

Disposable Miniature Pressure Sensor for Cardiologist Use

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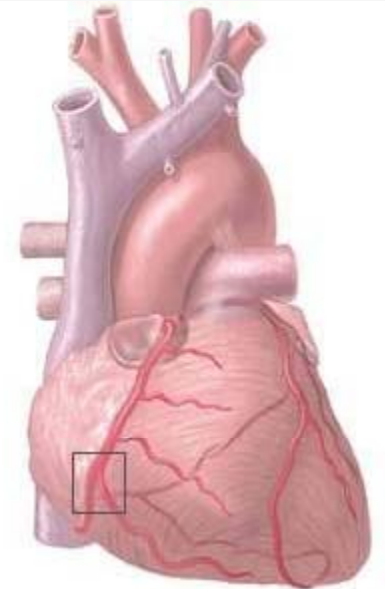
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Coronary Artery Disease

- ◆ Build up of **plaque** (fat and cholesterol)
- ◆ Arteries become narrowed and hardened
- ◆ Less blood flow to the heart muscle
- ◆ Heart muscle tissue can be damaged
- ◆ Atherosclerosis - hardening of the arteries



Blockage in right coronary artery



Symptoms?

Angina (chest pain)

- ◆ Exercise or stress
- ◆ Arteries are too narrow
- ◆ Not enough blood and oxygen to meet the increased demand

Heart attack

- ◆ Artery becomes completely blocked
- ◆ Cutting off blood and oxygen to part of the heart
- ◆ Causing that tissue to die

Background

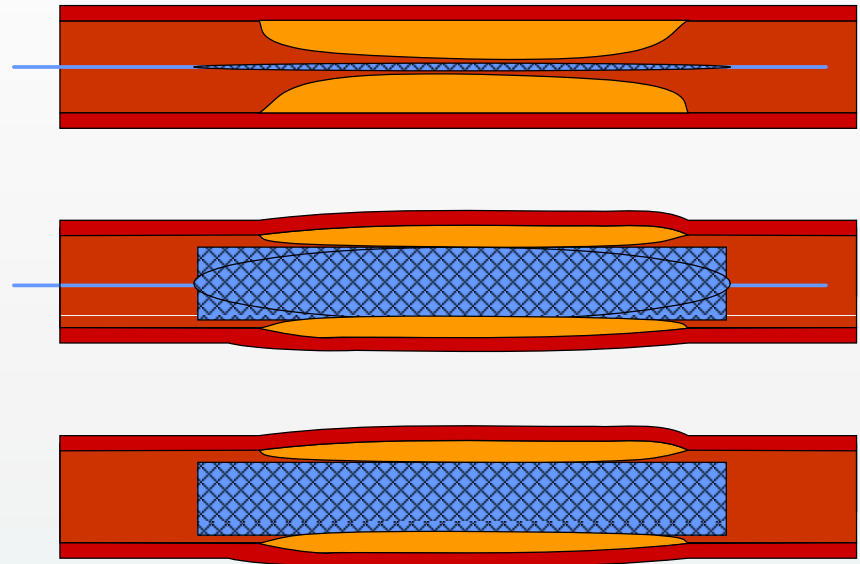
- ◆ **Coronary artery disease (CAD)**
 - ◆ Kills ~ 871,000 people/year
 - ◆ Leading cause of death in US
 - ◆ 14 million US patients /year ^[1]
- ◆ **Coronary angioplasty**
 - ◆ ~650,000 U.S. patients /year
 - ◆ More than 2 million /year worldwide
 - ◆ Nearly 3 million /year by 2010
 - ◆ Annual medical cost > 112 Billion

The 1st Balloon Angioplasty

- ◆ Dr. Andreas Gruentzig
- ◆ The first successful balloon angioplasty in the heart
- ◆ in (which year?)
1977
- ◆ in (which country?)
Switzerland
- ◆ Launched a new medical subspecialty - **interventional cardiology**
- ◆ Using **catheters** with a variety of devices on the tip, to treat heart problems without surgery.

What is Angioplasty?

- ◆ Surgery?
Non-surgical procedure
- ◆ Open blocked heart arteries
- ◆ Coronary: The arteries that supply the heart muscle with blood.



Interesting Latin Words:

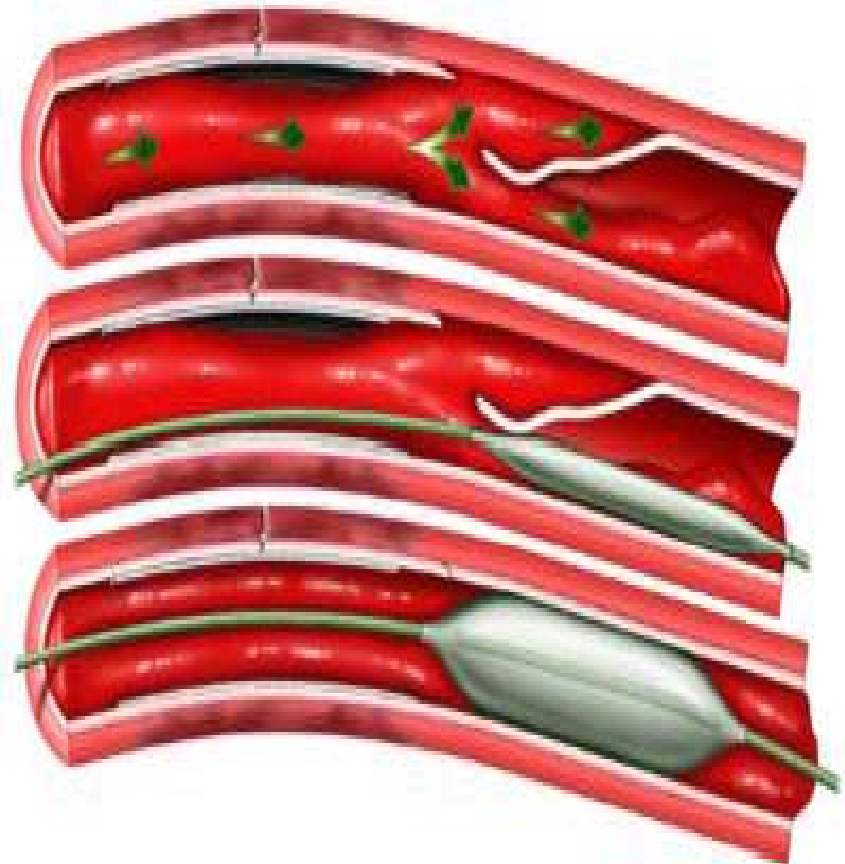
Coronary: crown

Angio: vessel

Plasty: repair

Balloon Angioplasty

- ◆ Guide a catheter with a small balloon tip to the narrowing
- ◆ Inflate the balloon
 - ◆ Compress the fatty matter into the artery wall
 - ◆ Stretch the artery open to increase blood flow to the heart



Stent-a Small Metal Mesh Tube

- ◆ Inflate the balloon tip
- ◆ Expand the stent to the size of the artery to hold it open
- ◆ Release and remove the balloon
- ◆ First coronary **stent** was approved in (which year?)

1993



Rotoblation

- ◆ Guide a special catheter with an acorn-shaped, **diamond**-coated tip
- ◆ The tip **spins** around at a high speed and **grinds** away the plaque
- ◆ The microscopic particles are washed safely away in your blood stream and filtered out by your liver and spleen
- ◆ Hard, calcified plaque

Atherectomy

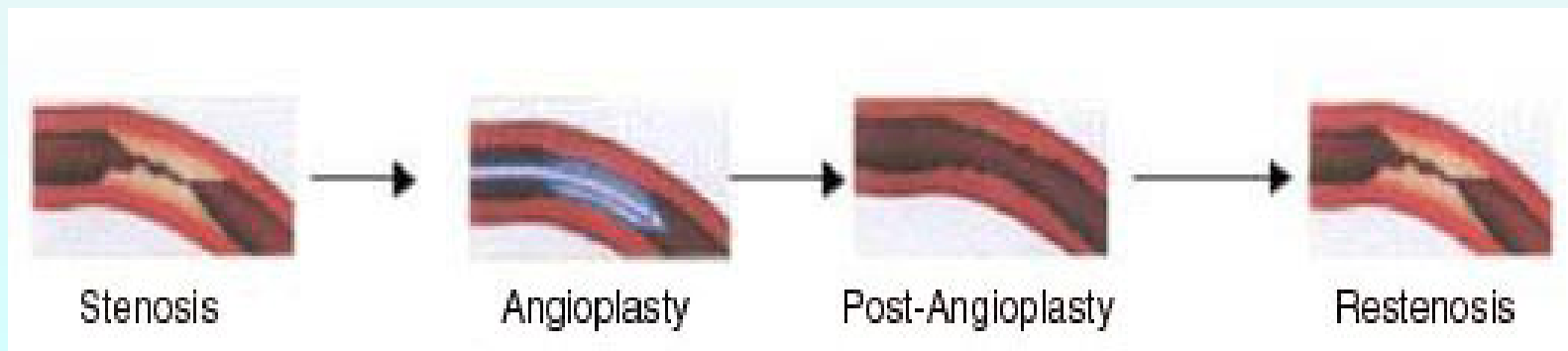
- ◆ Catheter has a hollow cylinder on the tip with an open window on one side and a balloon on the other
- ◆ Inflate the balloon
- ◆ Pushing the window against the fatty matter
- ◆ A **blade (cutter)** within the cylinder rotates and shaves off any fat that protruded into the window. (up to 1,200 revolutions per minute)
- ◆ The shavings are caught in a chamber within the catheter and removed.

Cutting Balloon

- ◆ Catheter has a special balloon tip with small **blades**
- ◆ Inflate the balloon
- ◆ Small blades score the plaque
- ◆ Balloon compresses the fatty matter into the artery wall.
- ◆ **Laser** angioplasty uses laser energy to destroy plaque

Restenosis

- ◆ Gradual re-narrowing of the artery
- ◆ Blood clots at or near the site of the treatment.
- ◆ Anti-clotting drugs
- ◆ Coronary stents coated with anti-clotting drugs



Why restenosis?

- ◆ Walls of the artery may **recoil** to their original position (**hours** after angioplasty)
- ◆ Angioplasty create tiny cracks in the plaque -> Causes **injury** to the artery wall
- ◆ Body attempts to **heal itself**
 - ◆ **Platelets** accumulate causes blood clots
 - ◆ **Thrombin** causes cells of artery to multiply and form new tissues

Angioplasty VS. Bypass Surgery

- ◆ Open up the narrowed vessel
- ◆ **1-2 days** hospital stay
- ◆ **Local** anesthesia
- ◆ Chest not opened
- ◆ No heart-lung machine
- ◆ Death rate ~**0.1%**
- ◆ Successful in **98%** patients
- ◆ Major complications: **1.5%**
- ◆ Emergency bypass surgery: **0.1%**
- ◆ Restenosis – redo the angioplasty next few months
- ◆ Create a different blood vessel
- ◆ **1-2 weeks**
- ◆ **General** anesthesia
- ◆ Open chest
- ◆ Needs; risk of stroke
- ◆ **1% to 2%**
- ◆ Severe plaques
- ◆ Many narrowings in arteries -> higher risk
- ◆ Weakly pumping heart

Angioplasty V.S. Medication

	Angioplasty	Medication
Rate of deaths, heart attacks and strokes	20%	19.5%
Hospitalization rate for heart attacks and worsening chest pain	12.4%	11.8%
Hospitalization rate for heart attacks alone	13.2%	12.3%
Pain free after 5 years	74%	72%
Initial Cost	~ \$8,000	~ \$2,700

Riskier and no more beneficial than medication

Drug therapy could account for as much as \$1 billion a year in medical savings (\$5,000 * 200,000 patients ~ \$1,000,000,000)

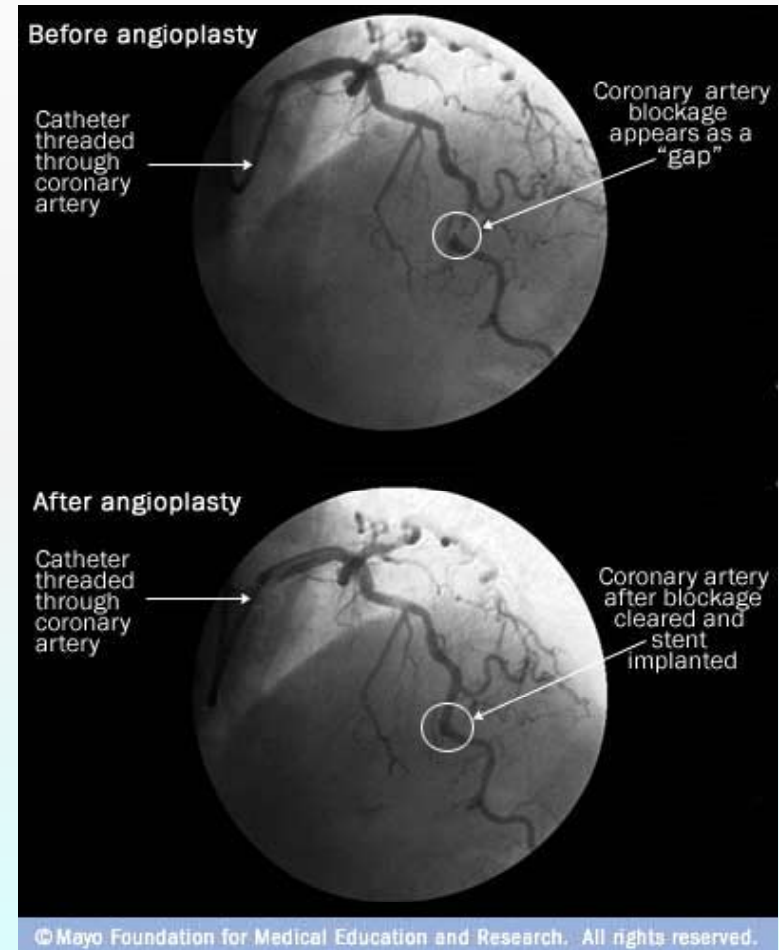
Source: *The New England Journal of Medicine*, March 2007 (2,287 patients)

Comments from Doctors

- ◆ “In low-risk patients with stable coronary artery disease, aggressive lipid-lowering therapy is **at least as effective as** angioplasty and usual care in reducing the incidence of ischemic events.” [4]
- ◆ “In this small pilot study, intensive medical therapy and PTCA were **comparable at** suppressing ischemia in stable patients after AMI. ..Corroboration of these preliminary findings in a larger cardiac-event trial is warranted.” [5]

Who Needs Angioplasty?

- ◆ How many blockage
- ◆ Where is the blockage
- ◆ Extent of the blockage
- ◆ Evaluate the last angioplasty
- ◆ Assess blood flow

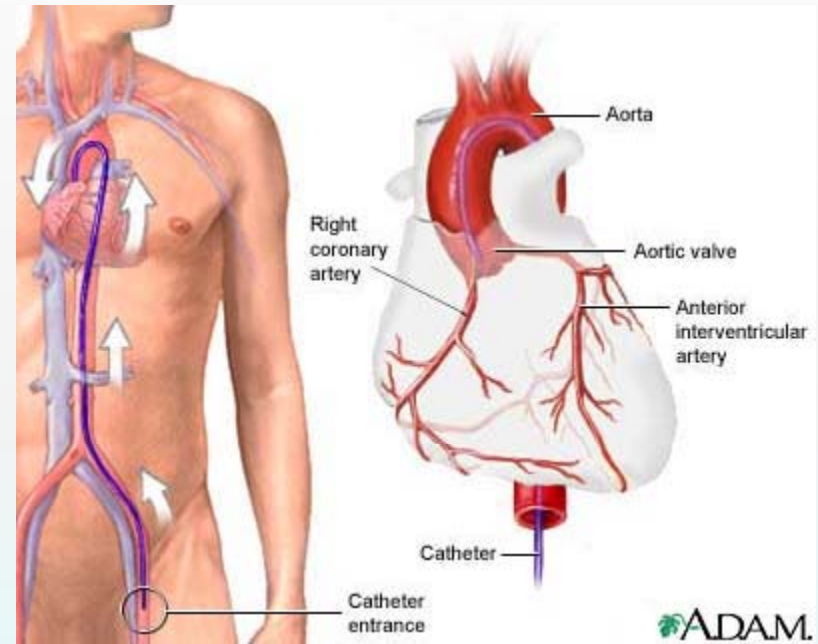


Coronary angiogram (cardiac catheterization)

- ◆ Thread a **catheter** through the blood vessels to the heart
- ◆ Inject a special contrast **dye** that shows up on x-rays into the arteries
- ◆ Take **X-ray** images
- ◆ Look for narrowed areas in the arteries
- ◆ Determine how severe the narrowings are

How to do Angiogram?

- ◆ Numb: local anesthesia
- ◆ Insert a **sheath** (a thin plastic tube) into an artery from groin or arm
- ◆ Pass a **catheter** through the sheath and guide up the blood vessel to the arteries surrounding the heart.



<http://www.mayoclinic.com/health/coronary-angiography/HB00048>

How to do Angiogram (2)?

- ◆ Inject a small amount of **contrast material** through the catheter
- ◆ **Photograph** as it moves through the heart's chambers, valves, and major vessels
- ◆ Tell whether the coronary arteries are narrowed and/or whether the heart valves are working correctly

Problems of Angiogram

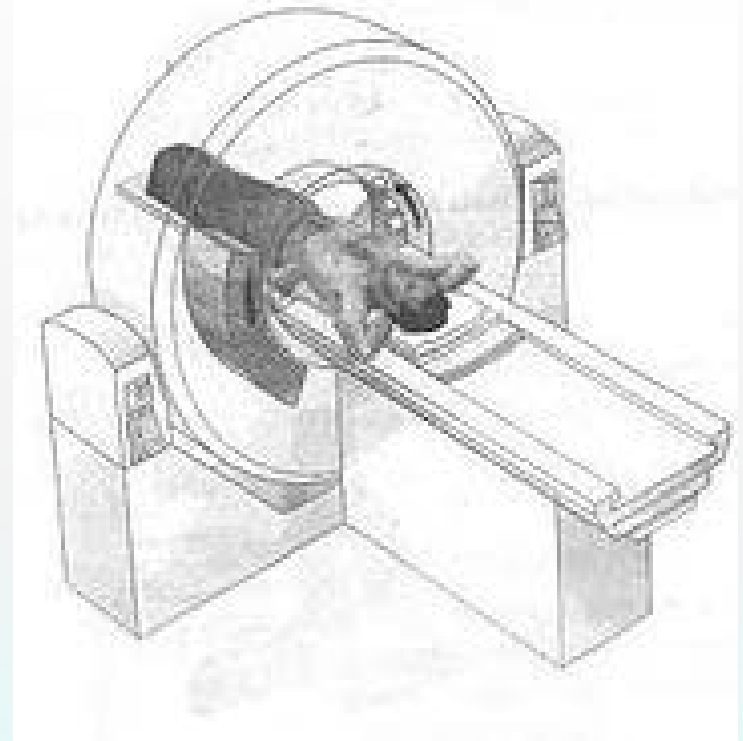
- ◆ Potential risks -> stroke; heart attacks
- ◆ Allergic to the iodine dyes
- ◆ Kidney damage
- ◆ Infection
- ◆ Trauma to the catheterized arteries
- ◆ Radiation exposure from the X-rays

X-Ray

- ◆ Body is made up of various substances with differing densities
- ◆ Denser substances (e.g. calcium rich bones) absorb X-ray photons -> film unexposed ->translucent blue
- ◆ Lower-density tissues (e.g. fat, skin, organs) -> black part of the film
- ◆ Reveal the internal structure of the body on film

Computerized Tomography (CT)

- ◆ An X-ray source rotates around the object
- ◆ X-ray sensors are positioned on the opposite side of the circle from the X-ray source
- ◆ large series of 2D X-ray images
- ◆ 3D image inside of an object



Greek words:
Tomography *tomos*
(slice) and *graphein* (to
write).

Problems of Cardiac CT Angiography

- ◆ Heart is effectively imaged more than once
->a relatively high radiation exposure
around 12 mSv
- ◆ A chest X-ray: ~0.02 to 0.2 mSv
- ◆ Natural background radiation exposure:
~0.01 mSv/day
- ◆ **100-600** chest X-rays or over **3 years**
worth of natural background radiation

Angiogram -> ??

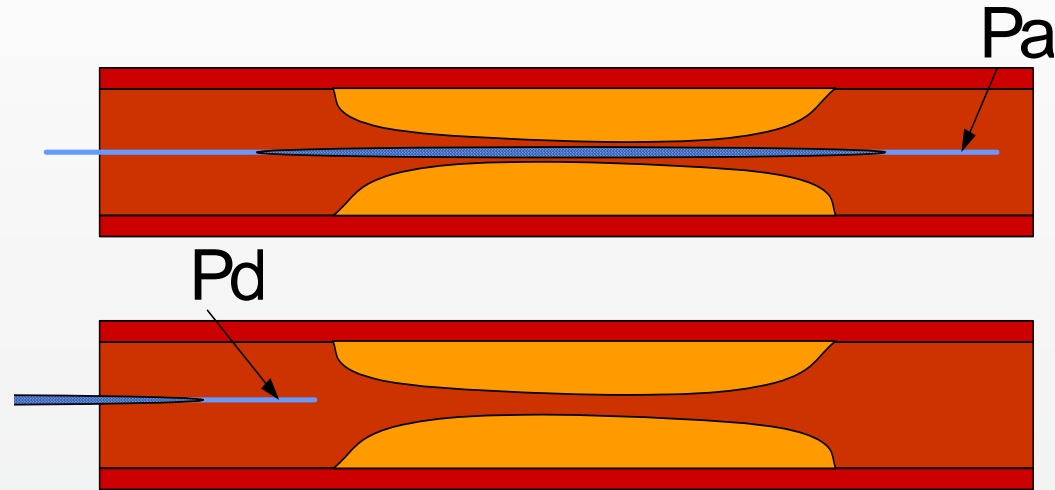
Angiogram

- ◆ Not always clear to decide which narrowing is the culprit lesion
- ◆ May underestimate or overestimate narrowing

??

- ◆ Account collateral flow
- ◆ Functional evaluation

Fractional Flow Reserve (FFR)



$$\text{FFR} = P_d / P_a$$

- ✓ P_d = pressure behind (distal to) a stenosis
- ✓ P_a = pressure before the stenosis

Abnormal?

- ◆ **Maximal flow** down a vessel in the **presence of a stenosis** compared to the maximal flow in the hypothetical **absence of the stenosis**
- ◆ No absolute cut-off point
- ◆ Cut-off point: 0.75-0.80

Radi's hydrophilic PressureWire® Certus

- ◆ <http://www.radi.se/home.aspx?n=10&m=6&s=8&r=1>

Can These Procedures Cure Coronary Artery Disease?

- ◆ Operation: 1.5-2.5 hours
- ◆ Preparation and recovery: several hours
- ◆ Several weeks for arteries heal (stent)
- ◆ Rarely used: Rotablation; atherectomy; cutting balloon.
- ◆ Cure coronary artery disease?
 - ✓ Will not cure.
 - ✓ Lifestyle factors: smoking and diet
 - ✓ An exercise program

References

- ◆ [\[1\] http://www.redwoodeditor.com/content/SCAI/scai/](http://www.redwoodeditor.com/content/SCAI/scai/)
- ◆ [\[2\]](#) Tonino PA, De Bruyne B, Pijls NH, *et al* (January 2009). "Fractional flow reserve versus angiography for guiding percutaneous coronary intervention". *N. Engl. J. Med.* 360 (3): 213–24. [doi:10.1056/NEJMoa0807611](https://doi.org/10.1056/NEJMoa0807611). [PMID 19144937](https://pubmed.ncbi.nlm.nih.gov/19144937/).
- ◆ [3] Cohen D. J., Carrozza J. P., Baim D. S., Ricciardi M. J., Davidson C. J., Bloom J. M., Pitt B., Waters D., Brown W. V., (Dec 9, 1999), [“Aggressive Lipid-Lowering Therapy Compared with Angioplasty in Stable Coronary Artery Disease”](#)
N Engl J Med 1999; 341:1853-1855.

References

- ◆ [4] Habib A. Dakik, MD; Neal S. Kleiman, MD; John A. Farmer, MD; Zuo-Xiang He, MD; Juliet A. Wendt, MD; Craig M. Pratt, MD; Mario S. Verani, MD; John J. Mahmarian, MD, (*Circulation*. 1998;98:2017-2023.) © 1998 American Heart Association, Inc. “Intensive Medical Therapy Versus Coronary Angioplasty for Suppression of Myocardial Ischemia in Survivors of Acute Myocardial Infarction - A Prospective, Randomized Pilot Study”, Presented in part at the 46th Scientific Sessions of the American College of Cardiology, Anaheim, Calif, March 17, 1997 and published in abstract form (*J Am Coll Cardiol*. 1997;29(suppl A):53A.