Six-Month Success of Intracoronary Stenting for Anomalous Coronary Arteries Associated With Myocardial Ischemia

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Anomalous coronary arteries, especially those that course between the aorta and the pulmonary trunk, are associated with increased cardiac events.[1–4] They are potentially catastrophic and not rare, being the second leading cause of sudden death in competitive athletes.[5] When recognized, anomalous coronary arteries have usually been treated by coronary bypass surgery.[6] We report our experience in 14 patients in whom intracoronary stents were successfully used to resolve objective and subjective evidence of myocardial ischemia.

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Fourteen patients (Table I) who underwent catheterization between June 1995 and August 1999 for objective (and usually subjective) evidence of myocardial ischemia were found to have their ischemia caused by an anomalous coronary artery. After the patient gave informed consent, it was elected to attempt coronary stenting as the revascularization option. The choice of stent used was often limited in our early experience by stent availability at the time of the procedure, although an attempt was made to assess the compressibility strength of the available stents before making a choice. The stents were implanted by standard percutaneous techniques, although technical difficulties with catheter support were often experienced because of the known difficulty in performing angioplasty in anomalous coronary arteries.[7] There were no complications during the procedures. Magnetic resonance imaging was used to confirm the course of anomalous coronary arteries that were suspected to pass between the aorta and the pulmonary trunk.[8] When anomalous left coronary arteries were known to pass between the aorta and the pulmonary trunk, concurrent transesophageal echocardiography was performed during stenting in an attempt to be sure that the stent was placed in the coronary segment between the aorta and the pulmonary trunk. This technique was useful in patients 2 and 10, but did not provide useful information in patient 5 due to limited echocardiographic visibility of the appropriate segment of the anomalous artery. In patient 3, intravascular ultrasound (CVIS 30-MHz transducer, Mountain View, California) was performed to determine whether an obstruction to flow was present that was not angiographically visible, because the patient had extensive objective evidence of ischemia despite an anomalous left coronary that had a posterior course behind the aorta and no apparent ostial abnormality. All patients underwent angiography and nuclear perfusion stress testing (patient 3 underwent stress echo testing) 6 months after the procedure, and similar stress testing yearly thereafter.

All patients had initially successful stent deployment with resolution of any luminal narrowing, if present (Figure 1). Follow-up angiography revealed continued wide patency in all but 1 patient. Patient 3 had early restenosis at the stent site, which recurred after the implantation of a different type stent. Finally, success was obtained by use of yet a third type of stent. All patients showed resolution of their noninvasively detected ischemia at the time that their follow-up angiograms showed continued patency. All patients but patient 3 (see the following) had abnormal nuclear perfusion imaging before stenting. All patients with successful stenting had normal perfusion imaging subsequently. All patients who had normal noninvasive testing 6 months after their procedure continued to do so for the duration of their follow-up; this noninvasive testing was conducted at a minimum of once per year.

Patient 3 was unusual in that the anomalous left coronary artery originated from the right coronary cusp adjacent to the right coronary ostium, and then passed posterior to the aorta, not between the aorta and the pulmonary trunk, and did not have any slit-like abnormality or any other obvious angiographic abnormality. The patient had angina even with mild exertion, and a stress echocardiogram confirmed marked hypokinesia of all segments, except the inferobasilar segment supplied by the right coronary artery. This patient had negative perfusion imaging believed to be due to global ischemia. Intracoronary ultrasonography at rest did not reveal any anatomic abnormalities that could explain an impairment of flow, but the angina and echocardiographic abnormalities disappeared after successful stenting of the proximal portion of the artery that passed through the aortic wall. However, the stress echocardiogram became abnormal again at the time that restenosis was documented. After repeat stenting episodes, the stress echocardiogram became normal and has continued to be normal with further follow-up.

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Surgical revascularization is often recommended when anomalous coronary arteries cause myocardial ischemia, especially when they pass between the aorta

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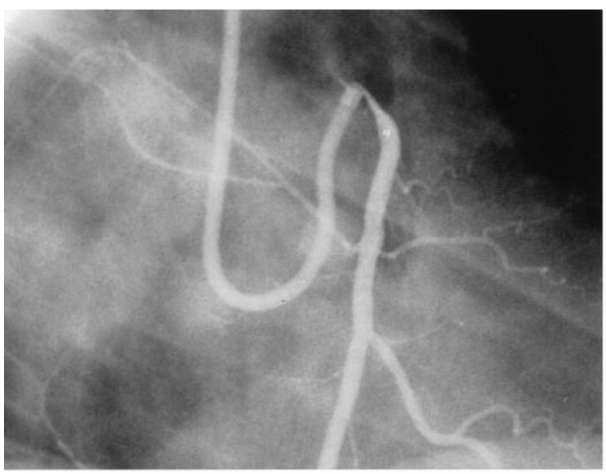
0002-9149/00/$–see front matter
PII S0002-9149(00)01023-7

TABLE I Stented Patients

Patient	Age/Sex (yrs)	Anomalous Coronary Artery	Course Between AA and PT	Slit at Ostium	Diameter Stenosis (%) Immediate	Diameter Stenosis (%) 6 Months	Interval Stenting to Stress Test (mo)	Stent Used
1	52/M	LM	+	O	<0%	0%	44	Palmaz-Schatz
2	61/F	LM	+	O	0%	—	—	ACE Duet
3	66/F	LM	O	O	0%	20%*	18	Palmaz-Schatz Cook GR2, AVE
4	72/M	LM	O	+	0%	0%	18	AVE GFX
5	44/M	Right	+	+	0%	—	—	Scimed PRIMO
6	48/M	Right	+	+	<0%	20%	54	Palmaz-Schatz
7	49/F	Right	+	+	0%	—	—	Scimed PRIMO
8	51/F	Right	+	+	0%	—	—	Scimed PRIMO
9	55/F	Right	+	+	0%	10%	12	AVE GFX
10	58/M	Right	+	+	10%	10%	12	AVE GFX
11	64/F	Right	+	+	10%	20%	6	ACE Duet
12	65/M	Right	+	+	0%	—	—	Scimed NIR
13	70/M	Right	+	+	10%	—	5	ACE Duet
14	51/F	LAD	+	O	0%	0%	12	AVE GFX

*Six months after third stent implantation.
AA = ascending aorta; LAD = left anterior descending; LM = left main; PT = pulmonary trunk.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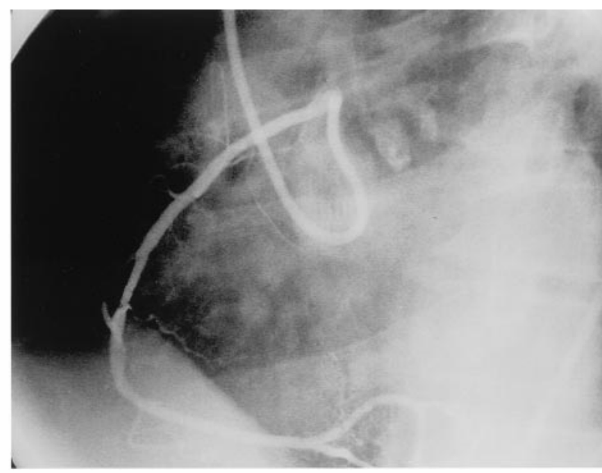
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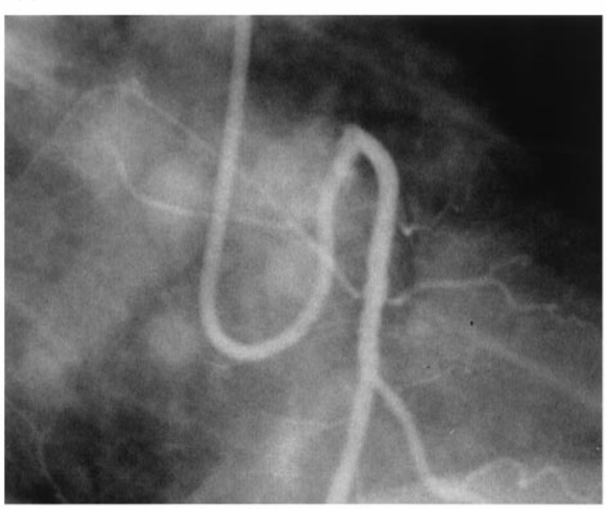
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FIGURE 1. The "slit-like" origin of the anomalous right coronary artery in the right anterior oblique projection *(A)*. This slit is typical of this coronary anomaly,[2] and persisted after catheter withdrawal and nitroglycerin administration, making catheter-induced spasm much less likely. This orifice was much less obvious in the left anterior oblique projection *(B)*. The right coronary artery after successful stent implantation in right anterior oblique projection *(C)*.

and the pulmonary trunk. Stent implantation had the same outcome as surgery in these patients, eliminating the subjective and objective evidence of ischemia. Although the exact mechanism of the associated morbidity and mortality of these anomalous coronary arteries is not fully defined, some contribution of com-

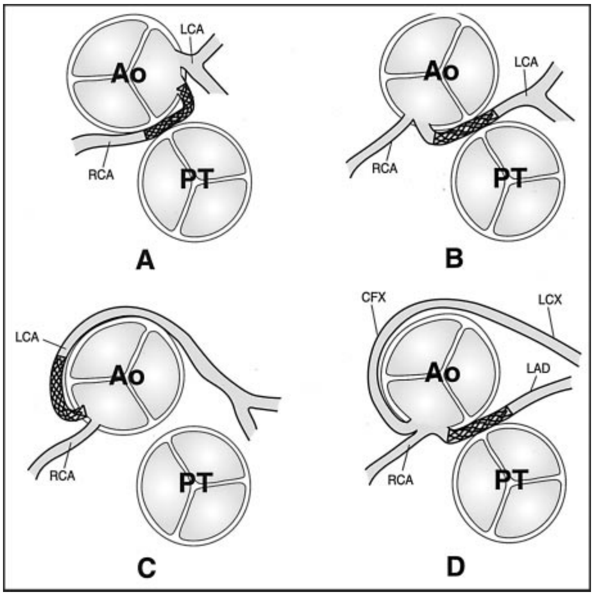

FIGURE 2. Schematic showing the anomalies encountered, with hatching showing the desired location of stent placement. *(A)* Anomalous right coronary artery from the left coronary cusp. Because the slit-like narrowing takes place at its origin, some minimal stent extension into the aorta was desired. *(B)* Anomalous left coronary artery from the right coronary cusp, passing between the ascending aorta and pulmonary trunk. Where feasible (see text) optimal stent location was defined intraprocedurally by transesophageal echocardiography. *(C)* Patient 3, in whom the left main artery was presumably compressed during exercise at its origin as it passed through the aortic wall. *(D)* Anomalous left anterior descending artery passing between the ascending aorta and the pulmonary trunk.

pression by the major vessels or the aortic wall exists (Figure 2).[1,2,3,9] Stents have considerable structural rigidity,[10] which may allow them to protect against such compression. Stenting was also able to correct the ostial slit-like lumen of the anomalous right coronary artery (Figure 2) and prevented the presumed aortic intramural compression during exercise of the anomalous left coronary that coursed behind the aorta. One episode of early stent restenosis occurred in a patient who had a Palmaz-Schatz stent. This stent appeared to be compressed in its midsegment, a complication that has previously been described for this stent.[11] This problem was not seen after restenting with a different stent or in subsequent cases using later generation stents.

The anomalous right coronary artery courses between the major vessels almost immediately after its origin, making stent placement in this setting relatively straightforward. Because the stent has to extend to the ostium of the vessel to treat the slit-like abnormality that is often present, standard 15- to 18-mm length stents will likely always also span the segment between the aorta and pulmonary trunk.[2] Correct stent placement is challenging when the left coronary courses between the major arteries because the target segment is not obvious using standard angiographic techniques.[8] We found the intraprocedural use of transesophageal echocardiography to be helpful in ascertaining that the stent was deployed in the correct position in our early experience when only 15-mm stents were available. The use of the longer stents that are now available made coverage of the critical segment between the aorta and the pulmonary trunk easier by covering much of the proximal portion of the anomalous vessel. Success in these cases was documented by the resolution of the ischemia by noninvasive testing.

In summary, coronary stenting may be an acceptable alternative to cardiac bypass surgery when anomalous coronary arteries cause myocardial ischemia.

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