Brachial Gradient in Cardiac Surgical Patients
Yvon Baribeau, MD; Benjamin M. Westbrook, MD; David C. Charlesworth, MD; Michael J. Hearne, MD; William A. Bradley, MD; Christopher T. Maloney, MD

Background—Review of the clinical and therapeutic implications of difference in arm blood pressure detected preoperatively in patients having heart surgery.

Methods and Results—Prospective study of 53 patients (Group 1) with gradient and comparison with a group of 175 patients without gradient (Group 2). All patients had preoperative carotid duplex interrogation and operative epiaortic scanning. There was no statistical difference regarding age, sex, status, redo, diabetes, ejection fraction, prior myocardial infarct, hyperlipidemia, or creatinine level. Risks factors for Group 1 included peripheral vascular disease ($P<0.0001$) and cerebrovascular symptoms ($P=0.0196$). Severe carotid disease ($>80\%$ stenosis) was seen in $41.5\%$ of Group 1 and $13.7\%$ of Group 2 ($P<0.0001$) patients. Severe atherosclerotic proximal aortic disease was found in $39.6\%$ of Group 1 and $10.8\%$ of Group 2 ($P<0.0001$) patients. There were $7$ patients with strokes in Group 1 ($13.2\%$) and $9$ in Group 2 ($5.14\%$; $P=0.06$). Four patients died in Group 1 ($7.54\%$) and $10$ died in Group 2 ($5.71\%$; $P=0.74$).

Conclusion—Brachial gradient is a marker for increased carotid and proximal atherosclerotic aortic disease. Preoperative arch study at the time of catheterization is strongly recommended, as well as preoperative carotid Doppler and operative epiaortic ultrasound. (Circulation. 2002;106[suppl I]:I-11-I-13.)

Key Words: surgery ■ blood pressure ■ cardiovascular diseases ■ angioplasty ■ vessels

Bilateral blood pressure measurements should be part of the initial assessment of a cardiovascular patient.$^{1,2}$ We instituted this practice in all cardiac patients in March of 1993, to a point at which now all cardiology patients have bilateral brachial cuff pressure measurement prior to catheterization. This is a first review of our experience and its implications for both cardiologist and cardiac surgeons.

Methods
We reviewed our surgical population from March 3, 1994 to March 14, 2000. During that period, 6539 patients had cardiac surgery at our institution. Significant gradient was defined as a value equal or greater than 15 mm Hg$^3$ on 2 consecutive measurements, confirmed by a third measurement in the catheterization laboratory before the examination. Blood pressure was taken sequentially in the right and left arms by the same nurse, using an automatic sphygmomanometric technique (Dynamap, GE Medical Systems, Milwaukee WI; Datascop, Mahwah, NJ). The gradient was calculated by subtracting the highest systolic measurement from the lower contralateral systolic value. No diastolic difference was taken into account. In confirmed cases, the greatest value of the 3 measurements was used to define the gradient. Group 1 constituted 53 patients in whom a brachial pressure difference was noted in the chart as equal or greater than $15\,$ mm Hg. Group 2 was composed of 175 patients without gradient who had been marked as such in our database. Many of the patients without gradient were not identified as such in the database and were excluded from this study. All data were collected prospectively. Limited (subclavian injection only) or full arch study was performed at the time of catheterization or the next day, according to the dye load and the patient renal function. Significant arch branch stenosis was defined as $50\%$ or greater stenosis angiographically.

All patients had preoperative carotid duplex and operative epiaortic ultrasound. Carotid duplex scanning was carried out with the 5 MHz scanning probe (Accuson, 128 XP Mountain View, CA). Carotid disease severity was defined as stenosis equal or greater than $80\%$ by duplex criteria.$^4$ Epiaortic ultrasound was performed with the 7 MHz probe (Accuson, 128 XP Mountain View, CA). The entire ascending and transverse aorta was imaged in both cross section and long axis.$^5$ Severity of atherosclerosis was graded as normal, mild ($<3\,$-mm intimal thickening), moderate (3- to $5\,$-mm intimal thickening or calcification), or severe ($>5\,$-mm thickness or protruding or mobile atheromas).$^6$

All carotid endarterectomies were performed at the same operation before sternotomy under general anesthesia and normothermia. In cases of circulatory arrest, auxiliary cannulation with antegrade cerebral perfusion was used.$^7$

Cerebrovascular symptoms were defined as transient ischemic attack or stroke. Stroke was defined as a localized neurological deficit persisting more than twenty-four hours. A neurologist confirmed all diagnosis of stroke, but no postoperative routine neurological consultation was obtained. Patients who were without deficit at discharge but who had a positive computed tomography of the head showing recent infarct postoperatively were still considered as having had a stroke. Mortality was defined as any death within 30 days of surgery if discharged or anytime during the initial hospitalization.

Comparison between groups for discrete variables (test of proportions) were performed using the two-sample Z test. Differences in proportions were compared using either the Chi-square test or the Fisher’s exact test when appropriate.

Results
In Group 1 mean gradient was $41\,$ mmHg. Most patients had a higher pressure on the right (35 patients) than on the left (18 patients) ($P<0.001$; Table 1). Of the 53 patients, 32 (60.4\%) had an arch study, 6 at the time of heart catheterization and 26 the next day.

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I-11
TABLE 1. Distribution of Brachial Gradients

<table>
<thead>
<tr>
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<th>Left:Right</th>
<th>Right:Left</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients (%)</td>
<td>18 (33.96%)</td>
<td>35 (66.04%)</td>
<td>0.001</td>
</tr>
<tr>
<td>Average gradient (mm Hg)</td>
<td>50.06</td>
<td>36.31</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Most of these patients had a greater pressure on the right (24 patients), and in that group there were 20 significant proximal left subclavian stenoses (15 patients) or occlusion (5 patients). In the 4 other patients, there was 1 patient with axillary artery stenosis and otherwise no subclavian or axillary artery lesions. Of the 8 patients with greater pressure on the left who were still studied, 3 had a significant left subclavian stenosis beside innominate stenosis. None of the patients complained of symptomatic clinical subclavian steal, although occasional ipsilateral arm weakness was sometimes expressed during questionnaire.

Risk factors for Group 1 included history of peripheral vascular disease (36 patients [67.93%] versus 46 patients [26.29%], with \( P < 0.0001 \)) and cerebrovascular symptoms (14 patients [26.42%] versus 21 [12.00%], with \( P = 0.0196 \)). Otherwise both populations were similar (Table 2).

The incidence of severe atherosclerotic proximal aortic disease was 39.62% in Group 1 (n = 21) and 10.86% in Group 2 patients (n = 19) (\( P < 0.0001 \)). Severe internal carotid disease (>80% stenosis) was seen in 41.50% of Group 1 (n = 22) and 13.71% of Group 2 patients (n = 24) (\( P < 0.0001 \) (Figure 1). By palpation, only 14 or 35% of the total severe aortas (according to ultrasonic epiaortic criteria) were detected. Within the patients with severe carotid disease, the incidence of severe aortic disease was 45.4% (n = 10) in the Group 1 and 12.5% (n = 3) in Group 2 (\( P = 0.032 \)). All patients with severe atherosclerotic disease of the aorta or extracranial carotid system also had coronary artery disease, even in cases of valve replacement.

In Group 1, selective arch studies were done at the time of catheterization in 6 patients, whereas full arch studies were performed at a different time preoperatively in 26 patients. No arch study was performed in 21 patients. Indication for carotid endarterectomy included asymptomatic patients with an internal carotid stenosis greater than or equal to 80% by Doppler. In cases of bilateral over 80% lesions, carotid endarterectomy was performed on the side of hemispheric dominance.

In Group 1, surgeries included 38 coronary artery bypass (CABG), 14 single valve replacements, and 1 arch replacement. Additional surgeries included 14 carotid endarterectomies, 4 arch vessel bypasses, and 2 arch endarterectomies. In Group 2, there were 139 CABG, 28 single valve replacements, 6 double valve replacements, 1 triple valve replacement, and 1 atrial septal defect repair. Other surgeries included 20 carotid endarterectomies, 2 arch endarterectomies, and 1 arch replacement. Therapeutic and strategic maneuvers in cases of left subclavian stenosis greater than 50% included left subclavian angioplasty and stenting at the time of catheterization or arch study, use of the right internal mammary, use of free mammary or all vein bypass, and carotid subclavian bypass and use of the left mammary. Manipulation of the aorta in cases of severe disease was avoided through different tactics including axillary cannulation and beating heart surgery. There were 7 strokes in Group 1 (13.20%), and 9 in Group 2 (5.14%) (\( P = 0.06 \)). Four patients died in Group 1 (7.54%) and 10 in Group 2 (5.71%; \( P = 0.74 \)).

### Discussion

Preoperative measurement of blood pressure in both arms has been recommended before in coronary artery bypass patients to avoid placing a mammary artery on a coronary with subsequent steal from a proximal subclavian stenosis or occlusion.8–11 This study adds to the contention by showing a significantly higher incidence of carotid and aortic disease in patients with a brachial gradient detected preoperatively. As mentioned, patients with severe atherosclerotic disease of the aorta or extracranial carotid system, also had coronary artery disease, even in cases of valve replacement. This obviously reflects an advanced stage of atherosclerotic disease with most territory involved. The presence of a brachial gradient identifies this subgroup of patients.

**TABLE 2. Population Comparison**

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age in years</td>
<td>70.5</td>
<td>70.5</td>
<td>0.0866</td>
</tr>
<tr>
<td>Male</td>
<td>45.30%</td>
<td>58.90%</td>
<td>0.0024</td>
</tr>
<tr>
<td>Female</td>
<td>54.70%</td>
<td>41.10%</td>
<td>0.0024</td>
</tr>
<tr>
<td>Elective</td>
<td>16.98%</td>
<td>10.29%</td>
<td>0.1364</td>
</tr>
<tr>
<td>Urgent</td>
<td>83.01%</td>
<td>85.14%</td>
<td>0.6506</td>
</tr>
<tr>
<td>Emergent</td>
<td>0%</td>
<td>4.57%</td>
<td>0.0001</td>
</tr>
<tr>
<td>Redo</td>
<td>11.32%</td>
<td>12.57%</td>
<td>0.9967</td>
</tr>
<tr>
<td>Diabetes</td>
<td>32.08%</td>
<td>31.42%</td>
<td>0.9636</td>
</tr>
<tr>
<td>Hypertension</td>
<td>66.04%</td>
<td>67.43%</td>
<td>0.9825</td>
</tr>
<tr>
<td>EF</td>
<td>49.70%</td>
<td>49.99%</td>
<td>0.8964</td>
</tr>
<tr>
<td>Hx MI</td>
<td>50.94%</td>
<td>46.29%</td>
<td>0.6619</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>54.72%</td>
<td>56.57%</td>
<td>0.3958</td>
</tr>
<tr>
<td>Creatinine</td>
<td>1.41%</td>
<td>1.37%</td>
<td>0.5446</td>
</tr>
<tr>
<td>PVD</td>
<td>26.93%</td>
<td>26.29%</td>
<td>0.9901</td>
</tr>
<tr>
<td>CVS</td>
<td>26.42%</td>
<td>12.00%</td>
<td>0.0196</td>
</tr>
</tbody>
</table>

EF indicates ejection fraction; Hx MI, history of myocardial infarct; PVD, peripheral vascular disease; CVS, cerebrovascular disease.
Unpublished data from us (Baribeau 2000) comparing a group of cardiac patients with internal carotid occlusion (88 patients) with a group without significant carotid disease (754 patients) showed a greater incidence of severe proximal aortic disease in the group with carotid occlusion: 18.2% versus 9.0% (P=0.012). Most of these patients did not have a brachial gradient. By contrast, in the current study, patients with severe carotid disease and a brachial gradient (Group 1) had an incidence of severe aortic disease of 45.4% (10 patients), whereas patients with carotid disease and no gradient only 12.5% (three patients) were found to have severe aortic disease (P=0.032). Presence of a gradient is thus an ominous sign for diffuse atherosclerotic disease at an advanced stage and should alert the surgeon to the risk of severely atherosclerotic aorta and its branches. To that effect, our study demonstrates in a similar manner as other studies, the greater sensitivity of the ultrasound, because only 35% of these “bad” aortas were detected by palpation.

Interestingly, even a contralateral gradient (left greater than right) still brought a 37.5% incidence of left subclavian stenosis. The incidence of left subclavian disease was higher when the gradient was higher on the right, with 83.33% of our patients studied having a greater than 50% stenosis. This obviously bears importance for avoiding eventual mammary steal syndrome. Most of the patients with brachial gradient will have at least a selective left subclavian injection in our catheterization laboratory, irrespective of the dominant side.

The different strategies suggested in this study range from preoperative subclavian angioplasty and stenting to use of the right catheterization laboratory, irrespective of the dominant side. Most of these patients did not have a brachial gradient. By contrast, in the current study, patients with severe carotid disease and a brachial gradient (Group 1) had an incidence of severe aortic disease of 45.4% (10 patients), whereas patients with carotid disease and no gradient only 12.5% (three patients) were found to have severe aortic disease (P=0.032). Presence of a gradient is thus an ominous sign for diffuse atherosclerotic disease at an advanced stage and should alert the surgeon to the risk of severely atherosclerotic aorta and its branches. To that effect, our study demonstrates in a similar manner as other studies, the greater sensitivity of the ultrasound, because only 35% of these “bad” aortas were detected by palpation.

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The different strategies suggested in this study range from preoperative subclavian angioplasty and stenting to use of the right internal mammary artery and carotid subclavian bypass and use of the left internal mammary artery. The easier route for the patient seems to be stenting of the left subclavian at the time of catheterization if the lesion is suitable, as described postoperatively in patients with coronary-subclavian steal syndrome. Long-term patency of subclavian angioplasty is lacking and may or may not prove this option reasonable. In cases of subclavian occlusion, carotid subclavian bypass and use of the ipsilateral left internal mammary artery would be favored, particularly in cases of arm claudication.

No strong conclusions can be made regarding stroke rate in this disparate group of patients. The stroke rate of 13.2% in the group with brachial gradient may reflect the high risks in these patients with carotid and aortic disease. Few series looking at stroke rate in patients with bad atherosclerotic aortas report high stroke rate if no modifications are done, in the range of 23% to 50%. We have previously showed that extra aortic (axillary) cannulation in these patients is one way of reducing the embolization rate with a similar stroke rate as that found in this study.

One problem of adopting this routine evaluation is the number of false-positive rates, in which a gradient was detected at first and than not detected. Normal variation in brachial pressures taken simultaneously or consecutively has been described, and as well our criteria of 15 mm Hg may be low. Others have suggested 20 mm Hg as a criteria. This would obviously lower the false-positive rate, although, as noted above, a high percentage of our patients who were studied by angiogram showed significant aortic arch branch disease. Lastly, the incidence of brachial gradient in cardiac surgical patients at large is unknown. This study cannot answer the question because the patients screened were not always identified in our database, and were excluded from this study. Frank and colleagues suggested a 3% incidence in patients with coronary artery disease and no evidence of peripheral vascular disease using a 20-mm Hg criteria.

In summary, measurements of blood pressures in both arms can provide invaluable information to both cardiologist and surgeons preoperatively. Preoperative left subclavian angiogram, carotid duplex, and epiarterial ultrasound at surgery are recommended in these patients.

References


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