Stenting in coarctation of the aorta—Shall all adolescent & adults receive covered stent?

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Aortic coarctation in adults

- Coarctation anatomy is complex
- Not all native coarctations are localised discrete stenosis
- Many have tortuous aorta
- Unknown incidence of cystic medial necrosis – especially in adults
Coarctation of the aorta in adolescents and adults

Options of treatment

- Surgery
- Balloon Angioplasty
- Stent Implantation
Surgery in adolescents and adults

- Death
- Paraplegia is higher than simple CoA -1%
- Recurrent or residual coarctation – 4-10%
- Late aneurysm – 10-20%
- Young age at operation favourably influenced the outcome

Aneurysms after surgery for coarctation

Courtesy: Dr Shakil Qureshi-Guys London
Balloon angioplasty in adults

Adolescents and adults are different

- Intrinsic aortic wall abnormalities in adults
- Aneurysm formation - 7-13%
- Persistent residual or recurrent coarctation
- Aortic rupture / dissection
- Persistent Hypertension

Balloon angioplasty - adults

Fawzy et al. JACC 2004

Some patients not suitable for ballooning

Figure 1. (A) Aortogram in left anterior oblique view showing apparently discrete coarctation (arrow). (B) Aortogram of the same patient in posterior anterior view showing long tortuous coarctation (arrow) not suitable for balloon angioplasty.
Stents in Coarctation of the aorta

- **Stenting in native coarctation of the aorta**
  - Prevents elastic recoil
  - Can address long segment lesions
  - Reduces risks like rupture, dissection, aneurysms
  - Results are comparable with surgery

  **Much higher patient acceptability**
Stent in aortic coarctation

Adult coarctation treated with bare metal CP stent
Complications of stenting native and recurrent coarctation of the aorta: CCSI data

- Successful outcome 580/588 (98.6%) procedures
- Total complications (major and minor): 84 (69/588 pts)-11.7%

- Peripheral vascular complications in 22 procedures
  - Cerebral vascular accident 6/588

Positive association between CVA and old age

Complications of stenting native and recurrent coarctation

**Technical complications**

- **Stent migration** 28 (4.8%)
- **Stent fracture** 6 (1.0%)
- **Balloon rupture** 13 (2.2%)
- **Overlap of brachiocephalic vessels** 61 pts
Complications of stenting native and recurrent coarctation: CCSI data

Aortic wall complications

- Aneurysms 5 (<1%)
- Intimal tears 8 (1.3%)
- Dissections 9 (1.5%)
- Aortic rupture 0
Aortic Dissection

- Risk of dissections 1-2%
  - Age above 20 years
  - Location in abdominal aorta
  - Pre-stenting angioplasty
  - Bare CP stent
Aortic Rupture

A rare (4 reported cases) but catastrophic complication

- Advanced patient age
- Presence of calcification
- Vessel tortuosity
- Pre-dilatation without stent placement
- Attempting to dilate more than 3 times the size of coarctation
- Subsequent balloon dilatation to flare the stent to ensure apposition
Why covered stent

- Aortic wall dissection
- Aneurysms
- Stent fractures
- Aortic rupture

Hence the need for covered stent

- Important bail out following any complications
Covered Stents

Available stents
Gore & Cook stent grafts

Jomed
Numed
(covered Cheatham-Platinum)
V12 Atrium – recently available
Transverse arch coarctation
Coarctation with PDA
Complex aortic recoarctation – treated with covered CP stent
Complex coarctation with transverse arch hypoplasia

Treated with a bare and covered CP stent
Large dissection post bare stent placement & treated with covered stents
Large dissection post bare stent placement & treated with covered stents
 Interruption of aorta – covered CP stent

P.Ewert
Our Experience

- October 1999- September 2008
- Ongoing study on stenting in native coarctation of the aorta
- Single tertiary referral center-Punjab Institute of Cardiology, Lahore. Pakistan
- Native coarctation of the aorta
- Age above 12 years (Weight > 35Kg)
Patient Selection – Covered Stents

- Critical long segment (tubular) coarctation
- Critical transverse arch coarctation
- Turner Syndrome
- Associated PDA (2 pts)
- Aortic dissection following previous attempted stenting
- Complex coarctation
- Old Age->50 years
Results

- **Patient Population**
  - Total stent implantation = 56 procedures in 54pts
  - Total number of stents = 59
  - Covered Stents = 32/56 (57%)
  - Male: Female (1:5)
  - Age: 12 to 56 Years (median = 24 Years)
  - Sheath size: 11-16 F
Outcome

- Adequate implantation in 31/32 (97%)
- Failure to cross- 1 pt with interrupted arch
- 31 procedures – 34 stents
- PDA closed in both pts with associated duct
- No paradoxical hypertension or post caoarctectomy syndrome
Complications

- Death: 1 pt
- Left SCA sacrificed (transverse arch coarctation) - 4 pts
- No rupture or aneurysm
- No thromboembolism or other major vascular complications
  - Local haematoma (2 pt)
  - Transient left arm paresis (1 pt)
Follow-up

4.6 yrs (0.2-6.5) years

- Re-dilatation (1pt)
- No Recoarctation (clinical, echo)
- Spiral CT (23 pts- 74%):
  - No aneurysm
  - No dissection
- Hypertension:
  - Antihypertensive treatment (29/31 pts- 93%)
Spiral CT at 24 months
Use of covered stent

- 7 studies with 96 pts
- Effective in near atretic and complex aortic coarctation, associated PDA or aneurysm and as rescue

**Follow-up complications**

- Aneurysm formation - 2 pts
- Stent fractures - 3 pts (initial series)
- Re-dilation - 9 pts
- No other major complications

Tzifa A et al. J Am Coll Cardiol 2006;47:1457-63
Point of concern

Spinal artery occlusion

- Spinal artery originates below the level of ninth thoracic vertebra in over 90% of the patients

- So unlikely complication after implantation in thoracic aorta

Occlusion of significant aortic side branches

Left subclavian artery occlusion

- Stent-graft-induced occlusion of the ostial left subclavian artery is well tolerated without chronic functional deficit
- In the absence of stenotic vertebral and or carotid arteries and with a documented intact vertebrobasilar system

Aortic Rupture

- Reported with a covered stent as well
- Second balloon dilatation within the stent was required as distal stent remained under deployed

- CP covered stent has rounded edges (theoretically)
- The covering PTFE shortens variably being less than the length of the stent
- An induced wall tear within the stent margins may not be covered by the membrane
Re-dilation

Can they be re-expanded a great deal? so should be avoided in growing children? Intimal proliferation?

- 7 pts with restenosis after covered stent
  - Native coarctation- 4 pts
  - Post-surgical recoarctation- 3 pts
- Mean age 14.2 ± 3.0 years
- Procedure done at a mean of 20 (12-24) months
- Stent diameter increased of 20-50% predilation value
- At median follow up of 12 months stable with no immediate or late complications

Covered stents in aortic coarctation in adults

- **Surgery** - the gold standard but technically demanding, a high risk of paraplegia, re-coarctation & aneurysms

- **Balloon angioplasty** in only selected pts - discrete coarctation, significant risk of re-coarctation & risk of aneurysms, dissection and rupture

- **Stenting** with bare stents prevents recoil but risk of aneurysms, dissection and rarely rupture stays
Covered stents in aortic coarctation

- **Covered stents** may be used as first line treatment in adults and all pts (adolescents and adults) with complex CoA
  - Long segment / tortuous native coarctation
  - Atretic or near atretic coarctation
  - Transverse arch coarctation
  - Coarctation with PDA

- **Covered CP stents** may be used as the therapy of choice in patients with complications after CoA repair:
  - Aneurysm, dissection or rupture

- **In adults, may be considered as primary treatment of choice for aortic coarctation**
Covered stents in aortic coarctation

- September 2001 - February 2005
- Covered Cheatham-Platinum CP stents implanted in 30 patients in 3 centers
- Mean age 28 ± 17.5 years, range 8-65 yrs
- 4 patients were children below 14 years old of age (8, 12, 13 and 13 yrs old)
- Mean weight 62 ± 13 kg, range 28-86 kg
Covered stents in aortic coarctation

- Systolic gradient across coarctation decreased from mean 36±20mmHg before, to a mean of 4±4mmHg after the procedure.
- Diameter of the coarctation site increased from 6.4 ± 3.8mm to 17.1 ± 3.1 mm.
- The only complication encountered was fracture of the covered stent welds during the procedure in 2 patients, necessitating the use of a second covered stent in one.
Follow up period was up to 40 months (median 12)

All stents were patent

No fractures

Good position on CT or MRI performed 3-6 months after the procedure

21/30 patients were on antihypertensive medication prior to the procedure

In 9/21 (43%) of the patients the medication was either decreased or discontinued altogether
Native aortic coarctation

12 yrs old, primary stent implantation
Covered stents
12 yrs old, 55 kg, developed aneurysm after balloon angioplasty. Covered stent implantation 1 mth later.
21 yr old female
CoA repairs age 6 weeks & 2 yrs

14 x 90 mm
Cook device
What about these native coarctations

- Suitable for balloon dilation?
Covered stents with transverse arch hypoplasia - treated with bare stent
Covered stents with transverse arch hypoplasia - treated with bare stent
Near interruption of aorta
Near interruption of aorta
Aortic coarctation
Aortic coarctation
Aortic atresia

Courtesy P Ewert
Catheter treatment of aortic coarctation

- Balloon dilation offers a reasonable alternative to surgery in all but newborns where all forms of treatment have problems.
- Stent implantation is limited to older children and adults but is a better alternative because it is more controllable.
- A small incidence of aneurysm formation is inevitable in all forms of treatment.
- Most complications can be treated with covered stents.
- Covered stents may become treatment of choice in adolescents and adults.
Stent Migration

- The learning curve
- Use of a single balloon as opposed to BiB balloon

- Migration is related to higher risk of aortic wall damage and hence aneurysm formation and dissection.
Intrastent proliferation

- Usually mild
- More with Palmaz stent
- Since vascular lumen is large a mild proliferation does not result in flow obstruction and local gradient generation
Stent Fracture

- Localised fracture between 2 rows may be benign
- Circumferential tear may result in distal embolisation of the fragments and unpredictable consequences
- Refinements in the welding process using gold has been employed
Complications of stenting native and recurrent coarctation of the aorta: A 17-institution study

Aneurysms

- In native: 5
- In recurrent coarctation: 0
- All aneurysms localized to the mid-portion of the stent, were small (< 5 mm), and being followed conservatively
- Follow-up at a mean of 17.8 months showed no progression
Aneurysms

- 0-7% in pts treated with bare stents
- Form in the vessel wall crossed by the stent or edges of the stent
- Palmz stents have sharp edges and theoretically has a higher chance of dissection or aneurysm formation but well reported with CP stents as well although they have rounded edges
- Covered stents may be an answer
- Late aneurysm formation - teras or shrinkage in PTFE membrane!

## Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pre</th>
<th>Post</th>
<th>p-value</th>
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<tbody>
<tr>
<td>Peak Systolic Gradient</td>
<td>50mmHg (40-71)</td>
<td>02mmHg (0-07)</td>
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<tr>
<td>Mean diameter</td>
<td>04±3.5mm</td>
<td>19±4.2mm</td>
<td>&lt;0.001</td>
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Stents in Coarctation of the aorta

- **Coarctation of the aorta**
  - Not uncommonly missed in early life
  - Diagnosed in adult life:
    - Hypertension
    - Stroke
    - Heart Murmur

- **Management in adolescents and adults**
  - Special challenge
  - Co-existent conditions
Age: aortic isthmus diameter & recoarctation after balloon dilation

Kaine et al 1996

Freedom from recoarctation

months follow-up

Kaine et al 1996
<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>n</th>
<th>Morbidity</th>
<th>Mortality</th>
<th>Reinterventions</th>
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<tbody>
<tr>
<td>Suarez de Lezo</td>
<td>2005</td>
<td>73</td>
<td>7% 2 late aneurysms, 1 residual stenosis, 2 stent migrations</td>
<td>1% *</td>
<td>?</td>
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<tr>
<td>Johnston</td>
<td>2004</td>
<td>32</td>
<td>6% 1 dissection, 1 stent migration</td>
<td>0</td>
<td>10 repeat angioplasties</td>
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<tr>
<td>Tyagi</td>
<td>2003</td>
<td>21</td>
<td>5% 1 stent embolized</td>
<td>0</td>
<td>0</td>
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<td>Harrison</td>
<td>2001</td>
<td>27</td>
<td>19% 3 aneurysms and 1 requiring surgery, 1 stroke, 1 failure</td>
<td>0</td>
<td>1 angioplasty, 3 aneurysms</td>
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<td>Hamdan</td>
<td>2001</td>
<td>34</td>
<td>18% 1 retroperitoneal hematoma, 1 embolized balloon, 1 stent migration, 1</td>
<td>3% b</td>
<td>4 patients, 2 referred to</td>
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<tr>
<td></td>
<td></td>
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<td>failed intervention requiring surgery</td>
<td></td>
<td>surgery</td>
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<td>Cheatham</td>
<td>2001</td>
<td>46</td>
<td>20% 2 aneurysms, 2 stents embolized, 1 stent dislodged, 1 hemothorax, 1</td>
<td>0</td>
<td>5 additional stents, 4</td>
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<td>stent fracture, 2 failures</td>
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<td>angioplasties</td>
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<tr>
<td>Ledesma</td>
<td>2001</td>
<td>54</td>
<td>9% 2 aneurysms</td>
<td>0</td>
<td>4 patients, 2 referred to</td>
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<td>surgery</td>
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<tr>
<td>Marshall</td>
<td>2000</td>
<td>33</td>
<td>9% 1 acute MI, 1 cardiac arrest, 1 femoral thrombosis (7 blood transfusions)</td>
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<td>1 stent migration, 8</td>
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<td>Ebeid</td>
<td>1997</td>
<td>9</td>
<td>0 none reported</td>
<td>0</td>
<td>1 repeat angioplasty</td>
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</table>
Complications of stenting in CoA

- Most common complications
  - Traumatic aneurysm formation
  - Aortic dissection
- No pt had paralysis
- Restenosis was 0-25% (mean 11%)
- Repeat intervention was 0-31% (mean 14)
  - Repeat angioplasty
  - Additional stenting
  - Referral for surgery
- Cure of hypertension was 18-88% (mean 61%)

Carr JA. J Am Coll Cardiol. 2006 Mar 21;47(6):1101-7
Stents in coarctation of aorta

*Disadvantages*

- May alter vessel wall compliance, pressure wave propagation and blood pressure
- In young patients will require additional dilations to keep pace with growth, so confined to adults
Procedure details

- General Anaesthesia
- Cut down and femoral arteriotomy (3pts)
- 14F 0r 12 F Sheath, 16 F (3 pts)
- Balloon expandable CP Stent -6 0r 8 Zig/row
- BIB Balloon (NuMed)
CONCLUSIONS

- Covered stent is an important addition to the armamentarium of the interventional cardiologist AND an important bail out
- Covered stent decreases potential of complications in complex coarctations, special situations and old age
- Can be used to seal the associated duct without additional device
Balloon dilation or stenting adults with native aortic coarctation

- 21 patients who received stents compared with 15 who had balloon dilation
- All adolescents or adults
- Greater gradient reduction after stents

Pedra et al, 2005
Morphology: aortic coarctation anatomy

Native aortic coarctation

Anatomy unsuitable for BD

Anatomy ? suitable for BD
Comparison of angioplasty and surgery

- 16 reports of stenting and/or angioplasty reported in the last 10 years (1995-2005)
- Compared them with 6 series of surgical repair in the adults
- Primary stenting had lowest risk of complications
- Need for reintervention was highest with stenting

Carr JA. J Am Coll Cardiol. 2006 Mar 21;47(6):1101-7
Coarctation of aorta - stent implantation

Primary stenting

- 9 studies with 320 pts (175 native aortic coarctation in children and adults)
- Gradient reduction from mean 41 mmHg to 4 mmHg
- Effective in severe, complex aortic coarctation

Follow-up complications

- Aneurysm formation in 3-4%
- Stent malposition in 4%
- Vascular complication including stroke 3%
- Death and need for emergent surgery have occurred but rare
Stents in Coarctation of the aorta

Factors affecting such decision

- Age
- Morphology of the coarctation of aorta
- Any previous intervention
- Local institutional results
- Expertise
Aortic Rupture

A rare but catastrophic complication

- 4 reported cases in the literature
- Two of them fatal (50% mortality)
- Youngest was infant and eldest was 65
- Native coarctation (1 pt) Recoarctation (3 pts)
- Dilatation following previous end to end anastomosis may be a particular risk factor – lack of compliance in a circumferential scar
- Re-dilatation is a particular risk factor
Covered stents in aortic coarctation

Available stents:

- Numed (covered Cheatham-Platinum)
- Jomed
- Stent grafts
- V12 Atrium – recently available
Current indications

- Covered Cheatham-Platinum (CP) stents currently used
  - as a rescue treatment in patients with aneurysms or previous stent related complications
  - in patients in whom increased risk of developing complications due to complex anatomy (e.g. near interruption or arch tortuousity) or advanced age
  - ? Use in all adults with coarctation of aorta
Covered Stents

Stent implantation – technical tips

- Amplatz super-stiff exchange guide wire (usually 0.035”), positioned in ascending aorta
- Rapid RV pacing is used
- BIB balloon used for mounting stents
- In adolescents and adults, per close suture used for haemostasis
Covered Stents

Stent implantation – technical tips

- Balloons longer than stents allow more precise placement and repositioning if necessary before fully inflating the balloon
- Or use the BIB balloon
- If lesion is tough and there is a residual waist on the stent, then high pressure balloons such as Opta, Power flex, Z-med or Mullins balloons are used
Covered Stents

Stent implantation – technical tips

- For covered stents, dilate to 70 – 100% at first procedure
- No attempt made to match stent to dilated aorta
- Aspirin for 6 months
Odds Ratios With 95% Confidence Intervals

- surgery
- stenting
- angioplasty

Carr JA. J Am Coll Cardiol. 2006 Mar 21;47(6):1101-7
Previous intervention: balloon dilation for aortic coarctation
Complications of stenting native and recurrent coarctation: A 17-institution study (CCISC data)

- 588 procedures
- Median age 15 years (range 1 month-64.9 years)
- Median weight 55 kg (range 1.8 to 145 kg)
- Stenting
  - Native coarctation 44%
  - Recurrent surgical coarctation 49%
  - Recurrent coarctation after balloon 3%
  - After previous stent placement 4%