Disclosures Dr. Kasprzak (grants, speaker fee, development, patents): Cook, Gore, Vascutek, Bard, Atrium, Aptus-Medtronic, Maquet, UCB

PM Kasprzak
Department of Vascular Surgery,
Endovascular Surgery
University Hospital Regensburg, Germany
Total aortic replacement – Ascendens open, FET and multibranched Stentgraft

No neurologic complications
## TAAA repair with BEVAR/TEVAR

<table>
<thead>
<tr>
<th>Author</th>
<th>Group</th>
<th>Year Published</th>
<th>Time Period</th>
<th>Institution(s)</th>
<th>BEVAR</th>
<th>30 d / in Hospital Mortality</th>
<th>Follow-up</th>
<th>Follow-up Mortality</th>
<th>SCI</th>
<th>Major Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maurel B</td>
<td>Haulon</td>
<td>2015</td>
<td>2004-2013</td>
<td>Lille</td>
<td>33</td>
<td>14/204*</td>
<td>1 y</td>
<td>27/149*</td>
<td>8/204</td>
<td>54/204</td>
</tr>
<tr>
<td>Bisdas Th</td>
<td>Torsello / Austermann</td>
<td>2015</td>
<td>2010-2014</td>
<td>Münster</td>
<td>83+10</td>
<td>4/142*</td>
<td>nd</td>
<td>nd</td>
<td>3/142</td>
<td>40#/142</td>
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<tr>
<td>Verhoeven</td>
<td>Verhoeven</td>
<td>2015</td>
<td>2004-2009;2009-2013</td>
<td>Groningen / Nürnberg</td>
<td>57+70</td>
<td>15/166*</td>
<td>2.5 y</td>
<td>40/151</td>
<td>2/166</td>
<td>27/166</td>
</tr>
<tr>
<td>Eagleton MJ</td>
<td>Greenberg / Mastracci</td>
<td>2014</td>
<td>1998-2010</td>
<td>Cleveland</td>
<td>472</td>
<td>1150/1251*</td>
<td>2 y</td>
<td>700/1251*</td>
<td>27/1251</td>
<td>nd</td>
</tr>
<tr>
<td>Marzelle J / Michel M</td>
<td>Becquemin</td>
<td>2015</td>
<td>2010-2012 (Window trial)</td>
<td>Creteil</td>
<td>268*</td>
<td>27*</td>
<td>nd</td>
<td>nd</td>
<td>11</td>
<td>26</td>
</tr>
<tr>
<td>Dias NV</td>
<td>Resch</td>
<td>2015</td>
<td>2008-2014</td>
<td>Malmö</td>
<td>72*</td>
<td>5</td>
<td>nd</td>
<td>nd</td>
<td>22/72</td>
<td>46/72</td>
</tr>
</tbody>
</table>

*FEVAR+BEVAR
Vascular and Endovascular Surgery, University of Regensburg, 2006 – 2014

Aortic Arch, BEVAR and FEVAR n = 326
Median Age 73 ±9 (31-90)
Mortality 6%
SCI 4%
Thoracic and thoracoabdominal aortic aneurysms

- Risk of paraplegia during BEVAR
  - varies between 10 – 20 %

Spinal cord ischemia during BEVAR for TAAA

- Direct occlusion of intercostal + lumbar arteries
- Secondary reduction of spinal cord perfusion by aneurysm sac thrombosis

Decreased perfusion of

- Segmental spinal arteries
- Anterior spinal artery

→ Spinal collateral network

Moritz S et al. Persp Vasc Surg Endovasc Ther 2011; 23(3) 214–222.
Role of hypogastric perfusion for risk of spinal cord ischemia during branched/fenestrated EVAR for TAAA

Options to reduce postoperative SCI:

- MAP > 80 mmHg
- normal / high Hb
- spinal cord drainage
- staged procedures
- TASP (temporary aneurysm sac perfusion)

Greenberg RK et al.,. Circulation 2008
Kasprzak P et al. 2014 Eur J Vasc Endovasc Surg
Etz et al. 2013. CT scan of a sagittal section of a juvenile pig infused with a barium/latex mixture shows the normal distribution of vessels in the collateral network surrounding the spinal cord, and then the increased numbers and density of these vessels in a pig 120 hours after interruption of all segmental arteries.

Geisbüsch et al. 2014. When pressure is monitored in the stump of a segmental artery (SA) after sacrifice of all SAs, the collateral network pressure (CNP) falls initially, reaches its lowest point about 5 hours after SA sacrifice, and recovers reliably between 72 hours to 5 days even in pigs that subsequently exhibit signs of functional spinal cord injury.
BEVAR for TAAA + TASP
Study: MEPs for indication of SCI risk

Step 1

BEVAR
SCI risk evaluation low / high
MEPs (BHT-test)

Step 2

TASP interval
side branch completion
early (1 week) / late (4 weeks)
MEPs (BHT-test)
Motor evoked potentials (MEPs)

- Intraoperative evaluation of integrity of spinal cord motor function

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**Ballon Occlusion Hypotension (BHT) Test (30 + 10 min)**

Intraoperative *online internet based* monitoring and analysis in cooperation with WH Mess, Institute of Neurophysiology, University of Maastricht, NL. Guidelines: Clin Neurophysiol 2013.
MEPs during TEVAR and BEVAR

Hypotension \rightarrow \text{temp. SCI (reversible)}
Patient 8: BEVAR for TAAA
- with intraoperative MEPs analysis

- side branch completion (day 0)

• Crawford IV TAAA
• 4 branched EVAR
• thrombosis left RA - intraop Lysis
• side branch completion (day 0)
  ➔ MEPs decreased
  ➔ periscope – secondary TASP
  ➔ persistent SCI / paraplegia

MEP monitoring
TAR, TAL, RFR and RFL amplituden - T1%
- RR

RR/TOF
TAR, TAL, RFR and RFL amplituden - T1%

RR
TAR
TAL
RFR
RFL

MEP monitoring
time

Staged endovascular repair of complex TAAA

Case report

Stage I: supraortic debranching, coronary bypass

Stage II: (7 d) left carotid to subclavian bypass
TEVAR

Stage III: (3 mo) four-fenestrated endograft

Staged procedure to prevent major adverse events in extensive aortic aneurysm repair.
JVS 2013; 57: 1671-1673.
Staged endovascular repair of complex TAAA

Techniques

**our concept (TASP)** 2008
- open branch of custom-made oder standard bEVAR

Chuter T et al. 2011
- secondary reperfusion of aneurysm sac after spinal ischemia – case report

Ivancev K et al. 2011/2012
- primary aneurysm sac perfusion using additional perfusion branches n= 10 + 1
Risk of spinal cord ischemia after Branched EVAR for TAAA

Group: 83 TAAA patients after bEVAR

<table>
<thead>
<tr>
<th>Neurological complications</th>
<th>Non-TASP (n = 43)</th>
<th>TASP (all patients) (n = 40)</th>
<th>$p^a$</th>
<th>TASP (completed) (n = 35)</th>
<th>$p^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute cerebrovascular events</td>
<td>0 (0)</td>
<td>3 (1)</td>
<td></td>
<td>1 (3)</td>
<td></td>
</tr>
<tr>
<td>Paraesthesia</td>
<td>1 (2)</td>
<td>5 (13)</td>
<td></td>
<td>3 (9)</td>
<td></td>
</tr>
<tr>
<td>Temporary paraparesis</td>
<td>1 (2)</td>
<td>5 (13)</td>
<td>NS</td>
<td>5 (14)</td>
<td>.04</td>
</tr>
<tr>
<td>Paraplegia (day 30 or discharge)</td>
<td>9 (21)</td>
<td>2 (5)</td>
<td>.03</td>
<td>1 (3)</td>
<td>.02</td>
</tr>
<tr>
<td>Subgroup of aneurysm type I–III</td>
<td>$n = 24$</td>
<td>$n = 29$</td>
<td></td>
<td>$n = 26$</td>
<td></td>
</tr>
<tr>
<td>Paraplegia (d 30 or discharge)</td>
<td>7 (29)</td>
<td>1 (3)</td>
<td>.01</td>
<td>0 (0)</td>
<td>&lt;.01</td>
</tr>
</tbody>
</table>

Kasprzak P et al. 2014 Eur J Vasc Endovasc Surg
Risk of spinal cord ischemia after Branched EVAR for TAAA

Group: 83 TAAA patients after bEVAR

Kasprzak P et al. 2014 Eur J Vasc Endovasc Surg
**Temporary aneurysm sac perfusion**

<table>
<thead>
<tr>
<th>secondary side branch/ aortic completion or extension (n=34)*</th>
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<tbody>
<tr>
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<tr>
<td></td>
</tr>
<tr>
<td>n</td>
</tr>
<tr>
<td>-----------------------------------------------------------</td>
</tr>
<tr>
<td>time interval (days, mean +/- SEM) 60,68+/- 12,86</td>
</tr>
<tr>
<td>technical success 31 91</td>
</tr>
<tr>
<td>local anesthesia 8 23</td>
</tr>
</tbody>
</table>

• technical success: implantation of branched endograft, one side branch not completed and patent, perfusion of renovisceral organs, no type I endoleak, secondary side branch completion.

• 6 patient were not completed: one patient died from apoplex, another from cancer. One side branch occluded, one patient refused side branch occlusion, one patient (2.5 %) died within the TASP interval (after 3 months).
Staged endovascular repair of thoracoabdominal aortic aneurysms limits incidence and severity of spinal cord ischemia

Adrian O'Callaghan, MD, Tara M. Mastracci, MD, and Matthew J. Eagleton, MD, Cleveland, Ohio


Table II. Development of spinal cord ischemia (SCI)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Total (N = 87, No. (%))</th>
<th>Single-stage repair (n = 32, No. (%))</th>
<th>Two-stage repair (n = 27, No. (%))</th>
<th>Unintentionally staged repair (n = 28, No. (%))</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCI</td>
<td>19 (21.8)</td>
<td>12 (37.5)</td>
<td>3 (11.1)</td>
<td>4 (14.3)</td>
<td>.025c</td>
</tr>
<tr>
<td>Time to development of SCI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.13a</td>
</tr>
<tr>
<td>None</td>
<td>68 (78.2)</td>
<td>20 (62.5)</td>
<td>24 (88.9)</td>
<td>24 (85.7)</td>
<td></td>
</tr>
<tr>
<td>Immediate</td>
<td>9 (10.3)</td>
<td>5 (15.6)</td>
<td>2 (7.4)</td>
<td>2 (7.1)</td>
<td></td>
</tr>
<tr>
<td>Delayed</td>
<td>10 (11.5)</td>
<td>7 (21.9)</td>
<td>1 (3.7)</td>
<td>2 (7.1)</td>
<td></td>
</tr>
<tr>
<td>Duration of SCI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.033a</td>
</tr>
<tr>
<td>None</td>
<td>68 (78.2)</td>
<td>20 (62.5)</td>
<td>24 (88.9)</td>
<td>24 (85.7)</td>
<td></td>
</tr>
<tr>
<td>Improved</td>
<td>11 (12.6)</td>
<td>7 (21.9)</td>
<td>3 (11.1)</td>
<td>1 (3.6)</td>
<td></td>
</tr>
<tr>
<td>Permanent</td>
<td>8 (9.2)</td>
<td>5 (15.6)</td>
<td>0 (0.0)</td>
<td>3 (10.7)</td>
<td></td>
</tr>
<tr>
<td>SCI severity score</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.025d</td>
</tr>
<tr>
<td>None</td>
<td>68 (78.2)</td>
<td>20 (62.5)b</td>
<td>24 (88.9)c</td>
<td>24 (85.7)</td>
<td></td>
</tr>
<tr>
<td>Weakness</td>
<td>8 (9.2)</td>
<td>5 (15.6)</td>
<td>2 (7.4)</td>
<td>1 (3.6)</td>
<td></td>
</tr>
<tr>
<td>No antigravity</td>
<td>2 (2.3)</td>
<td>0 (0.0)</td>
<td>1 (3.7)</td>
<td>1 (3.6)</td>
<td></td>
</tr>
<tr>
<td>Complete paralysis</td>
<td>9 (10.3)</td>
<td>7 (21.9)</td>
<td>0 (0.0)</td>
<td>2 (7.1)</td>
<td></td>
</tr>
</tbody>
</table>

A significance level of .017 was used for pairwise ad hoc comparisons.

*aFisher exact test.

*bSignificantly different from two-stage repair.

*cSignificantly different from single-stage repair.

Two-staged: time interval mean: 5 months (1-60 months)
2 patients rupturiert (7.4 %)
BEVAR for TAAA: the TASP concept

Step 1

BEVAR (n = 111)

SCI risk evaluation low/high
MEPs (BHT-test)

TASP

TASP interval

No recommendation for Immediate (day 0) side branch completion

Step 2

side branch completion early (5-14) / late (15-28)
MEPs (BHT-test)

MEPs:
detection of temp. SCI /hypotension 8 /29 (27 %)
Management: MAP↑, CSF↓ - reversible 7/8 (88%)

<table>
<thead>
<tr>
<th></th>
<th>nonTASP</th>
<th>TASP no MEPS</th>
<th>nonTASP + MEPS</th>
<th>TASP MEPs /LA BHT-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>45</td>
<td>28</td>
<td>8</td>
<td>30 (9 LA)</td>
</tr>
<tr>
<td>SCI</td>
<td>11 (24%)</td>
<td>3 (10.7 %)</td>
<td>1 (12.5 %)</td>
<td>1 (3.3 %) delayed SCI (&gt; 24h)</td>
</tr>
</tbody>
</table>
Concept F/BEVAR (long aortic segments)

- spinal fluid drainage
- MEPs monitoring (+ BHT-test)
- SCI - risk analysis
- MAP > 80, hemogl. > 9 mg/dl, prevention of hypotension

→ TASP 2015

shorter TASP intervals

- *side branch occlusion between 5-14 days*

![Graph showing TASP intervals](image)
Conclusions:

• detailed preoperative planning of TEVAR and F/BEVAR procedures

• spinal fluid drainage for monitoring and therapy of increased CSF pressure

• staged procedures for extensive procedures including the TASP concept during BEVAR for TAAA

• intraoperative MEPs analysis to detect patients at risk for SCI

  → reduction of temporary/persistent SCI
  → safe early side branch completion with reduction of TASP interval

• prevention of perioperative hypotension