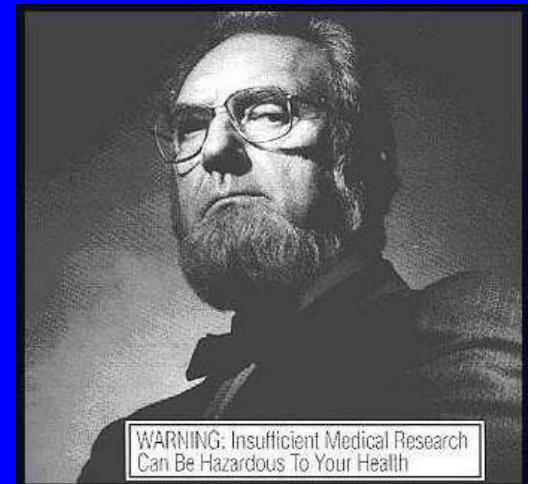


# BIOE 301

## Lecture Fifteen

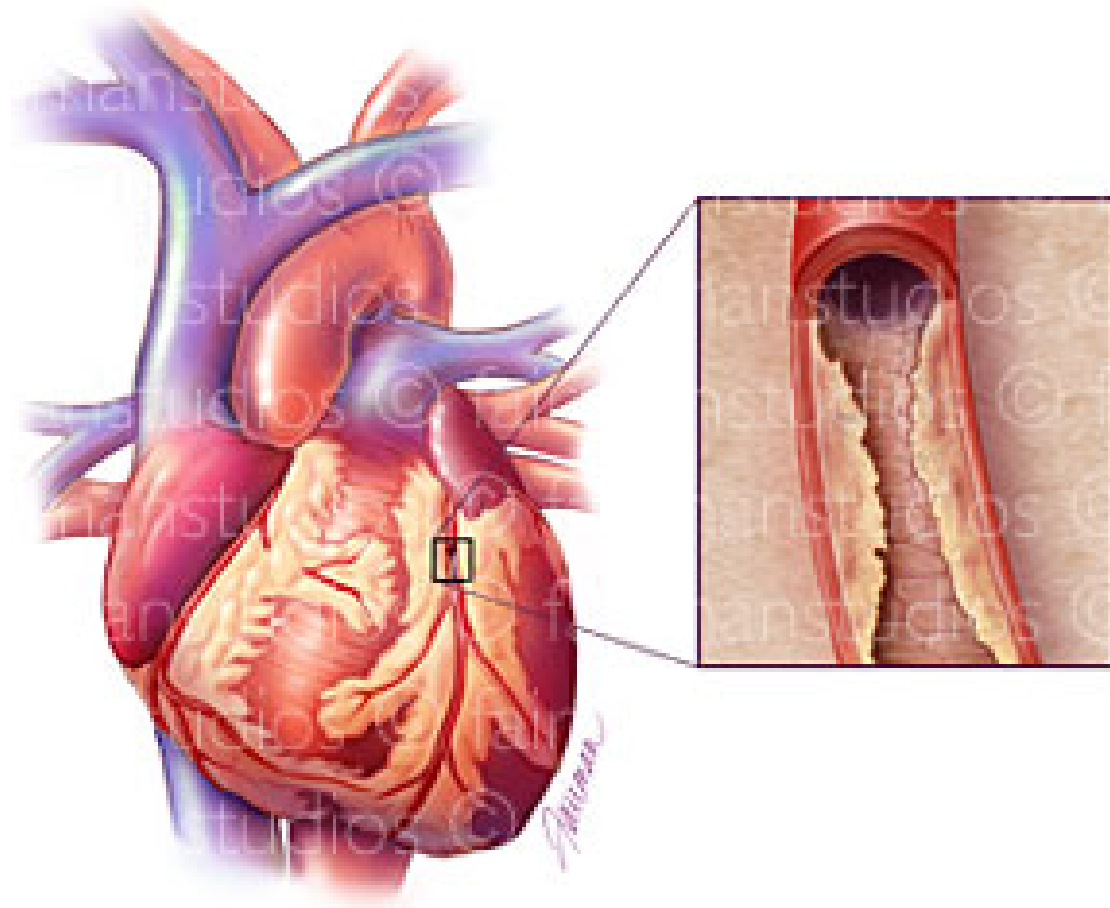


# Outline

- The burden of heart disease
- The cardiovascular system
- How do heart attacks happen?
- How do we treat atherosclerosis?
  - Open heart surgery
  - Angioplasty
  - Stents
- What is heart failure?
- How do we treat heart failure?
  - Heart transplant
  - Left ventricular assist devices
  - Artificial heart

# Early Warning Signs of Heart Attack

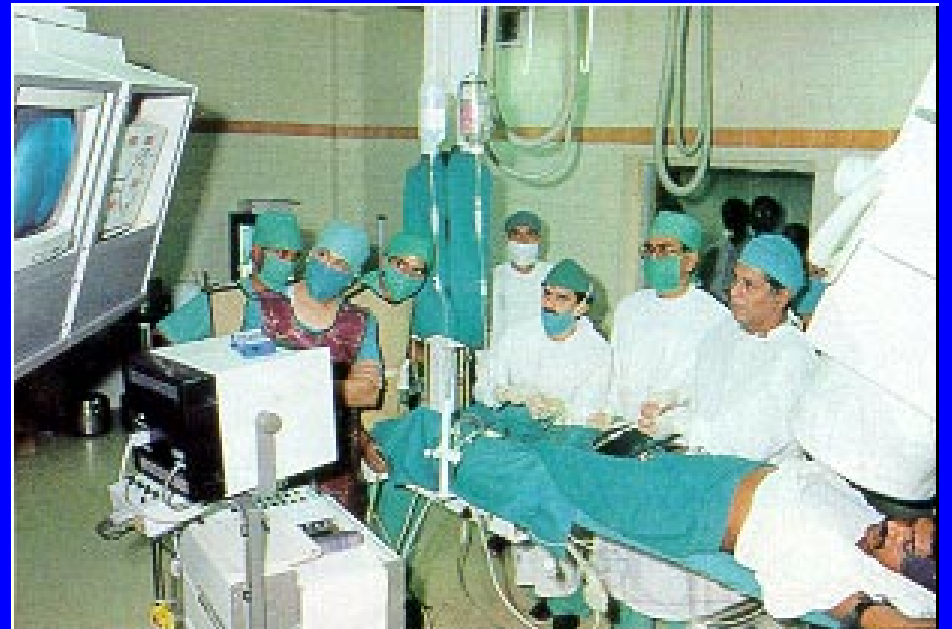
- Many heart attacks start slowly; symptoms may come and go
- Chest discomfort
  - Most heart attacks involve discomfort in the center of the chest that lasts for more than a few minutes, or goes away and comes back. The discomfort can feel like uncomfortable pressure, squeezing, fullness, or pain
- Discomfort in other areas of the upper body
  - Can include pain or discomfort in one or both arms, the back, neck, jaw, or stomach
- Shortness of breath
  - Often comes along with chest discomfort. But it also can occur before chest discomfort
- Other symptoms
  - May include breaking out in a cold sweat, nausea, or light-headedness



# Heart Attacks

Diagnosis of Atherosclerosis

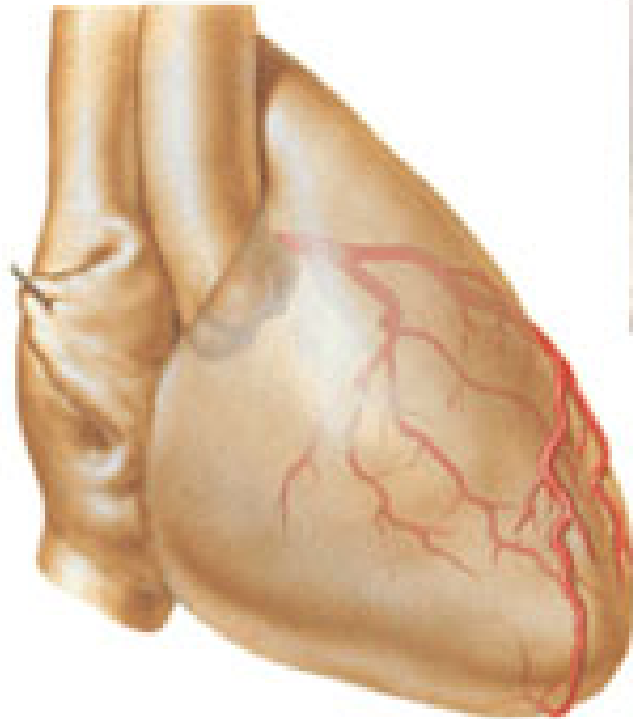
# Detection of Atherosclerosis



# Access to Cardiothoracic Surgery

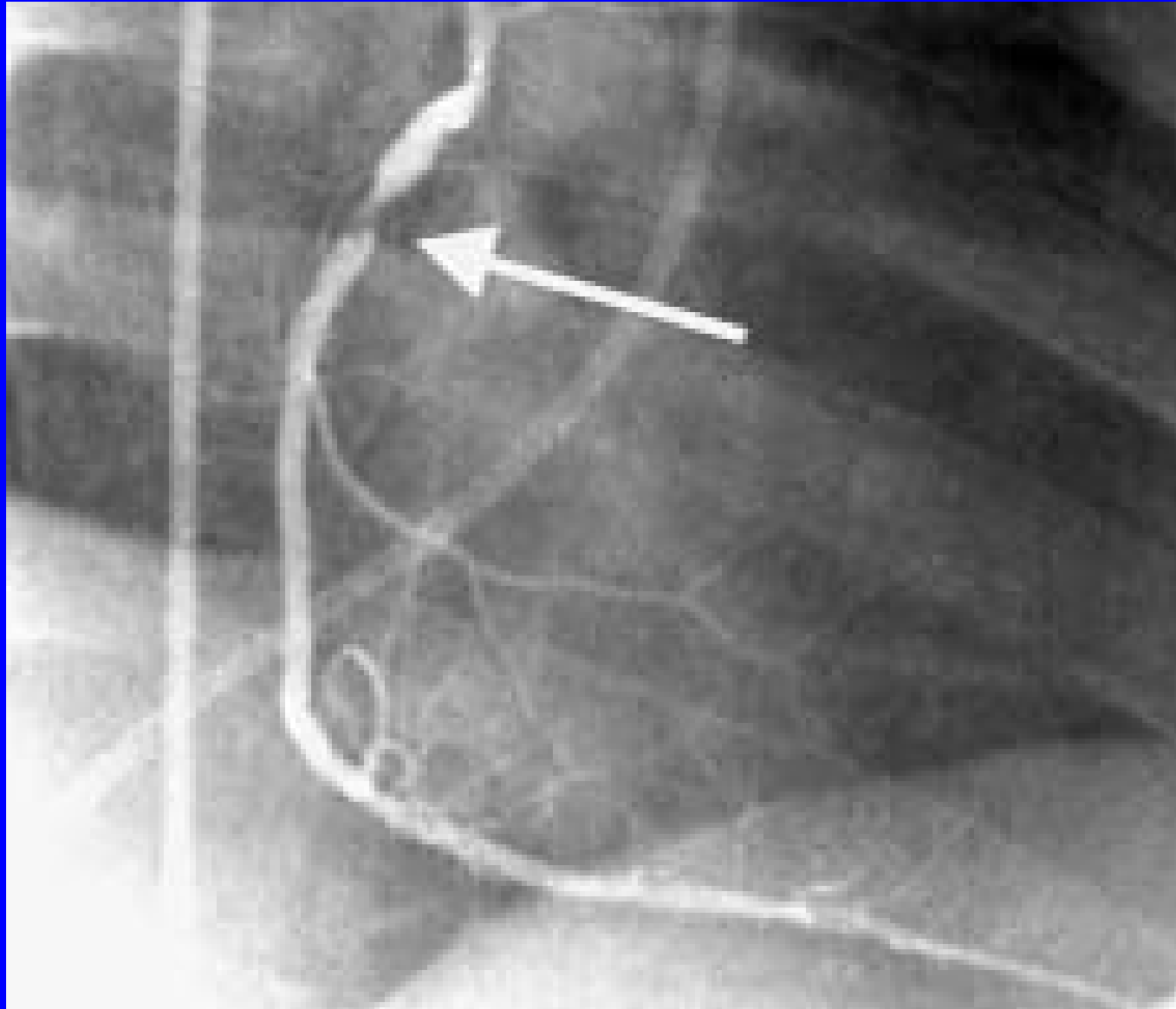
- surgery cost and availability of trained individuals and centers are significant issues for cardiothoracic surgery worldwide.
- It is estimated that >10,000 cardiothoracic surgeons in >6,000 centers globally perform more than 2M open heart operations per year.
- 1,222 open heart operations per
  - 1 million population in North America
  - 18 per million in Africa
- translates into 1 center per
  - 120,000 people in the USA
  - 33 million people in Africa

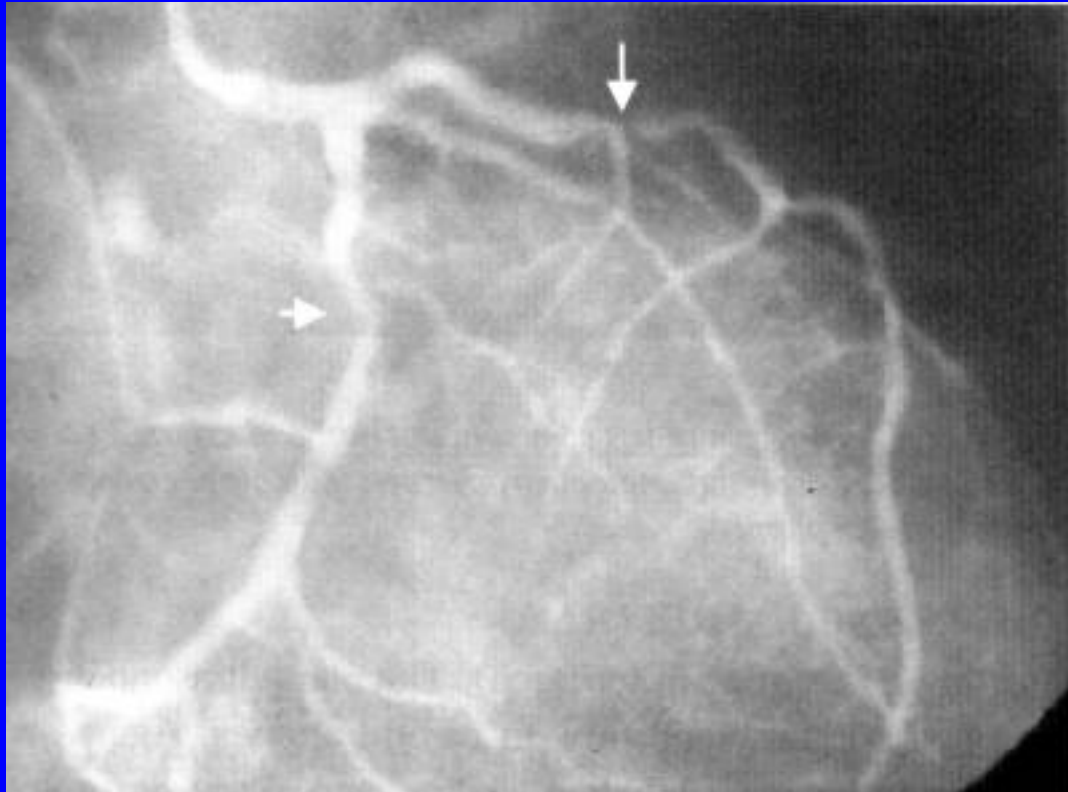
## Left Coronary Artery Arteriographic View 2



*Netter*  
© 2004 Thieme





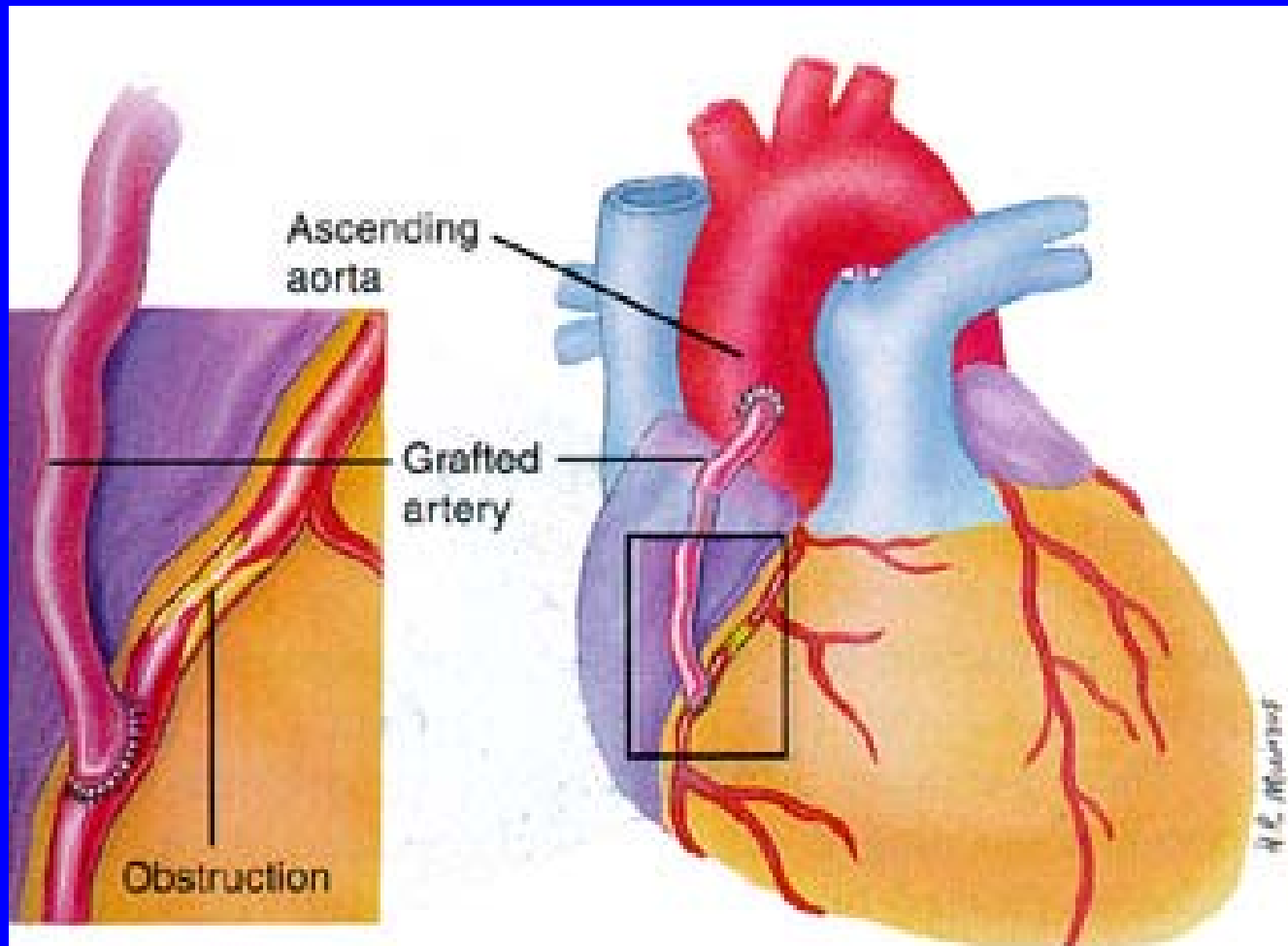


# Heart Attacks

Treatment of Atherosclerosis

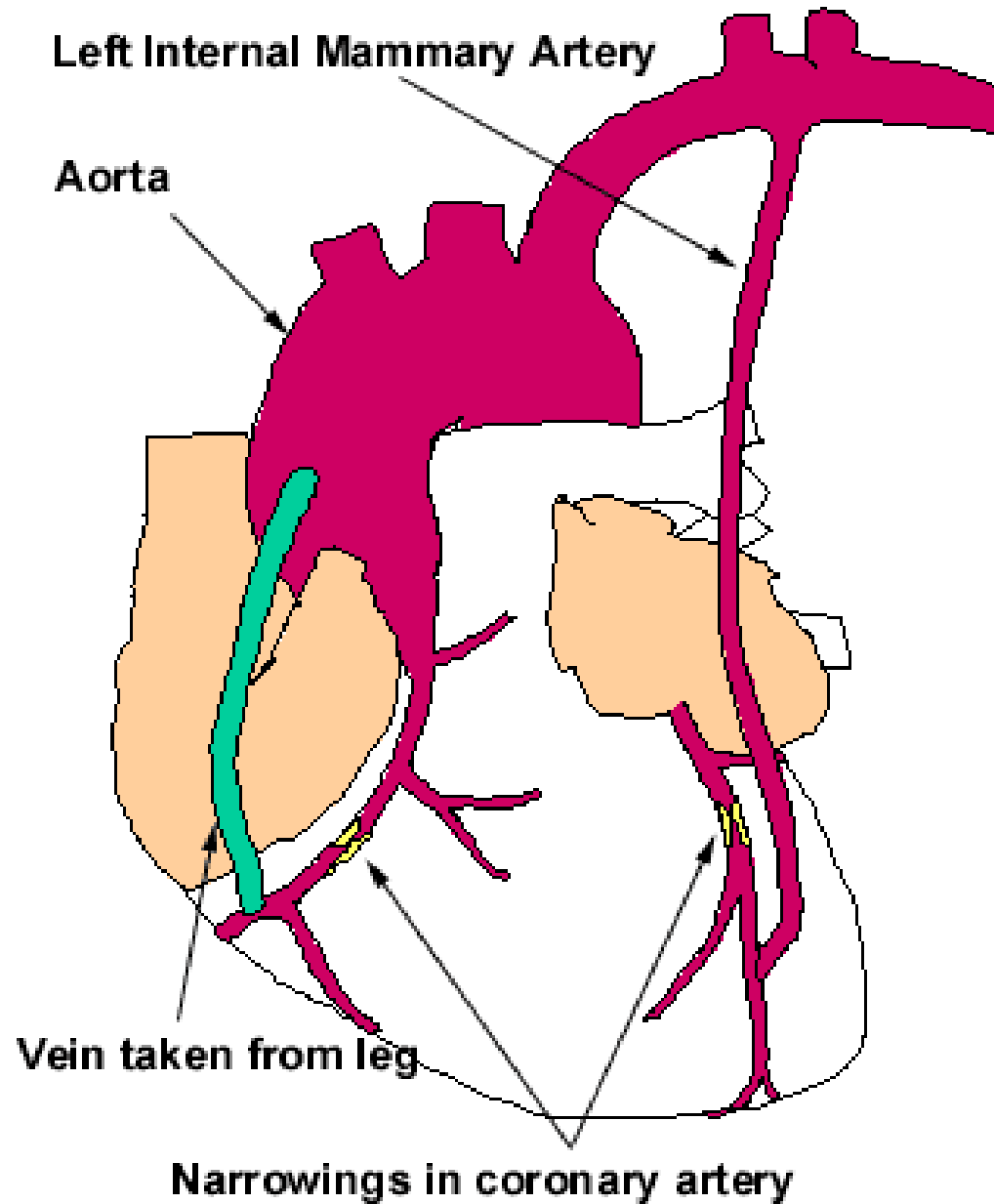
# How Do We Treat Atherosclerosis?

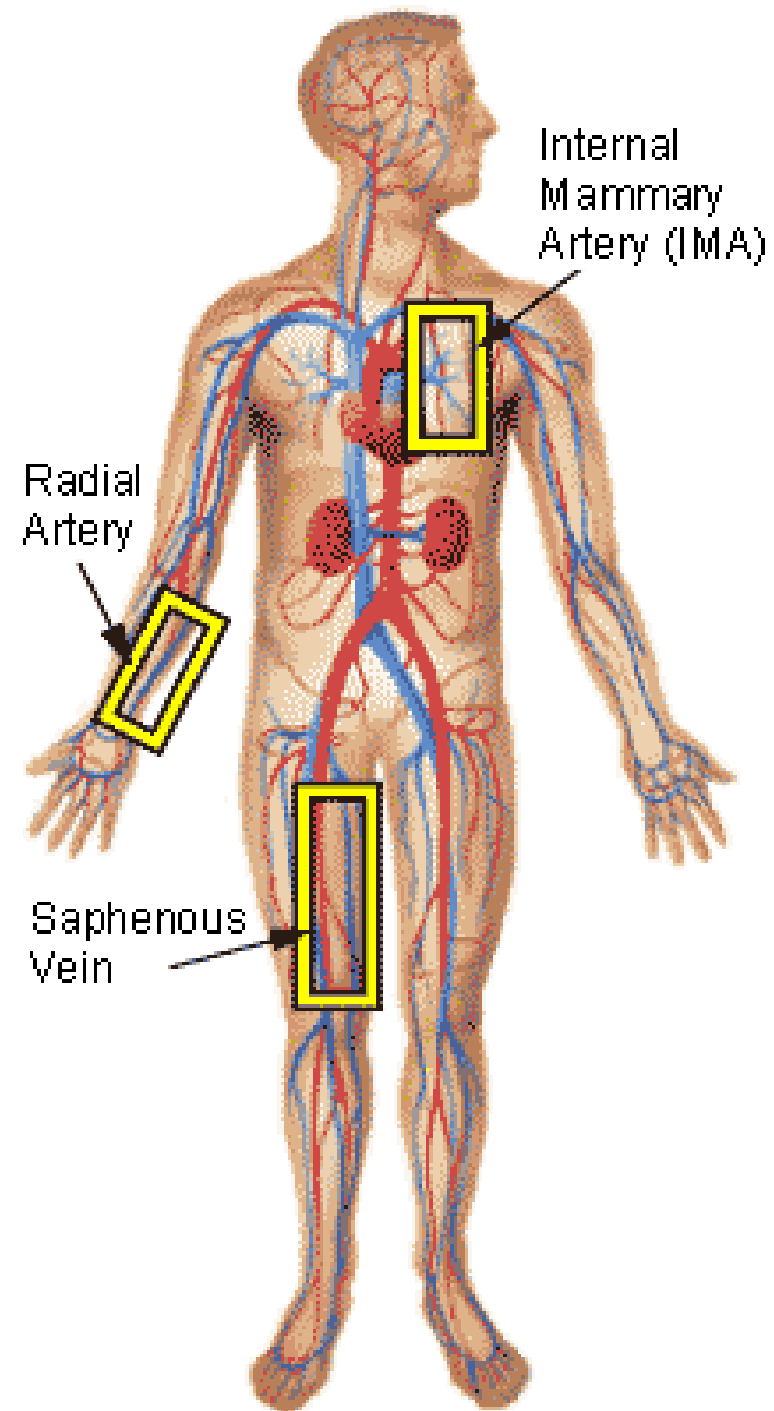
CABG



Coronary artery bypass grafting (CABG)

# Coronary Artery Bypass Graft





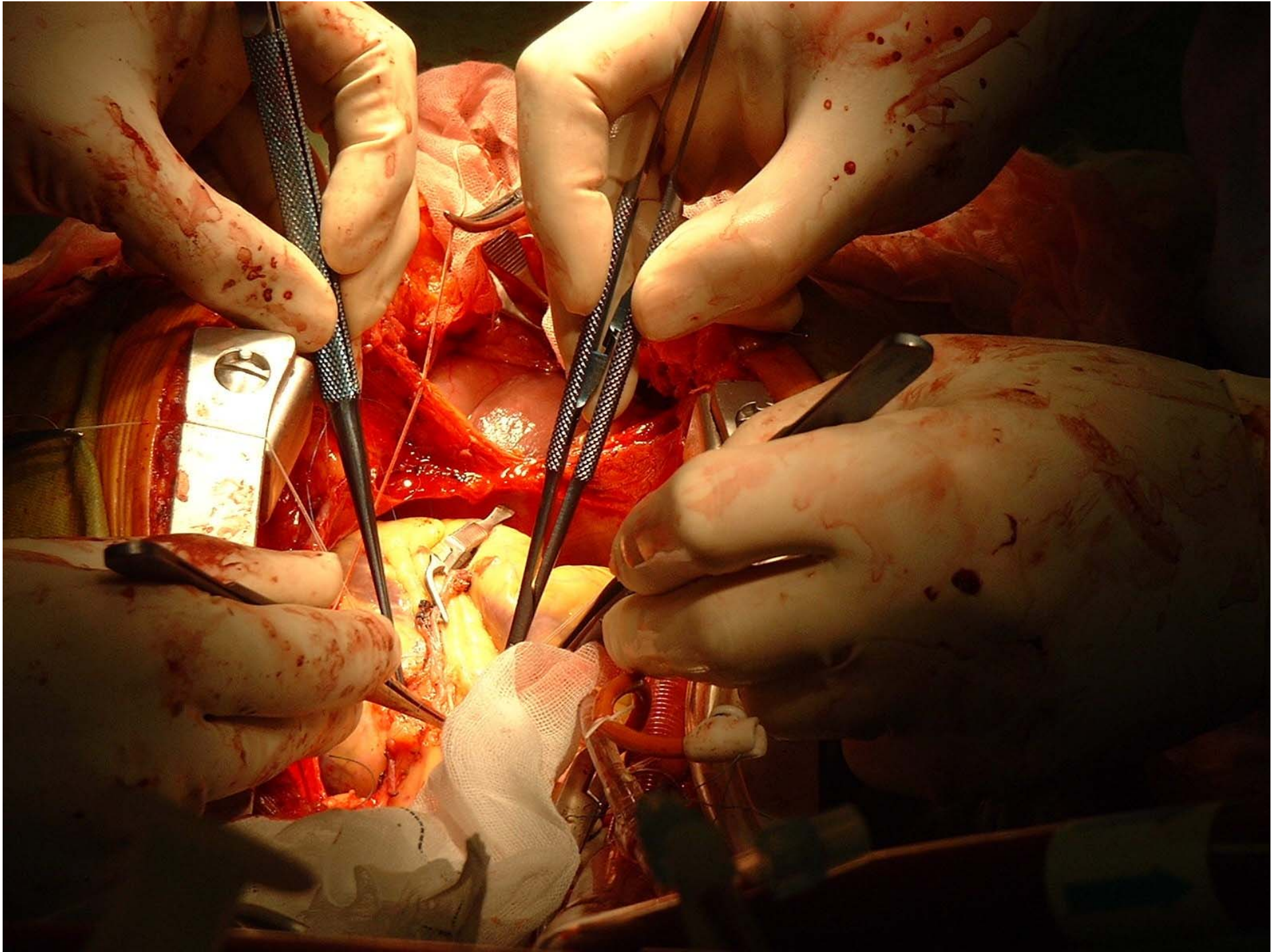
# CABG Procedure

- Patient is prepped, general anesthesia
- Chest access is gained, through sternum
- Graft vessel is retrieved
- Expose heart through pericardium
- Divert blood through heart lung machine
- Stop heart
- Insert graft
- Return circulation to heart
- Close incision





<http://www.ctsnet.org/sections/residents/lectureseries/grandrounds/article-8.html>

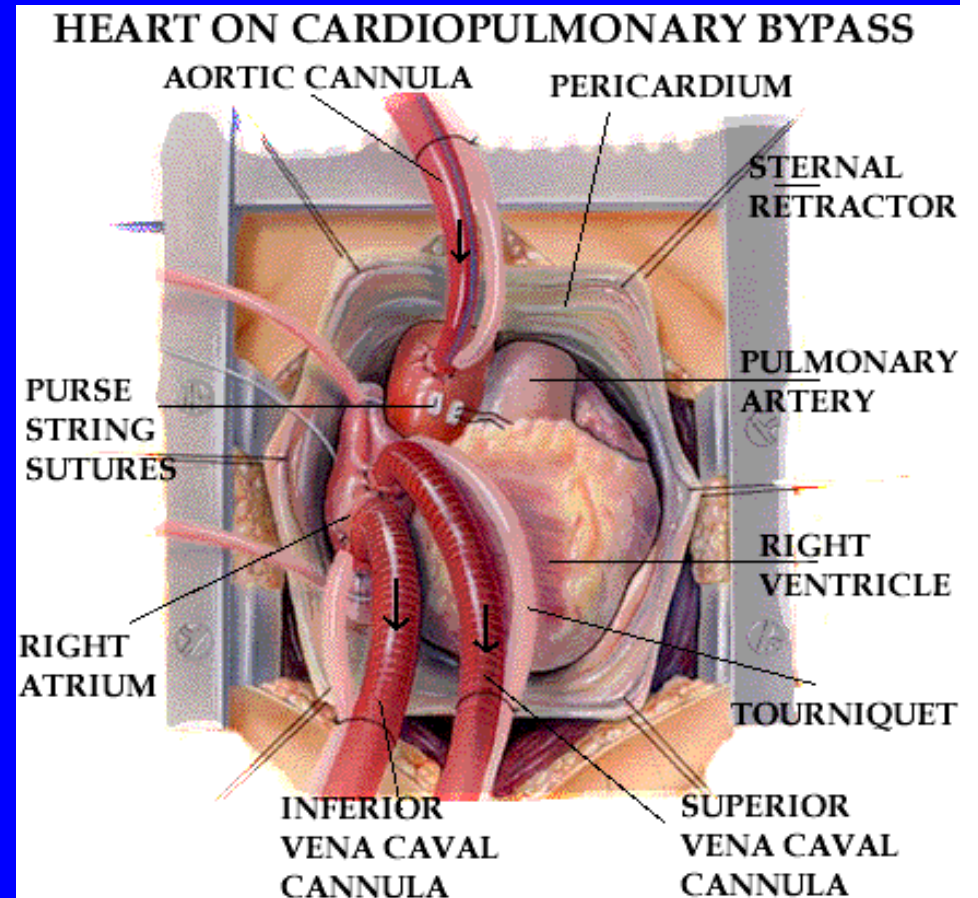
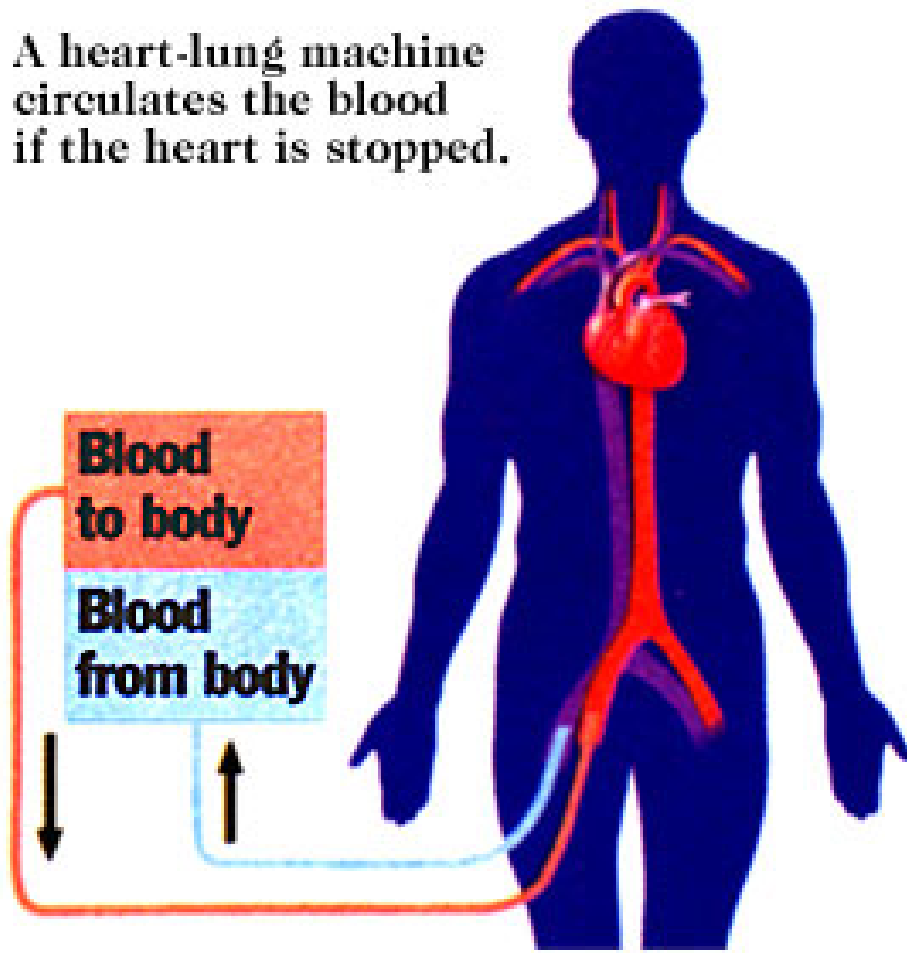


# Heart-Lung Machine

- The heart-lung machine:
  - Consists of a chamber that receives the blood from the body
  - Blood is pumped by machine through an oxygenator
  - Oxygenator removes CO<sub>2</sub> and adds oxygen
  - Pump then pumps this newly oxygenated blood back to the body
  - Connected to patient by a series of tubes that the surgical team places

# Heart Lung Machine

A heart-lung machine circulates the blood if the heart is stopped.



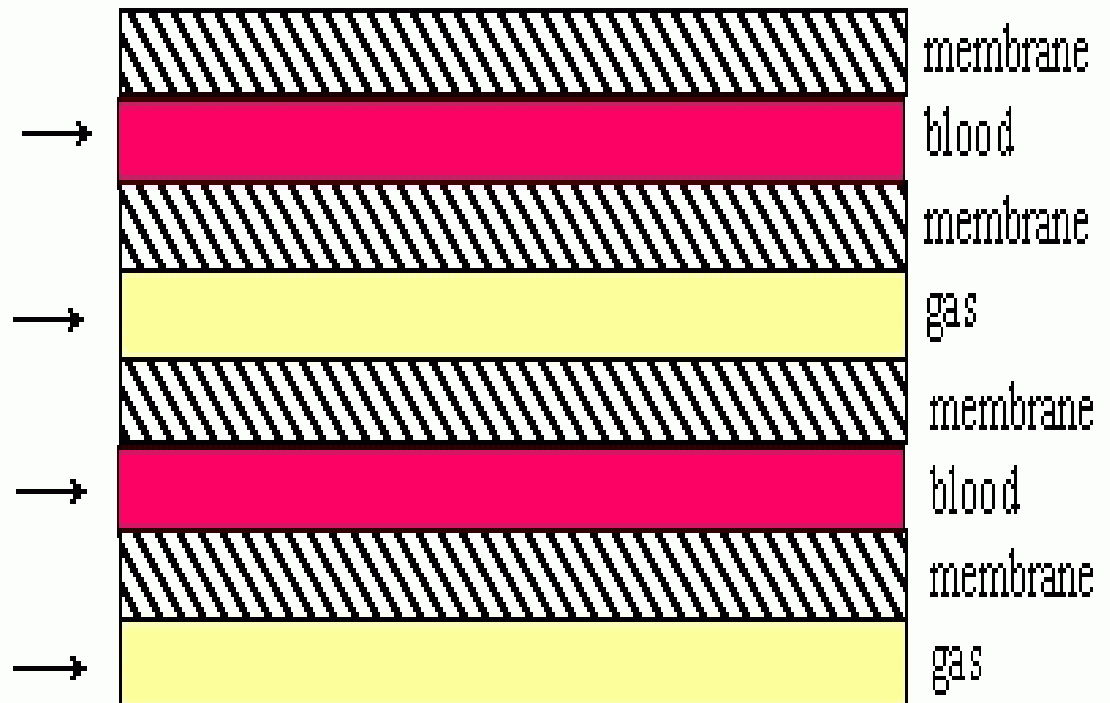
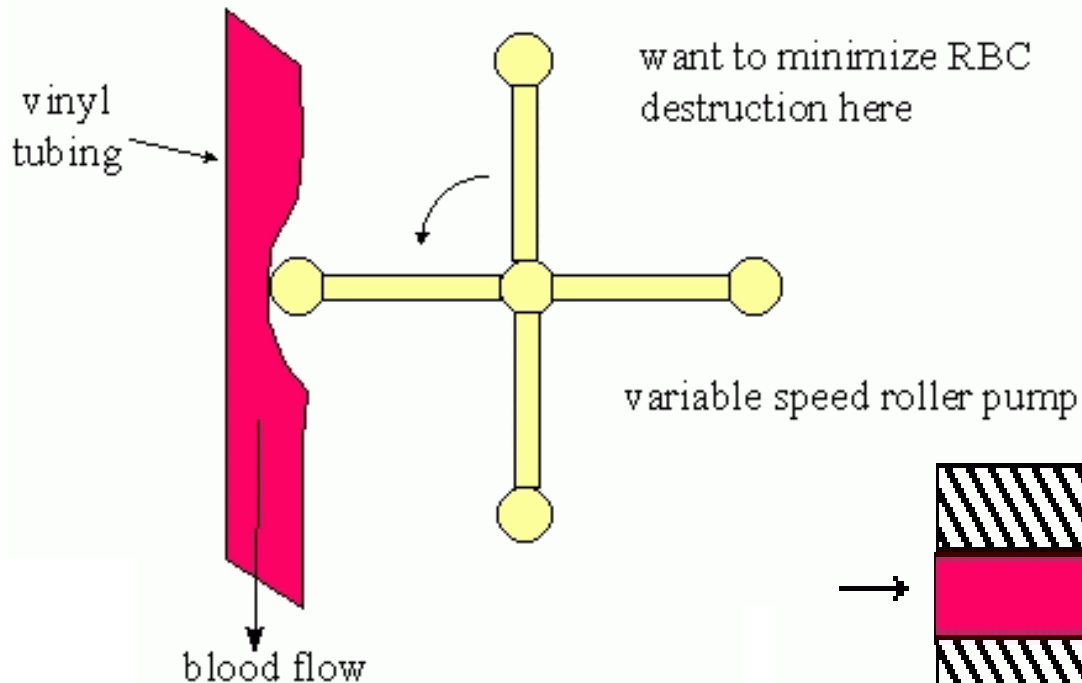


# Heart Lung Machine



[http://www.davidfary.com/hlm\\_small.jpg](http://www.davidfary.com/hlm_small.jpg)

# Heart Lung Machine



<http://enr.smu.edu/~cd/EE5340/lect31/sld014.gif>

<http://enr.smu.edu/~cd/EE5340/lect31/sld011.gif>

# CABG Effectiveness

- 2001: 516,000 CABG surgeries performed globally
- Procedure takes 4-6 hours, 5-7 day hospital stay
- Grafts remain open & functioning for 10-15 yrs
- Risks:
  - Heart attack (5%)
  - Stroke (5%) (risk greatest in those over 70 years old)
  - Death (1-2%)
  - Sternal wound infection (1-4%)
  - "Post-pericardiotomy syndrome" (30%)
    - Occurs few days to 6 months after surgery
    - Symptoms are fever and chest pain
  - Some people report memory loss and loss of mental clarity or "fuzzy thinking" following CABG

# Innovations

## ■ Off-pump CABG:

- <http://www.surgery.usc.edu/divisions/ct/videos-mpeg-offpumpcoronaryarterybypassgrafting.html>

## ■ Closed chest CABG:

- <http://www.hsforum.com/stories/st>

The Heart Surgery Forum #2000-0380  
4 (1):XXX-XXX, 2001

Online address: [www.hsforum.com/vol4/issue1/2000-0380.html](http://www.hsforum.com/vol4/issue1/2000-0380.html)

## Closed Chest Coronary Artery Bypass on the Beating Heart

(#2000-0380 ... June 8, 2000)

Utz Kappert, MD,<sup>1</sup> Romuald Cichon, MD,<sup>1</sup> Vassilios Gulielmos, MD,<sup>1</sup>  
Jens Schneider, MD,<sup>1</sup> Ina Schramm, MD,<sup>1</sup> Joachim Nicolai, MD,<sup>2</sup>  
Sems-Malte Tugtekin, MD,<sup>1</sup> Stephan Schueler, MD, PhD<sup>1</sup>

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Dr. Kappert



### ABSTRACT

Minimally invasive surgical procedures have become a part of routine cardiac surgery. The surgical techniques have been developed for the treatment of coronary artery disease in order to minimize surgical trauma.

With the introduction of a 3-D-based totally endoscopically functioning system into minimally invasive cardiac (MIC) surgery, further reduction of skin incisions became possible and enhanced MIC techniques could be improved. Due to the 6° freedom of motion allowed by wrist-enhanced instruments and a newly developed endoscopic stabilizer, totally endoscopic coronary artery bypass procedures on a beating heart became feasible.

We present here our initial series of totally endoscopic "off-pump" coronary artery bypass grafting in patients suffering from coronary artery single vessel disease. In all patients, the procedure was successfully performed via four 1 cm chest incisions as closed-chest procedures.

four-point stab incision, thus avoiding sternotomy and minithoracotomy [Falk 1999, Falk 2000]. After performing over 120 minimally invasive surgical procedures since May 1999 (including a series of uni- or bilateral internal mammary artery harvesting and totally endoscopic coronary artery bypass (TECAB) grafting on an arrested heart), we present this report reflecting our observations regarding the feasibility of TECAB grafting on a beating heart. An initial series of closed-chest OPCAB grafting using wrist-enhanced robotic instrumentation in three male patients suffering from single-vessel coronary artery disease (SVCAD) using the left internal mammary artery (LIMA) is presented.

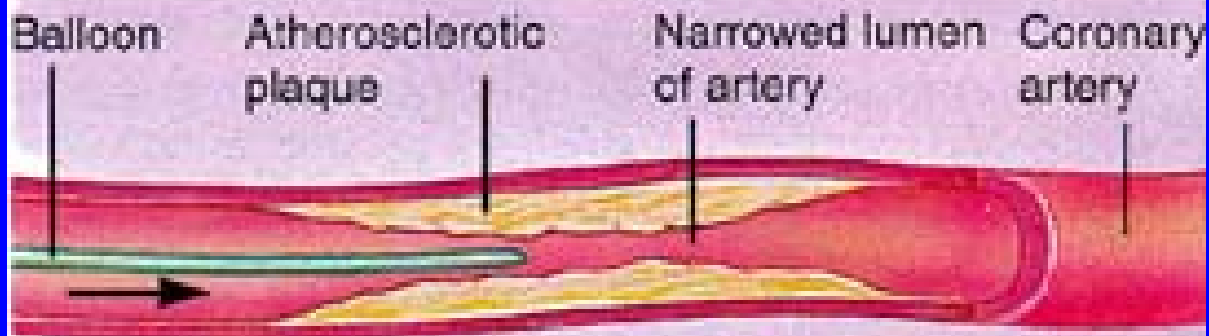
### MATERIALS AND METHODS

The da Vinci™ 3-D based robotic system (Intuitive Surgical, Mountain View, CA) has been described in detail before [Carpentier 1999, Falk 1999, Loulmet 1999]. Three

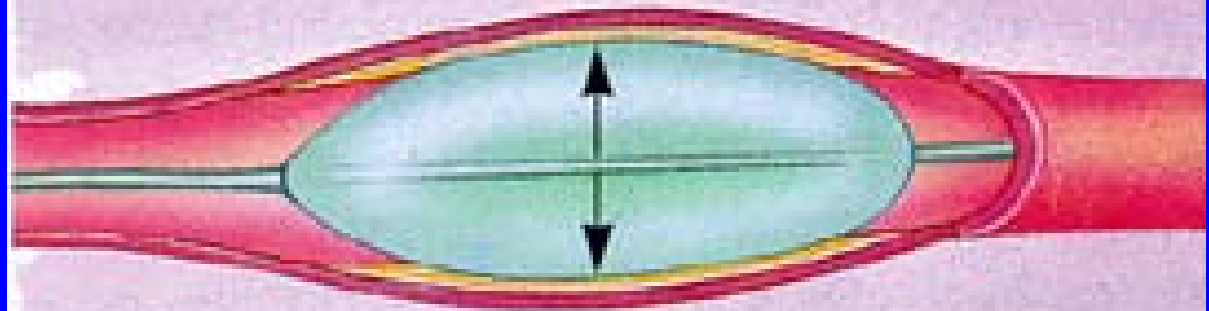


# How Do We Treat Atherosclerosis?

Angioplasty



Balloon catheter with uninflated balloon approaches obstructed area in artery

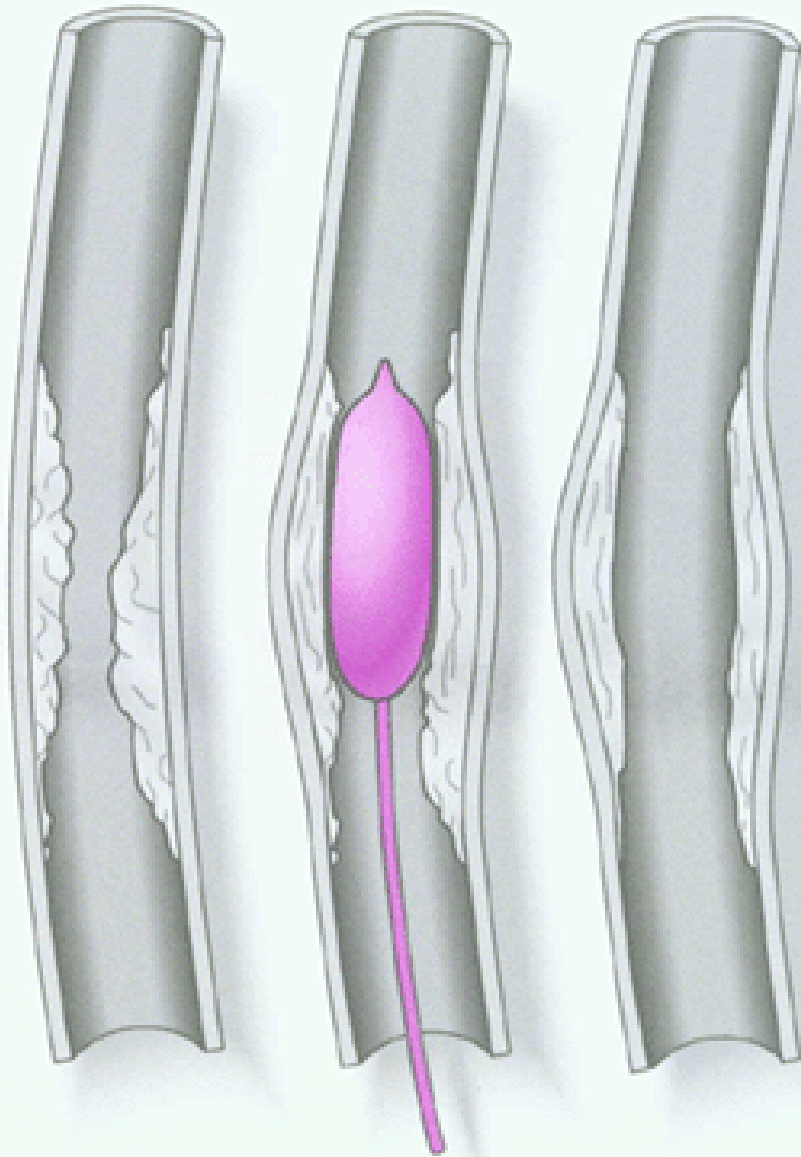
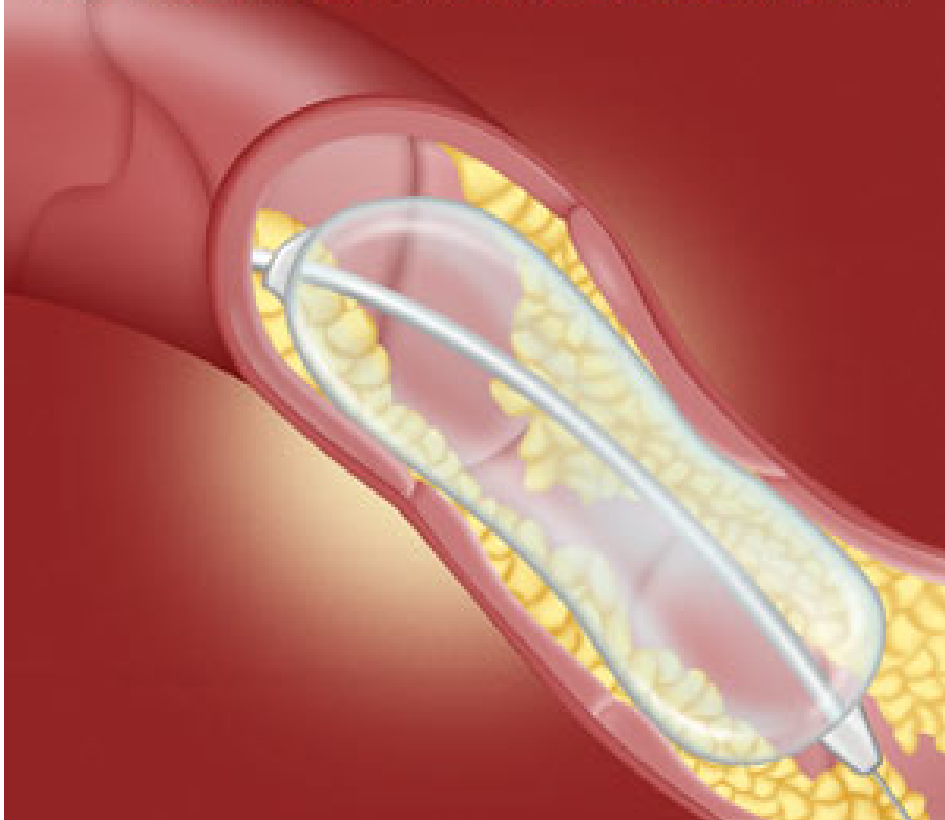


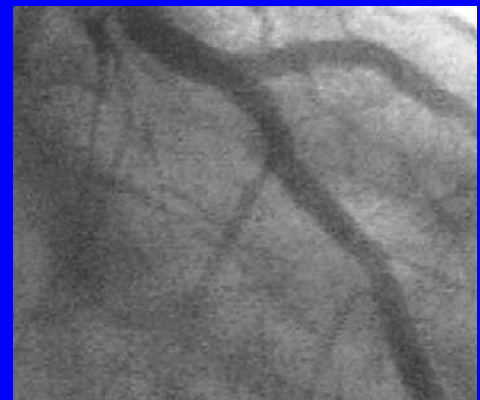
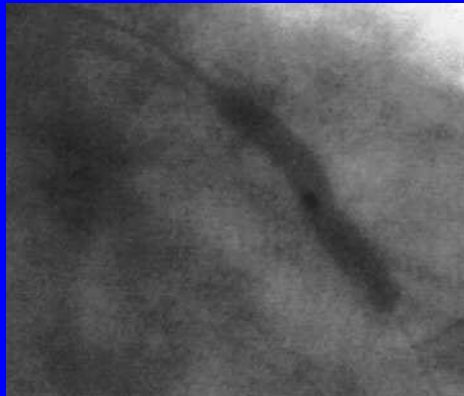
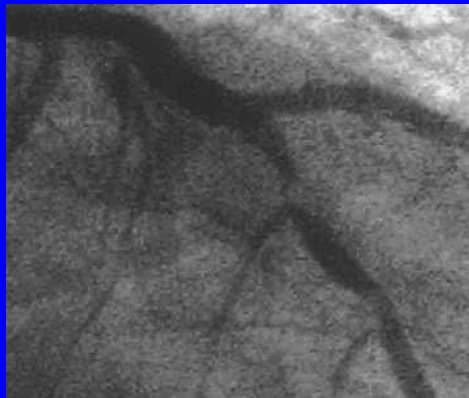
When balloon is inflated, it breaks up atherosclerotic plaque

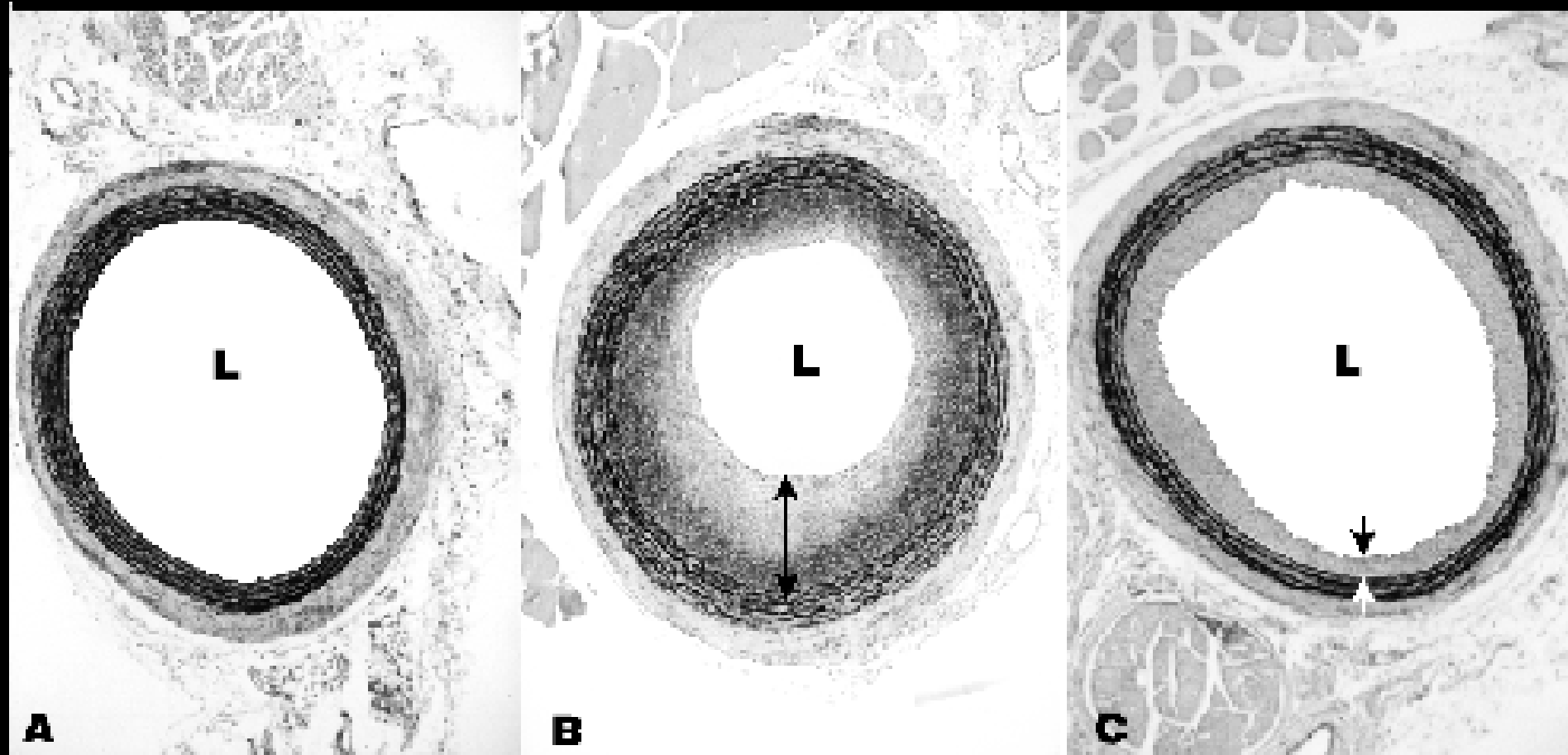


After lumen widened, balloon catheter with deflated balloon is withdrawn

# BALLOON ANGIOPLASTY







# PTCA: Effectiveness

- Cannot always successfully perform procedure
  - Diffuse disease
  - Total occlusion
  - Calcified disease
- Restenosis
  - Occurs in 25-54% of patients
  - Usually occurs within 6 months

# How Do We Treat Atherosclerosis?

Stent

# Stents

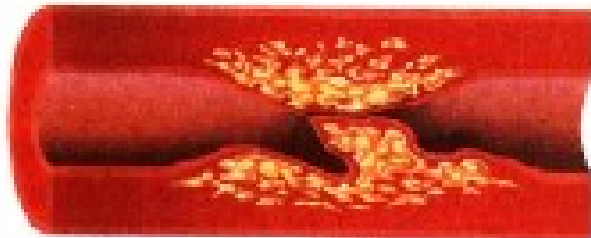
<http://www2.cajun.net/~wpharo/stent.jpg>



<http://www.wbamc.amedd.army.mil/images/newsphotos/stent%20implantation.jpg>

## How is a Coronary Stent Implanted?

<http://www.insel.ch/kardio/kardiorehab/bilder/stent.jpg>



A stent is mounted on a balloon catheter.



The balloon is inflated and the stent is expanded.



The balloon is removed and the stent is implanted in the vessel.



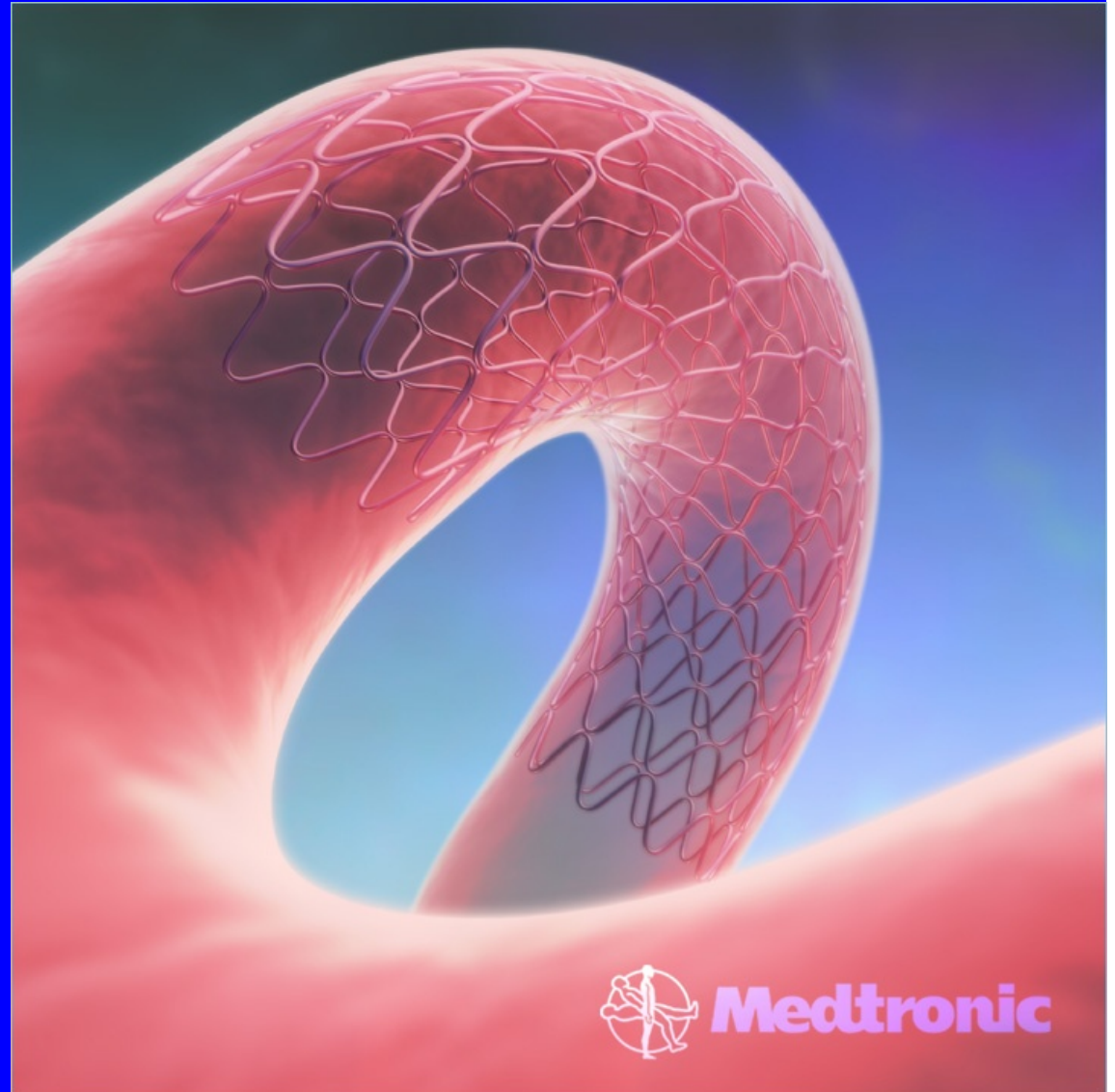
Image provided courtesy of Cordis Corporation.



# Stents



<http://www.priory.com/cmol/stent3.jpg>



[http://www.hybridmedicalanimation.com/media/mdtrnc\\_stent.jpg](http://www.hybridmedicalanimation.com/media/mdtrnc_stent.jpg)



**Medtronic**

# Drug Eluting Stents

- <http://www.npr.org/features/feature.php?wfid=1452217>

# Comparison of RX Methods

## ■ Hospital Stay:

- CABG – 4-7 days
- Angioplasty – 1-2 days
- Stent – 1-2 days

## ■ Restenosis:

- CABG – 5-6%, usually after 5 years
- Angioplasty – 25-45%, usually within 6 months
- Stent – 15-20%, usually within 6 months

# Comparison of RX Methods

## ■ Cost

- CABG \$35,000
- Angioplasty \$17,000
- Stent \$19,000

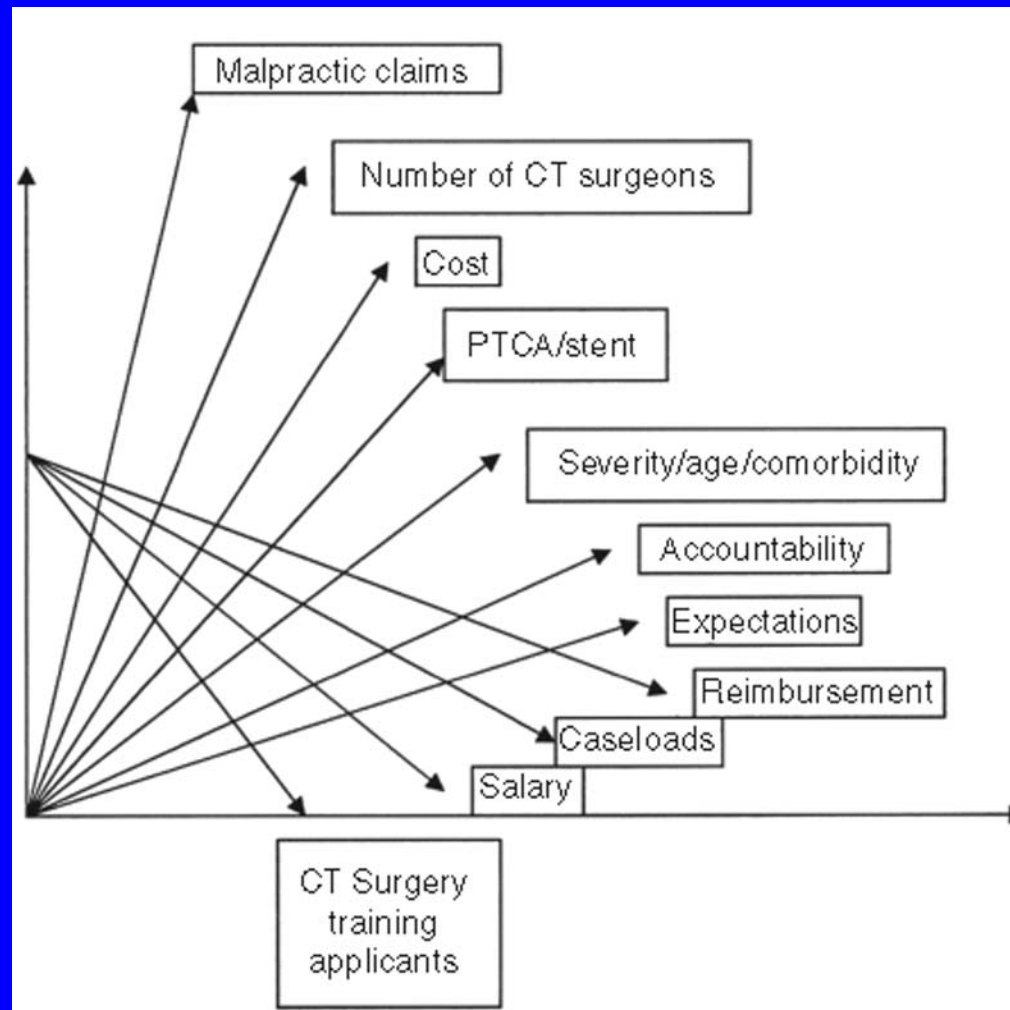
## ■ Cost-effectiveness

- Additive procedures:
  - Within 5 years, 20-40% of patients have second PTCA, 25% have CABG
- Additive costs:
  - 0 years: per patient costs of PTCA 30-50% those of CABG
  - 1 year: 50-60%
  - 3 years: 60-80%
  - >3 years: >80%
- Moving Target Problem

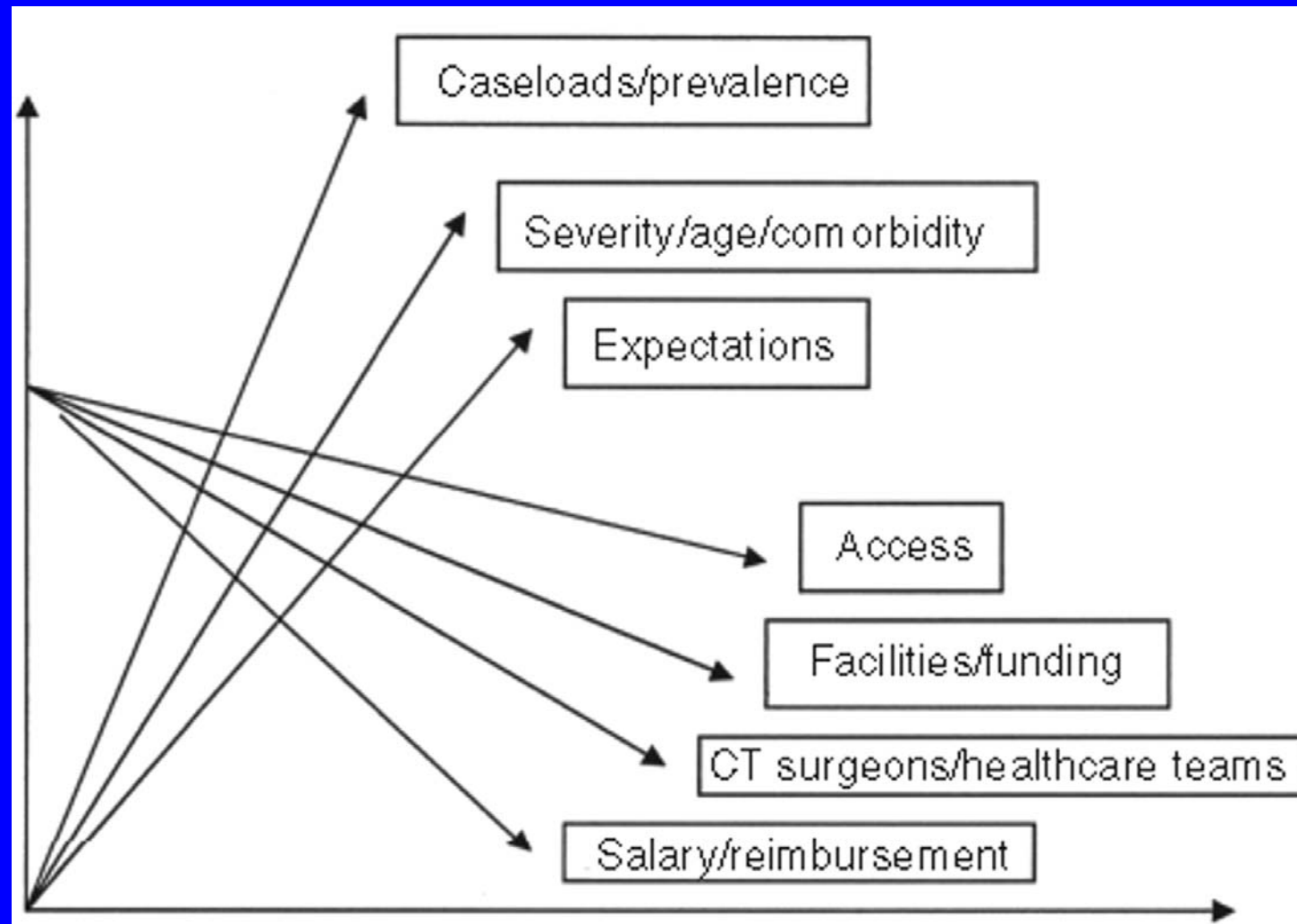
# What Would You Do?

- Angioplasty
  - Stent
  - CABG
- 
- A 28% decrease in coronary artery bypass operations between 1997 and 2005, and a 121% increase in stent procedures over the same period.

# The challenges for cardiothoracic (CT) surgery in the USA and developed countries



# The challenges for cardiothoracic (CT) surgery in developing countries



# Cost-Effectiveness

Therapy	Patient Group	\$ per yr life saved
tPA	Post MI high risk	\$3,600
tPA	Acute MI, large infarct, treatment started >2 hours post	\$24,200
Counseling	Smoking cessation	\$1300-\$3900
CABG	Two vessel disease, severe angina	\$9,200-\$42,500

[http://www.sciencedirect.com/science?\\_ob=ArticleURL&\\_aset=B-WA-A-A-A-MsSAYZA-UUA-AUYWDCBYZYAUUYUBBVZZYBWAUBWEUBAU&\\_rdoc=1&\\_fmt=full&\\_udi=B6T1048NJXK25&\\_coverDate=5%2F22%2F2003&\\_cdi=4876&\\_orig=search&\\_st=13&\\_sort=d&view=c&\\_acct=C000004378&\\_version=1&\\_urlVersion=0&\\_userid=108429&md5=5f493caa5f65762c23c0d90eaea8b92d](http://www.sciencedirect.com/science?_ob=ArticleURL&_aset=B-WA-A-A-A-MsSAYZA-UUA-AUYWDCBYZYAUUYUBBVZZYBWAUBWEUBAU&_rdoc=1&_fmt=full&_udi=B6T1048NJXK25&_coverDate=5%2F22%2F2003&_cdi=4876&_orig=search&_st=13&_sort=d&view=c&_acct=C000004378&_version=1&_urlVersion=0&_userid=108429&md5=5f493caa5f65762c23c0d90eaea8b92d)



# Prevention or Treatment?

- <http://www.nytimes.com/2004/03/21/health/21HEAR.html>

# Progression of Heart Disease

High Blood Pressure  
High Cholesterol Levels

Atherosclerosis

Ischemia

Heart Failure

Heart Attack

