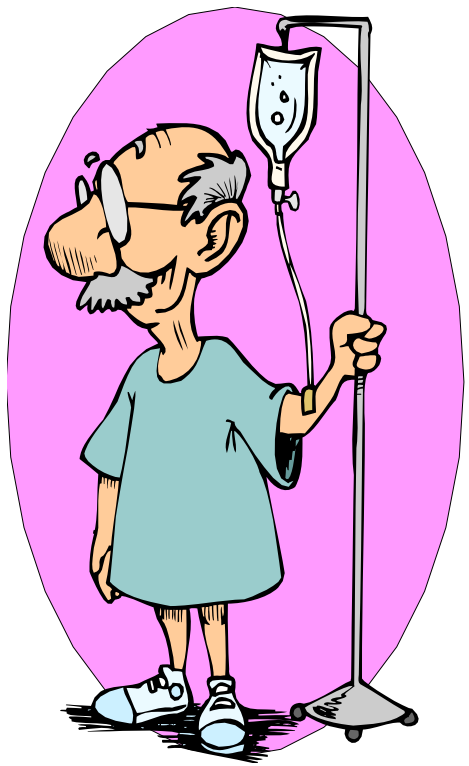
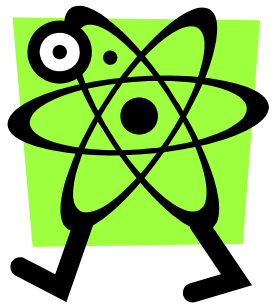
You know that you are a Senior Medical Physicist… When?



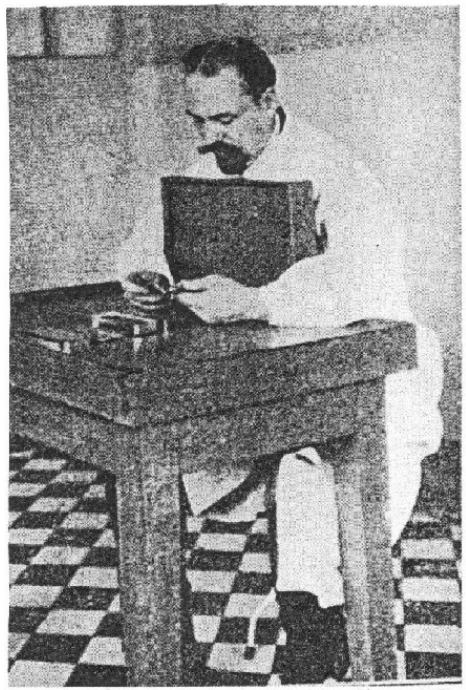
- You have calibrated the output of external beam treatment units in terms of Roentgens.
- You remember brachytherapy before remote after loading devices.
- You remember when CT was first introduced in diagnostic radiology.



- You have participated in implants which actually used Ra-226 sources.
- You practiced radiation oncology physics before computers and hand compounded isodose curves.

- You still have a slide rule in your desk.
- Becquerels remain a strange unit of activity.
- The Paterson-Parker rules are second nature to you.

When you can remember these working conditions.



Courtesy: Masson & Cie.

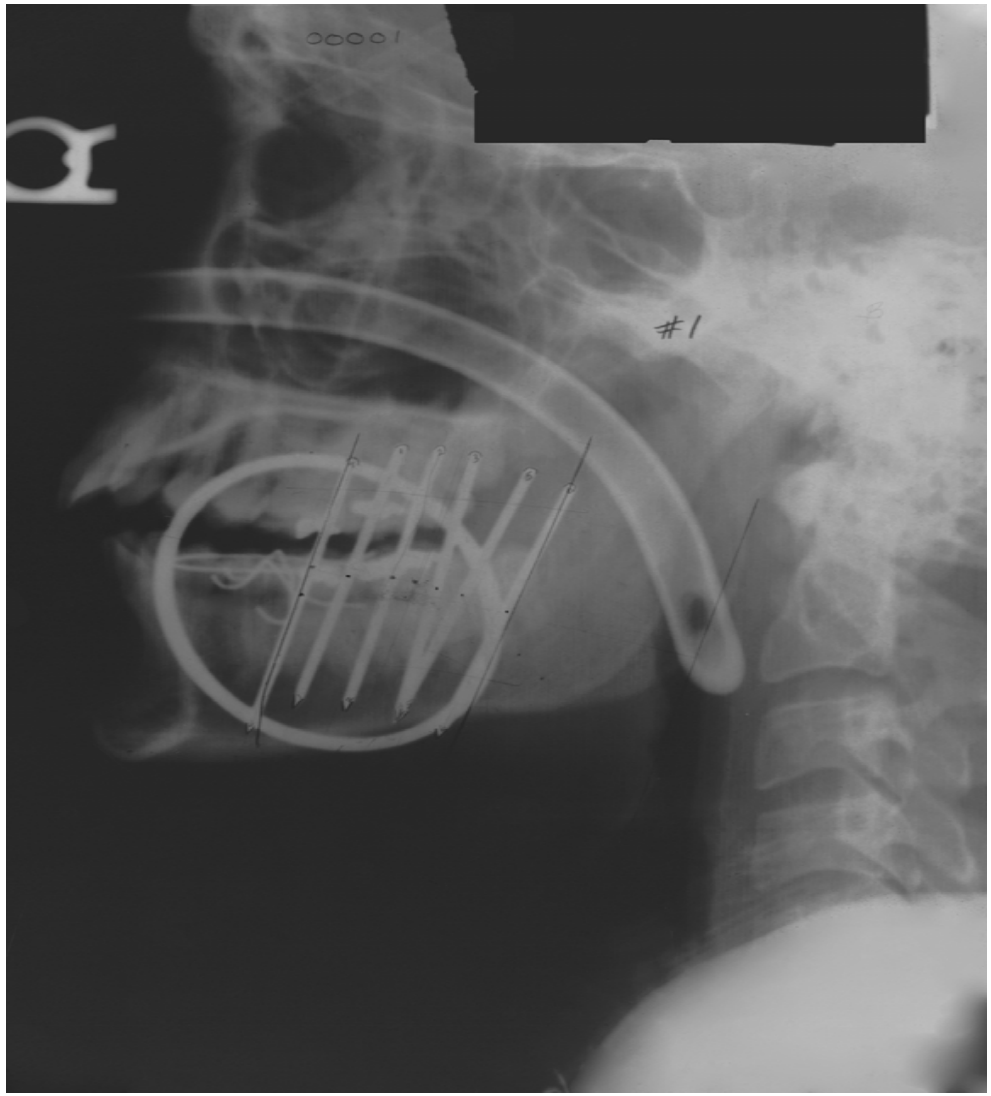
PROTECTIVE LEAD SHIELD. At the Institut du Radium of the University of Paris, in 1919, A. Félix hugs the wood-covered lead shield mounted on an extra-heavy table with built-in lead sheets for the operator's gonads. This picture appeared in the *Journal de Radiologie* of February, 1921 wherein Felix calls himself a *radiumlogiste opérateur*.

Classic Single Plane Radium Needle Implant from the 1960's

6 each

Ra-226 needles

3.5 cm active length



Left lateral margin of tongue

Physics:
Units are us.

The ability to convert activity from one isotope (Ra-226) to another isotope (Ir-192), for example, remains an important skill.

X mg Radium x 8.25 R cm^2/mg-hr =

Y mCi (Ir-192)x 4.69 cGy cm^2/mCi-h

Conversion of Activity

25.5 mg Ra-226

25.5 x 8.25/4.69

is equivalent to

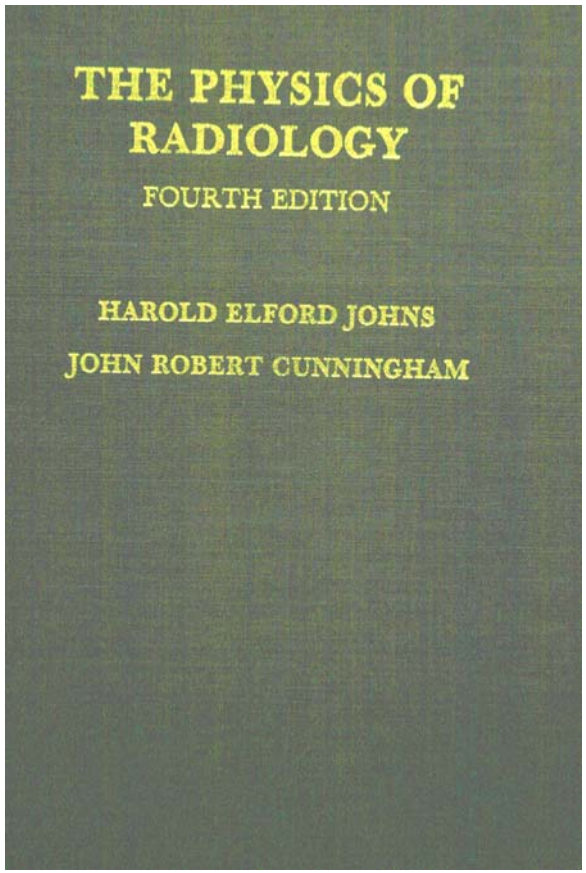
44.8 mCi Ir-192

Physics
Units are us.

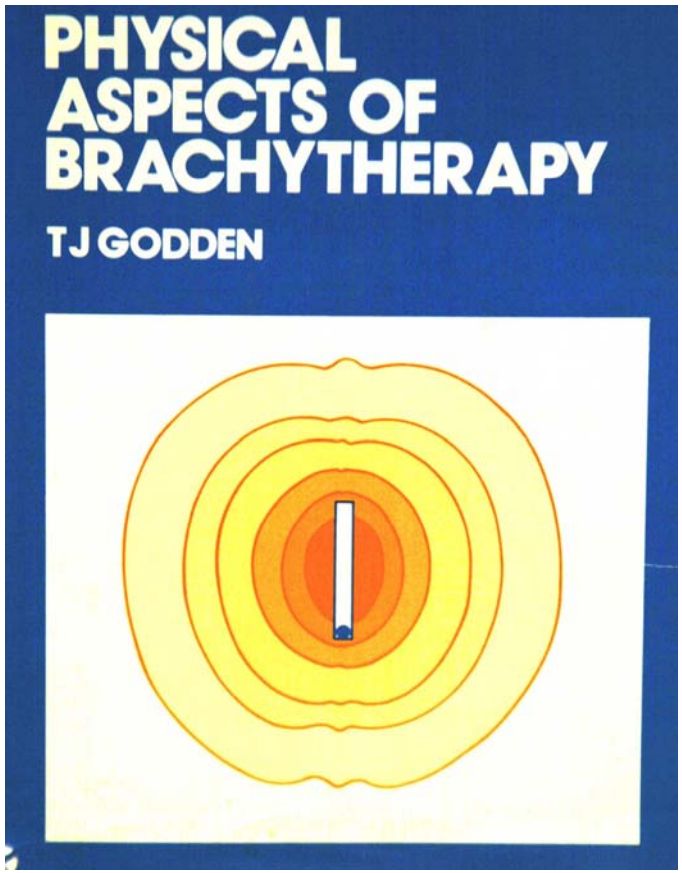
611 mg h (Radium) x
8.25 (Ra-226)/4.69 (Ir-192) =
1,075 mCi h (Ir-192)

Even in today's practice, the medical physicist must be able to convert using out-dated units into new confusing units.

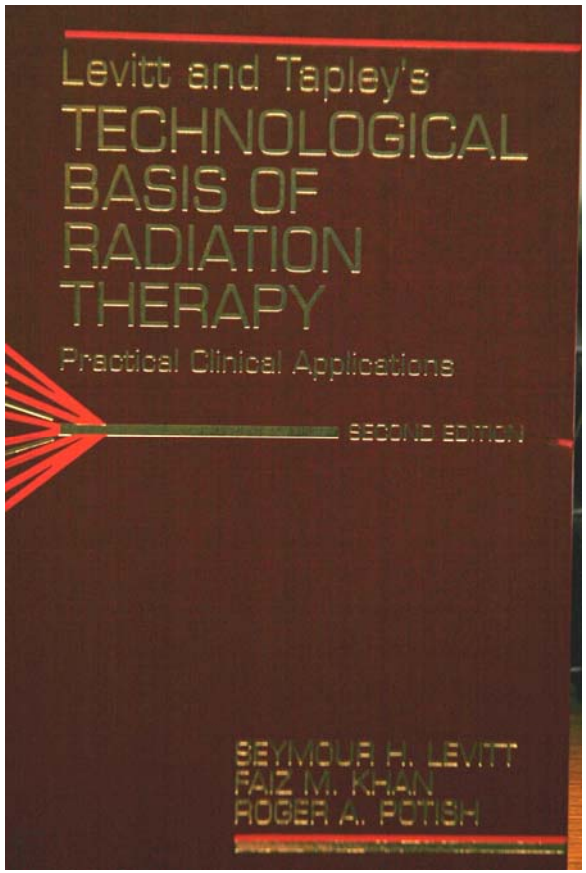
The Medical Physics Bible



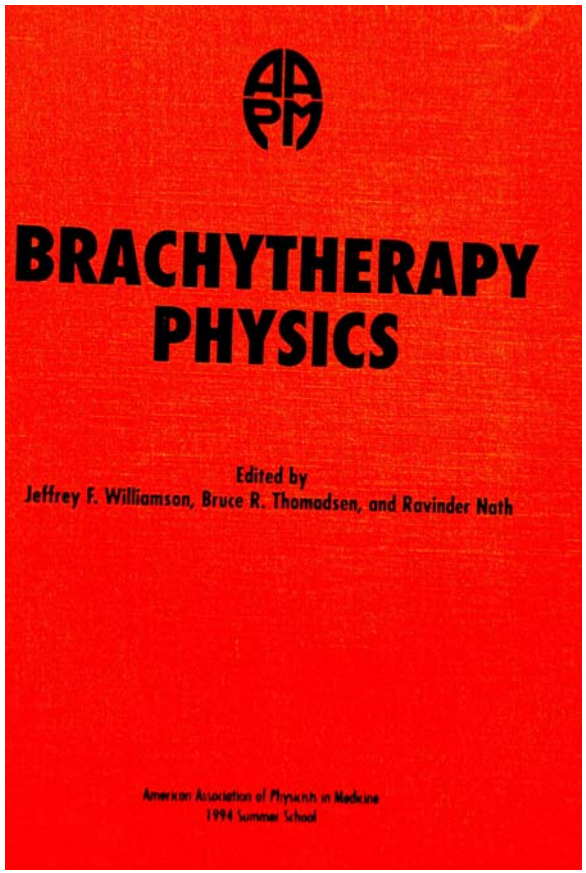
Medical Physics Handbooks 19



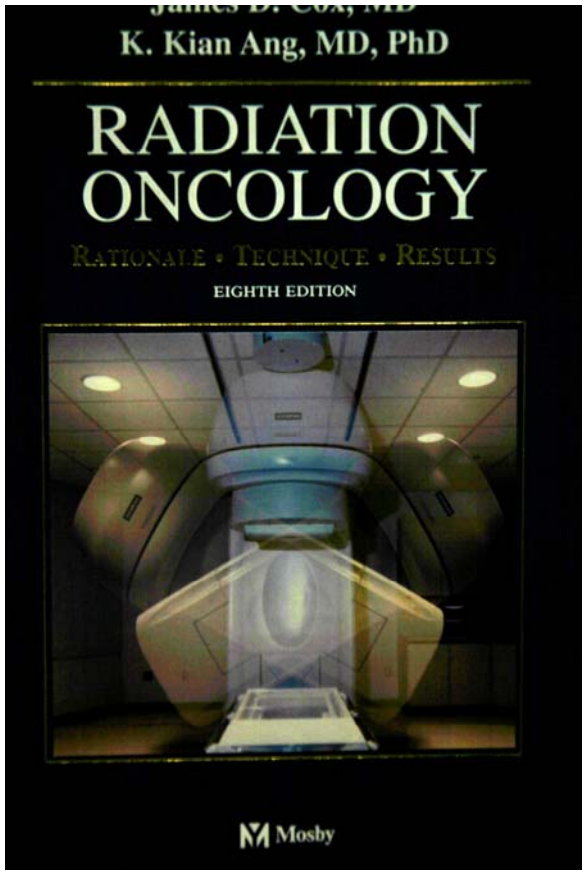
Practical Clinical Applications



AAPM Past Summer Schools



The Anderson Text - Eighth Edition



Marie Curie

I-1 **Marie Curie in the** winter of her **life at her laboratories**

Curies, milliCuries, and milligrams

- There are modern units of activity, e.g. the Becquerel.
- There are modern methods of specifying source strength, e.g. air kerma in air and the U.
- This presentation will use old fashion terms, e.g. mCi, and old fashion concepts, e.g. exposure rate constants.
- The excuse for not being modern is that the systems are not modern and the presenter is more comfortable with the older systems.

Ra-226 was important in the UK and the US up until the 1970's.

RADIUM
STANDARD CHEMICAL CO.

U. S. Bureau of Standards Measurement.

Radium element content and delivery guaranteed

Radium Chemical Company
Pittsburgh, Pa., U. S. A. 1916

RADIUM

A MONTHLY JOURNAL DEVOTED TO THE CHEMISTRY, PHYSICS AND THERAPEUTICS OF RADIUM AND OTHER RADIO-ACTIVE SUBSTANCES

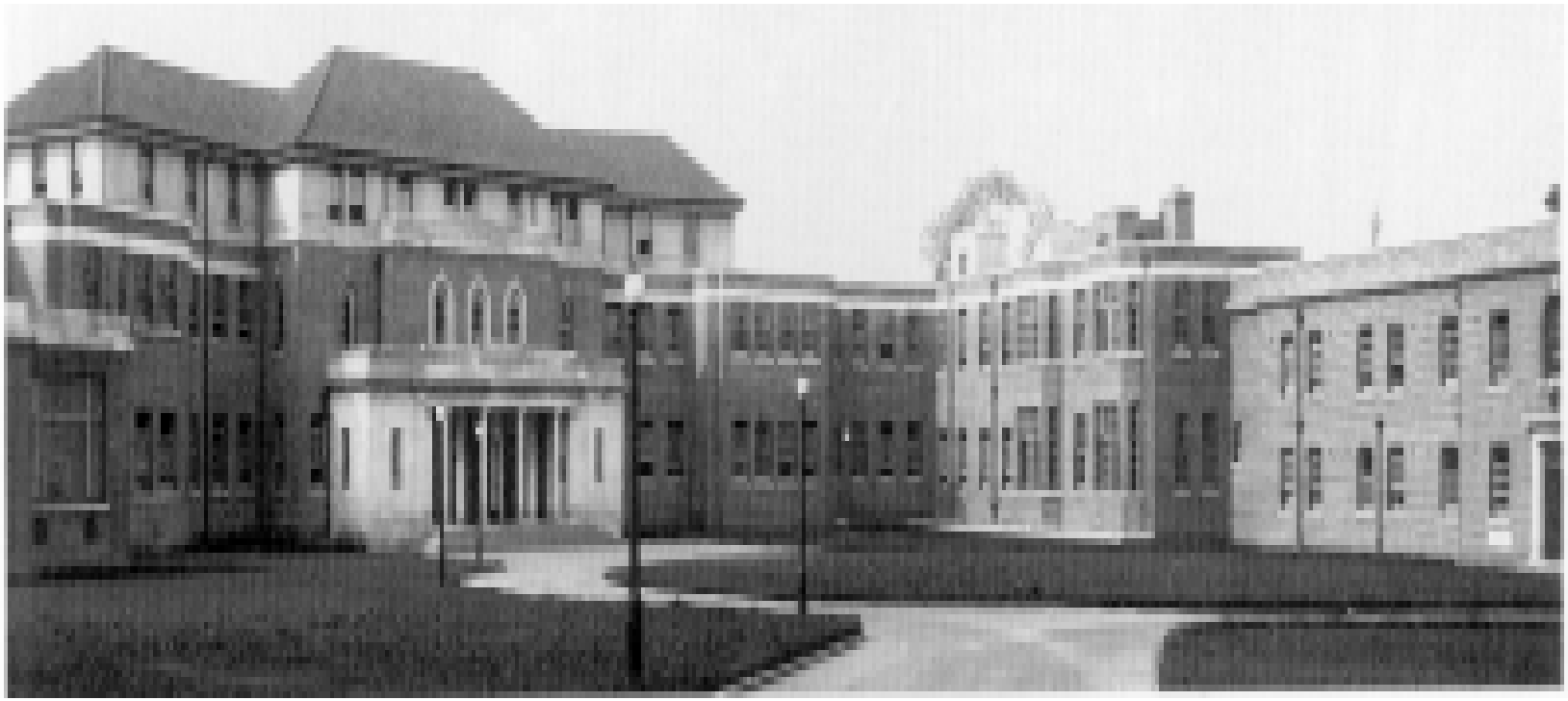
PUBLISHED BY THE RADIUM PUBLISHING COMPANY
FORBES AND MEYRAN AVENUES, PITTSBURGH, PA.

VOL. I APRIL, 1913 No. 1

Christie Hospital

pioneering the use of Roentgen X-rays for cancer therapy (1901); setting the first international

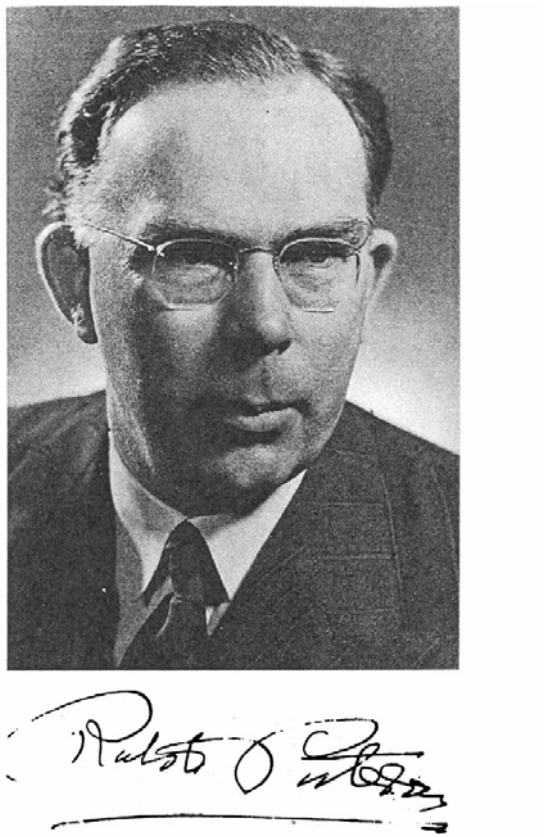
standards for radiation treatment (1932);



The hospital was first opened as the Cancer Pavilion and Home for Incurables in 1892. Nine years later, in November 1901, it was named The Christie Hospital in recognition of the pioneering work of both Mr. and Mrs. Christie.

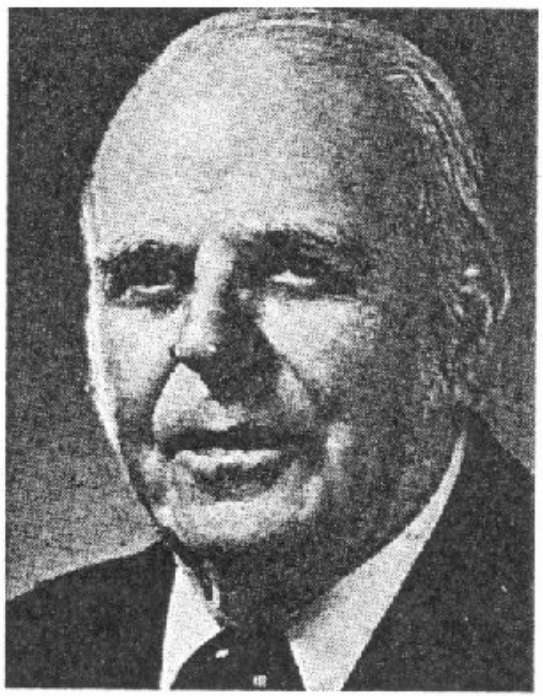
Every year Christie Hospital sees approximately 11,000 new patients registered; 15,000 in-patient stays; 14,500 day-case stays; and 139,500 out-patient visits. There are approximately 250 in-patient beds, which are intensively used, with an average length of stay of less than six days. Approximately 1,800 staff work on our site, plus around 300 volunteers.

Ralston Paterson, MD, FRCS, FFR



Ralston Paterson, M.D., C.B.E., President of the International Congress of Radiology (1950).

H. M. Parker, M.Sc., F. Inst. P.



PARKER, HERBERT MYERS (1910–1984),

The Paterson-Parker or Manchester System for Applicators

The original 1934 Paterson-Parker tables presented the amount of radium in milligram-hours (mg h) required to give a dose of 1000R to the treatment area which is at a distance ***h*** from the surface of the applicator, while achieving a $\pm$ 10% dose uniformity.

External Applicators and Molds

- The Paterson-Parker tables provide values for treatment distances of 0.5 to 5.0 cm at 5 mm increments.
- Classic Paterson-Parker molds have not been common in my experience - 1 in more than 30 years.
- There are distribution rules which depend on the diameter of the circle and the treatment distance.

Johns Example 13-10

- A 6 cm^2 area is to be treated using sources placed on an equal area 1.0 cm away. To deliver 60 Gy in 5 days, what activity is required?
- Area 6 cm^2 Treatment Distance **10 mm**
- mg-hr/10 Gy 354
- (60Gy/10Gy)(354 mg-hr/(5daysx24hrs/day)
- = 17.7 mg Ra-226

Surface Applicator

Depth:

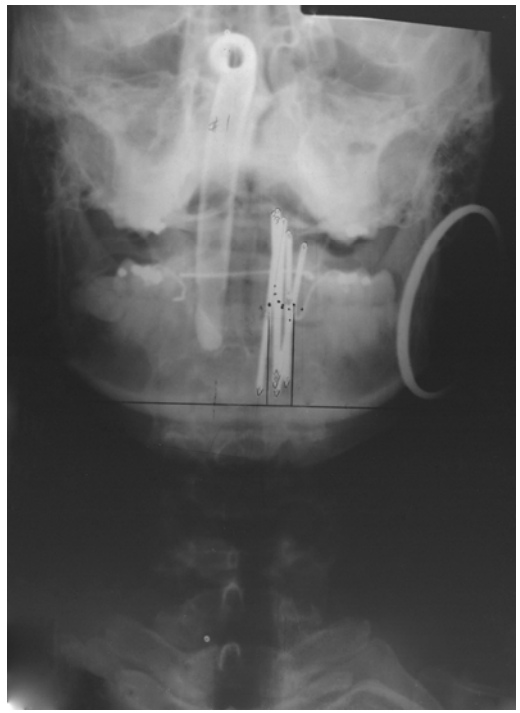
10 mm

TABLE 3: Surface Applicators and Planar Implants

The table gives R_A, the number of mg hr required to deliver 10 Gy to muscle tissue for different areas and treatment distances. Filtration 0.5 mm Pt. The table may be used for planar implants by using a treatment distance of 0.5 cm.

	Treatment Distance (cm)									
Area cm^2	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
0	32	127	285	506	792	1139	1551	2026	2566	3166
1	72	182	343	571	856	1204	1625	2100	2636	3295
2	103	227	399	632	920	1274	1697	2172	2708	3349
3	128	263	448	689	978	1331	1760	2241	2772	3383
4	150	296	492	743	1032	1388	1823	2307	2835	3450
5	170	326	531	787	1083	1436	1881	2369	2896	3513
6	188	354	570	832	1134	1495	1938	2432	2956	3575
7	204	382	603	870	1182	1547	1993	2490	3011	3634
8	219	409	637	910	1229	1596	2047	2548	3067	3694
9	235	434	667	946	1272	1645	2099	2605	3123	3752
10	250	461	697	982	1314	1692	2149	2660	3178	3809
12	278	511	755	1053	1396	1780	2247	2769	3284	3917
14	306	557	813	1120	1475	1865	2341	2870	3389	4027
16	335	602	866	1184	1553	1947	2429	2968	3490	4131
18	364	644	918	1245	1622	2027	2514	3063	3585	4240
20	392	682	968	1303	1690	2106	2601	3155	3682	4341

Single Plane Manchester Implant



- Lateral view

Anterior view

Paterson-Parker Interstitial Therapy

- The interstitial dose system (1938) was a natural extension of the surface applicator system.
- The definition of ‘stated dose’ is different between the two systems.
- In the interstitial system, the stated dose is defined to be 10% above the minimum dose in the plane of calculation.

Paterson-Parker Interstitial Therapy

- This system supports single and double plane implants and volume implants.
- Single plane implants: The sources are considered to be in the center of a 1 cm slab of tissue and the plane of calculation, which is 5 mm from and parallel to the source plane, is defined by the projection of the sources onto this plane.
- Single plane implants: 10 mm thick

Paterson-Parker Interstitial Therapy

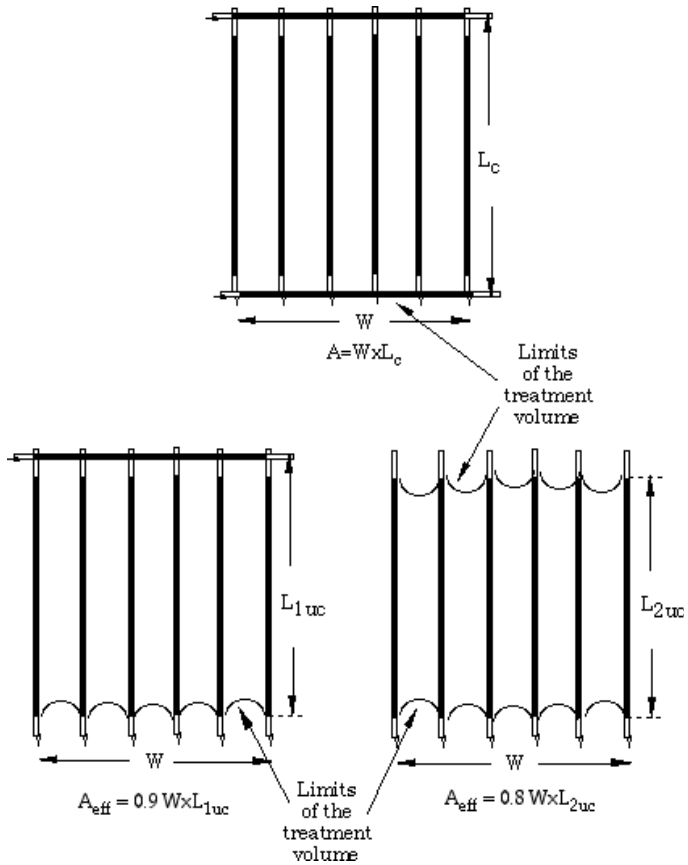
- Double plane implants: 15 mm, 20 mm or 25 mm in thickness
- Single and double planes use the same tables and the same rules.
- Volume implants: > 25 mm thickness
- Volume implants have their own rules and tables.

The Paterson-Parker Rules for Planar Implants

- 1. The needles should be in parallel rows at spacing not greater than 1 cm.
- 2. Crossing needles should ideally cross the active needle ends, but should not be more than 1 cm from the active ends.
- 3. Deduct 10% of the area for each uncrossed end and use the reduced area in the tables.

Areas covered by implants with 1. Two crossed ends

2. One crossed end and 3. No crossed ends



The Paterson-Parker Rules for Planar Implants

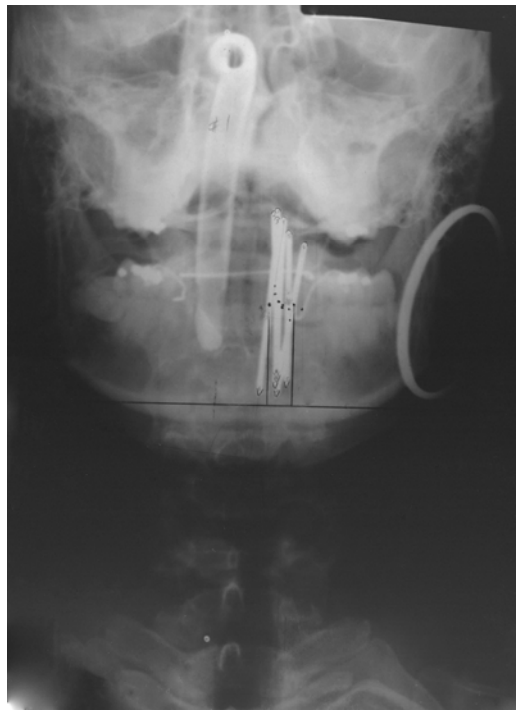
- 4. For implants using small sources (seeds or short needles) the distance between the active ends should not exceed 1 cm.
- 5. If two planes are to be used, the separate planes should be arranged as for single planes, parallel to each other, and if they differ in area, then the average area is used to determine the mg-hrs and the activity is proportioned to each plane.

The Paterson-Parker Rules for Planar Implants

Area	% Activity in periphery	% Activity in the center
$< 25\ cm^2$	2/3	1/3
$>25\ cm^2$ & $< 100\ cm^2$	1/2	1/2
$> 100\ cm^2$	1/3	2/3

Single Plane Manchester Implant

6 needles - 3. 5 cm Active Length, 2.28 mg/needle



- Lateral view

Anterior view

Both ends uncrossed

Single Plane Implant

- Length - 3.5 cm Width 3.0 cm
- Area - 3.5 x 3.0 x 0.8 = 8.4 cm^2 (0.8 for 2 uncrossed ends)
- Treatment distance - 0.5 cm
- 225 mg-h/10 Gy
- Total milligrams - 13.7 mg
- Dose rate: 1000 cGy * 13.7 mg/225 mg-h = 60.9 cGy/hr

Planar Implant

TABLE 3: Surface Applicators and Planar Implants

The table gives R_A, the number of mg hr required to deliver 10 Gy to muscle tissue for different areas and treatment distances. Filtration 0.5 mm Pt. The table may be used for planar implants by using a treatment distance of 0.5 cm.

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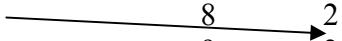
18	364	644	918	1245	1622	2027	2514	3063	3585	4240
20	392	682	968	1303	1690	2106	2601	3155	3682	4341

Depth:

5 mm



Single curved plane

- 5 Needles, 2.18 mg/needles, Active length 4.5 cm
- Both ends uncrossed.

Single Curved Plane

- My very old notes indicated that an inside the curve concave area, 5 mm from the curved source plane, was determined. Then the mg-h/10Gy was found for this area.
- The dose rate was also calculated for the outside area at 5 mm from the curved source plane.

Curved source plane

- Inside curved width - 2.8 cm
- Area - 2.8 cm x 4.5 cm x 0.8 = 10.1 cm^2
- 250 mg-hr/10Gy
- Inside curved dose rate - 1000 cGy x 10.9 mg/250mg-hr = 43.6 cGy/hr
- Outside curved width - 3.8 cm
- Area - 13.9 cm^2 306 mg-hr/10Gy
- Outside dose rate - 1000 cGy x 10.9/306 = 35.6 cGy/hr

Double Curved Plane

- This implant used 12 needles in 2 different curved planes. Active length 4.5 cm with 1.5 mg/needle

Paterson-Parker Contribution

- In the time before computers and megavoltage external beam units, a system of dosimetry which included rules of the placement of sources and rules for the distribution of the radiation were a major contribution to the practice of radiation oncology.

Floor of mouth - Double curved plane

- 6 Indian club needles were used in the outer curved plane plus 4 half intensity needles in the inner curved plane.

Double Curved Plane

- Total milligrams: 15.46
- Larger Plane: Area 3 cm x 3.75 cm x 0.9 = 10.13 cm^2 Activity 9.66 mg
- mg hr/1000 R = 234 (5 mm)
- Dose rate: 9.66 mg x 1000 R x 0.9 rad/R/ 234 mg hr = 37.2 rad/hr
- The dose rate at 10 mm was also calculated using the Manchester tables. 23.3 rad/hr

Double Curved Plane

- Total milligrams: 15.46
- Smaller Plane: Area 1.8 cm x 4.5 cm x 0.8 = 6.48 cm^2 Activity 5.8 mg
- mg hr/1000 R = 193 (5 mm)
- Dose rate: 5.8 mg x 1000 R x 0.9 rad/R/ 193 mg hr = 27.05 rad/hr
- The dose rate at 10 mm was also calculated using the Manchester tables. 14.2 rad/hr

Double Curved Plane

- The dose rates from the 2 planes at distances of 5 mm and 10 mm were then added.
- The total dose rate of 5 mm from the smaller plane and 10 mm from the larger plane is 50.35 rad/hr and visa versa from the smaller plane is 51.4 rad/hr.
- (It is fun to note that given the sources if this implant were to be performed today, the dose rates would be the same.)

Two Plane Implant

Example C page 36 Radium Dosage

- The lesion is a flat, plaque-like, solid tumor, just under the skin.
- The size is 5 cm x 6 cm and thickness is 1.5 cm.
- The treatment is a 2 plane implant with the larger plane undercutting the lesion (6 cm x 7 cm) and with a smaller superficial plane (5 cm x 6 cm).
- Dose (in modern units - 60 Gy in 6.5 days)

Radium Dosage The Manchester System

- Published in 1947 by The Williams and Wilkins Company
- Edited by W. J. Meredith (Christie Hospital and Holt Radium Institute, Manchester)
- Compiled from articles by: Paterson, Spiers, Stephenson, Parker, Tod, and Meredith

Two Plane Implant

Example C page 36 Radium Dosage

- Larger plane: 42 cm^2
- Smaller plane: 30 cm^2
- Average area: 36 cm^2
- From Johns table at a depth of 5 mm :
  594 mg-hr/10 Gy for 36 cm^2
- 1.5 cm separation factor: 1.25
- Total: 1.25 x 594 = 742 mg-hr/10 Gy
- Total mg-hrs = 742 x 6 = 4452 mg-hrs

Two Plane Implant

Example C page 36 Radium Dosage

- Total mg: 4452 mg-hr/156 hr = 28.5 mg
  This is to be distributed over both planes.
- 42 cm^2 + 30 cm^2 = 72 cm^2
- 42/72 = 58% or 16.6 mg
- 30/72 = 42% or 12 mg

- Note that both planes are > 25 cm^2

Two Plane Implant

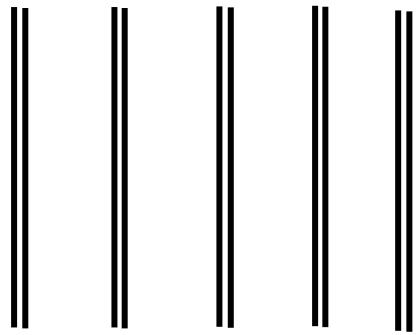
Example C page 36 Radium Dosage

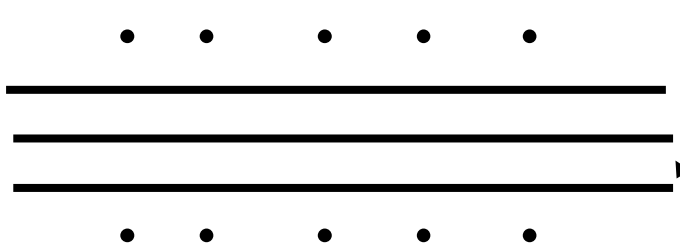
- Larger Plane needle distribution
  - 8 ea 1 mg needles around the periphery
  - 8 ea 1 mg needles in the center
- Smaller Plane needle distribution
  - 4 ea 1 mg needles + 2 ea 1.5 mg needles around the periphery
  - 4 ea 1.5 mg needles in the center.

Two Plane Implants

- Johns notes that the Paterson-Parker approach of using 5 mm distance and a correction factor is only approximate. Correction factors (1.25 for 1.5 cm, 1.41 for 2.0 cm, and 1.52 for 2.5 cm)
- Johns recommends determining the mg-hr/10 Gy for the center plane.

Double Plane Implant
Active Length: 3.0cm
Width: 4.0 cm
Separation 2.0 cm

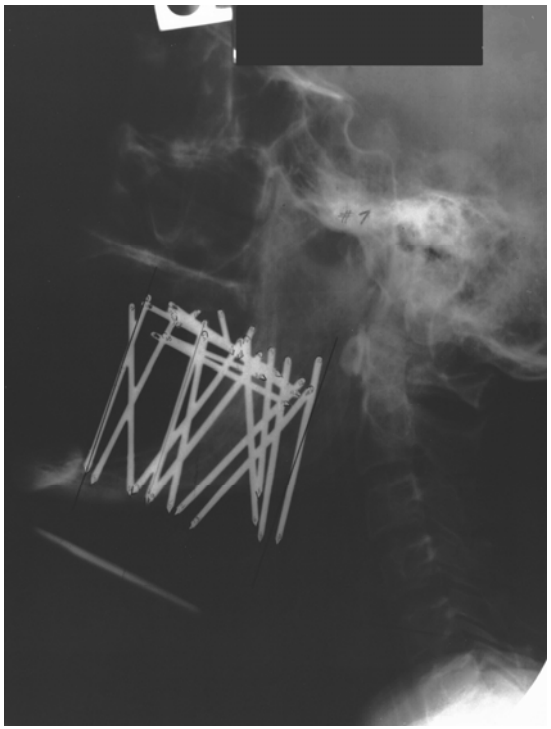


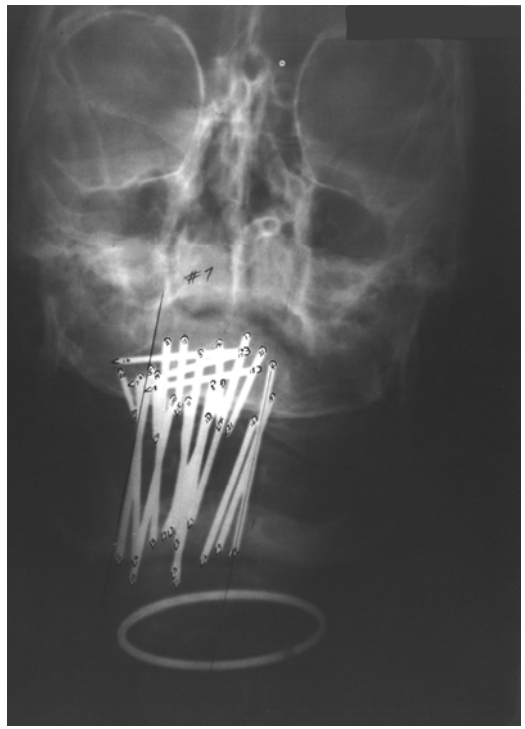


Source Plane
Calculation Planes
Source Plane

Johns recommends calculating the dose here.

Volume Implant of Right Posterior Border of Tongue





- 21 needles - 30.5 mg Ra-226 - One uncrossed end
- The calculated dose rate is 79.7 rad/hr.

Paterson-Parker Volume Implants

- New rules and new tables for spheres and for cylinders (Johns Table 13-8)
- Uncrossed ends - 7.5% reduction in volume.
- Sources on each face must be placed as evenly as possible.
- Sources must best be distributed throughout the core and not just at the center.
- Sources on each surface must be spaced evenly and not more than 1.0 to 1.5 cm apart.

Distribution of Activity for Volume Implants

Volume Shape	Distribution of Activity			
Sphere	Rind 6 parts		Core 2 parts	
Cylinder	Belt	Core	End A	End B
Crossed at active ends	4	2	1	1
1 end uncrossed	4	2	1	0
2 ends uncrossed	4	2	0	0
Crossed at needle tips	4	2	2	2
1 end uncrossed	4	2	2	0

Volume Implant Example
Radium Dosage
Tongue and Floor of Mouth

- Area of ulcerated induration of approximately 2 cm x 3 cm on the right side of the floor of the mouth and extending well into the under surface of the tongue.
- To be treated with an elliptical implantation of height 3.6 cm and cross-section 3 cm x 4 cm. Only one end is crossed.

TABLE 4: Volume Implants

R_v —mg hr to give 10.0 Gy to volume implant: Radium equivalent for filtration of 0.5 mm Pt		
Volume cm^3	R_v mg hr	Distribution Rules
5	106	Volume should be considered as a surface with 75% activity and core
10	168	with 125%
15	220	
20	267	Rules for cylinders
30	350	
40	425	Belt —50% activity with minimum 8 needles
50	493	Ends —12.5% of activity on each end
60	556	Core—25% with minimum of 4 needles
80	673	For each uncrossed end, reduce volume by 7.5%
100	782	
140	979	Length
180	1156	Diameter = 1.5% 2.0 2.5 3.0
220	1322	
260	1479	Increase mg hr 3% 6% 10% 15%
300	1627	
340	1768	
380	1902	

This table was prepared from the original by Meredith (M12) by multiplying his values by C = 1.064.

(From Johns, H.E., and Cunningham, J.R., The Physics of Radiology, Fourth Edition (1983) with permission of Charles C. Thomas Publisher)

Volume Implant Example
Radium Dosage
Tongue and Floor of Mouth

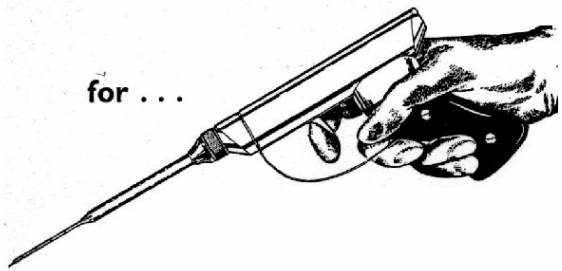
- Dose (in modern units) 70 Gy in 7 days
- Volume = Π/4 x 3.6 x 3 x 4 = 33.9 cm^3
- Effective volume: 33.9 x 92.5% = 31.4 cm^3
- mg-h/10Gy (Johns 13-8) = 360 mg-h/10 Gy
- 7 Days = 168 hrs
- 360 mg-h/168 hrs * 70Gy/10Gy = 15 mg

Permanent Volume Implant Based upon Example in Radium Dosage

- Long ago Radon seed implants were performed. The Ra-222 gas was encapsulated by 0.3 mm gold walls.
- Not so long ago, Au-198 gold seeds were used to replace the Ra-222 gold seeds. The half-life of Au-198 is 2.698 days. The exposure rate constant is 0.238 R m^2/h-Ci.

Gold Grain/Seed Applicator

ROYAL MARSDEN HOSPITAL DESIGN-



the Precise Implantation of RADIOACTIVE GOLD GRAINS

The technique of interstitial implantation of small radio active sources has been made easier, more precise, more economical and less hazardous by the substitution of radio-active gold grains for radon seeds and their insertion by means of this specially designed Implantation Gun.

Accommodating 15 grains at one loading, its use provides ease of control in implantation, especially in producing a pre-arranged pattern in a volume implant.

Single grains are expelled by operating the trigger, the next grain being held in position for expulsion at the next trigger pull. A numbered scale gives a visible indication of the number of grains used.

Experience has shown that irradiated gold grains produce reactions indistinguishable from those produced by radon seeds. There is less waste than with radon seeds because any unused grains can be reactivated.

1955

Full information on request from

THE MEDICAL SUPPLY ASSOCIATION LTI

PARK ROYAL ROAD, N.W.10., and 95 WIMPOLE STREET, W.1. Telephone: ELGar 40

Sole British Distributors for WESTINGHOUSE X-RAY EQUIPMEN

Permanent Volume Implant Based upon Example in Radium Dosage

- Consider a 4.0 cm diameter sphere, volume 33.5 cm^3, which is designed to deliver 65 Gy.
- The Manchester table for 33.5cm^3 yields 376 mg-h/10 Gy.
- 65/10 * 376 = 2444 mg-h
- This must now be converted to the appropriate Au-198 activity.

Permanent Volume Implant Based upon Example in Radium Dosage

- 1 mCi (Au-198) * 2.38/8.25 = 0.288 mg Ra-226
- 1 mCi decayed (Au-198) = 1.445 x 2.698 days x 24 hours/day x 0.288 mg = 26.9 mg-h (Ra-226)
- 2444 mg-hr/26.9 mg-h/mCi = 90.9 mCi Au-198

Permanent Volume Implant Based upon Example in Radium Dosage

- 90.9 mCi Au-198
- The classic Manchester Rules: 6 parts of the activity (68 mCi) are in the rind and 2 parts (23 mCi) are in the core.
- 12 seeds, 5.7 mCi/seed, should be placed on the surface of the 4 cm diameter sphere and 6 seeds, 3.8 mCi each, should be evenly distributed throughout the volume of the sphere.

Paterson-Parker System

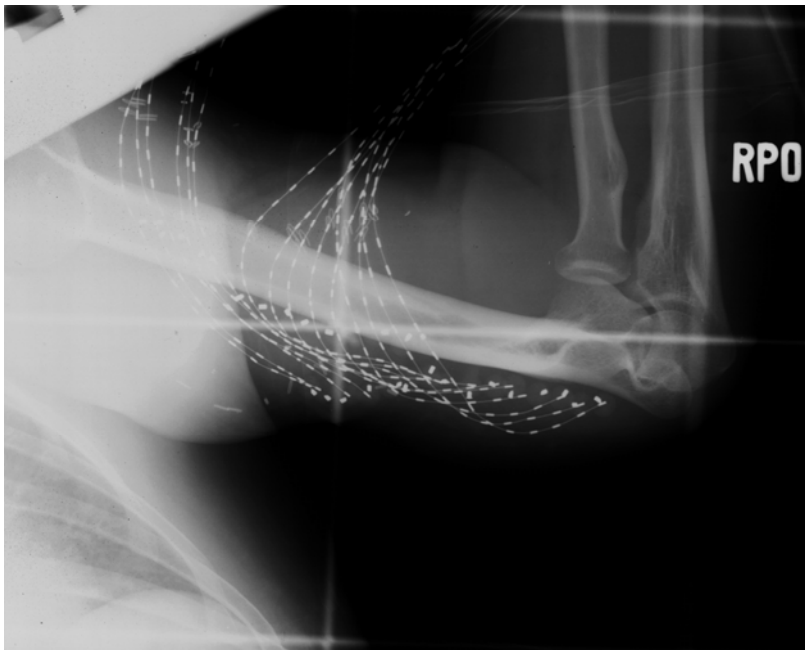
- Is it used today?
- Perhaps very limited use in the US and the UK. Perhaps, not at all.
- Prostate implants are not based upon this system, but reflect some of its heritage, e.g. peripheral loading.
- This system contains some sound basic principles.

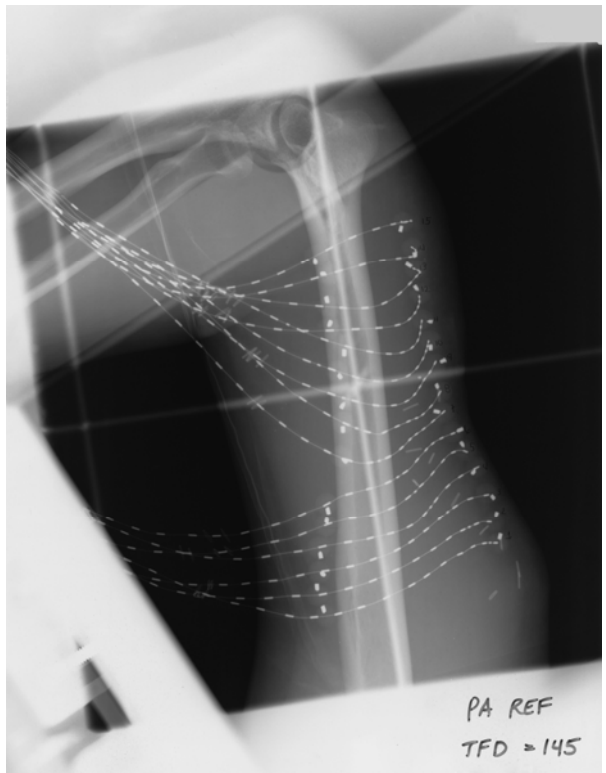
Nasal Septum Implant

- 6 each Ir-192 wires, 2.2 cm length

Oncologist placed the sources using best judgement, as opposed to a system. What will be done next time?

Malignant fibrohistiocytoma of right upper extremity





- 15 catheters, Ir-192 wire, 45 Gy in 76 hours

How did the oncologist decide on source spacing?

Robert Heinlein: A generation which ignores history has no past and no future.

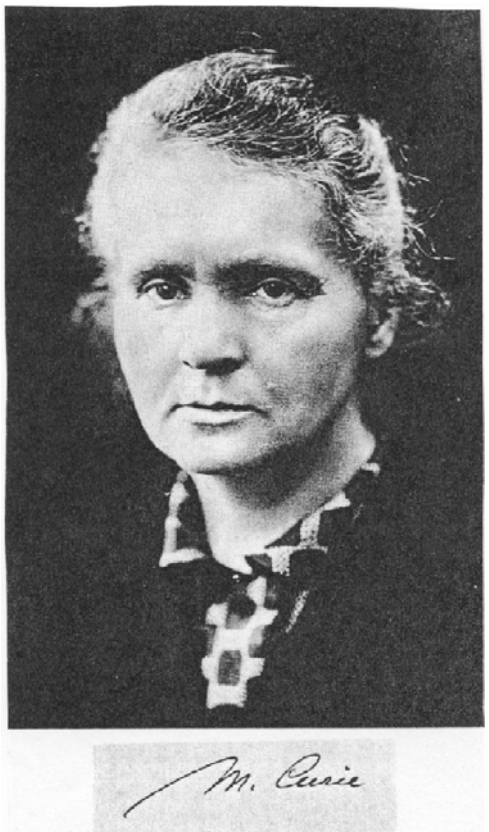


Fig. II-10. Marie Curie (1925)—signature.