Total Arterial Revascularization: The Gold Standard in 2017

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Director, Surgical Coronary Revascularization, Mount Sinai Health System

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Disclosures/Conflicts

- Royalties from coronary surgical instruments invented by the author and marketed by Scanlan, Inc.
- No other relevant financial COI’s.
Rationale:

- Arterial grafts have better patency and improve survival after CABG compared to SVGs.
- OPCAB has been associated with reduced early morbidity after CABG and lower mortality in higher risk patients.
- Clampless techniques reduce risk of stroke.
- Clampless OPCAB with all-arterial conduits may be the Gold Standard for surgical coronary revascularization.
“Two Better Than One” - BITA

Effects of bilateral IMA compared with single IMA

Random-effects meta-analysis of data from seven studies. Horizontal lines indicate 95% CI.
A Meta-analysis of Adjusted Hazard Ratios from 20 Observational Studies of Bilateral Versus Single Internal Thoracic Artery Coronary Artery Bypass Grafting


- 20 observational studies; 70,897 patients, pooled analysis
- BITA associated with significant reduction in long-term mortality relative to SITA (HR 0.80; 95% CI 0.77-0.84)
- Benefit of BITA increased in studies with higher proportions of males
1.2.1 Pedicled ITA

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>log[Hazard Ratio]</th>
<th>SE</th>
<th>BITA Total</th>
<th>SITA Total</th>
<th>Weight</th>
<th>Hazard Ratio IV, Fixed, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buxton 1998</td>
<td>-0.3415</td>
<td>0.1256</td>
<td>1269</td>
<td>1557</td>
<td>5.8%</td>
<td>0.71 [0.56, 0.91]</td>
</tr>
<tr>
<td>Carrier 2009, statin (+)</td>
<td>-0.0781</td>
<td>0.1562</td>
<td>1166</td>
<td>4835</td>
<td>3.8%</td>
<td>0.92 [0.68, 1.26]</td>
</tr>
<tr>
<td>Carrier 2009, statin (-)</td>
<td>-0.4368</td>
<td>0.1197</td>
<td>69</td>
<td>585</td>
<td>6.4%</td>
<td>0.65 [0.51, 0.82]</td>
</tr>
<tr>
<td>Grau 2012</td>
<td>-0.3955</td>
<td>0.1126</td>
<td>928</td>
<td>928</td>
<td>7.3%</td>
<td>0.67 [0.54, 0.84]</td>
</tr>
<tr>
<td>Kelly 2012</td>
<td>-0.2008</td>
<td>0.1004</td>
<td>1079</td>
<td>6554</td>
<td>9.1%</td>
<td>0.82 [0.67, 1.00]</td>
</tr>
<tr>
<td>Pick 1997</td>
<td>-0.2002</td>
<td>0.2489</td>
<td>160</td>
<td>161</td>
<td>1.5%</td>
<td>0.82 [0.50, 1.33]</td>
</tr>
<tr>
<td>Stevens 2004</td>
<td>-0.3081</td>
<td>0.1034</td>
<td>1808</td>
<td>2498</td>
<td>8.6%</td>
<td>0.73 [0.60, 0.90]</td>
</tr>
</tbody>
</table>

### Subtotal (95% CI)

<table>
<thead>
<tr>
<th></th>
<th>BITA</th>
<th>SITA</th>
<th>Weight</th>
<th>Hazard Ratio IV, Fixed, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subtotal</td>
<td>6479</td>
<td>17118</td>
<td>42.5%</td>
<td>0.74 [0.68, 0.81]</td>
</tr>
</tbody>
</table>

Heterogeneity: \( \chi^2 = 5.30, \text{df} = 6 \) (\( P = 0.51 \)); \( I^2 = 0\% 
Test for overall effect: \( Z = 6.44 \) (\( P < 0.00001 \))

1.2.2 Skeletonized ITA

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>log[Hazard Ratio]</th>
<th>SE</th>
<th>BITA Total</th>
<th>SITA Total</th>
<th>Weight</th>
<th>Hazard Ratio IV, Fixed, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bonacchi 2006</td>
<td>-0.4055</td>
<td>0.6551</td>
<td>320</td>
<td>332</td>
<td>0.2%</td>
<td>0.67 [0.18, 2.41]</td>
</tr>
<tr>
<td>Endo 2001</td>
<td>-0.0502</td>
<td>0.1787</td>
<td>443</td>
<td>688</td>
<td>2.9%</td>
<td>0.95 [0.67, 1.35]</td>
</tr>
<tr>
<td>Joo 2012</td>
<td>-0.0125</td>
<td>0.2222</td>
<td>366</td>
<td>366</td>
<td>1.9%</td>
<td>0.99 [0.64, 1.53]</td>
</tr>
<tr>
<td>Kinoshita 2012</td>
<td>-0.5906</td>
<td>0.2962</td>
<td>217</td>
<td>217</td>
<td>1.0%</td>
<td>0.55 [0.31, 0.99]</td>
</tr>
<tr>
<td>Kurlansky 2010</td>
<td>-0.1778</td>
<td>0.0426</td>
<td>2215</td>
<td>2369</td>
<td>50.7%</td>
<td>0.84 [0.77, 0.91]</td>
</tr>
<tr>
<td>Navia 2013</td>
<td>-0.0194</td>
<td>0.343</td>
<td>149</td>
<td>149</td>
<td>0.8%</td>
<td>0.98 [0.50, 1.92]</td>
</tr>
</tbody>
</table>

### Subtotal (95% CI)

<table>
<thead>
<tr>
<th></th>
<th>BITA</th>
<th>SITA</th>
<th>Weight</th>
<th>Hazard Ratio IV, Fixed, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subtotal</td>
<td>3710</td>
<td>4121</td>
<td>57.5%</td>
<td>0.84 [0.78, 0.91]</td>
</tr>
</tbody>
</table>

Heterogeneity: \( \chi^2 = 3.32, \text{df} = 5 \) (\( P = 0.65 \)); \( I^2 = 0\% 
Test for overall effect: \( Z = 4.31 \) (\( P < 0.00001 \))

Total (95% CI)

<table>
<thead>
<tr>
<th></th>
<th>BITA</th>
<th>SITA</th>
<th>Weight</th>
<th>Hazard Ratio IV, Fixed, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>10189</td>
<td>21239</td>
<td>100.0%</td>
<td>0.80 [0.75, 0.85]</td>
</tr>
</tbody>
</table>

Heterogeneity: \( \chi^2 = 12.94, \text{df} = 12 \) (\( P = 0.37 \)); \( I^2 = 7\% 
Test for overall effect: \( Z = 7.47 \) (\( P < 0.00001 \))

Test for subgroup differences: \( \chi^2 = 4.32, \text{df} = 1 \) (\( P = 0.04 \)); \( I^2 = 76.9\% 
Test for subgroup differences: \( \chi^2 = 4.32, \text{df} = 1 \) (\( P = 0.04 \))

Favours BITA

Favours SITA
Surgical Revascularization Techniques That Minimize Surgical Risk and Maximize Late Survival After Coronary Artery Bypass Grafting in Patients with Diabetes Mellitus
Raza et al. JTCVS 2014;148:1257-66

- 1972-2011, 11,922 patients with DM had isolated CABG
- Adjusted risk of late mortality 21% lower with BITA vs SITA
- BITA assoc. with increased DSWI (risk factors: female, obese, prior MI, PVD, medically treated DM)
- OPCAB vs ONCAB statistically similar results
- Complete vs incomplete revascularization had similar in-hospital outcomes; complete revasc associated with 10% lower late mortality
- BITA grafting with complete revascularization maximizes long-term survival in diabetic patients undergoing CABG
- Avoid in obese diabetic women with diffuse PVD—highest DSWI
Surgical Revascularization Techniques That Minimize Surgical Risk and Maximize Late Survival After Coronary Artery Bypass Grafting in Patients with Diabetes Mellitus
Raza et al  JTCVS 2014;148:1257-66

“\nWe identified BITA plus complete revascularization plus off-pump CABG as the strategy with the best predicted survival, and no ITA grafts plus incomplete revascularization plus on-pump CABG with the worst.\n
“We found that patients deriving the greatest survival benefit (greater than a 23% 10-year survival difference) from the best surgical combination were actually the sickest of all—older women undergoing emergency surgery, with higher bilirubin, previous stroke, PVD and IDDM”\n
Bypass Graft Conduits

When anatomically and clinically suitable, use of a second IMA to graft the left circumflex or right coronary artery (when critically stenosed and perfusing LV myocardium) is reasonable to improve the likelihood of survival and to decrease reintervention.

Complete arterial revascularization may be reasonable in patients ≤60 years of age with few or no comorbidities.
# Procedural aspects of CABG

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class</th>
<th>Level</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is recommended to perform procedures in a hospital structure and by a team specialized in cardiac surgery, using written protocols.</td>
<td>I</td>
<td>B</td>
<td>635,636</td>
</tr>
<tr>
<td>Endoscopic vein harvesting should be considered to reduce the incidence of leg wound complications.</td>
<td>IIa</td>
<td>A</td>
<td>577,578,580–582, 637,638</td>
</tr>
<tr>
<td>Routine skeletonized IMA dissection should be considered.</td>
<td>IIa</td>
<td>B</td>
<td>586–589</td>
</tr>
<tr>
<td>Skeletonized IMA dissection is recommended in patients with diabetes or when bilateral IMAs are harvested.</td>
<td>I</td>
<td>B</td>
<td>586–589</td>
</tr>
<tr>
<td>Complete myocardial revascularization is recommended.</td>
<td>I</td>
<td>B</td>
<td>594,598,600</td>
</tr>
<tr>
<td>Arterial grafting with IMA to the LAD system is recommended.</td>
<td>I</td>
<td>B</td>
<td>602,603,639</td>
</tr>
<tr>
<td>Bilateral IMA grafting should be considered in patients &lt;70 years of age.</td>
<td>IIa</td>
<td>B</td>
<td>165,606–610,640, 641</td>
</tr>
<tr>
<td>Use of the radial artery is recommended only for target vessels with high-degree stenosis.</td>
<td>I</td>
<td>B</td>
<td>618,642</td>
</tr>
<tr>
<td>Total arterial revascularization is recommended in patients with poor vein quality independently of age.</td>
<td>I</td>
<td>C</td>
<td>-</td>
</tr>
<tr>
<td>Total arterial revascularization should be considered in patients with reasonable life expectancy.</td>
<td>IIa</td>
<td>B</td>
<td>643</td>
</tr>
<tr>
<td>Minimization of aortic manipulation is recommended.</td>
<td>I</td>
<td>B</td>
<td>442,644</td>
</tr>
<tr>
<td>Off-pump CABG should be considered for subgroups of high-risk patients in high-volume off-pump centres.</td>
<td>IIa</td>
<td>B</td>
<td>626,627,629</td>
</tr>
<tr>
<td>Off-pump CABG and/or no-touch on-pump techniques on the ascending aorta are recommended in patients with significant atherosclerotic disease of the ascending aorta in order to prevent perioperative stroke.</td>
<td>I</td>
<td>B</td>
<td>443</td>
</tr>
<tr>
<td>Minimally invasive CABG should be considered in patients with isolated LAD lesions.</td>
<td>IIa</td>
<td>C</td>
<td>-</td>
</tr>
<tr>
<td>Electrocardiogram-triggered CT scans or epicardial scanning of the ascending aorta should be considered in patients over 70 years of age and/or with signs of extensive generalized atherosclerosis.</td>
<td>IIa</td>
<td>C</td>
<td>-</td>
</tr>
<tr>
<td>Routine intraoperative graft flow measurement should be considered.</td>
<td>IIa</td>
<td>C</td>
<td>-</td>
</tr>
</tbody>
</table>
Why Should OPCAB Be Better?

• CABG/CPB entails extracorporeal circulation, aortic cannulation and clamping, global myocardial ischemia, hypothermia, hemodilution etc.
• OPCAB avoids these deleterious effects of CPB by mechanically stabilizing each coronary artery target individually, while the rest of the heart beats and supports normal physiologic circulation.
• *If* a complete revascularization with precise anastomoses can be accomplished without CPB, then the patient will benefit.
SMART Trial: Early Results

Off-pump coronary artery bypass grafting provides complete revascularization with reduced myocardial injury, transfusion requirements, and length of stay; A prospective randomized comparison of two hundred unselected patients undergoing off-pump versus conventional coronary artery bypass grafting

Presented at AATS 2002
Published in JTCVS 2003

Similar completeness of revascularization in unselected patients

Significant in-hospital benefits of OPCAB:

- Lower enzyme release
- Less transfusion
- More rapid extubation
- Shorter length of stay
SMART Trial
Index of Completeness of Revascularization (ICOR)

- Number of grafts performed per patient:
  3.39 ± 1.04 OPCAB vs 3.40 ± 1.08 CABG/CPB

- Index of completeness of revascularization:
  1.00 ± 0.18 OPCAB vs 1.01 ± 0.09 CABG/CPB

- ICOR also similar for lateral wall:
  0.97 ± 0.23 OPCAB vs 0.98 ± 0.10 CABG/CPB

- Percent arterial grafts:
  41.3% OPCAB vs 40.8% CABG/CPB

(All comparisons, p=NS)
Coagulopathy and Transfusion

- CPB was an independent predictor of transfusion by multivariate analysis:

  Odds Ratio 2.42  \( p=0.0073 \)
SMART Trial: Length of Stay

- Postoperative LOS was shorter in OPCAB:

  \[5.1 \pm 6.5\text{ days OPCAB vs } 6.1 \pm 8.2\text{ days CABG/CPB}\]

  \[p=0.005\text{ Wilcoxon}\]
CPK-MB and Troponin I Release

CPK-MB

- CPB
- OPCAB

* p<0.001 Wilcoxon

Troponin I

- CPB
- OPCAB

* p<0.001

** p<0.01 Wilcoxon

Hours After Operation

NG/ML

Mount Sinai Heart
Off-Pump vs Conventional Coronary Artery Bypass Grafting: Early and 1-Year Graft Patency, Cost, and Quality-of-Life Outcomes
A Randomized Trial

Context Previous trials of off-pump coronary artery bypass (OPCAB) have enrolled selected patients and have not rigorously evaluated long-term graft patency. A preliminary report showed OPCAB achieved improved in-hospital outcomes, similar completeness of revascularization, and shorter lengths of stay compared with conventional coronary artery bypass grafting (CABG).

Objective To assess graft patency, clinical and quality-of-life outcomes, and cost among patients while in the hospital and at 1-year followup.

Design, Setting, and Patients Randomized controlled trial of patients selected for coronary anatomy, ventricular function, or comorbidities between March 10, 2000, and August 20, 2001, at a US academic center. A total of 200 patients were enrolled; 3 patients were withdrawn after randomization for mitral valve repair or replacement. Follow-up was complete for 197 patients at 30 days, 189 at 1 year.

Interventions One surgical session consisting of selective OPCAB or CABG with cardiopulmonary bypass. The surgeon had extensive experience performing off-pump surgery; patients were subsequently managed by blinded protocols.

Main Outcome Measures Coronary angiography documented graft patency prior to hospital discharge and at 1 year, health-related quality of life, and cost of the index and subsequent hospitalizations.

Results Graft patency was similar for OPCAB and conventional CABG with cardiopulmonary bypass at 30 days (absolute difference, 1.3%; 95% confidence interval [CI], -0.60% to 3.11%; P = .19) and at 1 year (absolute difference, -2.2%; 95% CI, -6.1% to 1.7%; P = .27). Rates of death, stroke, myocardial infarction, angina, and reintervention were similar at 30 days and 1 year. There were no significant differences in health-related quality of life. Mean total hospitalization cost per patient at hospital discharge was $2272 (95% CI, $1755-$2792) less for OPCAB (P = .002) and $1955 (95% CI, $1155-$2755) less at 1 year (P = .03).

Conclusions In this randomized single-surgeon trial among unsel ected patients with angiographic follow-up, OPCAB achieved similar graft patency in the hospital and at 1 year. Cardiac outcomes and health-related quality of life at 30 days and 1 year were similar and patients incurred a lower cost. OPCAB may provide complete revascularization that is durable and cost-effective.

Author Affiliations: Division of Cardiothoracic Surgery, Emory University, Atlanta, Ga (Dr Williams and Cates and Ms McCull). Patients, and Bailey), Cardiology (Dr Huiz, Black, Mathew, and Lambert), and Cardio Anesthesiology (Dr Duke, Staples, and Glue). University Hospital; Florida Hospital; and American Heart Center for Outcomes Research (Dr Williams and Whittenburg), Atlanta, Ga, and the New England

Complete follow-up:
- 100% at 30 days
- 94% at 1 year

Rates of death, stroke, MI, angina, reintervention similar at 30 days and 1 yr.

Graft patency similar in-hospital and at 1 year

QOL indices not significantly different (P<0.01) between groups

Cost: $2272 less for OPCAB in-hospital (P=0.002) and $1955 less at 1 year (P=0.08).
Acute Graft Patency by Fitzgibbon Score
184 of 197 Patients (93.4%)
622 Grafts

<table>
<thead>
<tr>
<th>Method</th>
<th>A</th>
<th>B</th>
<th>A + B</th>
<th>O</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPCAB</td>
<td>96.8</td>
<td>2.2</td>
<td>99.0</td>
<td>1.0</td>
<td>315</td>
</tr>
<tr>
<td>CPB</td>
<td>95.4</td>
<td>2.0</td>
<td>97.4</td>
<td>2.6</td>
<td>307</td>
</tr>
</tbody>
</table>
1 Year Graft Patency by Fitzgibbon Score
153 of 189 Patients (81.4%)
511 Grafts

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>A + B</th>
<th>O</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPCAB</td>
<td>90.0</td>
<td>3.6</td>
<td>93.6</td>
<td>6.4</td>
<td>251</td>
</tr>
<tr>
<td>CPB</td>
<td>94.3</td>
<td>1.5</td>
<td>95.8</td>
<td>4.2</td>
<td>261</td>
</tr>
</tbody>
</table>
Survival by Surgery Type

Survival Distribution Function

\[ p = 0.33 \]

\[ p = 0.71 \]  \[ p = 0.06 \]  \[ p = 0.02 \]  \[ p = 0.09 \]

years

STRATA:  
- TYPE=CABG on CPB
- TYPE=OPCAB

Mount Sinai Heart
Coronary Re-intervention at 8 Years FU

- 1/43 (2.3%) OPCAB pts had PCI
- 1/44 (2.3%) CPB pts had PCI

\[ p = 1.0 \]

- No patient in either group has had redo CABG
Off-Pump Techniques Benefit Men and Women and Narrow the Disparity in Mortality After Coronary Bypass Grafting

John D. Puskas, MD, Fred H. Edwards, MD, Paul A. Pappas, MS, Sean O’Brien, PhD, Eric D. Peterson, MD, MPH, Patrick Kilgo, MS, and T. Bruce Ferguson, Jr, MD

Emory University, Atlanta, Georgia; University of Florida, Jacksonville, Florida; Duke Clinical Research Institute, Duke University School of Medicine, Durham, and Eastern Carolina University, Greenville, North Carolina

Background. Women have historically had greater morbidity and mortality than men after conventional coronary artery bypass grafting (CABG) on cardiopulmonary bypass (ONCAB). It is controversial whether off-pump CABG (OPCAB) alters this gender-based disparity.

Methods. The Society of Thoracic Surgeons National Cardiac Database was reviewed for risk factors and clinical outcomes of 42,477 consecutive, nonemergency, isolated, primary ONCAB or OPCAB cases performed at 63 North American centers that performed more than 100 OPCAB cases between January 1, 2004, and December 31, 2005. Odds ratios for adverse events, adjusted for 32 clinical and demographic covariates, were compared by multiple logistic regression models between women and men who had OPCAB versus ONCAB. All analyses were by intention-to-treat; 355 (2.2%) patients converted from OPCAB to ONCAB intraoperatively were included in the OPCAB group.

Results. Women (n = 11,785) and those treated with OPCAB (n = 16,245) were older and had more comorbidities than men (n = 30,662) and those treated with conventional ONCAB (n = 26,202). Overall, adjusted odds ratios for death and most major complications in both men and women were significantly lower with OPCAB than with ONCAB. Among ONCAB cases only, women had a significantly greater adjusted risk of death, prolonged ventilation, and long length of stay than men. In contrast, among OPCAB cases, women had lower risk of reexploration than men and similar risks for death, myocardial infarction, and prolonged ventilation and hospital stay.

Conclusions. OPCAB is associated with lower adjusted risk of death and major adverse events than ONCAB. OPCAB benefits both men and women and reduces the gender disparity in clinical outcomes after CABG.

Study Cohort (Intent-to-Treat)

- 42,477 consecutive patients:
  - 16,245 OPCAB vs 26,232 CPB

- 63 North American centers, including 8 with cardiothoracic residency programs

- Of the 16,245 OPCAB cases, 355 (2.2%) were converted during surgery from an initial OPCAB approach to ONCAB and were analyzed within the OPCAB group.
## Risk-Adjusted Odds Comparisons

**OPCAB vs ONCAB:**  
(n=16,245)  
(n=26,232)

### Major Adverse Cardiac Events

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Adjusted OR</th>
<th>(95% CI)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death</td>
<td>0.83</td>
<td>(0.69, 0.98)</td>
<td>0.03</td>
</tr>
<tr>
<td>Stroke</td>
<td>0.65</td>
<td>(0.52, 0.80)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MI</td>
<td>0.67</td>
<td>(0.54, 0.84)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MACE</td>
<td>0.71</td>
<td>(0.63, 0.81)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
## Risk-Adjusted Odds Comparisons

### OPCAB vs ONCAB: Other Outcomes

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Adjusted OR</th>
<th>(95% CI)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renal Failure</td>
<td>0.74</td>
<td>(0.64, 0.86)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Dialysis</td>
<td>0.63</td>
<td>(0.50, 0.80)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sternal Infection</td>
<td>0.67</td>
<td>(0.46, 0.98)</td>
<td>0.04</td>
</tr>
<tr>
<td>Reoperation</td>
<td>0.86</td>
<td>(0.78, 0.95)</td>
<td>0.004</td>
</tr>
<tr>
<td>AF</td>
<td>0.88</td>
<td>(0.83, 0.94)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Prolonged Vent*</td>
<td>0.75</td>
<td>(0.69, 0.82)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LOS &gt; 14 days</td>
<td>0.70</td>
<td>(0.63, 0.78)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
Off-Pump Coronary Artery Bypass Disproportionately Benefits Patients With Higher Society of Thoracic Surgeons Predicted Risk Of Mortality


Emory University
Atlanta, USA

Society of Thoracic Surgeons
January 27, 2009
San Francisco
Results

- There were 14,766 consecutive patients; 7,083 OPCAB (48.0%) and 7,683 CPB (52.0%).

- There was no difference in operative mortality between OPCAB and CPB for patients in the lower two risk quartiles.

- In the higher risk quartiles there was a mortality benefit for OPCAB (odds ratio 0.62 and 0.45 for OPCAB in the third and fourth risk quartiles).
Off-Pump Coronary Artery Bypass Disproportionately Benefits Higher Risk Patients After Adjustment for Patient Factors, Center Volume and Surgeon Identity

John D Puskas MD*, Sean S. O’Brien PhD**, and Xia He MS**

*Division of Cardiothoracic Surgery, Emory University and
**Duke Clinical Research Institute, Duke University

American Association for Thoracic Surgery
Annual Meeting 2012
San Francisco
Methods

- The STS National Cardiac Database queried for all isolated, primary CABG cases between 1/1/2005 and 12/31/2010

- Of these 876,081 cases (“All Sites”), 210,469 were at participant sites that performed >300 OPCAB and >300 CPB cases during the 6-year study period (“High Volume Sites”).

- Operative mortality, stroke, ARF, M+M, and PLOS >=14d were analyzed with conditional logistic models, stratified by participant and by surgeon and adjusted for all 30 variables that comprise the STS PROM score.
Results

- OPCAB was associated with significant reduction in risk of death, stroke, ARF, M+M and PLOS>14d, compared to CABG/CPB after adjustment for 30 patient risk factors in the overall sample.

- This held true within high volume centers alone, and was somewhat more pronounced after adjustment for surgeon effect.
Mortality or Major Morbidity For All Patients: OPCAB vs CPB at Varying Levels of PROM
CVA to 12 Months

- **CABG** (N=897)
- **TAXUS** (N=903)

**ITT population**

Event Rate ± 1.5 SE. *Fisher’s Exact Test

*P=0.003*
STROKE

<table>
<thead>
<tr>
<th>Severe Disabling Scale</th>
<th>CABG</th>
<th>PCI/DES</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIH &gt; 4</td>
<td>55%</td>
<td>27%</td>
</tr>
<tr>
<td>Rankin &gt; 1</td>
<td>70%</td>
<td>60%</td>
</tr>
</tbody>
</table>

Logrank P = 0.034

PCI/DES N: 953 891 833 673 460 241
CABG N: 947 844 791 640 439 230
Meta-analysis of Stroke After Anaortic OPCAB vs Side-Clamp OPCAB and Anaortic OPCAB vs Conventional CABG


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### Figure 1.
peri-operative stroke: (a) anaortic OPCAB vs. OPCAB using side-clamp and (b) anaortic vs. conventional CABG [12,19].
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#### Table 1: Risk Ratio for Stroke After Anaortic OPCAB vs Side-Clamp OPCAB

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Anaortic Events</th>
<th>Total</th>
<th>Side-Clamp Events</th>
<th>Total</th>
<th>Risk Ratio M-H, Random, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calafiore</td>
<td>3</td>
<td>1533</td>
<td>5</td>
<td>460</td>
<td>0.18 [0.04, 0.75]</td>
</tr>
<tr>
<td>Emmert</td>
<td>2</td>
<td>271</td>
<td>13</td>
<td>567</td>
<td>0.32 [0.07, 1.42]</td>
</tr>
<tr>
<td>Kapetanakis</td>
<td>4</td>
<td>476</td>
<td>40</td>
<td>2527</td>
<td>0.53 [0.19, 1.48]</td>
</tr>
<tr>
<td>Kim</td>
<td>0</td>
<td>222</td>
<td>1</td>
<td>123</td>
<td>0.19 [0.01, 4.52]</td>
</tr>
<tr>
<td>Leacche</td>
<td>0</td>
<td>84</td>
<td>5</td>
<td>556</td>
<td>0.60 [0.03, 10.68]</td>
</tr>
<tr>
<td>Lev-Ran</td>
<td>1</td>
<td>429</td>
<td>6</td>
<td>271</td>
<td>0.11 [0.01, 0.87]</td>
</tr>
<tr>
<td>Patel</td>
<td>3</td>
<td>597</td>
<td>2</td>
<td>520</td>
<td>1.31 [0.22, 7.79]</td>
</tr>
<tr>
<td>Vallely</td>
<td>1</td>
<td>1201</td>
<td>3</td>
<td>557</td>
<td>0.15 [0.02, 1.48]</td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td><strong>4813</strong></td>
<td></td>
<td><strong>5581</strong></td>
<td></td>
<td><strong>0.35 [0.19, 0.64]</strong></td>
</tr>
<tr>
<td><strong>Total events</strong></td>
<td><strong>14</strong></td>
<td></td>
<td><strong>75</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Heterogeneity: Tau² = 0.00; Chi² = 5.60, df = 7 (P = 0.59); I² = 0%  
Test for overall effect: Z = 3.45 (P = 0.0006)

#### Table 2: Risk Ratio for Stroke After Anaortic OPCAB vs Conventional CABG

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Anaortic Events</th>
<th>Total</th>
<th>CABG Events</th>
<th>Total</th>
<th>Risk Ratio M-H, Random, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calafiore</td>
<td>3</td>
<td>1533</td>
<td>41</td>
<td>2830</td>
<td>0.14 [0.04, 0.44]</td>
</tr>
<tr>
<td>Emmert</td>
<td>2</td>
<td>271</td>
<td>51</td>
<td>2111</td>
<td>0.31 [0.07, 1.25]</td>
</tr>
<tr>
<td>Izumoto</td>
<td>1</td>
<td>59</td>
<td>2</td>
<td>132</td>
<td>1.12 [0.10, 12.10]</td>
</tr>
<tr>
<td>Kapetanakis</td>
<td>4</td>
<td>476</td>
<td>94</td>
<td>4269</td>
<td>0.38 [0.14, 1.03]</td>
</tr>
<tr>
<td>Kim</td>
<td>0</td>
<td>222</td>
<td>3</td>
<td>76</td>
<td>0.05 [0.00, 0.94]</td>
</tr>
<tr>
<td>Patel</td>
<td>3</td>
<td>597</td>
<td>19</td>
<td>1210</td>
<td>0.32 [0.10, 1.08]</td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td><strong>3158</strong></td>
<td></td>
<td><strong>10628</strong></td>
<td></td>
<td><strong>0.28 [0.16, 0.48]</strong></td>
</tr>
<tr>
<td><strong>Total events</strong></td>
<td><strong>13</strong></td>
<td></td>
<td><strong>210</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Heterogeneity: Tau² = 0.00; Chi² = 4.60, df = 5 (P = 0.47); I² = 0%  
Test for overall effect: Z = 4.52 (P < 0.00001)
Clampless OPCAB: State of the Art CABG
Borgermann et al, Circulation 2012; 126:S176-182

- 395 consecutive clampless OPCAB (310 PAS-Port; 85 all-arterial without proximals)
- Propensity Score matching on 15 preop risk variables to compare outcomes among 394 pairs of clampless OPCAB vs cCABG:

  In-hospital death (OR 0.25; 95% CI 0.05-1.18; p=0.08)
  Stroke (OR 0.36; 95% CI 0.13-0.99; p=0.048)
  Death or Stroke (OR 0.27; 95% CI 0.11-0.67; p=0.005)

- 2 years F/U:  
  Death (OR 0.39; 95% CI 0.19-0.80; p=0.01),
  Death or Stroke (OR 0.58; 95% CI 0.34-1.00; p=0.05)
- MACCE (OR 0.62; 95% CI 0.37-1.02; p=0.06)
- Repeat revasc (OR 0.74; 95% CI 0.40-1.38; p=0.35)
Two OPCAB groups: PC n=567 vs HS n=1365
Propensity-adjusted regression, HS vs PC:

Stroke (0.7% vs 2.3%; OR 0.39; CI 95% 0.16-0.90; p=0.04)
MACCE (6.7% vs 10.8%; OR 0.55; CI 95% 0.38-0.79; p=0.001)

Stroke rate similar between cCABG and PC OPCAB
Effect of Aortic Clamping Strategies on Neurologic Outcomes
Daniel...Puskas...Halkos JTCVS 2014;147:652-7

- 10,054 consecutive isolated CABG cases
- 141 (1.4%) patients with stroke matched 1:4 to 565 patients without stroke

<table>
<thead>
<tr>
<th>Analysis*</th>
<th>OR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-pump double clamp (crossclamp plus partial clamp) vs single clamp</td>
<td>2.60</td>
<td>1.03-6.67 (P = .044)</td>
</tr>
<tr>
<td>Off-pump partial clamp vs off-pump Heartstring</td>
<td>1.46</td>
<td>0.49-4.4</td>
</tr>
<tr>
<td>Off-pump partial clamp vs no clamp (Heartstring plus no touch)</td>
<td>1.21</td>
<td>0.48-3.03</td>
</tr>
</tbody>
</table>

*OR, Odds ratio; CI, confidence interval. *Controlled for epiaortic grade.
Strategies to Reduce Stroke

No CPB

No or minimal aortic clamp

Anaortic OPCAB is the gold standard to reduce stroke after CABG

Epiaortic Ultrasound

Epiaortic
Contraindication to CPB or Aortic Clamping
Heartstring Deployment
Clampless Anastomotic Devices Reduce Solid Cerebral Emboli

- TCD of MCA during 66 proximal anastomoses in 42 patients
  - 35 anastomoses with side-biting clamp
  - 20 anastomoses with Novare Enclose device
  - 11 anastomoses with Heartstring device
- Total microemboli: 11 clamp vs 11 Enclose vs 40 Heartstring (p<0.01)
- Proportion of solid microemboli higher in clamp group: 23% clamp vs 6% Enclose vs 1% Heartstring (p<0.01)

Wolf….Taggart et al JTCVS 2007:33;485-93
An Interesting Technical Challenge: Heartstring III with Arterial Grafts

Heartstring III punch sizes:
4.3mm and 3.8mm
vs
Average radial artery diameter in Texas: 2.2±0.4 mm

Piggyback: OPCAB with Arterial Grafts
Retractors for ITA Harvest

Couetil Retractor

Favaloro Retractor

Others
BITA Harvest: Skeletonization

• Creates extra length and increased flow in ITA conduits; facilitates complex sequential and composite grafting strategies
• Multiple alternative techniques
• Harmonic Scalpel may be least traumatic
• Instill 2-3ml solution of milrinone buffered in warm heparinized blood into lumen of harvested ITAs with atraumatic silastic bulb tip “needle” and clip end: causes dilation and eliminates spasm
• Milrinone mix: 10ml of milrinone 1mg/ml plus 18ml heparinized blood plus 2000 IU heparin (30ml total)
ITA Harvest with Harmonic Scalpel: Exposure
Ultrasonic Scalpel: Skeletonized ITA Harvest
Harmonic Scalpel (HS): Repertoire of Motions

• HS has a complex shape with multiple edges of different widths. Use each in specific ways.
• Curved Edge/Blade: cut parietal pleural and endothoracic fascia; also cut coagulated branches
• “Quick Touch”: rapid flutter motion with flat side of HS to liquify fat and expose the ITA
• “Cold” Dissection: mechanical blunt dissection without energy (foot off pedal)
• Forward Tip: coagulation of side branches with tip and esp with edge of tip; slow motion
Features of Harmonic Scalpel
Harmonic Scalpel: Ultrasonic Energy for Coagulation

• Tip vibrates at approx 55K Hz, causing heat and local protein denaturation/coagulation with limited collateral damage

• Generator and paired foot pedals:
  Max setting: 5 (“Cut”)
  Min setting: 3 (“Coag”)

• Use Max setting (5) for essentially everything in ITA harvest (faster!)
Harmonic Scalpel: Curved Edge to Cut Pleura and Endothoracic Fascia
Harmonic Scalpel: “Quick Touch” to Liquify Fat
Harmonic Scalpel: Forward Edge to Coagulate Branches
Radial Artery Grafting:
How To Do It

Helbert DeCastro, RNFA
John D. Puskas, MD, MSc, FACS, FACC

Mount Sinai Heart at Mount Sinai Beth Israel
Introduction

• Carpentier first introduced the RA graft for CABG in 1973

• Poor short term results, with 30-50% graft occlusion rate due to spasm and intimal hyperplasia.

• 1992, Acar et al. reported that some RA grafts were free from disease up to 15 years postop.

Characteristics

- Good length
- Suitable inner diameter
- Ease of handling
- Minimal donor site discomfort
- Remarkable early, mid and long term patency
- Prone to spasm due to muscular anatomy
Preoperative Exclusion for RA Harvesting

- + Allen & modified Allen test
- Forearm ischemia/trauma
- Raynaud’s Phenomenon:
- Severe atherosclerosis
- Lesions <80% stenosis
- Relative Contraindications:
  - Previous radial cath
  - Creation of A-V fistula in near future
  - Carpal tunnel syndrome
RA Harvesting: “Atraumatic Pedicle”

• Open or Endoscopic

• Electrocautery:
  Irreversible thermal damage
  Prone to spasm provoked by electrocautery

• Ultrasonic scalpel:
  Veins and fat are included, resulting in minimal handling of the artery.
  Limited use of electrocautery.
  No clipping of vessel side branches required.
  RA harvesting times 10-20min.
  Costs less, and complete bleeding control is possible.

Avoiding Spasm

• Reported to occur in up to 5%
• Multiple possible mechanisms, esp harvest trauma
• Multiple pharmacological agents:
  • Nitrates: Nitroglycerin, Isosorbide dinitrate
  • Calcium channel blocker: Diltiazem, amlodipine
  • Alpha blockers: Phenoxybenzamine, Prazocin
  • Phospodiesterase inhibitors: Papaverine, Milrinone
  • Others: CNatriuretic peptide, Cerivastatin, Glibenclamide, Thromboxane A2 antagonist.

Mount Sinai Protocol
To Avoid RA Spasm

- “Atraumatic” pedicled harvest with harmonic scalpel

- Intraoperative
  
  “RA Bath”: Milrinone 10 mg/10ml, 2000 UI heparin, 10ml blood, 8ml Plasmalyte (30 ml total), injected into harvested RAs and used as bath for RA conduits.

- Postoperative
  
  Isordil 5-10 mgs, po Q8hrs, beginning POD#1
  
  Imdur 30mg, po QD, beginning prior to hospital discharge, for 6 months
Anatomy of the Radial Artery
Complications

- ERH: Major complications reported up to 0.5%, including bleeding, compartment syndrome of the hand.
- Open technique: Wound infection, Motor and Sensory nerve injury 3% to 30%

A Meta-Analysis of Endoscopic Versus Conventional Open Radial Artery Harvesting for Coronary Artery Bypass Graft Surgery. Cao, Christopher; Tian, David; Ang, Su; Peeceeyen, Sheen; Allan, James; Fu, Benjamin; Yan, Tristan; MD, PhD

Endoscopic Radial Artery Harvest
RA Conduit Deployment
RA Conduit Deployment Options
Left Side Grafts for All-Arterial CABG:

LITA and RITA in situ grafts:

- LITA-LAD and RITA-OM via transverse sinus
  - LITA may sequence to Diagonal and LAD
  - RITA will generally not reach PLOM via TS

- RITA-LAD and LITA-OM(s)
  - RITA may not reach LAD without tension, esp to distal LAD
  - LITA will often reach two OMs

- Beware tension on grafts
- Protect RITA crossing midline
Left-Side Grafts for All-Arterial CABG:

LITA and RITA **Composite** Grafts:

- RITA sewn to side of LITA (“T”-graft):
  - LITA-LAD and RITA-OM(s)
  - LITA may sequence to Diagonal and LAD
  - RITA off LITA will generally reach PLOM and may sequence to >1 OM
  - RITA off LITA may reach PLV or even PDA

- RITA-LAD off LITA may be esp useful if LITA is damaged or short
  - RITA off LITA will reach even distal LAD without tension
  - (short) LITA may reach anterior OM

- RITA off LITA may also be useful if RITA is damaged or short
  - (short) RITA off LITA may reach diagonal, ALOM, MOM
LITA-RITA “T”-Graft
(LITA-RITA “T”-Graft; LITA-RA “T”-Graft)
Left-Side Grafts for All-Arterial CABG:

Radial Artery and *in situ* ITA Composite Conduits:

- Either LITA or RITA may be elongated with a (piece of) RA ("I"-graft)
- Either the *in situ* LITA or RITA may serve as inflow to a side-limb constructed with RA ("T"-graft)

- Construction of composite arterial conduits must be precise
- Beware tension on grafts or kinks in grafts
- Protect RITA crossing midline
Right-Side Grafts for All-Arterial CABG:

- RITA *in situ* to RCA (may reach proximal PDA)
- RITA “I”-graft with RA extension to RCA or PDA
- RA from aorta to RCA or PDA Either may sequence to RV acute marginal, RCA PDA or PLV branches of RCA
- rGEA *in situ* graft to PDA; less frequent option

- Use arterial grafts for severe stenosis of RCA only
An arterial graft should not be used to bypass the right coronary artery with less than a critical stenosis (<90%).
All-Arterial CABG: BITA plus One RA
Combination Strategies for Anaortic CABG:

**BITA inflow**, RA composite grafts with multiple outflows:

- RITA “I”-graft with RA extension to RCA
- LITA-RA “T”-graft with LITA-LAD (diagonal) and RA-OM(s)
- *In situ* BITA plus one RA can provide outflow to 3-5 targets:
  - LITA-Diagonal-LAD sequence with RA “T” to OM2 and OM3
  - RITA-RA “I”-graft to PDA and PLV
Anaortic CABG: *in situ* BITA plus RA
Combination Strategies for All-Arterial CABG: Alternative Ways to Use BITA plus 1 RA

- In situ BITA with LITA-LAD, RITA-OM and RA from aorta to PDA

- *In situ* BITA with RITA-RA “I” graft and LITA-RA “T” graft:
  - LITA-Diagonal-LAD sequence with RA “T” to OM(s)
  - RITA-RA ”I” graft to PDA and PLV

- Composite BITA with *in situ* LITA-RITA “T”:
  - LITA-Diagonal-LAD and RITA-OM(s)
  - RA from aorta to PDA and PLV

- More complex configurations to revascularize the more targets with arterial grafts: “K”-graft, bilateral RAs
All-Arterial CABG: LITA plus Bilateral RA
Anaortic BITA plus One RA: “K” Graft
Complex All-Arterial CABG x 5 with BITA and Bilat RA: LITA-RA “K”-Graft; RITA-RA “I”-Graft; RA From Aorta to OM
BITA Grafting: The Most Effective Therapy Commonly Denied CAD Patients

- Yet only approximately 5% of all primary isolated CABG cases in the STS Database have BITA; EACTS approx 10%.
- Japan and isolated sites elsewhere (much) higher
"Why Did You Not Use Both Internal Thoracic Arteries?"
John D. Puskas
Why Do US Surgeons Do So Few BITA Grafts?

- Practice environment: fear of deep sternal wound infection in an increasingly obese, diabetic population of patients (FREEDOM).
- Prevalence of DM among CABG patients rising in US (<15% to >50% in past 20 years)
- Political disincentives: Surgeon pays a large and immediate political price for a DSWI and receives little “credit” for the extra years that BITA grafting adds to a patient’s life.
- Financial disincentives: incremental payment for BITA is relatively small; more time; CMS labeled DSWI a “never event”.
- Surgeons are increasingly employed by hospitals and under intense pressure to optimize short-term metrics.
Bilateral Internal Thoracic Artery (BITA) vs. Single Internal Thoracic Artery (SITA) Grafts

- Compared to SITA, BITA is associated with:
  - Improved long-term survival
  - More durable relief of angina
  - Lower incidence of reintervention

- Potential drawbacks to BITA grafting:
  - Increased operative time
  - Increased technical complexity
  - Sternal wound infection

Endo M. *Circulation* 2001;104:2164-70.
Bilateral Internal Thoracic Artery Grafting Is Associated with Significantly Improved Long-Term Survival, Even Among Diabetic Patients

John D. Puskas, MD; Adil Sadiq, MS, MCh; Thomas A. Vassilisades, MD; Patrick D. Kilgo*, MS; Omar M. Lattouf, MD, PhD

Clinical Research Unit, Division of CT Surgery, Emory University

Society of Thoracic Surgeons Annual Meeting
January 30, 2012
Fort Lauderdale, FL
A total of 3527 elective multivessel CABG cases (812 BITA, 2715 SITA) were performed during the study period 2002-2010 at the discretion of 3 (of 17) faculty surgeons with an interest in BITA (these surgeons did 9.8% to 37.3% of cases with BITA).

The incidence of DM (prior Dx or HbA1c > 7.0) increased during the study period from 37% in 2002 to 50% in 2010.

DM was less common in BITA patients (28.6% BITA vs. 44.7% SITA; p<0.001)
BITA Improves Risk-Adjusted LT Survival

- BITA grafting conferred a 35% reduction (95% CI 12% - 52%, p=0.006) in risk-adjusted long-term hazard of death.

- This benefit was equal for non-DM and DM patients (p=0.93).
The graph illustrates the survival rates for patients with and without diabetes mellitus. It is divided into two main categories: BITA and SITA.

**BITA, Non-Diabetes Mellitus**
- Survival: High and consistent across all years.
- Patients at Risk:
  - 0 yr: 1461
  - 1 yr: 1389
  - 3 yr: 1322
  - 5 yr: 1230
  - 8 yr: 1076

**BITA, Diabetes Mellitus**
- Survival: Lower and declines faster than non-diabetes.
- Patients at Risk:
  - 0 yr: 557
  - 1 yr: 545
  - 3 yr: 535
  - 5 yr: 520
  - 8 yr: 503

**SITA, Non-Diabetes Mellitus**
- Survival: Lower than BITA non-diabetes but higher than SITA diabetes.
- Patients at Risk:
  - 0 yr: 1156
  - 1 yr: 1085
  - 3 yr: 991
  - 5 yr: 901
  - 8 yr: 701

**SITA, Diabetes Mellitus**
- Survival: Lowest and declines the fastest.
- Patients at Risk:
  - 0 yr: 220
  - 1 yr: 217
  - 3 yr: 209
  - 5 yr: 192
  - 8 yr: 192

The graph shows the percentage of patients remaining free from the event of interest (e.g., death) over time.
Ideal Diabetic BITA Patients: (When to do it)

- Young (<80)
- Multiple tight lesions in large bypassable, left-sided targets (large benefit from BITA)
- Male (less DSWI)
- Thin/fit (less DSWI)
- Non-smokers; no COPD (less DSWI)
- Poor alternative conduit: varicose veins, failed Allen’s test
- Good glucose control (A1c < 7.0)
Multivariable Regression Analysis of BITA vs. SITA and HbA1c Status in All Patients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Adjusted Odds Ratio for DSWI (95% CI)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BITA</td>
<td>2.84 (1.41, 5.74)</td>
<td>0.004</td>
</tr>
<tr>
<td>Dichotomous HbA1c (≥7% vs. &lt;7%)</td>
<td>2.88 (1.68, 4.95)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Continuous HbA1c*</td>
<td>1.31 (1.16, 1.49)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*AOR for every unit increase in HbA1c %
Worst Diabetic BITA Patients: (When not to do it)

- Very elderly
- Massively obese female
- No high-quality second target on the left side
- Poor glucose control, history of “poor healing” or frequent skin infections; poor hygiene
- Active smoker with COPD
- Good alternative conduits (RAs or SVGs)
HbA1c >10, BMI > 35, Female Smoker: Bilateral ERA Better Choice Than BITA (?)
All-Arterial CABG: Summary

- All-arterial CABG can be accomplished in the large majority of cases, by various alternative techniques.
- Patterns of native competitive flow and patient comorbidities influence decision-making; avoid RA grafting to moderate RCA lesions; beware differential native competitive flow in complex sequential and composite arterial grafting.
- Avoid tension on in situ grafts; protect the in situ RITA crossing the midline.
- Epiaortic U/S should be routinely used to identify patients who will benefit most from anaortic grafting strategies.
Conclusions:

• BITA grafting prolongs life
• Radial Arteries are (usually) better than veins
• OPCAB can be better than ONCAB, but requires special expertise
• Clampless OPCAB, by avoiding/minimizing manipulation of the ascending aorta, is associated with lower risk of stroke
• Clampless, all-arterial OPCAB is state-of-the-art CABG
• It may be best performed in a CABG Reference Center
Save the Date

1st International Coronary Congress: State of the Art Surgical Coronary Revascularization

August 21-23, 2015
New York Marriott Marquis Times Square, New York, NY
www.CoronaryCongress.com

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John D. Puskas, MD
Mount Sinai Heart, New York
David P. Taggart, MD, PhD
Oxford University, United Kingdom
INTERNATIONAL CORONARY CONGRESS 2016

State of the Art Surgical Coronary Revascularization

November 11 – 13, 2016
Hotel Taj Palace
New Delhi, INDIA

COURSE DIRECTORS
John D. Puskas
David P. Taggart
Naresh Trehan
Kunal Sarkar

www.aats.org/coronarycongress
2017 International Coronary Congress: State-of-the-Art Surgical Coronary Revascularization

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Mount Sinai Heart, New York
David P. Taggart, MD, PhD
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Co-Director:
Robert F. Carlucci, PA-C, New York

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New York, NY

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