Microbrachytherapy: Example - Microspheres

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Preliminaries

1. The presenter has no known conflicts of interest, doggonit!
2. The objective of this presentation is that we all understand some of the safety aspects of treatments using radioactive microspheres.

Safety Issues Discussed

- Procedure
- Safety
- Dosimetry

Purpose

- To treat cancer metastatic to the liver.
- The 20-40μm, ^{90}Y-labeled microspheres are injected intra-arterially through the hepatic artery.
- They then get caught in the mouth of the capillary bed and irradiate the tumor.

How it Works

- Liver tumors are selectively fed by the hepatic artery.
- Normal liver is mostly fed through the portal vein.

Availability

Vendors:

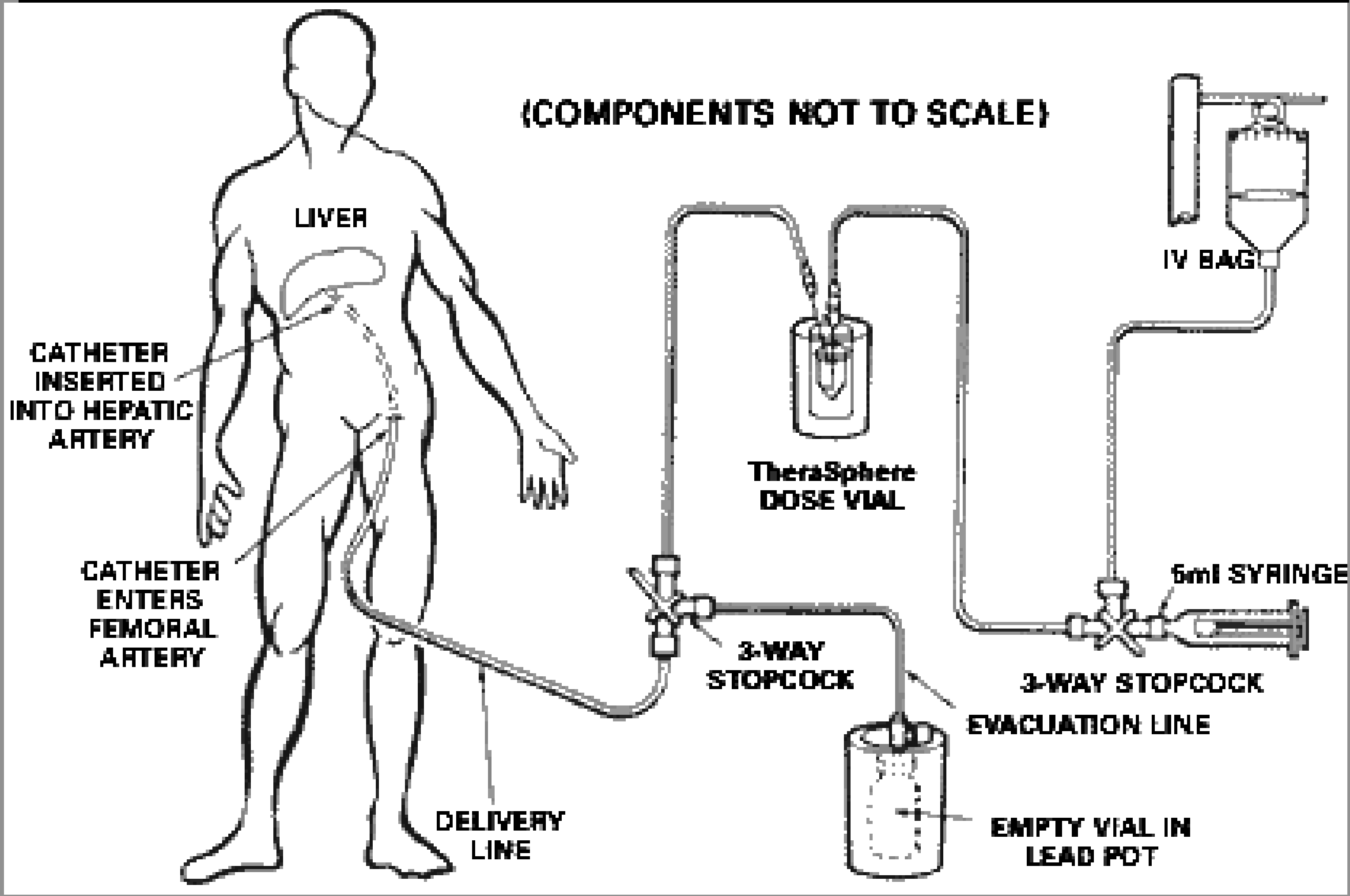
- SIRTex, maker of SIR-Spheres, polymer spheres approved for colorectal cancer.
- Nordion, maker of TheraSpheres, glass spheres approved for hepatocelluar cancer.

Caveat

My experience has only been with SIR-Spheres

Procedure

TheraSpheres Delivery



TheraSpheres Delivery System

SirSpheres Delivery Box

Delivery Box

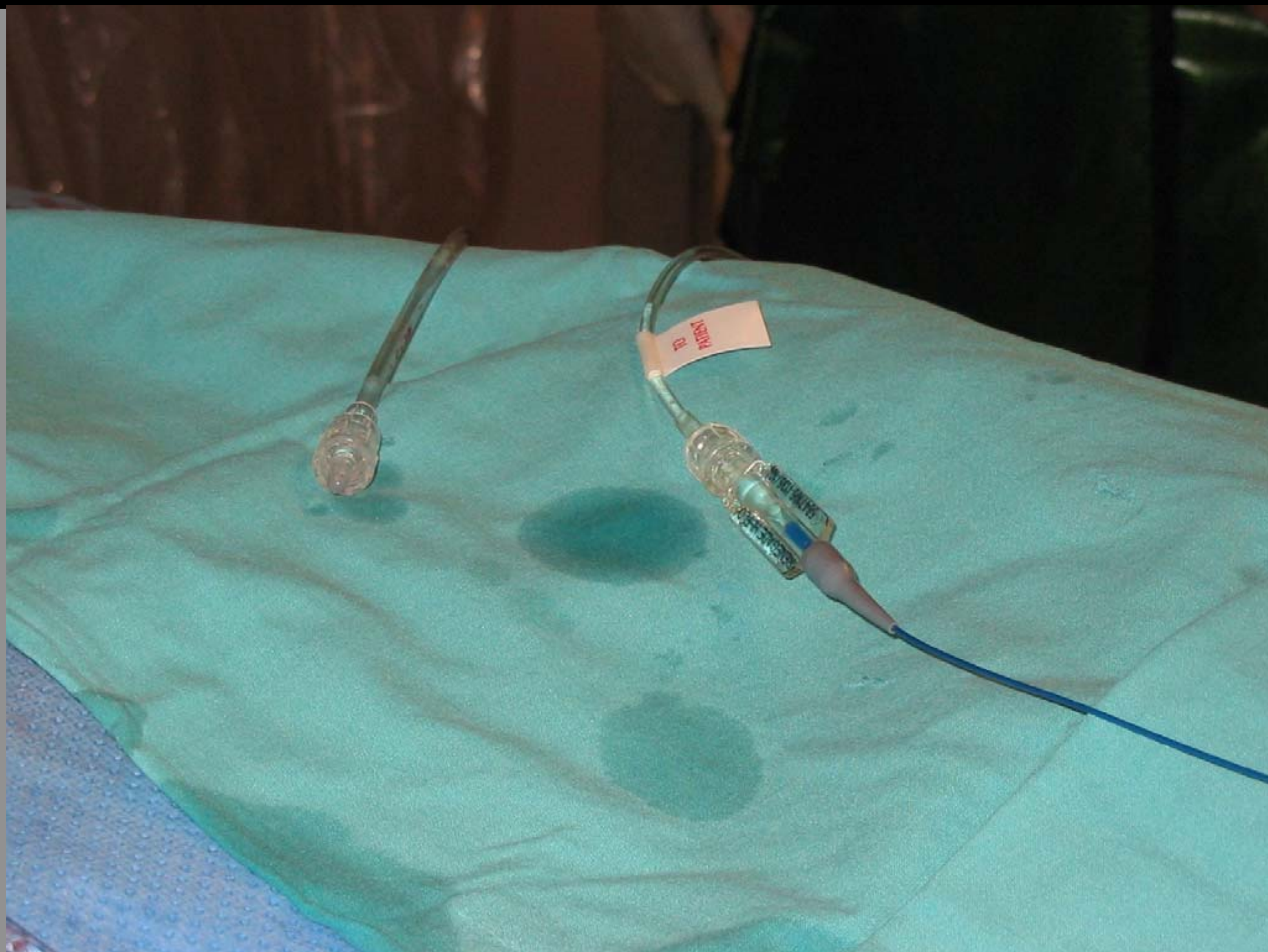
Delivery Box from the Side

Connections in the Box

SirSpheres Delivery

- The solution with the microspheres is a slurry (or a sludge).
- The injection uses pulses of water going into the vial to mix up the microspheres, taking them off the top.

Catheter Connection



Delivery (Continued)

- The first pulses must be short to prevent clogging (about 1/3 of the tube to the catheter).
- As the solution clears, the infusions can be larger.
- At the end, the outgoing needle is pushed to the bottom and the vial filled with air.

Safety

Dressing Up

During the delivery

Watching for

- Bubbles on the outside of the vial's diaphragm.
- Watching for clogging in the lines
- Watching to make sure the catheter hasn't moved or the capillary bed filled.

Surveying the Room

Surveying Participants

Surveying Feet

Measuring the Exposure from the Patient

- Measurement at 1 m.
- Maximum allowed reading is 5 mR/h
- Typical readings 0.3 – 3 mR/h

Dosimetry

Consistent, Accurate and Precise Assay of the Source Material

Part of delivering a consistent dose requires that the user be able to verify the manufacturer's assay *in each case*.

- That requires an *independent* calibration of the users dose calibrator.
- That also requires that the radiopharmaceutical be assayable.

Independent Calibration of the Users Dose Calibrator

This could be:

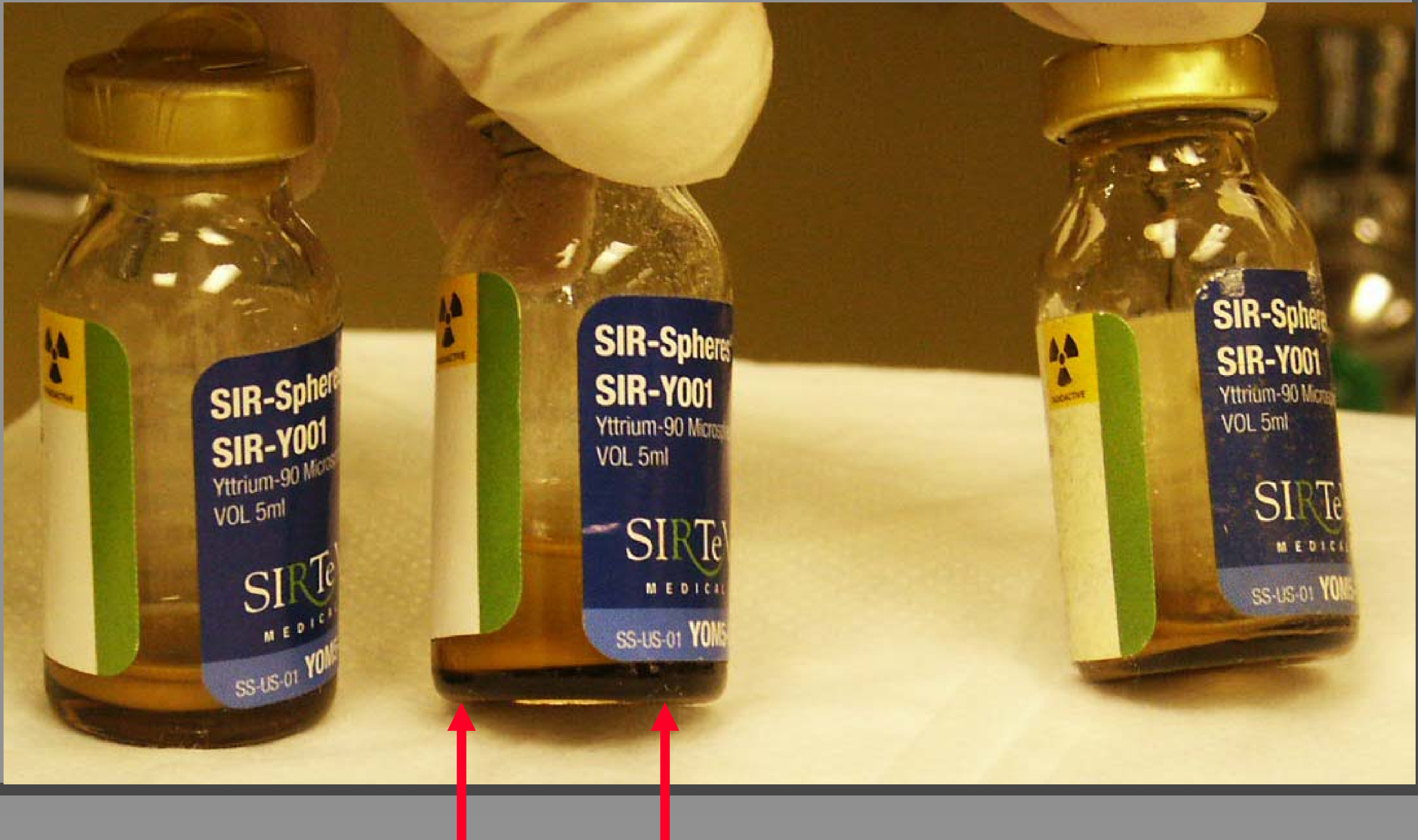
- Sources with an NIST traceable calibration independent of the therapeutic source manufacturer, but with identical geometry, or
- Sources from the manufacturer calibrated at NIST, or
- ADCL calibration of dose calibrations (using, assumedly sources as above).

UW Experience with Assay

Date	Calibration Factor
31-Jan-03	36.4
13-Feb-03	37.9
13_Feb-03	39
11-Mar-03	35.4
15-Apr-03	38
15-Apr-03	41.2
23-Apr-03	37.8
29-Apr-03	35.9
01-May-03	38.2
13-May-03	33.5
28-May-03	41.1
03-Jun-03	35.4
10-Jun-03	35.3
09_jun-03	39.6
16-Jun-03	35.3
16-Jun-03	37.4
24-jul-03	36.3
19-Aug-03	36.8
26-Aug-03	39.6
03-Sep-03	41.7
04-Sep-03	41.6
09-Sep-03	37
01-Oct-03	37.1
01-Oct-03	37.1
Average	**37.7**
Range	**33.5 -41.7**

- The shipping vials are each individual.
- The calibration factor = setting to read manufacturer’s assay.
- Dose calibrator is RadCal so factor is arithmetic not rheostat.
- Range covers ±11%.

Shipping Vials



Shipping Vials Closer

An Accurate Method of Relating the Assay to Dose

Here we have a problem.

- Dose is related to the radionuclide concentration.
- We assess the concentration using SPECT or (shudder) planar imaging using the bremsstrahlung.
  - Neither modality gives concentration
  - The conversion from counts is based on experiment and applies only to that geometry.

Dose Calculation

$$D_{liver} = \frac{50 Gy \cdot kg}{GBq} \frac{A_{instilled}(1 - F_{shunt})}{(T:N)M_{tumor} + M_{liver}}$$

where D_{liver} = nominal dose to the liver;

F_{shunt} is the fraction of counts shunted to the lungs on the 99mTc labeled MAA study;

M_{liver} = total mass of liver estimated by computed tomography;

M_{tumor} = total mass of metastases estimated by computed tomography;

$T:N = (A_{tumor}/M_{tumor})/(A_{liver}/M_{liver})$ from MAA scan

where A_{tumor}/M_{tumor} = activity per mass in tumor, and

A_{liver}/M_{liver} = activity per mass in liver (excluding tumor).

Radionuclide Engine

Y-90

- Equilibrium dose constant = 0.54 kg•Gy•GBq^{-1}•h^{-1}
- Mean life = 1.44•half-life = 1.44•64.2 h = 92.4 h
- Multiplying gives 49.8 Gy•kg/GBq

Dose to Tumor

$$D_{tumor} = \frac{50 Gy \cdot kg}{GBq} \frac{A_{instilled}(1 - F_{shunt})}{M_{tumor} + \frac{M_{liver}}{(T:N)}}$$

Actual Method for Prescribed Activity

Extent of Disease	Fraction of liver involvement	Base Activity in GBq
	>50%	3
	25% - 50%	2.5
	< 25%	2
Lung Shunting	Fraction of counts in the lung	Dosage Modifier
	< 10%	1.0
	10% - 15%	0.8
	15% - 20%	0.6
	> 20%	0.0 (DO NOT PROCEED)
Target	Part of Liver	Dosage Modifier
	Whole Liver	1.0
	Right Lobe Only	0.7
	Left Lobe Only	0.3

Calculation of the Prescribed Activity

The prescribed activity
= Base Activity x Lung-shunt Modifier x Fraction-of-liver Modifier.

Dose to Neighboring Structures

- Due to shunting
  - Lung shunting is measured
  - GI shunting can come from overfilling the hepatic capillaries (retrograde flow)
- Due to proximity
- Due to leaching

The Dose We Think We Want

The desired dose remains elusive.

- Treatments have been delivered in terms of activity injected, assuming we know that.
- Since the concentration depends on many variables, the doses patients have received have varied widely while remaining unknown.