Radiation protection issues in practice of pediatric radiotherapy

Ehab M. Attalla; PhD

National Cancer Institute;

Cairo University

IAEA

International Atomic Energy Agency

Introduction

- Radiation protection, is defined by the International Atomic Energy Agency (IAEA) as "The protection of people from harmful effects of exposure to ionizing radiation, and the means for achieving this". Exposure can be from a source of radiation external to the human body.

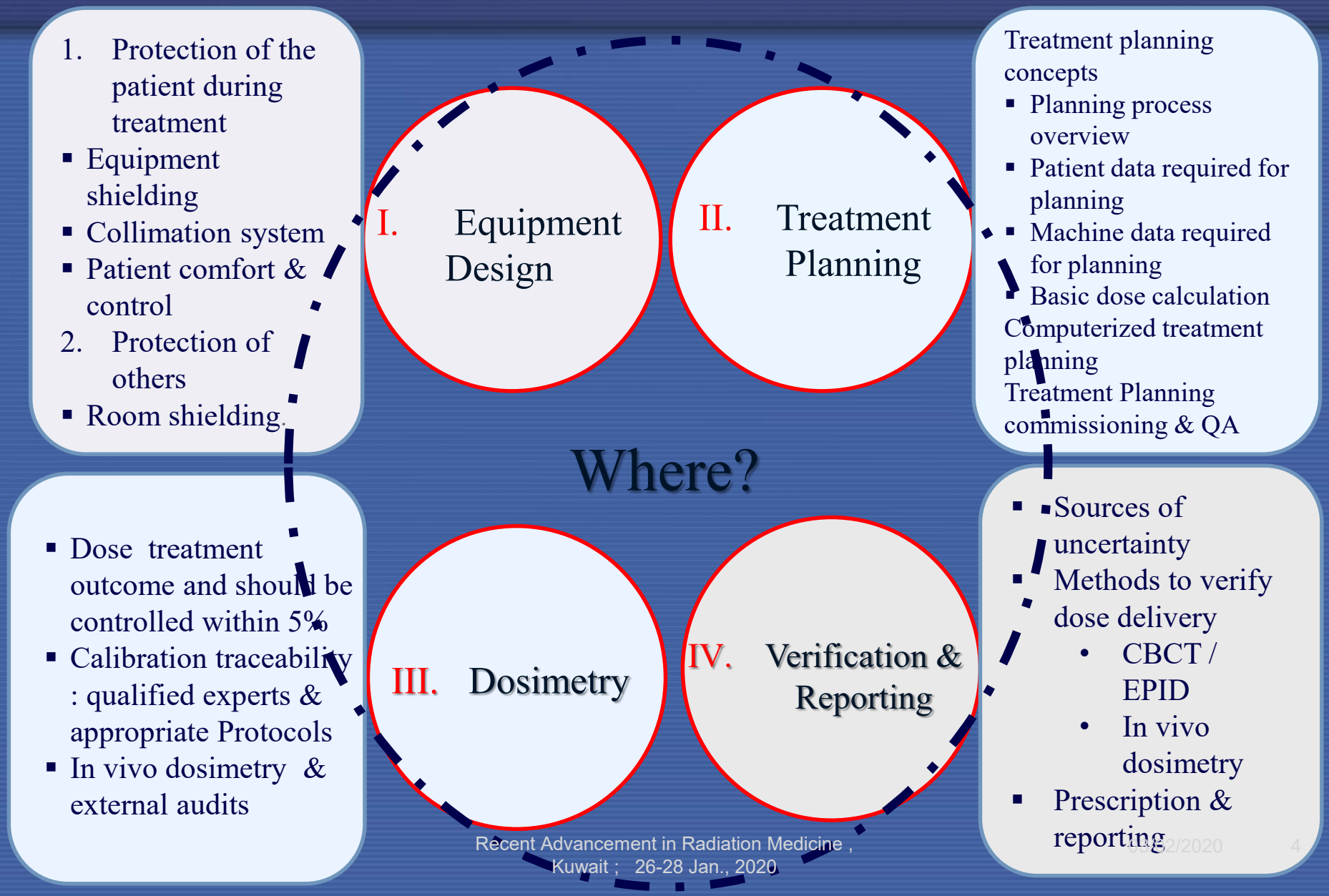
BASIC FRAMEWORK OF RADIATION ROTECTION

- Principles of radiation protection and safety upon which the radiation safety standards are based are those developed by the ICRP.

- A practice that entails exposure to radiation should only be adopted if it yields sufficient benefit to the exposed individuals or to society to outweigh the radiation detriment it causes or could cause. This means the practice must be justified.

- Dose limits are not applicable to medical exposures resulting from diagnostic procedures applied in diagnosis of disease or therapeutic procedures applied in treatment of disease.

Radiation protection in radiotherapy…



Optimum radiation energy to use for each treatment site

Megavoltage %DD

Energy	Surface	D_{max}	Depth 10 cm	Depth 20 cm	HVL mm	decrement
Cobalt-60	25 %	0.5	55	25	11	4.5% /cm
4 Mv	22 %	1.0	60	35	11.8	
6 Mv	15 %	1.5	65	40	13	3.5%/cm
10 Mv		2.5			14.3	
18 Mv	14%	3.0	80	50		2% / cm
25 Mv	13%	4.0	81	55	13.7	

Optimum radiation energy to use for each treatment site

Optimum energy versus site

Site	Optimum energy				
	Co-60	4MV	6MV	10-15MV	18MV
Brain	—	—	—	—	
Head & Neck	—	—	—		
Breast	—	—	—		
Lung		—	—	—	
Lymphoma		—	—	—	
Pancreas				—	—
Whole pelvis				—	—
Pediatrics		—	—		

Optimum energy versus site

Site group	Optimum energy				
	Co-60	4-6 MV X-ray	8-12 MV X-ray	>15MV X-ray	Electrons
Head & Neck	20%	55%	→	5%	20%
Gastro-intestinal	15%			80%	5%
Gynecological			20%	75%	5%
Breast	35%	30%			30%
Lymphomas		60%	→	35%	
Lung	10%		90%		
CNS	10%	70%		15%	5%
Bone		50%		50%	
Skin & Eye	←	15%	→		

Different Situations: Childhood / Adult Cancers

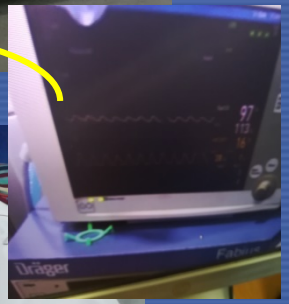
Childhood Cancer Incidence (2% of all cancers)

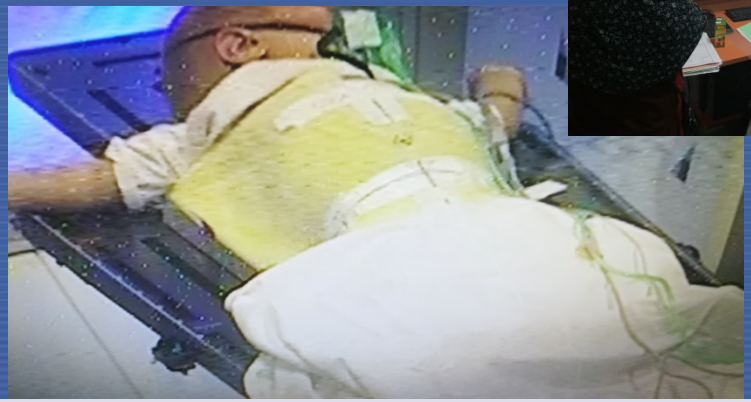
- **Leukemia (25-30%)**
- Brain
- Hodgkin's disease (other lymphoid)
- Non-Hodgkin's Lymphomas
- Bone/Joint
- Connective/soft tissue
- Urinary organs

Adult Cancer Incidence

Male	Female
Prostate	Breast
Lung/Bronchus	Lung/Bronchus
Colon / Rectum	Colon/Rectum
Bladder	Uterus
Lymphomas	Ovary
Oral cavity	Skin Melanoma
Skin Melanoma	Cervix
Leukemia	Leukemia

Patient preparation : Anaesthesia / sedation

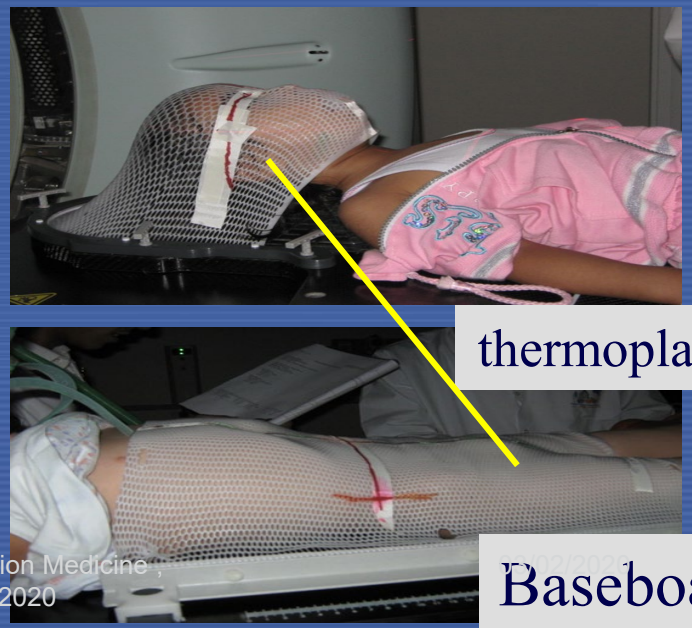




Anesthesia is a safe and effective method of immobilizing children (uncooperative)

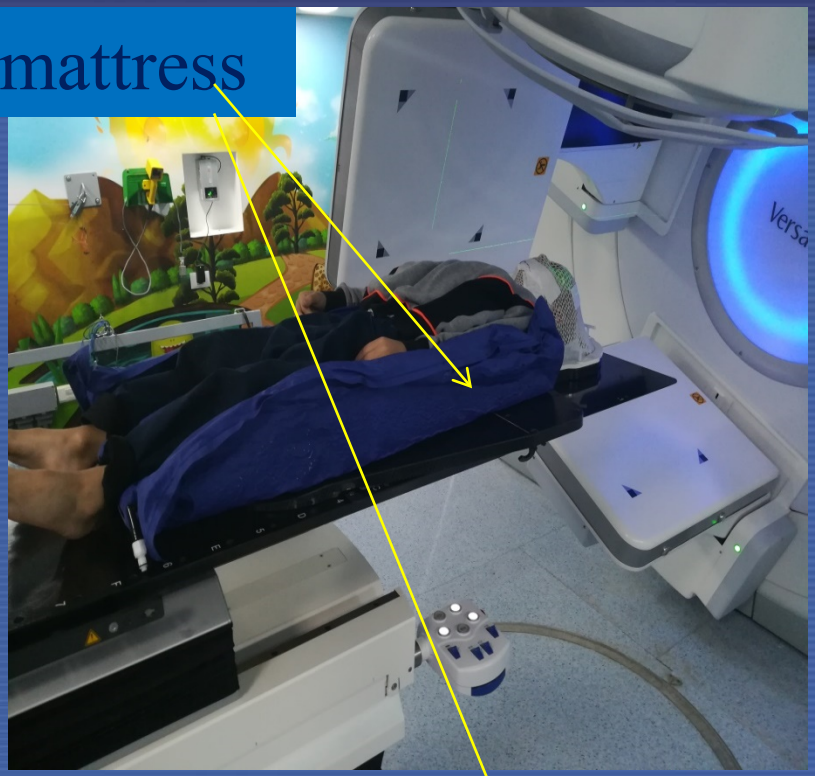
Patient preparation : **Immobilisation / Fixation**

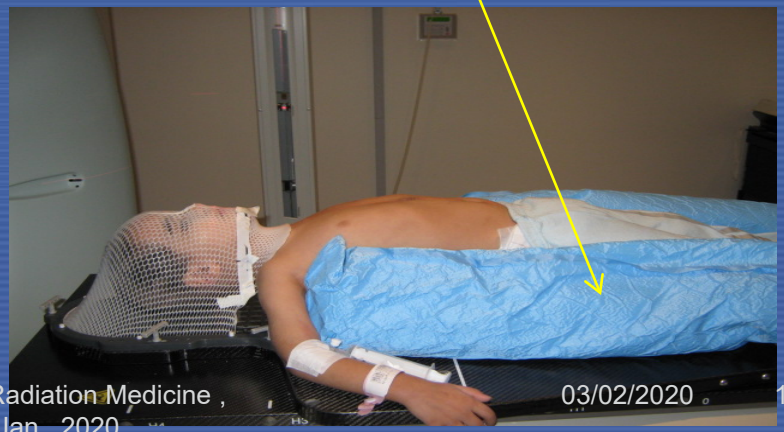
- Immobilises body in same position every day
- Reduces day to day variation in treatment position (potential source of error)
- Impression of the patient in the optimum treatment position:
  - Baseboard or any immobilization device (vacuum mattress, knee & ankle rests,)
  - sheet of thermoplastic (Orfit) moulded around body part, fixed onto baseboard



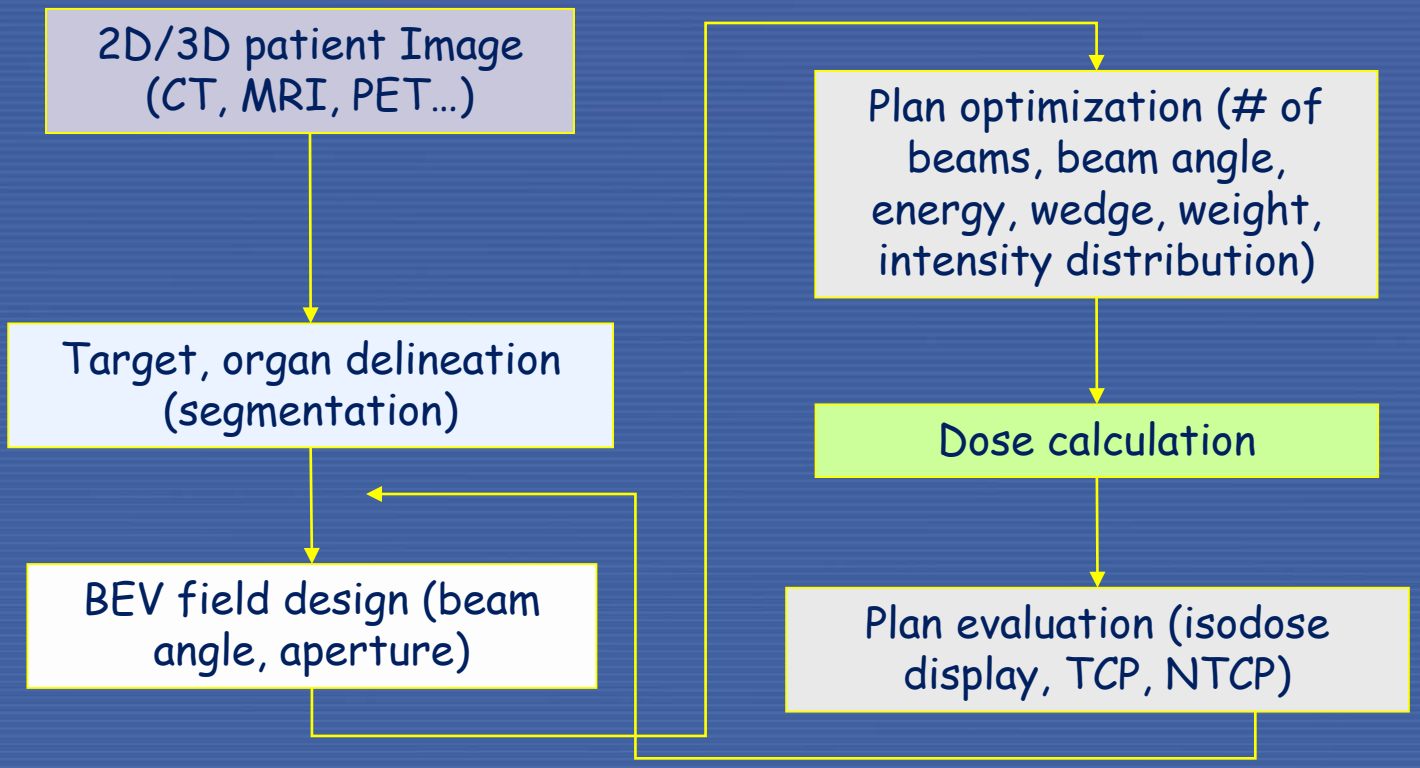
Patient preparation : Immobilisation / Fixation

Vacuum mattress





Treatment-Planning Process

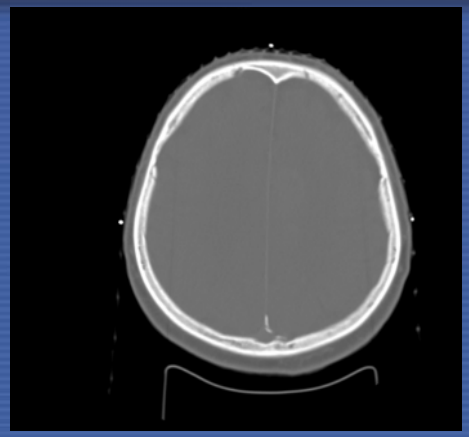


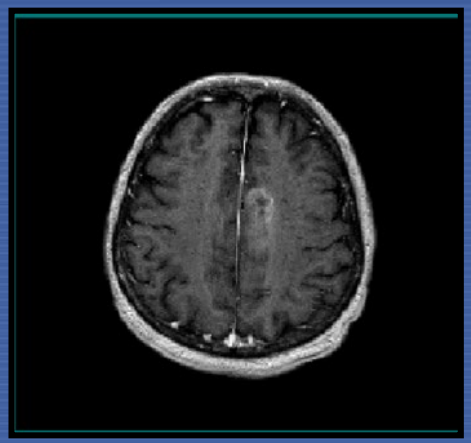
CT Simulator

Treatment-Planning Process : Imaging Data

CT scans provides the planning system with extremely accurate anatomical information but does not always optimally visualize the tumor

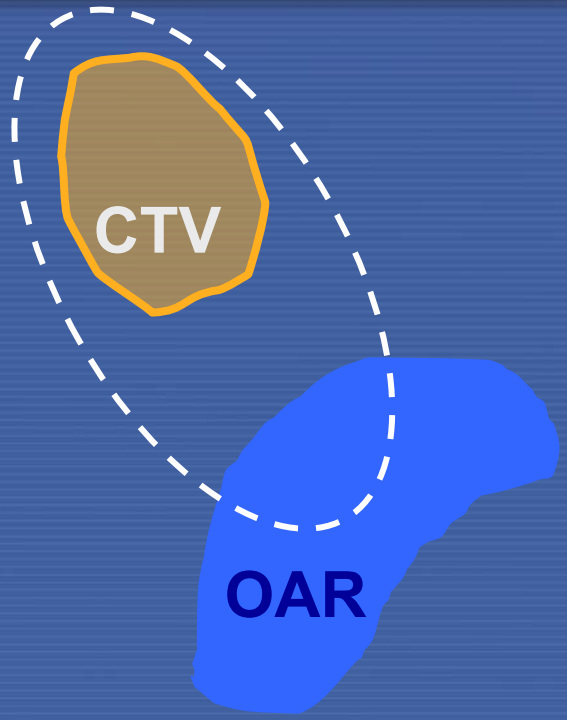
MRI scans can be used to provide a more detailed view of the tumor area, but requires additional process to be usable for planning.





→ CT and MRI data sets Aligned/Fused

Delienation I



- Margins are needed to account for uncertainties such as
  - Motion during treatment
  - Daily variations of motion
  - Volume changes (growth, shrinkage)
  - Heart beating, GI-motion
  - Patient setup errors (3-5 mm)

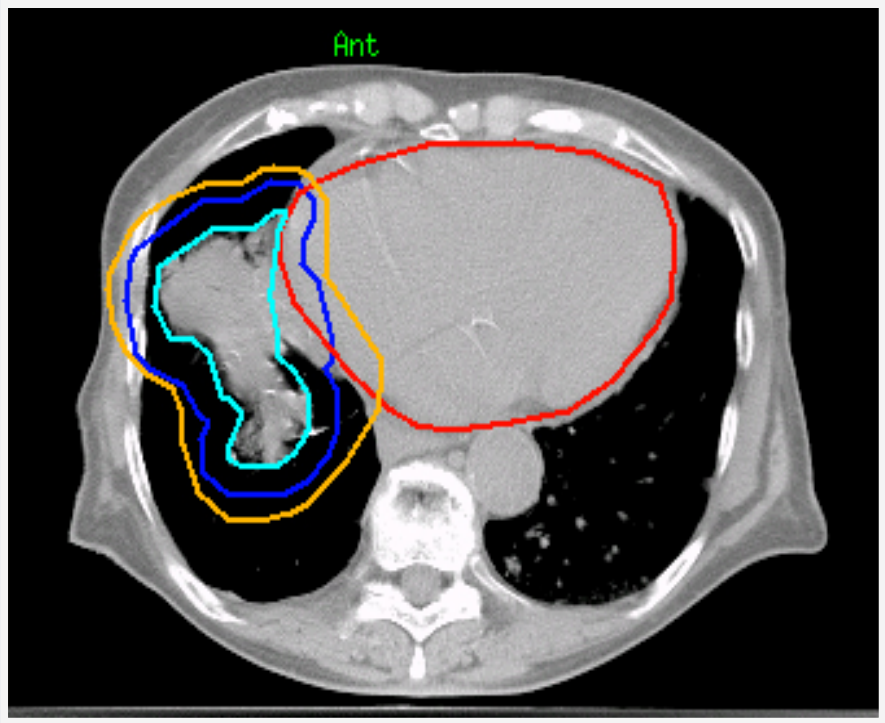
Treatment-Planning Process: Image Segmentation

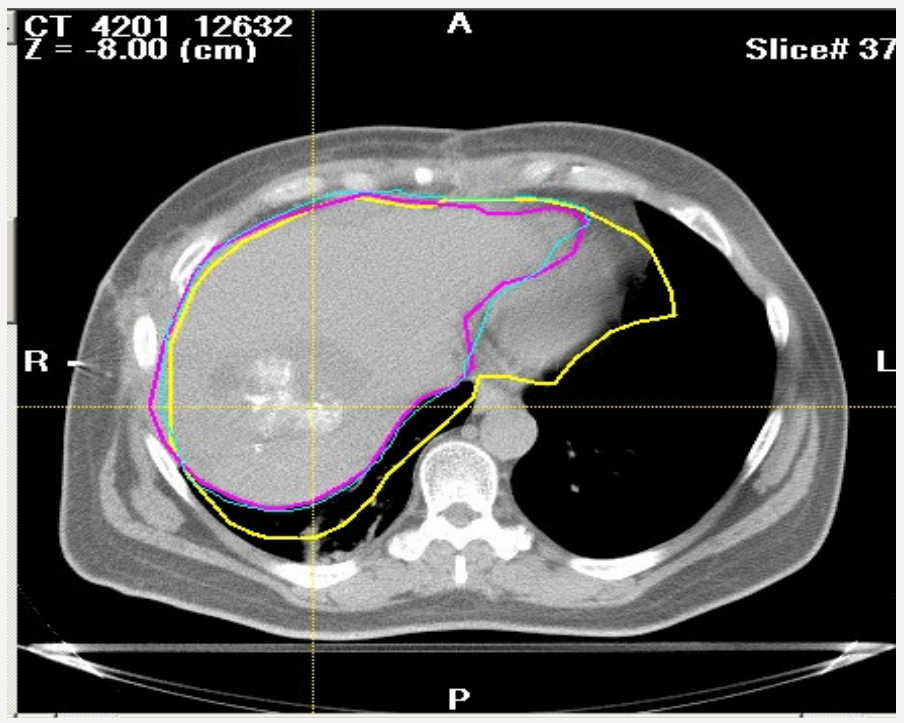
Manual segmentation

{ time-consuming}

Auto segmentation

{ review ?? }

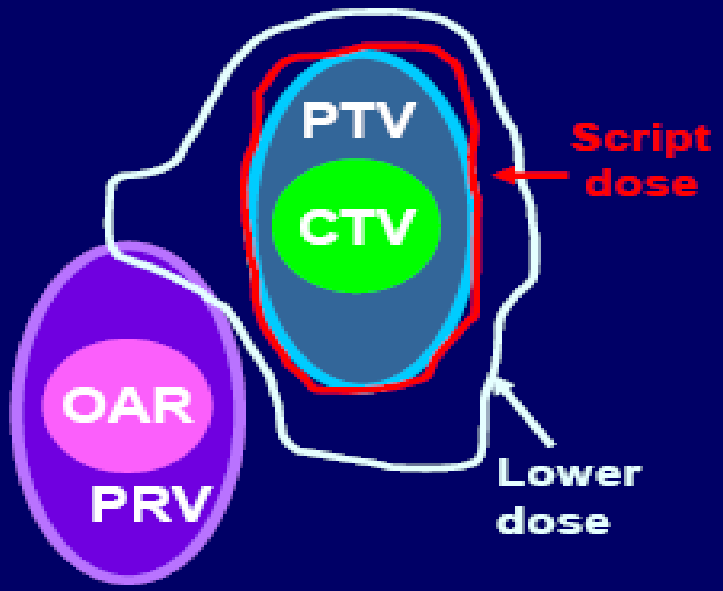




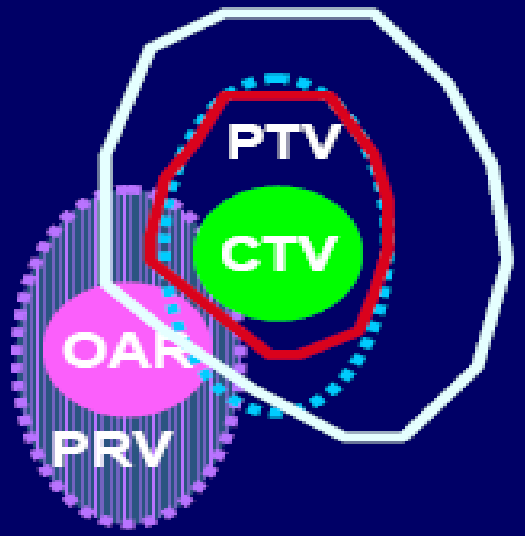
Contours drawn ……

Delienation II

PTV and PRV



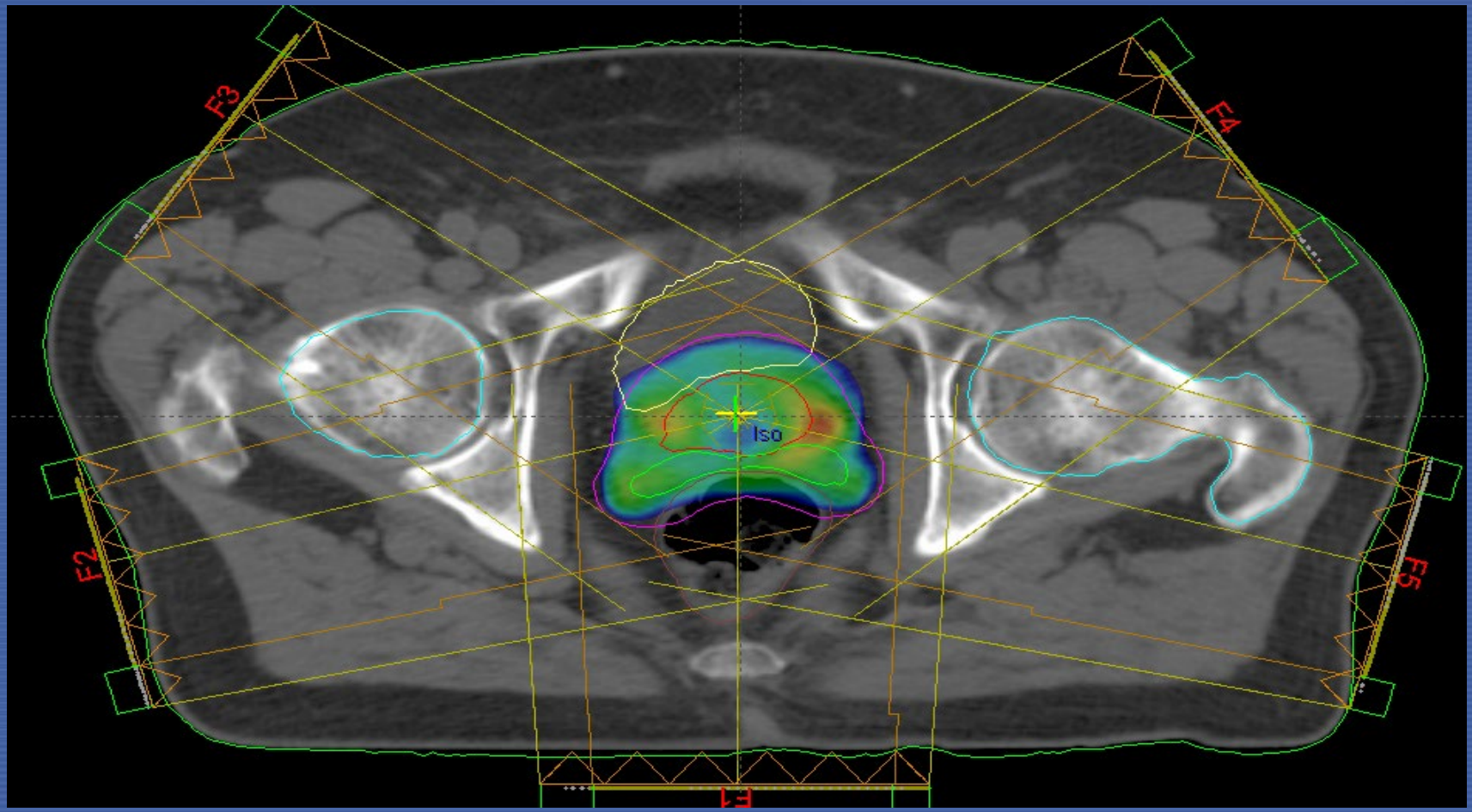
Margins are not problematic



Overlapping margins force complicated tradeoffs in Optimization!

Treatment-Planning Process

Field Multiplicity and Collimation

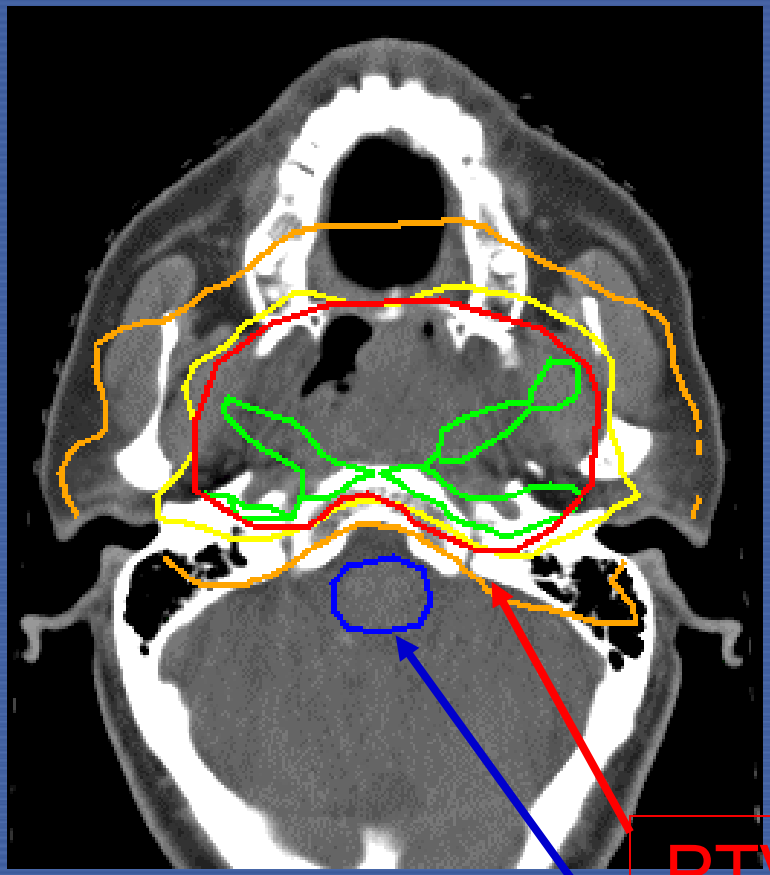


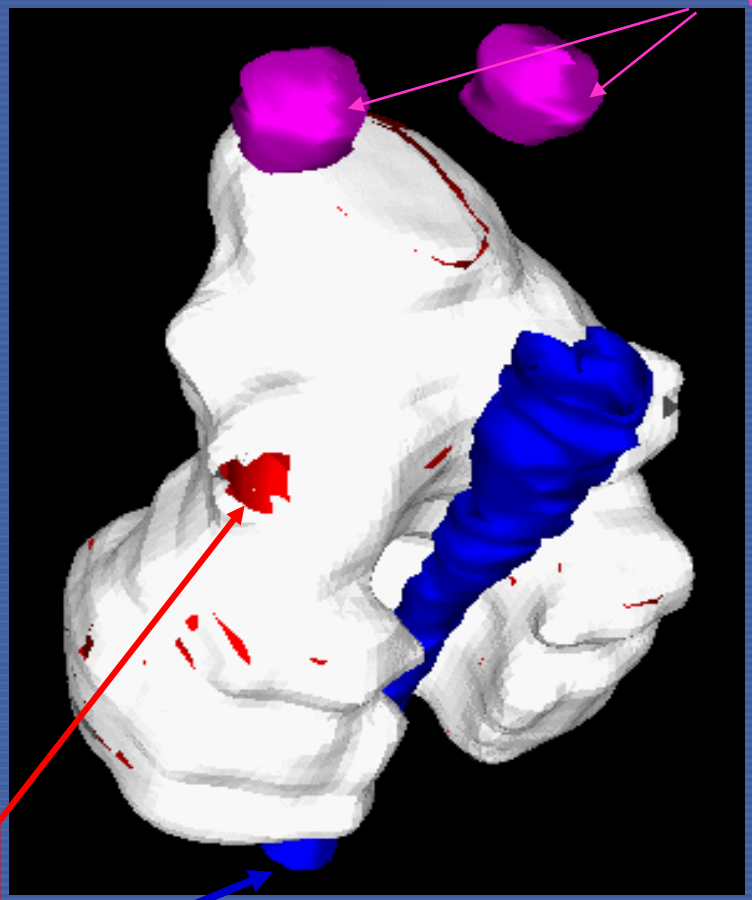
Treatment-Planning Process : Plan Optimization

Isodose curves

Isodose surface

eyes

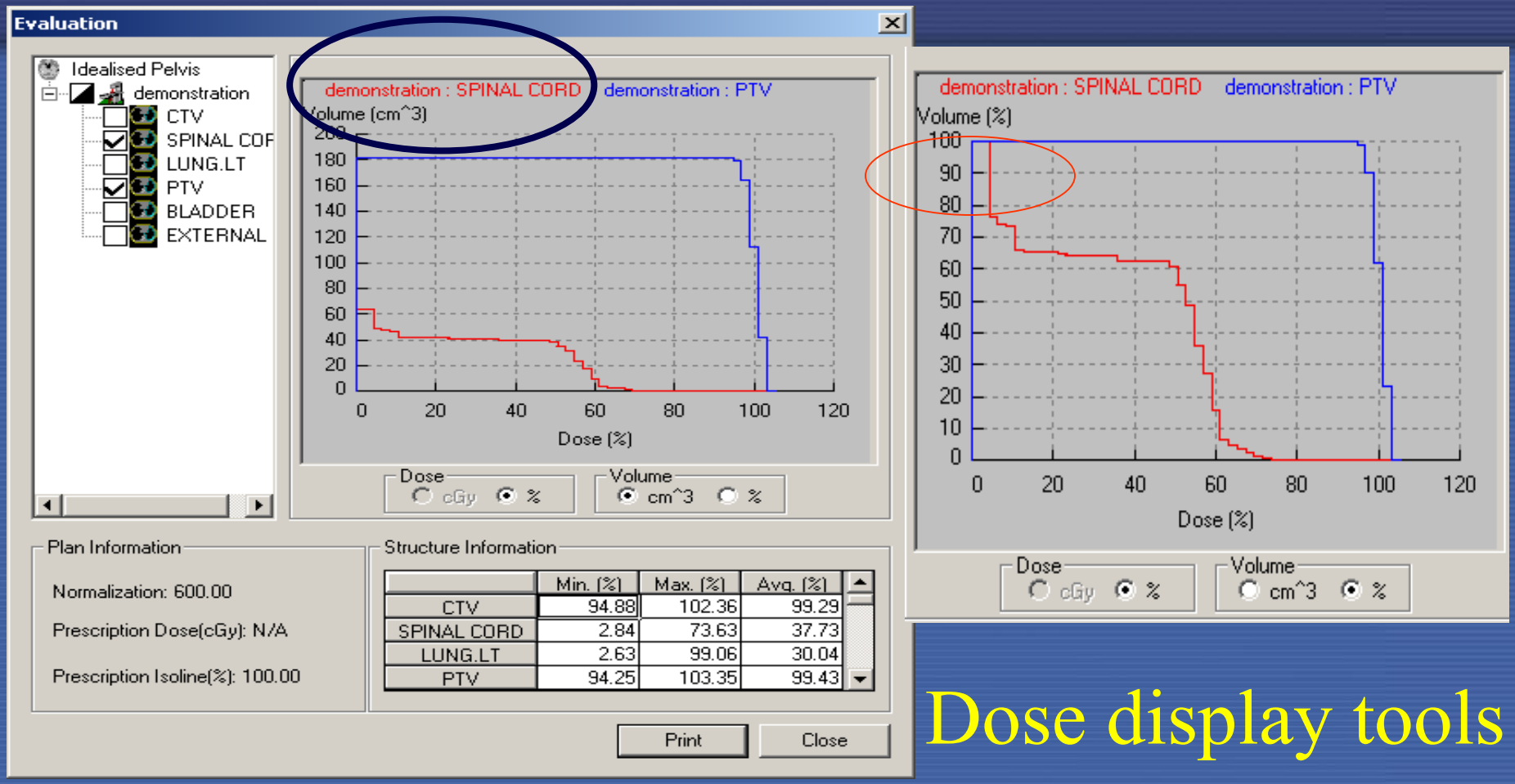




PTV

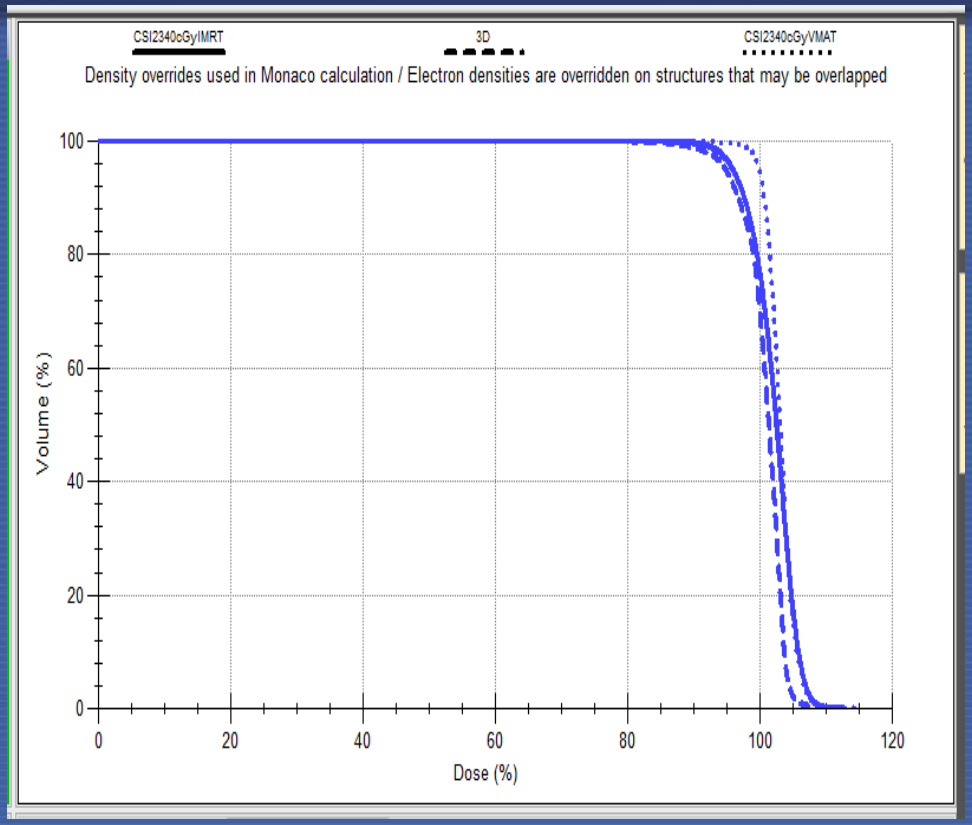
cord

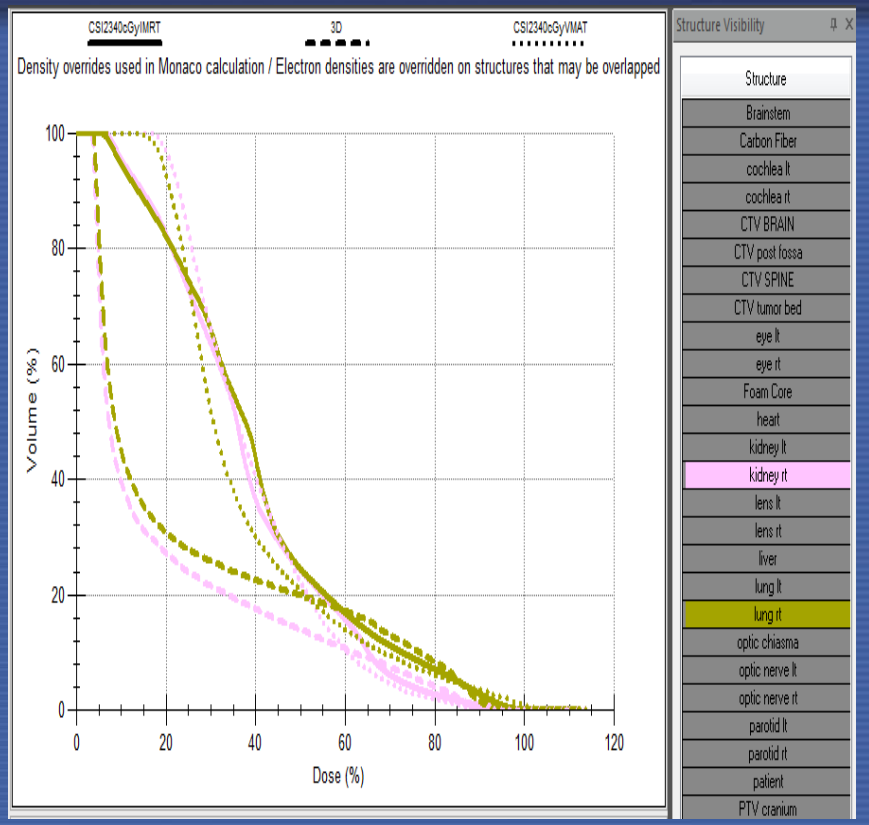
Dose volume histograms (DVHs)



Dose display tools

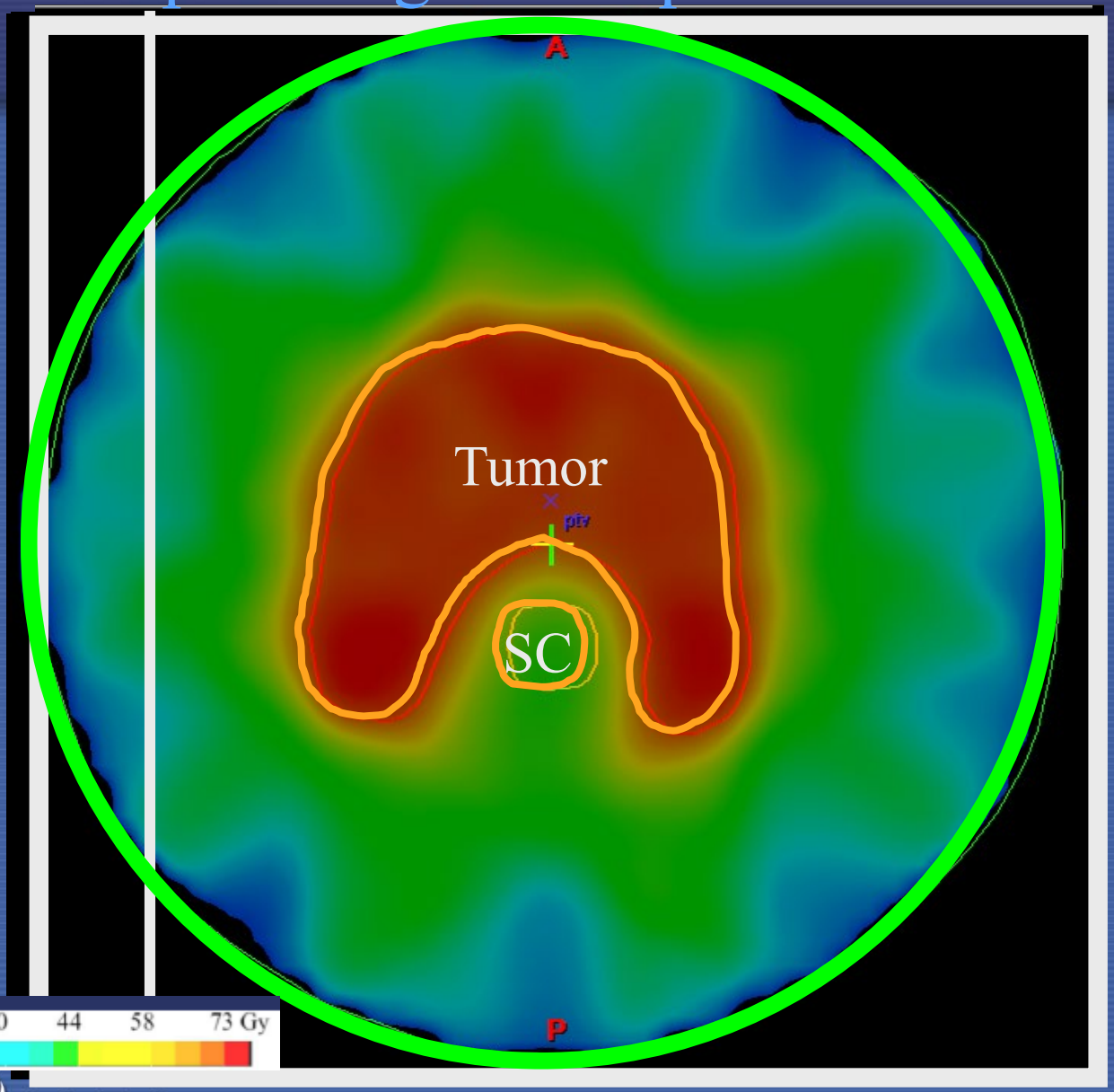
Treatment-Planning Process : Plan Optimization and Evaluation



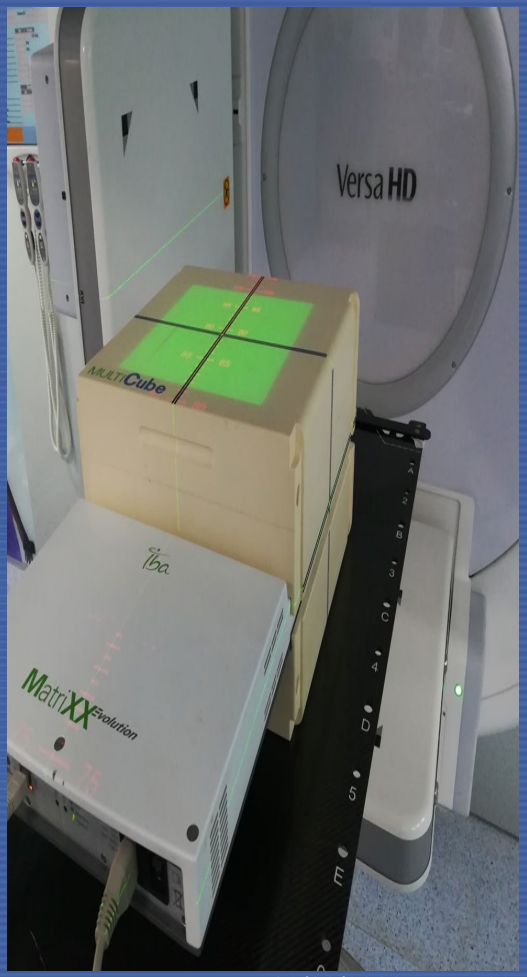


- Quantitative plan evaluation, DVH , homogeneity index (HI), conformity index (CI), conformity number (CN), Furthermore, radiobiological indexes like Niemierko's EUD-based tumor control probability (TCP) and normal tissue complication probability (NTCP) Qualitative plan evaluation,

Effect of planning techniques on the normal tissue



Plan Verification



Patient	MAHMOUD SAID IBRAHEM SAI	Plan Verification Report	Clinic N/A
Patient ID	20170240		Location N/A
Project	MAHMOUD SAID IBRAHEM		

Patient Info

Patient Birthday	12/6/2013
Patient Gender	Male

Reference

Machine	N/A
Radiation Type	N/A
Energy Value	N/A
Gantry Angle	N/A
Plane Position	361.4 mm
Dose Ratio (100%)	163.614 cGy

Compare

Machine	N/A
Radiation Type	N/A
Energy Value	N/A
Gantry Angle	N/A
Plane Position	0.0 mm
Dose Ratio (100%)	163.614 cGy

Result

Analysis Method	GammaIndex
Delta Dose Ratio	3.0 %
Delta Dose Abs	5.606 cGy
Dose Error Mode	Global
Delta Distance	3.0 mm
Search Distance	3.0 mm
Threshold	5.0 %

Histogram Info

Average Value	0.343
Passing Values	96.9 %
Failing Values	4.1 %
Threshold T1	0.002
Threshold T2	1.910
Values < T1	0.2 %
T1 < Values < T2	99.7 %
Values > T2	0.1 %

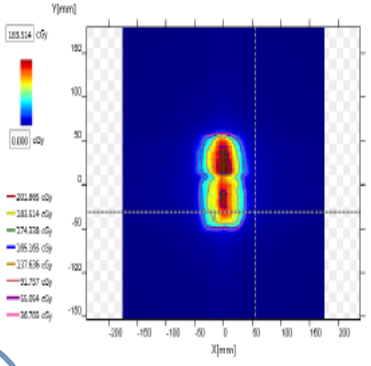
Points Of Interest

Name	Max Dose	Cursor Pos.
Coordinates	N/A	(65.2 ; -31.1)
Reference Value	163.614 cGy	5.564 cGy
Compare Value	161.968 cGy	5.677 cGy
Difference Value	1.646 cGy	2.267 cGy

Project Notes

NB

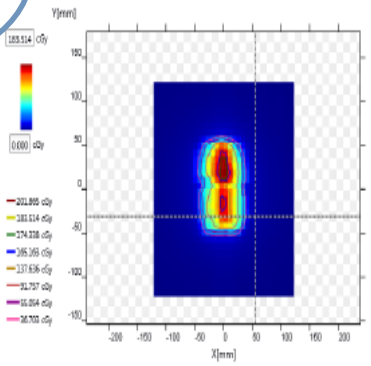
Reference : Dose_XY_087



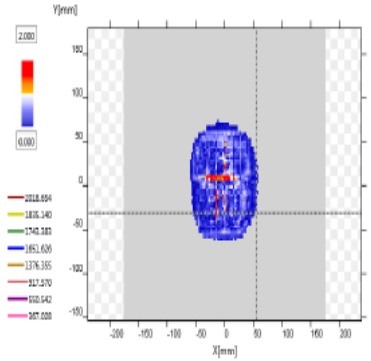
Result

Analysis Method	GammaIndex
Delta Dose Ratio	3.0 %
Delta Dose Abs	5.505 cGy
Dose Error Mode	Global
Delta Distance	3.0 mm
Search Distance	3.0 mm
Threshold	5.0 %

Compare : Integral 10/24/2017 10:11:26 DDSIMRT 24/10/2017 10:11:26.81

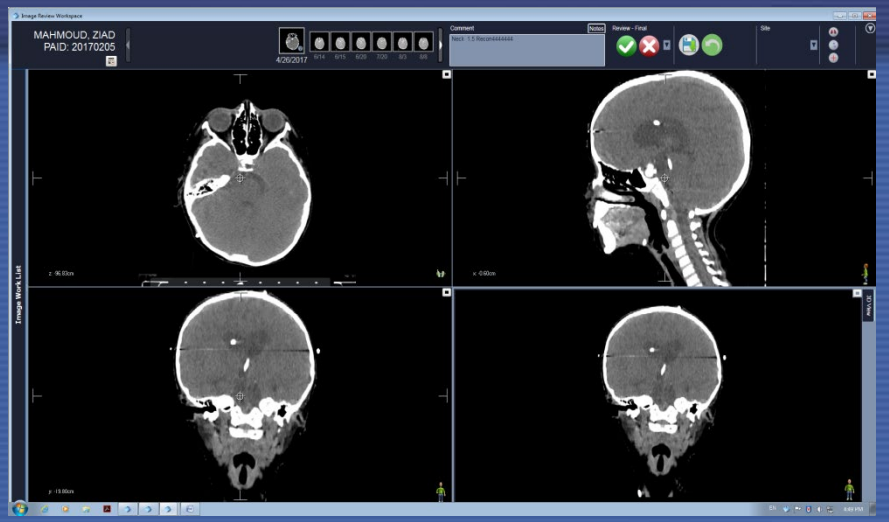


Result : [GammaIndex] of Dose_XY_087 / Integral 10/24/2017 10:11:26 DDSIMRT 24/10/2017 10:11:26.81

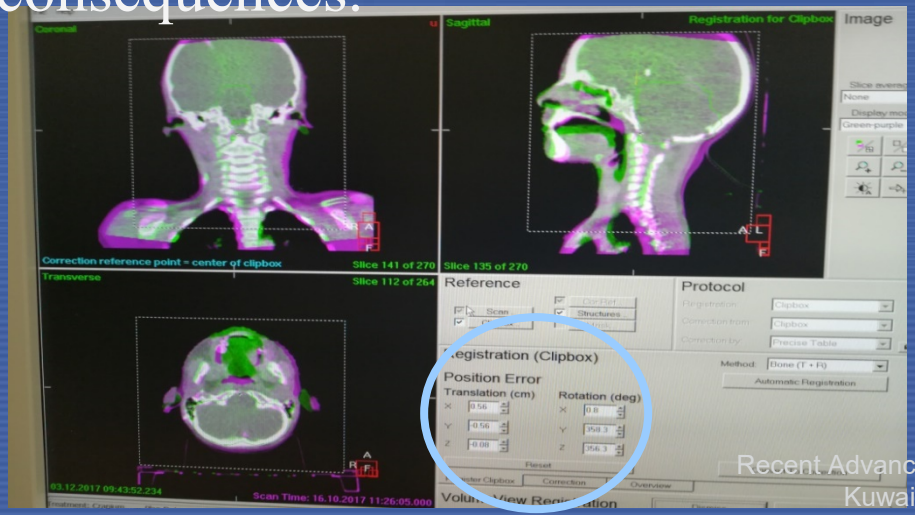


Approved Status	N/A	Approver Notes	Approver Signature
Approval Date	N/A	N/A	
Approver Name	N/A		
Last Changed By	N/A		

Treatment Verifications Cone-Beam CT CBCT



All radiotherapy steps involves risk because even a small error in treatment planning , delivery or dosimetry can lead to negative consequences.



Clinical Oncology 22 (2010) 850–861

Contents lists available at ScienceDirect

Clinical Oncology

journal homepage: www.elsevier.com/locate/clon

Original Article

Comparison of Electronic Portal Imaging and Cone Beam Computed Tomography for Position Verification in Children

M.S. Zaghloul *†, A.G. Mousa *†, E. Eldebawy *†, E. Attalla *†, H. Shafik *, S. Ezzat ‡

* Radiation Oncology Department, Children's Cancer Hospital, Cairo, Egypt
† National Cancer Institute, Cairo University, Cairo, Egypt
‡ Research Department, Children's Cancer Hospital, Cairo, Egypt

Received 27 January 2010; received in revised form 26 May 2010; accepted 12 August 2010

Abstract

Conclusions: The comparison between set-up error in EPID and MV-CBCT was not in favour of any of the two modalities. However, the two modalities were strongly correlated but fairly agreed and the differences between the shifts reported were small and hardly influenced the recommended planning target volume margin.

Original Article

Journal of Medical Physics

Volume 36 | No 4 | Oct - Dec 2011

Full text at www.jmp.org.in

Megavoltage cone beam computed tomography: Commissioning and evaluation of patient dose

Hassan S. Abou-elenein, Ehab M. Attalla, H. Ammar, Ismail Eldesoky, Mohamed Farouk, Mohamed S. Zaghloul

Department of Radiotherapy, Children's Cancer Hospital, Egypt

The additional dose to the patient from MV-CBCT study set with 5 MU at the isocenter of the treatment plan was 5 cGy. For EPID verification using two orthogonal images with 2 MU per image the additional dose to the patient was 3.8 cGy. These measured dose values were matched with that calculated by the TPS, where the calculated doses were 5.2 cGy and 3.9 cGy for MVCT and EPID respectively.

Cairo University
Journal of the Egyptian National Cancer Institute
www.nci.cu.adu.eg
www.sciencedirect.com

ORIGINAL ARTICLE

Geometrical uncertainty margins in 3D conformal radiotherapy in the pediatric age group

Eman Eldebawy, Ehab Attalla, Ismail Eldesoky, Mohamed S. Zaghloul *

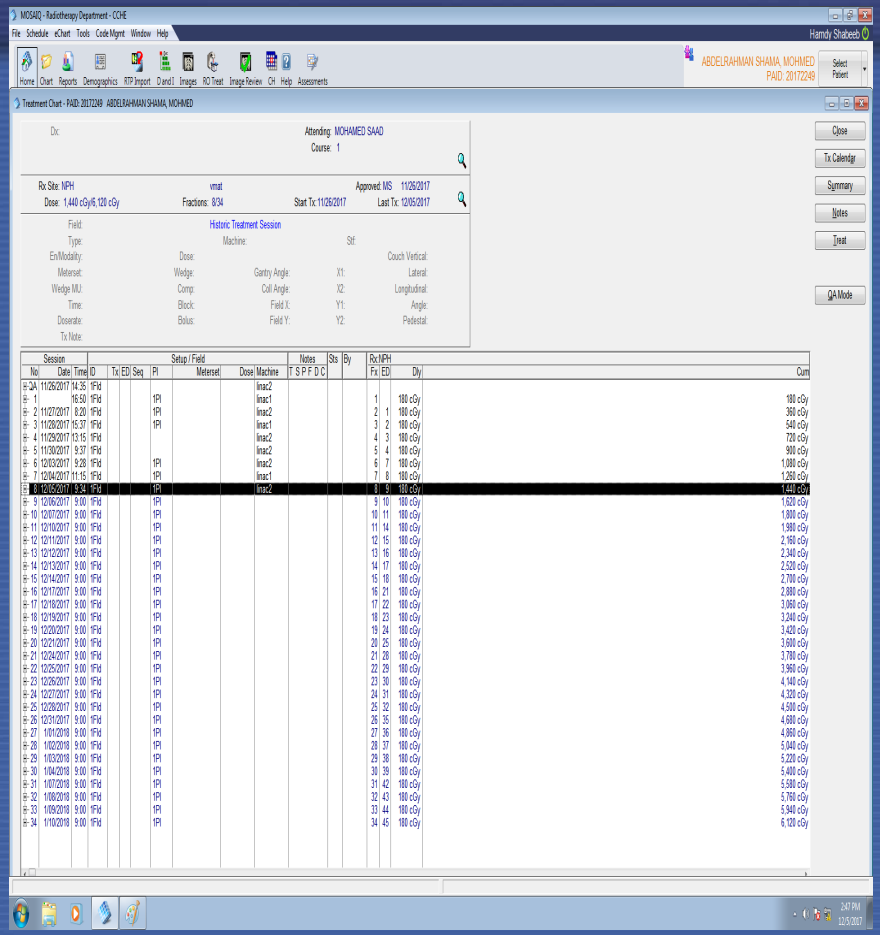
Radiation Oncology Department, Children's Cancer Hospital Egypt (CCHE), Egypt
National Cancer Institute, Cairo University, Cairo, Egypt

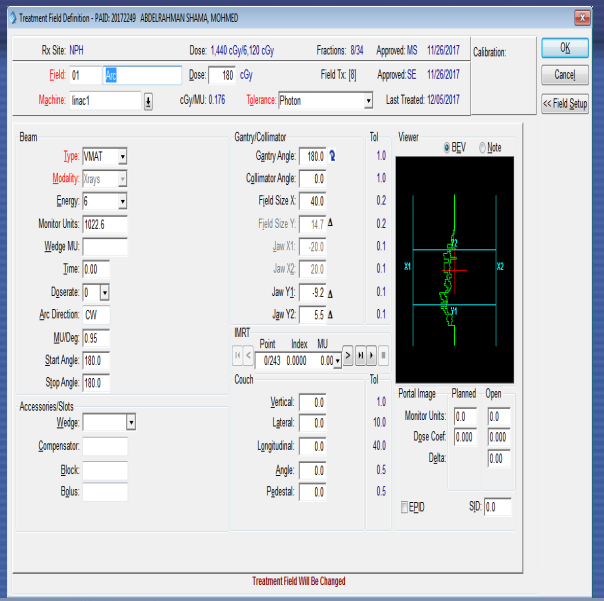
Received 4 April 2011; accepted 30 May 2011
Available online 10 October 2011

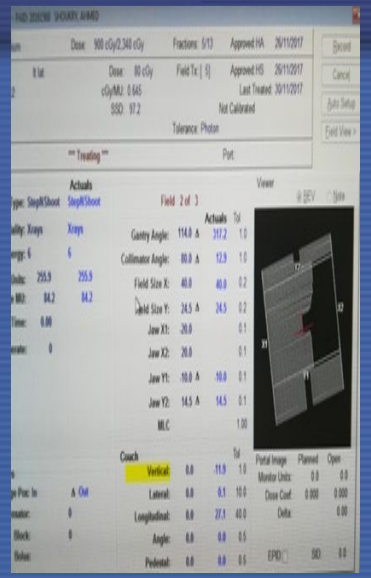
This study showed the range of systematic and random set-up errors during the course of radiotherapy treatment for pediatric patients.

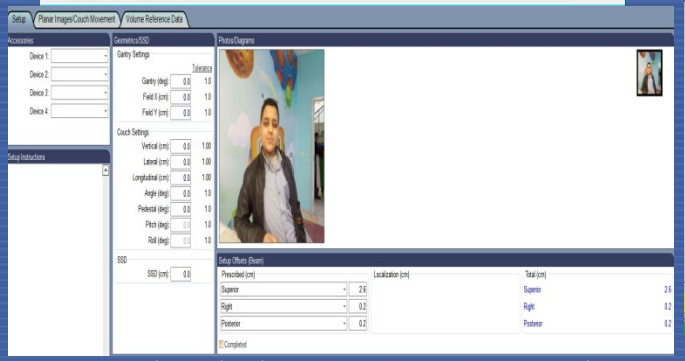
The estimated PTV margin was relatively larger in chest, abdomen and pelvis sites compared to head and neck patients owing to the less tight fixation and higher possibility for tilting and rotation in non head and neck sites.

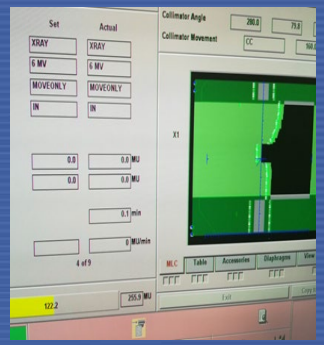
Oncology Information System









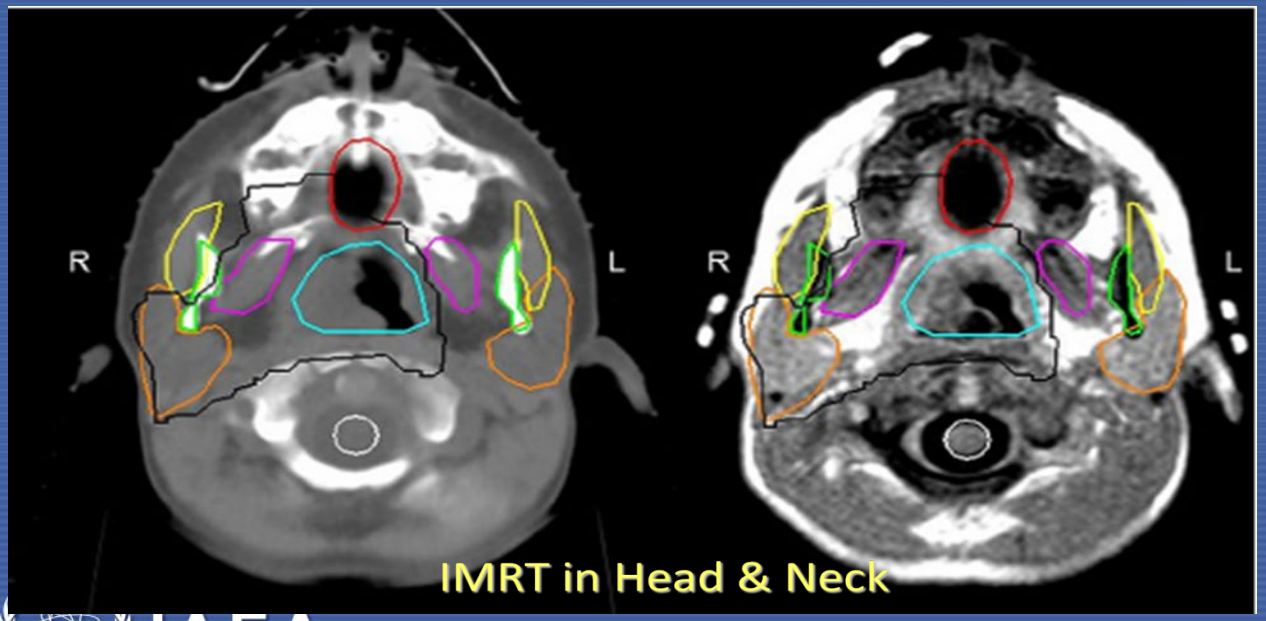


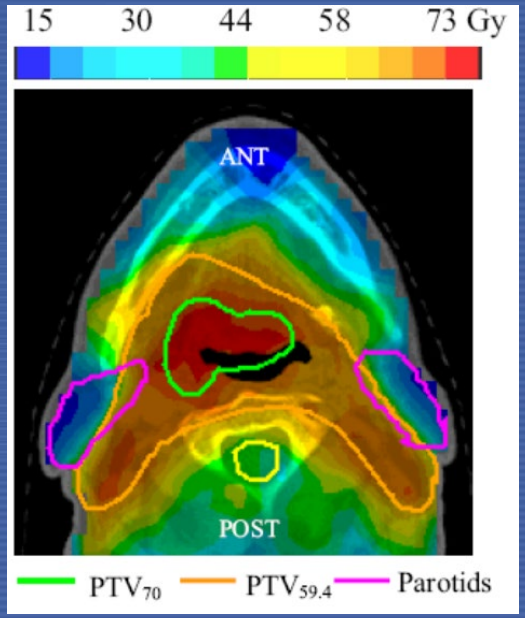
A system that can manage patient treatment schedules, treatment plans, treatment delivery, treatment summaries, and results is assured.

An oncology information system (OIS) can be used to manage these data.

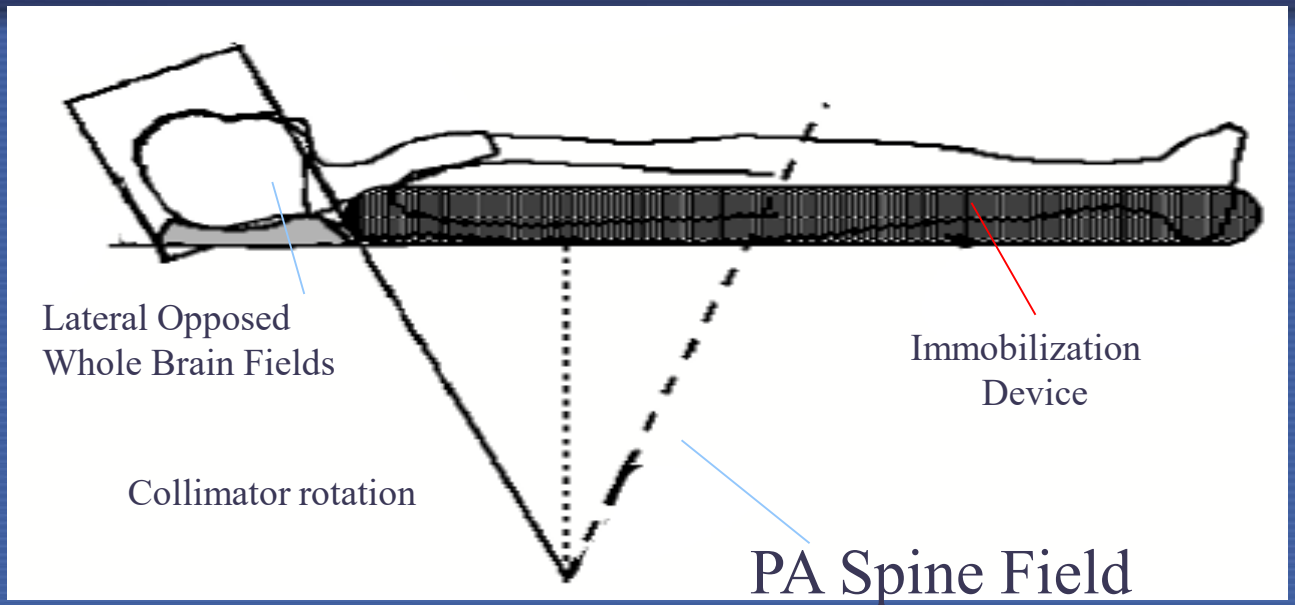
IMRT in Pediatric Oncology- Current status

- 80% of centers adopted IMRT since 2000
- Most international pediatric protocols for CNS and other solid tumors allow the use of IMRT
- Indications, limitations and preliminary results are all with IMRT usage.





Conventional Craniospinal Irradiation Technique (Can be supine or prone)



Historically, CSI has been treated using 3D CRT consisting of opposing whole brain and posterior spinal fields. With the increased use of IMRT techniques in the clinic today, these patients can also be treated step-and-shoot IMRT, sliding window IMRT, volumetric-modulated arc therapy (VMAT)

Supine Craniospinal Irradiation In Children: Patient Position Modification, Dose Uniformity And Early Adverse Effects

M.S. Zaghloul, E. Eldebawy, E. Attalah, S. Ahmed, M. Nazmy, H. Aboel Anin

Radiation Oncology Department, Children's Cancer Hospital, Egypt (CCHE) and National Cancer Institute, Cairo University, Cairo, Egypt

Abstract

Background:

Different craniospinal irradiation techniques are complex. The homogeneity of the dose to the target and the normal tissues at risk affect both the control rate and the level of adverse effects.

Patients and methods:

Thirty one patients were treated with CSI in the supine position. Custom-made Styrofoam was tailored for each patient to straighten the convexity and concavity of the spinal axis allowing better dose distribution uniformity during CSI technique. In the first 6 patients, CT simulation were performed twice: one time with the patient lying directly on the vacuum mattress without the foam (the conventional way) and the second while lying on the foam. Dose distribution was calculated using a 3D conformal planning. The gap between the fields was determined using isodose alignment method. All treatment portals were verified during the first 3 treatment sessions and once weekly thereafter using either cone-beam or portal image device. Weekly feathering (shifting of the junction between the 2 adjacent radiation fields) was routinely performed.

Results:

The 95% dose distribution had better coverage with the foam (p=0.042) while the hot volume of 110% and 105% dosage were significantly lesser than conventional technique (both p=0.028). The organs at risk received nearly similar radiation doses in the 2 positions. The CSI led to minimal immediate adverse effects that were reversible. Weight loss was experienced by 55% of patients.

Conclusion:

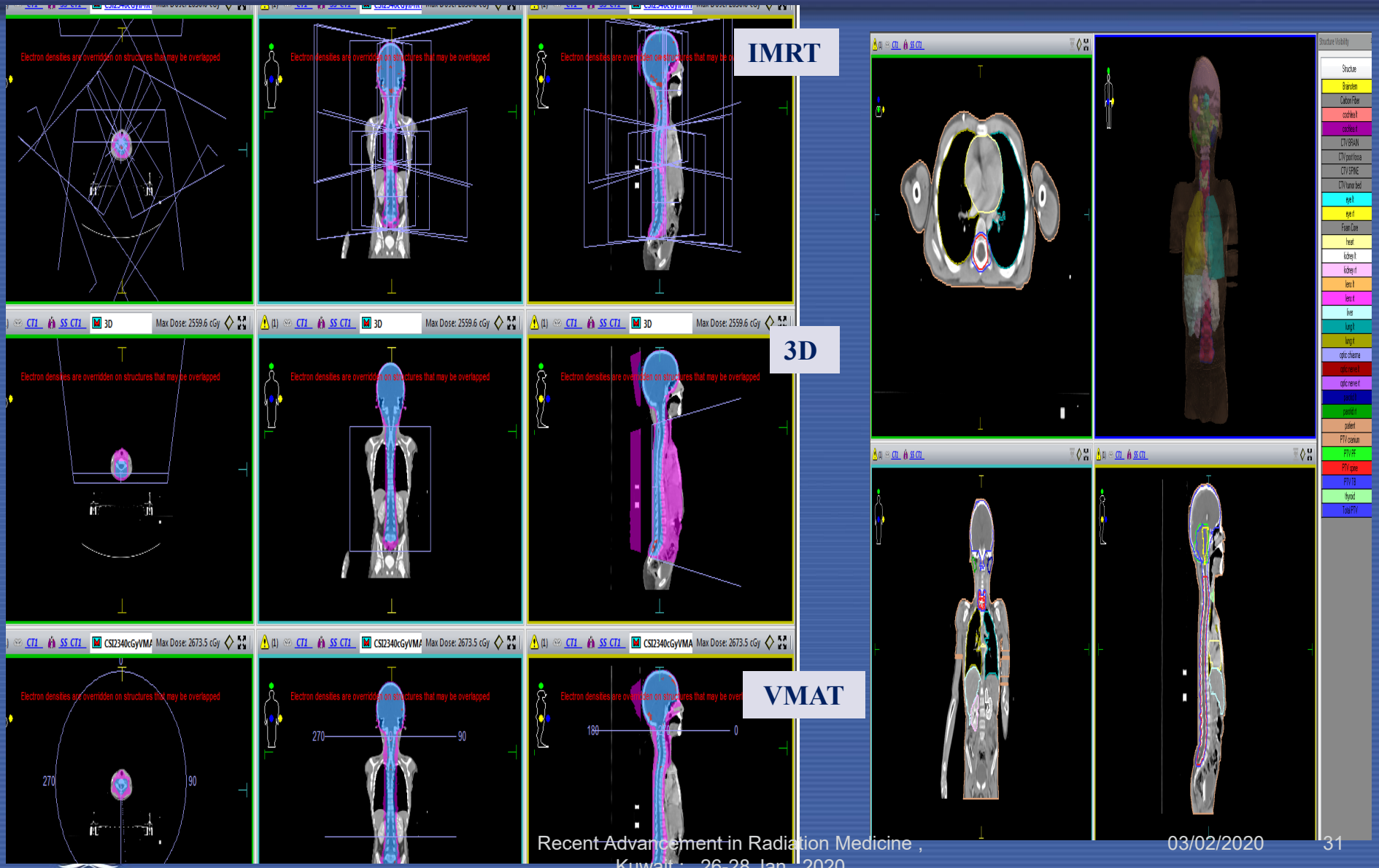
This modified technique of CSI is simple, ensuring better dose distribution to CSI target without increasing the dose to the surrounding organs at risk. It is tolerable and safe to apply.

Keywords

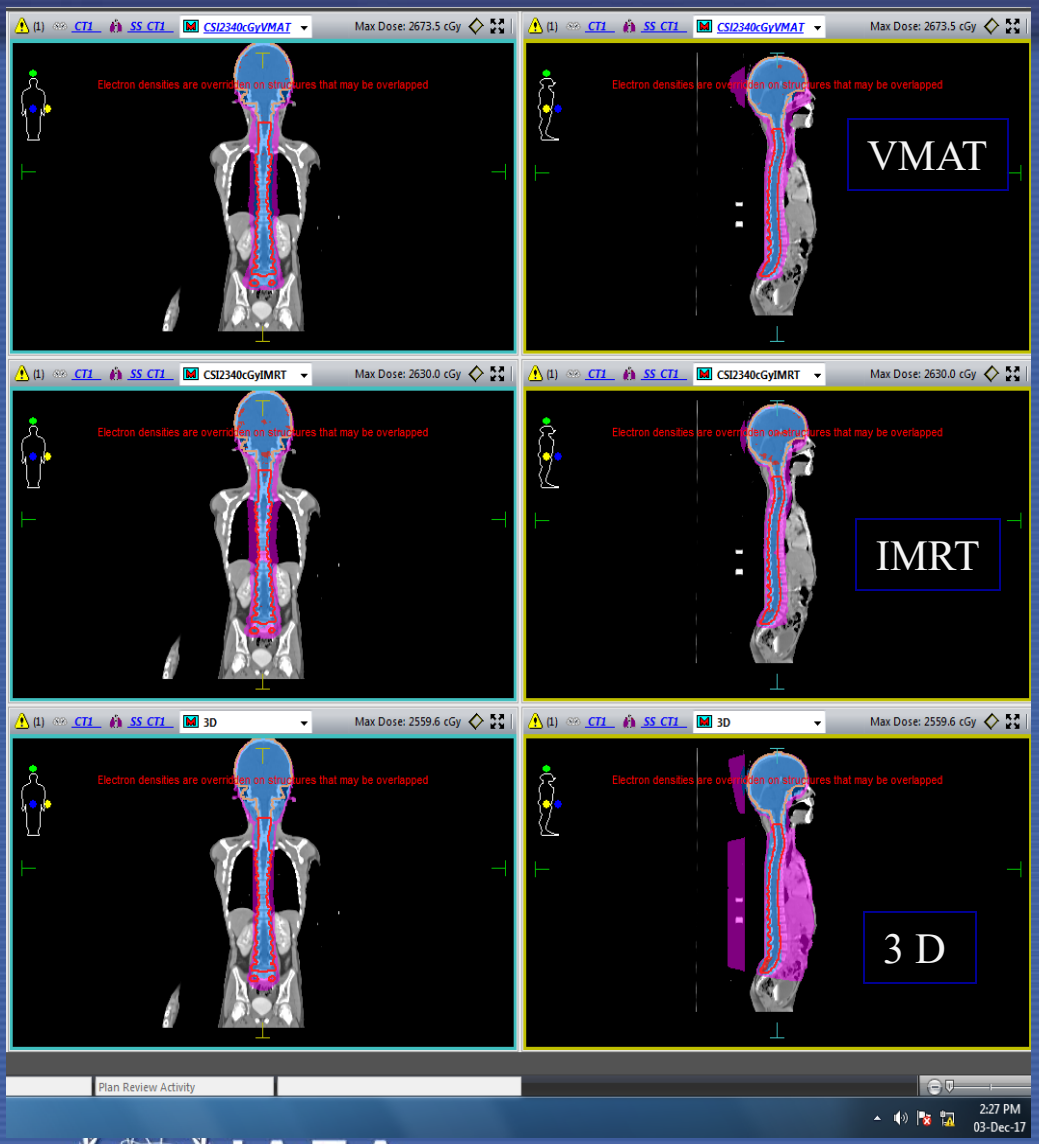
Craniospinal irradiation, supine, Medulloblastoma, CNS leukemia, Conformal radiotherapy, 3D-CRT, Immediate adverse effects.

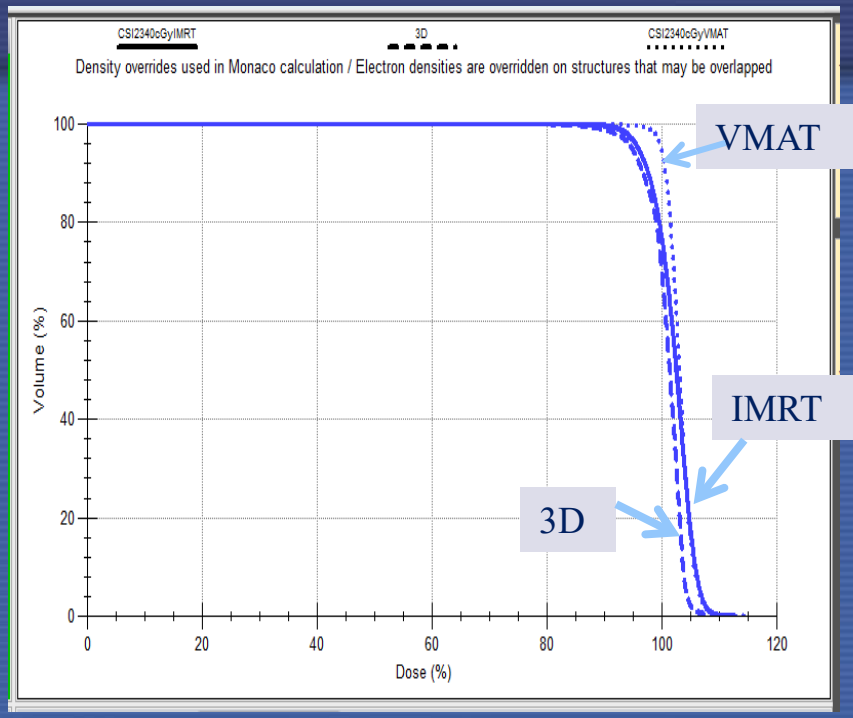
Pretreatment quality assurance dosimetry film demonstrating a position of the cranial and spinal fields. The film verified the evidence of the lack of overlap between the 2 fields and matching the divergence of spinal field with the inferior border of the half-beam blocked cranial field.

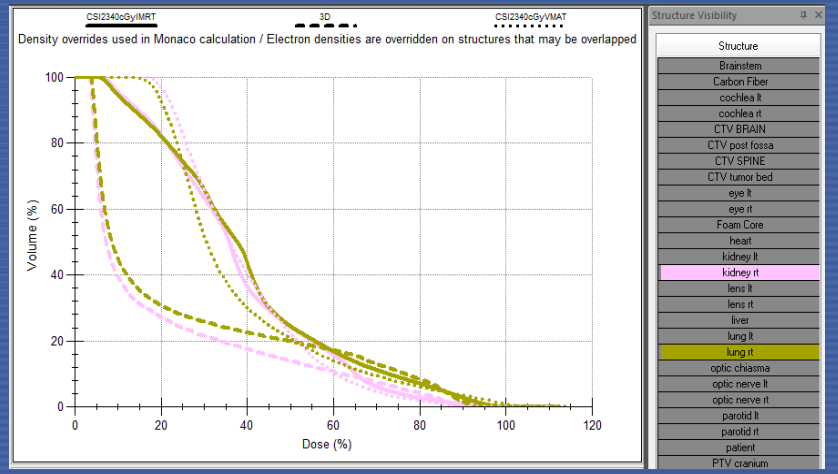
Craniospinal Irradiation Technique
Three techniques :3D,IMRT &VMAT



Craniospinal Irradiation Technique
Three techniques :3D,IMRT &VMAT



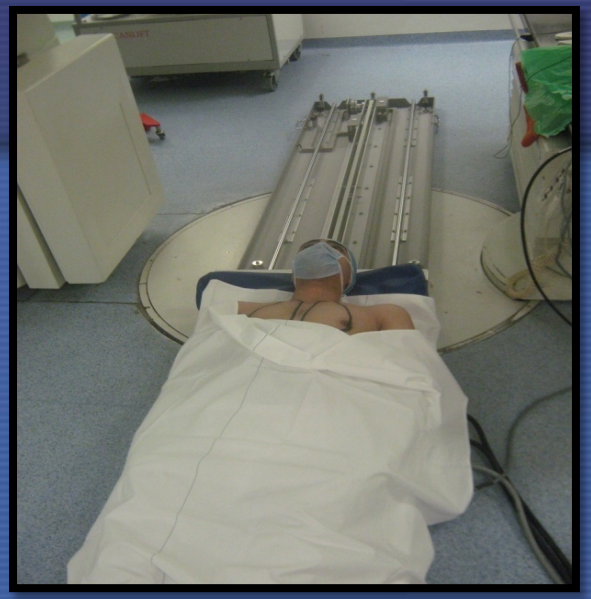


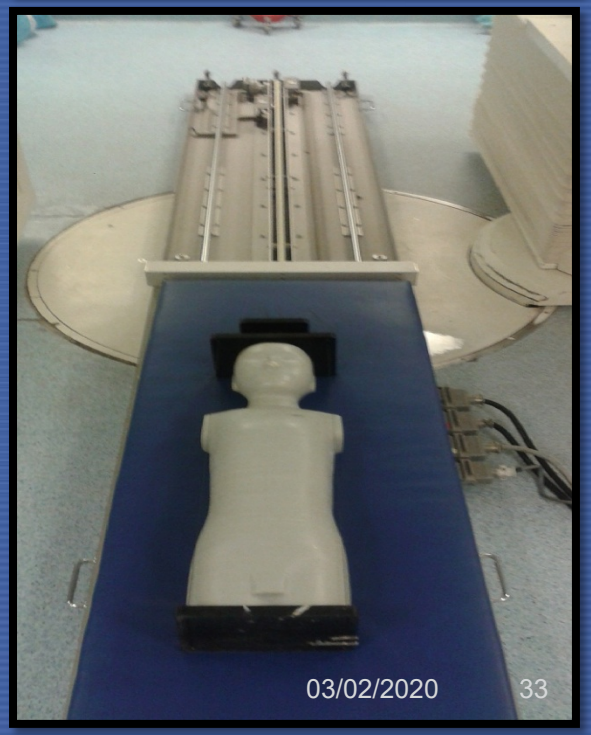


Total Body Irradiation for Leukemia

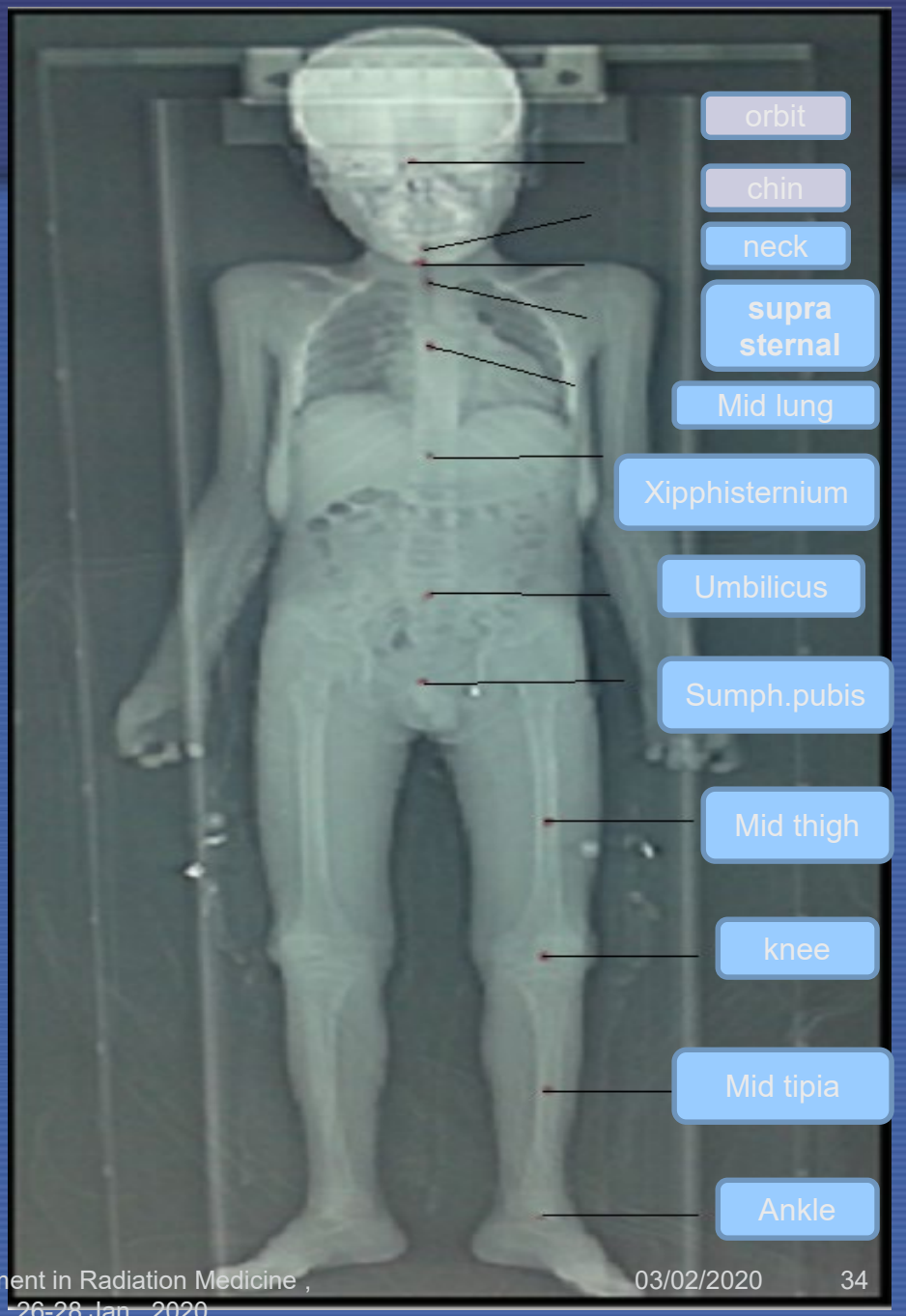
Movement couch & Beam Zone Technique

- The TBI technique studied is an AP/PA treatment , patient lies on a table placed directly on the floor with source-to-skin distance (SSD) of 200 cm
- Treatments are delivered using 6 MV photon beam, field size of 80 cm × 80 cm in extended SSD ,with constant speed ,constant dose rate 50 cGy/min and velocity .
- The prescribed dose is 12 Gy in five fractions 2.4 Gy per fraction delivered over five days. This technique uses a translating couch , and the velocities are optimized to deliver a uniform dose at patient midline along the craniocaudal midline axis (at the level of the umbilicus) .
- The dose variation throughout the body between the measured and calculated dose should maintain within ±10 % of the prescribed dose.



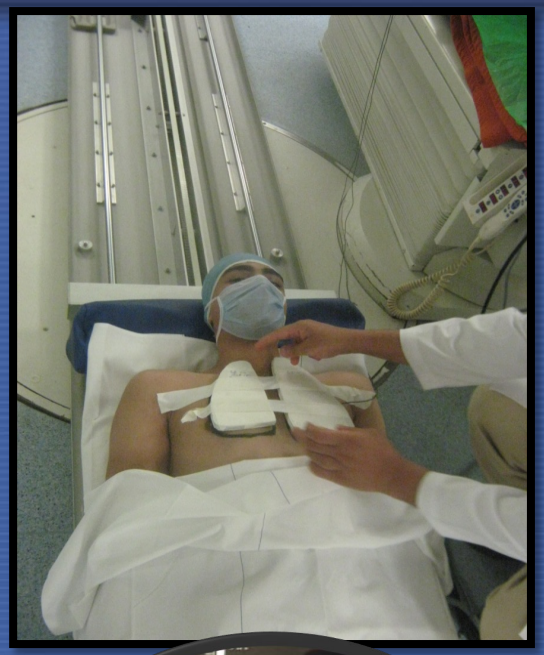


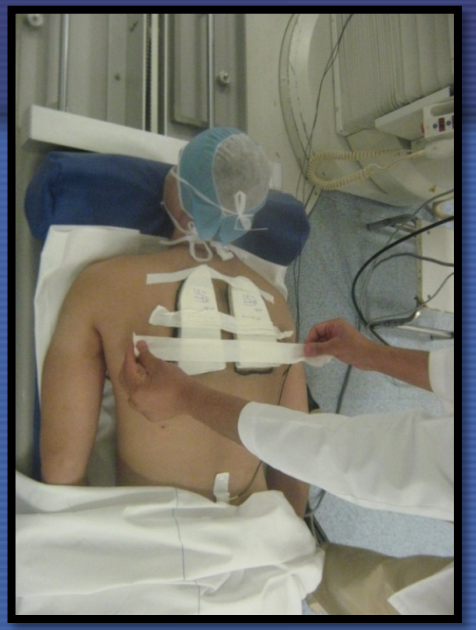
- The lungs dose must be reduced by (20 -25) % of the total prescribed dose due to the low lung density and due to scattered radiation from surrounding tissues.
- CT- localization is required in the treatment position for the determination of lung dose.
- Absorbed dose calculate d at the patients in (12) different regions ,
- the reference dose is specified as the total dose to mid abdomen dose in the level of the Umbilicus.

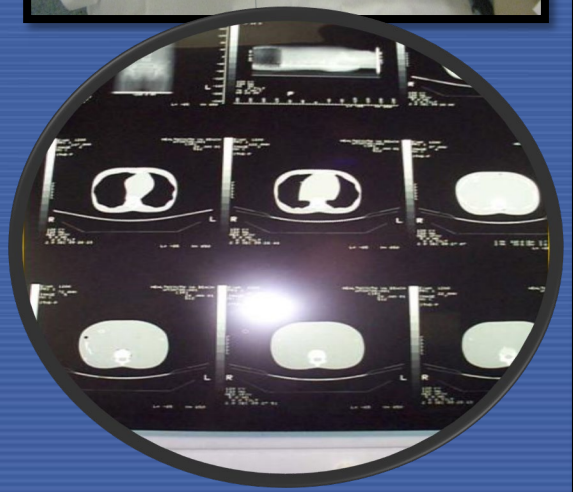


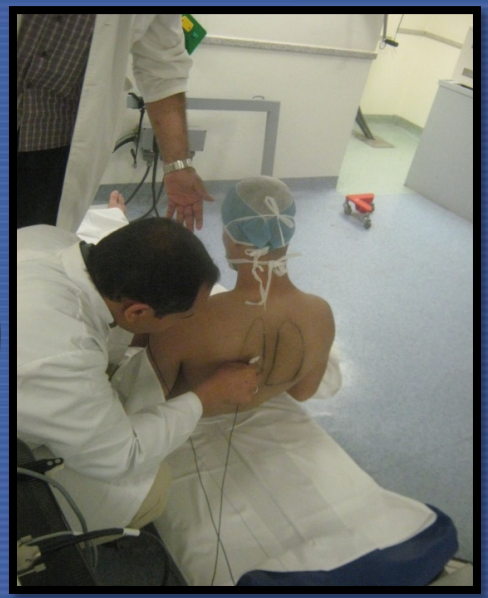
Lung shield calculation

- Dose reduction of the lung about (-20 %) of the total prescribed dose.
- Individually shaped partially transmitting shield of calculated thickness are used.
- Thorax wall separation, lung density, and mid lung separation are parameters for the lung shield thickness calculation can be measured from the CT localization.
- Verifying the calculated dose using INVIVO Dosimeter is mandatory.









IMRT- Potential Pitfalls

- Increased risk of "MARGINAL MISS"
- Less homogeneous dose distribution
- Higher total body dose (leakage through the collimator and internal scatter as a result of increased beam-on time)
- Potential increased risk of radiation-induced malignancies(from1% to 1.75% at 10y)
- Lower biologic effective doses for longer treatment times

Proton therapy

Int. J. Radiation Oncology Biol. Phys., Vol. 65, No. 1, pp. 1–7, 2006

0360-3016/06/$–see front matter

CRITICAL REVIEW

INTENSITY-MODULATED RADIATION THERAPY, PROTONS, AND THE RISK OF SECOND CANCERS

ERIC J. HALL, D.PHIL., D.SC.

Center for Radiological Research, Columbia University Medical Center, College of Physicians and Surgeons, New York, NY

Intensity-modulated radiation therapy (IMRT) allows dose to be concentrated in the tumor volume while sparing normal tissues. However, the downside to IMRT is the potential to increase the number of radiation-induced second cancers. The reasons for this potential are more monitor units and, therefore, a larger total-body dose because of leakage radiation and, because IMRT involves more fields, a bigger volume of normal tissue is exposed to lower radiation doses. Intensity-modulated radiation therapy may double the incidence of solid cancers in long-term survivors. This outcome may be acceptable in older patients if balanced by an improvement in local tumor control and reduced acute toxicity. On the other hand, the incidence of second cancers is much higher in children, so that doubling it may not be acceptable. IMRT represents a special case for children for three reasons. First, children are more sensitive to radiation-induced cancer than are adults. Second, radiation scattered from the treatment volume is more important in the small body of the child. Third, the question of genetic susceptibility arises because many childhood cancers involve a germline mutation. The levels of leakage radiation in current Linacs are not inevitable. Leakage can be reduced but at substantial cost. An alternative strategy is to replace X-rays with protons. However, this change is only an advantage if the proton machine employs a pencil scanning beam. Many proton facilities use passive modulation to produce a field of sufficient size, but the use of a scattering foil produces neutrons, which results in an effective dose to the patient higher than that characteristic of IMRT. The benefit of protons is only achieved if a scanning beam is used in which the doses are 10 times lower than with IMRT. © 2006 Elsevier Inc.

Intensity-modulated radiation therapy, Passive modulation, Pencil beams, Protons, Second cancers.

Proton / Carbon therapy

ELSEVIER

Int. J. Radiation Oncology Biol. Phys., Vol. 63, No. 2, pp. 362–372, 2005

0360-3016/05/$–see front matter

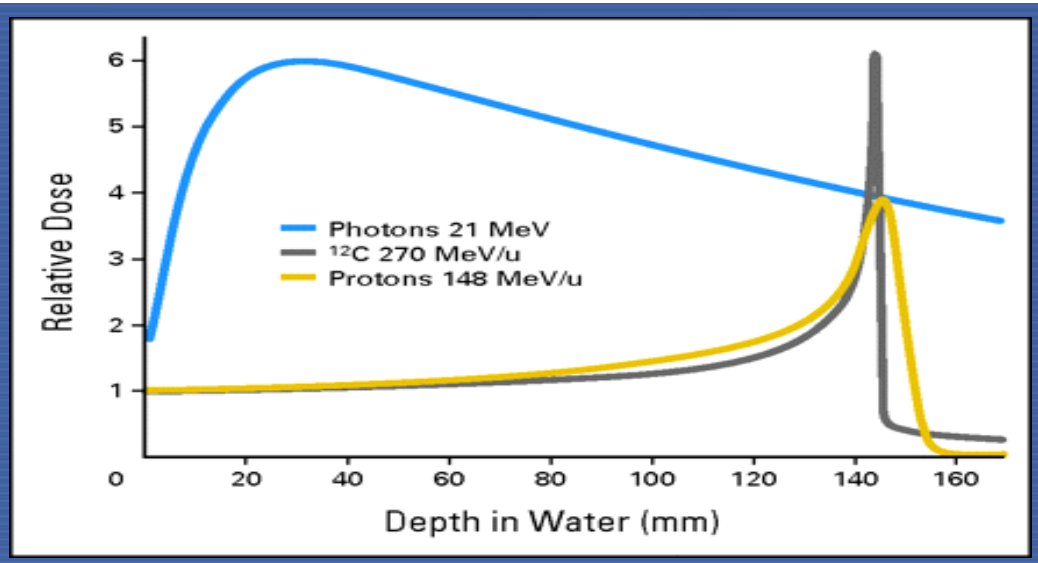
doi:10.1016/j.ijrobp.2005.01.060

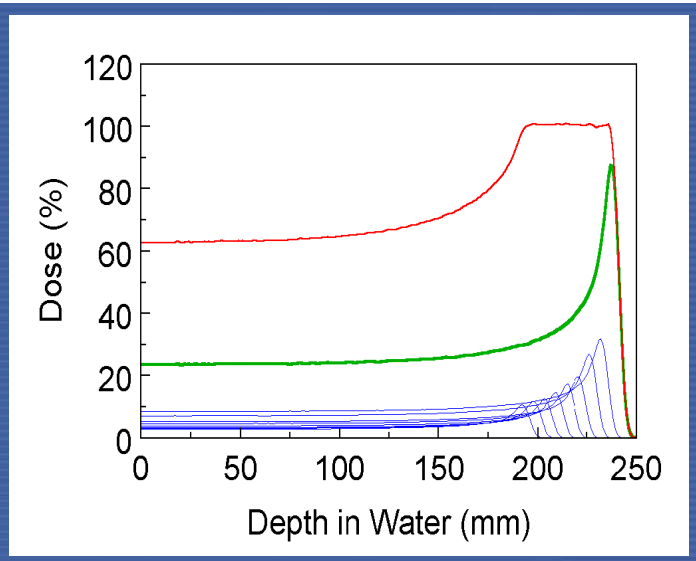
CLINICAL INVESTIGATION **Pediatric Tumors**

TREATMENT PLANNING WITH PROTONS FOR PEDIATRIC RETINOBLASTOMA, MEDULLOBLASTOMA, AND PELVIC SARCOMA: HOW DO PROTONS COMPARE WITH OTHER CONFORMAL TECHNIQUES?

CATHERINE T. LEE, M.D.,* STEPHEN D. BILTON, C.M.D.,† ROBIN M. FAMIGLIETTI, C.M.D.,†
BEVERLY A. RILEY, C.M.D.,† ANITA MAHAJAN, M.D.,* ERIC L. CHANG, M.D.,*
MOSHE H. MAOR, M.D.,* SHIAO Y. WOO, M.D.,* JAMES D. COX, M.D.,*
AND ALFRED R. SMITH, PH.D.†

Departments of *Radiation Oncology and †Radiation Physics, The University of Texas M. D. Anderson Cancer Center, Houston, TX





Depth dose profiles of photons, protons, and carbon ions. Spread-out Bragg peaks (SOBP): several beams of closely spaced energies are superimposed to create a region of uniform dose over the depth of the target.

THE EFFECT OF INTENSITY-MODULATED RADIOTHERAPY ON RADIATION-INDUCED SECOND MALIGNANCIES

JEREMY D. RUBEN, F.C.RAD.ONC., F.R.A.N.Z.C.R.,*† SIDNEY DAVIS, F.F.RAD.(T)., F.R.A.N.Z.C.R.,*† CHERIE EVANS, B.APP.SCI.,* PHILLIP JONES, B.APP.SCI.,* FRANK GAGLIARDI, M.SC.,* MATTHEW HAYNES, PH.D.,* AND ALISTAIR HUNTER, PH.D.‡

*William Buckland Radiotherapy Centre, Melbourne, Australia; †Monash University, Melbourne, Australia; and ‡Department of Radiation Oncology, Groote Schuur Hospital and University of Cape Town, Cape Town, South Africa

Purpose: To compare intensity-modulated radiotherapy (IMRT) with three-dimensional conformal radiotherapy (3D-CRT) in terms of carcinogenic risk for actual clinical scenarios.

Method and Materials: Clinically equivalent IMRT plans were generated for prostate, breast, and head-and-neck cases treated with 3D-CRT. Two possible dose–response models for radiocarcinogenesis were generated based on A-bomb survivor data corrected for fractionation. Dose–volume histogram analysis was used to determine dose and its distribution to nontargeted tissues within the planning CT scan volume and thermoluminescent dosimetry for the rest of the body. Carcinogenic estimates were calculated with and without a correction factor accounting for cancer patients' advanced age and reduced longevity.

Results: For the model assuming a plateau in risk above 2-Gy single-fraction-equivalent (SFE), IMRT and 3D-CRT produced risks of 1.7% and 2.1%, respectively, for prostate; 1.9% and 1.8%, respectively, for nasopharynx; 1% each for tonsil; and 1.4–2.2% and 1.5–1.6%, respectively, depending on technique, for breast. Assuming a reduction in risk above 2-Gy SFE, risks for IMRT and 3D-CRT were 1.1% and 1.5%, respectively, for prostate; 1.4% and 1.2%, respectively, for nasopharynx; 1% each for tonsil; and 1.3–1.8% vs. 1.3–1.6%, respectively, for breast. Applying a correction factor of 0.5 for cancer patients halved these risks and their relative differences.

Conclusions: Carcinogenic risks were comparable in absolute terms between modalities. Risks are dependant on technique used. Risks with IMRT are influenced by monitor unit demand and are therefore software/hardware dependant. The dose–response model accounting for cell killing at higher doses fitted best with actual observed risks.

IMRT, Carcinogenesis, Late effects, 3D conformal radiotherapy, Second malignancy.

Particle Therapy Co-Operative Group

A non-profit organisation for those interested in proton, light ion and heavy charged particle radiotherapy

News

- Conferences, Workshops
- IJPT, Newest Issue
- PTCOG Travel Fellowship
- Job Adverts
- Other News

Particle Therapy Centers

- Facilities in Operation
- Facilities under Construction
- Facilities in Planning Stage

Clinical Practice

- Clinical Trials, Protocols
- Clinical Subcommittees
- Patient Statistics

Registration, Login

Register as PTCOG Member -> Create an account.
Username
ehabattalla

You are here: Home ▸ Facilities in Planning Stage

Particle therapy facilities in a planning stage

COUNTRY	WHO, WHERE	PARTICLE	MAX. ENERGY (MeV), ACCELERATOR TYPE, (VENDOR)	BEAM DIRECTIONS	NO. OF TREATMENT ROOMS	START OF TREATMENT PLANNED
Australia	Australian Bragg Centre for Proton Therapy and Research (SAHMRI), Adelaide	p	230, synchrotron, (?)	2 gantries, 1 fixed beam	3	2020
Argentina	Instituto de Oncologia Angel Ruffo Hospital, Boenos Aires	p	230, cyclotron, (IBA)	1 gantry	1	2019
Belgium	University Hospitals Wallonia, Charleroi	p	230, cyclotron, (IBA)	1 gantry	1	2020
China	Hong Kong Sanatorium and Hospital PTC, Shau Kei Wan, Hong Kong	p	230 ? cyclotron, (?)	2? gantries	2?	2019?
China	Tianjin Taishan Cancer Hospital, Sino-US proton treatment & research center, TAEA, Tianjin	p	230, cyclotron, (?)	3 gantries	3	2018
China	Guangzhou Concord Cancer Hospital, Guangzhou, Guangdong	p	250, SC cyclotron, (Varian)	4 gantries	4	2020
China	Boao Evergrande International Hospital, Boao Lecheng, Hainan	p	250, synchrotron, (ProTom)	4 gantries	4	2019
Egypt	Children's Cancer Hospital Foundation, Cairo	p	230, cyclotron, (IBA)	1 gantry	1	2020

International Journal of Radiation Oncology biology • physics

www.redjournal.org

COMMENTARY

Consensus Report From the Stockholm Pediatric Proton Therapy Conference

Daniel J. Indelicato, MD,* Thomas Merchant, DO, PhD,† Normand Laperriere, MD, FRCPC,‡ Yasmin Lassen, MD, PhD,§ Sabina Vennarini, MD,‖ Suzanne Wolden, MD, FACR,¶ William Hartsell, MD,# Mark Pankuch, PhD,# Petter Brandal, MD, PhD,** Chi-Ching K. Law, MD,†† Roger Taylor, MD,‡‡ Siddhartha Laskar, MD,§§ Mehmet Fatih Okcu, MD, MPH,‖‖ Eric Bouffet, MD,¶¶ Henry Mandeville, MBChB, MRCP, FRCR, MD,## Thomas Björk-Eriksson, MD, PhD,*** Kristina Nilsson, MD, PhD,*** Hakan Nyström, PhD,*** Louis Sandy Constine, MD,††† Michael Story, PhD,‡‡‡ Beate Timmermann, MD,§§§ Kenneth Roberts, MD,‖‖‖ and Rolf-Dieter Kortmann, MD¶¶¶

*University of Florida Health Proton Therapy Institute, Jacksonville, Florida; †St. Jude Children's Research Hospital, Memphis, Tennessee; ‡Princess Margaret Cancer Centre/University Health Network, Toronto, Ontario, Canada; §Aarhus University Hospital, Aarhus, Denmark; ‖Agenzia Provinciale per la Protonterapia, Trento, Italy; ¶Memorial Sloan-Kettering Cancer Center, New York, New York; #Northwestern Medicine Chicago Proton Center, Chicago, Illinois; **Oslo Universitetssykhus, Oslo, Norway; ††Queen Elizabeth Hospital, Hong Kong, China; ‡‡Swansea University South West Wales Cancer Centre, London, United Kingdom; §§Tata Memorial Hospital, Mumbai, India; ‖‖Texas Children's Hospital, Houston, Texas; ¶¶The Hospital for Sick Children, Toronto, Ontario, Canada; ##The Royal Marsden NHS Foundation Trust, London, United Kingdom; ***The Scandion Clinic, Uppsala, Sweden; †††University of Rochester Medical Center, Rochester, New York; ‡‡‡University of Texas Southwestern Medical Center, Dallas, Texas; §§§Westdeutsche Protonentherapiezentrum, Essen, Germany; ‖‖‖Yale University School of Medicine, New Haven, Connecticut; and ¶¶¶Universitätsklinikum Leipzig, Leipzig, Germany

Received Apr 8, 2016, and in revised form May 26, 2016. Accept d for publication Jun 14, 2016.

According to the American Society for Radiation Oncology's Model Policy published in 2014 (1), solid tumors in children are considered among the highest priority for proton therapy. Worldwide, there are currently 54 facilities offering proton therapy and 61 more under construction (2).

As the number of institutions proliferates, expert opinion is important in guiding safe and rational adoption and use of this technology in young patients. In June 2015, 24 international leaders in pediatric radiation oncology, pediatric oncology, medical physics, and radiobiology convened in

Rombi *et al. Italian Journal of Pediatrics* 2014, **40**:74
http://www.ijponline.net/content/40/1/74

ITALIAN JOURNAL OF PEDIATRICS

REVIEW Open Access

Proton radiotherapy for pediatric tumors: review of first clinical results

Barbara Rombi[1*], Sabina Vennarini[1†], Lorenzo Vinante[1,2†], Daniele Ravanelli[1] and Maurizio Amichetti[1]

Abstract

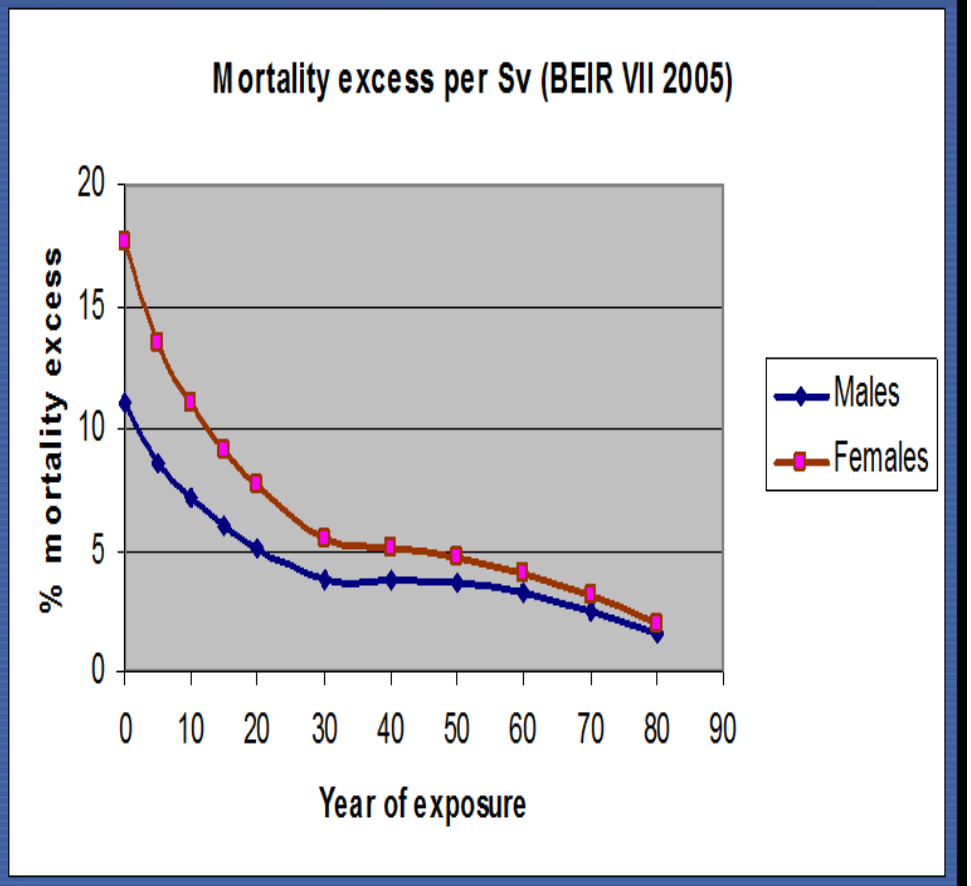
Radiation therapy is a part of multidisciplinary management of several childhood cancers. Proton therapy is a new method of irradiation, which uses protons instead of photons. Proton radiation has been used safely and effectively for medulloblastoma, primitive neuro-ectodermal tumors, craniopharyngioma, ependymoma, germ cell intracranial tumors, low-grade glioma, retinoblastoma, rhabdomyosarcoma and other soft tissue sarcomas, Ewing's sarcoma and other bone sarcomas. Moreover, other possible applications are emerging, in particular for lymphoma and neuroblastoma. Although both photon and proton techniques allow similar target volume coverage, the main advantage of proton radiation therapy is to sparing of intermediate-to-low-dose to healthy tissues. This characteristic could translate into clinical reduction of side effects, including a lower risk for secondary cancers. The following review presents the state of the art of proton therapy in the treatment of pediatric malignancies.

Keywords: Proton radiotherapy, Pediatric tumors, Late effects, Secondary tumors

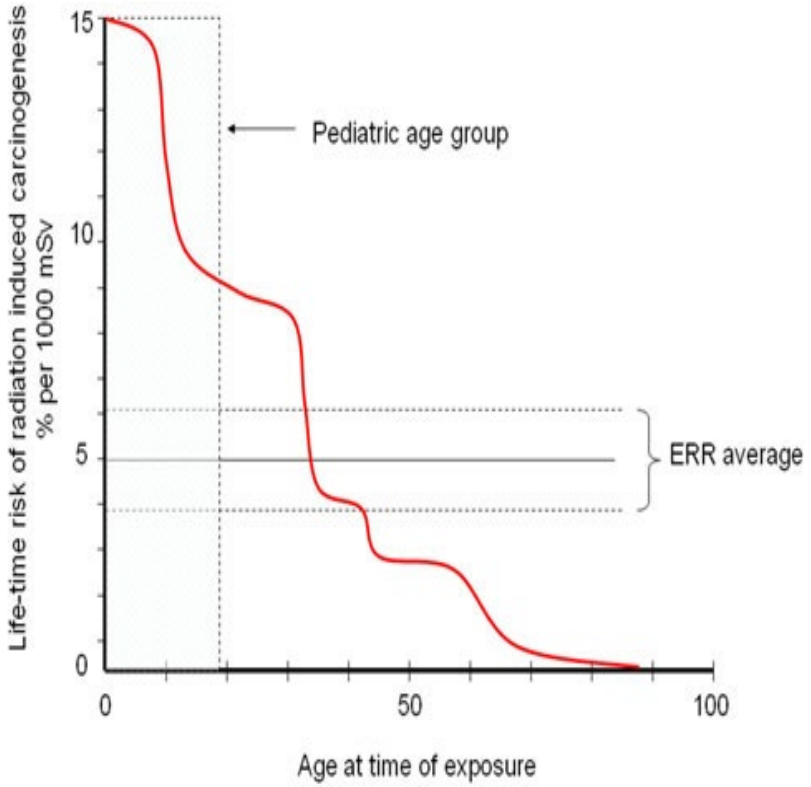
Conclusions

- RT is effective in increasing local control in several pediatric tumors, but it is often associated with severe late effects, including secondary tumors.
- The physical advantages of protons, which decrease the dose to healthy tissues, are promising in achieving significant clinical benefits.
- Dosimetric comparison studies pointed out the superiority of protons over photons in several tumor locations.

Children are more sensitive to radiation compared to adults



ICRP publication 60 ,1990



This shows that children have a 10% - 15% lifetime risk from radiation exposure while individuals above the age of 60 have minimal to no risk (due to the latency period for cancer and the person's life expectancy).

Journal of Medical Imaging and Radiation Oncology 61 (2017) 402–409

RADIATION ONCOLOGY—ORIGINAL ARTICLE

The risk of secondary cancer in nasopharyngeal carcinoma paediatric patients due to intensity modulated radiotherapy and mega-voltage cone beam computed tomography

Reham S Sherif,[1] Ehab M Attalla,[2,3] Wael M Elshemey[1] and Noha G Madian[1]

1 Department of Biophysics, Faculty of Science, Cairo University, Giza, Egypt
2 Radiotherapy & Nuclear Medicine Department, National Cancer Institute, Cairo University, Cairo, Egypt
3 Children Cancer Hospital, Cairo, Egypt

Radiation Physics and Chemistry 139 (2017) 120–125

Contents lists available at ScienceDirect

Radiation Physics and Chemistry

journal homepage: www.elsevier.com/locate/radphyschem

Dose estimation outside radiation field using Pinpoint and Semiflex ionization chamber detectors

Ahmed M. Abdelaal[a], Ehab M. Attalla[b], Wael M. Elshemey[c,*]

[a] Radiotherapy Department, Nasser Institute, Cairo, Egypt
[b] National Cancer Institute, Cairo University, Egypt
[c] Biophysics Department, Faculty of Science, Cairo University, Egypt

ARTICLE INFO

Keywords:
Pinpoint
Semiflex
Out-of-field dose
Dosimetry
radiotherapy

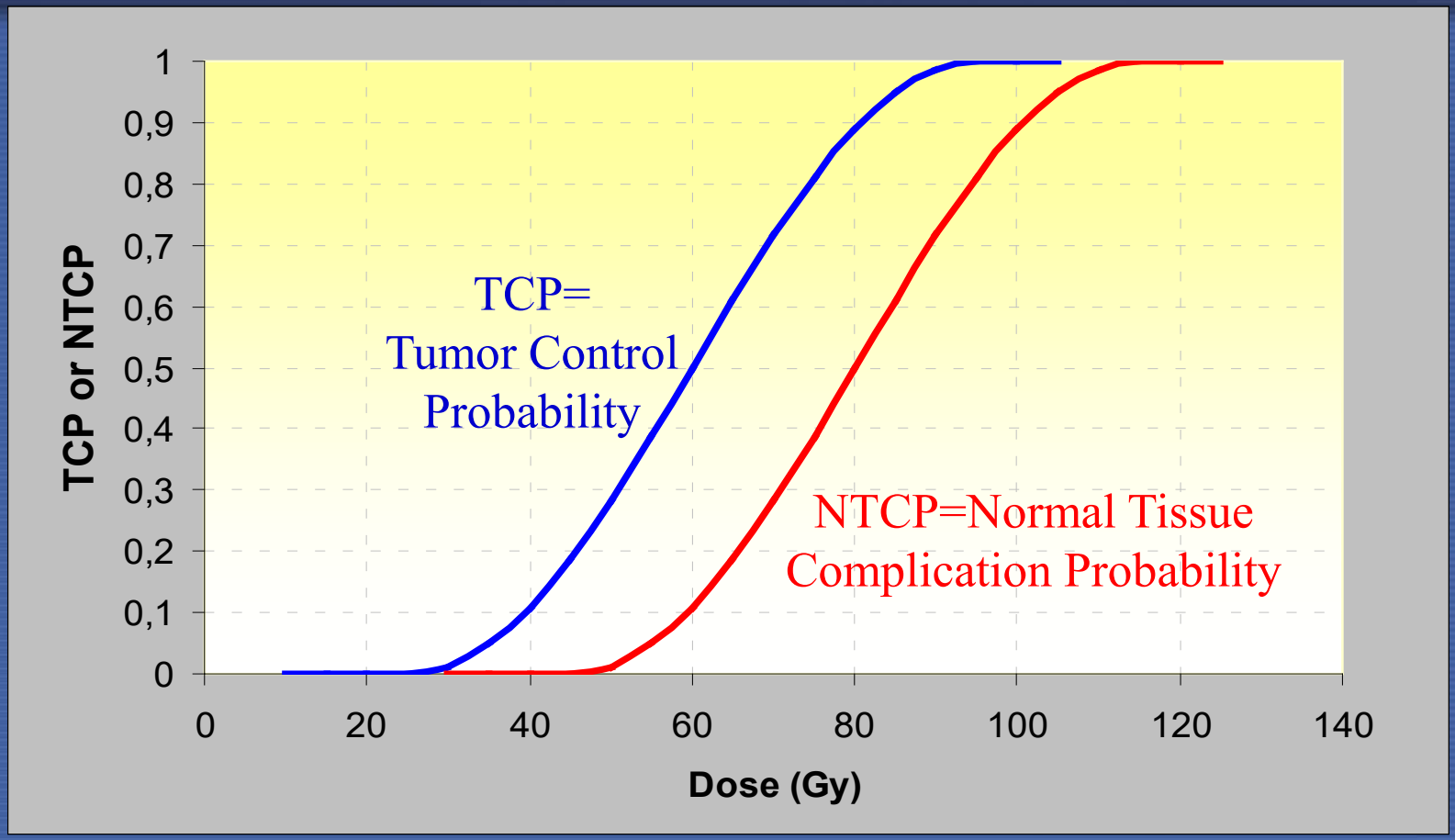
ABSTRACT

This work aims to provide a comparison between two important detectors (Pinpoint and Semiflex) that are frequently used in radiation dosimetery in radiotherapy. This is carried out through the employment of both detectors in a quantitative estimation of the change in out-of-field dose with important dosimetric parameters such as field size (from 5×5 cm^2 to 30×30 cm^2) and depth (from 1.5 cm to 30 cm) at two different energies (6 MV and 15 MV) and two different collimator angles (0–90°). The change in out-of-field dose with Source-Skin-Distance (SSD) from 80 to 115 cm is also studied using both detectors. Results show that, the Pinpoint and Semiflex detectors both reported an increase in out-of-field dose with field size, depth, energy and SSD. In almost all measurements, Pinpoint detector reported considerably higher out-of-field dose values compared to Semiflex. For 6 MV and 0° collimator angle, the out-of-field dose at field size of 30×30 cm^2 and at a depth of 1.5 cm is 7.3% for Pinpoint detector compared to 4.3% for Semiflex. At collimator angle of 90°, the out-of-field dose is 6.5% for Pinpoint detector compared to 5.5% for semiflex. The out-of-field dose for a depth of 30 cm and field size of 10×10 cm is 7.9% for Pinpoint detector compared to 5.9% for Semiflex. For 15 MV and 0° collimator angle, the out-of-field dose at field size of 30×30 cm^2 and at a depth of 1.5 cm is 7.5% for Pinpoint detector compared 5.1% for Semiflex. At 6 MV, field size of 10×10 cm^2 and depth of 1.5 cm, the out-of-field dose at SSD 115 cm is 3.7% for Pinpoint detector compared to 3.4% for Semiflex. The considerably higher out-of-field dose values reported by Pinpoint detector compared to Semiflex may be attributed to the relatively higher sensitivity of Pinpoint detector for low doses (such as out-of-field doses). Therefore, for reliable out-of-field dose measurements a Pinpoint detector is highly recommended.

The risk of secondary cancers attributable to verification imaging dose using MV-CBCT is very small compared to therapeutic dose using IMRT.

Therefore, it is important to focus on the risk of secondary cancers attributable to therapeutic dose especially when using IMRT, where the produced leakage radiation is considerably high compared to some other techniques (such as conformal radiotherapy).

Challenges In Radiation Therapy



Dose of radiation is limited by Normal Tissues Tolerance

Quantitative Analyses of Normal Tissue Effects in the Clinic (QUANTEC)

Table 1. QUANTEC Summary: Approximate Dose/Volume/Outcome Data for Several Organs Following Conventional Fractionation (Unless Otherwise Noted)*

Organ	Volume segmented	Irradiation type (partial organ unless otherwise stated)†	Endpoint	Dose (Gy), or dose/volume parameters†	Rate (%)	Notes on dose/volume parameters
Brain	Whole organ	3D-CRT	Symptomatic necrosis	Dmax <60	<3	Data at 72 and 90 Gy extrapolated
	Whole organ	3D-CRT	Symptomatic necrosis	Dmax = 72	5	from BE
	Whole organ	3D-CRT	Symptomatic necrosis	Dmax = 90	10	
	Whole organ	SRS (single fraction)	Symptomatic necrosis	V12 <5–10 cc		cc
Brain stem	Whole organ	Whole organ	Permanent cranial neuropathy			
	Whole organ	3D-CRT				
	Whole organ					
					1	Partial cord cross-section irradiated
					1	3 fractions, partial cord cross-section irradiated
C			hearing loss	Mean dose ≤45	<30	Mean dose to cochlear, hearing at 4 kHz
		(single fraction)	Sensory neural hearing loss	Prescription dose ≤14	<25	Serviceable hearing
Parc	parotid glands	3D-CRT	Long term parotid salivary function reduced to <25% of pre-RT level	Mean dose <25	<20	For combined parotid glands¶
	Unilateral whole parotid gland	3D-CRT	Long term parotid salivary function reduced to <25% of pre-RT level	Mean dose <20	<20	For single parotid gland. At least one parotid gland spared to <20 Gy¶

(Continued)

QUANTEC provided a comprehensive overview of dose volume-response relationships for adverse effects of radiation therapy in adults. Special attention for data on children treated with radiation therapy is needed, because of growth and development during radiation exposure as well as in the attained life span, the much longer life-expectancy for children.

PENTEC: Pediatric Normal Tissue Effects in the Clinic

A group of physicians (radiation and pediatric oncologists, subspecialists), physicists (clinical and modelers), epidemiologists who intend to critically synthesize existing data to:

- Develop quantitative evidence-based dose/volume guidelines to inform RT planning and improve outcomes
- Describe relevant physics issues specific to pediatric radiotherapy
- Propose dose-volume-outcome reporting standards to inform future RT guidelines.

SP-0171

Pediatric Normal Tissue Effects in the Clinic (PENTEC): An international collaboration

C. Ronckers[1], L. Constine[2], S.M. Bentzen[3], S. Dhakal[2], D. Hodgson[4], C.H. Hua[5], M.M. Hudson[6], L.C.M. Kremer[7], M. Martel[8], M. Milano[2], A.J. Olch[9], T. Schultheiss[10], M. Stovall[8], R. Ten Haken[11], J.P. Williams[12], E. Yorke[13]

[1]*Academic Medical Center, Department of Paediatric Oncology, Amsterdam, The Netherlands*

[2]*University of Rochester, Radiation Oncology, Rochester NY, USA*

[3]*University of Maryland, Epidemiology and Public Health/Biostatistics, Baltimore MD, USA*

[4]*Princess Margaret Hospital, Radiation Oncology, Toronto, Canada*

[5]*St. Jude Children's Research Hospital, Radiological Sciences, Memphis TN, USA*

[6]*St. Jude Children's Research Hospital, Oncology / Epidemiology and Cancer Control, Memphis TN, USA*

[7]*Academic Medical Center, Pediatric Oncology, Amsterdam, The Netherlands*

[8]*MD Anderson Cancer Center, Radiation Physics, Houston TX, USA*

[9]*Children's Hospital Los Angeles, Radiation Oncology/Physics, Los Angeles CA, USA*

[10]*City of Hope, Radiation Oncology/Physics, Duarte CA, USA*

[11]*University of Michigan Health System, Radiation Physics, Ann Arbor, USA*

[12]*University of Rochester, Environmental Medicine, Rochester NY, USA*

[13]*Memorial Sloan Kettering Cancer Center, Clinical Radiation Physics, New York NY, USA*

Challenges in RP issues in pediatric RT

- Normal tissue tolerance differences between children and adults
- Secondary Cancer Risk
- Dose from Verification : add/ subtract
- Concept about the Cancer patient with imaging modalities

Thank you