Optimal Conduit for Diabetic Patients: Propensity Analysis of Radial and Right Internal Thoracic Arteries

Darryl M. Hoffman, MD, Kamellia R. Dimitrova, MD, David J. Lucido, PhD, Gabriela R. Dincheva, BA, Charles M. Geller, MD, Sandhya K. Balaram, MD, Wilson Ko, MD, Daniel G. Swistel, MD, and Robert F. Tranbaugh, MD

Division of Cardiothoracic Surgery and Office of Grants and Research, Beth Israel Medical Center; and Division of Cardiothoracic Surgery, St. Luke’s-Roosevelt Hospital Center, New York, New York

Background. Multiple arterial grafts, in addition to the left internal thoracic artery, improve long-term survival after coronary artery bypass grafting (CABG); yet, the use of this procedure remains low for both the right internal thoracic artery (RITA) and the radial artery (RA). To identify the optimal arterial conduit to deploy for revascularization of diabetic patients, we compared the outcomes for RA and RITA grafts to the circumflex coronary.

Methods. From January 1, 1995, to December 31, 2011, 908 consecutive diabetic patients underwent first-time, isolated CABG (99% on-pump), 659 with the RA and 502 with the RITA, respectively, in two affiliated hospitals. Data were prospectively collected, and late mortality was determined from the Social Security Death Index. Propensity matching, based on preoperative and operative variables, identified 202 matched pairs from each group.

Results. Long-term survival was similar for matched patients. Mortality, myocardial infarction, reoperation for bleeding, stroke, sepsis, and renal failure were not significantly different between groups. However, deep sternal wound infection ($p < 0.035$) and respiratory failure ($p < 0.048$) favored the RA group, in which the total major adverse events were significantly fewer ($p = 0.002$).

Conclusions. In diabetic patients undergoing multivessel revascularization with either RA or RITA grafts to the circumflex coronary, long-term survival is similar. However, RA patients experienced significantly fewer respiratory or sternal wound adverse events. The RA is the preferred conduit to extend to more diabetic patients the recognized survival benefit of a multiple arterial graft strategy.


Patients with diabetes also have atherosclerotic coronary disease in disproportionate numbers, and surgical revascularization—coronary artery bypass grafting (CABG)—has consistently improved survival over medical therapy and percutaneous intervention [1, 2]. Inasmuch as the long-term patency of saphenous vein grafts (SVG) is known to be worse in diabetic patients [3], a multirterial graft strategy has been advocated [4, 5]. Internal thoracic artery (ITA) performance is excellent, even in diabetic patients, and some series have documented excellent long-term patient survival with the use of left (LITA) and right (RITA) arterial grafts [6–8]. However, bilateral ITA (BITA) harvest risks more sternal wound adverse events, and BITA use remains infrequent. The radial artery (RA) is an alternative arterial conduit [9] with mid-term and long-term favorable graft patency and patient survival compared with SVG [2, 10–13].

The RA, used with LITA in diabetic patients, might achieve patient and graft survivals similar to those obtained with BITA grafting but should avoid wound and other morbidity often reported with BITA harvest in diabetic patients. To test this hypothesis, we compared the outcomes in diabetic patients undergoing multivessel revascularization, including LITA bypass of the left anterior descending (LAD), wherein either the free RITA or the RA was used to bypass the circumflex territory.

Patients and Methods

Patients
Beth Israel Medical Center (BIMC) and St. Luke’s-Roosevelt Hospital Center (SLR) are closely affiliated and serve demographically similar communities in New York City. Each has long experience with arterial grafting: SLR, after the pioneering work of Dr George Green, has used the RITA liberally (consistently >60%) observing no age restrictions or specific contraindications. At BIMC, RA use started selectively in 1995 but has now been incorporated in 80% of CABG procedures. Since 2000, RA harvest has been exclusively endoscopic, and we have
reported equivalent outcomes for open and endoscopic RA harvest [14].

Each center maintains a New York State—mandated, prospectively collected, audited database mirrored in a separate institutional database. This study was approved by both institutional review boards, which waived written informed consent. Survival was determined from the Social Security Death Index (interrogated in October 2012).

We performed a retrospective cohort study of the experience from January 1, 1995, to January 1, 2012, in two affiliated institutions. Primary, isolated CABG was undertaken in 1,183 consecutive diabetic patients with multivessel coronary artery disease (CAD), anastomosed LITA-LAD and a second arterial graft with either RA (n = 659) or RITA (n = 502) to the circumflex system, and additional SVG as indicated. Excluded were 22 patients in whom both RA and RITA were used (SLR 16, BIMC 6).

Surgical Techniques
All ITAs were harvested as pedicled grafts at both institutions. Grafts were constructed on cardiopulmonary bypass with a single cross-clamp technique at BIMC; SLR used a partial occlusion clamp for proximal anastomoses and used the operating microscope (×12), and BIMC used loupe magnification (×2.5–3.5) for distal anastomoses. An off-pump procedure (1.1% each center) was used when aortic disease precluded safe cannulation or clamping. Our techniques of RA harvest, preparation, and CABG have been described [14]. Both RA and RITA were used as aortocoronary bypasses unless insufficient length or aortic disease precluded direct aortic anastomosis, when proximal origin was to another graft (but rarely LITA). Sequential (50%) and Y (6%) configurations were frequent for RITA patients but rare for RA (3% sequential), with manufactured Y (11%) preferred.

Study Endpoints
The primary endpoints were (a) all-cause mortality and (b) postoperative major adverse events, comprising operative death, stroke, myocardial infarction, deep sternal wound infection (DSWI), sepsis, reoperation for bleeding, respiratory failure, and renal failure occurring in the 30 days after CABG (except DSWI, for which the reporting period is 6 months). Data were collected prospectively as defined by the New York State Department of Health (NYSDOH) Cardiac Surgery Reporting System (http://www.health.ny.gov/statistics/diseases/ cardiovascular/index.htmNYS).

Another endpoint was graft patency determined from symptom-driven repeated angiography performed at our institutions from August 31, 1999, to December 18, 2012.

Propensity Matching and Statistical Analysis
All analyses were conducted with Stata statistical software version 13.1 (StataCorp, 2011; Stata Release 12, Statistical Software. StataCorp LP, College Station, TX) [15]. Univariate comparisons between RA and RITA patients used t tests for normally distributed variates and two-sample proportion tests for binary valued variates. Relationships with multivalued categoric variates were evaluated with χ² tests. We compared the two institutions’ risk-adjusted mortality for CABG (from the NYSDOH website).

To correct for selection bias in assigning patients to a specific conduit, a bias reduction technique was used to assess the relative effect of RA graft use on survival and other postoperative outcomes. A logistic propensity-scoring model was developed to summarize covariate information regarding treatment selection (RA vs RITA) into a single scalar value (propensity score), which was subsequently used in a nearest-neighbor, caliper-constrained matching technique. The 659 patients with RA grafts were matched against a sample of 502 patients who had RITA grafts; 202 matched pairs (n = 404) of RA and RITA graft recipients were thus identified and were compared in this study. Unadjusted long-term survival of the two covariate-matched patient/graft subgroups was evaluated by use of Kaplan-Meier estimates and the log-rank statistic. A Cox proportional hazards regression was constructed to evaluate the hazard ratio for mortality of RA recipients versus RITA recipients, adjusted for a set of covariates and comorbidities that were selected in a stepwise fashion by the use of backward elimination. The proportional hazards assumption was tested and was found to have been met.

To confirm that conduit choice had an independent effect on postoperative events, we developed a further logistic model for major adverse events to estimate the effect of the conduit, adjusted for the propensity score, on all patients. We also developed a Cox proportional hazards regression model to estimate the hazard of death in RA patients referenced to RITA patients; this model was also adjusted by use of the propensity score to reduce the effect of selection bias.

Results
Patient Data and Survival
Tables 1 and 2 show the preoperative and intraoperative data for unmatched and matched RA and RITA patients. Briefly, unmatched RA patients were younger and mostly male. Although CAD was more extensive in the RITA group, the number of bypasses per patient was similar. The SLR constructed more arterial grafts per patient (RITA 3.0 ± 0.72 vs RA 2.3 ± 0.56), with frequent use of LITA and RITA sequential grafts. Bilateral RA grafts were used in 6% of patients. More than two arterial grafts were constructed in 27.7% of RA recipients versus 78% of RITA recipients.

The long-term follow-up times averaged 10.57 ± 4.43 years in RA recipients and 9.87 ± 4.34 years in RITA recipients. Long-term survival by Kaplan-Meier analysis strongly favored the RA patients (Fig 1) (log-rank test, p < 0.0001). Table 3 summarizes the major adverse events. Briefly, operative mortality was 0.3% in RA patients and 3.3% in RITA patients (p < 0.001). All-cause mortality was 18.6% in RA patients and 39.1% in RITA patients (p < 0.001). Unmatched RA patients experienced lower
mortality and fewer major adverse events, probably linked to older age, more extensive disease, and more frequent comorbidities among the unmatched RITA cohort. Differing institutional strategies for conduit use produced the younger RA population at BIMC and the older RITA group at SLR.

### Propensity-Matched Patient Outcomes

Tables 1 and 2 show the preoperative and operative data for the 404 propensity-matched patients. The two groups were closely matched for age, gender, vascular disease, left ventricular function, extent of disease, and completeness of revascularization. The cross-clamp times were similar before and after matching, but bypass times remained longer for the RITA group (likely from the construction of proximal anastomoses after removal of the aortic cross-clamp).

Table 3 shows the data on major adverse events for the matched patients. Neither group had any hospital or 30-day death; all-cause mortality over the study was 33.7% (RA) and 41.6% (RITA) ($p = 0.100$). Comparison of the long-term survival of matched patients by the Kaplan-Meier method yielded a slight statistical difference ($p = 0.0485$) (Fig 2). However, with Cox regression modeling, there was no difference in survival by graft type (hazard ratio $[HR] = 1.00$, $p = 0.98$). Independent predictors of mortality were heart failure ($HR 1.97$), ejection fraction ($HR 0.98$), femoral vascular disease ($HR 2.09$), and age ($HR 1.08$). As seen in Table 3, the rates of stroke, myocardial infarction, sepsis, renal failure, and reoperation for bleeding were statistically similar; significant

### Table 1. Preoperative Data: Diabetic Radial Artery and RITA Patients

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Before Propensity Matching</th>
<th>After Propensity Matching</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Radial (n = 659)</td>
<td>RITA (n = 502)</td>
</tr>
<tr>
<td>Age, y: mean ± SD</td>
<td>58.69 ± 8.0</td>
<td>65.47 ± 9.6</td>
</tr>
<tr>
<td>Male, %</td>
<td>74.9</td>
<td>61.8</td>
</tr>
<tr>
<td>Female, %</td>
<td>25.1</td>
<td>38.2</td>
</tr>
<tr>
<td>Body mass index ± SD</td>
<td>29.7 ± 5.5</td>
<td>28.8 ± 5.8</td>
</tr>
<tr>
<td>Hispanic, %</td>
<td>29.3</td>
<td>32.0</td>
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<tr>
<td>Ejection fraction, %: mean ± SD</td>
<td>48.5 ± 5.5</td>
<td>43.3 ± 14.5</td>
</tr>
<tr>
<td>Transmural MI, %</td>
<td>49.0</td>
<td>37.0</td>
</tr>
<tr>
<td>Stroke, %</td>
<td>8.0</td>
<td>8.7</td>
</tr>
<tr>
<td>Cerebrovascular disease, %</td>
<td>7.9</td>
<td>12.1</td>
</tr>
<tr>
<td>Aortoiliac PVD, %</td>
<td>2.9</td>
<td>5.3</td>
</tr>
<tr>
<td>Femoropopliteal PVD, %</td>
<td>7.3</td>
<td>17.0</td>
</tr>
<tr>
<td>Creatinine, &gt;2.5 mg/dL, %</td>
<td>1.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Dialysis, %</td>
<td>0.2</td>
<td>2.3</td>
</tr>
<tr>
<td>Congestive heart failure, %</td>
<td>9.4</td>
<td>27.2</td>
</tr>
<tr>
<td>COPD, %</td>
<td>20.0</td>
<td>9.8</td>
</tr>
<tr>
<td>Hypertension, %</td>
<td>67.3</td>
<td>87.3</td>
</tr>
<tr>
<td>Left main stenosis, %</td>
<td>28.9</td>
<td>30.1</td>
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<tr>
<td>Coronary disease</td>
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<td></td>
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<tr>
<td>Triple, %</td>
<td>86.4</td>
<td>85.5</td>
</tr>
<tr>
<td>Double, %</td>
<td>9.8</td>
<td>13.1</td>
</tr>
<tr>
<td>Single, %</td>
<td>2.7</td>
<td>1.2</td>
</tr>
<tr>
<td>Previous PCI, %</td>
<td>21.8</td>
<td>16.0</td>
</tr>
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</table>

### Table 2. Operative Data: Diabetic RA and RITA Patients

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Before Propensity Matching</th>
<th>After Propensity Matching</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Radial (n = 659)</td>
<td>RITA (n = 502)</td>
</tr>
<tr>
<td>Calcified aorta (%)</td>
<td>3.8</td>
<td>10.2</td>
</tr>
<tr>
<td>Cross-clamp time, min: mean ± SD</td>
<td>72.1 ± 20.3</td>
<td>71.6 ± 24.1</td>
</tr>
<tr>
<td>Bypass time, min: mean ± SD</td>
<td>95.7 ± 25.8</td>
<td>131.5 ± 34.4</td>
</tr>
<tr>
<td>Grafts per patient ± SD</td>
<td>3.9 ± 0.91</td>
<td>4.0 ± 0.87</td>
</tr>
<tr>
<td>Arterial grafts per patient ± SD</td>
<td>2.3 ± 0.56</td>
<td>3.0 ± 0.72</td>
</tr>
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RA = radial artery; RITA = right internal thoracic artery; SD = standard deviation.

COPD = chronic obstructive pulmonary disease; MI = myocardial infarction; PCI = percutaneous intervention; PVD = peripheral vascular disease; RITA = right internal thoracic artery; SD = standard deviation.
differences were detected for respiratory failure (1.5% RA vs 5.0% RITA; \( p < 0.048 \)) and DSWI (0.5% RA vs 3.5% RITA, \( p < 0.032 \)). The total major adverse events were significantly fewer in the RA group (5.4% vs 14.9%; \( p = 0.002 \)). By logistic regression modeling, RA conduit use was a significant predictor of reduced major adverse events (odds ratio [OR] = 0.34; 95% confidence interval [CI]: 0.16–0.71; \( p = 0.004 \)), which suggests a 66% reduction in major adverse events when a RA conduit was chosen.

**Graft Patency**

Among the total cohort of 1,180 diabetic patients, 118 RA patients (23.5%) and 61 RITA patients (15%) had symptom-driven cardiac catheterization at our institutions, 4.7 \( \pm \) 3.6 years (BIMC) and 5.4 \( \pm \) 4.0 years (SLR) after CABG. The data are displayed in Figure 3: graft patency was 83% (RA) and 87.5% (RITA) (\( p = 0.355 \)), respective LITA patency was 91% (BIMC) and 92% (SLR), and SVG patency was 56% (RA) and 58% (RITA). LITA patency (\( p < 0.0001 \)), RITA patency (\( p < 0.0001 \)), and RA patency (\( p < 0.0001 \)) were each significantly better than SVG patency. For purposes of comparison, in a contemporary group of 244 patients with diabetes mellitus who underwent bypass procedures at BIMC with LITA–LAD (n = 244) and SVG (n = 579) without other arterial conduits, and were recatheterized for symptoms, LITA patency was 92% and SVG patency was 58% (unpublished data).

**Comment**

Diabetes is a global epidemic. In patients with diabetes, abnormal glucose levels and injected insulin subject the vascular tissues to conditions that can inflict potent injury and impede repair [16]. Patients with diabetes experience early and more diffuse atherosclerosis, producing a greater disease burden, unfavorable anatomic distribution, and impairment of the ability to develop collateral circulation. Coronary disease causes three in four diabetes-related deaths [17]. Revascularization is the established, evidence-based treatment for complex coronary disease and diabetes; the FREEDOM trial [18], the latest in a long series of major trials, has confirmed the superiority of CABG over percutaneous intervention for such patients [19].

Nevertheless, the outcomes in diabetic patients are not as good after CABG as in comparable patients without diabetes [20]. Vein grafts in diabetics remain more vulnerable to atherosclerosis [21]. Enhancing long-term outcomes after CABG for diabetic patients is imperative; all-arterial revascularization improved survival for a subgroup of diabetic patients [22], and the multiple arterial graft strategy is attractive. The mechanisms of endothelial activity that protect arterial grafts have been partly elucidated [23]. Bilateral ITA grafts confer a survival advantage for diabetic patients [8]. The relative performance of LITA and RITA is the subject of an ongoing randomized trial [24].

The RA yields better patency than does SVG, and it offers an attractive alternative arterial conduit to RITA [25]. We have reported reduced mortality (>30%) for diabetic patients revascularized with LITA plus RA as opposed to LITA plus vein [26]. In another propensity-matched comparison of RA and RITA, survival in the subgroup of diabetic patients was not significantly different (HR 0.86; 95% CI 0.57–1.29; \( p = 0.474 \)); however,

![Figure 1: Kaplan-Meier survival curves: unmatched patients. (CABG = coronary artery bypass grafting; RA = radial artery; RITA = right internal thoracic artery.)](image)

**Table 3. Postoperative Major Adverse Events**

<table>
<thead>
<tr>
<th>Event (%)</th>
<th>Before Propensity Matching</th>
<th>After Propensity Matching</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Radial (n = 661)</td>
<td>RITA (n = 519)</td>
</tr>
<tr>
<td>Operative mortality</td>
<td>0.3</td>
<td>3.3</td>
</tr>
<tr>
<td>Permanent stroke</td>
<td>1.4</td>
<td>3.1</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>0.8</td>
<td>0.4</td>
</tr>
<tr>
<td>Sternal wound infection</td>
<td>1.5</td>
<td>4.0</td>
</tr>
<tr>
<td>Septicemia</td>
<td>1.4</td>
<td>1.3</td>
</tr>
<tr>
<td>Reoperation (bleeding)</td>
<td>1.2</td>
<td>3.7</td>
</tr>
<tr>
<td>Respiratory failure</td>
<td>2.0</td>
<td>6.6</td>
</tr>
<tr>
<td>Renal failure</td>
<td>0.5</td>
<td>2.1</td>
</tr>
<tr>
<td>All-cause mortality</td>
<td>18.6</td>
<td>39.1</td>
</tr>
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</table>

RITA = right internal thoracic artery.
major adverse events were reduced with RA use (OR 0.32; 95% CI 0.15–0.68; p = 0.003) [27].

There are few direct comparisons of RA and RITA in diabetic patients with long-term follow-up. Fortuitously, our system includes two hospitals with sufficient experience to allow such analysis. The average annual risk-adjusted mortality (NYSDOH) did not differ between the centers (2.2% BIMC vs 2.4% SLR) over the study period.

We focused specifically on diabetic patients with multivessel CAD, and we found that long-term survival was similar for patients revascularized with LITA and either RA or RITA as the second arterial conduit. However, RA use was associated with fewer DSWI and episodes of respiratory failure, and it provided a strong protective effect against major adverse events.

Although multiple arterial grafts improve survival, DSWI is increased with the use of BITA in diabetic patients. Taggart [25] reported increased DSWI especially among diabetic patients in the ongoing randomized trial (BITA vs SITA). Puskas and colleagues [7] reported, from their registry subgroup of diabetic patients with BITA, an 85% increase in DSWI, although this did not achieve statistical significance (compared with the DSWI rate in their diabetic patients who received one ITA).

Superimposed on the particular vulnerability of diabetic individuals to infection, DSWI causes major morbidity and mortality. CABG is increasingly needed in diabetic patients, who more often are obese and have other comorbidities. With the concern about wound complications in the devascularized sternum, it is not surprising that most surgeons avoid BITA; therefore, despite the evidence of survival benefit, BITA use in the Society of Thoracic Surgeons database is below 6% [24] (and presumably even lower in diabetic patients). Evidence that skeletonized harvest can mitigate the increased risk of DSWI from BITA in diabetic patients is suggestive [28] but not yet conclusive. The lower rates of DSWI and respiratory failure in our RA cohort suggest cautious use of BITA in diabetic patients, and they support, instead, a wider use of RA to achieve the benefits of multiple arterial graft revascularization.

Lin and colleagues [29] reported significant survival benefit from RA (over SVG) in their subgroup of diabetic patients at 12 years (HR 0.59). We and others [27, 30, 31] have previously reported consistent and excellent clinical and angiographic results with use of the RA and the RITA: 5-year patency (83.9% RA vs 87.5% RITA) [27], as have Tatoulis and colleagues [30] (RA 79% at 10 years). The 2010 update by Hayward and Buxton [32] from their randomized trial showed equivalent patency also.
Despite such reports of excellent RA patency [33], RITA is considered the preferred conduit by many [33, 34], perhaps because of extrapolation from the original LITA data or lingering concerns about early RA failure. Unusually, Khot and colleagues [35] reported worse RA patency (51% at 18 months) than even SVG! Was the RA grafted to vessels that had lesser obstructions (when the effect of competitive flow on RA patency was not yet understood)? Important details of RA harvest and handling were not provided. More recently, Ruttmann and colleagues [36] reported remarkably better event-free survival for RITA patients than in RA patients in a propensity-matched study. The RA patency (62%) was strikingly worse than that of RITA (90%) and even SVG (79%)! The RA patients experienced markedly increased rates of perioperative adverse events. The results by Ruttmann and colleagues [36] may reflect technical issues in RA harvest or graft deployment; one explanation for their poor RA results is found in their reply to a letter to the editor concerning their article: “moderate supraphysiological distension of the RA after harvesting was performed in all cases” [37]. We carefully avoid this and follow the principles elucidated by Acar and colleagues [38] when they determined the reasons for RA failure, which prompted successful reintroduction of the RA.

Conduit patency rates, by angiography in our symptomatic diabetic patients, revealed similar midterm RA and RITA patency, each far superior to that of SVG. Comparison of SVG patency with our other patients who had LITA plus SVG without another arterial graft detected a similar rate of SVG occlusion. Our findings accord with those of others [12, 22, 31, 32] and strongly refute the reports from Khot and colleagues [35] and from Ruttmann and colleagues [36].

Limitations

Our study is inherently biased by patient selection; significant heterogeneity between cohorts reflects differing institutional preferences for arterial conduits. Although propensity matching and bias-reduction techniques were used to minimize the effect of patient selection, uncontrolled confounding effects may still exist. Available data points were limited to those reported to the New York State database. However, the persistence of similar findings after the inclusion of more patients and 3 more years of follow-up in this current study strengthens our findings. All-cause mortality was used to determine survival; cause of death and other cardiac events were not available. Follow-up angiographic data captured only symptomatic patients studied at our institutions, and graft failure mechanism was not determined. Comparisons of LITA and SVG patency in RA, RITA, and LITA plus SVG only cohorts (without other arterial conduit) do provide reassurance that LITA and SVG patency rates were not different between the cohorts, supporting conclusions about the respective RITA and RA patency.

Conclusions

Either the RA or the RITA may be used to achieve the documented survival benefit of multiarterial coronary bypass for diabetic patients. However, RITA use is attended by increased adverse events plausibly related to harvest, namely, DSWI and respiratory failure, which increase the total of major adverse events in RITA patients to a statistically significant extent. The RA offers the advantage of lower morbidity and therefore should be the recommended second arterial conduit for use (in conjunction with the LITA) to extend to most diabetic patients the established benefits of multiple arterial graft revascularization while minimizing adverse events.

References

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support graphing, and covariate imbalance testing. Statistical Software Components S432001, Boston College Department of Economics, revised 21 Dec 2012.


26. Hoffman DM, Dimitrova K, DeCastro H, et al. Late results of the RITA going back to George Green’s days; so, two very experienced high-adopter centers. And as I tried to show in my bar graphs, the comparative LITA patency and vein patency between the two centers was no different.


DISCUSSION

DR ROBERT A. GUYTON (Atlanta, GA): That is a very nice study and nicely done. I would suspect, because this is a retrospective study, that the RITA grafts tended to be done by a certain group of surgeons and the radial grafts also tended to be done by a certain group of surgeons. I wonder if you looked at the data to see whether there was some correlation between the patency of the grafts and the patency of the left internal mammary artery? In other words, did the surgeons who had better secondary arterial graft patency also have better primary graft patency or better vein patency, which would tend to bias your results, given that the surgeons who potentially are better technical surgeons might have better patency and those might be the ones using the RITA or the radial in your situation.

DR HOFFMAN: Thank you, Dr. Guyton. I failed to explain clearly that this was a cohort comparison of two centers, one of which used the radial routinely and the other which had a very high usage of the RITA going back to George Green’s days; so, two very experienced high-adopter centers. And as I tried to show in my bar graphs, the comparative LITA patency and vein patency between the two centers was no different.

DR GUYTON: Can you also tell us the procedure used and what medications you used with the radial artery, because that is an area of controversy and concern for all surgeons that use the radial artery. There are varying techniques for prevention of spasm in the early postoperative period, and what have you settled on? Thank you.

DR HOFFMAN: Thank you. We have used continuous diltiazem infusion throughout the procedure maintained until the patient is extubated, after which we switch to oral nitrates based on some work from the Mayo Clinic quite a long time ago that showed nitrates do better than calcium channel blockers in abolishing the risk of radial spasm. In terms of harvesting, we switched in 2000 to 100% minimally invasive harvest using endoscopic techniques and a Harmonic scalpel via a short incision at the wrist, and we maintain and very gently distend the radial conduit in a solution of the patient’s heparinized blood containing the circulating diltiazem with some added nitroglycerin.

DR DAVID LORAN (Harrisburg, PA): I appreciate your talk very much. Two questions: if you could comment on how you go about determining whether the radial artery is safe for use preoperatively or just intraoperatively, and also the degree of stenosis to the target vessel to try to avoid a steal type of syndrome on the arterial grafts.
DR HOFFMAN: Thank you. Two very important technical points. I would say that we don’t do any preoperative evaluation of the patient before harvesting. In the operating room we use an Allen’s test modified by the use of pulse oximetry and Doppler evaluation. If there is any doubt on the collateral, we actually will expose the radial and clamp it with a soft bulldog and wait to see what happens. We restrict use of radial grafts to target vessels with tight stenosis, visually more than 75%.

DR JOHN D. PUSKAS (Atlanta, GA): Congratulations on a beautifully presented series of consecutive patients with multiple arterial grafting. My question, Darryl, relates to the harvest technique for the RITA. You commented, I think appropriately, that the RITA had spectacular patency, but it came at a cost of adverse events, which were, I think your phrase was, plausibly related to the harvest. Elegantly put. I wonder if a Harmonic approach to a skeletonized harvest rather than cautery used for a pedicled harvest might have changed that and whether that is something that your group has studied.

DR HOFFMAN: Thank you. We are aware of your work, of course, and thank you for your polite comment. Of course, you have gone right to the heart of this. All these RITAs were harvested as pedicled grafts with loupé magnification, and distals were performed using an operating microscope, which is the legacy of the George Green contribution. A Harmonic scalpel was not used for RITA harvest. And undoubtedly as the information begins to solidify, skeletonized harvest would seem to mitigate the risk of sternal wound adverse events in all patients and probably, but not yet certainly, in the diabetic subgroup.

DR JOSEPH F. SABIK (Cleveland, OH): I just worry a little bit about the propensity matching. There is a little bit of overuse of propensity matching here. We had different techniques being done in two different hospitals. That is a confounder that propensity matching cannot take care of. And then the second thing is that you said that patients who had right internal thoracic artery grafting essentially had more arterial grafts than those that had radial artery grafts. This is probably due again to that major confounder of being in two different hospitals with different surgeons with different issues. But the second question really has to revolve around this: when you did your propensity matching, did you only match them on preoperative characteristic or did you include operative characteristics, because if you don’t include the operative characteristics here, what you are really testing is trying to test whether you have a similar operation, but you already told us your operations are different. Again, propensity matching can’t fix that. Thank you.

DR HOFFMAN: Thank you, Dr Sabik. I take your points about the limitations. In fact, I had a slide addressing this. I didn’t bring it up in the interest of time, but explain simply that these two are affiliated institutions with very similar practices, including a common postoperative order set. Over the course of this study, the annual, risk-adjusted New York State mortality difference was nonexistent between the two centers. Patency rates for the left internal thoracic and vein grafts were conveniently used as controls. Those showed no difference between the centers also. And so we felt more comfortable with the propensity analysis. We did also, to address your first question, incorporate operative data as part of the risk adjustment process for propensity matching, and in the article you will see the result of various statistical manipulations to try and deal with the question of multiple measures.

DR ELSAYED ELMISTEKAWY (Ottawa, Ontario, Canada): Excellent study and presentation. How do you treat those patients after operation in the long term to guard against radial spasm, and if yes, for how long? Thank you.

DR HOFFMAN: We recommend oral nitrates for at least 6 months and perhaps indefinitely, but we don’t control the follow-up with the patients beyond a 1-month follow-up visit. We simply write to the referring cardiologists and suggest to them that they continue these medications.