Consequences of Radial Artery Harvest
Results of a Prospective, Randomized, Multicenter Trial

William L. Holman, MD; James E. Davies, MD; Julia Y. Lin, PhD; Yajie Wang, PhD; Steven Goldman, MD; Faisal G. Bakaeen, MD; Rosemary Kelly, MD; Stephen E. Fremes, MD; Kelvin K. Lee, PhD; Todd H. Wagner, PhD; Gulshan K. Sethi, MD; for the VA CSP 474 Investigators

**IMPACT**
To date, no study has defined the consequences of radial artery harvest based on a large number of patients in a prospective randomized trial.

**OBJECTIVE**
To compare pain at the harvest site and functional changes associated with harvesting the radial artery vs saphenous vein for coronary artery bypass grafting.

**DESIGN, SETTING, AND PARTICIPANTS**
This study compares the consequences of radial artery harvest with saphenous vein harvest in patients undergoing elective coronary artery bypass grafting procedures in Veterans Affairs hospitals.

**MAIN OUTCOMES AND MEASURES**
Eleven hospitals screened 6148 patients, of whom 751 were included in this trial. We analyzed 2 variables: pain at the harvest site as measured on a scale of 0 to 100 (least to most painful) and hand performance testing. Patients included in this analysis had radial artery only (n = 80) or saphenous vein only (n = 337) harvest. Pain score, grip strength, and dexterity were measured before surgery and at 3 and 12 months after surgery. We adjusted for pain scores of the nonharvested extremity, age, whether the patient underwent endoscopic vein harvesting, and comorbid health conditions (smoking history, type 2 diabetes mellitus, hypertension, and heart failure).

**RESULTS**
There was a significant difference in change of pain score at 3 months from the preoperative baseline between radial artery and saphenous vein groups after adjusting for covariates (P < .001) but not at 12 months (P = .07). No significant changes occurred in grip strength or dexterity from preoperative baseline to 3 and 12 months after surgery. We observed similar levels of pain in both groups at 12 months after surgery. Grip strength and manual dexterity were not changed by radial artery harvesting at 3 and 12 months.

**CONCLUSIONS AND RELEVANCE**
The radial artery group reported significantly more pain than the saphenous vein group 3 months after surgery; however, similar levels of pain were observed in both groups at 12 months after surgery. Grip strength and manual dexterity were not changed by radial artery harvesting at 3 and 12 months.

Published online September 25, 2013.


**Supplemental content at jamasurgery.com**

The Department of Veterans Affairs (VA) Cooperative Studies Program (CSP) 474 is a multicenter prospective randomized trial with a primary end point of angiographic graft patency at 1 year following coronary artery bypass grafting. The CSP 474 trial compares the radial artery with the saphenous vein, with the study conduit used as the graft to the best epicardial target vessel after the left anterior descending artery. Data acquisition included measurements of hand and forearm neuromuscular function, as well as leg pain, before and after surgery.

This report is a post hoc analysis of prospectively gathered data describing arm and leg neurologic outcome for the patients enrolled in CSP 474. The purpose is to quantitatively define the severity of pain and motor impairment associated with procurement of the radial artery and then compare pain and motor impairment with the unoperated-on arm. Postoperative data were obtained to measure recovery toward the preoperative baseline. Also, data describing pain in the lower extremities were collected to compare radial artery and saphenous vein procurement.

Based on a review of previously published information, the hypothesis tested in this study is that sensory and motor dysfunction associated with procurement of the radial artery largely resolves within a year of surgery and is not substantially worse than the discomfort associated with procurement of the saphenous vein. To our knowledge, no trial to date includes all attributes of CSP 474 (i.e., a multicenter prospective randomized trial with quantitative assessments of pain and motor function by trained personnel that use widely accepted measurement tools at specified times before and after surgery) (details of prior literature in Table 1).
Table 1. Summary of Neurologic Function After Radial Artery Harvest

<table>
<thead>
<tr>
<th>Source, y</th>
<th>Centersa</th>
<th>Study Design</th>
<th>Randomb</th>
<th>PE or Q</th>
<th>Metricc</th>
<th>Baselined</th>
<th>Postoperative Points</th>
<th>Within-Patient Comparison</th>
<th>Complete Patient Follow-up, %</th>
<th>S/Md</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grossenbner et al,1999</td>
<td>Single</td>
<td>Prospective</td>
<td>No</td>
<td>PE</td>
<td>Qualitative</td>
<td>Yes</td>
<td>1</td>
<td>Yes (right vs left hand)</td>
<td>100</td>
<td>M</td>
</tr>
<tr>
<td>Saeed et al,2001</td>
<td>Single</td>
<td>Retrospective</td>
<td>No</td>
<td>Q</td>
<td>Semiquantitative</td>
<td>No</td>
<td>2</td>
<td>No</td>
<td>85</td>
<td>Both</td>
</tr>
<tr>
<td>Mehran and Trehan,2001</td>
<td>Single</td>
<td>Retrospective</td>
<td>No</td>
<td>78% PE, 16% Q</td>
<td>Qualitative</td>
<td>Yes</td>
<td>4</td>
<td>No</td>
<td>94</td>
<td>Both</td>
</tr>
<tr>
<td>Denton et al,2001</td>
<td>Single</td>
<td>Retrospective</td>
<td>No</td>
<td>Q</td>
<td>Qualitative</td>
<td>No</td>
<td>1</td>
<td>No</td>
<td>91</td>
<td>Both</td>
</tr>
<tr>
<td>Budillon et al,6 2003</td>
<td>Single</td>
<td>Prospective</td>
<td>No</td>
<td>PE before, Q after</td>
<td>Semiquantitative</td>
<td>Yes</td>
<td>3</td>
<td>No</td>
<td>NA</td>
<td>Both</td>
</tr>
<tr>
<td>Siminelakis et al,2004</td>
<td>Single</td>
<td>Prospective</td>
<td>No</td>
<td>Both</td>
<td>Semiquantitative</td>
<td>No</td>
<td>1</td>
<td>No</td>
<td>100</td>
<td>Both</td>
</tr>
<tr>
<td>Desai et al,8 2004</td>
<td>Multicenter</td>
<td>Prospective</td>
<td>Yes</td>
<td>Q</td>
<td>Semiquantitative</td>
<td>Yes</td>
<td>2</td>
<td>No</td>
<td>NA</td>
<td>Both</td>
</tr>
<tr>
<td>Shapiro et al,2006</td>
<td>Single</td>
<td>Retrospective</td>
<td>No</td>
<td>Q</td>
<td>Semiquantitative</td>
<td>No</td>
<td>1</td>
<td>No</td>
<td>NA</td>
<td>Both</td>
</tr>
<tr>
<td>Oz et al,10 2007</td>
<td>Single</td>
<td>Prospective</td>
<td>Yes</td>
<td>PE</td>
<td>Qualitative</td>
<td>No</td>
<td>1</td>
<td>No</td>
<td>100</td>
<td>Both</td>
</tr>
<tr>
<td>Medalion et al,11 2008</td>
<td>Single</td>
<td>Retrospective</td>
<td>No</td>
<td>Q</td>
<td>Semiquantitative</td>
<td>No</td>
<td>1</td>
<td>No</td>
<td>NA</td>
<td>Both</td>
</tr>
<tr>
<td>Shah et al,12 2007</td>
<td>Single</td>
<td>Retrospective</td>
<td>No</td>
<td>Q</td>
<td>Qualitative</td>
<td>No</td>
<td>1</td>
<td>No</td>
<td>NA</td>
<td>Both</td>
</tr>
<tr>
<td>Collins et al,13 2008</td>
<td>Single</td>
<td>Prospective</td>
<td>Yes</td>
<td>PE</td>
<td>Quantitative</td>
<td>Yes</td>
<td>1</td>
<td>No</td>
<td>100</td>
<td>Both</td>
</tr>
<tr>
<td>Dick et al,14 2011</td>
<td>Single</td>
<td>Retrospective</td>
<td>No</td>
<td>Q</td>
<td>Semiquantitative</td>
<td>No</td>
<td>1</td>
<td>Yes (arm vs leg)</td>
<td>73</td>
<td>S</td>
</tr>
<tr>
<td>Zhu et al,15 2013</td>
<td>Single</td>
<td>Prospective</td>
<td>Yes</td>
<td>Q</td>
<td>Semiquantitative</td>
<td>Yes</td>
<td>2</td>
<td>Yes (arm vs leg)</td>
<td>83</td>
<td>Both</td>
</tr>
</tbody>
</table>

Abbreviations: NA, not applicable; PE, physical examination; Q, questionnaire; S/M, sensory or motor function.

a Single institution (single) or multicenter study.
b Randomized study design (yes or no).
c Qualitative, semiquantitative, or quantitative metric.
d Preoperative measurement included (yes or no).
e Postoperative assessments (number).
f Within-patient comparison included in trial design.
g Sensory and/or motor functional assessments included.

Methods

The CSP 474 trial was approved by each site’s institutional review board, and written consent was obtained from each patient before screening. Patients undergoing primary sternotomy for coronary artery bypass grafting with no concomitant valve surgery were included. Other details of the study are available in a previous publication.1

Demographic data and data describing the patients’ cardiac disease were obtained. Intraoperative variables included the quality of the conduits used for grafts, the site of harvesting for all conduits, and a description of the proximal and distal anastomotic sites.

With regard to arm and leg function, data were collected before surgery (preoperative baseline) and 3 and 12 months postoperatively. The case report forms for hand and leg pain, hand strength, and hand sensory function are included in the eFigure in the Supplement. Questions with a 0 (no pain) to 10 (most intense pain imaginable) scale that describes pain at rest and during activity were included. Right and left hand strengths were measured in pounds of grip using a commercially available dynamometer.15 Three attempts were averaged for the final value. Right and left manual dexterity was measured in seconds using the 9-hole peg test.17

Patients were stratified according to the operative sites so that the following comparisons could be made: arm pain, sensation, strength, and dexterity before and after radial artery harvest; arm pain, sensation, strength, and dexterity comparing the side of radial artery harvest with the unoperated-on side; saphenous vein harvest site pain before and after vein harvest; and saphenous vein harvest site pain compared with the unoperated-on leg. Additional descriptors for hand and forearm neurologic dysfunction obtained at each time point are listed on Form 10 in the eFigure in the Supplement.

Data were gathered and then reviewed for spurious values. Study coordinators attended a national meeting every year to review data collection methods and discuss problems. All patients provided informed consent before inclusion in the study, and each site obtained approval from its local institutional review board before participation. Data analysis occurred at a core VA facility affiliated with the Palo Alto VA Medical Center. Statistical comparisons assessed for significant changes in pain score from the preoperative baseline to 3 and 12 months postoperatively using mixed regression models to account for within-patient correlation of the outcomes. The analysis adjusted for pain scores of the nonharvested extremity, age, whether the patient underwent endoscopic vein harvesting, and comorbid health conditions (smoking history, type 2 diabetes mellitus, hypertension, and heart failure). A simi-
Results

Forearm or hand pain and pain at the saphenous vein harvest site are shown in Table 2 and Figure 1.

There was an increase in pain at 3 months after radial artery harvest; however, the pain resolved during 12 months. Pain noted in the control (non–radial artery harvest) arm may be related to placement of a radial artery catheter for pressure monitoring, positioning during surgery, or the placement of intravenous catheters for infusion. This discomfort also resolved over time.

Pain after surgery in the leg used for vein harvesting was less intense at 3 months after surgery compared with the radial harvest site; however, the pattern of pain diminution during the first year after surgery was similar to that of the upper extremity following radial artery harvesting (Figure 1).

Changes in grip strength and manual dexterity at 3 months and 1 year after surgery are described in Table 2 and illustrated in Figure 2 and Figure 3. A statistically insignificant decrease in grip strength after surgery remained stable at 1 year. There was an insignificant change in the 9-hole peg test performance after radial artery harvest.

Discussion

In the CSP 474 multicenter trial, a primary end point was conduit patency (ie, radial artery vs saphenous vein) at 1 year after coronary artery bypass grafting. When the executive committee developed the trial’s design, it recognized the importance of measuring pain and assessing neurologic function of the operated-on extremity and then comparing arms and legs after conduit procurement. The final study design had structured examinations for pain (arm and leg) and neurologic function (sensory and motor examinations; arm only) by specially trained personnel. Pain assessment was measured using scripted questions with Likert-type scales. Scripted questions were used together with devices for rating manual dexterity (9-hole peg test) and grip strength (dynanometer).16,17

Table 2. Comparisons for Radial Artery and Saphenous Vein Harvest

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Preoperative</th>
<th>Postoperative, mo</th>
<th>3</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA paina</td>
<td>7.6 (1.6)</td>
<td>17.5 (2.8)b</td>
<td>13.0 (2.8)c</td>
<td></td>
</tr>
<tr>
<td>SV paind</td>
<td>12.6 (1.2)</td>
<td>13.4 (1.2)b</td>
<td>15.2 (1.4)c</td>
<td></td>
</tr>
<tr>
<td>Grip strength, lb*</td>
<td>72.6 (3.1)</td>
<td>66.4 (4.3)</td>
<td>65.0 (3.6)</td>
<td></td>
</tr>
<tr>
<td>Peg test, s’f</td>
<td>25.1 (0.6)</td>
<td>25.6 (0.8)</td>
<td>26.9 (0.9)</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: RA, radial artery; SV, saphenous vein.

a Pain (score 1-100) at the radial artery harvest site.

b P < .001 for change in pain score from the preoperative baseline to the 3-month postoperative measurement.

c P = .07 for change in pain score from the preoperative baseline to the 12-month postoperative measurement.

d Pain (score 1-100) at the saphenous vein harvest site.

* Hand dynamometer testing of grip strength measured in pounds.

f Nine-hole peg test, a standardized test of dexterity; time to complete test is measured in seconds.
Consequences of Radial Artery Harvest

The statistical analysis included a consideration of risk factors for pain and motor dysfunction. The study group was confined to patients with only radial artery or saphenous vein harvest so that simultaneous postincision arm and leg pain never confounded the arm and leg comparison.

The consequences of radial artery harvest with regard to pain and hand function are important. Prior investigations examined this issue as part of studies of patient survival or graft patency or as a separate entity. To our knowledge, this study is the only one that has used a prospective randomized multicenter trial design that included scripted questions and examinations by specially trained personnel. This study provides the most secure and detailed information yet to address an important question for patients considering coronary artery bypass grafting with the use of a radial artery.

In summary, analysis of data collected as part of CSP 474 found that pain after radial artery procurement was slightly greater than pain after saphenous vein harvest. However, the pain was not severe and resolved within 12 months following surgery. There was no statistically significant change in manual dexterity or grip strength at 3 or 12 months after surgery compared with the preoperative status. The 9-hole peg test and grip strength cannot discern changes in sensory or motor function for especially demanding situations (eg, the hands of a pianist) but are nevertheless reassuring regarding the outcome for most patients who undergo this procedure.

ARTICLE INFORMATION
Accepted for Publication: May 23, 2013.
Published Online: September 25, 2013.

Author Contributions: Drs Holman and Goldman had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Holman, Davies, Bakaeen, Lee, Wagner, Sethi.
Acquisition of data: Holman, Wang, Goldman, Lee, Wagner, Sethi.
Analysis and interpretation of data: All authors.
Drafting of the manuscript: Holman, Davies, Lin, Sethi.
Critical revision of the manuscript for important intellectual content: Holman, Davies, Wang, Goldman, Bakaeen, Kelly, Frances, Lee, Wagner, Sethi.
Obtained funding: Goldman, Wagner, Sethi.
Administrative, technical, and material support: Holman, Davies, Kelly, Lee, Wagner, Sethi.
Study supervision: Holman, Goldman, Frances, Sethi.

Conflict of Interest Disclosures: None reported.

Previous Presentation: This study was presented at the 2013 Association of VA Surgeons Annual Meeting: April 22, 2013; Milwaukee, Wisconsin.

REFERENCES