001), and small impingement regions (76%, p=0.0006) compared to unruptured aneurysms. Inter-observer variability analyses indicate that all the classifications performed are in very good agreement, i.e., well within the 95% confidence interval.

Conclusions—A qualitative hemodynamic analysis of cerebral aneurysms using image-based patient-specific geometries has shown that concentrated inflow jets, small impingement regions, complex flow patterns, and unstable flow patterns are correlated with a clinical history of prior aneurysm rupture. These qualitative measures provide a starting point for more sophisticated quantitative analysis aimed at assigning aneurysm risk of future rupture. These analyses highlight the potential for CFD to play an important role in the clinical determination of aneurysm risks.
AneurysmFlow, Philips in Cerebral Aneurysm

Evaluation of blood flow before and after Flow diverter

Initial 3D angio + DSA with 60 frames/sec 5 cc contrast /s for 4 seconds

Contrast Transit time
Contrast concentration
Flow velocity
Flow direction
Study Design

Purpose: Evaluation of blood flow in AAA with real time individual patient model

Inclusion Criteria: Patient with AAA without renal insufficiency

Exclusion Criteria: Patient with AAA with renal insufficiency

AneurysmFlow before and after EVAR

AlluraClarity FD20/15, Philips.

1. Average flow pattern in Aneurysm
2. Flow stability during cardiac cycle
3. Contrast flow transition time through aneurysm
4. Contrast concentration ratio through aneurysm
5. Flow impingement in aneurysm
## AAA with/out Thrombus

<table>
<thead>
<tr>
<th>AAA size (mm)</th>
<th>AAA with intramural thrombus</th>
<th>64</th>
<th>AAA without intramural thrombus</th>
<th>64</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thrombus burden</td>
<td>Circumferential</td>
<td>minimal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiation dose (RD)</td>
<td>RD, mGycm² (DAP)</td>
<td>Percentage of RD from total dose</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow Pattern</td>
<td>Average flow pattern</td>
<td>Flow stability during cardiac cycle</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flow impingement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contrast Time/volume</td>
<td>Contrast transit time through aneurysm</td>
<td>Contrast concentration ratio through aneurysm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Real time hemodynamics for individual AAA

Concentric thrombus  Without thrombus
<table>
<thead>
<tr>
<th>AAA with intramural thrombus</th>
<th>AAA without intramural thrombus</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAA size (mm)</td>
<td>64</td>
</tr>
<tr>
<td>Thrombus burden</td>
<td>Circumferential</td>
</tr>
<tr>
<td>Radiation dose, mGycm2 (DAP)</td>
<td>13144</td>
</tr>
<tr>
<td>Percentage of radiation dose from total dose during EVAR</td>
<td>8.7%</td>
</tr>
<tr>
<td>Average flow pattern</td>
<td>Relatively laminated</td>
</tr>
<tr>
<td>Contrast transit time (second)</td>
<td>faster</td>
</tr>
<tr>
<td>Maximum contrast intensity at proximal to distal aorta</td>
<td>high</td>
</tr>
</tbody>
</table>
Flow stability during cardiac cycle
Average flow pattern in Aneurysm

- Laminated
- Circular
- Vortex
Flow impingement

Diffuse

Small

Diffuse

Small

Diffuse
6 cm sized AAA without intramural thrombosis

Treatment: EVAR
AF Dose: 20.3% of total procedural AK (mGy)

Contrast transition time

Pre: 1.2s from proximal to distal side of the aneurysm

Post: 0.5s from proximal to distal side of the aneurysm
5.9cm sized AAA

Treatment: EVAR
AF Dose: 15.8% of total procedural AK (mGy)

Pre: 2s from proximal to distal side of the aneurysm

Post: 1s from proximal to distal side of the aneurysm
5.0cm sized AAA
Treatment: EVAR
AF Dose: 9.1% of total procedural AK(mGy)

Contrast transition time

Pre:
- 4 sec from proximal to Rt iliac
- 3.6 sec from proximal to Lt iliac

Post:
- 2 sec from proximal to Rt iliac
- 1.7 sec from proximal to Lt iliac
**5.0cm sized AAA**

Treatment: EVAR  
AF Dose: 11.3% of total procedural AK (mGy)

**Contrast transition time**

Pre:
- 3.5sec from proximal to Rt iliac  
- 3.6sec from proximal to Lt iliac

Post:
- 2.7sec from proximal to Rt iliac  
- 3.6sec from proximal to Lt iliac

Pre-  
: 0.7(Yellow) ~ 3 (purple) : 2.3sec
Post  
: 0.7 (Yellow) ~3 (purple) : 2.3sec
1. Average flow pattern in Aneurysm
   • Laminated
   • Circular: a single recirculation zone
   • Vortex: flow divisions or separations within the aneurysm sac and containing more than one recirculation zone or vortex structure.

2. Flow stability during cardiac cycle
   • Stable (S): persistent flow (do not move or change) during the cardiac cycle.
   • Unstable (U): flow divisions and/or vortex structures move or are created or destroyed during the cardiac cycle.

3. Contrast flow transition (volume/time)
   • Slow: inflow passes aneurysm slowly / Fast: inflow passes aneurysm fast
   • Low concentration in distal to aneurysm / High concentration distal to aneurysm

4. Flow impingement
   • Diffuse impingement (D): if the area of impingement is large compared to the area of the aneurysm (more than 50%).
   • Localized impingement (L): if the area of the impingement region is small compared to the area of the aneurysm (less than 50%).
Finite element analysis (FEA) for AAA Rupture Risk Prediction Model

- More detailed hemodynamics in AAA
- Aorta wall strength in AAA
- Thrombus strength in AAA
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