AN UPDATE ON BALLOONS: FROM POBA TO THE NEWEST TECHNOLOGIES

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Disclosures

Speaker’s Bureau:
• None

Honorarium:
• None

Consultant:
• None

Stockholder:
• None

Grant/Research Support:
No Personal Financial Support
Clinical Trial Investigator for:
• W.L Gore & Associates, Inc
• C.R. Bard, Inc.
• Boston Scientific
• Juventas Therapeutics
• Boehringer Ingelheim
• Intelligent Delivery Systems, LLC

Medical/Scientific Boards:
• None
Balloon Angioplasty
BALLOON ANGIOPLASTY

➢ Historical perspective

➢ Principles and mechanisms

➢ Current and Emerging technologies
HISTORICAL PERSPECTIVE
Balloon on Catheter

• 1960: 1st catheter

➢ Ingredients - size 5 latex glove, 6Fr ureteral catheter
➢ Skill - luring techniques from fly fishing
➢ Testing - Jell-O in a test tube

• 1961: 1st patient (63-yo iliac embolectomy)

• 1963: Open surgical balloon thrombectomy introduced


Thomas J. Fogarty, MD
Charles T. Dotter, MD 1920-1985

Father of Intervention

• “My favorite conceptual trademark is a sketch that I did years ago of a crossed pipe and wrench. It's a gross oversimplification, of course, but what it means to me is that if a plumber can do it to pipes, we can do it to blood vessels.”

• January 16, 1964: 1st percutaneous transluminal angioplasty (Dotter Technique)
Andreas R. Gruentzig, MD 1939-1985

Father of Balloon Angioplasty

- Created a semi-compliant balloon made of polyvinyl chloride in his kitchen
- February 12, 1974: PTA of femoral artery
- September 16, 1977: 1st PTCA in Zurich, Switzerland

Gruentzig's 1st angioplasty balloon

“New Dilatation Catheter”
• **1982:** Invented over-the-wire balloons
• **1985:** Invented directional atherectomy (Simpson AtheroCath)

*JOHN B. SIMPSON, MD*

**FATHER OF AHERECTOMY**

Principles and Mechanisms of Balloon Angioplasty
Angioplasty ≠ Plaque Compression

Plaque Fracture → Vessel Stretching → Lumen expansion

“Controlled Injury” - Andreas Gruentzig

“Controlled Injury” and Consequences

Dissection

- Elastic recoil
- Neointimal hyperplasia
- Restenosis

Thrombosis
Physics of Balloon Angioplasty

Laplace’s Law

Cylindrical Vessel

\[ T = PR \]

Pascal’s law

Pressure applied on one point of liquid transmits equally in all directions
Wall Stress of POBA

Torsional Stress
Radial Stress
Longitudinal Stress
Complex Plaque Morphologies

About half as much tension
\[ T = \frac{PR}{2} \]
Much less wall tension

Maximum wall tension
\[ T = PR \]

Very little wall tension

Same pressure in all regions according to Pascal's principle.

Lower Wall Stress

Higher Wall Stress
Semi Compliant

- Composition: Polyolefin copolymer, Polyurethanes
- $\uparrow$ pressure = $\uparrow$ growth
- Grow in areas of least resistance (“dog bone”)
- Softer, thinner wall = $\uparrow$ trackability, may burst at ultra high pressures
- Re-wraps better

Non Compliant

- Composition: Polyethylene terephthalate
- $\uparrow$ pressure = $\downarrow$ growth
- Intended for resistant lesions
- Thicker walled balloon (withstands higher pressure)
- Less flexibility and tracking
- Re-wraps worse
Strain Rate and Vessel Injury

Strain rate

Vessel injury is related to the RATE at which the vessel wall is stretched.

• Slow, low pressure inflations minimize trauma

Solar, R. Cardio Radiation Medicine, 2003
Shawl F. Cath Cardiovasc Diag., 1993
Banka V, eya I. Am Heart J., 1993
Non-randomized, unblinded, and totally fun
Kindergartener's “Silly Putty” Strain Rate Experiment

Fast Strain Rate
“Uncontrolled Injury”

Slow Strain Rate
“Controlled Injury”
**Tips and Tricks with “Peripheral” POBA**

- Slow inflations
- Longer inflations (2-3 minutes)
- Understand balloon characteristics
  - wire compatibility
  - shaft lengths
  - crossing profiles
  - rapid exchange versus OTW
  - compliance

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**Peripheral PTA: Effect of Short vs Long Balloon Inflation Times on the Morphologic Results**

<table>
<thead>
<tr>
<th></th>
<th>Inflation Time (sec)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30</td>
<td>180</td>
</tr>
<tr>
<td>Major dissection (grades 3 or 4)</td>
<td>16</td>
<td>5</td>
</tr>
<tr>
<td>Minor or no dissection (grades 1 and 2)</td>
<td>21</td>
<td>32</td>
</tr>
<tr>
<td>Further interventions (Stent, repeat dilatation, dilation with larger diameter)</td>
<td>20</td>
<td>9</td>
</tr>
<tr>
<td>Residual stenosis (&gt;30%)</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>Complication (embolization, thrombosis)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mean ankle-brachial index (before, after intervention)</td>
<td>0.66, 0.87</td>
<td>0.65, 0.84</td>
</tr>
</tbody>
</table>

Current and Emerging Specialty Balloon Technologies (Beyond POBA)
Focal Force Balloons

Increased dilating force to “crack” the resistant lesion

✓ Wires
✓ Cutting
✓ Scoring
Focal Force: VascuTrak

Semi-Compliant Balloon with 2 external wires

- Lengths from 20 mm to 300 mm
- Diameters from 2 mm to 7 mm
- 0.014/0.018 Short Rapid Exchange
Focal Force: Cutting Balloon

- Designed by Barath 1991
- 3-4 atherotomes ("cutting blades") mounted on a noncompliant balloon
- Controlled dissection
- Size 1.0:1.1 (balloon:vessel)
- Slow inflation/deflation

<table>
<thead>
<tr>
<th></th>
<th>SFA</th>
<th></th>
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<th></th>
<th></th>
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<tbody>
<tr>
<td>Patency at 6 months</td>
<td>PTA (%)</td>
<td>CBA (%)</td>
<td>P</td>
<td>PTA (%)</td>
<td>CBA (%)</td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>Primary</td>
<td>92.7</td>
<td>93.7</td>
<td>0.42</td>
<td>88</td>
<td>92.3</td>
<td>0.05</td>
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<tr>
<td>Secondary</td>
<td>97.6</td>
<td>97.9</td>
<td>0.50</td>
<td>92</td>
<td>92.3</td>
<td>0.76</td>
<td></td>
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<tr>
<td>Patency at 12 months</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary</td>
<td>85.2</td>
<td>91.6</td>
<td>&lt;0.001</td>
<td>79.6</td>
<td>88.3</td>
<td>&lt;0.001</td>
<td></td>
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<tr>
<td>Secondary</td>
<td>92.6</td>
<td>95.8</td>
<td>0.06</td>
<td>92</td>
<td>92.3</td>
<td>0.76</td>
<td></td>
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<tr>
<td>Patency at 24 months</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary</td>
<td>68.3</td>
<td>80</td>
<td>&lt;0.001</td>
<td>63.7</td>
<td>79.6</td>
<td>&lt;0.001</td>
<td></td>
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<tr>
<td>Secondary</td>
<td>78.5</td>
<td>86.8</td>
<td>&lt;0.001</td>
<td>77.4</td>
<td>83.7</td>
<td>&lt;0.001</td>
<td></td>
</tr>
</tbody>
</table>


Boston Scientific

Diameter 2-8mm
Length: 15-20mm
Focal Force: AngioSculpt

Components

1. Angioplasty Ballon
   → Semi-compliant

2. Scoring Element
   → Laser-cut Nitinol hypotube
   → Helical configuration
   → Rectangular edges

Advantages

➢ Minimal Slippage - Precision
   Locks in without “watermelon seeding”

➢ More Dilating Force - Power
   15-25 x the dilating force of conventional balloons

➢ Low dissection and perforation rates - Safety


Diameter: 2-8mm
Length: 10-200mm

Increased luminal gain
Focal Force: Advance Enforcer 35

Diameter: 6-12mm
Length: 40mm
Wire: 0.035-inch

Cook Medical
Focal Force: Serranator
Caged Balloon: Chocolate Balloon

- Nitinol constrained semi-compliant balloon
- OTW, 2.5-6.0mm balloons
- “Pillows” - reduces strain and trauma
- “Valleys” - stress relief, plaque modification
# Choclate BAR: Below-the-Knee Outcomes

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Chocolate BAR BTK Cohort PTA Balloon</th>
<th>Literature BTK References PTA *</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Procedural Outcomes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bail-Out stent placement</td>
<td>3.5%</td>
<td>9.9%</td>
</tr>
<tr>
<td><strong>30-Day Outcomes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Target lesion revascularization</td>
<td>2.2%</td>
<td>8.1%</td>
</tr>
<tr>
<td>Major amputation</td>
<td>1.3%</td>
<td>4.4% - 6.6%</td>
</tr>
<tr>
<td>Mortality</td>
<td>0.9%</td>
<td>1.7% - 3.3%</td>
</tr>
<tr>
<td><strong>6-Month Outcomes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Target lesion revascularization</td>
<td>9.0%</td>
<td>16.0%</td>
</tr>
<tr>
<td>Major amputation</td>
<td>3.2%</td>
<td>11.8%</td>
</tr>
<tr>
<td>Mortality</td>
<td>2.9%</td>
<td>7.7%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>N=174</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Flow Limiting Dissection</td>
<td>97% (219/226)</td>
</tr>
<tr>
<td>Achieved &lt;30% Diameter Stenosis</td>
<td>94% (212/226)</td>
</tr>
<tr>
<td>Freedom from Bail-Out Stenting</td>
<td>96% (218/226)</td>
</tr>
</tbody>
</table>

Drug Coated Balloons

Two Currently Available DCBs:

1. Lutonix (Bard)
   Platform: 0.035”, 4-7mm x 40-150mm
   Excipient: urea
   Paclitaxel dose: 2.0 µg/mm²

2. In.Pact Admiral (Medtronic)
   Platform: 0.035”, 4-7mm x 40-150mm
   Excipient: polysorbate/sorbitol
   Paclitaxel Dose: 3.5 µg/mm²
DCB’s > POBA (in the SFA)

IN.PACT SFA Trial
Freedom from CD-TLR through 3 Years

Primary Patency Kaplan-Meier


http://www.peripheral.medtronicendovascular.com/
CONCLUSIONS: “In comparison with uncoated balloons or drug-eluting stents, the treatment of infra-popliteal arteries with DCBs is associated with similar clinical outcomes and favorable angiographic efficacy at 1-year follow-up. Further studies in larger numbers of patients are still needed to definitely address the role of DCB technology in this setting.”

Cassese S, et al. JACC Intvn. May 2016; Volume 9, Issue 10
Calcium: The Kryptonite to DCB’s?

IN.PACT DCB and Calcium Propsective Study (n=60)
12 month results

- Calcium distribution and severity affect late lumen loss and primary patency
- Calcium serves as a barrier to optimal drug absorption
- Solution – Debulking?

### FDA Approved Treatments for ISR

1. Laser atherectomy
2. Viabahn
3. **In.Pact Admiral DCB**

### IN.PACT Global ISR Imaging Cohort (N=131)

<table>
<thead>
<tr>
<th>In-Stent Restenosis</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lesion Length (Mean ± SD, cm)</td>
<td>17.17 ± 10.47</td>
</tr>
<tr>
<td>Primary Patency (KM @ 360 days)</td>
<td>88.7%</td>
</tr>
<tr>
<td>CD-TLR</td>
<td>7.3%</td>
</tr>
<tr>
<td>Thrombosis</td>
<td>0.8%</td>
</tr>
<tr>
<td>Major Amputation Target Limb</td>
<td>0.0%</td>
</tr>
</tbody>
</table>
Drug Coated Balloons

- Leave nothing behind
- ...except Paclitaxel
  - cytotoxic agent prevents microtubule depolymerization arresting cells in mitosis (G2/M phase) – leads to apoptosis

Paclitaxel and Doses
- DCBs 2-3 µg/mm²
- ≈7-10mg in 120mm DCB
- Limited data beyond 21mg
- Chemotherapy at 170-300mg
Cryoplasty

Proposed Mechanism of Action

➢ Apoptosis: ↓smooth muscle cells

➢ Altered plaque response: limit vessel trauma, ↓flow limiting dissections

➢ Reduced Elastic Recoil: ↓elastin fiber function

NuCryo Vascular LLC

Non-Compliant Balloon
Diameter: 2-8mm
Length: 40-150mm
Compatibility: 0.014” and 0.035”
Liquid Nitrogen: 14º F
PROTEUS Angioslide

A. Guide Wire Insertion

B. Balloon Inflation

C. Folding Inward

D. Negative Pressure

E. Debris Capture

F. Debris Removal

Lithoplasty
Stay Tuned America

• New DCBs (Stellarex [SPNC], Ranger [BoSci])
• Drug Coated Focal Force Balloons (e.g. AngioSculpt X, SPNC)
• Drug Coated Caged Balloons (e.g. Chocolate Touch, QT Vascular)
• Occlusion perfusion balloons (Advanced Catheter Therapies)
• Sizing balloons (IDS, LLC)
• ...and so much more
Conclusion

• POBA is cheap and works best if you understand the:
  1. Physics
  2. Plaque morphology
  3. Proper technique

• When POBA fails or clinical judgement dictates consider specialty balloons.

• DCBs may be the future for PAD intervention, but we still have much to learn.
Thank You

18th Annual Conference
May 31 - June 02
THE PERIPHERAL EVENT OF THE YEAR
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