Physics and Techniques of Large Field Radiotherapy

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Outline of the Presentation

- Introduction to Large Field Radiotherapy
- Historical Perspectives
- Physics and Dosimetric Considerations
- Treatment Equipment and Technologies
- Treatment Planning
- Treatment Techniques
- Treatment Verification
- Challenges and Future Directions
- Summary and Conclusion

What is Large Field Radiotherapy?

- Large field Radiotherapy or Magna Field Irradiation

  - aims to deliver radiation to a whole body or half-body or to a large field than field size available in the machine (e.g.>40x40cm^2).

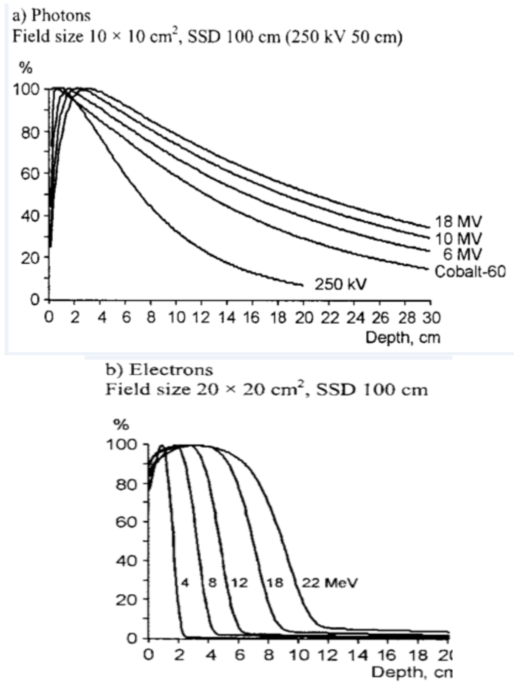
- Types of Large Field Radiotherapy;

  Photon Beam

  - Total Body Irradiation (TBI)
  - Hemi Body Irradiation (HBI)
  - Total Marrow Irradiation (TMI)
  - Total Lymphoid Irradiation (TLI)

  Electron Beam

  - Total Skin Electron Therapy (TSET)



- Goal: To achieve dose homogeneity to patient's whole body to ± 10% of prescribed dose and limit OAR dose.

Total Body Irradiation (TBI): Photon Beam

- TBI is a specialized technique for Hematological malignancies
  (e.g.).leukemia, lymphoma, rarely solid tumors

- Potential of TBI :
  - Myeloablative high dose therapy
  - Immunoablative conditioning therapy prior to stem cell transplantation

- Need for TBI
  - Eradicating diseased marrow
  - Reducing tumor burden
  - Immuno-suppression:
    - lymphocyte elimination to allow grafting of donor bone marrow
  - Eradication of cells with genetic disorders
    - Fanconi's anemia, Thalassemia Major, Wiskott-Aldrich syndrome

Clinical Indications for TBI

Certain indications: Leukaemias in adults and childhood:

- Acute lymphoblastic leukaemia (ALL),
- Acute myeloid leukaemia (AML),
- Chronic myeloid leukaemia (CML),
- Myelodysplastic syndrome (MDS).

Optional indications: Solid tumors in childhood:

- Neuroblastomas,
- Ewing sarcomas,
- Plasmocytomas / multiple myelomas

In Clinical test:

- Morbus Hodgkin’s disease (MHD)
- Non-Hodgkin’s lymphomas (NHL)

Historical Perspective of TBI

1905	German biophysical engineer F.J.Dessauer first described principles of TBI named as X-ray bath
1923	Chaoul and lange introduced in TBI Europe
1927	Teschendrof reported the results of TBI for lymphoma
1932	Heublein at MSKCC first TBI in North America
1969	First report of successful cure of patient with leukemia with allogeneic transplantation after TBI by E.Donnall Thomas
1971	Dedicated cobalt unit was designed to treat TBI at PMH, Canada
1970-1980	TBI with low dose therapy
1990s	TBI with high dose therapy
2000s	TBI, TMI using Tomotherapy and also linac-based VMAT

Physics Challenges in TBI

- Large treatment field to cover entire body (more scatter)
- Variable body thickness and tissue densities
- treatment extended SSD (source to surface distance): 3-5m
  - beam characteristics obtained in normal treatment distance vary
- Low dose rate (change in beam stability and flatness and symmetry)
- Backscatter from walls or floors to monitor chambers
- When beam is horizontally directed,patient positioning, treatment aid devices –challenging
- Large dose variation across the body target volume
- Limitation in normal tissue tolerance (e.g. Lung)

Dose homogeneity should be within $\pm$10%

Physics and Dosimetric Considerations

- Machine Type : Telecobalt/ Linac/ Helical tomotherapy
- Beam Energy : 6MV/10MV/15MV
- Dose rate : normal, Low dose rate or high dose rate- FFF
- Dose/Fractionation : Hyper or hypo fractionations
- Treatment geometry : Field size & distance- standard/extended SSD
- Patient positioning : Sitting, standing, laying down, reclining position
- Use of beam modifiers : compensator, bolus, shields and beam spoilers
- Irradiation technique : AP/PA, Lateral, Translational, Rotational, Helical, VMAT)
- Boost irradiation technique : localized photon or electron therapy

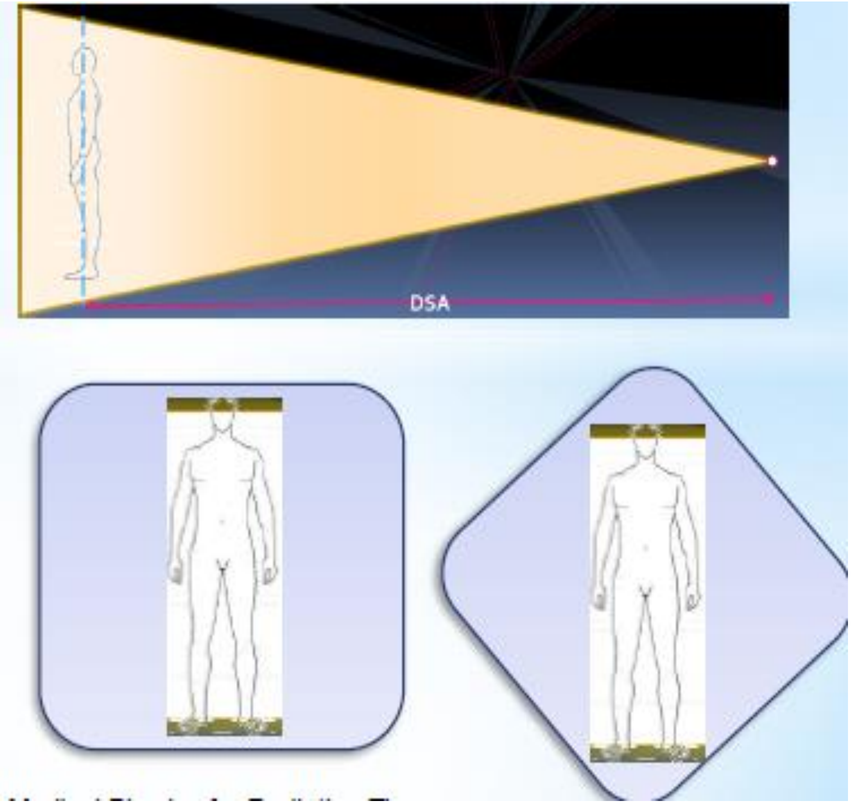
Treatment Geometry

Radiotherapy Unit and Bunker size

Treatment distance:
    more than 3-4m

Larger field: >40x40 cm^2

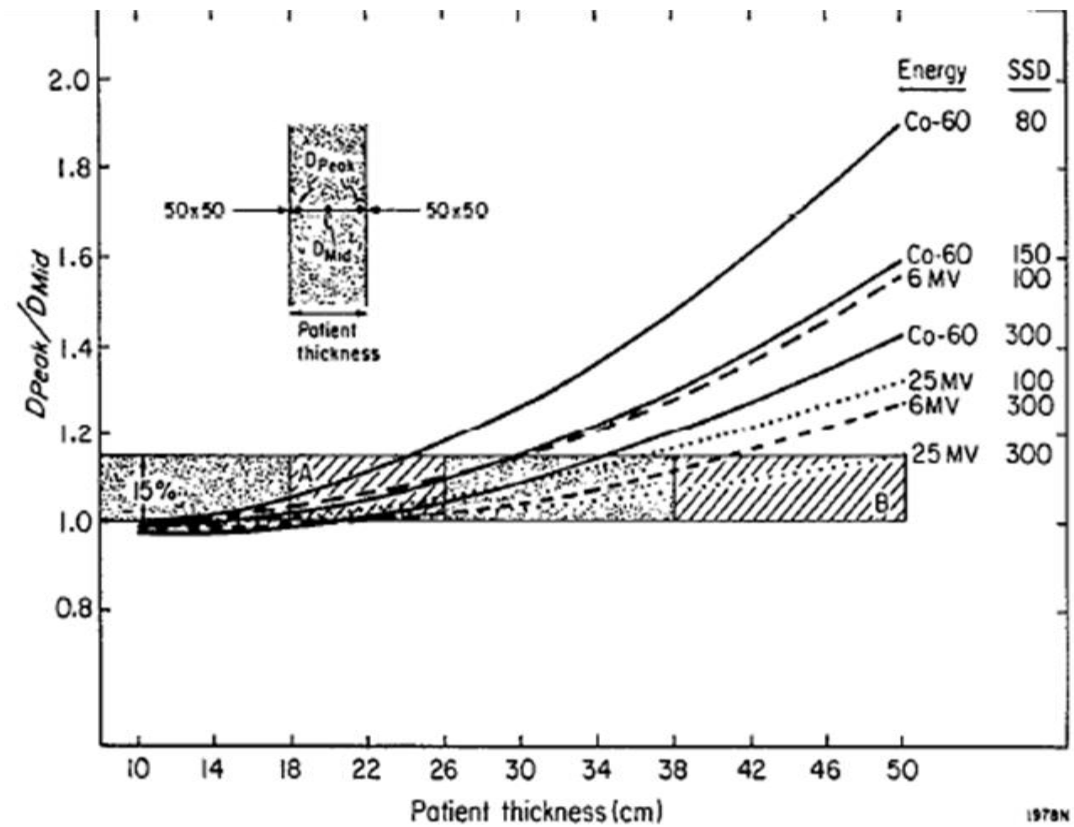
All measurements at larger SSD



- Inverse square law does not hold in large distance (6% difference)

Beam Energy

- Choice of beam energy depends on patient's thickness and degree of dose uniformity
- 4-15MV photon beam is recommended.



✓ Higher the energy, the lower the dose variation.

✓ Larger the treatment distance the lower the dose variation.

✓ Larger the patient diameter, the larger the dose variation.

✓ AP/PA treatments will yield a variation not larger than 15% for most megavoltage energies and distances.

✓ Greater dose variation for lateral opposed beams compared to AP/PA treatments especially for adult patients.

AAPM TG-17

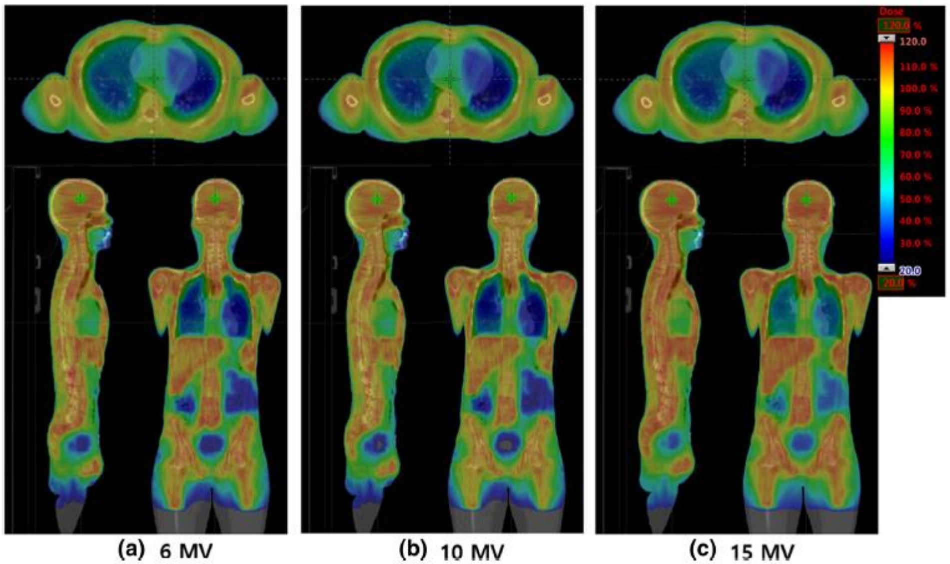


Fig. 3 Isodose distributions. Isodose distributions in colorwash of TMI by VMAT for 6 (**a**), 10 (**b**), and 15 MV (**c**). Dose range: 20% (blue) to 120% (red)

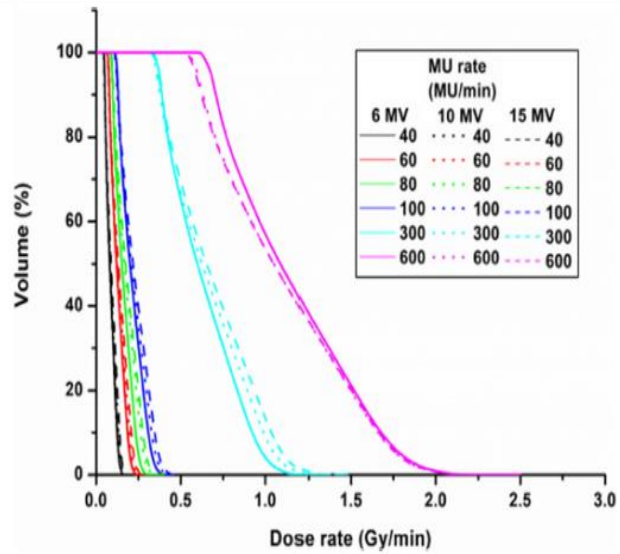


Fig. 4 Dose-rate versus lung volume histogram. Dose-rate versus lung volume histogram of representative case for 6 MV (solid line), 10 MV (dotted line), and 15 MV (dashed line) according to the monitor unit (MU) rate. Black: 40 MU/min, red: 60 MU/min, green: 80 MU/min, blue: 100 MU/min, cyan: 300 MU/min and magenta: 600 MU/min

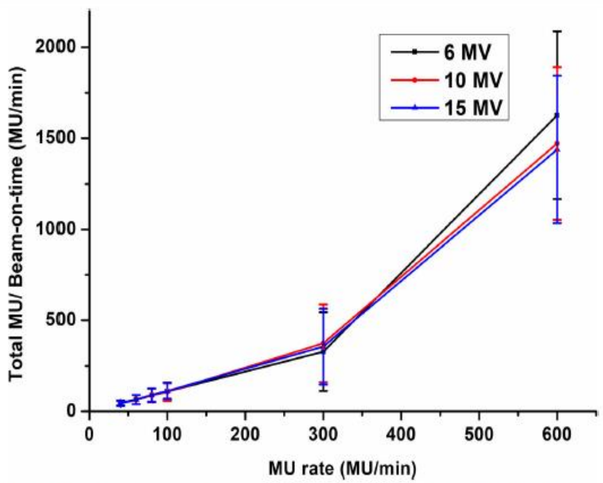


Fig. 2 Non-linear correlation factor. The factors were defined as a ratio of total MU to beam-on time. 6 MV (black solid line), 10 MV (red solid line) and 15 MV (blue solid line)

Table 3 Average volume (%) of lung irradiated at dose rate of more than 20 cGy/min

Energy (MV)	MU rate (MU/min)					
	40	60	80	100	300	600
6	1.47 ± 1.56	24.42 ± 14.08	49.19 ± 14.28	69.59 ± 13.56	53.96 ± 28.69	54.40 ± 28.88
10	3.91 ± 3.90	30.81 ± 14.01	54.18 ± 12.02	71.24 ± 12.15	100.00 ± 0.00	100.00 ± 0.00
15	6.22 ± 6.14	35.10 ± 13.30	57.63 ± 11.59	74.58 ± 11.95	100.00 ± 0.00	100.00 ± 0.00

Dose Rate effect

“A higher TBI dose rate has been shown to be an adverse prognostic factor for developing IP (Interstitial Penumonia)…The use of fractionated TBI at a dose rate of 7.5 cGy/min or less rather than 15 cGy/min is recommended…”

B J Cancer. 2004 Jun 1; 90 (11): 2080.4. Carruthers SA, Wallington MM. Total body irradiation and penumonitis risk: a review of outcomes.

“The last twenty years has demonstrated that fractionated and hyperfractioned TBI are associated with a lower incidence of side effects than STBI (8-10Gy) at a high dose rate.”

- Report ISTISAN 05/47 Guidelines for quality assurance in total body irradiation”

Recommendations for the dose rate ⇨

- Fractionated Dose ≥ 10 – 12 Gy ⇨ dose-rate < 15-16 cGy/min
- Single dose (10Gy low dose – rate) ⇨ dose-rate < 15-16 cGy/min
- Mini-TBI: 2 Gy in one fraction dose-rate < 10 cGy/min

- The reduction of dose rate can be obtained by increasing the treatment distance or lowering the dose-rate of the accelerator.

Patient Positioning

Supports (bed, support for irradiation while standing

Beam Degrader/Spoiler

Beam Spoiler Effect

- In TBI it's desirable to ensure that the skin surface receives close to the fully prescribed dose.

- High energy beams needs the use of PMMA plate of such a thickness as to absorb the build-up region of the depth dose curve

- PMMA beam spoiler must be placed close to the patient (10-30 cm).

- The build-up region is minimized, additional scatter component increases the input dose.

- must evaluate the attenuation (typically on the order of 5%) and the influence on beam quality.

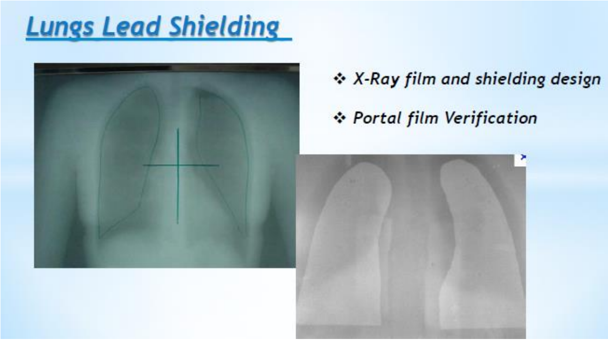
Tissue Compensators and Shielding

Tissue compensators:

- Simple tissue compensators that extend completely across the patient can be used to decrease the dose to thinner body sections like the necks or ankles.

- If room geometry forces the use of lateral fields, much more extensive compensation will be needed.

- The compensator can be placed on the treatment unit using the block tray.



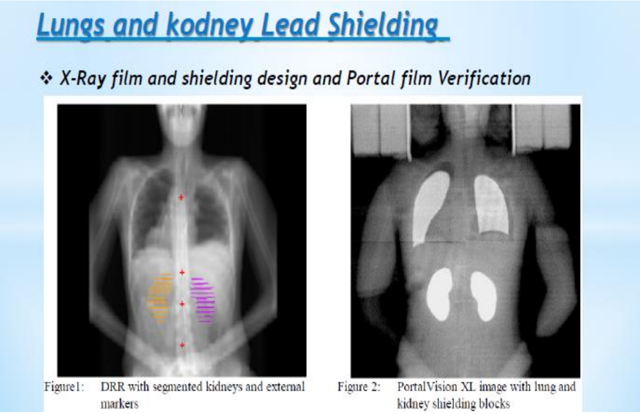
Shielding critical structures:

- The lungs are an example of an organ system that is particularly sensitive to radiation.

- Two methods for reducing the dose to critical structures:

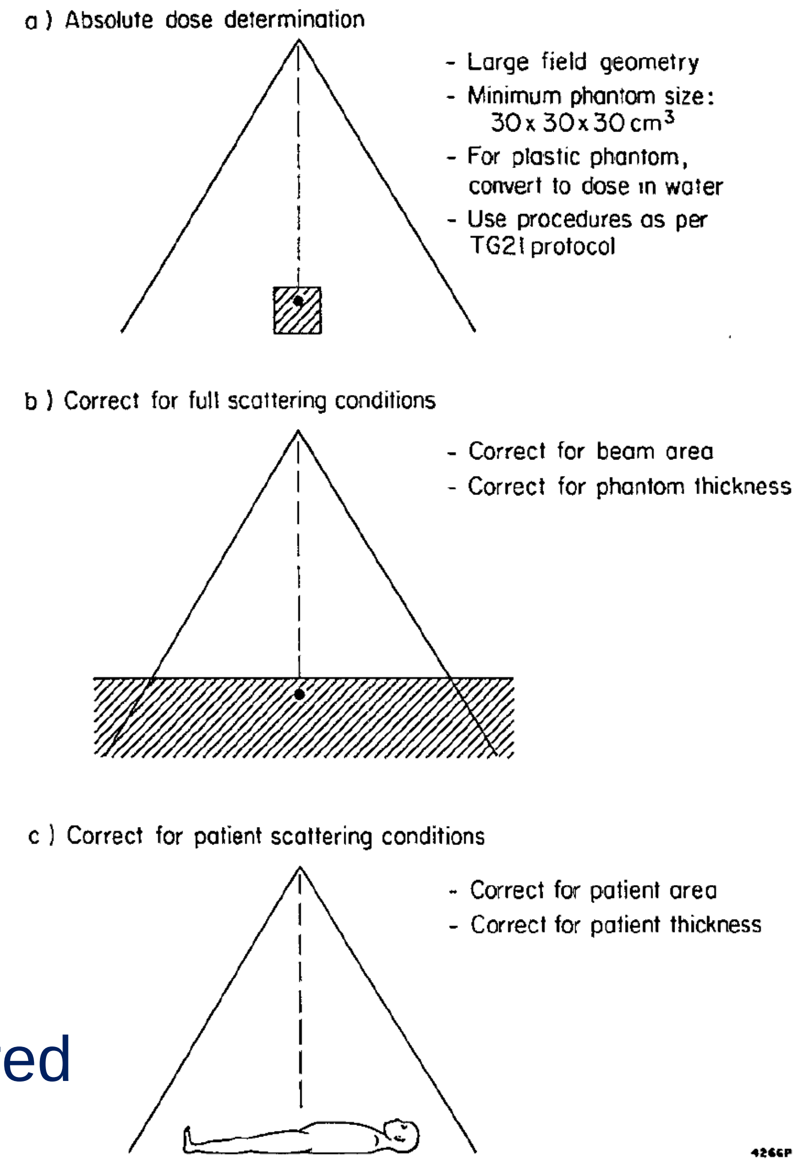
  - It is possible to place strips of absorbing material completely across the patient to shield these regions.

  - More shielding for the lungs by placing cerrobend blocks between the source of radiation and the patient.



Basic Beam Phantom Dosimetry

- Dosimetric phantoms
- Dosimeters/detectors
- Dose monitor calibration
- Central axis depth-dose data
- Beam profiles
- Output factors
- Attenuation data

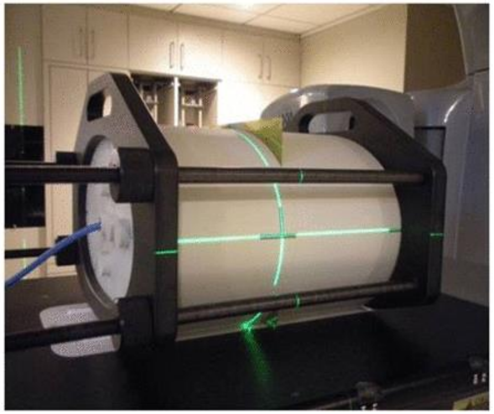


All measurement should be measured under TBI condition

Phantom for TBI dosimetry

- Choice of Phantom material is water
- minimum phantom size- 30 x30x30 cm^3
- water equivalent plastic phantoms used
- Phantom size should provide full scatter conditions (5cm margins all around) and 10 cm phantom materials beyond the detector depth
- If the dose is determined with limited dimension of the phantom, it needs to be corrected with multiplicative factor for full scattering conditions (AAPM TG-17 report,1986)
- Proposed phantoms for TBI dosimetry

TBI	AP/PA	Bilateral
Adults	40x40cm^2 thickness 20cm	25x25cm^2 thickness 40cm
Children	25 x25cm^2 thickness 10cm	15 x15cm^2 thickness 25cm

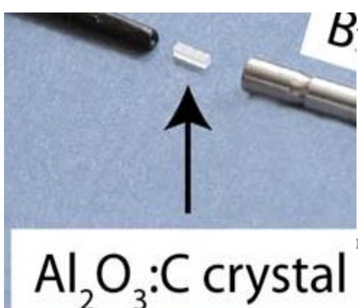


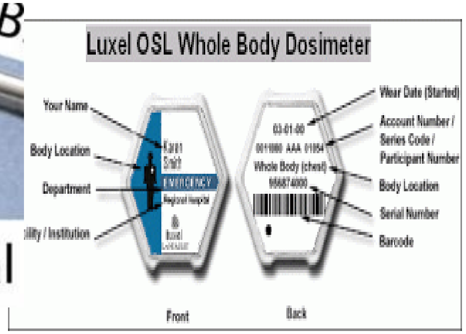
Detectors for TBI dosimetry

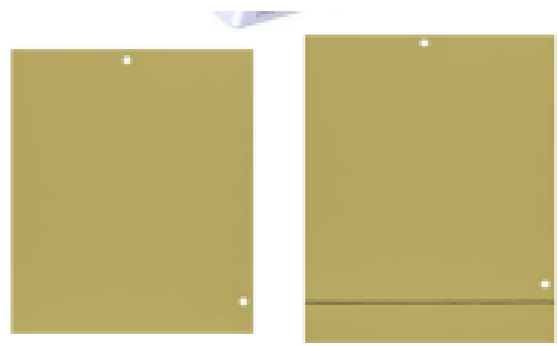
Ion chambers (cylindrical and parallel plate)

TLD

Diodes



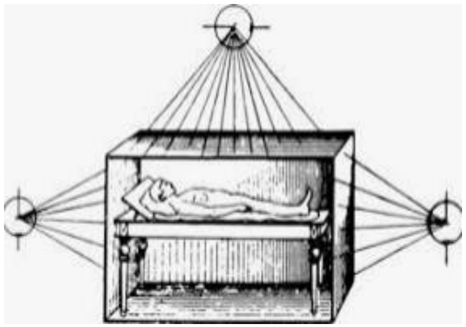




Radiochromic films

MOSFET

TBI Equipment/Technologies



250 KV X-ray unit

Dedicated cobalt unit

Dedicated Linac

Dedicated commercial telecobalt unit

Linac with Conventional AP/PA TBI technique

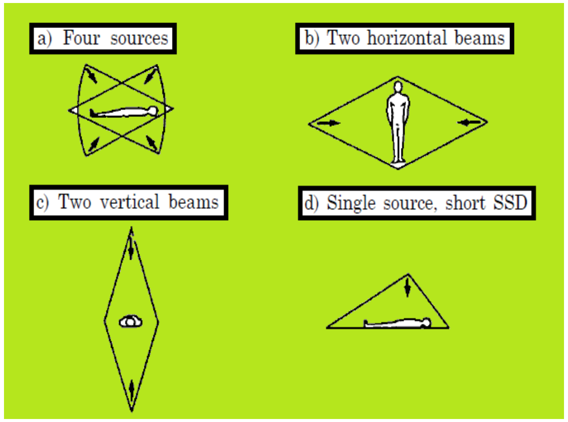
Linac Based VMAT-Extended SSD

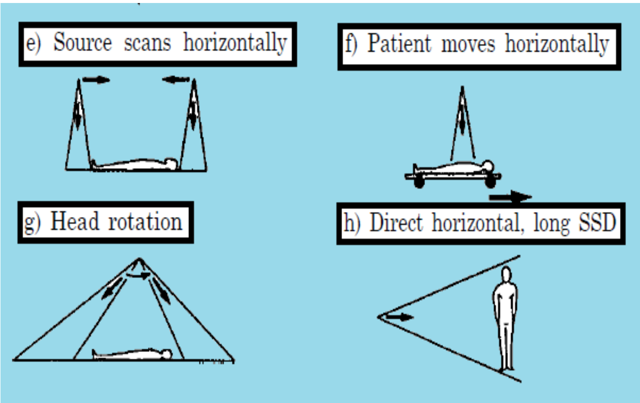
Linac Based VMAT-standard SSD

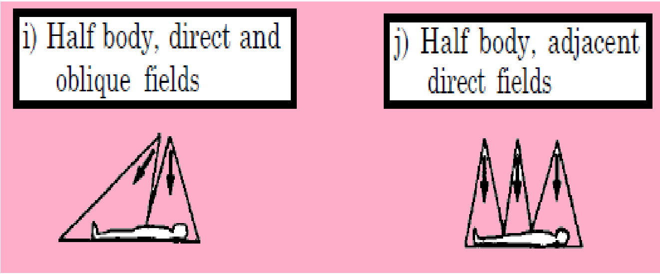
Helical Tomotherapy

Conventional Irradiation Methods for TBI/HBI

- Dedicated facilities with multiple sources
- Dedicated facilities with dual sources
- Dedicated facilities with single sources
- Conventional units modified for large field treatments
- Conventional treatment units
- Multiple abutting fields
- Selecting a large field technique
- Back-up treatment technique



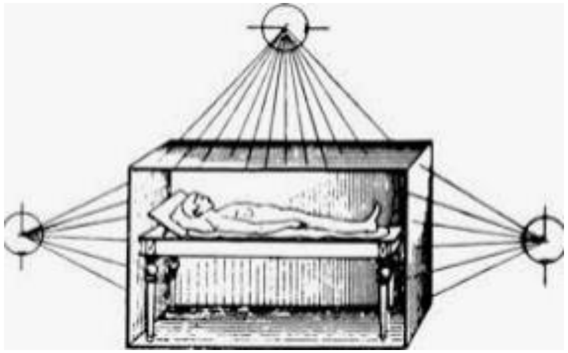




Historical TBI Techniques : Kv X-ray Unit

- First dedicated TBI facilities in North America was described by Heublein, MSKCC in 1932

- In a lead lined ward, with four beds at one end and a Coolidge “deep therapy” tube at the other end, four patients could be simultaneously irradiated.



- The beds were about 5 m and 7 m from the tube, which was operated continuously for 20 hours at 185 kVp, 3 mA, with a 2 mm Cu filter.

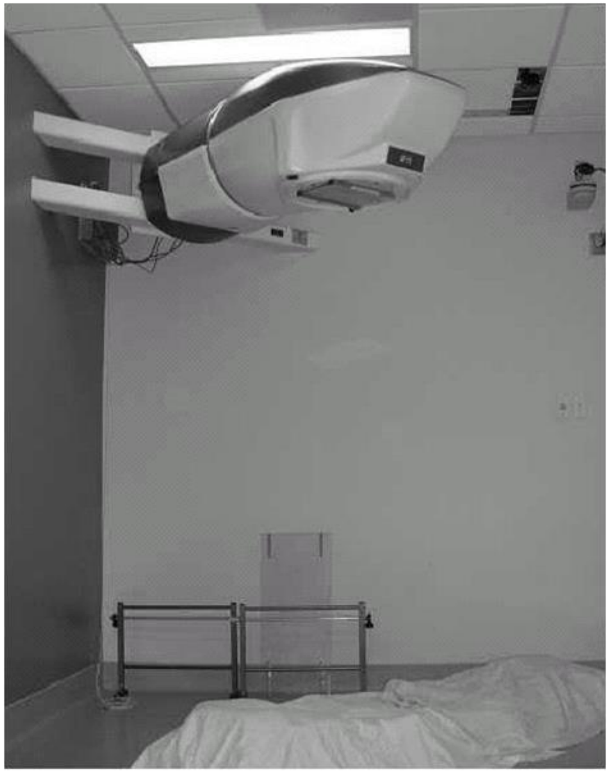
- Exposure rates ranged from 0.68 ‘R’/h to 1.26 ‘R’/h and doses were prescribed as a percentage of an erythema dose which was about 750 ‘R’ (‘R’ represents the unit of exposure as determined at that time).

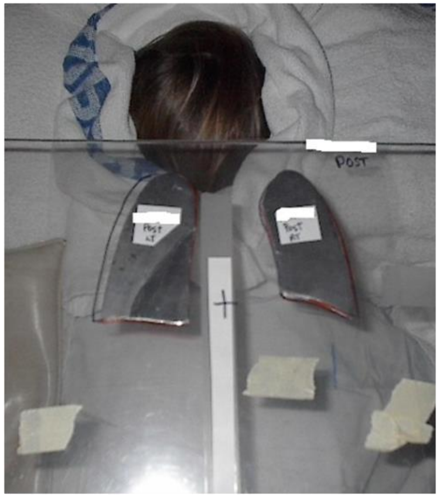
Historical TBI Technique: Cs-137

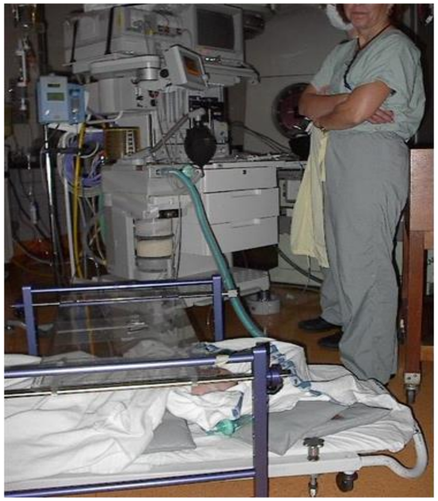
- Oak Ridge Labs (1960)
- patient lies on uniform density bed at the center of the room
- eight Cs-137 sources
- a source placed at each corner of the room
- each source: 500 Ci

Historical TBI Technique: Co-60 Unit

- McGill University
- supine / prone
- requires mattress on the floor
- free-standing frame to support lung shields



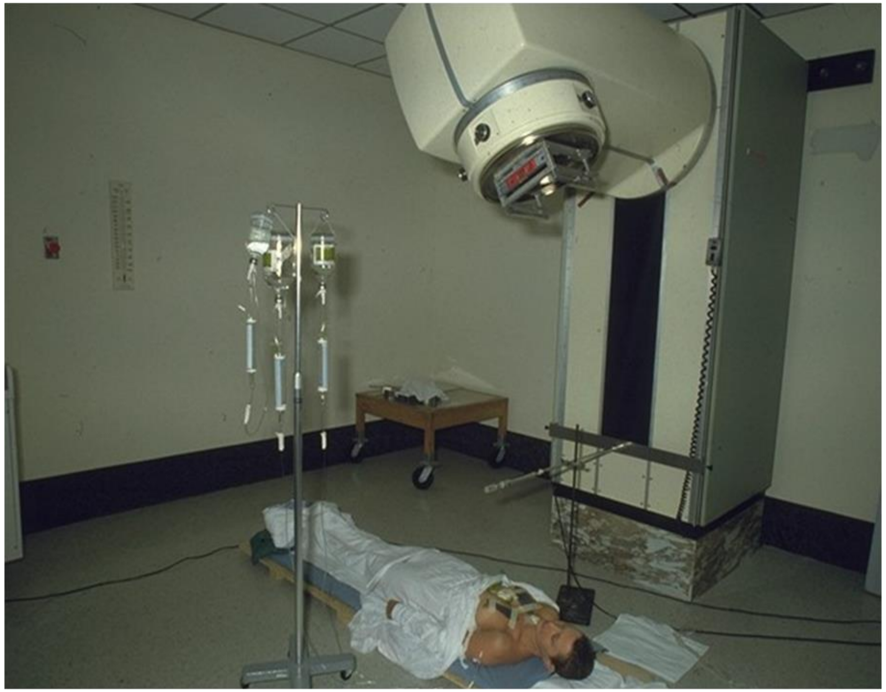


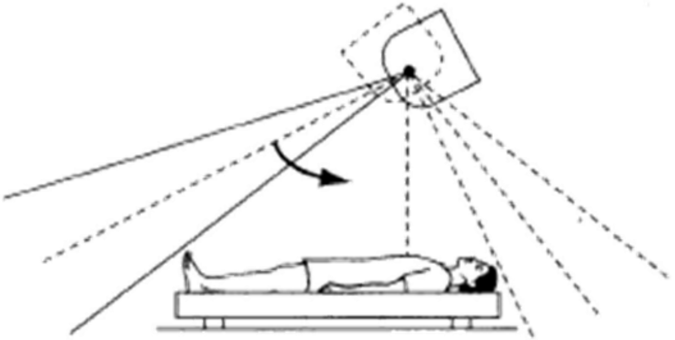


Historical TBI Technique: Co-60 Unit

McGill University

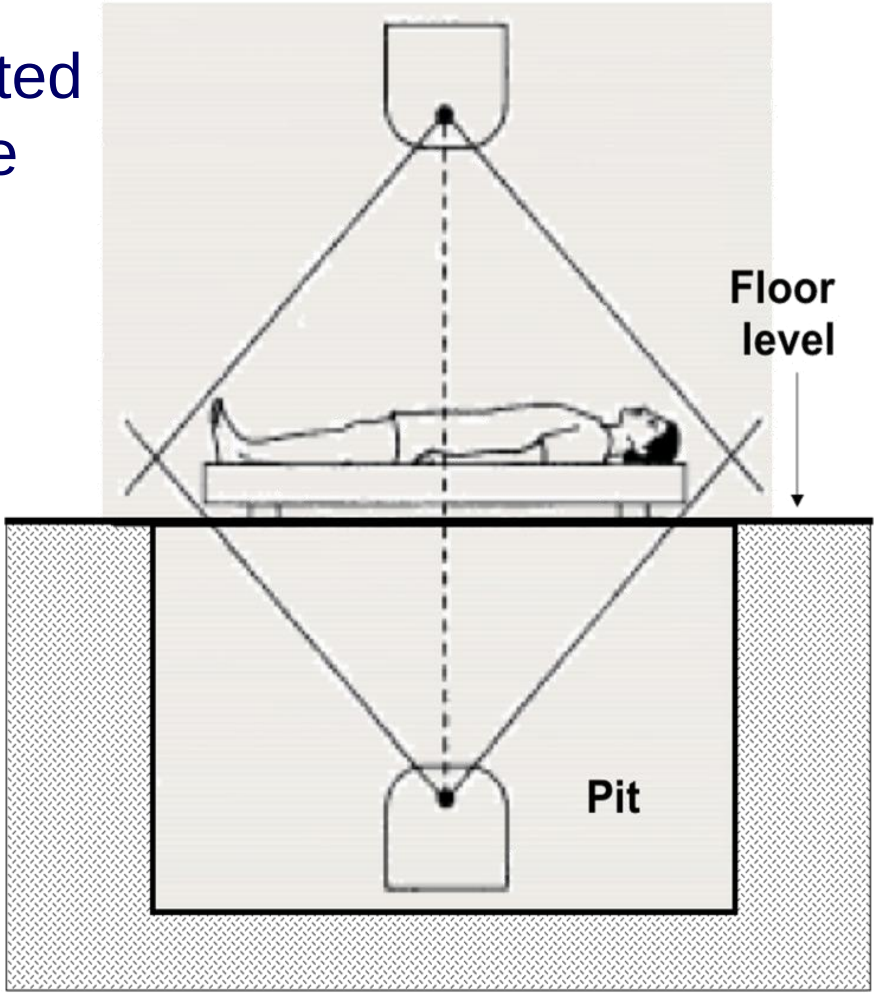
- sweeping beam technique with a column mounted cobalt unit
- specially designed unit
- custom shields can be used
- can be used in small rooms





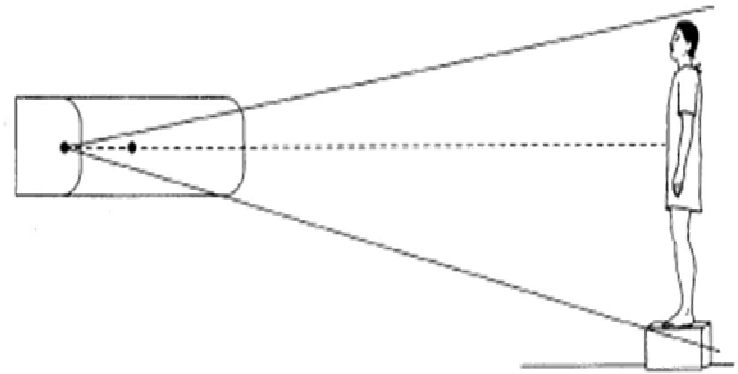
Historical TBI Technique: Linacs

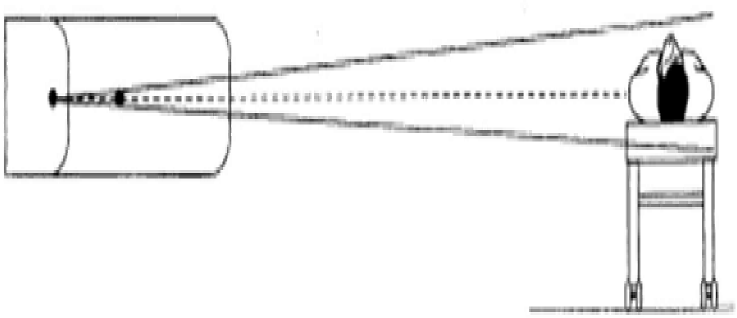
- Two linear accelerators mounted in such a way that they produce two parallel-opposed beams simultaneously



Conventional TBI Techniques: Linacs

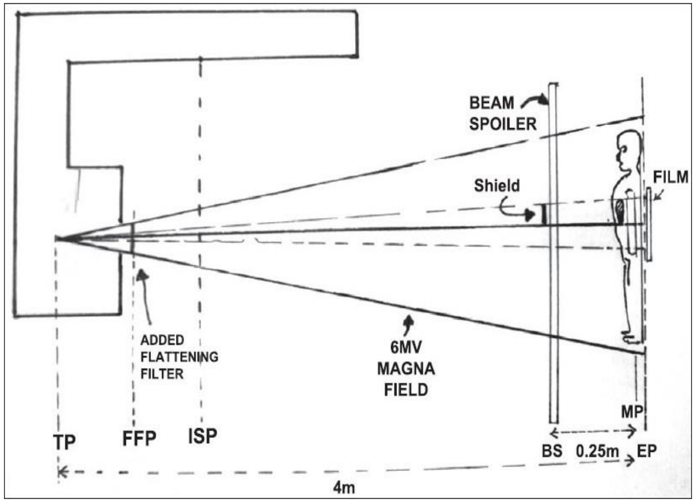
- Extended SSD
- Treatment at extended source-surface distance
- Radiation field covers the whole patient





Conventional TBI technique: AP/PA

- patient is in the standing position
- requires large treatment room
- extended SSD (4-6 m)
- shielding is possible

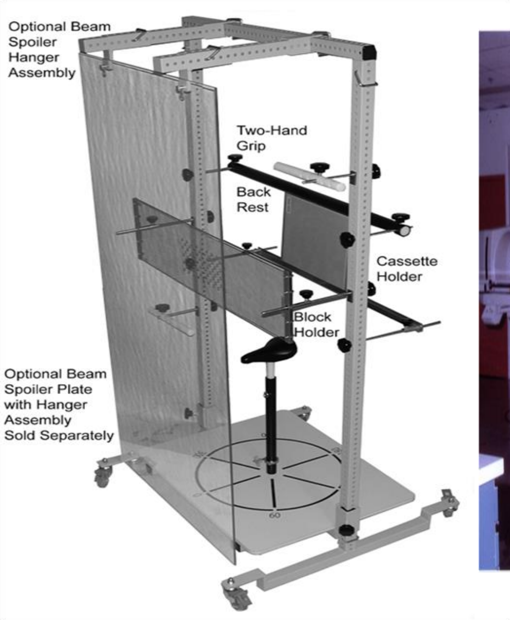


Advantage

- more homogeneous dose distribution

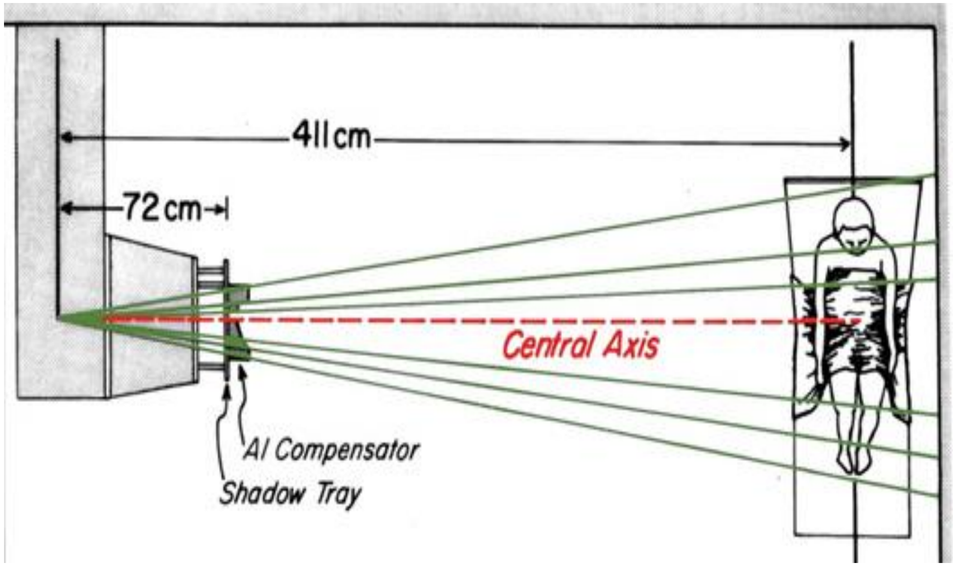
Disadvantage

- standing position result in poor setup reproducibility



Conventional TBI technique: Bi-lateral

- patient can be semi seated/ lying down position
- compensator is used

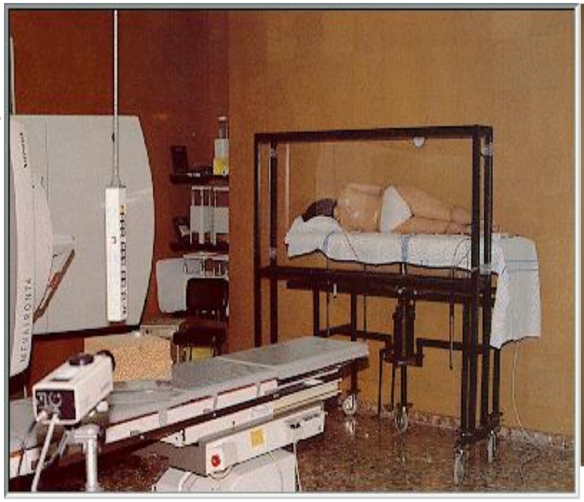


Advantages

- overcome the limitation of treatment room dimension
- set-up reproducibility good

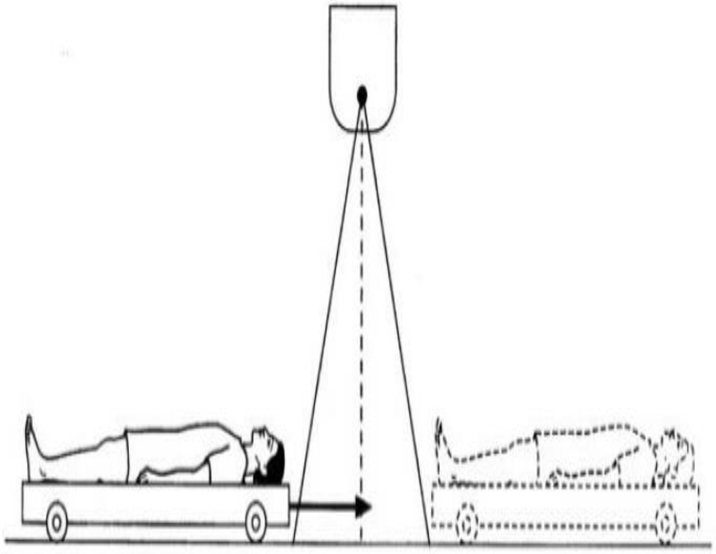
Disadvantages

- Lateral body thickness varies
- Less dose homogeneity
- Does not allow shielding



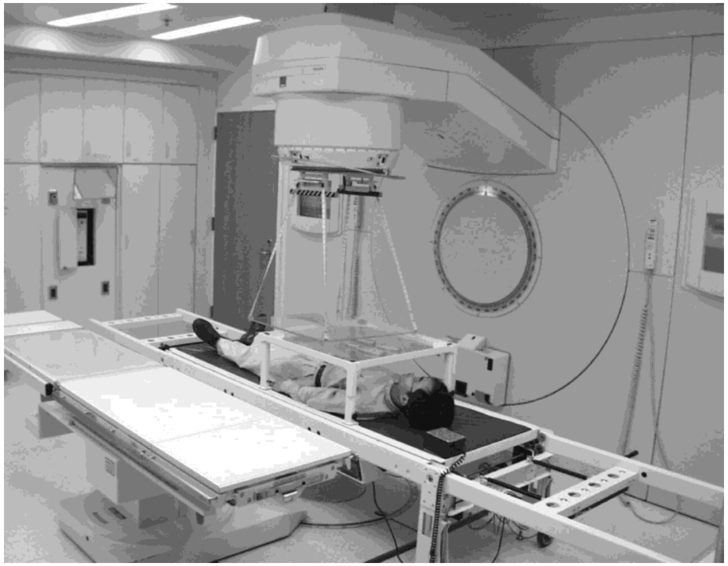
Translational TBI Technique

- patient rest in couch in supine position
- transported horizontally through a vertical beam
- radiation beam and couch motion is synchronized
- Couch velocity modulation over patient thickness
- Custom shield is possible



Advantages

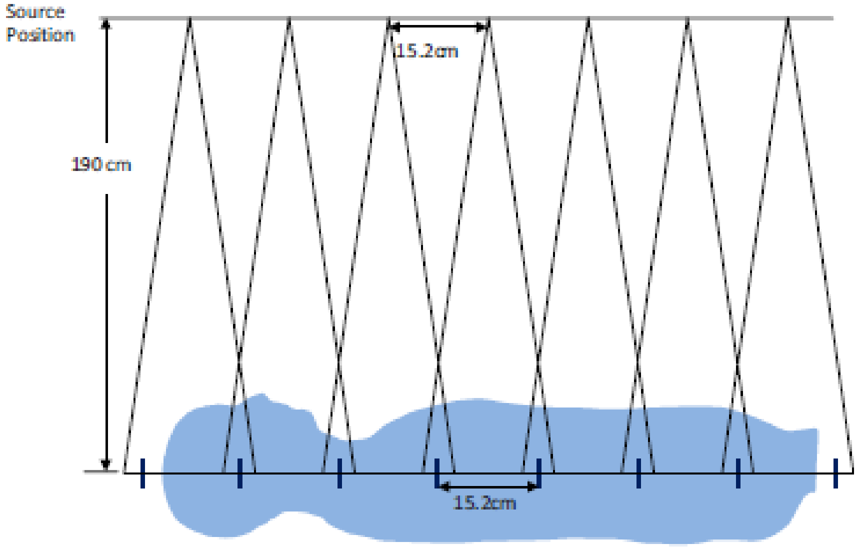
- less treatment time
- requires small treatment room
- Increased dose uniformity
- reproducibility

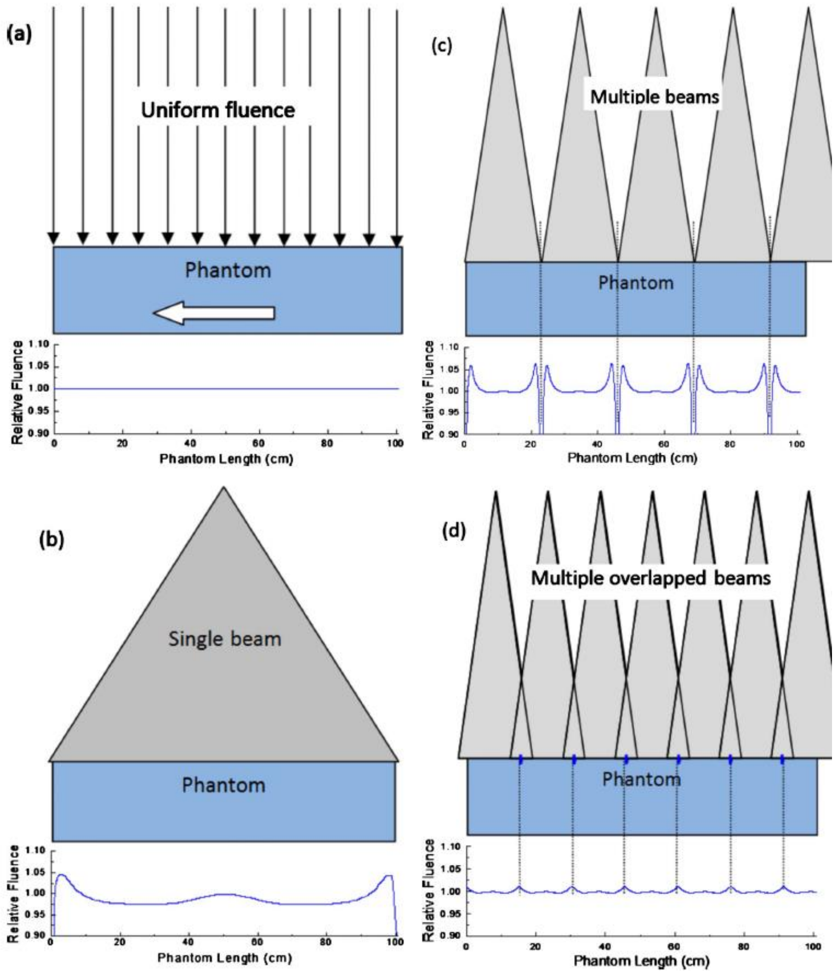


Disadvantages

- dosimetry is complex
- costly

Linac- IMRT based TBI





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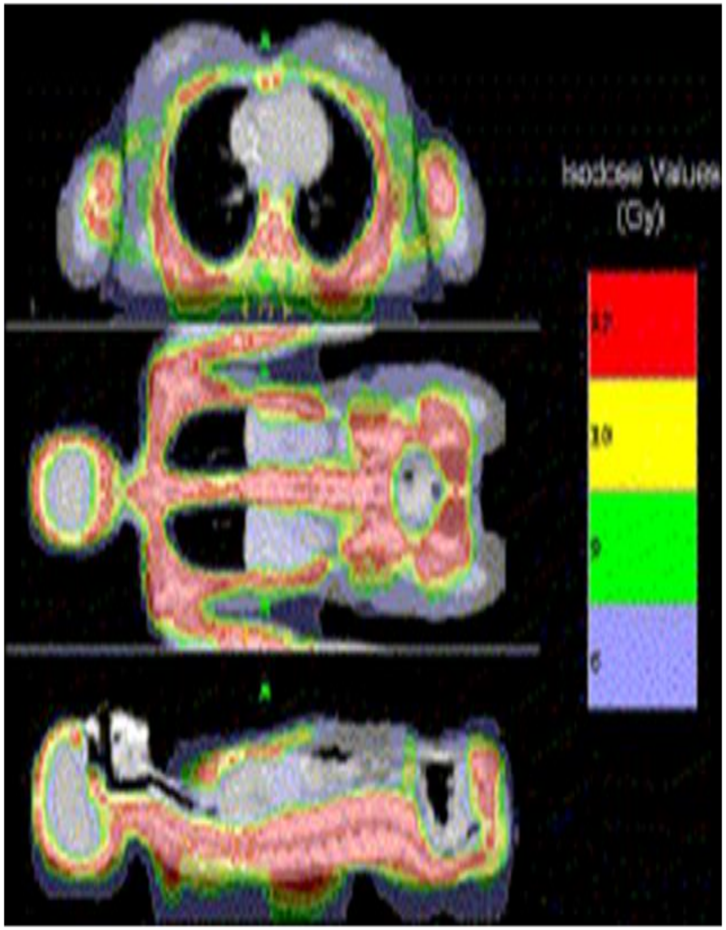
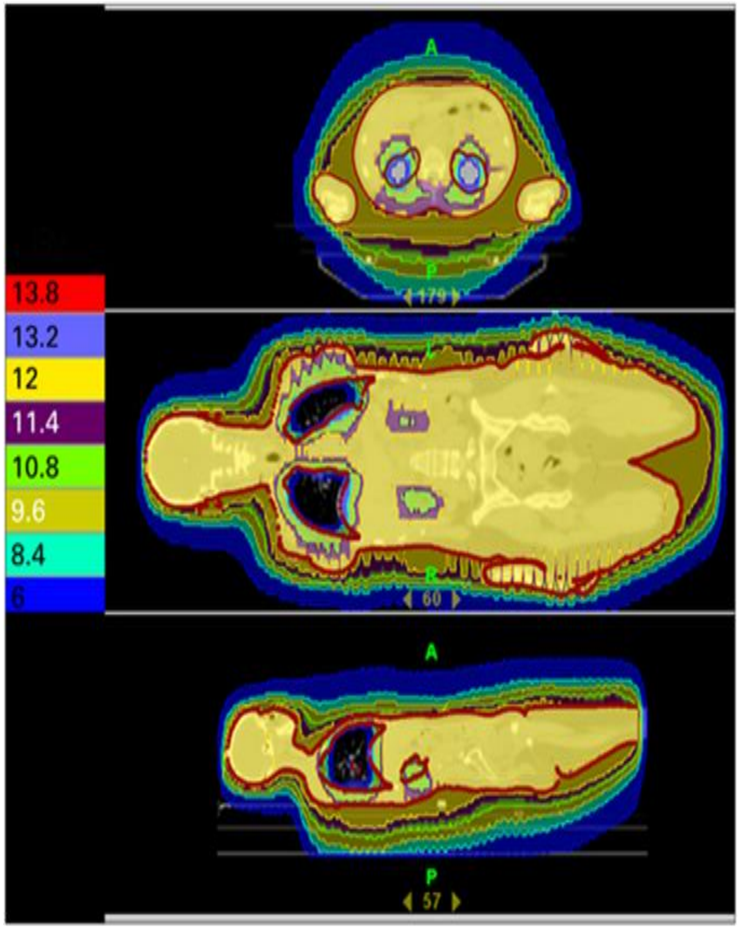
Modern TBI Technique: Helical Tomotherapy





Planning average doses 12Gy to OAR were set not to exceed 8 Gy and 10 Gy to the lungs and the kidneys, respectively. Dose escalation upto 20Gy possible.

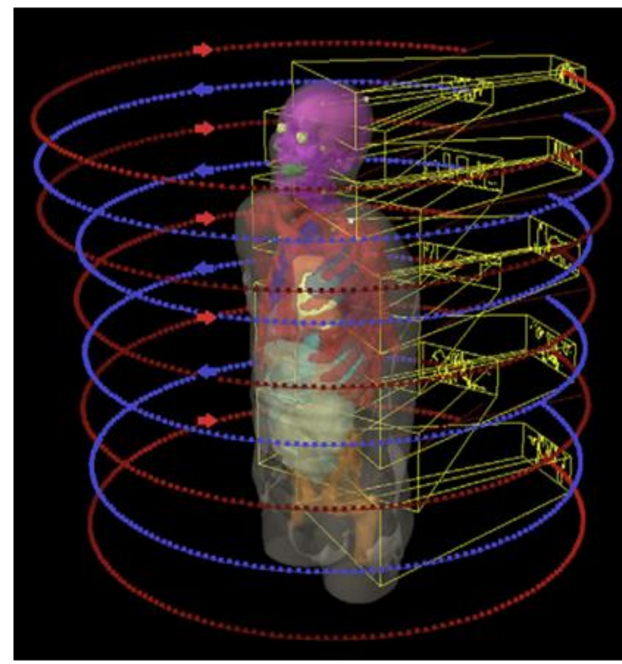
Treatment Techniques: TMI with RapidArc

PHYSICS CONTRIBUTION

TOTAL MARROW IRRADIATION WITH RAPIDARC VOLUMETRIC ARC THERAPY

Bulent Aydogan, Ph.D.,[*†] Mete Yeginer, Ph.D.,[‡] Gulbin O. Kavak,[†‡] John Fan, Ph.D.,[§]
James A. Radosevich, Ph.D.,[‡] and Kim Gwe-Ya, Ph.D.[¶]

Lower extremities treated separately

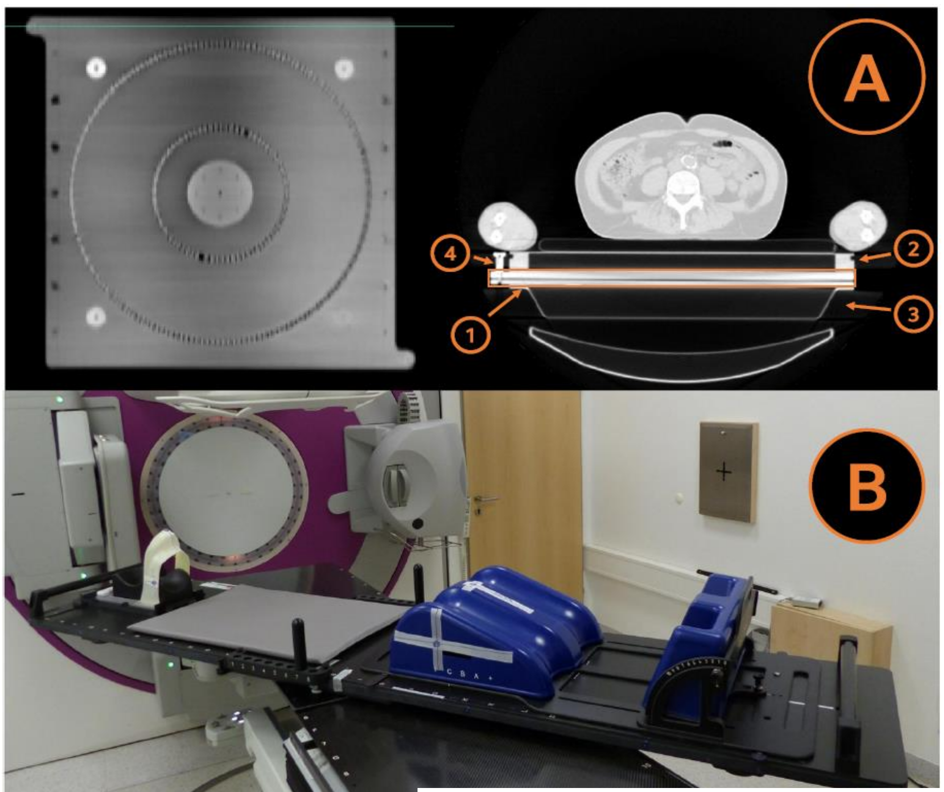


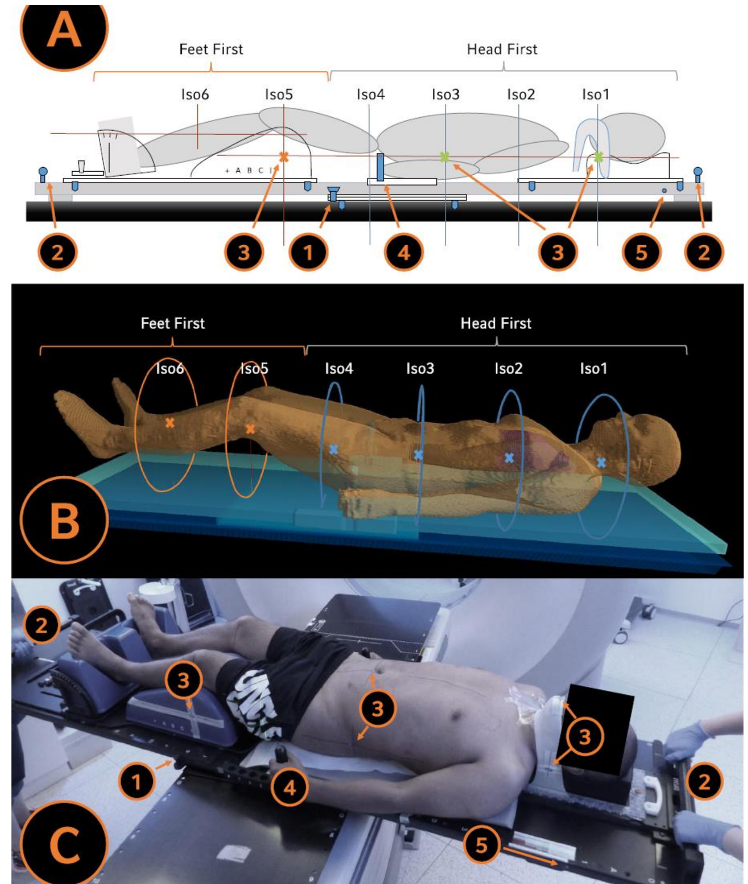
Int. J. Radiation Oncology Biol. Phys., Vol. 81, No. 2, pp. 592–599, 2011

RESEARCH Open Access

Novel rotatable tabletop for total-body irradiation using a linac-based VMAT technique

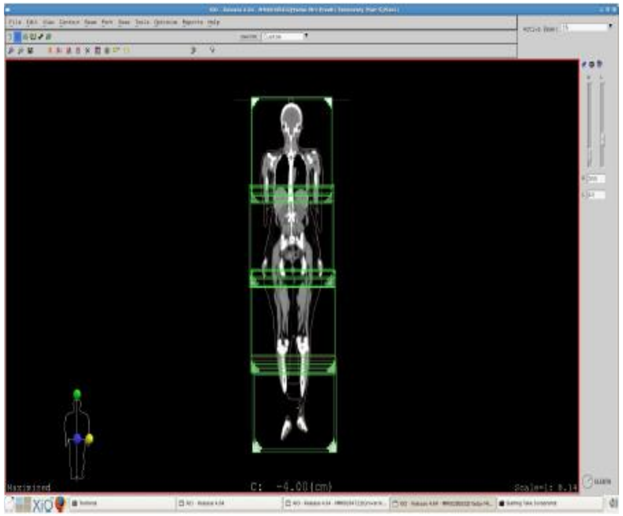
Christoph Losert[†], Roel Shpani[†], Robert Kießling, Philipp Freislederer, Minglun Li, Franziska Walter, Maximilian Niyazi, Michael Reiner, Claus Belka and Stefanie Corradini[*]

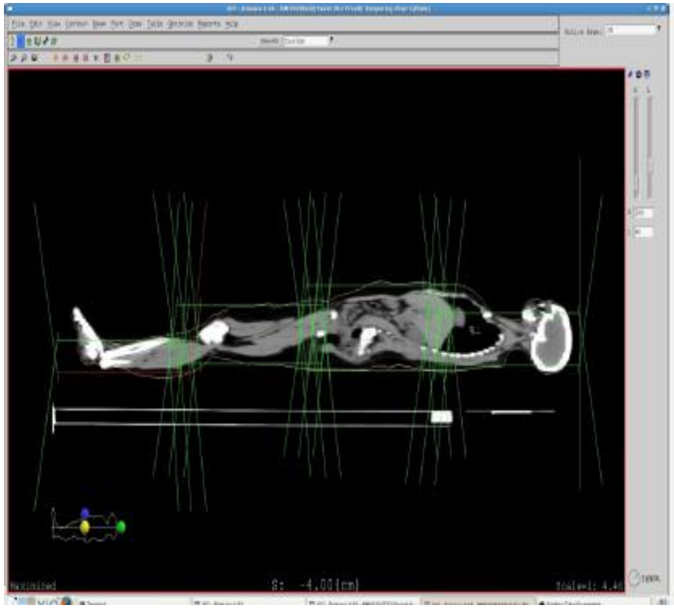




Losert *et al. Radiation Oncology* (2019) 14:244

Newer TBI Techniques-VMAT





Modern TBI Techniques

Advantage

- no need for blocks or compensators, extended source to skin distances, beam spoilers or uncomfortable patient positioning .
- standard-sized treatment room is adequate

Challenges

- needs more time for Treatment Planning
- In case of VMAT needs to take care of junctioning.
- patient set up
- patient specific QA

Patient in-vivo dosimetry

In-vivo dosimeters Calibration

- calibration of in-vivo dosimeters should be done at TBI conditions.
- calibrate the samples to the known absorbed doses
- use appropriate build-up thickness and also backscatter materials
- calibrate dosimeter when dose/beam modifiers is in place
  - TLD
  - Diodes
  - MOSFET
  - OSLD
  - Radiochromic films

Patient dose verification

Site	*Measured dose (in % of prescription dose)*		
	Minimum	*Maximum*	*Average*
Forehead	90.2	104.07	97.33
Ant. mediastinum	81	104.93	95.65
Post. upper chest	80.6	103.73	96.4
Right anterior chest	87.8	112.73	99.89
Right posterior chest	90.47	112.8	100.61
Left anterior chest	91.6	111.47	98.73
Left posterior chest	90.13	109.4	98.4
Abdomen	85	104.47	96.99
Umbilicus	85.27	100.27	96.07
Posterior pelvis	85.13	102.27	96.75
Right anterior thigh	86.47	111.4	97.75
Right posterior thigh	89.27	105.87	97.85
Left anterior thigh	84.2	108.8	97.32
Left posterior thigh	87.4	105.33	97.39
Right anterior calf	87.07	115.47	101.29
Right posterior calf	86.73	111.93	101.78
Left anterior calf	96.6	107.33	101.01
Left posterior calf	84.27	111.47	100.67

Implementation of TBI Program

- Close interdisciplinary co-operation : Radiation oncologists,, Medical oncologists/ hemato-oncolgists, medical physicist, technologists and nursing staff
- Preferable to have all facility in same center: enabling joint consultations on treatment course, patient care, follow-up
- Effective communication – right info, at right time to right people
- Performed at large centers (high frequency of patients/ sufficient qualified personnel / including trained stand-ins/ premises and technical support
- The roles and responsibilities have to be clarified and documented

Future Directions in TBI treatment

- Linac-IMRT/VMAT based TBI/TMI/TLI
- Organ-sparing Marrow-Target TMI with Linac and HT
- Field-in-field technique
- Flattening filter free beams for TBI
- Proton beams
- Image Guidance system
- Treatment planning system (Eclipse, Monaco,HT TPS)
- Dosimetric verification system
- EPID Dosimetry

Total Skin Electron Beam Therapy

- Total skin electron beam therapy (TSET) is specialized radiotherapy technique for coetaneous T-cell Lymphoma (mycosis fungoides)

Purpose

To deliver uniform prescription dose +10% throughout the entire body surface

- up to limited depth

-and protecting the underlying organs

-low energy electron beams have rapid falls of dose beyond a shallow depth

- without exceeding bone marrow tolerance

Brief History

1902- Radiation was used for coetaneous T-cell Lymphoma

1931- X-ray bath using superficial x-ray machine were used.

1958- Karzmark, Stanford University introduced electron therapy for MF

1987- AAPM , 2004- EORTC 2015-ACPSEM for TSET Guidelines

Special Requirements for TSET

- Large treatment room-Large SSDs (Technique dependent)
  - large SSD 2-6 m

- High dose rate- shorten treatment time

- Scatter/energy degrader plate
  - lucite/plexiclass
  - thickness of 1cm
  - cross section of 2mx1m
  - location at minimum of 20cm from patients

- Good ventilation, frequent air exchange.
  - significant ozone production from ionizing large volume of air in the treatment room

TSET Irradiation Techniques

- Many different methods

- Single beam
- Pair of parallel beams
- Pair of angled beams
- Pendulum arc
- Patient rotation

Physics and Dosimetric Considerations

- TSEI dose is prescribed on the patient's skin surface at the level of the umbilicus (dose prescription point)
- The depth at which 80% of the administered dose is absorbed should be not less than 4 mm.
- At the depth of 20 mm the absorbed dose value is not supposed to exceed 20%.
- Nominal energy of electron radiation used during electron radiotherapy should range from 4 MeV to 8 MeV.
- The patient should be positioned in such a way as to receive irradiation to the maximum area of skin surface.
- Total dose of 31 Gy to 40 Gy in 6-9 weeks

In addition, the skin areas that receive doses lower than 80% of those prescribed during electron treatment should also be supplemented.

Physics and Dosimetric Considerations

- The dose prescribed to sole-of-foot fields is typically 26 Gy-28 Gy.

- Radiation energy for boost fields is prescribed depending on the depth of skin infiltration.

- In the case of skin lesions, radiation energy for boost fields ought to range from 3 MeV to 6 MeV.

- When lymph nodes are affected, the prescribed energy depends on the depth and the location of the node (typically from 6 MeV to 12 MeV).

- Various techniques involving beam spoilers/energy degrader (to degrade the electron beam energy) or special filters/scatterer (to improve the electron beam flatness) are used to produce the large, clinical electron beam at an extended SSD.

TSET Irradiation techniques

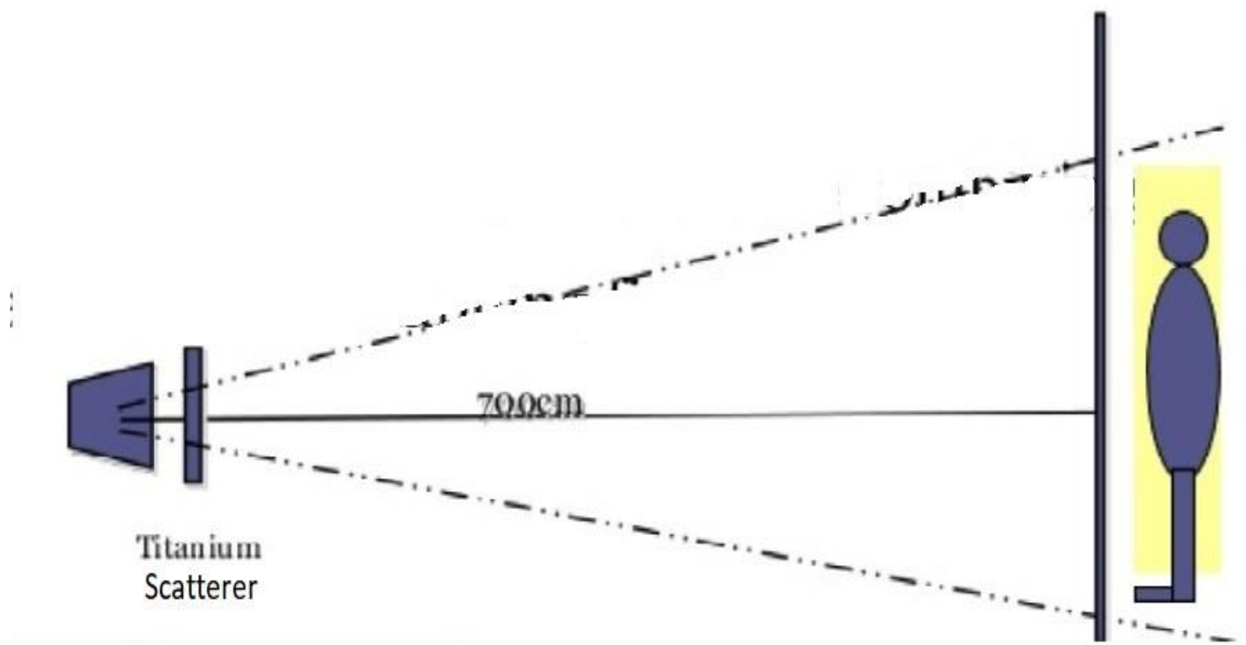
- TSEI techniques in use today may be grouped into three main categories:
  - Large electron field techniques, in which a standing stationary patient is treated at a large SSD with a single large electron beam or a combination of large electron beams.

  - Rotational techniques, in which the patient is standing on a rotating platform in a large electron field.

  - Translational techniques, in which the patient is translated on a stretcher through an electron beam of sufficient width to cover the patient's transverse dimensions.

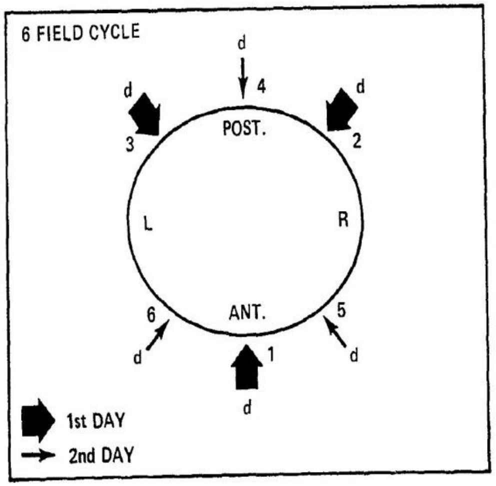
TSET Irradiation techniques

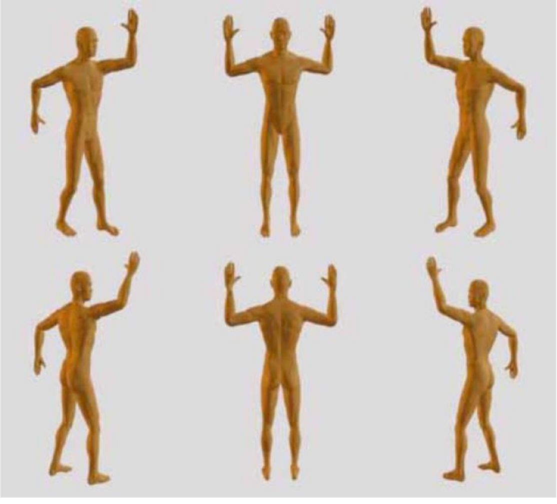
- Large electron field techniques: Single field
  - In larger treatment room machine (SSD = 7OO cm)
  - SSD of seven meters provides treatment field size which encompasses the entire patient body surface



TSET Irradiation techniques

- Large electron field techniques
  - Treatment positions change every 60° about the patient's longitudinal axis.
  - Treatment delivered in sequential two-day treatment cycle
  - Further categorized into
    - Single field
    - Dual field

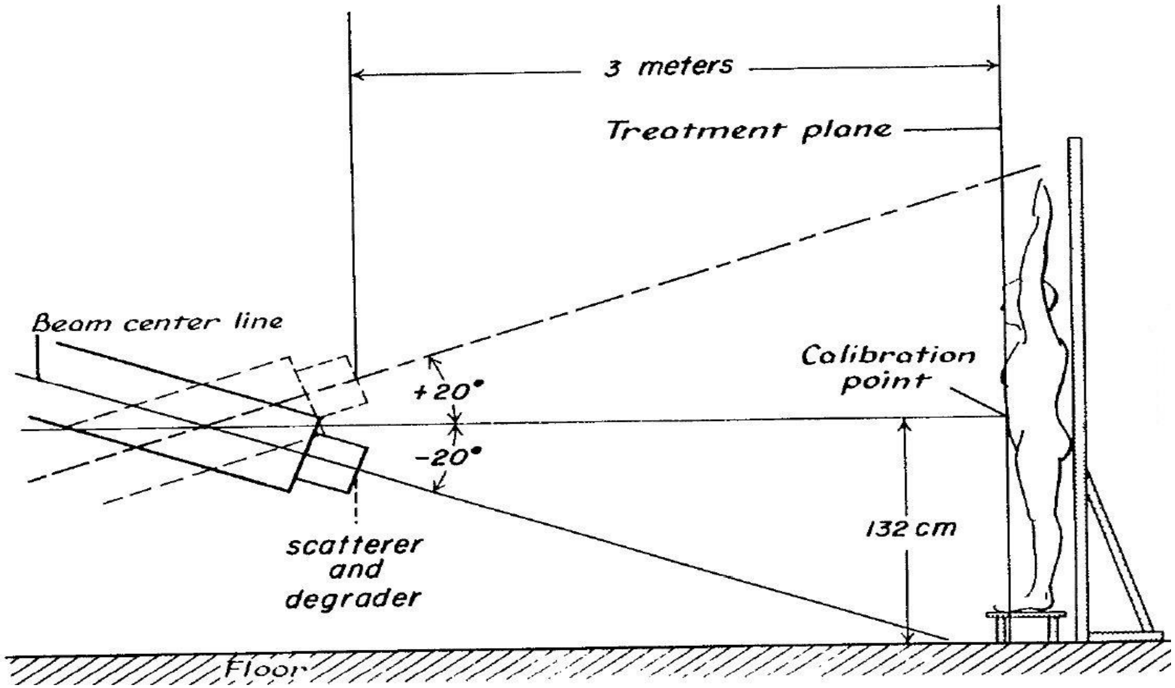




TSET Irradiation techniques

Large electron field techniques: Dual field

- With SSD of 3 m it is possible to obtain the dual field by using two fields for which the gantry is located +20° and –20° in relation to the axis.



Advantage

- Large angle scatter of the emergent electrons improves dose uniformity
- Also reduces penetration and depth dose falls off at shallower depth dmax shifts towards surface

TSET Irradiation techniques

Rotational techniques:

Two main subcategories

- Classic
- Rotary-dual

Classic

- In the classic rotational technique, the patient is placed on a rotation platform and one field is used in the process of irradiation (the gantry of medical accelerator is positioned along the horizontal axis).

- The patient is rotated at a constant speed about the vertical axis of the body using motorized platform.

- Similar to single field technique of large electron fields, it is necessary to use large SSDs (~7 m) so that the treatment field of an adequate size covering patient's entire body can be produced.

- it is essential to use scatters ensuring uniform dose distribution along the longitudinal axis of the patient.

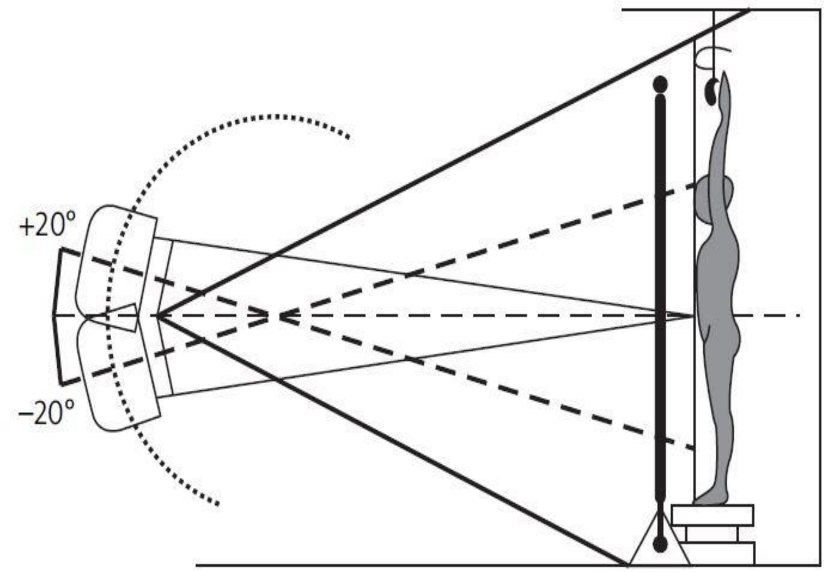
- Dose homogeneity across the patient, is compensated by constant rotation during irradiation

TSET Irradiation techniques

Rotational techniques:

Rotary-dual

- The patient is rotated about his/her vertical axis is delivered using one dual field.
- Like in the Stanford technique, a dual field offers the possibility of a significant reduction of SSD (up to 3 m) without the use of the scattering filter and larger treatment room.
- Similar to the classic rotational technique, the rotational movement of the patient in the course of irradiation eliminates the necessity to apply scatters, which improve dose homogeneity across the patient's body.
- Better dose homogeneity than any other techniques



TSET Irradiation techniques

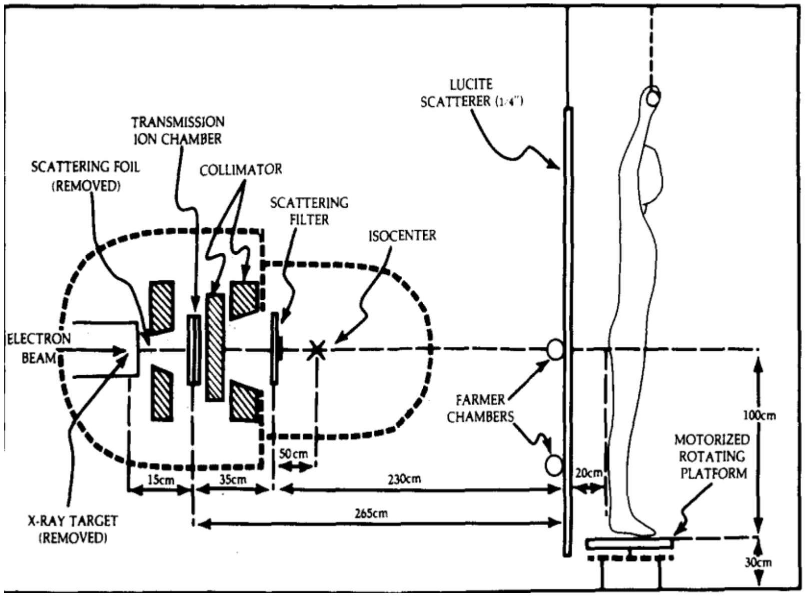
Translational techniques:

- The patient is placed on a specially modified treatment table, which moves along the longitudinal axis of the body to deliver two opposing fields.

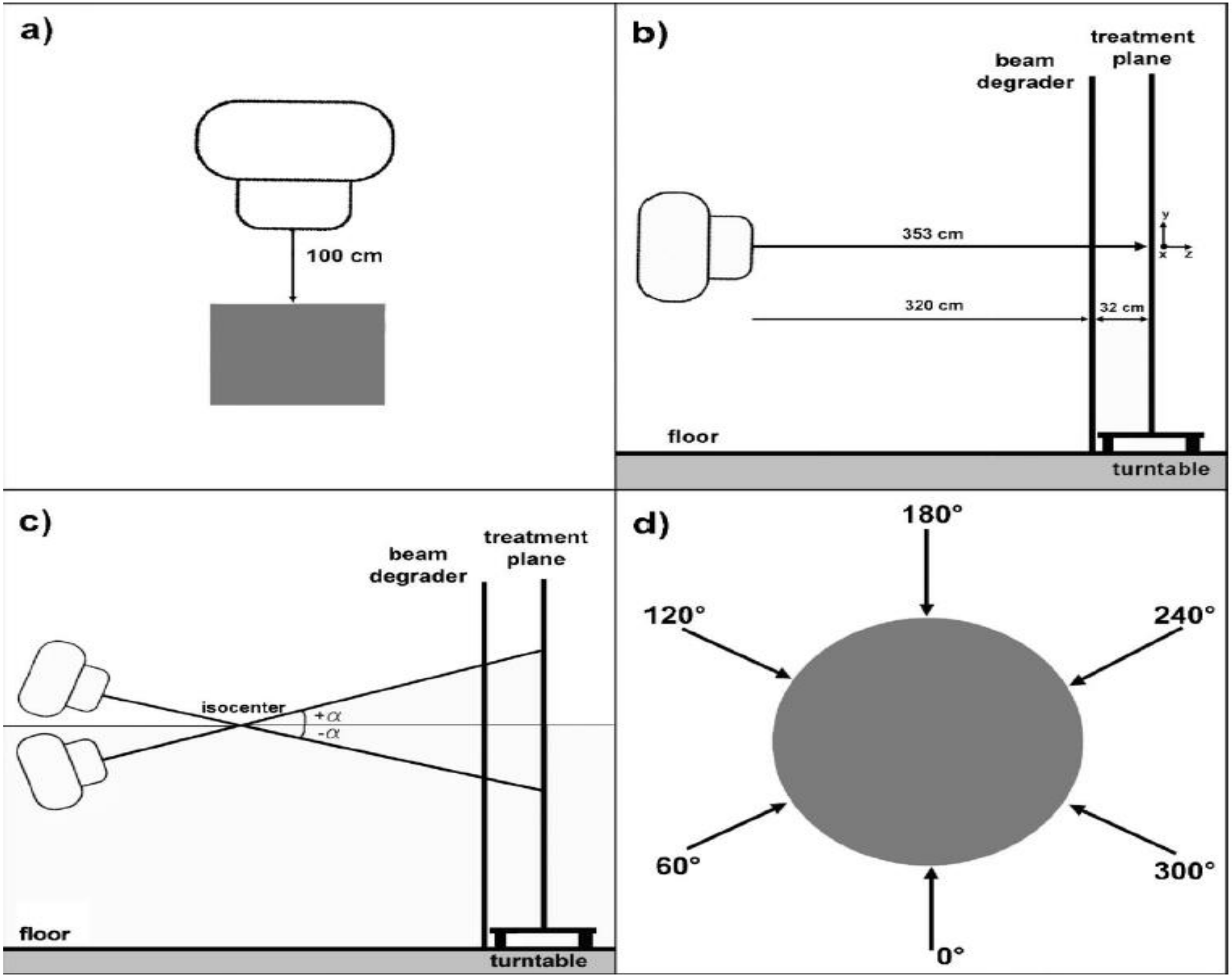
- Another form of this method, which dispenses with continuous patient shift, involving patient irradiation with four or five sets of fields, each requiring a separate positioning.

- In the process of irradiation with each set of fields, the patient remains stationary and is moved along during setup alteration.

- In both these techniques, it was possible to treat in SSD of 1.5 m which can be achieved in treatment table position .



Dosimetric Measurements for TSET



X-ray Contamination-Limiting factor

- Source-x ray interactions with exit window, scattering foil, ion chamber, collimator, air and patient.

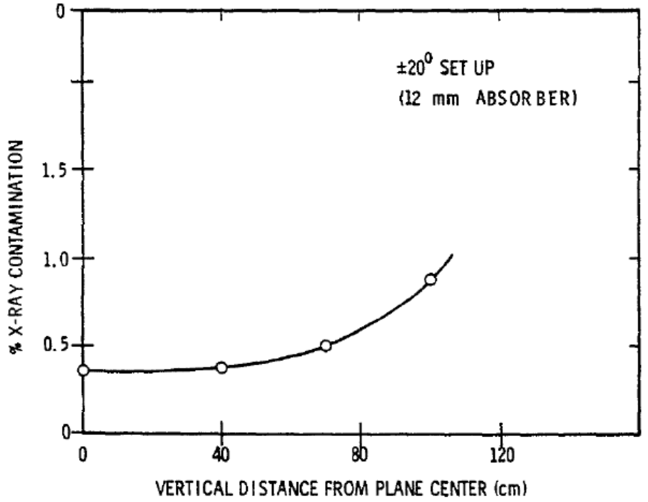
- Depends on numbers of treatment fields used as all fields contributes

- Cumulative x-ray dose measured at 10cm depth averaged over patient volume typically 1-4%

•Desirable dose is >1% at dmax (AAPM TG-30)

- e.g < 0.36Gy acceptable for a prescription of 36 Gy

•EROTC recommends- 0.7Gy



Patient In-vivo dosimetry

- In-vivo dosimetry (IVD) is important to measure doses in specific locations during course of treatment.

- Excessive dose regions (120%-130%) ,hot spot, can occur in areas of sharp projections, curved surfaces, region of multiple field overlap.

- Low regions occur when skin is shielded by other parts of the body or overlying body folds. e.g. axillary folds,perneum, soles of feet.

- Areas receiving less dose can be boosted.

- IVD also for the purpose of dose verification QA

Future Directions in TSET

- Six-dual field stand ford techniques will remain
- TSET treatment in the lying on the floor
- Hypofractionation in TSET treatment
- Helical Tomotherapy is also useful for TSET (using varying thickness bolus application)
- Cerenkov imaging is used for TSET verification

Challenges in Large field Radiotherapy

- Long treatment time for TBI (around 1.5 hours)
- In modern technology based IMRT/VMAT based TBI, treatment planning is labour intensive
- Multipurpose linac or HT will occupy significant time for TBI treatment
- TSET treatment planning system is not yet available
- Independent verification systems is not yet available

Summary and Conclusion

- Irradiation techniques determines the amount of dosimetry
- AP/PA& bilateral is standard method and reliable and time tested
- IMRT/VMAT based TBI is eliminating additional aid devices & larger room size
- Modern technology based VMAT-TBI
- Enhance the dose homogeneity and better sparing of OAR dose
- Eliminates the treatment aid devices fabrication.
- Reduce the treatment time
- Reduce the complexity of the treatment
- Transition from Conventional TBI, IMRT/VMAT based TBI and Targeted TMI/TLI
- Stanford six-dual field TSET techniques are commonly used method
- Rotational dual field techniques improves dose homogeneity
- X-ray contamination is important factor for treatment related complications.
- Latest technology of Helical Tomotherapy is useful for both TBI and TSET.
- TLD, Diodes, MOSFET, Radiochromic films and OSLD are used for in-vivo dosimetry

Thank You for your attention

MCQs

I. What is goal of total body irradiation dose homogeneity

1. To achieve $\underline{+}$ 10% dose homogeneity throught the body
2. To achieve $\underline{+}$ 10% dose homogeneity of 50% of the body area
3. To achieve $\underline{+}$ 5% dose homogeneity throught the body
4. To achieve $\underline{+}$ 5% dose homogeneity of 50% of the body area

II. The year in which MSKCC has introduced TBI treatment in North America?

1. 1932
2. 1923
3. 1905
4. 1971

III. The benefit of the modern technology based VMAT-TBI compared to traditional TBI techniques:

1. Enhance the dose homogeneity and better sparing of OAR
2. Reduce treatment time
3. Eliminate the treatment aid devices
4. Reduce the complexity of the treatment

A. 1,2.3
B. 1,3
C. 1,3,4
D. 1,2,3,4

IV The choice of the beam energy mainly depends on

1. patient thickness and degree of dose uniformity
2. tissue densities
3. Critical tissue dose tolerance
4. surface dose

V. Patient in-vivo dosimetry in TBI is mainly used for

1. To ensure the delivered dose as prescribed dose
2. To assess the dose homogeneity
3. To determine the boost dose
4. As a part of quality assurance process

A. 1,3
B. 2, 3
C. 3,4
D. 1,2,3,4

VI. In TSET, multiple oblique beams do all the following except;

1. improve uniformity of the skin dose
2. decrease the effective depth of dmax
3. Increase uniformity of the target volume
4. Decrease the x-ray contamination dose

VII. Which of the following may be used in TSET treatment?

1. Low energy electron
2. Multiple patient positions
3. Beam scatterer or diffuser
4. Boost fields and eye shields

A. 1,2.3
B. 1,3
C. 1,3,4
D. 1,2,3,4

VIII. In TSET, when a large lucite screen of 1 cm is placed in front of the patient, this is done in order to:

1. Protect the patient from the scattered radiation
2. Attenuate the Bremsstrahlung component of the beam
3. Increase depth dose
4. Reduce skin dose