Deployment of bare stent reduce the pressure of false lumen in acute aortic dissection: Animal model and computer simulation.


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Stent for aortic dissection

- Vanishing or decreasing of false lumen
- Inducing thrombosis in false lumen
False lumen thrombosis after aortic stenting
Thrombosis of false lumen after aortic stenting
Radial force of our aortic stents (20-30 mm)
Purpose

• We reported that bare stent induced thrombosis in false lumen in acute aortic dissection (AAD) in animal model. We attempted to study the mechanism of efficacy using stent in AAD by computer simulation or animal AAD model.
Methods in computational fluid dynamics

Computational Fluid Dynamics (CFD) simulation: ANASYS (CFX15.0)
The length of acute aortic dissection (AAD) was set as 10 cm, the diameter of aorta as 30 mm, the width of entry tear as 10 mm and that of re-entry as 5 mm. Stenotic area of true lumen (TL) was set as 60% before stent deployment and that set as 20% after stent. Cardiac output (CO) was set as 5L/min. And the size of entry and re-entry on the aorta was designed as 10 mm, 5 mm and 2 mm.
Computational fluid dynamics study in aortic dissection model design (ANSYS, CFX 15.0)

Figure 1: the conditions of CFD calculations
60% stenotic area of true lumen by dissection

Blood flow proximal to dissection: 5 L/min
Diameter of aorta: 30 mm

Mean pressure difference: \( \text{Ave} P_b - \text{Ave} P_a = 15 \text{ [Pa]} \)

Max pressure difference: \( \text{Ave} P_b - \text{Ave} P_a = 30 \text{ (Pa)} \)

Pressure of true lumen: \( P_a \)

Pressure of false lumen: \( P_b \)
60% stenotic area of true lumen by dissection

Blood flow proximal to dissection：5 L/min、Diameter of aorta：30 mm

Flow line

Blood flow in false lumen: 0.1 L/min
20% stenotic area of true lumen after stent

Blood flow proximal to dissection: 5 L/min, Diameter of aorta: 30 mm

Mean pressure difference: \( \text{Ave} P_b - \text{Ave} P_a = 2.5 \text{ [Pa]} \)
Max pressure difference (stenotic area) \( P_b - P_a = 4 \text{ [Pa]} \)
20% stenotic area of true lumen after stent
Blood flow proximal to dissection: 5 L/min
Diameter of aorta: 30 mm

Flow line

Blood flow in false lumen: 0.025 L/ml
Efficacy of stent for aortic dissection

Entry/re-entry = 10mm/10mm

Decreasing pressure of FL

False limen

True lumen 40%

FL : TL = 3:2

FL : TL = 1:4

True lumen 60%

Decreasing pressure of FL
Computational fluid dynamics study in aortic dissection model design (ANSYS, CFX 15.0)

Figure 1: the conditions of CFD calculations

<table>
<thead>
<tr>
<th>Entry (mm)</th>
<th>Re-entry (mm)</th>
<th>Flow conditions (l/min)</th>
<th>Aorta stenosis (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>10 5 2</td>
<td>5 2</td>
<td>60 40 20</td>
</tr>
<tr>
<td>5</td>
<td>10 5 2</td>
<td></td>
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</tr>
<tr>
<td>2</td>
<td>10 5 2</td>
<td></td>
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</tr>
</tbody>
</table>
Maximum pressure difference

Stenosis area of true lumen

Pressure Difference (Pa)

10-10 (5l/min) - 10-10 (2l/min)
10-5 (5l/min) - 10-5 (2l/min)
10-2 (5l/min) - 10-2 (2l/min)
Methods in animal model

In animal model, we used 14 goats with 40-56 kg. We made AAD by Shiraishi methods with the 5-10 cm length of AAD. The aortic stents had 25 mm wide (diameter) and 15 cm length with 2.0 - 2.5 N/m² of radial force.

The pressure of both TL and false lumen (FL) were directly measured by 24 G intra-luminal needle.
Acute aortic dissection by Shiraishi methods
Aortic dissection
Measured pressure in true and false lumen
Case 1 goat

Blood flow velocity after stent

True lumen

False lumen
Blood pressure of true and false lumen

Case 1 goat
Case 1 goat

Before aortic stent

After aortic stent
Aortic stent after resection
Aortic dissection after resection

Case 1 goat

Entry 8mm
Re-entry 4mm
Case 2 goat

Entry 10 mm, Re-entry 12mm
Case 3 goat

- Entry 10mm
- Re-entry 10mm
Case 4 goat

Entry 5mm, Re-entry 10mm
Case 8 goat
Case 5 goat

Entry 10mm, Re-entry 10 mm
Case 6 goat

Before stent

After stent
Decreasing of pressure in false after stent
Decreasing of pressure in false after stent
Decreasing of pressure in false lumen after stent

Entry length/Re-entry length

- 10mm/5mm: 10 animals
- 8mm/4mm: 10 animals
- 10mm/5mm: 23 animals
- 10mm/10mm: 37 animals
- 10mm/20mm: 7 animals
Conclusion

- Enlargement of true lumen by stent may induce decreasing of pressure or blood flow velocity in false lumen under some conditions.
- Entry / re-entry size and blood pressure may affect pressure difference between false and true lumen.
- Further study is needed to find adequate conditions for treatment of acute aortic dissection by bare stent and to create instruction for use (IFU) for clinical study.
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