Control of the microembolic burden of the carotid bifurcation lesion: comparison of various endovascular strategies

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Disclosure

Speaker name:

..................................................SUMAIRA MACDONALD..................................................

I have the following potential conflicts of interest to report:

☐ Consulting

☐ Employment in industry

☐ Stockholder of a healthcare company

☐ Owner of a healthcare company

☐ Other(s)

☐ I do not have any potential conflict of interest
Lecture Plan:

• Comparative DWMRI incidence: filter-protected TF CAS, unprotected CAS & CEA

• Comparative TCD MES incidence: filter-protected TF CAS, unprotected TF CAS, CEA & TCAR

• Influence of alternative EPD strategy for CAS

• Clinical relevance of microembolization
Relative Incidence

DWMRI Lesions:

Unprotected CAS,

Filter - Protected Transfemoral CAS & CEA
Filter-Protected versus Unprotected Carotid Artery Stenting: A Randomised Trial

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Graham S. Venables\textsuperscript{d} Trevor J. Cleveland\textsuperscript{e} Peter A. Gaines\textsuperscript{e}

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Filter-Protected versus Unprotected Carotid Artery Stenting: A Randomised Trial - TCD

![Graph 1: Total (panprocedural) HITs](chart1.png)
- Events: Unprotected (p = 0.01), Protected (p < 0.01)
- Particulate emboli: Unprotected (p = 0.02), Protected (p = 0.16)
- Gaseous emboli: Unprotected (p = 0.08), Protected (p = 0.08)

![Graph 2: Absolute count of embolization by SVL parameter](chart2.png)
- Events: Unprotected (p < 0.01), Protected (p = 0.02)
- Particulate emboli Category of event: Unprotected (p < 0.01), Protected (p = 0.03)
# Filter-Protected versus Unprotected Carotid Artery Stenting: A Randomised Trial

- NEW WHITE LESIONS ON DW-MRI BRAIN

<table>
<thead>
<tr>
<th></th>
<th>Protected</th>
<th>Unprotected</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procedural new lesions (1–3 h plus 24 h; n = 46)</td>
<td>7/24 (29%)</td>
<td>4/22 (18%)</td>
<td>0.4</td>
</tr>
<tr>
<td>Total new lesions (1–3, 24 h plus 30 days; n = 66)</td>
<td>9/33 (27%)</td>
<td>4/33 (12%)</td>
<td>0.1</td>
</tr>
</tbody>
</table>
ICSS Primary Analysis CEA Vs. CAS in 1713 symptomatic patients

ICSS Substudy: \( N = 231 \)

New white lesions on DWI

62 of 124 (50%) transfemoral distal filter CAS

18 of 107 (17%) CEA

\((\text{OR} 5.21, 2.78-9.79; p < 0.0001)\)
ICSS Substudy: \( N = 231 \)

2/7 centres performed unprotected CAS

5/7 centres performed filter-protected CAS

<table>
<thead>
<tr>
<th>Centre policy of using cerebral protection devices</th>
<th>No</th>
<th>Yes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25 (34)</td>
<td>73</td>
<td>62 (50)</td>
</tr>
<tr>
<td></td>
<td>10 (16)</td>
<td>51</td>
<td>124</td>
</tr>
<tr>
<td></td>
<td>61</td>
<td>8 (17)</td>
<td>107</td>
</tr>
</tbody>
</table>

*Transfemoral Distal - Filter Type EPD*
Lesion Volumes:

Individual lesion volume significantly smaller for TF CAS vs. CEA (p < 0.001)

Total lesion volume: Not significantly different (p = 0.18)
Influence of EPD Strategy
On DWMRI Findings
Proximal Protection:

Randomized Trial:

*Filter* - Protected Vs. *MoMa*
PROFI: A Prospective, Randomized Trial of Proximal Balloon Occlusion vs. Filter Embolic Protection in Patients Undergoing Carotid Stenting

Incidence of new Cerebral Ischemic Lesions
(Primary Endpoint)

N = 62

\( p = 0.001 \)

Incidence of Cerebral Ischemic Lesions %

<table>
<thead>
<tr>
<th>Group</th>
<th>Incidence</th>
<th>(Cases/Total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter</td>
<td>87.1 %</td>
<td>(27/31)</td>
</tr>
<tr>
<td>Balloon</td>
<td>45.2 %</td>
<td>(14/31)</td>
</tr>
</tbody>
</table>

Bijuklic K et al. JACC 2012;59:1383-1389
Mean Volume of new Cerebral Ischemic Lesions

(Secondary Endpoint)

\[ p = 0.0001 \]

<table>
<thead>
<tr>
<th></th>
<th>Volume (cm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter</td>
<td>0.59</td>
</tr>
<tr>
<td>Balloon</td>
<td>0.16</td>
</tr>
</tbody>
</table>
Proximal Protection:

Prospective Analysis:

Filter - Protected Vs.

Gore Flow Reversal
Assessment of reverse flow as a means of cerebral protection during carotid artery stent placement with diffusion-weighted and transcranial Doppler imaging.

Goode SD, Hoggard N, Macdonald S, Evans DH, Cleveland TJ, Gaines PA.

<table>
<thead>
<tr>
<th>Finding</th>
<th>Reverse Flow</th>
<th>Filter-protected</th>
<th>Unprotected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n = 11)</td>
<td>(n = 7)</td>
<td>(n = 4)</td>
</tr>
<tr>
<td>Total MES</td>
<td>192 ± 201</td>
<td>469 ± 181</td>
<td>129 ± 73</td>
</tr>
<tr>
<td>P Value</td>
<td></td>
<td>.01</td>
<td>.55</td>
</tr>
<tr>
<td>Embolicogenic MES</td>
<td>46 ± 42</td>
<td>169 ± 110</td>
<td>65 ± 40</td>
</tr>
<tr>
<td>P Value</td>
<td></td>
<td>.004</td>
<td>.47</td>
</tr>
<tr>
<td>During protection device deployment</td>
<td>87 ± 102</td>
<td>220 ± 71</td>
<td>NA</td>
</tr>
<tr>
<td>P Value</td>
<td></td>
<td>.009</td>
<td>NA</td>
</tr>
</tbody>
</table>
Assessment of Reverse Flow as a Means of Cerebral Protection during Carotid Artery Stent Placement with Diffusion-weighted and Transcranial Doppler Imaging

Stephen D. Goode, MRCS, FRCR, PhD, Nigel Hoggard, MD, MRCP, FRCR, Sumaira Macdonald, FRCR, PhD, David H. Evans, PhD, DSc, Trevor J. Cleveland, FRCS, FRCR, and Peter A. Gaines, FRCP, FRCR

<table>
<thead>
<tr>
<th>Finding</th>
<th>Reverse Flow (n = 15)</th>
<th>Filter-protected (n = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DWI scans in 24 h</td>
<td>29</td>
<td>24</td>
</tr>
<tr>
<td>Positive DWI scans (%)</td>
<td>17.2</td>
<td>29.0</td>
</tr>
<tr>
<td>Lesions on DWI</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>Total lesions (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ipsilateral ACA/MCA distal to stent</td>
<td>4/6 (67)</td>
<td>12/14 (86)</td>
</tr>
<tr>
<td>Ipsilateral PCA and contralateral ACA/MCA or PCA territories</td>
<td>2/6 (33)</td>
<td>2/14 (14)</td>
</tr>
</tbody>
</table>
The Arch Is A Hostile Territory:

The incidence of microemboli to the brain is less with endarterectomy than with percutaneous revascularization with distal filters or flow reversal.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>N</th>
<th>Incidence MES</th>
<th>Procedural Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEA</td>
<td>15</td>
<td>15.3 (+/- 22)</td>
<td>Post procedure</td>
</tr>
<tr>
<td>Filter protected CAS</td>
<td>20</td>
<td>319.3 (+/- 110.3)</td>
<td>During protection</td>
</tr>
<tr>
<td>Flow reversal CAS</td>
<td>7</td>
<td>184.2 (+/- 110.5)</td>
<td>Pre protection</td>
</tr>
</tbody>
</table>

**CEA vs filter p = 0.001**  
**CEA vs flow reversal p = 0.007**  
**Flow reversal vs filter p = 0.053**
PROXIMAL PROTECTION:
TCAR (ENROUTE Transcarotid NPS)
TCAR - Surgically Inspired
CEA - like Neuroprotection

Continuous high rate of _flow reversal_ to remove micro and macro debris throughout intervention

Direct Carotid Access
CCA Clamp or Loop Control

TCAR Procedure
TransCarotid Artery Revascularization
PROOF First In Man DWMRI Sub Study

- Baseline scan within 72 hours
- Post-procedure scan within 12-48 hours
- Submitted to core laboratory for blinded evaluation by two independent neuroradiologists

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value (n=48)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects with new DW-MRI lesion(s)</td>
<td>8 (16.7%)</td>
</tr>
</tbody>
</table>
**A diffusion-weighted magnetic resonance imaging-based study of transcervical carotid stenting with flow reversal vs transfemoral filter protection**

**N = 64**

### DWI Multivariate Analysis*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Relative Risk</th>
<th>95% CIs</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1.022</td>
<td>1.021 - 1.041</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Recent symptoms</td>
<td>4.109</td>
<td>1.74 – 9.65</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Stent design (OC Vs. CC)</td>
<td>0.082</td>
<td>0.019 – 0.359</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

*Impacted on transfemoral filter CAS **BUT not** TCAR*

---

Leal I et al JVS 2012;56:1585-1590
TCAR Demonstrates TCD Embolization Rates Comparable to CEA¹

• CEA vs TCAR vs TF-CAS Patients monitored w/TC Doppler during 3 procedural phases:

http://jet.sagepub.com/content/23/2/249

1. Pre-protection
   • Before clamping, filter deployed, or reverse flow established

2. Protection
   • Until clamp removed, filter retrieved, or antegrade flow reestablished

3. Post-protection
   • After clamp/filter removed, or normal flow established
TCAR DEMONSTRATES TCD EMBOLIZATION RATES COMPARABLE TO CEA
<table>
<thead>
<tr>
<th>Study</th>
<th>Procedure</th>
<th>Embolic Protection</th>
<th># subjects</th>
<th>% w/ New DWI Lesions</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICSS¹</td>
<td>Transfemoral CAS</td>
<td>Distal filter (various)</td>
<td>51</td>
<td>73</td>
</tr>
<tr>
<td>ICSS¹</td>
<td>CEA</td>
<td>Clamp, backbleed</td>
<td>107</td>
<td>17</td>
</tr>
<tr>
<td>PROFI²</td>
<td>Transfemoral CAS</td>
<td>Distal filter (Embosheild)</td>
<td>31</td>
<td>87</td>
</tr>
<tr>
<td>Leal⁴</td>
<td>Transfemoral</td>
<td>Distal Filter (FilterWire)</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>PROFI²</td>
<td>Transfemoral CAS</td>
<td>Proximal occlusion (MoMA)</td>
<td>31</td>
<td>45</td>
</tr>
<tr>
<td>PROOF³</td>
<td>TCAR</td>
<td>High flow rate flow reversal</td>
<td>48</td>
<td>16.7</td>
</tr>
<tr>
<td>Leal⁴</td>
<td>TCAR</td>
<td>Flow Reversal</td>
<td>31</td>
<td>12.9</td>
</tr>
<tr>
<td>CARENET⁵  (CGuard stent)</td>
<td>Transfemoral</td>
<td>Distal filter (26 pts, MoMa 1 pt)</td>
<td>27</td>
<td>48%</td>
</tr>
</tbody>
</table>

3. JVS 2011;54:1317-1323
4. JVS 2012;56:1585-1590
5. J Am Coll Cardiol Intv 2015;8:1229-1234
Clinical Relevance:
**DWI Lesions Correlate With Stroke Risk In Carotid Interventions**

71 studies, reporting 75 separate CAS treatment groups (4455 procedures) and 29 separate CEA treatment groups (1708 procedures)

Observed crude risks of stroke and DWI+ in all 104 treatment subgroups

<table>
<thead>
<tr>
<th>Stroke risk</th>
<th>DWI lesion risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1%</td>
<td>11%</td>
</tr>
<tr>
<td>2%</td>
<td>23%</td>
</tr>
<tr>
<td>3%</td>
<td>34%</td>
</tr>
<tr>
<td>4%</td>
<td>43%</td>
</tr>
<tr>
<td>5%</td>
<td>50%</td>
</tr>
<tr>
<td>6%</td>
<td>56%</td>
</tr>
</tbody>
</table>

Correlation between log odds of DWI lesions and log odds of stroke (coefficient 0.68 [95% CI 0.36-0.88], p=0.00024)

Correlation between true risks of stroke and DWI+ in all included studies (corrected for measurement error and study size)
The clinical importance of white matter hyperintensities on brain magnetic resonance imaging: systematic review and meta-analysis

46 longitudinal studies; general population & hospital based

Association WM lesions & incident dementia

**General population**
- Kuller 2003
- Prins 2004
- Debette 2009

<table>
<thead>
<tr>
<th>Hazard ratio (95% CI)</th>
<th>Test for heterogeneity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.9 (1.3 to 6.3)</td>
<td>P=0.001, I²=85.1%</td>
</tr>
</tbody>
</table>

**High risk population**
- Geroldi 2006
- Firbank 2007
- Smith 2008
- Bombois 2008
- Kantarci 2009
- Jokinen 2009

<table>
<thead>
<tr>
<th>Hazard ratio (95% CI)</th>
<th>Test for heterogeneity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.4 (0.9 to 2.3)</td>
<td>P=0.04, I²=57.7%</td>
</tr>
</tbody>
</table>

**Overall**

<table>
<thead>
<tr>
<th>Hazard ratio (95% CI)</th>
<th>Test for heterogeneity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.9 (1.3 to 2.8)</td>
<td>P&lt;0.001, I²=72.9%</td>
</tr>
</tbody>
</table>
Conclusions:

• DWMRI lesions more numerous following TF-CAS than after CEA

• CAS procedural modifications improve the DWMRI/TCD MES rate
  
  • EPD strategy (proximal/TCAR)
  • The arch is hostile
  • The utility of carotid membrane mesh stent strategy is unclear

• There is no direct correlation between lesions & cognitive decline in carotid intervention but reasonable evidence linking baseline lesion burden to stroke, mortality & subsequent dementia
Clinical Relevance:
Cognitive Function:
A Dark Art?
N = 32 studies (25 CEA, 4 CAS)

“No consistent findings...”

“Assessment of cognition after carotid revascularisation is probably influenced by many confounding factors such as learning effect, type of test, type of patients, & control group”
An ICSS Sub-Study:

N = 177 patients recruited in two Dutch centres

N = 140 Cognitive Function Assessment at baseline

N = 120 Cognitive Function Assessment at 6/12

10 Domains including executive function
DWMRI & Cognitive Function:

**New white lesions:**

17 in 34 CAS (50%)

7 in 30 CEA (23%)

\[ \text{RR 2.1; 95\% CI 1.0 – 4.4}, \]
\[ p = 0.041 \]

**Cognitive Function:**

*No significant difference*
New brain lesions after carotid revascularization are not associated with cognitive performance

N = 24 CAS (9 filter-protected, 15 unprotected)

N = 31 CEA

N = 27 Healthy Controls

Neurophychometry: *(6 domains)*, T=pre, 72 hrs, 3/12

DWMRI: *(3T, 6mm slice)*, T=pre, 72 hrs, 3/12
<table>
<thead>
<tr>
<th>Cognitive domain</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attention</td>
<td>TAP, subtest alertness</td>
</tr>
<tr>
<td></td>
<td>TAP, subtest divided attention</td>
</tr>
<tr>
<td>Short-term and working memory</td>
<td>TAP, subtest working memory</td>
</tr>
<tr>
<td></td>
<td>First trial of Selective Reminding Test</td>
</tr>
<tr>
<td></td>
<td>First trials of WMS-R logic memory and verbal pair association</td>
</tr>
<tr>
<td>Executive functions</td>
<td>Wisconsin Card Sorting Test</td>
</tr>
<tr>
<td></td>
<td>Regard’s Five-Point Test</td>
</tr>
<tr>
<td></td>
<td>RWT, subtests lexical fluency with and without alterations</td>
</tr>
<tr>
<td>Verbal learning and memory</td>
<td>Last trials and delayed recall of Selective Reminding Test</td>
</tr>
<tr>
<td></td>
<td>Last trials of WMS-R, subtests logical memory and verbal pair association</td>
</tr>
<tr>
<td>Nonverbal learning and memory</td>
<td>Delayed recall of Rey-Osterrieth Complex Figure Test</td>
</tr>
<tr>
<td></td>
<td>Non-Verbal Learning Test</td>
</tr>
<tr>
<td></td>
<td>Spatial Recall Test</td>
</tr>
<tr>
<td></td>
<td>Lern-und Gedächtnistest (Learning and Memory Test)</td>
</tr>
<tr>
<td>Visuoconstructive functions</td>
<td>Copy of Rey-Osterrieth Complex Figure Test</td>
</tr>
</tbody>
</table>
**ExF** = Executive functions

**NVLM** = Nonverbal learning memory

**STM** = Short term & working memory

**VCF** = Visuoconstructive functions

**VLM** = Verbal learning & memory

**With & Without DMRI lesions**
CAS versus CEA
The Authors’ Conclusions:

“The findings support the assumptions that new brain lesions, as detected by DWI after CAS or CEA do not affect cognitive performance in a manner that is long-lasting or clinically relevant”

“Despite the higher embolic load detected by DWI, CAS is not associated with greater cognitive decline than CEA”
Follow Up Imaging:

**CAS**: 89/537 DWI lesions (17%) FLAIR* +ve at 1/12

**CEA**: 18/34 DWI lesions (53%) FLAIR* +ve at 1/12

“*Signifying persistent infarction*”
Recurrent stroke OR TIA (5 year cumulative)

**CAS:**

DWMRI +ve: 12/62

DWMRI -ve: 6/62

22.8% vs. 8.8% (p=0.04)

HR 2.85 (1.05-7.720)

“But the risk of stroke alone was not significantly increased”

Bonati L et al. European Stroke Congress May 2013
Recurrent stroke OR TIA (5 year cumulative)

**ICSS Substudy: **<n>231

**CEA**

<table>
<thead>
<tr>
<th>DWI +VE</th>
<th>DWI – VE</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;No difference&quot;</td>
<td></td>
</tr>
</tbody>
</table>
Evaluation of small ischemic lesions after carotid artery stenting: the usefulness of thin-slice diffusion-weighted MR imaging

$N = 20$ CAS procedures in 17 patients

1.5 Tesla Magnet

“Standard” DWMRI: Slice Thickness: 6mm

“Thin Slice” DWMRI: Slice Thickness: 2mm

Imaged: 2-7 days post CAS
## Number of Lesions

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Ipsilateral</th>
<th>Contralateral</th>
<th>Posterior fossa</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thin-slice DWI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of the hyperintense lesions</td>
<td>31 (14 MR exam)</td>
<td>24</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Average size (mm)</td>
<td>5.33</td>
<td>5.70</td>
<td>6.45</td>
<td></td>
</tr>
<tr>
<td><strong>Standard DWI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of the hyperintense lesions</td>
<td>10 (7 MR exam)</td>
<td>8</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Average size (mm)</td>
<td>5.16</td>
<td>5.60</td>
<td>–</td>
<td></td>
</tr>
</tbody>
</table>

p < 0.005
Lesion Size

Mean size significantly different (larger on thin slice)

\[ p < 0.005 \]
Technical Considerations:

Slice Thickness

Field Strength
Acute and Subacute Ischemic Stroke at High-Field-Strength (3.0-T) Diffusion-weighted MR Imaging: Intraindividual Comparative Study

N = 25 patients: acute ischemic stroke

• 1.5T & 3T imaging
• Signal to Noise Ratio (SNR)
• Contrast to Noise Ratio (CNR)
• Image Quality
• Diagnostic confidence
Mean Signal To Noise Ratios

Mean averaged lesion SNR

- 1.5T b=1000
- 3.0T b=1000

SNR

Cerebellum | Pons | Thalamus | Striatum | Deep WM | Lesion

Mean averaged lesion SNR
Mean Contrast To Noise Ratios

- lesion CNR 1.5T
- lesion CNR 3.0T

Patients with ischemic lesions:
Lesion Detection:

48 lesions in 19 of 25 patients

47 (98%) diagnosed at 3T

36 (75%) diagnosed at 1.5T

$p < 0.001$
Late Evaluation of Silent Cerebral Ischemia Detected by Diffusion-Weighted MR Imaging after Filter-Protected Carotid Artery Stenting

<table>
<thead>
<tr>
<th>Location</th>
<th>Postoperative DWI</th>
<th>MR Imaging Follow-Up</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Persisted</td>
<td>Disappeared</td>
<td>Lost</td>
</tr>
<tr>
<td>Cortical</td>
<td>19</td>
<td>4 (25%)</td>
<td>12 (75%)</td>
</tr>
<tr>
<td>Subcortical</td>
<td>10</td>
<td>7 (70%)</td>
<td>3 (30%)</td>
</tr>
<tr>
<td>Deep white matter</td>
<td>3</td>
<td>1 (33%)</td>
<td>2 (66%)</td>
</tr>
<tr>
<td>Basal ganglia</td>
<td>1</td>
<td>0</td>
<td>1 (100%)</td>
</tr>
<tr>
<td>Total</td>
<td>33</td>
<td>12 (40%)</td>
<td>18 (60%)</td>
</tr>
</tbody>
</table>

*N = 110*: transfemoral filter-protected CAS

*P value by χ² test.*
## Size of postoperative DWI and follow-up MR imaging ischemic lesions

<table>
<thead>
<tr>
<th>Size</th>
<th>Postoperative DWI</th>
<th>Follow-Up MR Imaging</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Persisted</td>
<td>Disappeared</td>
</tr>
<tr>
<td>0–5 mm</td>
<td>19</td>
<td>3 (17%)</td>
<td>14 (83%)</td>
</tr>
<tr>
<td>5–10 mm</td>
<td>14</td>
<td>9 (69%)</td>
<td>4 (31%)</td>
</tr>
<tr>
<td>Total</td>
<td>33</td>
<td>12</td>
<td>18</td>
</tr>
</tbody>
</table>

*P value by $\chi^2$ test.
### Analysis of possible factors influencing patient reversibility rate

<table>
<thead>
<tr>
<th>Factors</th>
<th>No. Patients with DWI Lesions</th>
<th>No. Patients with Persistent MR Imaging Lesions</th>
<th>$P^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative microinfarctual brain</td>
<td>6</td>
<td>3 (50%)</td>
<td>.3</td>
</tr>
<tr>
<td>Normal brain</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Age $\geq$ 80 years</td>
<td>3</td>
<td>3 (100%)</td>
<td>.1</td>
</tr>
<tr>
<td>Age $&lt;$ 80 years</td>
<td>10</td>
<td>5 (50%)</td>
<td></td>
</tr>
<tr>
<td>Types 1 and 2 carotid plaque</td>
<td>1</td>
<td>0</td>
<td>.2</td>
</tr>
<tr>
<td>Types 3–5 carotid plaque</td>
<td>12</td>
<td>8 (67%)</td>
<td></td>
</tr>
<tr>
<td>Asymptomatic</td>
<td>8</td>
<td>5 (62%)</td>
<td>.9</td>
</tr>
<tr>
<td>Symptomatic</td>
<td>5</td>
<td>3 (60%)</td>
<td></td>
</tr>
</tbody>
</table>

*$P$ values by $\chi^2$ test.*
SRM-sponsored C-CAS trial
Toledo, Spain: Using standard C-CAS (not SRM)

<table>
<thead>
<tr>
<th>30 day results</th>
<th>C-CAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>30</td>
</tr>
<tr>
<td>% Symptomatic</td>
<td>40%</td>
</tr>
<tr>
<td>Technical Success</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Pts with new lesions on DW-MRI**

<table>
<thead>
<tr>
<th>Number of lesions</th>
<th>9 (all ipsilateral)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death</td>
<td>0</td>
</tr>
<tr>
<td>Major Stroke</td>
<td>0</td>
</tr>
<tr>
<td>Minor Stroke</td>
<td>0</td>
</tr>
</tbody>
</table>

**Death/Major Stroke**

|                                | 0                   |

*AHA “Surgical Risk” Guideline:* Symptomatic ≤6%; Asymptomatic ≤3%

*Note: all DW-MRI images read by independent, blinded readers*
TRANSCRANIAL DOPPLER (TCD): TF-CAS averages 300-500 MES

- Measures flow velocity in cerebral vessels
- Counts microembolic signals (MES) – signatures of embolic phenomenon detected during procedure
- Being used to monitor embolic potential of procedures & distinguish high risk from low risk asymptomatic patients
The Impact of *Baseline* White Matter Changes on Subsequent Intervention:
ICSS: Baseline Age-Related White Matter Changes

1713 patients randomised

1649 procedure initiated per protocol

613 excluded
- 603 no baseline brain imaging available
- 10 baseline imaging of non-diagnostic quality

1036 included in ARWMC analysis

525 ARWMC score < 7
511 ARWMC score ≥ 7

Study profile
ICSS: 30-day cumulative incidence of stroke by severity of white matter lesions
Timing & Fate
of DWMRI Lesions:
Subclinical embolization after carotid artery stenting: New lesions on diffusion-weighted magnetic resonance imaging occur postprocedure.

N = 48 (pre & 48 hours post)

N = 23 (pre & 1 hour & 48 hours post)

<table>
<thead>
<tr>
<th>Group</th>
<th>Patients (n)</th>
<th>Positive at 1 h</th>
<th>Positive at 48 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imagined at 48 h</td>
<td>54</td>
<td>—</td>
<td>36 (67%)</td>
</tr>
<tr>
<td>1 h and 48 h</td>
<td>23</td>
<td>2 (9%)*</td>
<td>18 (78%)*</td>
</tr>
</tbody>
</table>

*P < .001.
Influence of Periprocedural Pharmacological Regime & Technical Parameters On DWMRI Incidence
Abciximab Does Not Prevent Ischemic Lesions Related to Cerebral Angiography: A Randomized Placebo-Controlled Trial

Nature of the embolic burden?

N = 184 undergoing cerebral angiography

Pre & 3-24 hours post 1.5T DWMRI

1: 1 randomisation: abciximab or placebo
RESULTS

15/90 (16.7%) Abciximab Group DWMRI lesions

16/94 (17%) Placebo Group DWMRI lesions

“ Our findings indicate that solid blood clots are not the origin of hyperintense lesions observed on DWI and enhance the role of alternative mechanisms ”

\( P = \text{NS} \)
Heparin and Air Filters Reduce Embolic Events Caused by Intra-Arterial Cerebral Angiography

A Prospective, Randomized Trial

N = 150
Microscopic air embolism during cerebral angiography and strategies for its avoidance

Fig 2—Typical transcranial doppler recordings from marginal artery in sheep during injection of contrast into the ipsilateral proximal carotid artery.

A = during fast injection of iohexol 350 mg/mL; B = after allowing contrast to stand for 1 min; C = after allowing contrast to stand for 10 min.
Technical Considerations:

Slice Thickness (2mm Vs. 6mm)

Field Strength (1.5 Vs. 3T)