Transcatheter Angioplasty for Acquired Pulmonary Vein Stenosis After Radiofrequency Ablation

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Background—Pulmonary vein stenosis has recently been recognized as a complication of radiofrequency ablation for atrial fibrillation. This study evaluates the presentation of affected patients and the role of transcatheter therapy for this patient population.

Methods and Results—This study used a retrospective review of data from 19 patients (age, 51±13 years) with pulmonary vein stenosis who underwent catheterization and angiography between December 2000 and December 2002. Quantitative perfusion and spiral CT scans were performed for initial diagnosis and follow-up. The median duration between radiofrequency ablation and the reported onset of respiratory symptoms for 18 of 19 patients was 7.5 weeks (0.1 to 48). After the onset of symptoms, all but two patients were initially misdiagnosed with a symptoms-to-diagnosis duration of 16 weeks (2–59). At initial catheterization, 17 of 19 patients had angioplasty in 30 veins with stent placement in 5 vessels when a flap occurred. Overall vessel diameter increased from 2.6±1.6 to 6.6±2.4 mm (P<0.0001). There were 4 procedure-related adverse events but no long-term sequelae. Immediate follow-up showed improved flow to involved lung segments. At a median follow-up of 43 weeks (2–92), although repeat angioplasty for restenosis was necessary in 8 of 17 patients, 15 of 17 patients currently have no or minimal persistent symptoms.

Conclusions—Pulmonary vein stenosis after radiofrequency ablation for atrial fibrillation is often misdiagnosed. Although further follow-up is necessary to determine long-term success, our data indicate better pulmonary vein flow and symptomatic improvement in the majority of patients undergoing dilation of postablation pulmonary vein stenosis. (Circulation. 2003;108:1336-1342.)

Key Words: stenosis ■ ablation ■ fibrillation ■ angioplasty

Since the pioneering work of Haissaguerre and colleagues,1 ablation in the pulmonary veins has become an acceptable alternative therapy for atrial fibrillation unresponsive to medical therapy.1–8 Since these initial reports, pulmonary vein stenosis (PVS) is a well-known but underreported complication after radiofrequency ablation (RFA). The incidence of PVS could depend on the study definition as well as the ablative technique used and has been reported as high as 42%.9 However, few data exist regarding the presentation and treatment options for patients who have this life-altering and potentially serious condition. Lack of awareness of this procedural complication among the medical community and a diversity of clinical presentations has resulted in patients being misdiagnosed.9

The objective of this study was to review our experience with transcatheter intervention for acquired PVS as a complication of RFA.

Methods

Patients

Data from patients with PVS after RFA referred to us from December 2000 to December 2002 were reviewed in accordance with our institutional review board guidelines and policy. Patients were stratified by New York Heart Association functional classification (class 1–4). The diagnosis of PVS was confirmed by contrast-enhanced spiral CT scan (retrospectively gated helical scanning with overlapping 1.00- to 1.25-mm-thick images for multiplanar reconstructions or maximal intensity projections, using a 4-detector volume zoom or 16-detector sensation 16, Siemens Medical Systems).10 Once evidence of PVS was demonstrated, a baseline quantitative nuclear perfusion scan was performed to assess the percentage of blood flow to different segments of the lung before the cardiac catheterization. Informed consent for the procedure was obtained from each patient. All patients then proceeded to the cardiac catheterization laboratory, and pulmonary vein angioplasty was performed only in those patients who had a patent pulmonary vein ostium.

Received March 7, 2003; revision received June 13, 2003; accepted June 16, 2003.


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Circulation is available at http://www.circulationaha.org

DOI: 10.1161/01.CIR.0000086322.21781.6A
Catheterization Procedure
All procedures were performed with patients under general endotra-
cheal anesthesia. Access was obtained in both femoral veins. Patients
were given 5000 U of intravenous heparin. Activated clotting times
(Act) were monitored throughout the procedure with the goal to
maintain an ACT >250 U. Right heart hemodynamic data were
obtained with a 7F balloon wedge catheter through the left femoral
sheath. This catheter was used to obtain pulmonary artery wedge
pressures and perform a wedge angiogram for mapping the individ-
ual pulmonary vein flow and to determine if any segments were
completely occluded. The left atrium was entered by the transseptal
technique. A V-18 floppy-tipped control wire (Boston Scientific)
was manipulated across the target lesion within the pulmonary vein.
Subsequently, a 5F Angled Glide catheter (Medi-tech, Boston
Scientific) was coaxially introduced and used to measure a mean
pressure gradient across the target lesion, angiographically study
individual pulmonary vein anatomy, and position the V-18 wire into
the distal pulmonary vein. The diameter and length of the target
lesion and the distal pulmonary vein were measured digitally.
angiographic measurements were calibrated with the diameter of the
catheter across the target lesion. An appropriately sized angioplasty
balloon was chosen not to exceed the diameter of the stenotic lesion
by a factor of 4 or the distal vessel by a factor of 1.5. Standard
angioplasty was performed in each lesion. Stent angioplasty was
reserved for when standard angioplasty resulted in a flap or when
restenosis occurred during follow-up. In general, lesions were
gradually dilated with a goal final diameter ≥8 to 10 mm. After
balloon angioplasty, a mean pressure gradient across the lesion was
again measured. Angiography was performed to measure the target
lesion diameter and assess the degree of vessel injury.
A different protocol was used to engage the right lower pulmonary
vein. To cannulate this vessel, we used a 7F modified (length)
hockeystick coronary guide catheter (Medtronic/AVE) within the
left atrium and deflected off the lateral wall to allow a direct position
among the right lower pulmonary vein. This catheter was then used
to guide the V-18 wire and 5F angled glide catheter as described
above.

Follow-Up
Patients were evaluated 1 month after the procedure and at 3-month
intervals thereafter. Clinical evaluation and quantitative perfusion
scan were performed at each interval. Depending on the clinical
course, other noninvasive evaluations include a chest radiograph,
echocardiogram, or spiral CT scan. Repeat cardiac catheterization
was performed in all patients with recurrence of symptoms and
evidence of restenosis by noninvasive imaging. Although a quanti-
tative perfusion scan was performed in all patients to document the
percentage of flow across the involved lung segment, group analysis
of these data are difficult to interpret secondary to bilateral involve-
ment and collateral blood flow.

Statistical Analysis
Data were tabulated retrospectively on specific data collection forms
and summarized as mean±SD. A paired Student’s t test was used
to compare patient data. A probability value of <0.05 was considered
statistically significant. Where a data set was missing, the results are
reported based on number (n) of subsets available. The degree of
PVS was graded as mild, moderate, or severe, based on a luminal
narrowing of <50%, 50% to 70%, or >70%, respectively.9 Reference
values for normal pulmonary vein size in adults was based on
estimates from healthy control subjects.10 Briefly, each pulmonary
vein narrowing was compared with nonstenotic segment dimensions
in the same vessel or other pulmonary veins in the patient undergoing
the procedure.

Results
Patients
Nineteen patients (male:female ratio=13:6) with a mean age of
51±13 years were considered for transcatheter dilation
secondary to PVS (Figure 1). Four patients had proximal
ablation in the region of the pulmonary venous ostia and 15
patients had distal ablation within the pulmonary veins.2,3

Clinical Presentation
The median onset of symptoms after RFA was 7.5 weeks
(range, 0.1 to 48), with 1 patient in NYHA class 1, 3 patients
in class 2, 8 patients in class 3, and 7 patients in class 4
(mean, 3.1±0.9) by the initial evaluation in our center. The
median duration from the onset of symptoms to definitive
diagnosis of PVS was 16 weeks (range, 2 to 59). With the
exception of one patient, all were symptomatic with cough,
hemoptysis, or dyspnea and had an abnormal chest radiograph
with either pleural effusion or nonspecific haziness (Table 1). All
but two patients were initially misdiagnosed with either pneu-
omia (n=11), new-onset asthma (n=3), pulmonary embolism (n=6),
and/or lung cancer (n=4). Because of the incorrect diagnosis, one patient underwent
placement of an IVC filter and 1 patient underwent partial
resection of the left lung, which had no evidence of tumor
pathologically. The correct diagnosis of PVS was rarely made
before evaluation by the electrophysiologist who performed the
RFA.

Catheterization
All patients proceeded to the catheterization laboratory for
further investigation and possible angioplasty (Figure 1). In
two patients with single pulmonary vein involvement, pul-
monary artery wedge angiography demonstrated complete
vein occlusion and thus angioplasty could not be performed.
In one of these patients, attempted radiofrequency recanal-
zation of the occluded pulmonary vein was unsuccessful.
The remaining 17 patients underwent angioplasty of 30
pulmonary veins (Figure 2). Precatheterization spiral CT
graduated the vessel lesion as mild (n=4), moderate (n=8),
severe (n=10), or occluded (n=13). Pulmonary artery bal-

Figure 1. Flow diagram of study cohort. Pts indicates patients;
f/u, follow-up.

TABLE 1. Frequency of Clinical Signs/Symptoms at Presentation

<table>
<thead>
<tr>
<th>Sign/Symptom</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cough</td>
<td>17 (89)</td>
</tr>
<tr>
<td>Hemoptysis</td>
<td>12 (63)</td>
</tr>
<tr>
<td>Dyspnea on exertion</td>
<td>11 (58)</td>
</tr>
<tr>
<td>Pleuritic chest pain</td>
<td>11 (58)</td>
</tr>
<tr>
<td>Wheezing</td>
<td>8 (42)</td>
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<tr>
<td>Dyspnea at rest</td>
<td>7 (37)</td>
</tr>
<tr>
<td>Orthopnea</td>
<td>6 (32)</td>
</tr>
<tr>
<td>Asymptomatic</td>
<td>1 (5)</td>
</tr>
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</table>
A number of imaging modalities have been used in the evaluation of PVS, including transthoracic echocardiography, transesophageal echocardiography, quantitative perfusion scan, spiral CT scan (Figure 5), and MRI. Although previous reports have demonstrated MRI to be superior to transesophageal echocardiography in defining pulmonary venous anatomy, there are few data comparing MRI to spiral CT. MRI was useful in confirming the findings of the other modalities and in defining the precise location of the obstructing vein.

**Discussion**

Acquired PVS is a known but often underrecognized complication of RFA for atrial fibrillation. Our study emphasizes the importance of early recognition of signs and symptoms of PVS. In addition, our data support that this is a significant cause for death and life-altering problems. Since catheter ablation for atrial fibrillation is a relatively new procedure, not only patients but physicians outside the realm of a tertiary care center are often unaware of the specifics of the procedure and hence the potential complication. All but two patients in our series were misdiagnosed as having other respiratory ailments, and there was significant delay in the definitive diagnosis. Patients underwent unnecessary procedures including bronchoscopy, pleurocentesis, IVC filter, and lung resection. Many patients were also inappropriately treated for pneumonia or pulmonary emboli. Prompt recognition and early referral to an interventional cardiologist could theoretically preclude unnecessary procedures and ineffective treatment as well as prevent development of completely occluded vessels.

A number of imaging modalities have been used in the evaluation of PVS, including transthoracic echocardiography, transesophageal echocardiography, and spiral CT scan (Figure 5). Although previous reports have demonstrated MRI to be superior to transesophageal echocardiography in defining pulmonary venous anatomy, there are few data comparing MRI to spiral CT. For our patients, we consistently used spiral CT.
scan as the imaging modality to delineate abnormalities of pulmonary venous anatomy as well as associated abnormalities of the mediastinum/hilum (eg, enlarged nodes) or of the lung (eg, focal edema or hemorrhage). Although spiral CT scans were accurate in defining mild to severe degrees of stenosis, many vessels deemed occluded were found to be patent by use of the balloon wedge angiogram technique. This probably is related to the dye being forced through a collapsed and severely stenotic vessel, with otherwise undetectable flow under normal conditions. Angiography with balloon wedge injection is the definitive diagnostic modality, and we recommend catheterization in all patients, even if the pulmonary veins appear occluded by other imaging modalities.

<table>
<thead>
<tr>
<th>TABLE 2. Primary Catheterization and Recatheterization</th>
<th>Angio, mm</th>
<th>Balloon/Stent*</th>
<th>Angio, mm</th>
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<td>9.5</td>
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<tr>
<td>LLPV (Left Lower Pulmonary Vein)</td>
<td>1.8</td>
<td>6-mm Jupiter</td>
<td>5.5</td>
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<td>10-mm Intrastent</td>
<td>10</td>
</tr>
</tbody>
</table>

Change in vessel diameter is given for each pulmonary vein. LUPV indicates left upper pulmonary vein; LLPV, left lower pulmonary vein; RUPV, right upper pulmonary vein; and RLPV, right lower pulmonary vein.

*Where stent placement is not specified, only balloon dilation was performed.

†This portion of the table shows the involved pulmonary veins at the primary catheterization that was amenable to intervention with a balloon and/or stent.

‡This portion of the table shows data from additional procedures performed for restenosis.
In both the acquired and congenital forms, PVS uniformly has been a frustrating lesion to treat for cardiac surgeons and interventional cardiologists, with restenosis being a common occurrence. Surgical approach has been tried in some instances, with variable results, depending on the technique used, anatomy, and timing of surgery. In children, balloon angioplasty for PVS has been uniformly unsuccessful. In addition, endovascular stenting of the pulmonary veins in children has met with little clinical success. On the other hand, stent placement in the pulmonary veins after extrinsic compression in adults has yielded some clinical success.

The application of energy in the region of the pulmonary veins results in formation of organizing thrombus, necrotic myocardium, endovascular contraction, and proliferation of elastic lamina, in addition to intimal proliferation. This provides a substrate for angioplasty or stent placement different from other acquired or congenital forms of PVS and hence transcatheter therapy could potentially be successful. Surgery for this lesion may not be optimal because of the often-found long segment of stenosis, which may extend beyond the surgical field and be a significant risk for restenosis. Currently, there are no published series on the transcatheter management of PVS secondary to RFA, and the few published case reports available have variable results. Our results show that transcatheter management performed early after diagnosis and aimed at producing a widely patent pulmonary vein ostium can significantly improve the patient’s outcome. Importantly, our patients had an overall significant improvement in NYHA functional class. However, these results must be viewed with caution as restenosis was common, and 8 patients required repeat catheterization.

Although restenosis has occurred with balloon as well as stent angioplasty, some case reports have demonstrated early success. Vance et al reported a case in which they used a balloon and self-expandable stent in stenotic pulmonary veins with effective 1-year follow-up. We performed (when a flap occurred) stent angioplasty in affected veins. Though longer follow-up is needed to evaluate the restenosis rate in our series, restenosis within the stent occurred in 6 vessels in 4 patients, with resolution after repeat balloon angioplasty within the previously deployed stent. For the latter 4 of these 6 vessels, a cutting balloon was used initially followed by standard balloon angioplasty, with complete resolution of the balloon waist and a 1- to 2-mm increase in the stent diameter. Hosking et al concluded that restenosis within stents in
Angioplasty for Acquired Pulmonary Vein Stenoses

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angioplasty has encouraging midterm results, restenosis con-

vascular veins appear occluded by other imaging modalities. Although

phy should be performed on all patients, even if pulmonary

patient has undergone RFA for atrial fibrillation. Angiogra-

lem. A high index of suspicion should be maintained after a

significant morbidity and is a potentially life-altering prob-

addition, with only mid-term follow-up the true incidence of

PVS caused by RFA, remains limited by sample size. In

Figure 5. Spiral CT scan. A, What appeared to be complete

occlusion of the left upper pulmonary vein (arrows) 30 days after

radiofrequency ablation therapy for atrial fibrillation was found to

be amenable to angioplasty during balloon wedge angiography.

B, Subsequent angioplasty resulted in reestablishment of for-

ward flow despite the thickened edematous walls of the vein

with adjacent inflammatory changes of the left hilum.

pulmonary veins is due to the inherent nature of the pulmo-

nary vein and stent diameter rather than a function of the stent

itself. Thus, if distal vessel diameter is adequate, large stent

diameters would be crucial in maximizing patency of the

pulmonary veins.

Although there is clearly a procedural risk for these

patients, 3 of our 4 adverse events occurred during our early

experience. The only adverse event in the last 20 procedures

was 1 patient with a transient pulmonary hemorrhage. We

therefore recommend vigilance when performing balloon

pulmonary artery wedge contrast injections to avoid trauma

to the alveoli when there is minimal or no outlet to the left

atrium.

In addition to anatomic obstructions, a number of factors

have been postulated as influencing restenosis of the pulmo-

nary veins, including low-velocity venous flow, vessel cali-

ber, and intimal proliferation. Sadr et al have shown that

the myofibroblastic neoproliferative process plays a key

role in restenosis within congenitally stenotic pulmonary

veins. Perhaps future therapies for patients with PVS after

RFA could also be targeted at arresting the neoproliferative

stage, such as the use of immunosuppressive agents, chemo-

therapy, and radiation.

This study, despite being the largest series of patients with

PVS caused by RFA, remains limited by sample size. In

addition, with only mid-term follow-up the true incidence of

restenosis as well as symptomatic relief remain unknown.

Other limitations are inherent to the fact that this is a

retrospective analysis.

In conclusion, pulmonary vein stenosis after RFA causes

significant morbidity and is a potentially life-altering prob-

lem. A high index of suspicion should be maintained after a

patient has undergone RFA for atrial fibrillation. Angiogra-

phy should be performed on all patients, even if pulmonary

veins appear occluded by other imaging modalities. Although

angioplasty has encouraging midterm results, restenosis con-

tinues to be a limiting factor, as it has been with various other

forms of pulmonary vein stenosis. Patients with this lesion

require lifetime follow-up and potentially multiple proce-

dures to prevent the loss of lung segments. Further follow-up

is critical to evaluate the true success of this therapy and

patterns of restenosis. In the future, the number of patients in

whom PVS develops may decrease significantly with revision

of ablative techniques for atrial fibrillation.2,3

Acknowledgments

The authors thank Shelby Scouten for her dedication toward the

preparation of the manuscript.

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_Circulation_. 2003;108:1336-1342; originally published online September 2, 2003; doi: 10.1161/01.CIR.0000086322.21781.6A

_Circulation_ is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/108/11/1336

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