Chimneys and snorkels during EVAR

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Complex Aortic Anatomy

- There’s no approved off the shelf device
- No data driven solution
- Not every case is elective allowing to plan ahead and order a complex graft

So how can an operator deal with a complex case without waiting for a graft to be personalized?
What's the role of parallel grafts?
Endovascular “Slang”

- Chimney/Snorkel
- Periscope
- Sandwhich
- Double barrel
Chimney
Historical Evolution

- Greenberg 2001: renal
- Criado 2003: arch (left carotid)
- Larzon 2004: arch (left carotid)
- Criado 2007: longer chimneys
- Malina 2008: 'chimneys'
- Mayer-Lachat 2008: periscopes
- Lobato 2008: sandwich graft1
- Lobato 2009: sandwich graft2
- Kasirajan 2010: TAAA PGs
- Galvagni 2011: TAAA PGs

Double barrel
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>Greenberg et al: first chimney (renal artery)</td>
</tr>
<tr>
<td>2003</td>
<td>Criado: first arch branch chimney (left carotid artery)</td>
</tr>
<tr>
<td>2004</td>
<td>Larzon et al: first planned arch branch chimney (left carotid artery)</td>
</tr>
<tr>
<td>2007</td>
<td>Criado: suggested/illustrated use of longer chimneys</td>
</tr>
<tr>
<td>2008</td>
<td>Malina et al: popularized the term “chimneys”</td>
</tr>
<tr>
<td>2008</td>
<td>Mayer, Hechelhammer, Lachat: first periscope graft (visceral/renal arteries)</td>
</tr>
<tr>
<td>2008</td>
<td>Lobato: sandwich graft procedure (hypogastric artery)</td>
</tr>
<tr>
<td>2009</td>
<td>Lobato: sandwich graft procedure (visceral arteries)</td>
</tr>
<tr>
<td>2010</td>
<td>Kasirajan: two inverted bifurcated abdominal stent-grafts plus multiple thoraco-abdominal long conduits coming antegrade from the iliac limbs</td>
</tr>
<tr>
<td>2011</td>
<td>Galvagni: modified Kasirajan procedure with use of a single inverted bifurcated endograft</td>
</tr>
</tbody>
</table>
Parallel Grafts

½

Branch - vessel flow

Parallel conduit - parallel to aortic

BMS Bx or Sx, CS, SG

length: S, M, L

Gutters 10-15%
Snorkel/Chimney Stent Morphology Predicts Renal Dysfunction after Complex Endovascular Aneurysm Repair

Kenneth Tran, Brant W. Ullery, and Jason T. Lee, Stanford, California

Background: Despite the high technical success and midterm patency of snorkel stents, concerns remain about structural durability and its effect on long-term renal function. We sought to evaluate the luminal stability of renal snorkel stents to investigate morphologic predictive factors of renal dysfunction after snorkel/chimney endovascular aneurysm repair (sn-EVAR).

Methods: Patients with high quality computer tomography angiography after sn-EVAR between 2009 and 2013 were included for analysis. Luminal diameters of renal snorkel stents were measured on a 3-dimensional workstation at the proximal, main-body junction, and distal locations. Creatinine values and estimated glomerular filtration rates (eGFR) were recorded throughout the preoperative, perioperative, and postoperative course. Acute kidney injury (AKI) and chronic renal decline were evaluated using the risk, injury, failure, loss of function, end stage renal disease (RIFLE) criteria and chronic kidney disease (CKD) staging system, respectively.

Results: 52 patients underwent sn-EVAR (33 double renal, 19 single renal) with a 2-year primary patency of 95% at a mean follow-up of 21 months, of which 34 had suitable imaging protocols. In this subset, snorkel stents had mean deformations of $-0.14 \pm 0.52$ (2.8%), $-0.23 \pm 0.52$ (4.6%), and $-0.04 \pm 0.16$ mm (1.8%) at the proximal, junction, and distal segments. Four cases of significant >50% stent collapse occurred during follow-up, all of which occurred at the junctional segment. In the total cohort, 17 (32.6%) and 16 (30.7%) patients developed AKI and chronic renal decline, respectively. Multivariate regression identified larger proximal luminal diameters at latest follow-up (odds ratio 0.67; confidence interval $[0.006, 0.740]$; $P = 0.037$) as the only protective morphologic risk factor for developing chronic renal decline. No independent predictor factors for AKI were found. Rates of renal decline were significantly worse with smaller measured proximal lumens with a 1-year freedom from renal decline of 50% vs. 77–83% for diameters measured less than 4 mm vs. greater than 4 mm ($P = 0.010$). Degree of oversizing also affected rates of decline with greater oversizing associated with improved freedom from renal decline at 1 year of 100% vs. 57% ($P = 0.012$). Using a multivariate Cox model, stent oversizing (hazard ratio [HR], 0.039; $P = 0.018$) and baseline CKD (HR 0.033, $P = 0.004$) were the only independent factors, both of which resulted in slower rates of renal decline during follow-up.

Conclusions: Renal snorkel stent grafts maintain a high degree of patency and luminal stability at 2-year follow-up. However, stent collapse remains a rare but concerning risk, with the junctional segment most prone to significant stent deformation. Renal snorkel stents must be critically sized relative to native renal anatomy, and we recommend using at least stents sized ≥6 mm to minimize the risk of renal dysfunction. Frequent and regular radiographic and laboratory follow-up remains important as we further optimize the approach to complex EVAR.
Two representative examples (A, B, C, D) of collapsed snorkel stents at the main-body junctional segment. Areas of collapse are highlighted by red arrows in the 3-dimensional reconstruction (A, C) and by red boxes in the 2-dimensional centerline reformat images (B, D).

Table III. Measured renal stent luminal diameters and deformations

<table>
<thead>
<tr>
<th>Stent location</th>
<th>Luminal diameter, initial scan Mean ± SD (mm)</th>
<th>Luminal diameter, latest follow-up Mean ± SD (mm)</th>
<th>Change in luminal diameter Mean ± SD (mm)</th>
<th>Change in luminal diameter Mean ± SD (%)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal</td>
<td>4.65 ± 0.68</td>
<td>4.51 ± 0.77</td>
<td>0.319</td>
<td>0.14 ± 0.52</td>
<td>0.319</td>
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<tr>
<td>Junction</td>
<td>4.11 ± 1.15</td>
<td>3.92 ± 1.01</td>
<td>0.23 ± 0.62</td>
<td>4.1 ± 15.6</td>
<td>0.364</td>
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<tr>
<td>Distal</td>
<td>4.68 ± 0.63</td>
<td>4.60 ± 0.59</td>
<td>0.04 ± 0.16</td>
<td>1.1 ± 8.7</td>
<td>0.497</td>
</tr>
</tbody>
</table>

SD, standard deviation.

Table IV. Measured luminal diameters at initial scan segregated by manufactured stent diameter

<table>
<thead>
<tr>
<th>Demographics</th>
<th>5-mm stent (n = 8)</th>
<th>6-mm stent (n = 27)</th>
<th>7-mm stent (n = 18)</th>
<th>8-mm stent (n = 1)</th>
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<tr>
<td>Proximal</td>
<td>3.77 ± 0.68</td>
<td>4.63 ± 0.41</td>
<td>5.11 ± 0.55</td>
<td>4.47 ± 0.55</td>
</tr>
<tr>
<td>Junction</td>
<td>3.31 ± 0.42</td>
<td>4.11 ± 0.12</td>
<td>4.37 ± 0.24</td>
<td>5.84 ± 0.52</td>
</tr>
<tr>
<td>Distal</td>
<td>3.76 ± 0.36</td>
<td>4.66 ± 0.43</td>
<td>5.03 ± 0.52</td>
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P value

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SD, standard deviation.

>6mm

Tran et al. Annals of Vascular Surgery
The good...

• Great to get out of trouble
• Great for emergent cases
• Simple case planning and delivery
• Truly “off the shelf” option
• Good technical success and patency
The bad...

- Endoleak type I 10%
- No long term data
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