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Heart Attack Physics

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Heart Attack Physics

Abstract

I recently had a first-hand opportunity to learn some interesting biomedical applications of physics which provide application examples for introductory classes. While there were many such applications, from X-rays to ultrasonic imaging, I'll focus on fluid flow through clogged coronary arteries and the use of radioactive materials in a nuclear stress test.

Keywords

heart attack, blood flow, arteries, radioactive substances, stress echocardiology

Disciplines

Biological and Chemical Physics

Comments

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Heart Attack Physics

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Disclaimer: This is not medical advice!!!!

Background/Outline:

January - heart attack and 3 stents placed

May - 3 more stents

September – nuclear stress test

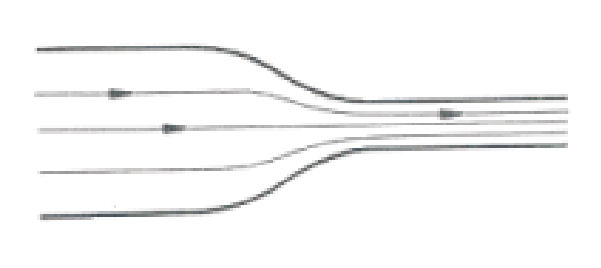
We'll consider:

Fluid flow

Nuclear tracers

Fluid Flow

Two key equations:

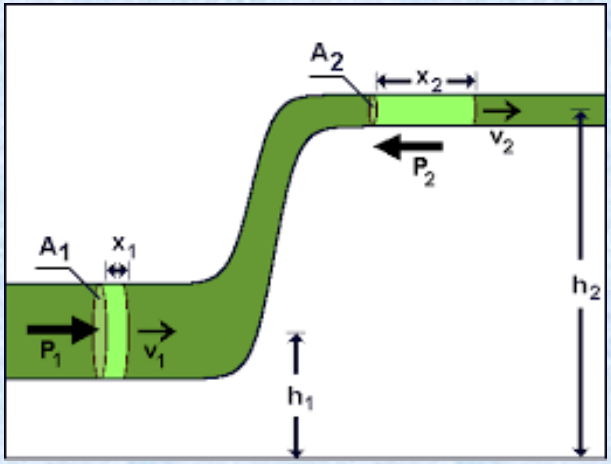


“Equation of Continuity”

Flow rate = Av = constant

A = cross sectional area

v = fluid speed



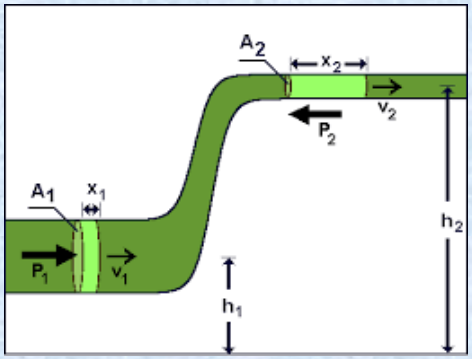
“Bernoulli’s Equation”

$P + \rho gh + (1/2)\rho v^2 = \text{constant}$

P = pressure

h = elevation

ρ = fluid density



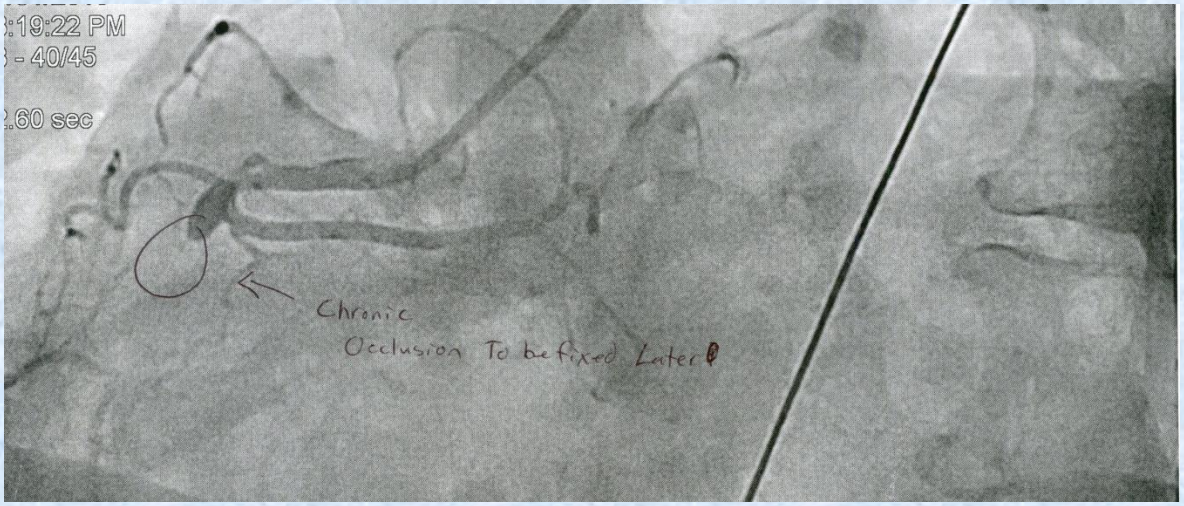
Flow rate = Av = constant

$P + (1/2)\rho v^2$ = constant (h is ~constant in heart)

Both equations assume ideal fluid, no viscous effects, steady flow, area not varying in time,….

So, approximate applications to blood flow in coronary arteries.

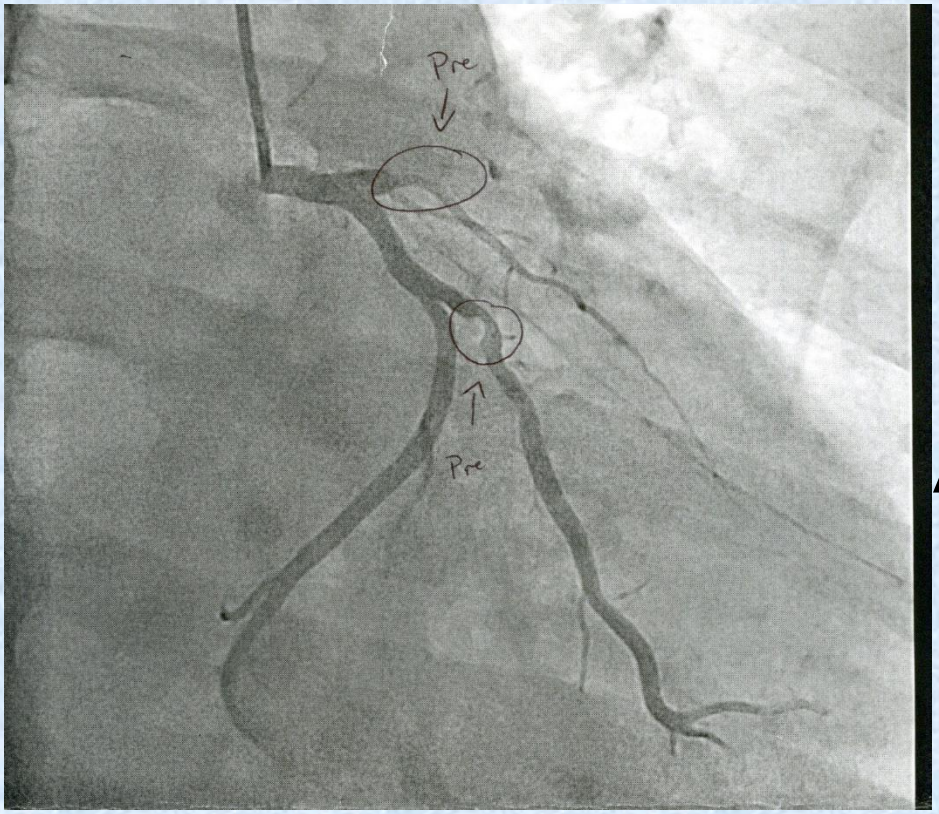
X-ray image of blocked right coronary artery



Note ballooning at blockage site

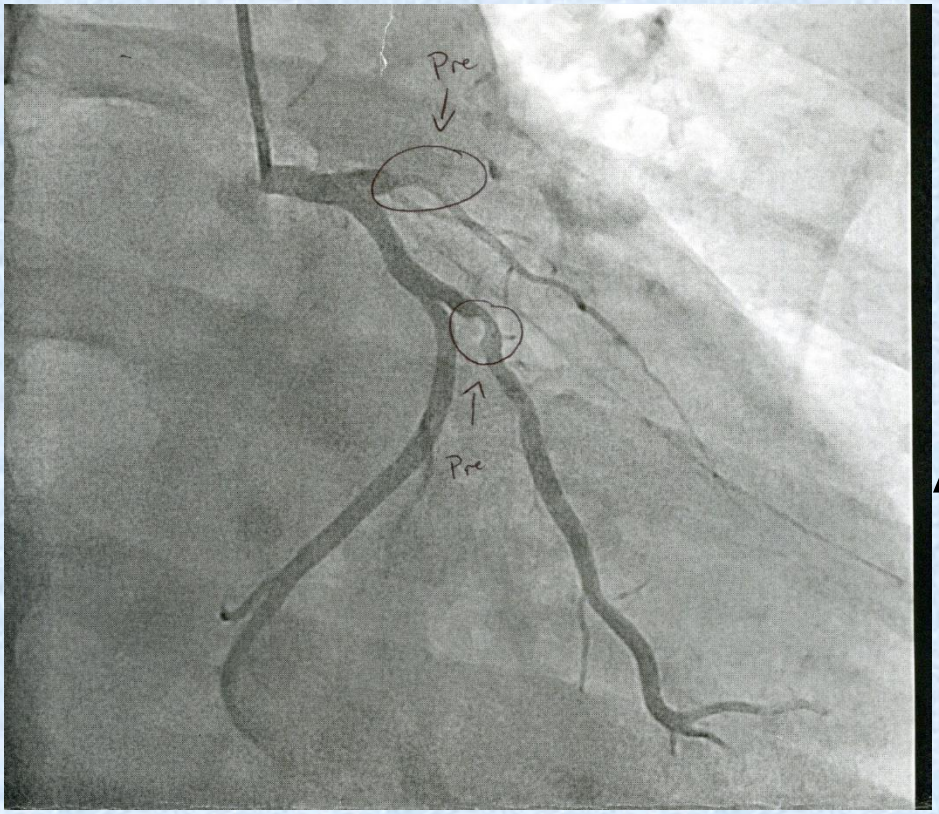
$P + (1/2)\rho v^2 = \text{constant}$

decreased v → increased P



$Av = \text{constant}$

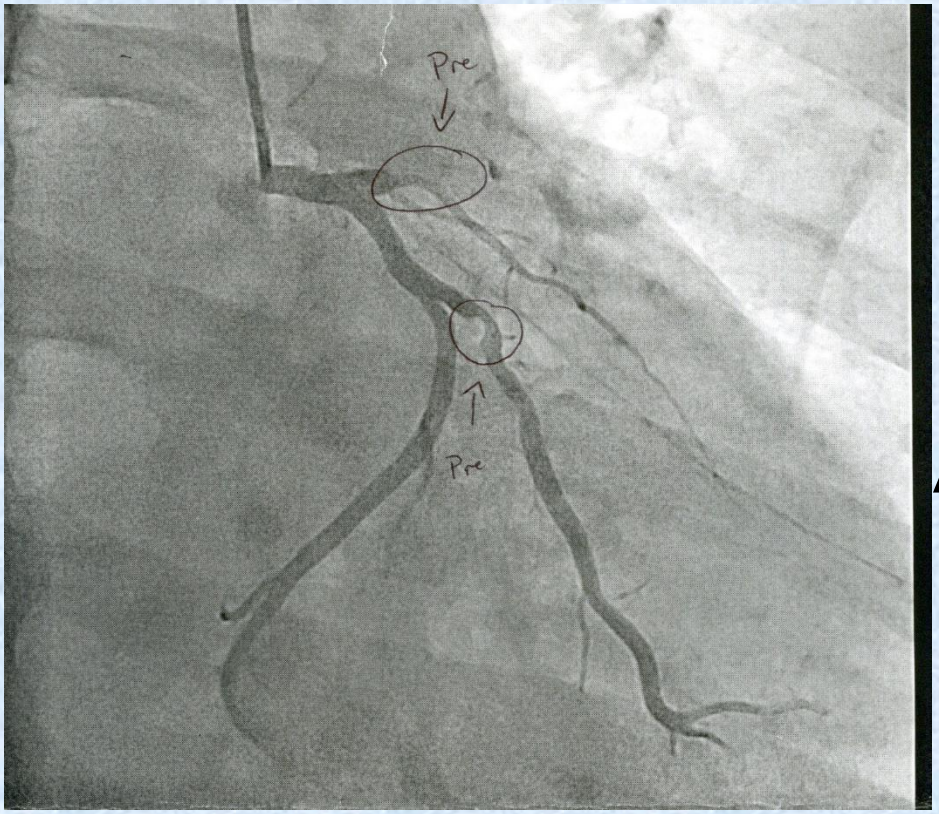
$P + (1/2)\rho v^2 = \text{constant}$



$Av = \text{constant}$

$P + (1/2)\rho v^2 = \text{constant}$

Decreased area → increased speed

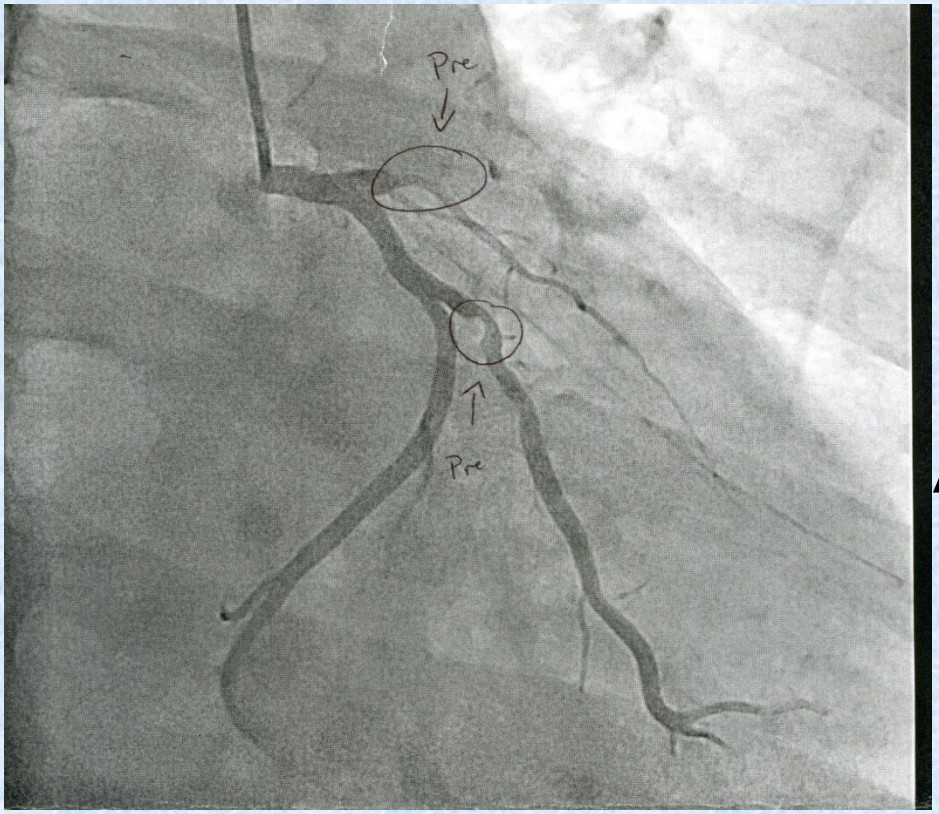


$Av = \text{constant}$

$P + (1/2)\rho v^2 = \text{constant}$

Decreased area → increased speed

Increased speed → decreased pressure



$Av = \text{constant}$

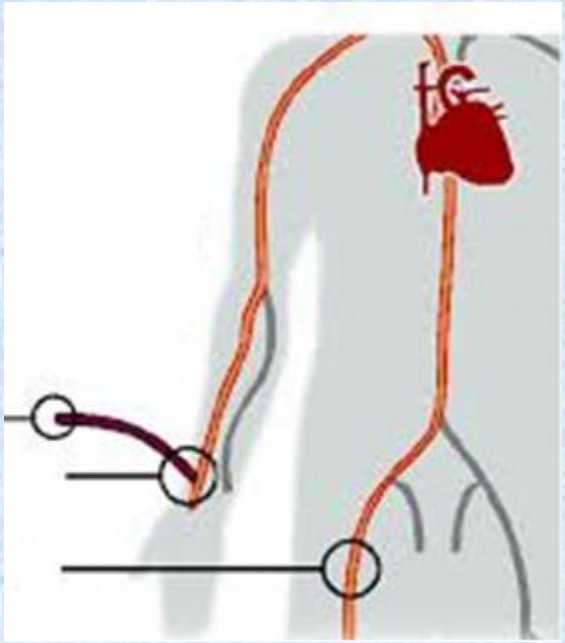
$P + (1/2)\rho v^2 = \text{constant}$

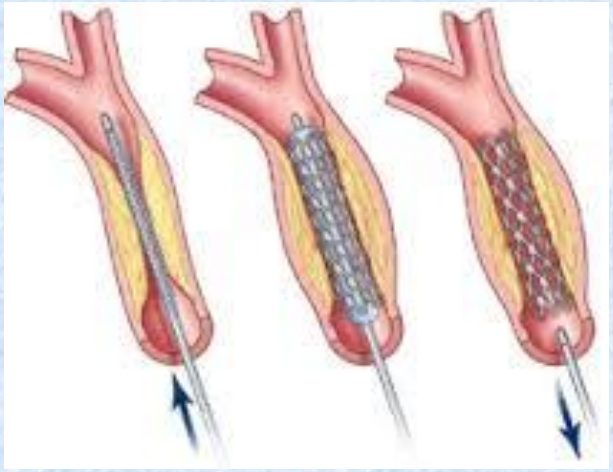
Decreased area → increased speed

Increased speed → decreased pressure

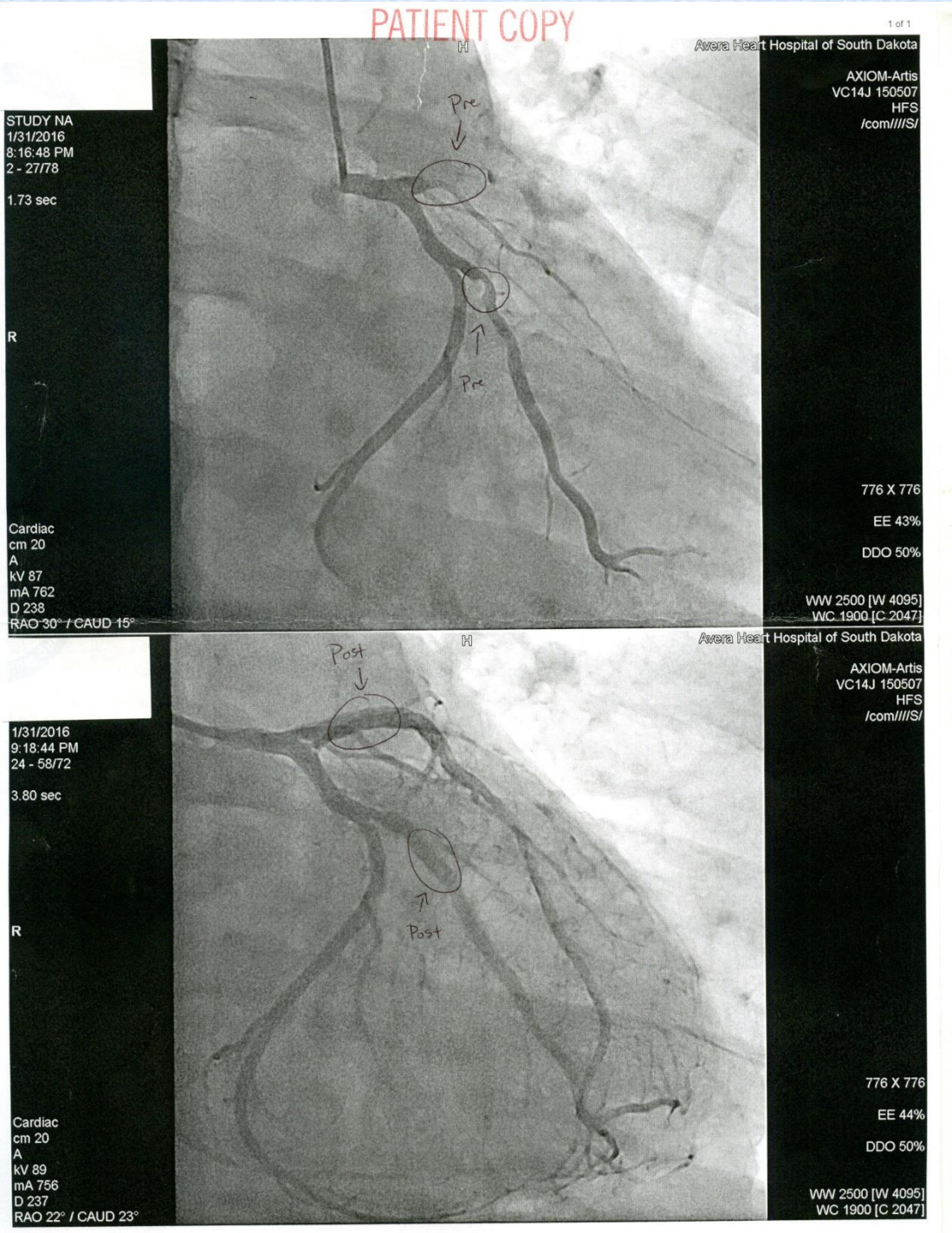
Decreased pressure → surrounding tissue compresses artery

The fix - Stenting



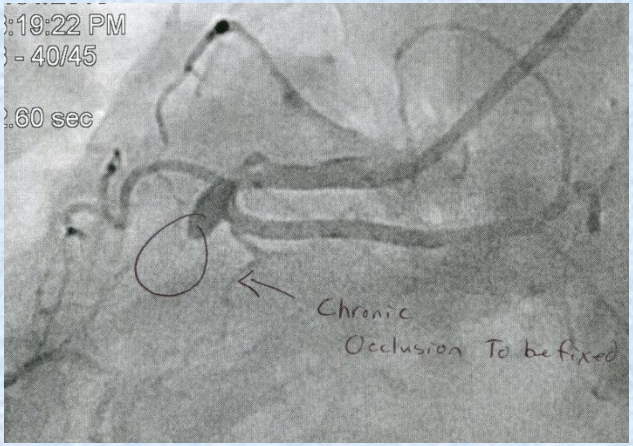


Stents varied from 2.5 - 3.5 mm diameter, 12 – 38 mm long



Before and after January stenting

After and before May stenting



January image

PATIENT COPY

1 of 1

H

Avera Heart Hospital of South Dakota

AXIOM-Artis
VC14J 150507
HFS
/com////S/

STUDY NA
5/25/2016
8:02:21 AM
19 - 25/49

2.40 sec

A

776 X 776

EE 45%

DDO 50%

Cardiac
cm 20
A
kV 86
mA 761
D 170
LAO 55° / CAUD 2°

WW 2500 [W 4095]
WC 1900 [C 2047]

M H

Avera Heart Hospital of South Dakota

AXIOM-Artis
VC14J 150507
HFS
/com////S/

5/25/2016
7:12:24 AM
1 - 24/50

2.30 sec

R

960 X 960

EE 41%

DDO 50%

Cardiac
cm 25
A
kV 81
mA 749
D 169
LAO 41° / CAUD 5°

WW 2500 [W 4095]
WC 1900 [C 2047]

Nuclear Stress Test

Regular stress test:

Monitor heart while exercising on treadmill

Nuclear stress test:

- Before exercise, inject compound with radioactive isotope that is taken up by heart tissue

- Use a ‘gamma ray camera’

to see image heart to see

if blood goes where it should

- Repeat at end of exercise

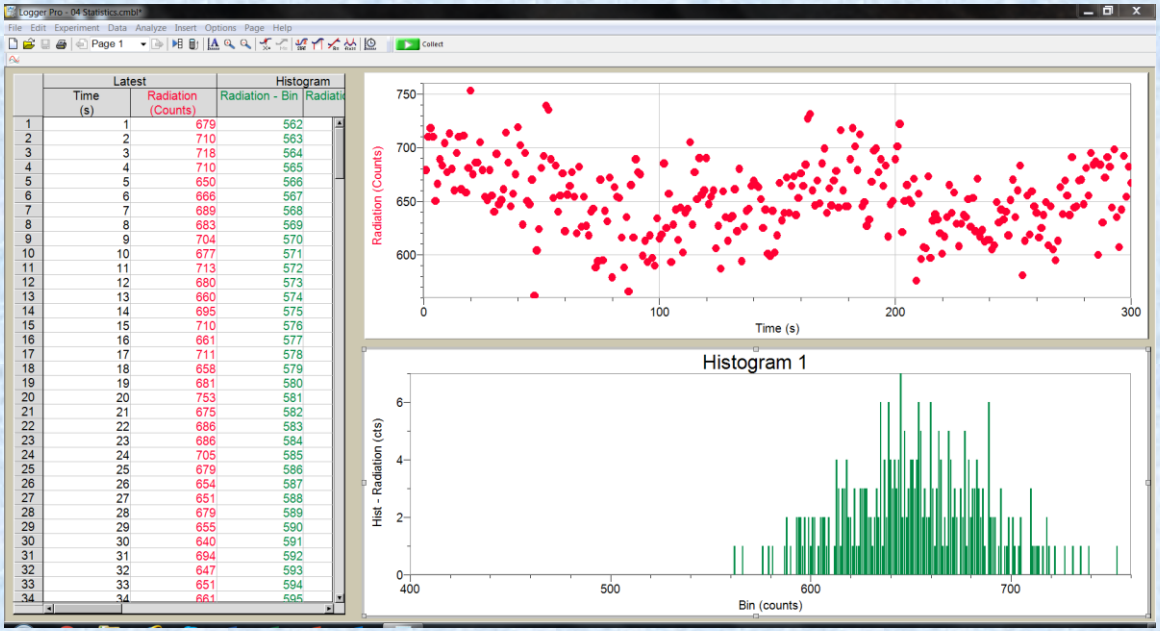
The isotope

- Technetium-99 metastable state(Tc-99m) is the tracer
- Prepared by irradiating weapons grade uranium in a reactor, producing Molybdenum 99, which is shipped to nuclear pharmacies
- Mo-99 beta decays with 60 hour half life to Tc-99m which is chemically extracted
- Tc-99m gamma decays to Tc-99 with a 6 hour half-life

The test

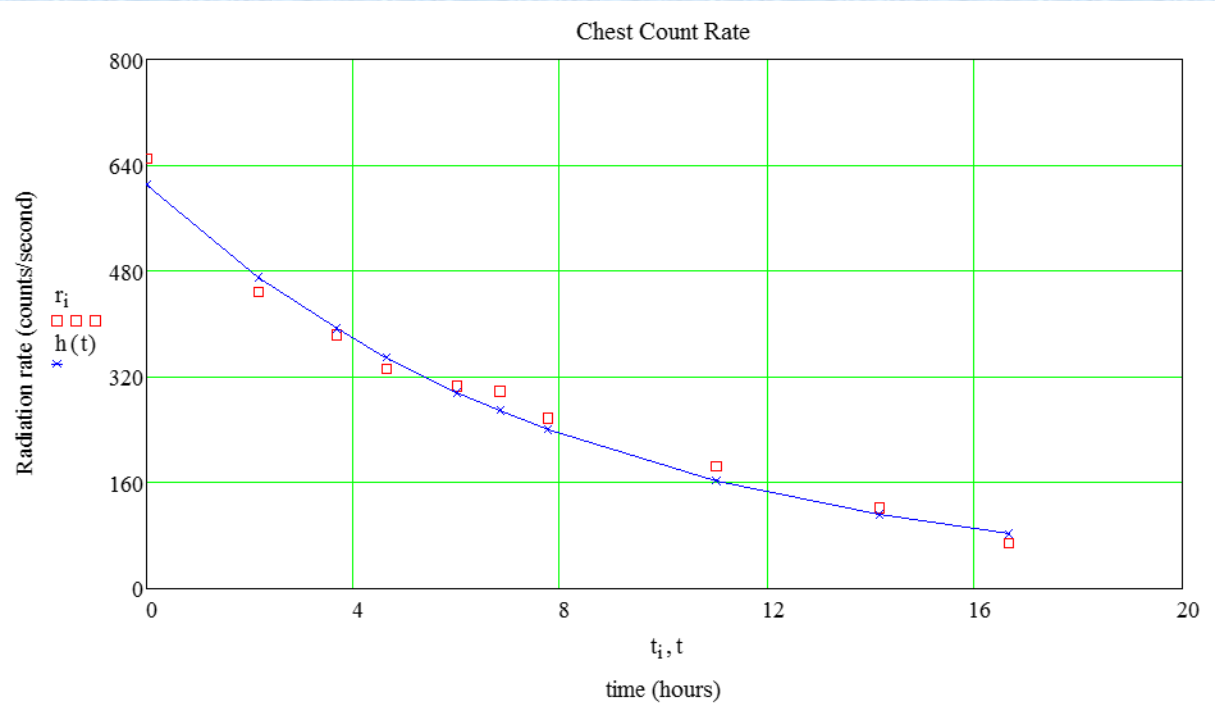
- 9 mCi (not µCi !)Tc-99m sestamibi is injected into bloodstream
- Wait a half hour before getting first gamma image
- Wait again before stress test
- Inject 30 mCi with one minute of exercise to go
- Take second gamma image

After getting back to campus



	Time (s)	Radiation (Counts)	Radiation - Bin
1	1	679	562
2	2	710	563
3	3	718	564
4	4	710	565
5	5	650	566
6	6	666	567
7	7	689	568
8	8	683	569
9	9	704	570
10	10	677	571
11	11	713	572
12	12	680	573
13	13	660	574
14	14	695	575
15	15	710	576
16	16	661	577
17	17	711	578
18	18	658	579
19	19	681	580
20	20	753	581
21	21	675	582
22	22	686	583
23	23	686	584
24	24	705	585
25	25	679	586
26	26	654	587
27	27	651	588
28	28	679	589
29	29	655	590
30	30	640	591
31	31	694	592
32	32	647	593
33	33	651	594
34	34	661	595

Count rate measurements



- More scatter than counting statistics (non-point source)
- Liver area rate ~5 times heart rate
- Fit yields half-life of 5.8 hours (accepted value is 6.0 hours)

If anyone is interested in a copy of this for use in a class, see me during a break or e-mail me at john.zwart@dordt.edu

Thanks to: Laurey Zwart for recognizing the signs and getting me to ER quickly; medical staff at Sioux Center Hospital and the Avera Heart Hospital; Kayt Frisch, Ethan Brue, and Carl Fictorie for handling my classes for 5 weeks

Questions?