Gas Endarterectomy of Right Coronary Artery
The Importance of Proximal Bypass Graft


SUMMARY
Results of gas endarterectomy of the right coronary artery were evaluated in 29 consecutive patients. There were one surgical and two early postsurgical deaths. All three had postmortem examination, and in two there was occlusion of the gas endarterectomy. Five patients did not have repeat catheterization. Twenty-one patients were completely re-evaluated and had repeat cardiac catheterization one to sixteen months after surgery (mean eight months). Ten patients (Group A) had gas endarterectomy without a saphenous vein graft to the right coronary artery. Only one patient had significant vessel patency. Eleven patients (Group B) had the combined procedure of a saphenous vein graft anastomosed to the segment of artery that had the endarterectomy. There was excellent graft patency in seven patients (64%) and good distal flow into the segment that had endarterectomy in six of the seven patients. In conclusion, gas endarterectomy is not of value unless it can be combined with a saphenous vein graft to provide good flow to the distal vessel that had endarterectomy. Results with the combined procedure suggest that even with a severely diseased artery, gas endarterectomy can often provide continuing distal runoff for the graft.

Additional Indexing Words:
Coronary artery disease  Graft patency  Plus vein graft

In 1965, Gas ENDARTERECTOMY was first used for peripheral vascular disease and in October, 1965, gas endarterectomy was introduced by Sawyer for coronary artery disease. Since his report in 1967, there have been scant literature and follow-up data on the procedure. Because we had the initial impression that many of the gas endarterectomies done here resulted in early postsurgical occlusion, it was reasoned that a concomitant saphenous vein graft anastomosed to the segment of vessel that had endarterectomy would improve the incidence of vessel patency. We studied 29 consecutive patients who had a right coronary gas endarterectomy for coronary occlusive disease. Results in the subgroup of patients who had the combined procedure of endarterectomy plus vein graft are compared with the results in those patients who had an endarterectomy alone.

Methods
Of the 29 consecutive patients in whom coronary gas endarterectomy was attempted, three died at surgery or shortly thereafter, three refused postoperative investigation, and one was lost to follow-up. In only one patient did it prove impossible to accomplish the endarterectomy; he was not catheterized after surgery. Follow-up data on the remaining 21 patients, all of whom had repeat catheterization, is the subject of this paper.

An extensive history regarding the duration, frequency, and character of angina before and after surgery was obtained from the patients and their hospital records. Physical examination, electrocardiograms, and chest films were obtained before and after surgery and at the time of follow-up. Right and left heart catheterizations were carried out with coronary angiography. Pressures were measured on an Electronics for Medicine DR8 recorder, using Statham P23DB gauges, with midchest as the reference point. Ventriculography was performed with the power injection of meglumine and sodium diatrizoate USP (Renografin 76, Squibb) through a Cordis pigtail catheter. Coronary angiography was performed with the Judkins or Sones technique with multiple views in the left and right anterior oblique positions. Eight to ten ml of meglumine
and sodium diatrizoate were used for each injection. The saphenous vein grafts were studied with a right coronary Judkins catheter or a vein graft catheter.

Indications for surgery were angina that was unresponsive to medical therapy, and the demonstration of 70% occlusion or more of a major vessel on coronary angiography. Gas endarterectomy of the right coronary artery was recommended only if the vessel was completely occluded or so significantly diseased that grafting alone was precluded. Surgery was performed through a median sternotomy incision. The right atrium was cannulated for cardiopulmonary bypass. Oxygenated blood was returned to the femoral artery from a roller pump. The heart was fibrillated and the coronary arteries were inspected. The left ventricle was vented through the superior pulmonary vein. Gas endarterectomy was performed only on the right coronary artery. The technique involved piercing the coronary artery with a 25 gauge needle through which carbon dioxide gas flowed to develop the plane of endarterectomy. An arteriotomy was then performed and further dissection continued with the aid of a small carbon dioxide spatula or with an endarterectomy spatula without gas flowing through it. In our early cases the entire length of the vessel was endarterectomized. As the series progressed, more dependable flow was obtained by making the arteriotomy in the right coronary artery distal to the acute margin of the right ventricle, then performing distal endarterectomy, and Anastomosing a saphenous bypass graft between the aorta and the distal arteriotomy. In the latter cases, no attempt was made to open up flow from the aorta itself. In the great majority of endarterectomies, the tip of the atheromatous core was nicely tapered and not broken off sharply. Almost all of the cores contained several small side branches. It should be mentioned that after endarterectomy, back flow was obtained in all vessels except one. Surgery also included grafts to the left anterior descending artery or circumflex artery, aneurysmectomy, and internal mammary implants when indicated. Flows were measured through the saphenous vein grafts at the time of surgery with an electromagnetic flow meter while the patient was off cardiopulmonary bypass.

Results

Of the 29 patients who had gas endarterectomy, there were three deaths. One patient could not be taken off bypass following ventricular aneurysmectomy and gas endarterectomy. At post mortem he had occlusion of the right coronary artery due to blood dissecting in the plane of endarterectomy distal to the completed endarterectomy. This is the only vessel in which the distal core did not break off cleanly. One patient died 17 days after surgery and at post mortem had thrombosis of the saphenous vein graft to the right coronary artery and occlusion of the segment of artery where gas endarterectomy was done. The third patient died two months after surgery, and at post mortem the gas endarterectomy was open. The death of this patient was related to multiple factors, including a perforated ulcer, jaundice, hypotension, and mediastinitis.

Three of the 29 patients refused follow-up catheterization. One of the 29 patients was lost to follow-up. A gas endarterectomy could not be accomplished in one patient, and therefore, he has not had repeat catheterization.

The 21 patients who had complete follow-up, including cardiac catheterization, are divided into two groups (Table 1). Group A consists of ten patients who had gas endarterectomy of the right coronary artery without a saphenous vein graft to that vessel. Follow-up catheterization was at a mean of eight months after surgery (range 1-14 months). Group B is composed of the remaining 11 patients who had a saphenous vein graft to the right coronary artery as well as gas endarterectomy. Mean follow-up time was 7% months (range 2-16 months).

Only one of the ten patients in Group A showed significant angiographic improvement of the right coronary artery after surgery. In five patients, the diameter of the artery was narrowed to the extent that the flow through the vessel was unlikely to be of clinical significance. In one of the five patients

### Table 1

<table>
<thead>
<tr>
<th>Results of Postoperative Right Coronary Angiography in 21 Patients Who Had Gas Endarterectomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
</tr>
<tr>
<td>GE alone</td>
</tr>
<tr>
<td>10 patients</td>
</tr>
<tr>
<td>Patent</td>
</tr>
<tr>
<td>1 patient</td>
</tr>
<tr>
<td>Almost Closed</td>
</tr>
<tr>
<td>5 patients</td>
</tr>
</tbody>
</table>

Abbreviations: GE = gas endarterectomy of right coronary artery; SVG = saphenous vein graft to right coronary artery.
there was 90% distal obstruction preoperatively with
no change after surgery; in one patient distal filling
was only by collaterals from the proximal right
coronary artery; in one patient there was total
occlusion preoperatively with 90% obstruction after
surgery; and in two patients there was progression
from moderate disease preoperatively to greater
than 90% occlusion postoperatively. In the remain-
ing four patients of Group A, the artery was
completely occluded at postoperative catheteriza-
tion.

In Group B, seven of the eleven patients had a
patent saphenous vein graft to the right coronary
artery. Graft flows, at surgery, ranged from 60 to
170 cc/min (mean 80). In one of seven patients,
the endarterectomy was occluded distal to the
graft. The proximal right coronary artery was
patent and upon injecting dye into the native vessel,
contrast media flowed retrograde through the graft
and back into the aorta. Its only side branch was a
collar from the conus branch to the left coronary
artery. In six of the seven patients with a patent
graft, the gas endarterectomy remained patent
distally, with a large smooth lumen in five of the
patients (fig. 1) and a small localized obstructive
lesion (50% obstruction) in one patient. In four of
the six patients with a patent vein graft and filling
of the distal right coronary artery, there was
marked progression of disease proximal to the vein
graft (fig. 1). In four of the patients in Group B,
the saphenous vein graft to the right coronary
artery was occluded. Graft flows, at surgery, were
60–165 cc/min. (mean 95). In none of these patients
was the gas endarterectomy patent.

Thirteen patients had, in addition, grafts to the
left anterior descending artery. Table 2 summarizes
these results. Four of the 13 patients were in Group
A, and three had patent grafts to the left anterior
descending artery. Nine of the 13 patients were in
Group B and six had patent grafts to the left
anterior descending artery. Two patients had a
graft to the circumflex branch and the graft was
patent in one of these patients. Five patients had
progression of the disease in the native left coronary
artery. This was not severe in any of the patients.
Two patients had internal mammary artery im-
plants, but these were not studied selectively. Two
patients had ventricular aneurysmectomy.

Discussion

Theoretically, the advantage of gas over mecha-
nical endarterectomy is that it dissects along the path
of least resistance and also goes down along the side

Figure 1

Patient A.S. (Group B): Top panel) Preoperatively there is
complete occlusion of the right coronary artery with distal
filling by collaterals. Middle panel) Postoperatively the
saphenous vein graft is widely patent with distal filling of
the segment of right coronary artery that had endarterec-
tomy. Lower panel) Injection into the native right coronary
artery shows complete occlusion proximal to the site of
the graft anastomosis.
branches. The gas breaks back into the lumen if it meets an area where the tunica intima is firmly attached, thus producing a smooth terminal end of the endarterectomy. It is reported that the raw surface left does not lead to thrombosis and after two weeks a new healthy intima forms.8

However, other studies warn that the side branches may be compromised by mechanical endarterectomy.4 This has been described as the "snowplow effect." This was never confirmed or disproved but the same institution has recently repudiated the "snowplow" theory.5 The advantage of using gas is that endarterectomy of side branches is completed along with endarterectomy of the main vessel. We have noted that almost all the cores removed had side branches attached. However, the success of the procedure should not be judged by the appearance of the core itself, but whether flow into the side branches can be demonstrated after surgery. Only one of our patients with a patent gas endarterectomy had a compromised side branch (patient A. El.) and it could not be determined whether this was due to progression of disease or a "snowplow effect."

In addition, a successful gas endarterectomy requires good inflow, good distal run-off, and the laying down of a new healthy intima. It works poorly for patients with peripheral vascular disease and diabetes6 and likewise is often unsuccessful for coronary artery disease in the diabetic patient.3 We reasoned that a bypass graft would improve inflow. We have found, by follow-up coronary angiography 1 to 16 months after gas endarterectomy of the right coronary artery, that the incidence of patency is very low unless a saphenous vein graft is also present and provides good proximal flow to the right coronary artery. These results are in contrast to other studies which suggest that gas endarterectomy is adequate by itself.7-9

Gas (or mechanical) endarterectomy of the right coronary artery plus saphenous vein graft to that vessel has been proposed by several investigators.5,10-13 It is implied that the combined procedure has better results than gas endarterectomy alone. We found, by comparing the recatheterization and clinical data of ten patients who had endarterectomy alone with the data of 11 patients who had the combined procedure, that the

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**Table 2**

**Surgical Procedures and Results of Follow-up Coronary Angiography**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age</th>
<th>GE</th>
<th>SVG</th>
<th>Progression disease</th>
<th>Other surgery</th>
<th>Months post-op</th>
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</thead>
<tbody>
<tr>
<td>A. El.</td>
<td>58</td>
<td>P</td>
<td>P</td>
<td>RCA</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>T.R.</td>
<td>45</td>
<td>AC</td>
<td>P**</td>
<td>CIRC</td>
<td>Implant</td>
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<tr>
<td>C.C.</td>
<td>54</td>
<td>AC</td>
<td>C</td>
<td>Aneurysectomy</td>
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<tr>
<td>C.B.</td>
<td>50</td>
<td>AC</td>
<td>P</td>
<td></td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>J.L.</td>
<td>35</td>
<td>AC</td>
<td>C*</td>
<td></td>
<td></td>
<td>8</td>
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<tr>
<td>A.Ev.</td>
<td>46</td>
<td>AC</td>
<td>P</td>
<td></td>
<td></td>
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<tr>
<td>R.H.</td>
<td>46</td>
<td>C</td>
<td>P</td>
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<tr>
<td>C.F.</td>
<td>58</td>
<td>C</td>
<td>P</td>
<td></td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>J.De.</td>
<td>46</td>
<td>C</td>
<td>LAD &amp; Circ</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>J. Do.</td>
<td>52</td>
<td>C</td>
<td>2 implants</td>
<td></td>
<td></td>
<td>8</td>
</tr>
</tbody>
</table>

**Group A**

| F.S.    | 45  | P  | P   | LCA & RCA |               | 12            |
| J.V.    | 45  | P  | P   | prox. RCA |               | 6             |
| J.M.    | 37  | P  | P   | prox. RCA |               | 6             |
| A. St.  | 44  | P  | P   | Aneurysectomy |         | 7             |
| J.O.    | 55  | P  | P   | prox. RCA |               | 12            |
| F.W.    | 45  | P  | P   | Aneurysectomy |         | 12            |
| A. Sc.  | 51  | C  | P   | LAD       |               | 5             |
| P.M.    | 53  | C  | C   | LAD       |               | 5             |
| H.F.    | 58  | C  | C   | LAD       |               | 8             |
| C.S.    | 53  | C  | C   | LAD       |               | 5             |
| C.M.    | 54  | C  | C   | LAD       |               | 6             |

**Group B**

Abbreviations: P = patent; C = closed; AC = almost closed; LCA = left coronary artery; RCA = right coronary artery; LAD = left anterior descending artery; Circ = circumflex artery; GE = gas endarterectomy; SVG = saphenous vein graft.

*Graft was to circumflex artery; all other LCA grafts were to the left anterior descending artery.
combined procedure is superior. In fact, our results suggest that gas endarterectomy alone is inadequate and should not be done. Patency of the right coronary artery was significant in only one patient who had gas endarterectomy alone. All but one of the patients with a patent graft to the right coronary artery had an open distal right coronary artery. Thus, there is firm evidence that the patients in Group B had better surgical results.

Gas endarterectomy was done on the right coronary artery only. Gas endarterectomy of the left coronary artery has not been attempted in this hospital because of the reported high surgical mortality. Sawyer collected data on 28 patients who had gas endarterectomy of either the right or left coronary artery and of the five deaths reported, four of the patients had gas endarterectomy of the left coronary artery.

It is concluded that gas endarterectomy is not of value unless combined with a saphenous vein graft that will provide good flow to the segment of artery on which endarterectomy is done. We are currently performing endarterectomies only on completely occluded or severely diseased right coronary arteries, and only with a concomitant vein graft. With the combined procedure 7/11 (64%) grafts were patent, with distal flow in 6/11 (55%) of the endarterectomies. This suggests that even with a severely diseased right coronary artery, gas endarterectomy can often provide adequate distal runoff for the graft. In a less severely diseased artery, where a bypass graft alone would be adequate, better patency rates could be expected. Therefore, it should be emphasized that bypass grafting without endarterectomy is preferable but that sometimes the combined procedure is necessary.

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