A Novel Low Pressure Self Expanding Nitinol Coronary Stent (vProtect): Device Design and FIH Experience

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Mechanical Stabilization of TCFA

Mechanical Objectives

Plaque Features
- Soft Tissular Matrix
- Thin Fibrous Cap
- Prominent Lipidic Core
- Thin Plaque Shoulders

Mechanical Stabilization
- Mechanical Compression
- “Neo-Cap” Formation
- Minimal Lipidic Core
- Healthy Thin Neointima

Picture on the right acquired from Moreno PR.
Objectives of Focal VP Therapy

Biological Principle

- Prevention of Thrombosis
- Regulation of Inflammation and Cell Growth
- Promotion of Vascular Healing
- Mechanical Stabilization and Reinforcement of Fibrous Cap
- Prevention of Thrombosis
Stress in the Circumferential Direction

Strain in the Circumferential Direction

Strain in the Radial Direction

Displacement Distribution

Picture Courtesy Prof. Chen. U of H, Houston, Texas.
Prescient vProtect Luminal Shield: Device Features
Mechanics of the vProtect Vascular Shield: RRF and COF

- **Radial Resistive Force (RRF):** Force the Shield resists the recoil of the plaque and vessel wall.
- **Chronic Outward Force (COF):** Force the Shield exerts on the plaque and vessel wall.

Graph showing the relationship between radial force and diameter, with arrows indicating force directions.
Mechanics of the vProtect Vascular Shield Compared to Other SE Stents

Balloon Expandable Stent > 1000 mmHg (20psi)

Maximum to Minimum Indicated Diameter.
High crush resistance / chronic outward force ratio

Testing performed on MSI tester May 2007
Experimental Data: 28 Days

- Porcine normal coronary model (11 animals).
- 30 coronary arteries were randomized to receive:
  - Vascular shields (3.5 x 16.8 mm, n=10)
  - VisionTM stents (Abbott, 3.0 x 18 mm, n=10)
  - XienceTM stents (Abbott, 3.0 x 18 mm, n=10)

- Devices deployed at 110% of pre-intervention RVD.

- Stented arteries were imaged with angiography and IVUS at baseline, post-implant and after 1 month.

- Optical Coherence Tomography (OCT) at 1 month.

- Pathology analysis at CVPath.
Lumen / Shield Areas at 1-Month: IVUS Overexpansion Analysis

- Lumen Area: Post Implant: 7.12, Stent Area: 5.65
  - P < 0.01
- Stent Area: Post Implant: 7.12, month FU 1: 7.04
  - P = N.S
Average Calculated Neointimal Thickness at 1 month by IVUS

<table>
<thead>
<tr>
<th>Device</th>
<th>Neointimal Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHIELD</td>
<td>0.22</td>
</tr>
<tr>
<td>VISION</td>
<td>0.27</td>
</tr>
<tr>
<td>XIENCE</td>
<td>0.21</td>
</tr>
</tbody>
</table>

(N=8 for each group)
Histological Data at 28 Days

- Neointima Area (mm²)
  - Shield (n=8): 0.13 ± 0.07
  - Vision (n=8): 0.32 ± 0.32
  - Xience (n=8): 0.38 ± 0.21

  - P=0.01

- EEL Area (mm²)
  - Shield (n=8): 6.85 ± 0.90
  - Vision (n=8): 8.78 ± 1.25
  - Xience (n=8): 8.29 ± 1.09

  - P=0.05

- Injury Score
  - Shield (n=8): 1.53 ± 0.34
  - Vision (n=8): 1.99 ± 0.55
  - Xience (n=8): 1.50 ± 0.57

  - P=NS

- PAS (%)
  - Shield (n=8): 27.65 ± 9.04
  - Vision (n=8): 42.34 ± 10.94
  - Xience (n=8): 21.21 ± 7.66

  - P=NS
Long Term Porcine Data
90-Day GLP – QCA Data

<table>
<thead>
<tr>
<th></th>
<th>Post-Implant</th>
<th>90 Day Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reference Vessel Diameter (mm)</td>
<td>Minimum Lumen Diameter (mm)</td>
</tr>
<tr>
<td>Shield n=11</td>
<td>2.69 ± 0.23</td>
<td>2.54 ± 0.30</td>
</tr>
<tr>
<td>Vision N=11</td>
<td>2.64 ± 0.19</td>
<td>2.45 ± 0.18</td>
</tr>
</tbody>
</table>
Evaluation of the vProtect Vascular Shield Mechanics on the LDLr(-) Swine

Baseline vs Post-Shield images for different time points.
Evaluation of the vProtect Vascular Shield Mechanics on the LDLr(-) Swine

Granada JF, Kaluza GL, Kolodgie F, Virmani R
vProtect Luminal Shield: Study Design

Non-randomized 30 patients study
Consecutive enrollment
2 OUS centers
10 to 20 patients/center

General inclusion criteria
• Symptomatic CAD undergoing PCI
• Single de novo lesion: >50% DS by QCA
• IVUS: minimal calcification
• RVD 2.75 – 3.5 mm, LL < 20 mm

Exclusion Criteria
• Known allergy or sensitivity to Nitinol
• Contraindication to anticoagulants
• Major surgery within 30 days
• Severe calcification by IVUS
• Anatomical exclusion criteria

PRIMARY ENPOINT
• Post-procedural DS <30%
• IVUS MLA > 4 mm²
• In-hospital through 30 days MACE*

SECONDARY ENDPOINT
• 9 month angiographic restenosis
• 9 month TLR, TVR, TVF
• 9 month MACE*

*MACE: Death, MI, stent thrombosis, TLR
## First in Human Study: Study Design of the vProtect Luminal Shield

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>All Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N=30</td>
</tr>
<tr>
<td>Age (mean yrs.)</td>
<td>59.0 ± 7.7</td>
</tr>
<tr>
<td>Gender</td>
<td>Male: 17 (57%)</td>
</tr>
<tr>
<td></td>
<td>Female: 13 (43%)</td>
</tr>
<tr>
<td>Diabetes Mellitus (%)</td>
<td>37%</td>
</tr>
<tr>
<td>Hypertension (%)</td>
<td>70%</td>
</tr>
<tr>
<td>Previous MI (%)</td>
<td>33%</td>
</tr>
<tr>
<td>Coronary Artery Disease</td>
<td>1-Vessel 11/30 (37%)</td>
</tr>
<tr>
<td></td>
<td>2-Vessel 14/30 (47%)</td>
</tr>
<tr>
<td></td>
<td>3-Vessel 5/30 (17%)</td>
</tr>
</tbody>
</table>
Can we add more data, like treated vessel (culprit), TIMI flow, etc... I would like to make this table to look more robust.

jgranada, 2009-03-17
# First in Human Study: Study Design of the vProtect Luminal Shield

<table>
<thead>
<tr>
<th>Variable</th>
<th>All Patients (N=28)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference Vessel Diameter</td>
<td>3.05 ± 0.22mm</td>
</tr>
<tr>
<td>Diameter Stenosis QCA (mean)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Baseline TV DS: 59.4 ± 9.2%</td>
</tr>
<tr>
<td></td>
<td>Post-Shield DS: 35.9 ± 8.2%</td>
</tr>
<tr>
<td></td>
<td><em>Post-Dilatation DS: 9.23% ± 5.54</em></td>
</tr>
<tr>
<td>#Pts w/ DS&lt;20% (on-line QCA)</td>
<td>2 (7.14%)</td>
</tr>
<tr>
<td>#Pts w/ Single Procedure Dilatation Resulting in DS&lt;30%</td>
<td>28 (100%)</td>
</tr>
<tr>
<td>Dilatation Pressure (mean)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre: 7.8±2.7ATM (6-16)</td>
</tr>
<tr>
<td></td>
<td>Post: 9.46±3.56 ATM (3-18)</td>
</tr>
<tr>
<td>Mean Luminal Area (IVUS)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre: 2.4±0.64mm²</td>
</tr>
<tr>
<td></td>
<td>Post: 4.7±0.98mm²</td>
</tr>
<tr>
<td>Pts. Requiring Bailout Procedure</td>
<td>0</td>
</tr>
</tbody>
</table>
ACS – Anterior Wall Ischemia
LAD at Bifurcation Point
ACS – Anterior Wall Ischemia

LAD – Pre-Dilatation and Positioning
ACS – Anterior Wall Ischemia
Following Deployment and Post Balloon
ACS Patient: Shield in mid-LAD. Post-Implantation & 9 Month Angiographic Follow-Up.

Baseline Angiogram
Mid-LAD

Shield Deployment
No-Post Dilatation

9-Month Angiographic Follow-Up

Final Result

ACS Patient: Shield in mid-LAD. Post-Implantation & 9 Month Angiographic Follow-Up.
## Summary of Clinical Outcomes

<table>
<thead>
<tr>
<th>Variable</th>
<th>All Patients (n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intra-Procedural Follow Up</td>
<td>30/30 (100%)</td>
</tr>
<tr>
<td>#Pts achieved &lt;30% DS post shield implant w/ or w/out post dilatation</td>
<td>30/30 (100%)</td>
</tr>
<tr>
<td>Peri-procedural complications</td>
<td>0%</td>
</tr>
<tr>
<td>MACE Rate</td>
<td>0%</td>
</tr>
<tr>
<td>30 Days Clinical Follow Up</td>
<td>30/30 (100%)</td>
</tr>
<tr>
<td>MACE Rate</td>
<td>0%</td>
</tr>
<tr>
<td>90 Days Clinical Follow Up*</td>
<td>30/30 (100%)</td>
</tr>
<tr>
<td>180 Days Clinical Follow Up*</td>
<td>17/28 (60%)</td>
</tr>
<tr>
<td>9-Month Angiographic Follow Up*</td>
<td>5/28 (18%)</td>
</tr>
</tbody>
</table>

*By second week of May*
Second Generation vProtect: Nanotextured Surfaces

Section Analysis

Surface distance 6.609 μm
Horiz distance(L) 6.018 μm
Vert distance 18.201 μm
Angle 0.174 °

Spectrum

Surface distance
Horiz distance
Vert distance
Angle
Spectral period 500.00 nm
Spectral freq 2.000 /μm
Spectral RMS amp 8.478 nm

Roughness Analysis

Image Statistics

Depth [nm]

0 450 300 150 0

HWHM 1.0

Second Generation vProtect: Biological Coating
• A self-expandable “vascular shield” has been successfully developed aiming to match the mechanical forces needed to “compress” the necrotic core avoiding fibrous cap rupture.

• Preliminary animal experience suggest that this device achieves smaller lumen areas, significantly less degree of vascular injury and comparable degree of neointimal formation compared with state of the art vascular devices.

• In animals vascular shields have demonstrated favorable biocompatibility with no marked difference to control stents in the qualitative or quantitative indices of healing of the arterial injury, foreign body reaction and endothelialization.

• Diseased animal models suggest that the vascular shield could compress and remodel the necrotic core, maintaining acceptable luminal gain and not causing additional vascular injury.
Conclusions (2)

- The implantation of a low pressure self-expandable scaffolding (vPredict™ Luminal Shield) is feasible and safe in patients with obstructive CAD achieving an adequate luminal gain and complete apposition after implantation.
- Complete device apposition is the rule, however, smaller lumen areas are consistently found.
- The primary safety endpoint was achieved. Thirty days clinical follow up demonstrated that the early safety profile is maintained.
- Due to its intrinsic mechanical properties, this device may improve the outcomes of PCI by inducing less injury at the time of implantation. Thus, this device could be indicated in specific patient subsets such as acute coronary syndromes.