

XII Meeting on Nuclear Applications (XII ENAN)



"Perspectives on the Medical Uses of Radiation"

Radiotherapy and Brachytherapy - Hospital Sirio Libanês



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Cancer in the world

2008 CA new cases - 12.7 million - (56%) CA deaths - 7.6 million - (64%)



2012

CA new cases- 14.1 million

CA deaths – 8.2 million

Living with CA after 5 years of diagnosis - 32.6 million

WHO - World Health Organization

Expanding global access to radiotherapy

Rifat Atun, David A Jaffray, Michael B Barton, Freddie Bray, Michael Baumann, Bhadrasain Vikram, Timothy P Hanna, Felicia M Knaul, Yolande Lievens, Tracey Y M Lui, Michael Milosevic, Brian O'Sullivan, Danielle L Rodin, Eduardo Rosenblatt, Jacob Van Dyk, Mei Ling Yap, Eduardo Zubizarreta, Mary Gospodarowicz



Total incidence of, and mortality from, cancer in 2012 worldwide (A), in high and very high HDI countries (B), in medium HDI countries (C), and in low HDI countries (D) The top five cancers are shown in the dark grey portion of the pie chart. HDI=Human Development Index.

The Lancet Oncology Commission-Vol 16 September 2015

Radiation Therapy: ionizing radiation for treatment



Radiation therapy Objective Maximize dose to the tumor Minimize dose to normal tissue



Techniques of Radiation

 Teletherapy: sources far from the area to be treated

 Brachytherapy: source close, contact or implanted in the area to be treated

Teletherapy





1 Dimension



hypofractionated technique Important skin reactions → necrosis "Radiobiological Model" observation of the skin

Conventional Radiation Therapy

2 Dimensions



Portal Film





Individual blocks



Manual Isodose Curve

3 Dimensions

3D Conformacional



Spatial Relation : Tumor and Normal Tissue

Tomography Images



Godfrey Hounsfield



1972



Nobel Medicine 1979

Attenuation coefficient matrix converted to electron density

Attenuation coefficient: CT n° = 1000[μ_i - μ_w / μ_w]

 μ_w = coef linear attenuation for water

Base:

The attenuation of the photons through different tissues is different!

Allows:

Localization of volumes (Tu and OAR) Dose distribution calculation Determines the anatomy in 3D as a map of values of electronic density





3D Radiation therapy: It is necessary



CT scanner Simulator

Flat bed, laser system and specific software for virtual simulation









Target definition: challenge

Complementary Images



MRI

PET-CT : RXT



Decreases the target volume

Increase the target volume



HOSPITAL SING-LIBANES GN Marta, SA Hanna, CMK Haddad, JLF da Silva Hospital Sírio-Libanês - Sao Paulo - Brazil

ASTRO 2010

Imaging Modality?

Depends on the tissue characteristics to be analyzed

CT:

- Pulmonary nodules
- Lung
- Liver (contrast)



MRI:

- Brain
- Prostate
- Spinal
- Abdomen

PET-CT:

Site of an active disease •Lung •HN •Colon •Liver





New Tools



MLC Collimators Multi Leaf







Transfers (images, data) Verifies and records the data





Software automation

New Algorithms TPS

Intensity-Modulated Radiation Therapy **IMRT**



3D + Intensity-Modulated Beam = IMRT



IMRT: Inverse Planning

Start:

Define dosimetric and clinical objectives:

- Volumes
- Dose constraints

Prostate

Rectum

≤ 17% a ≥ 65Gy ≤ 35% a ≥ 40Gy

Bladder

≤ 25% a ≥ 65Gy≤ 50% a ≥ 40Gy

Objective Function (Cost)

↓

"Fuel in the optimization process"

Objective Funtion (Cost) Sum of quadratic difference between desired and obtained dose for all points of interest in the patient





IMRT: Treatment

Challenge: Dose delivery

Sophisticated mechanisms of MLC movement





Step and Shoot MLC movement and irradiation performed sequentially Sliding Window Continuously irradiation while MLC moves in a predetermined way

Head & Neck





HSL



October 13, 2000: Performed: 1**st IMRT**



Prostate

Clinical implementation of IMRT

- Equipment
- 3D experience
- Practical change
 - Multimodality images
 - Inverse planning
- Quality Assurance:
 - Individual treatments
- Staff trainning



Acceptance and Comissioning of LINACS

1-Check manufacture's requirements and recommendations

Acquired data

- Percentage Depht Dose (PDD)
- Dose profiles
- Air profiles
- Specific scans
- Point measures and relative factors:
- Absolut measures
- Output factors Water/Air
- Acessories/Transmission
- MLC specific parameters







2- Treatment Planning System requirements

Validation Dose calculation Heterogeneity IMRT/ VMAT.....









Quality Assurance Equipment



K) 4E 28 EE 20 40 KB

QA: Validation of each patient



Plan calculated on Phantom CT





Patient



Phantom





Matrixx

Gamma Function



Irradiation Techniques

Radiosurgery: SRS

Use of *stereotactic* apparatus to guide radiation beams to treat tumours with *one* or at most five fractions







QA: Check coincidence between lasers and radiation isocenter

Organ movement and anatomic changes



Geometric Uncertainty

Interfraction



Geometric Uncertainty

Intrafraction

Due to respiratory, digestive and cardiac systems



IGRT

Image Guided Radiotherapy:

"Use of image inside treatment room to improve precision on dose delivery"



Different Strategies!

IGRT Strategies



CT-on-rails



Exac Trac



Tomotherapy





Flat Panel: a-Si



Parameter	Specification	
Total Pixel Number	1024 x 1024	
Pitch	400 µm	
Total Area	40.96 x 40.96 cm ²	
Scintillator	Lanex fast	
Contrast to noise ratio (CNR)	600	
Readout time	~ 145 ms	
Spatial resolution at f50	0.41 Ip/mm or higher	



Detector Cross Section

IGRT: Different Techniques



Daily Portal Imaging EPID- Eletronic Portal Image Device 2D





2D : EPID Eletronic Portal Image Device





3D : IGRT

Cone Beam CT:

Integrates the CT imaging acquisition directly on ALX mechanism



1 slice per rotation 1D detector line Cone beam CT



Total volume on only 1 rotation 2D detector plane

Cone Beam CT



Fini

Finish

Cancel

Rtn [deg] 0.0 Session Images Timeline 4 Dimensions

"Explicit inclusion of anatomy's temporal variation"



Objective: To reduce treatment margins, allowing to increase the dose to the tumors while keeping the same or even lower doses to the normal tissues

Treatment: Respiratory Gating

Dose delivered only in specific phases of the cycle, in order to reduce dose to normal tissue and target underdosing



Un-Gated

Respiratory Waveform

Mid phase 3DCT Inhale 3DCT



Exhale 3DCT





Courtesy of P. Keall

SBRT: Stereotactic Body Radiotherapy

Emerging technique of radiotherapy with high accuracy in which high dose is given to the tumor





SBRT: 3 x 20Gy



Dose Constraints ≠ Radiobiology

IGRT is Mandatory

Treatment Planning

SBRT









Treatment Planning



Today: Volumetric Modulated Arc Therapy VMAT

 Radiation is continuously delivered during gantry rotation.

- It can modulate simultaneously:
 - MLC shape;
 - Dose Rate;
 - Gantry Rotation Speed;



Rapid Arc

Volumetric Modulated Arc Therapy



Special considerations of dosimetry and calculation: SBRT + SRS + IMRT

Small Field Dosimetry

Detector Volume/ Lack of electronical equilibrium

- Maximum internal diameter of the detector should be less than half of the FWHM fo the smallest field

Calculation Algorithm

Needs algorithms that consider lack of scattering (for lung cancer)

- Pencil Beam
- Monte Carlo
- Convolution/Superposition





^{1 –} Classic Pencil Beam w/correction 2 – Classic Pencil Beam clássico without correction

End-to-End Test

Simulates a "treatment of a detector", including all the stages to assess the final error of the entire process



Localizer nd Registration

Contourning



Image Acuisition

Treatment Planning and Calculation



exportation



Positioning and Treating

Proton Accelerators



Gantry and Table at manufacturer



Depth in tissue (cm)









Photons

Protons

Brachytherapy

Low Dose Rate:
 I¹²⁵ Permanent
 Ir¹⁹² Temporary



High Dose Rate: Ir¹⁹²



Low Dose Rate: I¹²⁵ Prostate Permanent Implant







I¹²⁵ seed prototipe of IPEN



I¹²⁵ Seed Laboratory - IPEN

In 2014, 25.116 I¹²⁵ seeds were sold

IPEN

Procedure Steps



Hospital Sírio Libanês Experience

June 1998 – October 2015 **1027 implants**

Average: 92 seeds / implant I¹²⁵



Low Dose Rate: Ir¹⁹²

Hot cells for the production of Ir¹⁹² wires - IPEN



Hot cell - External view



Hot cell - Internal view





Low Dose Rate: Ir¹⁹²





High Dose Rate: Ir¹⁹²

119 HDR Equipment - Brazil





Building where it will be installed laboratory for preparation of IPEN HDR I¹⁹² sources

High Dose Rate: Ir¹⁹²

3D















Complexity in Radiation Therapy But the goal is simple: Optimizing Therapy Ratio

- Standardized Procedures
- Staff well trained and updated
- Hardware and software features
 maintenance
- Clear communication throughout the team





TG 100 – AAPM

New approaches: Quality Assurance and Quality Control TG-100 Philosophy:

"All QA programs should be based on risk analysis of the various processes involved in patient care"



Brazilian Association of Medical Physics

Number of Members by year



Updated: Oct/14



BFM







Approved Programs in Medical Physics (MEC e MS)

Institution	Radiotherapy	Nuclear Medicine	Radiology
Instituto Nacional de Câncer (RJ) - 2013	04	-	02
Hospital AC Camargo (SP) - 2013	03	-	-
Hospital das Clínicas USP São Paulo (SP) - 2013	04	02*	-
Hospital das Clínicas USP Ribeirão Preto (SP) - 2013	01	-	01
Hospital São Paulo UNIFESP (SP) - 2013	02*	02*	03*
Hospital de Clínicas UNICAMP (SP) - 2014	02	01	01
Hospital de Câncer de Barretos (SP) - 2014	01	-	-
Hospital Sírio-Libanês (SP) - 2013	02	-	-
Hospital Erasto Gaertner (PR)	01	-	-
Hospital São Lucas PUC (RS) - 2013	01	01	01
Overall	21	06	08

* Partially occupied vacancies



New Programs in Medical Physics Potential in short-term

Institution	Radiotherapy	Nuclear Medicine	Radiology
Hospital de Câncer de Barretos (SP)	-	01	01
Instituto de Física da USP - InRad (SP)	-	-	02*
Hospital Universitário Clemente F. Filho (RJ)	01	01	01
Irmandade da Santa Casa de Misericórdia (SP)	01	01	01
Hospital Beneficência Portuguesa de São Paulo (SP)	02	-	-
Hospital Israelita Albert Einstein (SP)	02	01	01
Hospital de Clínicas de Uberlândia (MG)	01	01	01
Clínicas Oncológicas Integradas (RJ)	02	-	-
Centro de Oncologia D'Or (RJ)	01*	-	-
Associação de Combate ao Câncer (GO)	01*	-	-
Hospital do Câncer de Pernambuco (PE)	01	-	-
Universidade Federal de Sergipe UFS (SE)	01	01	01
Real Sociedade Portuguesa de Beneficencia (BA)	01	-	-
Hospital de Clínicas de Porto Alegre (RS)	-	01	01
Overall	14 - 06	07 - 01	09 - 03

* Operation programs with own funding



Distribution and Equipment Clinics by Country Region

Region	Accelerators	Co (60)	HDR	Clinics
Southeast	185	37	72	128
South	54	9	12	48
Northeast	47	8	18	35
Midwest	18	2	6	35
North	10	6	11	12
Overall	314	62	119	241

Expansion plan of Radiotherapy - Brazil

80 radiotherapy solutions:

- 39 expansions of existing sites
- 32 new sites
- 9 new brachytherapy equipment
- All solutions include dosimetry, positioning and QA accessories

Other items:

- 41 sources of strontium Sr-90
- 9 gynecological tables
- 9 X-ray equipament

Projects:

• 80 projects running and subject to approval of ANVISA and CNEN

Technological compensation :

• Factory opening in Brazil (Jundiai)



Cancer in the world



- Longer life expectancy in patients with Ca
- Improve treatment and quality of life

In radiotherapy with technological developments



CURSOS E CONGRESSOS

XV CURSO DE RADIOTERAPIA DE ÚLTIMA GERAÇÃO E CONTROLE DE QUALIDADE

03 e 04 / DEZ / 2015

CURSO DE BRAQUITERAPIA DA PRÓSTATA 05 / DEZ / 2015



ICRU 62 : Taking into account the internal motion

Defining the Internal Target Volume (ITV) to individualize margins

