e23 Atlas of Percutaneous Revascularization

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As indicated in Chap. 240, percutaneous coronary intervention (PCI) has assumed a major role in the management of coronary artery disease. It is used most commonly in patients with chronic stable angina, unstable angina, and primary therapy in acute ST segment elevation myocardial infarction.

This chapter illustrates some complex uses of percutaneous techniques, including management of cardiogenic shock, stent thrombosis, management of distal coronary vascular disease, and stenting of a chronic totally occluded vessel. In addition, pressure tracings obtained at left heart catheterization in the diagnosis of obstructive hypertrophic cardiomyopathy are shown, as is the percutaneous insertion of an experimental aortic valve. The latter has not yet been approved for clinical use but demonstrates one of the future extensions of percutaneous techniques.

CASE 1: CARDIOGENIC SHOCK WITH LEFT MAIN CORONARY ARTERY OBSTRUCTION

(Figs. e23-1 to e23-5; Videos e23-1 to e23-10)

- A 93-year-old man presented to the emergency room with 9 h of dyspnea and a sense of "dread"
- Prior subendocardial MI 2 months earlier managed medically (no catheterization done)
- Entry systolic pressure 70 mmHg, rales 2/3 way up, cool clammy extremities, arterial saturation 85% on 100% oxygen rebreathing mask
- Brought emergently to the catheterization laboratory—right heart catheterization performed

VIDEO e23-1 (Play video) Baseline left coronary angiogram shows severe ulcerated stenosis of the distal left main coronary artery.

FIGURE e23-2 Cardiogenic shock is present. The mean pulmonary capillary wedge (PCW) pressure is elevated at 23 mmHg, with prominent *v* waves (peaking after the ECG T wave), suggestive of mitral regurgitation. Arterial pressure is reduced (91/55 mmHg) despite dopamine infusion, and the respiratory rate (24/min) plus arterial desaturation (93%) on 100% O_2 suggest incipient pulmonary edema.

VIDEO e23-2 (Play video) As seen also in this right anterior oblique projection.
VIDEO e23-3 (Play video) There is also significant stenosis in the midportion of the dominant right coronary artery.
VIDEO e23-4 (Play video) Intraaortic balloon pump placed via contralateral groin. 8 Fr guiding catheter is used to place separate wires into the left anterior descending (LAD) and circumflex (CX) arteries.
VIDEO e23-5 (Play video) Simultaneous inflation of two 3.0-mm adjacent "kissing" balloons.
VIDEO e23-6 (Play video) Simultaneous kissing stent deployment in the LAD and Cx.
VIDEO e23-7 (Play video) Post-stent result.
VIDEO e23-8 (Play video) Post-stent result.

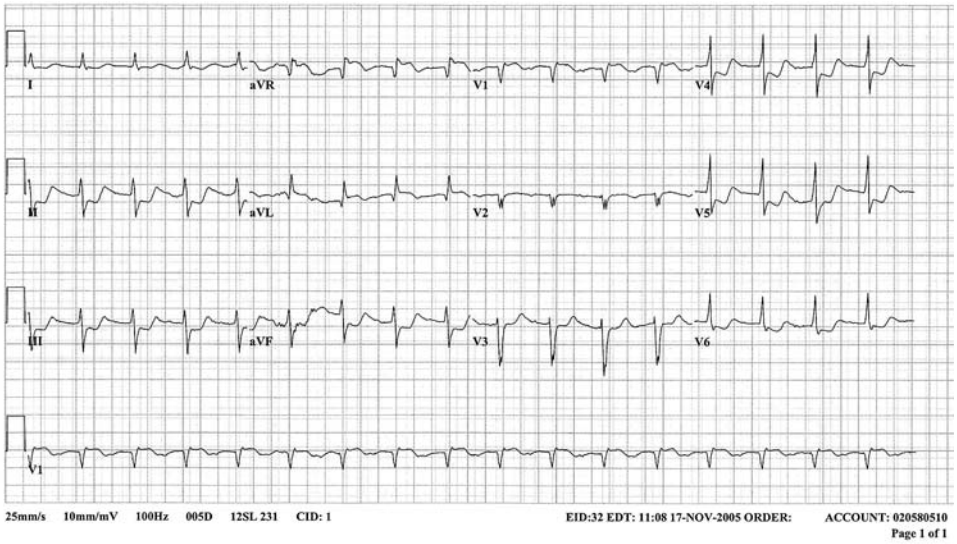

FIGURE e23-1 Presenting ECG—marked inferior and anterolateral ST depression.

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FIGURE e23-3 The aortic (Ao) pressure is reduced (78/52 mmHg), the pulmonary artery (PA) pressure is elevated (59/32 mmHg) and the Pa_{O_2} saturation (32%) corresponds to a cardiac index of 1.4 (L/min)/m^2, confirming the cardiogenic shock state.

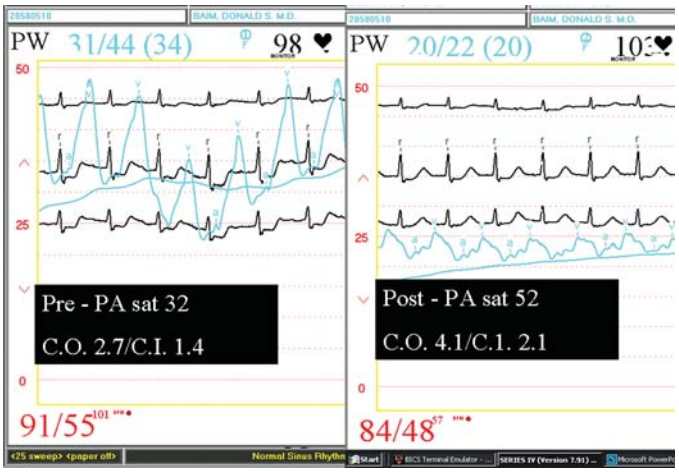

FIGURE e23-5 The PCW fell from 34 mmHg preintervention to 20 mmHg post-intervention with resolution of the tall *v* waves, and PA saturation increased from 32 to 52%, while cardiac index (CI) rose from 1.4 to 2.1 (L/min)/m^2.

VIDEO e23-9 **(Play video)** Shock persists, so the right coronary artery lesion was also stented.
VIDEO e23-10 **(Play video)** Result.

LEFT MAIN CORONARY ARTERY STENOSIS WITH CARDIOGENIC SHOCK

- Cardiogenic shock requires emergent revascularization
- Right heart catheterization is useful to assess and monitor hemodynamics, in this case showing profound shock and probable ischemic mitral regurgitation
- Coronary angio showed the cause—a critical ulcerated stenosis of the distal left main and right coronary artery (RCA)
- With intraaortic balloon pump insertion via the contralateral groin, and double wire, "kissing" balloon and kissing stent implantation were performed via 8 Fr guide
- Because of ongoing shock, RCA stenting also performed
- This stabilized hemodynamics with PCW falling to 10 mmHg, and cardiac output normalizing over first 8 h in CCU
- Patient recovered despite a peak CPK of 2300, CKMB 274
- Discharged on day 7, despite a pre-procedure 85% estimated PCI mortality!

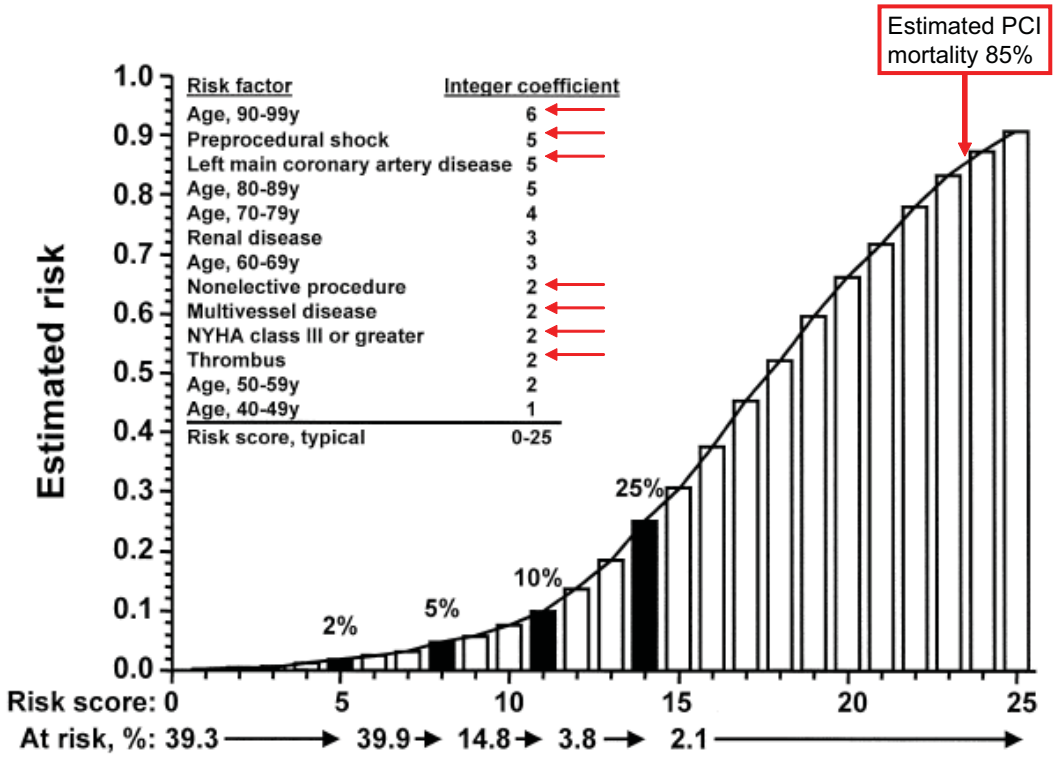

FIGURE e23-4 Estimation of risk of mortality of percutaneous coronary intervention (PCI). *(From M Singh et al: J Am Coll Cardiol 40:387, 2002.)*

CASE 2: INFERIOR MI WITH CARDIOGENIC SHOCK

(Figs. e23-6 and e23-7; Videos e23-11 to e23-19)

- A 67-year-old man with no prior cardiac history has 20 min of chest pain
- He is hypotensive and hypoxic (oxygen saturation 85% on 100% O_2)

VIDEO e23-11 (Play video) Angiography of the non-infarct left coronary shows unexpected distal left main bifurcation stenosis with possible superimposed thrombus.
VIDEO e23-12 (Play video) The right coronary artery is occluded proximally.
VIDEO e23-13 (Play video) Guidewire passage restores antegrade flow, exposing extensive linear thrombus and stenosis in the mid-RCA. Elapsed time since arrival in the catheterization laboratory—10 min.
VIDEO e23-14 (Play video) Some improvement in the filling defect after suction thrombectomy.
VIDEO e23-15 (Play video) Positioning a 3.5 × 32 mm drug-eluting stent to cover the culprit lesion.
VIDEO e23-16 (Play video) Stent deployment.
VIDEO e23-17 (Play video) Post-stent.
VIDEO e23-18 (Play video) Post-stent in shallow RAO cranial projection shows brisk flow in a very dominant right coronary artery. Elapsed time since catheterization laboratory arrival < 20 min.
VIDEO e23-19 (Play video) Sheath injection shows entry into the common femoral artery just above a moderate lesion. An intraaortic balloon pump was placed to stabilize the patient for bypass surgery of the left coronary artery the following day. Peak CPK was 337 (upper limit of normal = 200), indicating an aborted myocardial infarction with this very early reperfusion.

INFERIOR MI WITH CARDIOGENIC SHOCK

- Inferior MIs are usually more benign than anterior MIs
- When there *is* hypotension in an inferior MI, it may reflect right ventricular involvement as might have been the case here with the very proximal right coronary occlusion
- The severity of the hypotension and coexistent hypoxia here, however, suggest associated global ischemia due to the left main disease
- The patient was clinically stable after the intervention on the right coronary artery, and an intraaortic balloon was placed preparatory to bypass surgery of the left system
- The very early presentation and rapid intervention virtually completely aborted this life-threatening MI

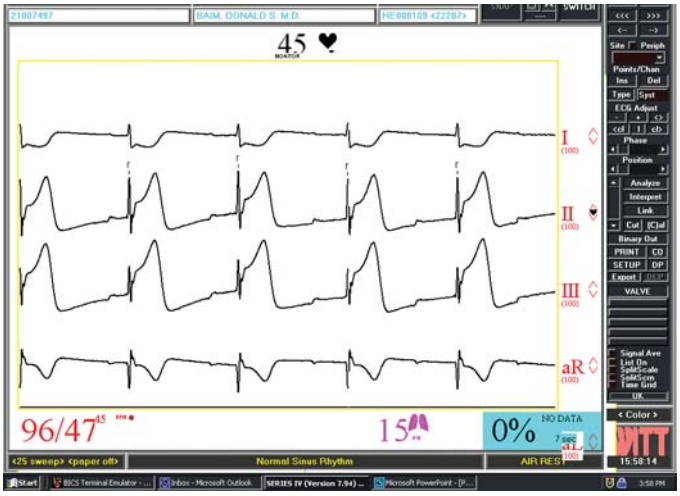

FIGURE e23-6 ECG shows sinus bradycardia, an accelerated idioventricular rhythm and isorhythmic dissociation, and profound inferior ST elevation.

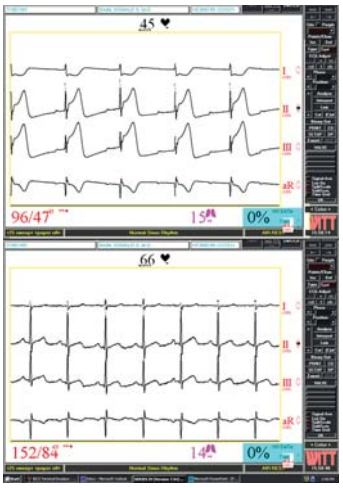

FIGURE e23-7 ***Top:*** Preintervention. ***Bottom:*** Postintervention. As soon as flow was restored, rhythm returned to normal sinus, ST elevation resolved, blood pressure rose to 152/84 mmHg despite discontinuation of dopamine, and oxygen saturation normalized (not shown). Right heart catheterization post-stent (not shown) revealed normal hemodynamics with wedge pressure of 12 mmHg and cardiac index of 2.4 (L/min)/m^2.

CASE 3: ANTERIOR MI STENT, WITH STENT THROMBOSIS

(Videos e23-20 to e23-25)

- A 37-year-old admitted cocaine user presented with severe chest pain and an anterior wall myocardial infarction
- Baseline angiography showed LAD thrombus, which was treated with thrombectomy
- The LAD and diagonal were then treated with "kissing" Cypher drug-eluting stents

VIDEO e23-20 Baseline angiography showing bifurcation thrombus in the LAD. ***A.*** (Play video) ***B.*** (Play video)
VIDEO e23-21 Rheolytic thrombectomy, with post-thrombectomy result. ***A.*** (Play video) ***B.*** (Play video)
VIDEO e23-22 Simultaneous drug-eluting stenting of the LAD-diagonal bifurcation (***A***) (Play video), with an excellent result (***B***) (Play video).
VIDEO e23-23 (Play video) The patient self-discontinued clopidogrel at 2 months after stenting, and developed recurrent pain 10 days later. Emergency coronary angiography shows recurrent LAD occlusion due to subacute stent thrombosis.
VIDEO e23-24 The stent thrombosis was crossed with wires into the distal LAD and diagonal (***A***) (Play video), restoring flow but showing filling defects representing thrombus. This was again treated with thrombectomy (***B***) (Play video).
VIDEO e23-25 (Play video) The result after thrombectomy was again excellent, although a small filling defect remains.

MYOCARDIAL INFARCTION STENTING, WITH STENT THROMBOSIS

- Coronary occlusions causing myocardial infarction usually contain some thrombus
- Although *routine* thrombectomy has not been shown to produce benefit, large thrombi respond well to thrombectomy
- The underlying, presumably atherosclerotic bifurcation lesion was then treated with "kissing" drug-eluting stents (DES) with a good result
- It is imperative that dual antiplatelet therapy be continued for at least 6 months post DES, since early discontinuation increases the risk of subacute stent thrombosis (SAT)
- In this case, as in most, SAT was associated with a substantial myocardial infarction

This case was contributed by Dr. James Kirshenbaum, Brigham and Women's Hospital, Boston; with permission.

CASE 4: DISTAL CORONARY DISEASE IN A DIABETIC PATIENT

(Videos e23-26 to e23-32)

- This 67-year-old non-insulin dependent diabetic developed refractory angina
- The culprit lesions were in the posterior descending and posterolateral branches of the dominant right coronary artery
- While bypass surgery is still the standard of care in diabetic patients with multivessel coronary disease, drug-eluting stenting may be an option in selected patients
- They present challenges for intervention because of distal location, small vessel diameter, diffuse disease, and a high restenosis rate due to diabetes mellitus

VIDEO e23-26 (Play video) Baseline angiogram in the shallow right anterior oblique view with cranial angulation shows the culprit lesions.
VIDEO e23-27 (Play video) Dilation of the posterior descending artery (PDA) with a 2-mm balloon.
VIDEO e23-28 (Play video) Post-angioplasty result shows significant residual stenosis.
VIDEO e23-29 Positioning a 2.5 × 24 mm drug-eluting stent in the distal posterior descending artery (PDA) (***A***) (Play video) and a 2.5 × 16 mm stent in the proximal PDA (***B***) (Play video).
VIDEO e23-30 (Play video) After documenting an excellent result in the PDA, the guidewire is relocated to the posterolateral branch, which is also predilated with a 2-mm balloon.
VIDEO e23-31 (Play video) Stent deployment.
VIDEO e23-32 (Play video) Excellent result in both vessels poststenting.

STENTING DISTAL CORONARY ARTERY DISEASE IN DIABETIC PATIENTS

- Diffuse distal disease in diabetics remains very challenging for both PCI and bypass surgery (due to poor distal targets)
- In this patient, poor prospects for a favorable outcome with surgery swung the balance to PCI
- The availability of flexible stents for small vessels has made treatment of such vessels possible
- Drug-eluting stents also reduce the incidence of restenosis (increased in patients with diabetes) to roughly 7% compared to roughly 25% with bare metal stents

CASE 5: CHRONIC TOTAL OCCLUSION STIFF GUIDEWIRE

(Videos e23-33 to e23-41)

- 75-year-old man with angina and inferior ischemia on exercise thallium-201 scan
- Catheterization shows moderate left anterior descending (LAD) coronary artery lesion, and chronic total occlusion of the circumflex (Cx) and right coronary arteries (RCA)

VIDEO e23-33 (Play video) Baseline left coronary injection shows LAD disease and occluded Cx-OM, plus left-to-right collaterals from AV groove Cx.
VIDEO e23-34 (Play video) Double (also known as "simultaneous") injection of the left and right coronaries demonstrates area of distal occlusion.
VIDEO e23-35 (Play video) Stiff guidewire slightly below trajectory.
VIDEO e23-36 (Play video) Stiff guidewire now across the occlusion and in a small branch of the PDA.
VIDEO e23-37 (Play video) After stenting, the RCA is widely patent, and now supplies right to left collaterals to the Cx.
VIDEO e23-38 (Play video) Poststenting view in AP cranial projection.
VIDEO e23-39 (Play video) Return of angina 10 months later—restudy shows widely patent RCA.
VIDEO e23-40 (Play video) Progression of the proximal LAD lesion, with slow flow at the apex.
VIDEO e23-41 (Play video) Post LAD stenting.

TOTAL OCCLUSION—STIFF WIRES

- The presence of one or more chronic total occlusions often leads to referral to surgery
- Using stiff (3.0–9 g) specialty guidewires, double injection, and painstaking technique, roughly 70% of these lesions can be crossed and, once crossed, stented with good long-term results.
- This patient declined to return for an attempt on the occluded Cx and did well for 10 months. Then he returned with a patent RCA and progressive disease in the LAD, which was in turn stented.
- If the RCA had not been opened, and the stents had not remained patent, the consequences of the severe LAD lesion progression might well have been more risky.

See Chaps. 22, 24, and 29.

CASE 6: HYPERTROPHIC CARDIOMYOPATHY (HCM) WITH OBSTRUCTION

HYPERTROPHIC CARDIOMYOPATHY (HCM) WITH OBSTRUCTION

(Figs. e23-8 to e23-11)

- Asymmetric hypertrophy of the upper septum can cause an intracavitary gradient within the LV due to contact of the anterior leaflet with the septum during systole

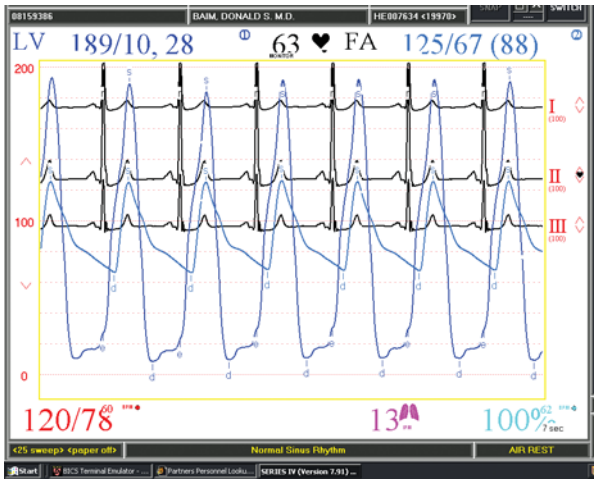

FIGURE e23-8 Simultaneous recording of the left ventricular (yellow) and femoral artery (orange) pressures shows a 60 mmHg pressure gradient. This could represent aortic stenosis, but this patient had a normal aortic valve on echo and asymmetric thickening of the upper left ventricular septum.

FIGURE e23-9 A spontaneous ventricular premature beat is followed by an augmented sinus beat marked by increased LV pressure and LV-Ao gradient, but a *decrease* in femoral artery pulse pressure, consistent with HCM with obstruction (Braunwald-Brockenbrough sign).

FIGURE e23-10 Slow pull-back of the end-hole catheter from the apex of the LV to the area just under the aortic valve shows disappearance of the pressure gradient.

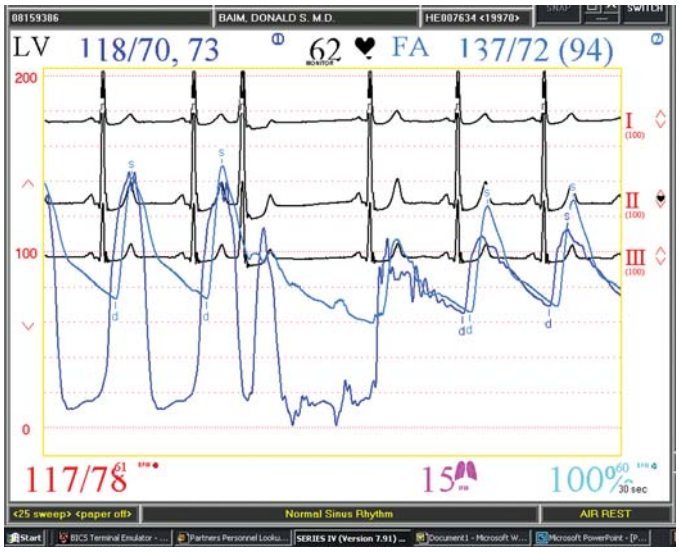

FIGURE e23-11 Continued pull-back into the aorta shows another VPB with reduced aortic pulse pressure and a "spike and dome" central aortic pressure tracing, again consistent with HCM with obstruction. Note that the femoral artery systolic pressure is slightly higher than the central aortic pressure due to peripheral augmentation.

- While the LV-Ao pressure gradient may look superficially like that seen in aortic stenosis, the characteristic decrease in aortic or peripheral arterial pulse pressure and spike-and-dome pattern in a post-ventricular premature contraction are seen only in HCM with obstruction
- An end-hole catheter positioned towards the LV apex allows recording this dynamic gradient, and intracavitary localization of the gradient during pull-back
- The diagnosis and evaluation of this disease, however, is more often made by echocardiography in current practice

CASE 7: PERCUTANEOUS AORTIC VALVE REPLACEMENT

(Figs. e23-12 to e23-15)

- The preferred treatment for severe aortic stenosis is surgical replacement of the aortic valve
- Although the average surgical mortality for this procedure is ~4%, some patients are at significantly higher risk due to advanced age, poor LV function, or other comorbidities
- Percutaneous balloon valvuloplasty was evaluated in the late 1980s, and provided limited benefit
- A new class of investigational percutaneous aortic valve replacement techniques, using pericardial valves mounted in an outer stent, are now under investigation

The case and data shown here were provided by Dr. Eberhard Grube of Sieburg, Germany; with permission.

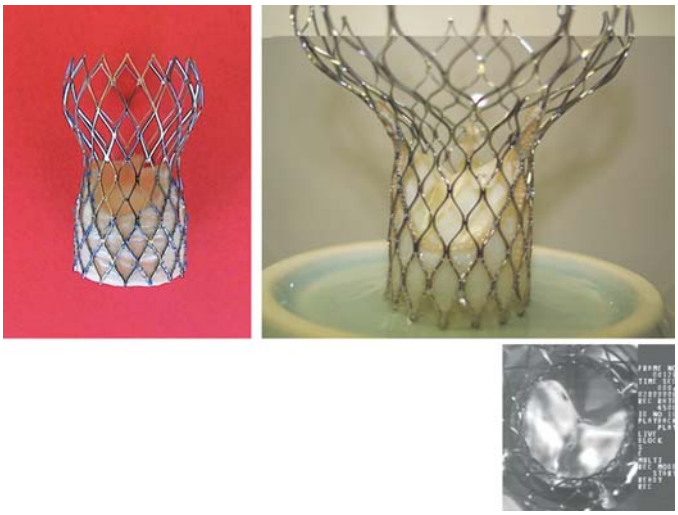

FIGURE e23-12 Self-expanding AV prosthesis: the CoreValve. A pericardium tissue valve fixed to the frame in a surgical manner.

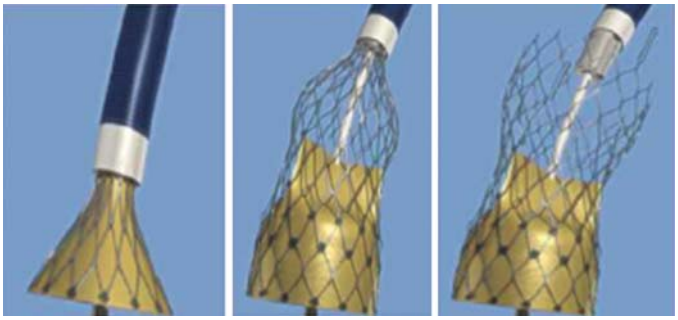

FIGURE e23-13 CoreValve delivery by sheath withdrawal.

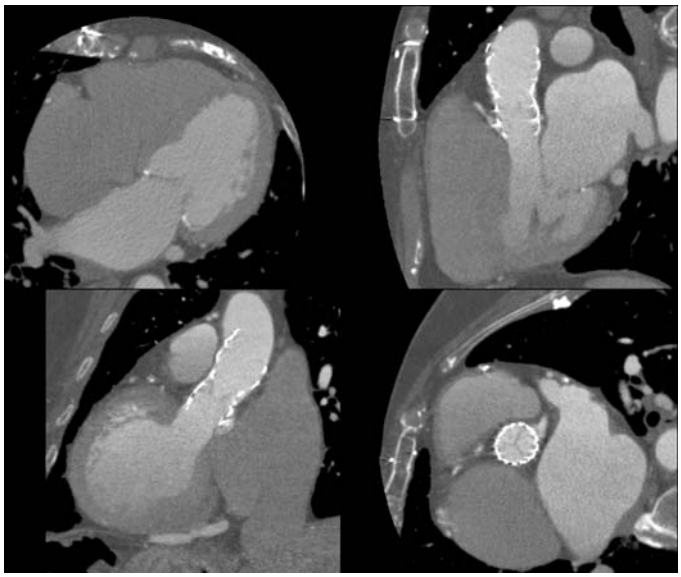

FIGURE e23-14 CoreValve follow-up: Post-implant morphologic assessment by CT scan.

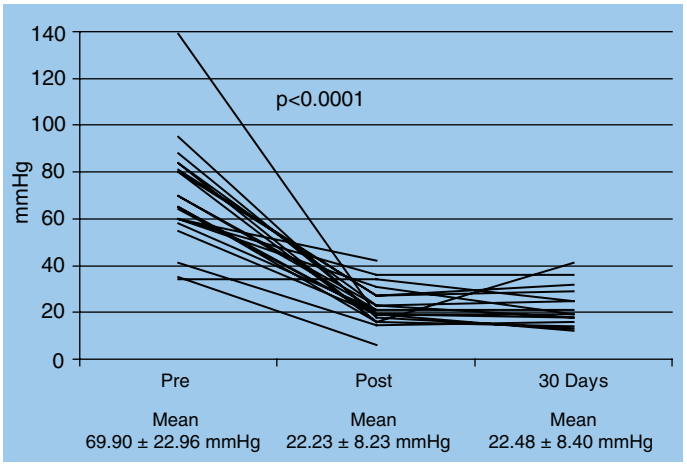

FIGURE e23-15 CoreValve study: Peak pressure gradients.