SURFACE MOULD BRACHYTHERAPY

Dr. GUNASEELAN K.
HEAD OF THE DEPARTMENT
RADIATION ONCOLOGY
RCC, JIPMER

HISTORY

Emil H. Grubbé

- Claimed to be the first to treat cancer with radiation (X-rays)
- Treated a Breast cancer patient with X-rays in Chicago in January, 1896 only 2 months after discovery of X-rays by Wilhelm Conrad Roentgen.

Many investigators then began testing the therapeutic potential of X-rays in several benign and malignant conditions.

By 1899, several physicians had successfully treated different types of malignancies particularly skin malignancies with X-rays.

HISTORY

Marie and Pierre Curie discovered Radium in 1898.

Was subsequently tested for radio'therapy'.

Henri-Alexandre Danlos

- Successfully treated Lupus (skin) using Radium in 1901.

Radium was soon seen used to treat disorders where X-ray treatment was not feasible because it could be applied in a multitude of ways in which X-rays could not.

HISTORY

In the Early 1900s, Radium BRACHYTHERAPY was tested in malignancy.

Provided the advantage of more specific application to tissues as compared to X-rays.

Small tubes of radium strapped to the skin to treat malignancy

Radium applicator strapped to the skin

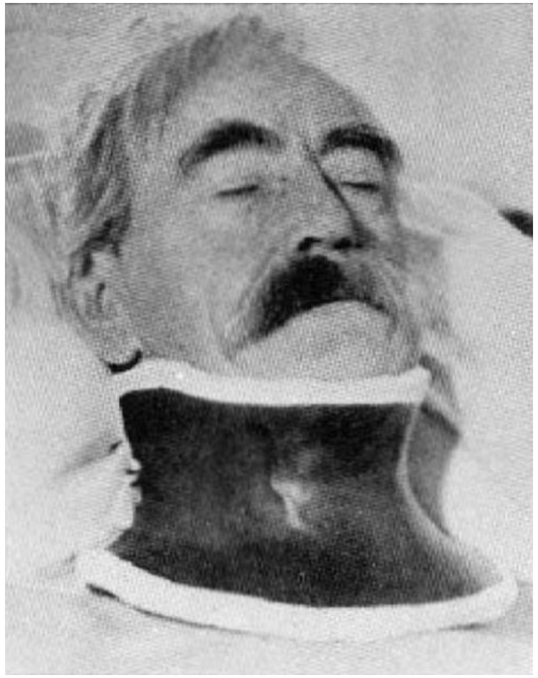
Mould, Richard Francis (1993). A century of x-rays and radioactivity in medicine

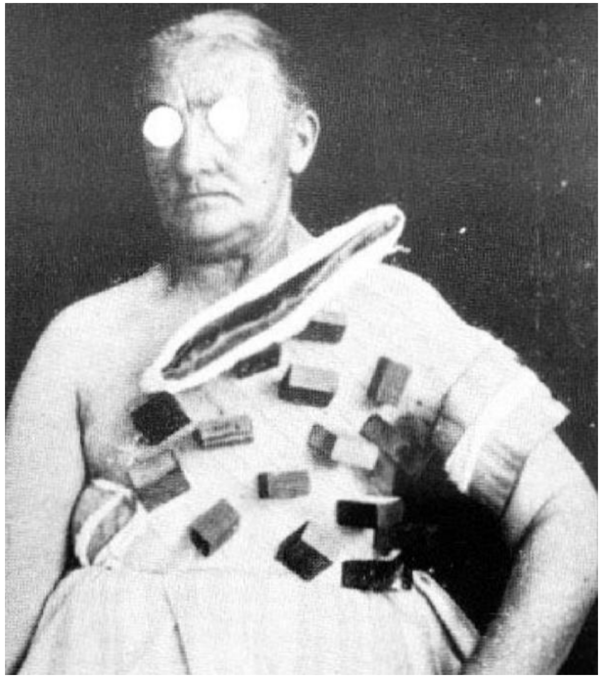
HISTORY

The 1st Brachytherapy applications were Surface moulds & plaques.

In these early applications, Radium was uniformly distributed in the applicator.

- It was later realized that this resulted in a non-homogeneous dose distribution.





Various forms of Radium Surface Moulds

Mould, Richard Francis (1993). A century of x-rays and radioactivity in medicine

HISTORY

Paterson & Parker later showed that:

"To achieve a homogeneous radiation dose distribution, a non-uniform distribution of Radium content is required"

They laid the Manchester Rules

Ralston Paterson and H. M. Parker

A DOSAGE SYSTEM FOR GAMMA RAY THERAPY

PART I

By RALSTON PATERSON, M.D., F.R.C.S., D.M.R.E.

(*Received June* 7, 1934)

PATERSON, R., and PARKER, H. M., *British Journal of Radiology,* vii, 1934, p. 592

HISTORY

But,

- The construction and use of brachytherapy surface moulds was associated with Radiation Hazard.

- Linear accelerators were introduced and high-energy electron beams became available, that began to be extensively used for skin and superficial treatment.

- This made ***surface mould brachytherapy become less popular.***

HISTORY

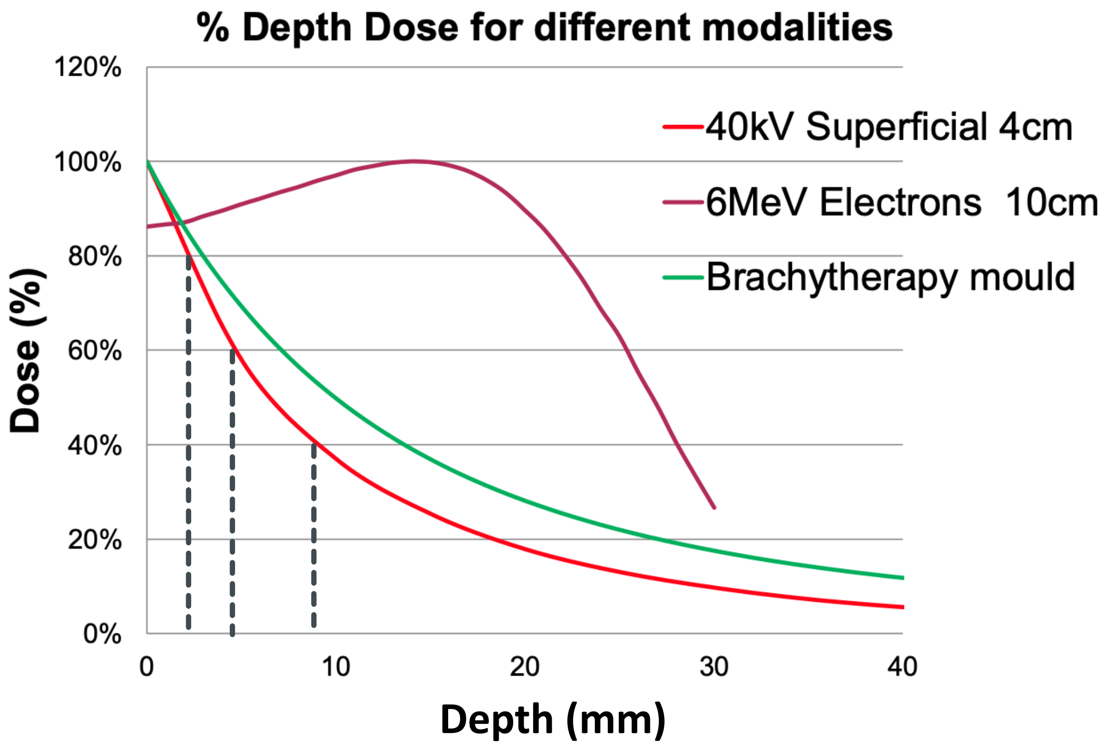
However,

- With the development of after-loading techniques and in particular **HDR remote after-loading**, the issues associated with personnel radiation protection were overcome.

- HDR brachytherapy units became more widely used and this led to a ***revived interest in surface moulds.***
- Radiation safety hazards associated with LDR moulds are no longer present and the treatment could be delivered safely over a short time as an outpatient procedure.

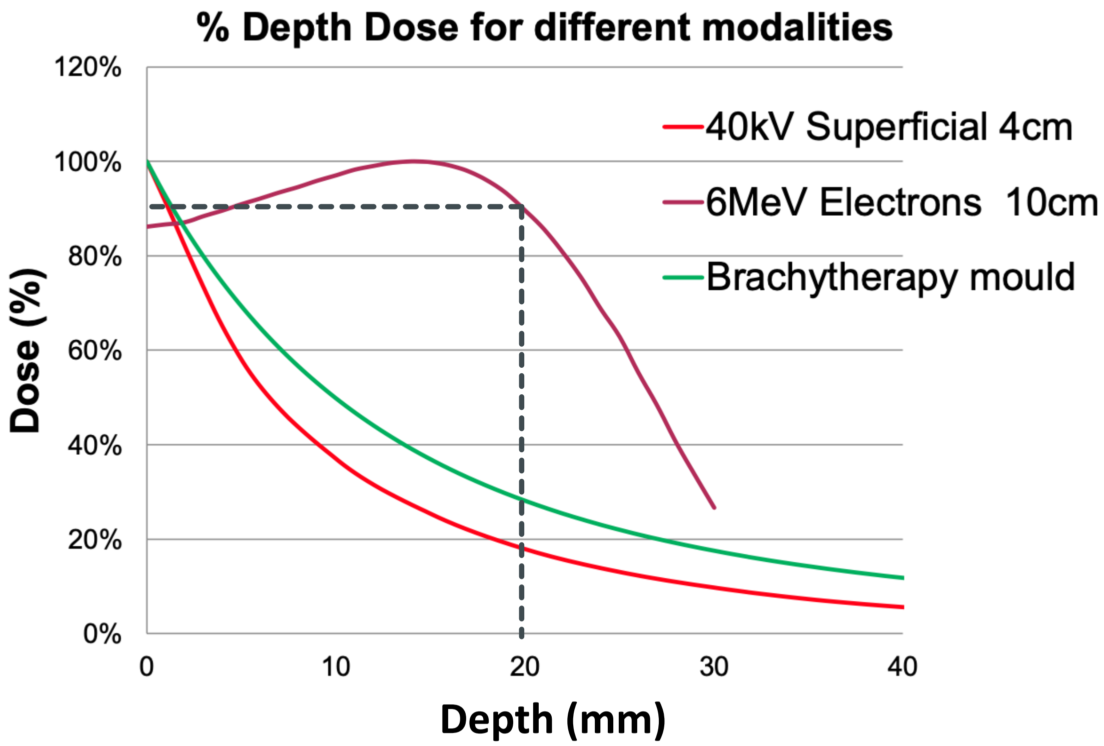
RADIATION MODALITIES FOR SKIN & SUPERFICIAL TUMOURS

- **kV X-Rays**
  - Useful for smaller tumours
  - Short Focus to Skin Distance (FSD) → High output & large influence of Inverse square law → Rapid dose fall-off.
  - Electron contamination
  - Calibration made difficult by the rapid dose gradient & Electron contamination
  - Dosimetric issues with curved treatment areas



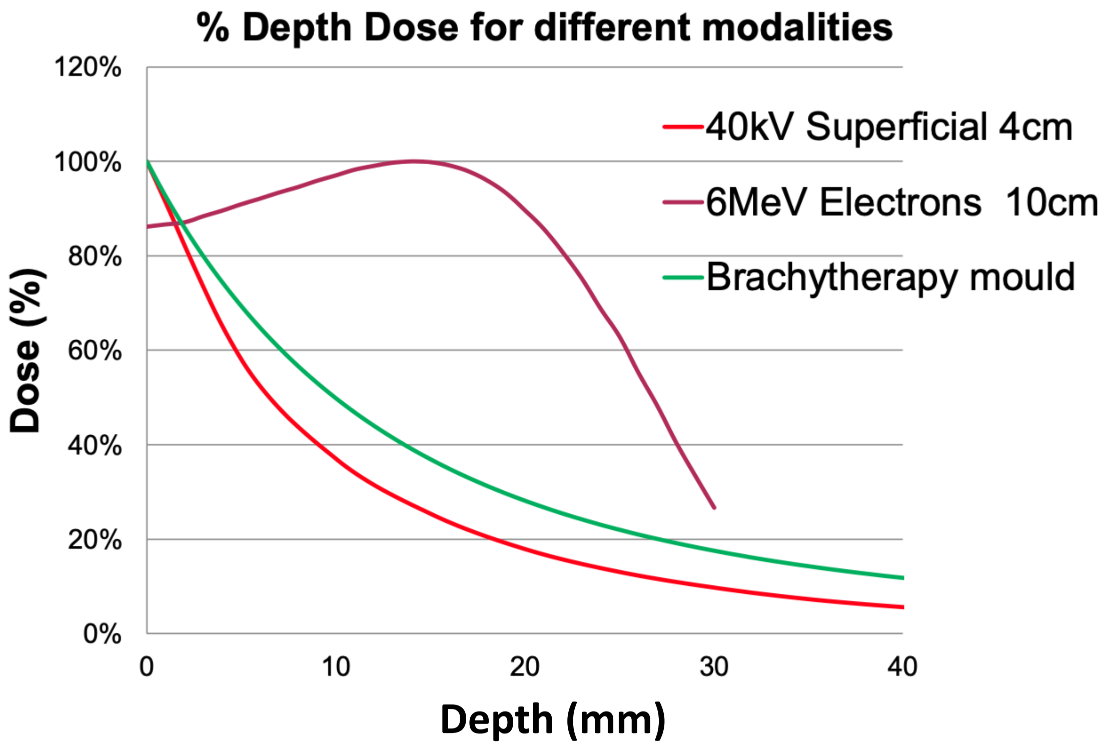
RADIATION MODALITIES FOR SKIN & SUPERFICIAL TUMOURS

- **High Energy Electrons**
  - Increasingly used.
  - Skin sparing.
  - Gives significant dose at depth (even with lower energies).
  - Therefore, beneficial for deeper tumours.
  - Can not account for curvature in treatment area.
  - Dosimetric planning uncertainities.



RADIATION MODALITIES FOR SKIN & SUPERFICIAL TUMOURS

- **Mould Brachytherapy**
  - Can position source to precisely cover treatment area
  - Conformal dose distribution
  - Small effective penumbra
  - Relative dose at depth can be controlled by adjusting height of source dwells above skin surface.
  - Due to close source to skin distance, depth dose profile falls off quickly sparing tissue at depth.
  - Can account for surface curvature



WHAT IS MOULD BRACHYTHERAPY ?

- A technique of delivering brachytherapy by an ***applicator*** that is usually ***custom*** made and designed to provide a more ***constant*** & ***reproducible*** frame for ***source positioning***.
- Can be used for flat surfaces as well as irregular shapes.
- Can be constructed from variety of material such as:
  - Specialized polymers
  - Acrylic resin
  - Wax
  - Thermoplastic material

  into which catheters are embedded
- They fit to the external patient surface & the catheters must remain in the exact position
- Intended to be as close as possible to tumour surface so as to provide adequate dose coverage of tumour and increase distance to normal surrounding structures.

GUINOT JL et al. GEC-ESTRO ACROP recommendations in skin brachytherapy. Radiother Oncol (2018)

WHAT MAKES SURFACE MOULD BRACHY ATTRACTIVE ?

- No associated pain or discomfort
- No invasive surgical procedure involved
- Does not require anaesthesia
- No risk of tissue injury or infection
- No risk of transplanting tumour cells
- Doesn’t restrict the patient to bed
- No post-procedure effects
- Good cosmesis
- Conformal dose distribution & Sparing of deeper tissues
- Surface curvature can be accounted fo
- Fewer treatment visits (compared to External RT)

IDEAL CASE FOR SURFACE MOULD ?

- Accessible site
- Superficial tumour
- Well defined margins.
- No regional or distant spread

Suitable sites for mould therapy include:

- Skin
- Scalp
- Face
- Pinna
- Lip
- Buccal mucosa
- Hard palate
- Oral cavity
- Maxillary antrum
- External auditory canal
- Orbital cavity after exenteration.

GUINOT JL et al. GEC-ESTRO ACROP recommendations in skin brachytherapy. Radiother Oncol (2018)

WORKFLOW

Selection of patient	• Selection of patient after discussion in tumour board after relevant investigations • Evaluation of patient by radiation oncologist, medical physicist and radiotherapy technician (and dental department)
Preparation of mould	• Preparation of the carrier material in the mould room • Preparation of the dental carrier when required • Fixation of the nylon catheters
RT planning	• Check CT to confirm absense of airgap • CT stimulation with the mould in situ (1-1.25 mm slice thickness)
RT planning and evaluation	• Planning with stepping source dosimetry • Dose point optimisation and prescription at specified depth (based on clinical evaluation) • Plan evaluation: slice by slice evaluation of the dose distribution and dose volume indices
Treatment	• Ensuring proper fitting of carrier before delivery of each fraction by radiation oncologist • Treatment delivery with HDR brachytherapy ^{192}Ir source • Follow up at 2 weeks of completion, then 3 monthly for 2 years and subsequently 6 monthly

BUDRUKKAR A, *J Contemp Brachytherapy*. 2017;9(3):242-250

PLANNING

- MANCHESTER SYSTEM
- IMAGE GUIDED PLANNING

MANCHESTER SYSTEM

Showed 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 + /-10% dose uniformity

Answered:

1. How much radium will be required?

2. How radium must it be arranged? (to achieve a homogeneous dose +/- 10% across skin surface)

PATERSON, R., and PARKER, H. M., *British Journal of Radiology,* vii, 1934, p. 592

MANCHESTER SYSTEM

1. How much radium will be required?

   Depends on the

   - Area to be treated
   - Treating distance
   - Filtration

If filtration other than 0.5 mm Platinum used

Platinum—Thickness	0·8	1	1·5	2
Per cent correction—*Add*	5%	10%	20%	35%

Gold .. .. As platinum.
Lead and Silver .. .. As half their thickness in platinum.
Monel, Brass, etc. .. .. As one-third their thickness in platinum.

TABLE A.12.1A Milligram-Hours per 1,000 R for Different Areas and Various Treating Distances[a]

Area[b]	0.5[c]	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
0	30	119	268	476	744	1,071	1,458	1,904	2,412	2,976
1	68	171								
2	97	213	375	598	865	1,197	1,595	2,043	2,545	3,117
3	120	247								
4	141	278	462	698	970	1,305	1,713	2,168	2,665	3,243
5	161	306								
6	177	333	536	782	1,066	1,405	1,822	2,286	2,778	3,360
7	192	359								
8	206	384	599	855	1,155	1,500	1,924	2,395	2,883	3,472
9	221	408								
10	235	433	655	923	1,235	1,590	2,020	2,500	2,987	3,580
11	248	456								
12	261	480	710	990	1,312	1,673	2,112	2,603	3,087	3,682
13	274	502								
14	288	524	764	1,053	1,386	1,753	2,200	2,698	3,185	3,785
15	302	546								
16	315	566	814	1,113	1,460	1,830	2,283	2,790	3,280	3,883
17	328	585								
18	342	605	863	1,170	1,525	1,905	2,363	2,879	3,370	3,985
19	355	623								
20	368	641	910	1,225	1,588	1,979	2,445	2,965	3,461	4,080
22	393	674	960	1,280	1,650	2,049	2,522	3,047	3,550	4,174
24	417	707	1,008	1,335	1,712	2,117	2,598	3,126	3,639	4,267
26	442	737	1,056	1,388	1,768	2,188	2,670	3,200	3,724	4,356
28	466	767	1,100	1,438	1,826	2,254	2,742	3,275	3,804	4,446
30	490	795	1,142	1,487	1,880	2,320	2,817	3,348	3,883	4,534
32	513	823	1,185	1,537	1,936	2,380	2,888	3,420	3,966	4,620
34	537	854	1,226	1,587	1,992	2,442	2,956	3,490	4,047	4,700
36	558	879	1,268	1,638	2,048	2,502	3,022	3,559	4,125	4,783
38	581	909	1,308	1,685	2,100	2,562	3,088	3,627	4,198	4,863
40	603	934	1,346	1,732	2,152	2,620	3,150	3,695	4,273	4,942
42	624	962	1,384	1,780	2,203	2,677	3,215	3,762	4,348	5,020
44	644	990	1,420	1,825	2,255	2,733	3,275	3,826	4,423	5,096
46	665	1,015	1,457	1,870	2,305	2,788	3,335	3,890	4,494	5,174
48	685	1,043	1,490	1,915	2,354	2,843	3,395	3,954	4,565	5,250
50	705	1,072	1,522	1,958	2,402	2,897	3,455	4,018	4,633	5,327
52	725	1,098	1,554	2,004	2,450	2,950	3,513	4,080	4,702	5,400
54	744	1,125	1,588	2,047	2,500	3,003	3,569	4,142	4,768	5,475
56	762	1,152	1,618	2,092	2,548	3,055	3,625	4,205	4,835	5,548
58	781	1,177	1,650	2,137	2,597	3,106	3,678	4,267	4,903	5,620
60	800	1,206	1,682	2,180	2,646	3,160	3,735	4,328	4,970	5,690
62	818	1,230	1,712	2,222	2,692	3,212	3,790	4,389	5,037	5,760
64	837	1,260	1,740	2,262	2,736	3,262	3,845	4,447	5,105	5,830
66	855	1,285	1,769	2,302	2,782	3,310	3,900	4,505	5,171	5,900
68	873	1,313	1,798	2,342	2,828	3,360	3,950	4,562	5,232	5,967
70	890	1,340	1,827	2,380	2,875	3,410	4,001	4,618	5,294	6,033
72	908	1,367	1,857	2,420	2,922	3,460	4,053	4,675	5,355	6,098
74	927	1,394	1,887	2,455	2,968	3,510	4,105	4,733	5,417	6,162
76	945	1,421	1,915	2,490	3,013	3,560	4,158	4,791	5,480	6,225

[a]Filtration = 0.5 mm platinum.
[b]Area is in centimeters squared.
[c]Treating distance is in centimeters.

PATERSON, R., and PARKER, H. M., *British Journal of Radiology,* vii, 1934, p. 592

MANCHESTER SYSTEM

1. How much radium will be required?

   Depends on the

   - Area to be treated
   - Treating distance
   - Filtration

Example:

To treat a 10cm^2 area at a distance of 0.5cm to a dose of 1000R, 235 mg-hrs of Radium is required (0.5mm Platinum)

TABLE A.12.1A Milligram-Hours per 1,000 R for Different Areas and Various Treating Distances[a]

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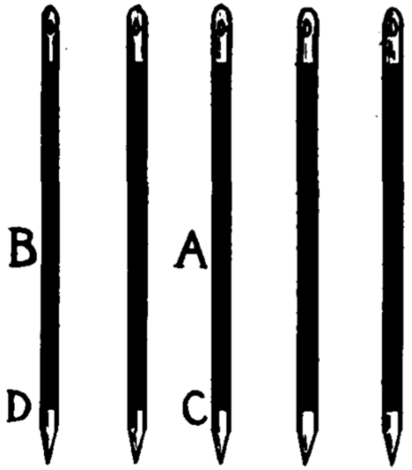
[a]Filtration = 0.5 mm platinum.
[b]Area is in centimeters squared.
[c]Treating distance is in centimeters.

PATERSON, R., and PARKER, H. M., *British Journal of Radiology*, vii, 1934, p. 592

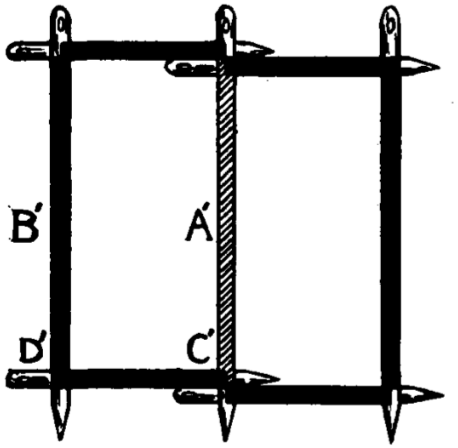
MANCHESTER SYSTEM

2. How Radium must be arranged?

   Why is it important?



	r PER HOUR
A =	42·5
B =	30·5
C =	30·5
D =	23·0

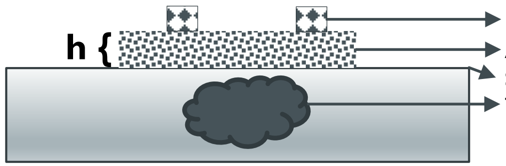


	r PER HOUR
A′ =	20·0
B′ =	18·5
C′ =	20·0
D′ =	19·2

Diagram illustrating the extreme importance of correct arrangement.
Intensity produced at 1 cm. by two different radium distributions over the same area.

PATERSON, R., and PARKER, H. M., *British Journal of Radiology*, vii, 1934, p. 592

MANCHESTER SYSTEM



Distance (h) refers to the distance separating the plane on which the radium is mounted, and the plane at which the dose is assessed (*i.e.*, the treated area).

2. How Radium must be arranged?

- After determining the amount of Radium to be used, that amount is to be arranged in the following ways.
- Use **CIRCLES** arrangement wherever possible
  - If diameter < 3x distance → Single circle sufficient
  - If diameter >3x and <6x distance → 5% radium at the centre; remaining 95% in the circle
  - If diameter > 6x distance → 3% radium at the centre; use 2 concentric circles (inner circle = ½ dia of outer)

Diameter divided by "distance"	6	7½	10
Per cent Radium outer circle	80%	75%	70%
Radium in inner circle	17%	22%	27%

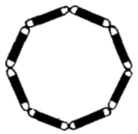
- Use other arrangements if required → Separate rules exist for Square / Rectangle / Irregular fields.

PATERSON, R., and PARKER, H. M., *British Journal of Radiology*, vii, 1934, p. 592

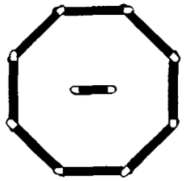
MANCHESTER SYSTEM

2. How Radium must be arranged?

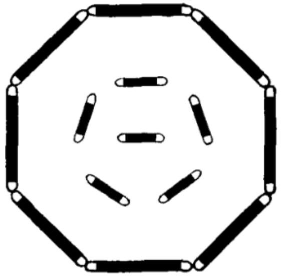
- **CIRCLES** arrangement
  - If diameter < 3x distance →



  - If diameter >3x and <6x distance →



  - If diameter > 6x distance →



PATERSON, R., and PARKER, H. M., *British Journal of Radiology*, vii, 1934, p. 592

MANCHESTER SYSTEM

Various arrangements

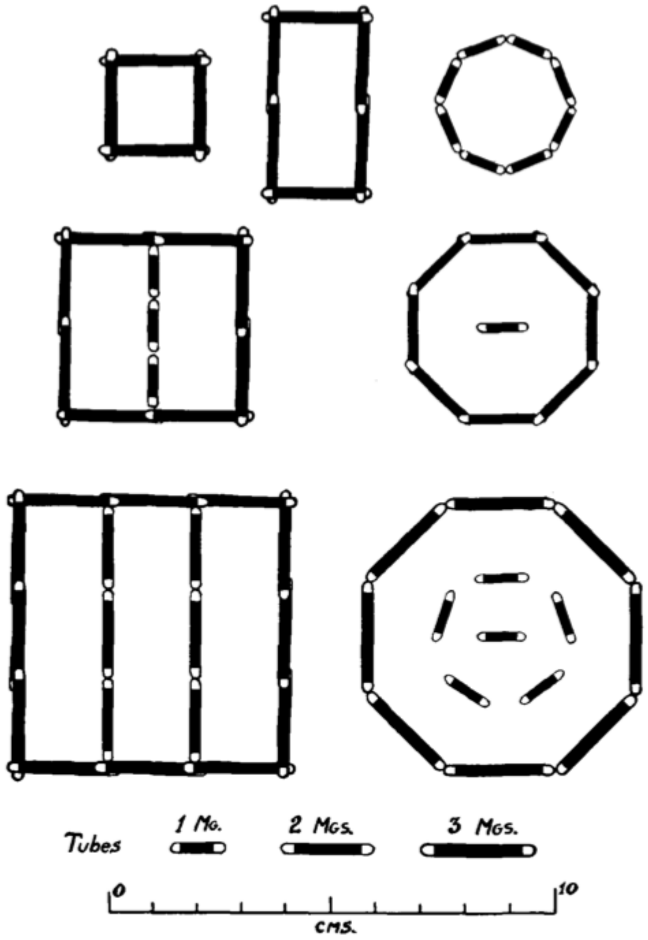


Fig. 2.
Diagram illustrating the "Rules for Distribution," depicting typical arrangements to produce homogeneity at 1 cm.

PATERSON, R., and PARKER, H. M., *British Journal of Radiology,* vii, 1934, p. 592

MANCHESTER SYSTEM

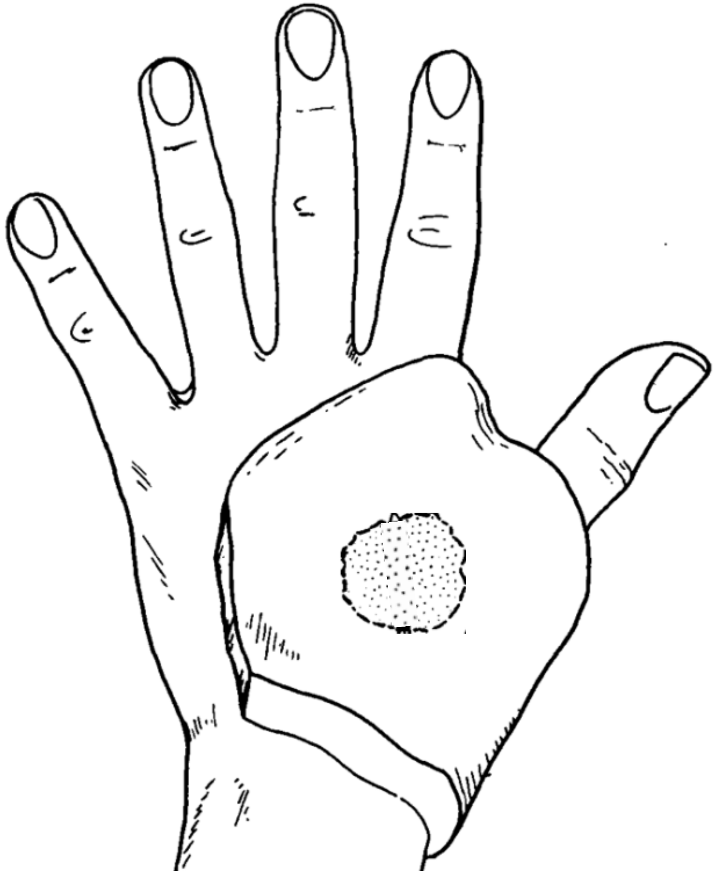
EXAMPLE:

Treat this lesion of 3.5 cm diameter by 1cm mould

With 1 mm filtration to a dose of 6000 R in 20 days

(16 hrs per day)

- We'll treat 5 cm area (for margin) with circles
- Area of treatment = $\pi d^2/4 \sim 20\ cm^2$
- Distance (h) = 1cm
- Total Treatment time = 20x16 = 320 hrs



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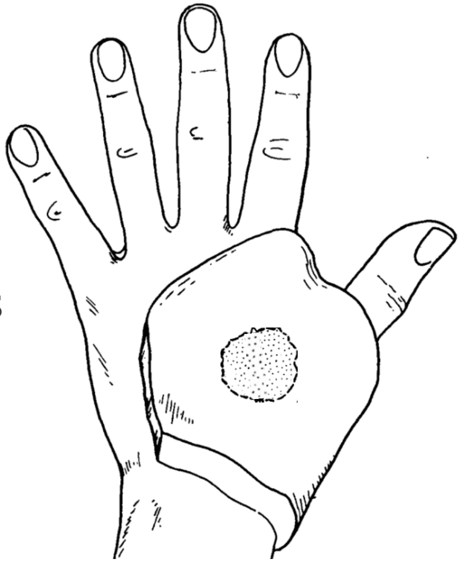


- We'll treat 5 cm area (for margin) with circles
- Area of treatment = $\pi d^2/4 \sim 20\ cm^2$
- Distance (h) = 1cm
- Total Treatment time = 20x16 = 320 hrs

RADIUM REQUIREMENT

- Radium required for 1000R = 641 mg-hrs
- Radium required for 6000R = 641x6 ~ 3,850 mg-hrs + 10% (fil)~ 4200 mg-hrs
- Total Radium required = **13 mg** (given for 320 hrs)

[a]Filtration = 0.5 mm platinum.
[b]Area is in centimeters squared.
[c]Treating distance is in centimeters.

TABLE A.12.1A Milligram-Hours per 1,000 R for Different Areas and Various Treating Distances[a]

Area[b]	0.5[c]	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
0	30	119	268	476	744	1,071	1,458	1,904	2,412	2,976
1	68	171								
2	97	213	375	598	865	1,197	1,595	2,043	2,545	3,117
3	120	247								
4	141	278	462	698	970	1,305	1,713	2,168	2,665	3,243
5	161	306								
6	177	333	536	782	1,066	1,405	1,822	2,286	2,778	3,360
7	192	359								
8	206	384	599	855	1,155	1,500	1,924	2,395	2,883	3,472
9	221	408								
10	235	433	655	923	1,235	1,590	2,020	2,500	2,987	3,580
11	248	456								
12	261	480	710	990	1,312	1,673	2,112	2,603	3,087	3,682
13	274	502								
14	288	524	764	1,053	1,386	1,753	2,200	2,698	3,185	3,785
15	302	546								
16	315	566	814	1,113	1,460	1,830	2,283	2,790	3,280	3,883
17	328	585								
18	342	605	863	1,170	1,525	1,905	2,363	2,879	3,370	3,985
19	355	623								
20	368	641	910	1,225	1,588	1,979	2,445	2,965	3,461	4,080
22	393	674	960	1,280	1,650	2,049	2,522	3,047	3,550	4,174
24	417	707	1,008	1,335	1,712	2,117	2,598	3,126	3,639	4,267
26	442	737	1,056	1,388	1,768	2,188	2,670	3,200	3,724	4,356
28	466	767	1,100	1,438	1,826	2,254	2,742	3,275	3,804	4,446
30	490	795	1,142	1,487	1,880	2,320	2,817	3,348	3,883	4,534
32	513	823	1,185	1,537	1,936	2,380	2,888	3,420	3,966	4,620
34	537	854	1,226	1,587	1,992	2,442	2,956	3,490	4,047	4,700
36	558	879	1,268	1,638	2,048	2,502	3,022	3,559	4,125	4,783
38	581	909	1,308	1,685	2,100	2,562	3,088	3,627	4,198	4,863
40	603	934	1,346	1,732	2,152	2,620	3,150	3,695	4,273	4,942
42	624	962	1,384	1,780	2,203	2,677	3,215	3,762	4,348	5,020
44	644	990	1,420	1,825	2,255	2,733	3,275	3,826	4,423	5,096
46	665	1,015	1,457	1,870	2,305	2,788	3,335	3,890	4,494	5,174
48	685	1,043	1,490	1,915	2,354	2,843	3,395	3,954	4,565	5,250
50	705	1,072	1,522	1,958	2,402	2,897	3,455	4,018	4,633	5,327
52	725	1,098	1,554	2,004	2,450	2,950	3,513	4,080	4,702	5,400
54	744	1,125	1,588	2,047	2,500	3,003	3,569	4,142	4,768	5,475
56	762	1,152	1,618	2,092	2,548	3,055	3,625	4,205	4,835	5,548
58	781	1,177	1,650	2,137	2,597	3,106	3,678	4,267	4,903	5,620
60	800	1,206	1,682	2,180	2,646	3,160	3,735	4,328	4,970	5,690
62	818	1,230	1,712	2,222	2,692	3,212	3,790	4,389	5,037	5,760
64	837	1,260	1,740	2,262	2,736	3,262	3,845	4,447	5,105	5,830
66	855	1,285	1,769	2,302	2,782	3,310	3,900	4,505	5,171	5,900
68	873	1,313	1,798	2,342	2,828	3,360	3,950	4,562	5,232	5,967
70	890	1,340	1,827	2,380	2,875	3,410	4,001	4,618	5,294	6,033
72	908	1,367	1,857	2,420	2,922	3,460	4,053	4,675	5,355	6,098
74	927	1,394	1,887	2,455	2,968	3,510	4,105	4,733	5,417	6,162
76	945	1,421	1,915	2,490	3,013	3,560	4,158	4,791	5,480	6,225

Platinum—Thickness	0·8	1	1·5	2
Per cent correction—*Add*	5%	10%	20%	35%

Gold	As platinum.
Lead and Silver	As half their thickness in platinum.
Monel, Brass, etc.	As one-third their thickness in platinum.

PATERSON, R., and PARKER, H. M., *British Journal of Radiology*, vii, 1934, p. 592

MANCHESTER SYSTEM

EXAMPLE:

Treat this lesion of 3.5 cm diameter by 1cm mould

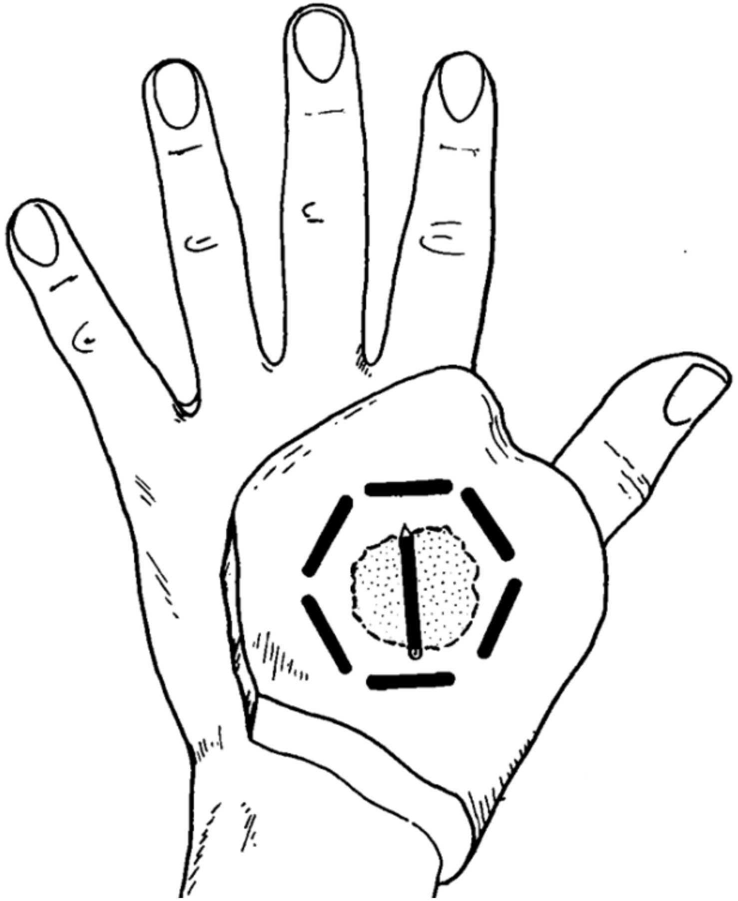
With 1 mm filtration to a dose of 6000 R in 20 days

(16 hrs per day)

- We'll treat 5 cm area (for margin) with circles
- Area of treatment = $\pi d^2/4 \sim 20\ cm^2$
- Distance (h) = 1cm
- Total Treatment time = 20x16 = 320 hrs

RADIUM ARRANGEMENT

- Diameter is 5X distance i.e. >3x and <6x distance.
- Therefore, 5% radium at the centre → 0.05 x 12 = 0.65 ~ **1 mg at centre**
- Remaining 95% in the circle ~ **12 mg in the circle** (use 6 '2mg' tubes)

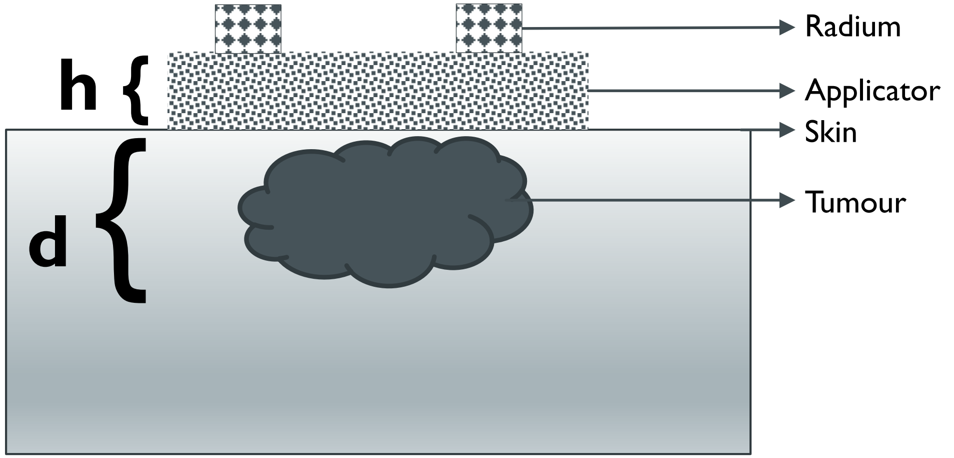


PATERSON, R., and PARKER, H. M., *British Journal of Radiology*, vii, 1934, p. 592

MANCHESTER SYSTEM

How to choose thickness of applicator or ‘h’:

- Determined by the treatment depth required
- Governed by the Inverse Square Law
- If greater depths are to be treated, source are kept at a greater height



Distance, h, to surface, in mm	*Area of mould, in cm²*				
	3	**7**	**10**	**20**	**30**
5	1.4	1.5	1.6	1.9	1.4
10	2.2	2.3	2.4	2.8	3.1
15	2.6	2.9	3.1	3.7	4.3
20	3.3	3.5	3.7	4.2	4.8

PATERSON, R., and PARKER, H. M., *British Journal of Radiology,* vii, 1934, p. 592

IMAGE GUIDED PLANNING

Imaging, and target and organ at risk definition

Imaging methodology, purpose of imaging, organ at risk volume and target volume definitions

Treatment planning

Applicator reconstruction
Plan optimization and evaluation
Final dose prescription
Dose reporting
Plan verification and approval

Plan transfer to afterloader

Verification of transferred treatment parameters

Pre-delivery quality control

For example, connection of transfer tubes and applicator position

Treatment delivery

In vivo dose measurements (desirable)
Dose recording

Ideal for superficial tumours (<5mm)

A distance from the source to the skin of 5mm is recommended to obtain homogeneity on the surface of the skin, & avoid an overdosage

Dose is prescribed to 3–5mm under the skin surface.

Recommended BT schedules for surface moulds:

- 3Gy per fraction, 17–18 fractions, 3 times a week, total dose 51–54Gy.
- 4Gy per fraction, 10–12 fractions, 3 times a week, total dose 40–48Gy.
- 5Gy per fraction, 10–12 fractions, twice a week, total dose 50–60Gy.
- 5Gy per fraction, 8 fractions, twice a day, daily, total dose 40Gy.
- Higher doses per fraction, once a week

IAEA Human Health 12 - The Transition from 2-D Brachytherapy to 3-D High Dose Rate Brachytherapy
GUINOT JL et al. GEC-ESTRO ACROP recommendations in skin brachytherapy. Radiother Oncol (2018)

THANK YOU