Joint ICTP-IAEA Workshop on Radiation Protection in Image-Guided Radiotherapy (IGRT)

An international survey of imaging practices in radiotherapy

Session 6: IGRT for different sites and treatment intentions

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Trieste, October 7th, 2024

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ICRP TG116 member

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Session 6: IGRT for different sites and treatment intentions

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ICRP Committee 3 on Protection in Medicine

Trieste, October 7th, 2024

Sebastien Gros

ICRP TG116 member

Outline

Introduction to ICRP and TG-116

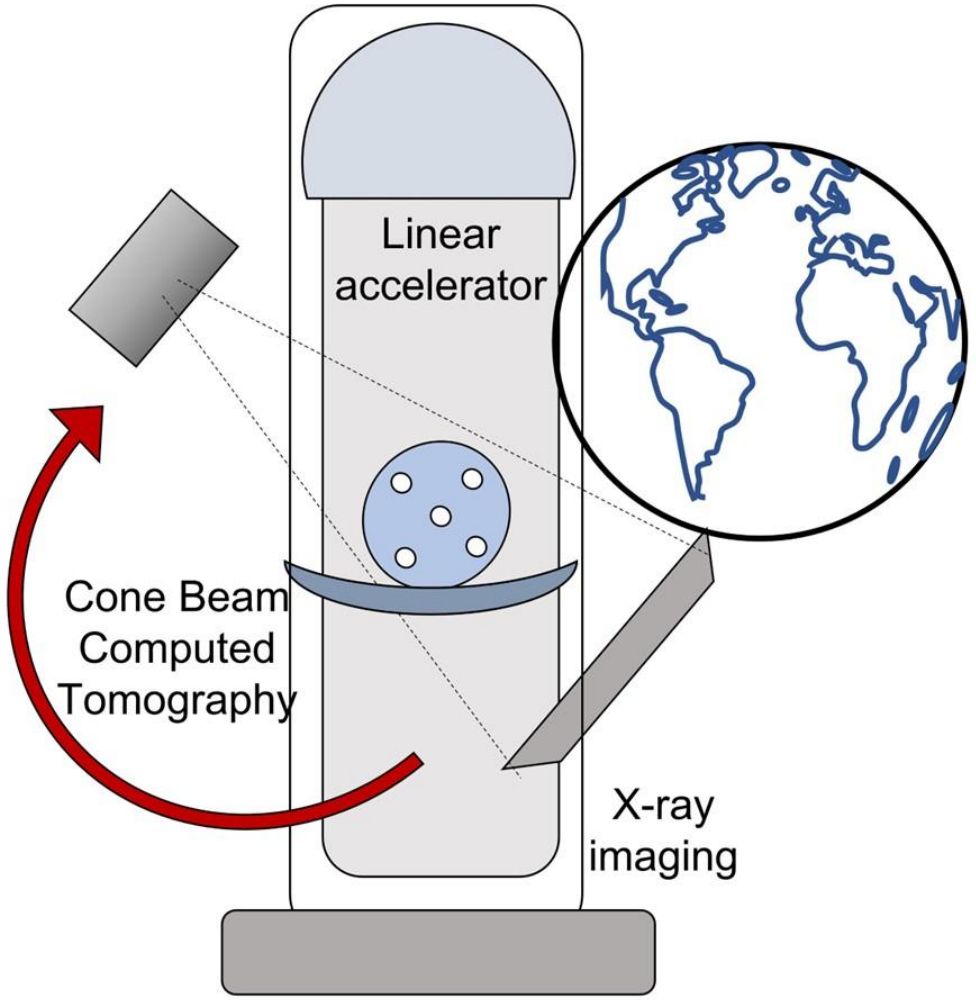
- ICRP Task Group 116
- ICRP Mentorship program

Survey on Imaging Practices

- Methodology
- Key results

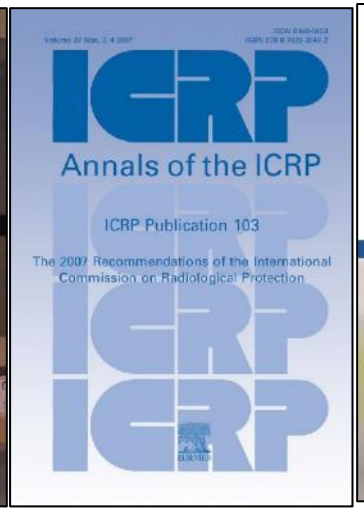
Conclusion

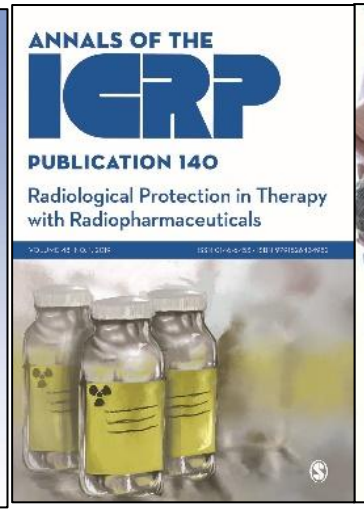
Next steps



ICRP Mission

*Advance for the **public benefit** the science of radiological protection, in particular by providing **recommendations and guidance** on all aspects of protection against **ionising radiation***



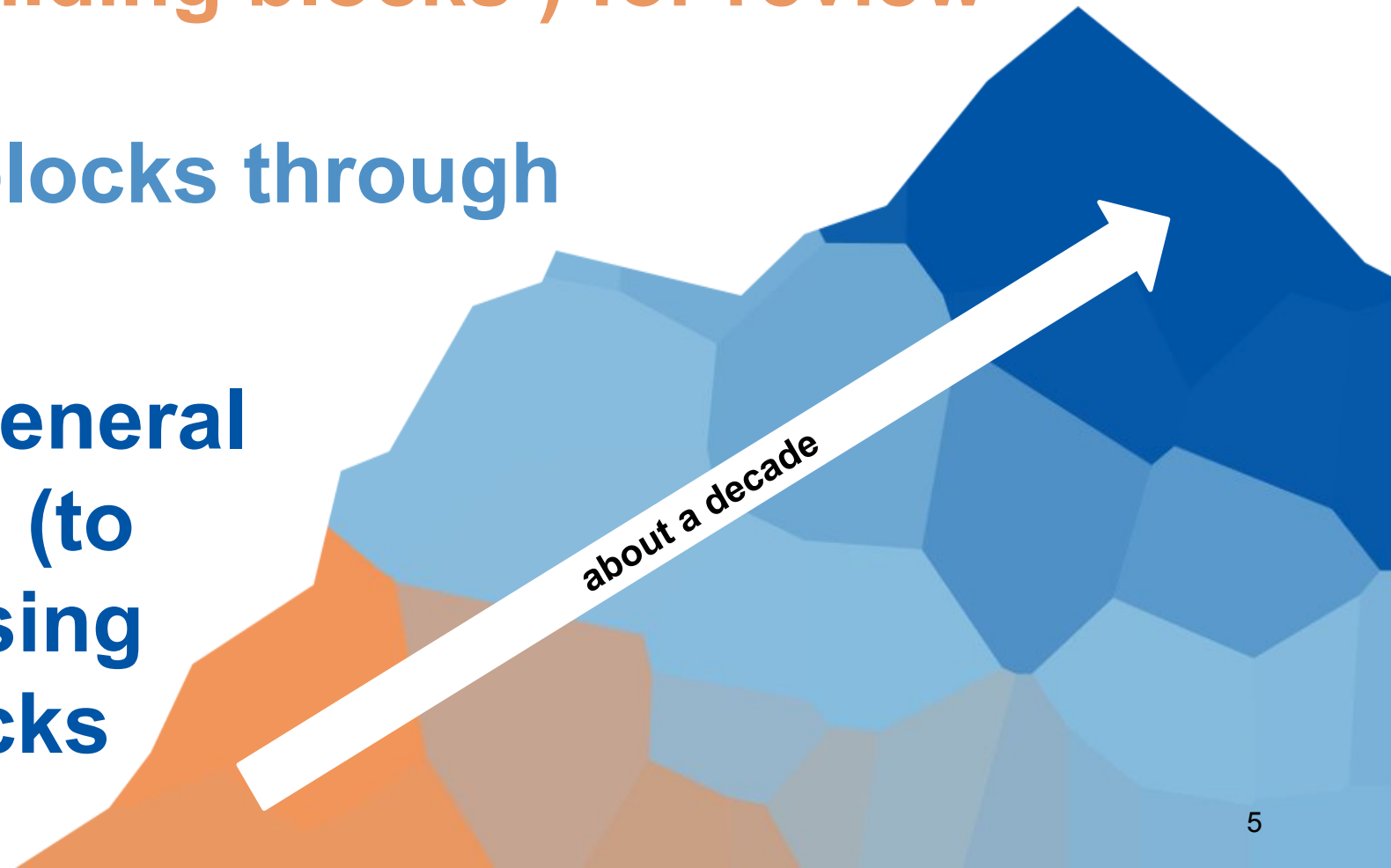


Review & Revision of the System of RP

Identify topics ('building blocks') for review

Develop building blocks through ICRP Task Groups

Prepare the next General Recommendations (to replace Pub103) using these building blocks



Active task groups under C3: Medicine

Active Task Groups under Committee 3

Task Group 36
Radiation Dose to Patients in Diagnostic Nuclear Medicine

Task Group 108
Optimisation of Radiological Protection in Digital Radiography, Fluoroscopy, and CT in Medical Imaging

Task Group 109
Ethics in Radiological Protection for Medical Diagnosis and Treatment

Task Group 111
Factors Governing the Individual Response of Humans to Ionising Radiation

Task Group 113
Reference Organ and Effective Dose Coefficients for Common Diagnostic X-ray Imaging Examinations

Task Group 116
Radiological Protection Aspects of Imaging in Radiotherapy

Task Group 117
Radiological Protection in PET and PET/CT

Task Group 126
Radiological Protection in Human Biomedical Research

Task Group 128
Individualisation and Stratification in Radiological Protection: Implications and Areas of Application

9 active Task Groups directly under C3

C3 Members' Participation in other TGS

--Multiple current TGs have C3 member involvement:
TG114, TG118, TG119, TG121, TG124, TG125

https://www.icrp.org/icrp_group.asp?id=9

Radioprotection issues with IGRT

- **Historical paradigm: “Imaging dose is much lower that RT dose, therefore we can just ignore it” is no longer valid**
  - Focus on Tissue reactions from RT beam
  - But patient live longer can be at risk of developing secondary cancer from RT
  - Cumulative imaging dose delivered over >30 fraction may no longer be insignificant wrt. therapeutic dose

- **Technical limitations with Treatment Planning Systems**
  - Magnitude of imaging dose is within the uncertainty level of modeling out of field scatter dose
  - kV imaging dose not included in clinical TPS dose calculations
  - Cannot yet manage imaging dose in the same manner as RT dose

TG-116 goals

- **Produce a report on radiological protection aspect of imaging in RT**
  - Introduction to risk, imaging requirements, clinical perspective on imaging and the process of optimisation
  - Specific chapters on treatment planning/linac/brachytherapy imaging, alongside paediatric exposures
  - **Evaluation and management of doses from imaging, including dose levels and auditing**
  - **Quality assurance, errors and education**
  - **Recommendations to improve optimisation:**
    - **Actions to promote optimisation in RT**
    - **Actions for equipment vendors and software developers**
    - **Actions for regulators and professional bodies**
  - A project is underway to develop the work undertaken by IPEM in the UK, and acquire data from across the globe in a wide range of RT centres, using the ICRP Mentee Programme to assist with data collection

(Courtesy of Tim Wood)

ICRP Task Group 116

Colin Martin C3, William Small C3, Daniel Berger, Aurelie Isambert, Stine Korreman, Tomas Kron, Choonsik Lee, Tom Merchant, Ung Ngie Min (Vincent), Jenia Vassileva, Tim Wood

TG116 Mentees Survey of RT practices

Abdel-Hai Benali, Abdullah Abuhaimed, Hossam Ragab Shaaban, María Cristina Plazas d'Leon, Mario Djukelic, Sebastien Gros, Yiannis Roussakis

www.ICRP.org

Radiological protection aspects of imaging in radiotherapy

1. INTRODUCTION
2. RADIOTHERAPY TREATMENT PLANNING AND DELIVERY
3. CLINICAL JUSTIFICATION FOR IMAGING IN RADIOTHERAPY
4. THE PROCESS OF OPTIMISATION OF IMAGING
5. EVALUATION AND MANAGEMENT OF DOSES FROM IMAGING
6. IMAGING FOR TREATMENT PLANNING
7. IMAGING DURING THE TREATMENT CYCLE
8. IMAGING FOR BRACHYTHERAPY
9. PAEDIATRIC IMAGING IN RADIOTHERAPY
10. THE IMAGING EQUIPMENT LIFE-CYCLE, QA AND AUDIT
11. AVOIDANCE OF ERRORS ORIGINATING FROM IGRT
12. EDUCATION AND ONGOING TRAINING OF RADIOTHERAPY STAFF
13. RECOMMENDATIONS TO IMPROE OPTIMIZATION OF RADIOLOGICAL PROTECTION

A. IMAGING TECHNIQUES USED IN RADIATION THERAPY

B. CONE BEAM CT DOSIMETRY

C. ERRORS IN TREATMENT INVOLVING THE APPLICATION OF IMAGING

- Draft submitted to Main commission in 09/24
- Public □ 2025
- Publication □ 2025-2026

ICRP mentorship programme (2020 -)

- Engage university students and early-career professionals and scientists as mentees in ICRP Task Groups with the guidance of an ICRP member as mentor.
- This is a part-time voluntary arrangement, with mentees continuing to work at their home organisation most of the time.
- Mentees are assigned specific roles or tasks, defined in advance. The assignment is typically 1 - 3 years. The mentee will be a member of the Task Group.
- The mentor, Task Group member, is responsible for providing guidance and support to the mentee, including discussing and reviewing the tasks assigned.
- At the end of the mentorship period the mentor and the mentee each submit a brief confidential report which will be used to progressively improve the mentorship programme.

Motivations

- Practices vary between RT centres in the imaging modalities used, including the frequency of imaging, the dose levels used, and the level of optimisation.
- **Limited available information on imaging practices**
- This survey has been carried out through ICRP TG116 to provide information about the use of imaging for RT in different parts of the world.
- Guide the work and recommendations from TG-116

International Survey of imaging practice

Country	HDI
Germany	0.947
Australasia	0.944
USA	0.926
Cyprus	0.887
Saudi Arabia	0.854
Malaysia	0.810
Colombia	0.767
Algeria	0.748
Egypt	0.707

ICRP TG116 Mentee Project

Questionnaire containing 130 items

Survey Monkey July - November 2020

143 RT centres registered

100 RT centres completed the full questionnaire

Data in 9 country sent to Mentees for analysis

Ordered in terms of HDI to highlight trends

Human Development Index (HDI) combines measures of life expectancy, education (literacy rate and levels of education) and per capita income.

Martin et al. 2021, Physica Medica, 90, 53-65.

Survey Structure: Questions

Pages	Information requested
1	Background
2	Contact information
3	General facility information • Type of facility: Public / Private / Academic • Number of patients treated per month • Percentage of treatments using image guidance • Imaging physicists available for consultation • Radiotherapy physicists with expertise in imaging • The three anatomical sites treated most frequently
4	Planning X-ray equipment (Nos. of units and vendors) • CT Systems • Conventional X-ray simulator • Other imaging modalities
5	Treatment Imaging Systems • No. of linear accelerators (linacs) and dates of commissioning • No. of Cobalt-60 treatment units • No. of linacs with kV imaging capabilities with make and model
6	Use of on-treatment imaging • Types of imaging procedures used • Use of specific paediatric imaging protocols
7-12	Use of imaging during treatment of specific conditions • Frequency of imaging for radical treatments 7. Neuro-oncology / Brain 8. Head and neck 9. Breast 10. Lung 11. Gynaecology 12. Prostate
13-16	Protocol use and optimisation for different imaging modalities • Use of protocols as supplied by the manufacturer • Adaptation of protocols for individual patients • Adjustment of jaw/blade settings and fields for paediatric and adult patients • Recording of dose quantities for individual patients • Taking account of imaging dose in treatment plan 13. kV cone beam CT 14. kV planar imaging 15. MV cone beam CT 16. MV planar imaging
17	Additional information • Frequencies for performing QC on imaging systems • Performance tests on: Geometric accuracy, image quality, imaging dose • Use of published guidance for QC protocols • Staff performing QC tests • Working with diagnostic imaging physicist on the optimisation of imaging

Key Results

Table 2. Data on radiotherapy centres completing the questionnaire for each country, types of centre, numbers of linear accelerators and the numbers of patients treated.

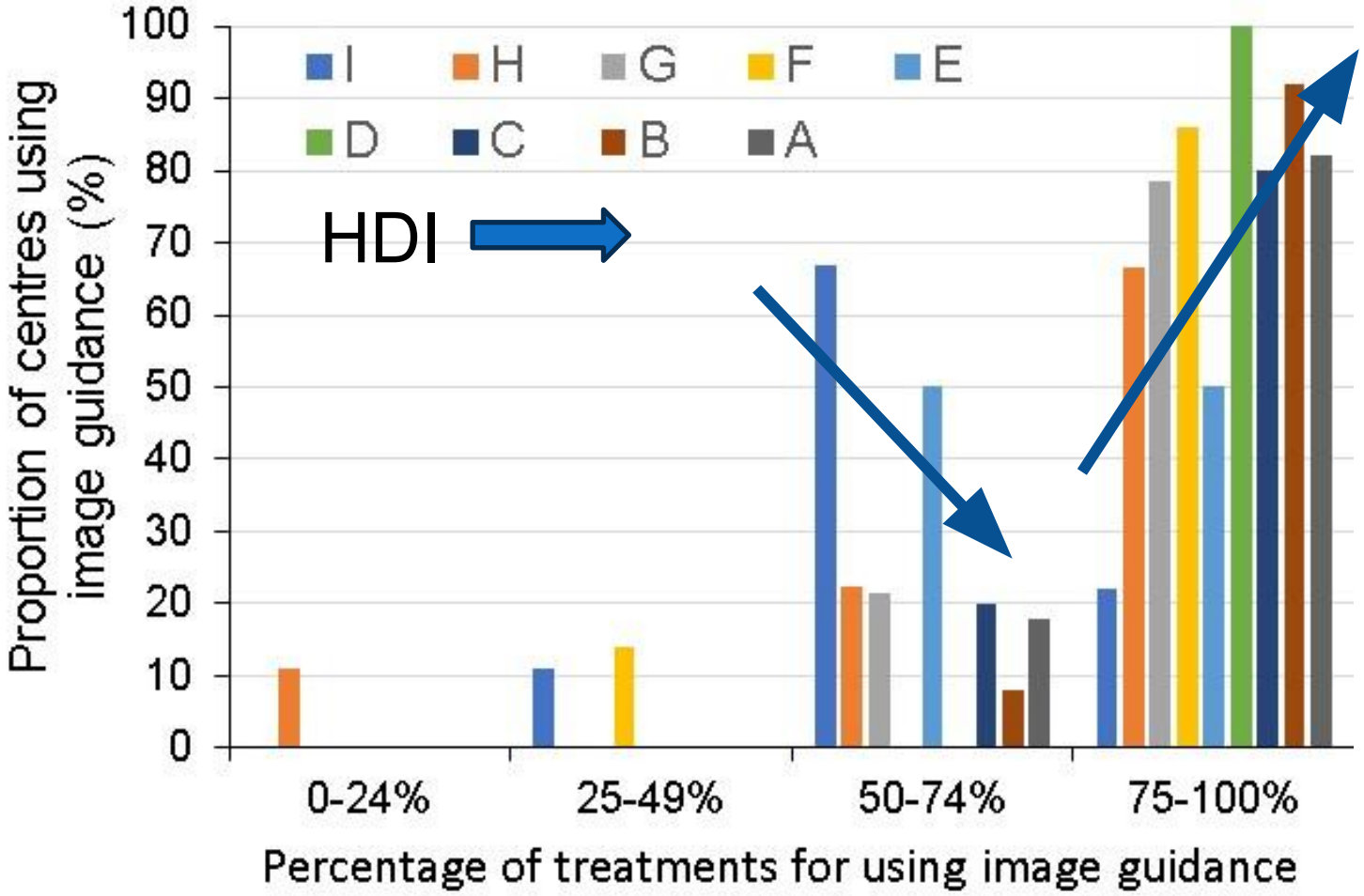
Country	No. of RTCs in survey	No. of RTCs in country	Public hospitals (%)	Private hospitals (%)	Academic connectn. (%)	Linacs in RTCs in survey	Median no. of linacs per RTC
Germany (10) / Switzerland (1)	11	293 / 38	82	18	55	30	3
Greece (2) / Cyprus (2)	4	29 / 2	50	50	-	8	2
Algeria	9	16	66.7	33.3	-	24	3
Egypt	9	72	44	22	36	13	1
Saudi Arabia	4	14	100		75	16	2
Malaysia	7	29	14	71	29	9	1
Australia (10) / New Zealand (2)	12	103 / 8	62	31	9	55	3
Colombia	14	58	29	64	7	24	2
USA	30	2,300	37	63	56.7	143	4
Survey totals	100	-	48	46	33	322	2

1 Verification images used to guide treatment

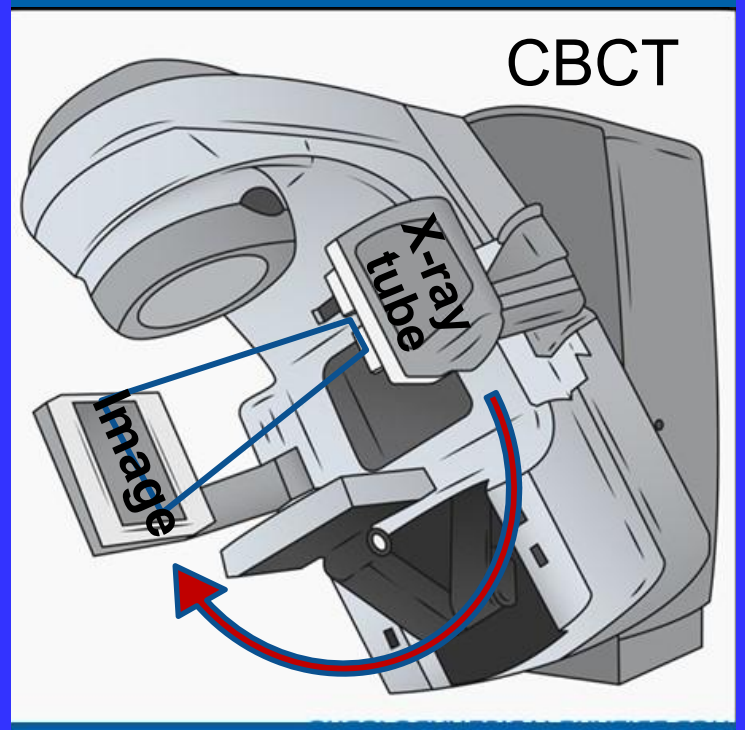
Use of IGRT is more frequent in countries with high HDIs.

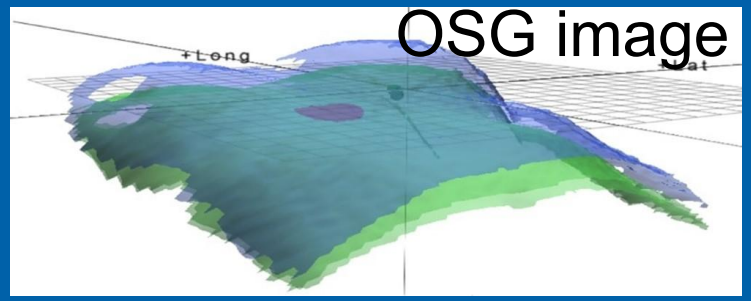
IGRT is starting to be used in the majority of radiotherapy centres in all countries

Percentages of treatments for which centres use some image guidance



2 Imaging modalities for IGRT





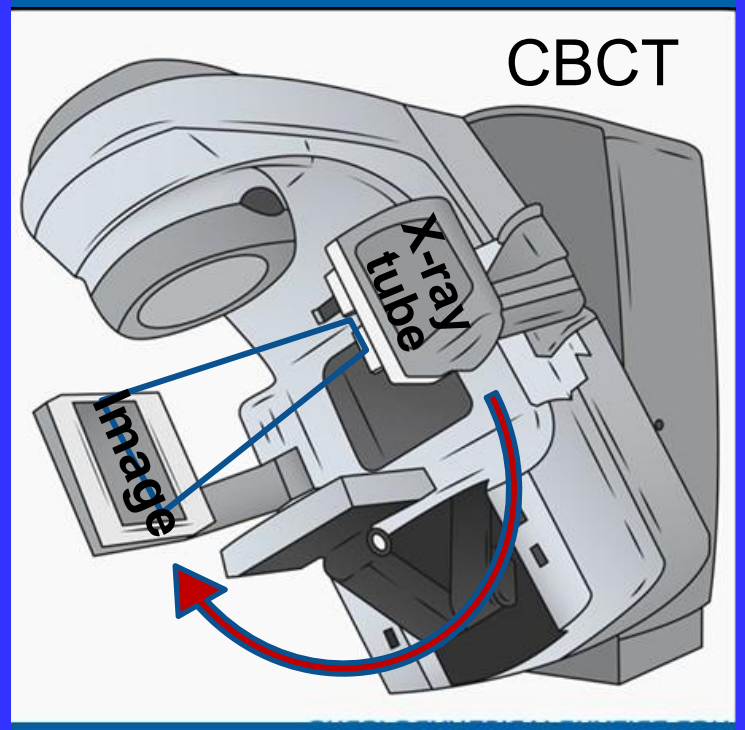
Planning

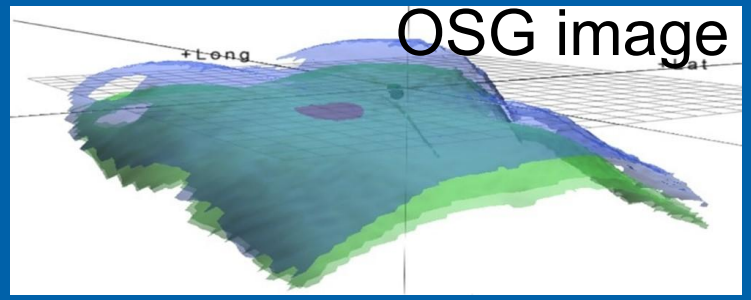
- CT scanning used in all centres, but other imaging modalities, such as MRI, PET/CT, SPECT and ultrasound may also be used.
- Use of secondary imaging scaled with HDI

Treatment (IGRT)

- **kV cone beam CT** (CBCT) is the modality most widely used for imaging during treatment
- kV-kV pair and MV-MV pair are widely used
- A few centres use MV cone beam CT
- **Optical surface guidance** (OSG) and/or ultrasound were used in about half of the centres and MRI in 10%-25%

2 Imaging modalities for IGRT





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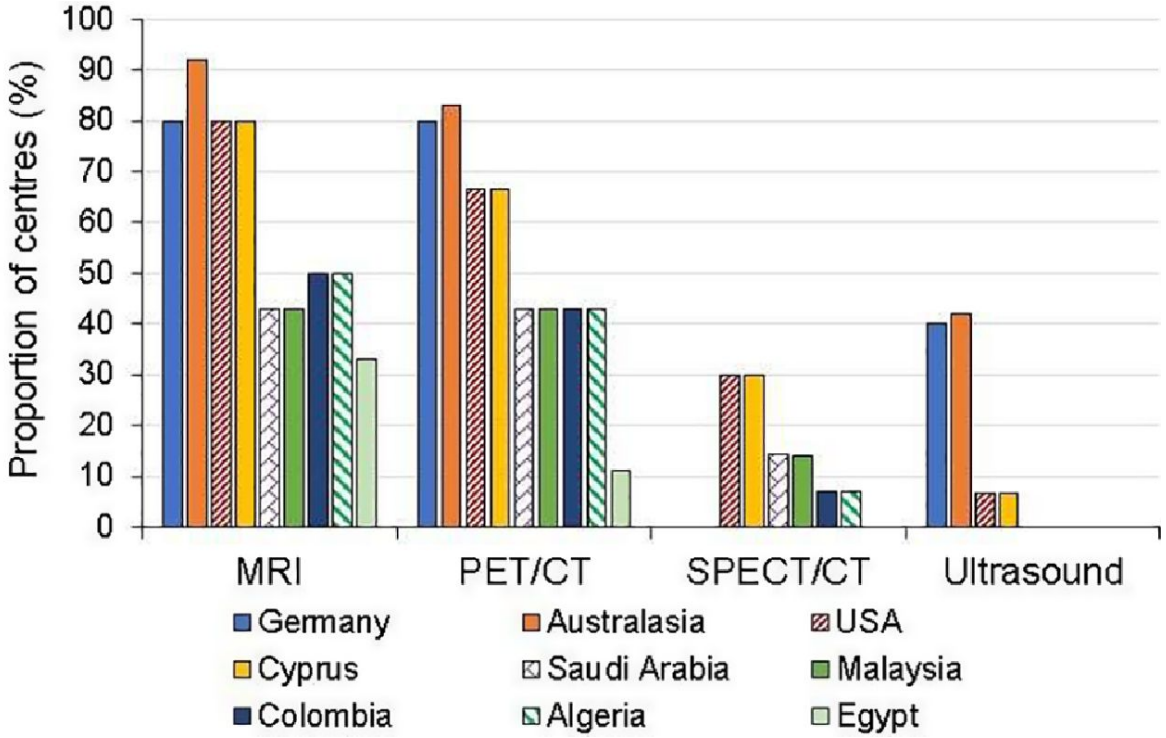

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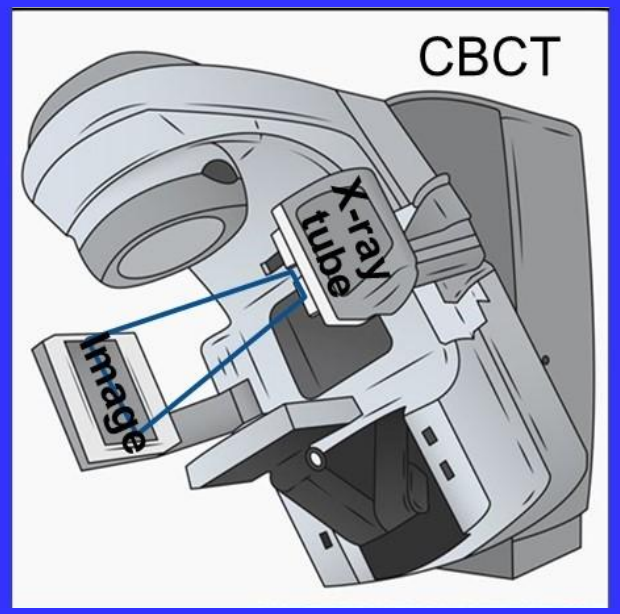
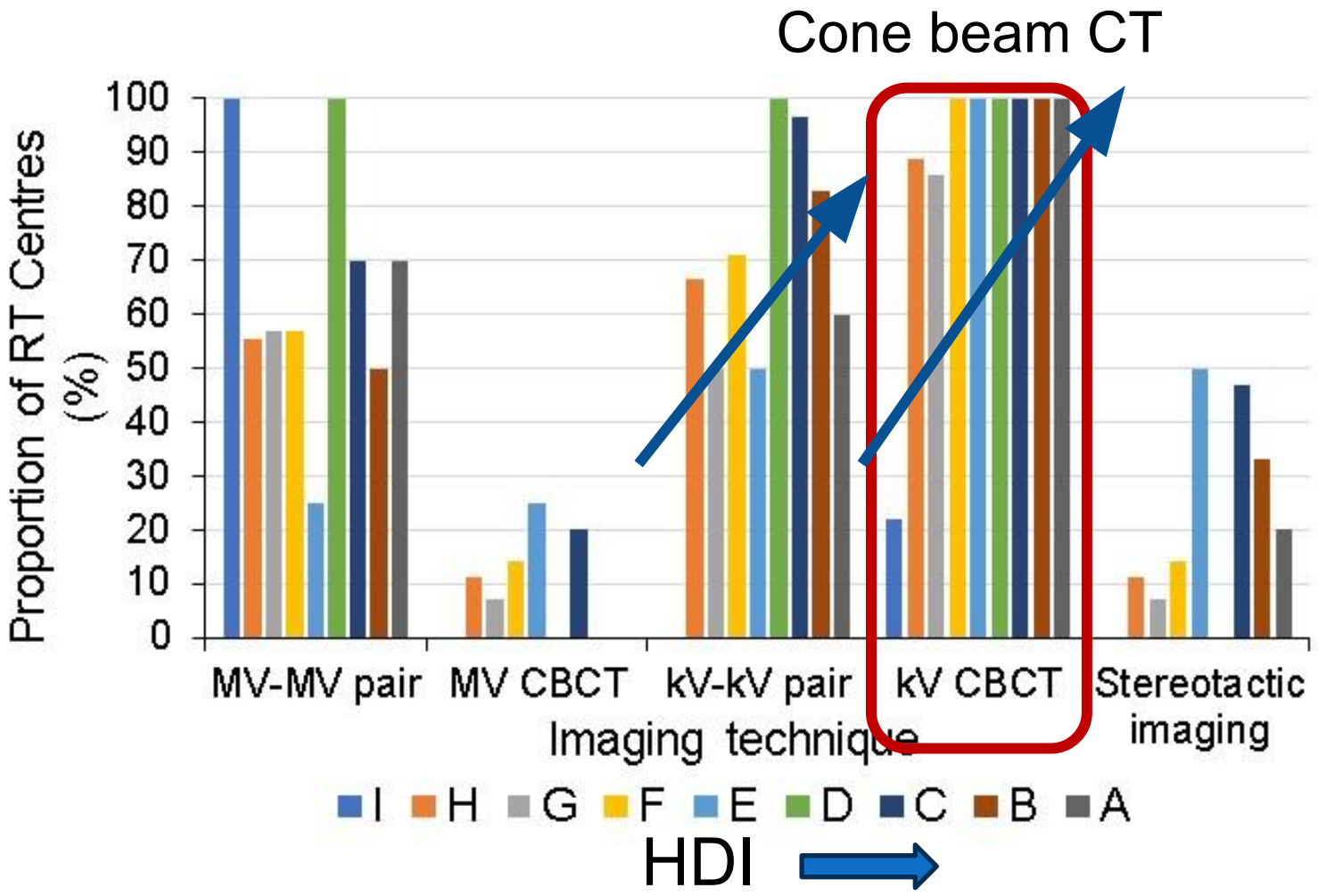


kV cone beam CT (CBCT) is the main technique used for verification imaging



Countries with lower HDI values have fewer Linacs with kV imaging facilities

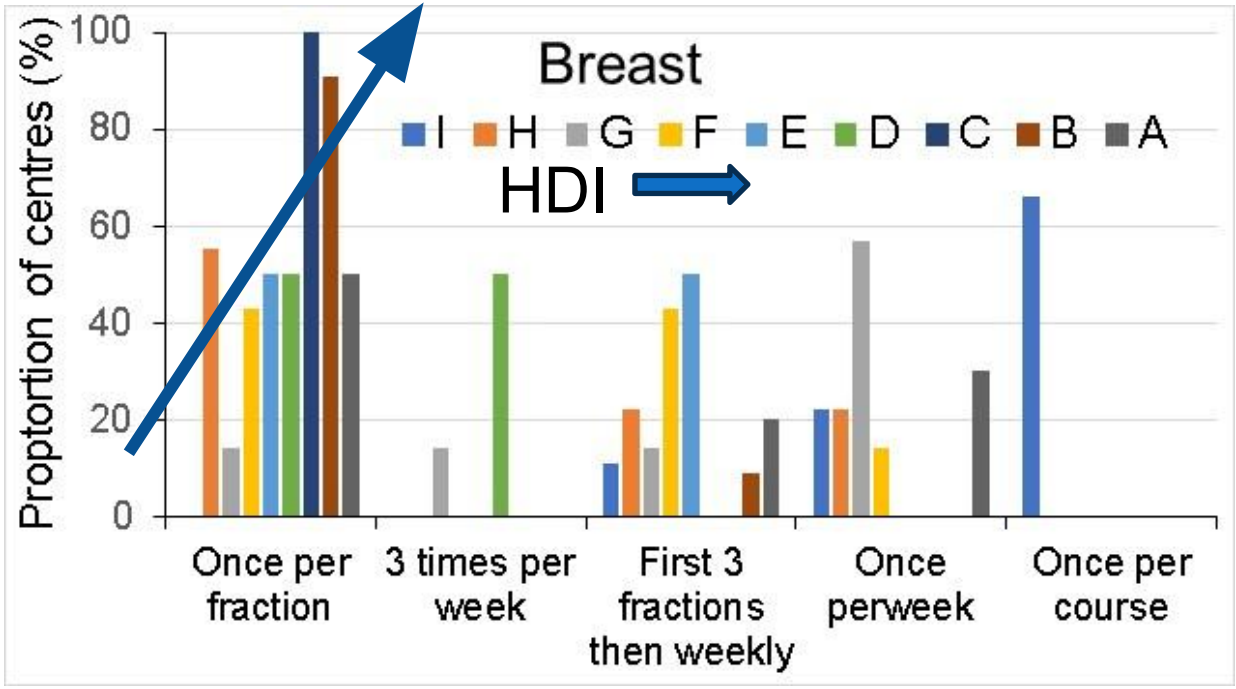
3 Frequency of verification imaging

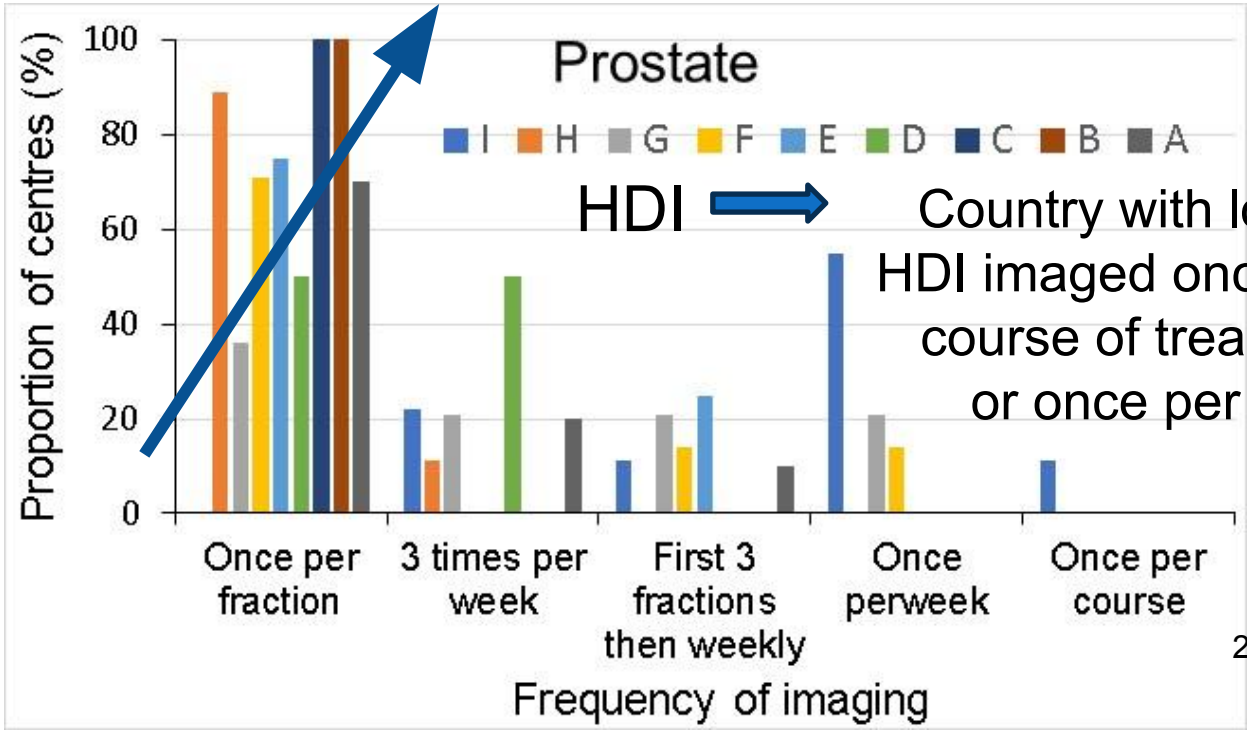
Breast and Prostate

Higher income countries frequently image at every fraction, but numbers decline with HDI

Reasons are:

- Availability of kV imaging equipment
- More patients treated per linac



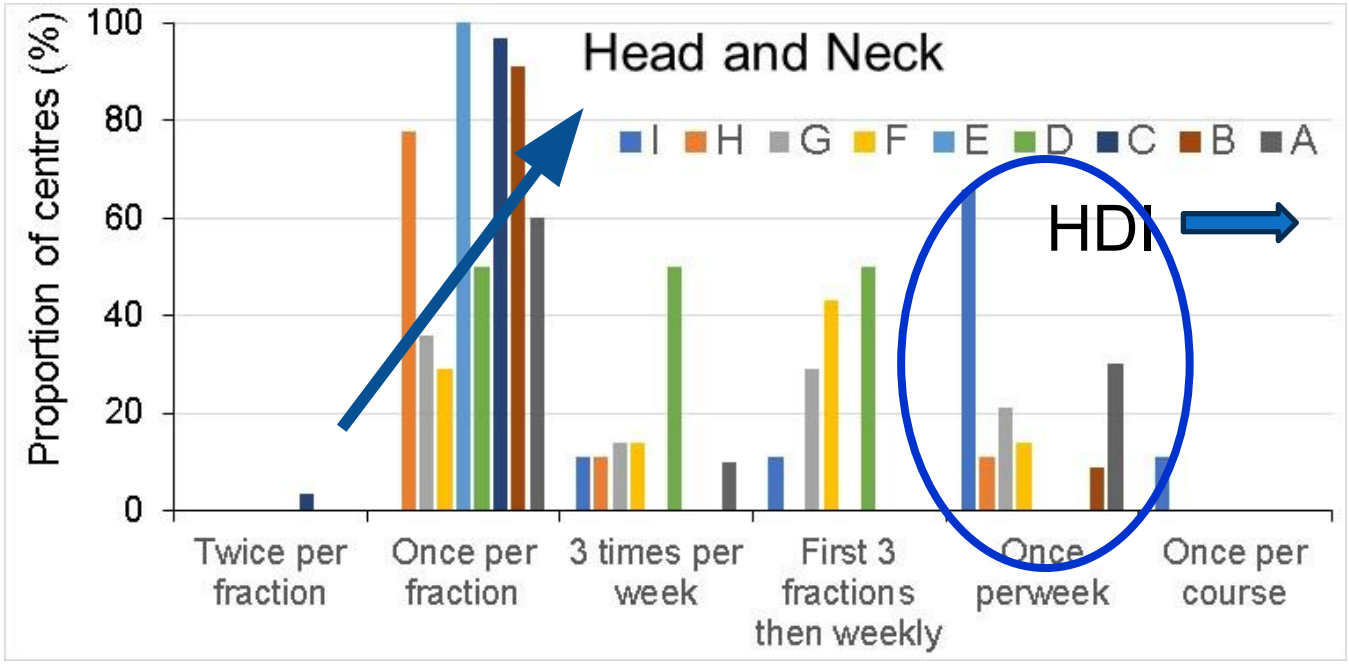


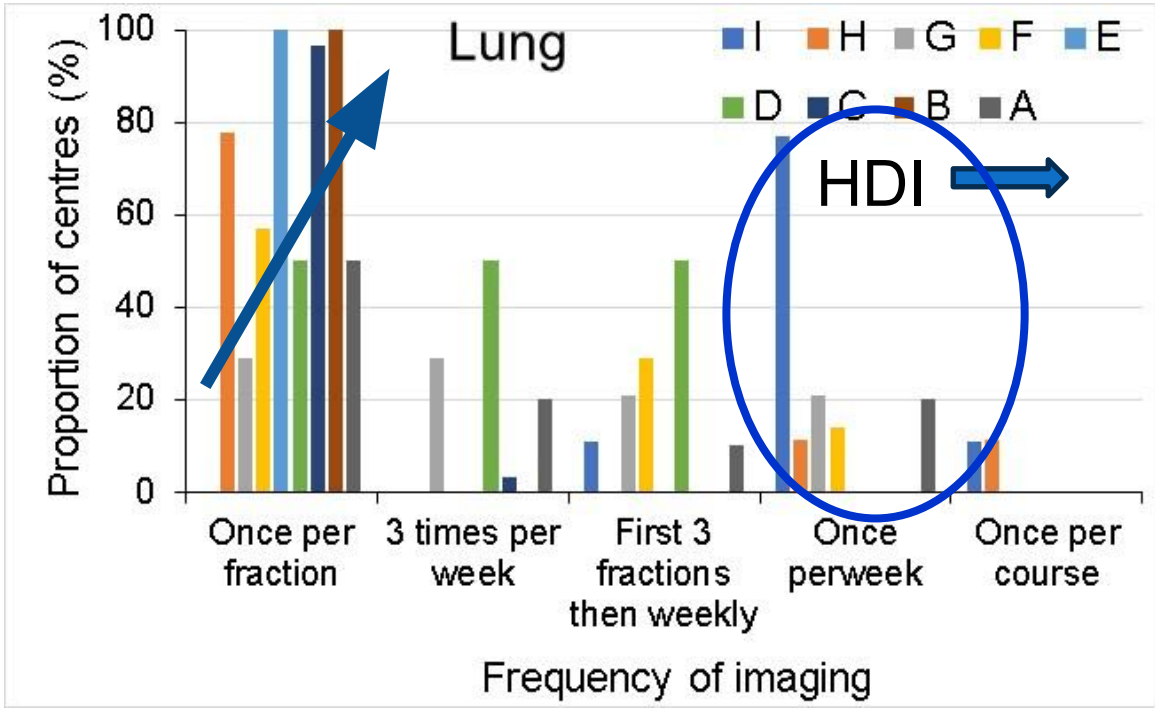
Country with lowest HDI imaged once per course of treatment or once per week

3 Frequency of verification imaging

Head & neck and Lung

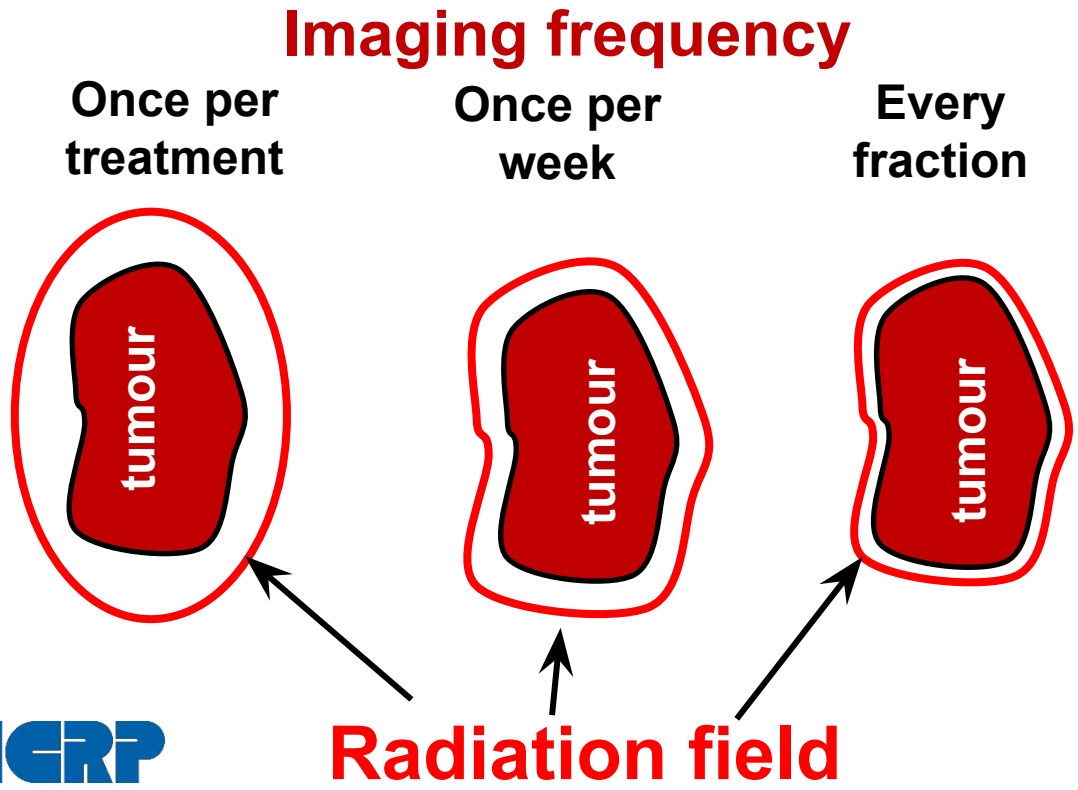
- Higher income countries image at every fraction
- Country with lowest HDI had few linacs with kV imaging
- RT centres imaged once per week or once per course of treatment





The balance between imaging dose and reduction in treatment margins

- Dose margins around tumour targets are used to account for uncertainty in delineation, anatomical changes, motion, patient positioning (ICRU 50, 62, 83)
- The smaller the margin, the higher the imaging frequency



- Cumulative doses from imaging will contribute to risk of secondary cancers.
- There is a balance between reducing the high dose margin around the target and lowering the dose from imaging to surrounding normal tissues

4 Adaption of imaging protocols and recording of imaging doses

Choices in optimisation of IGRT:

- Frequency of imaging
- Volume of tissue to be imaged
- Level of image quality required

Survey results

- 90% of RT centres use vendor imaging protocols for CBCT in 2/3rd countries
- Surveys have shown that vendor protocols are often not optimised for radiological protection
- Fewer than 50% of RT centres make adjustments to protocols for individual patients

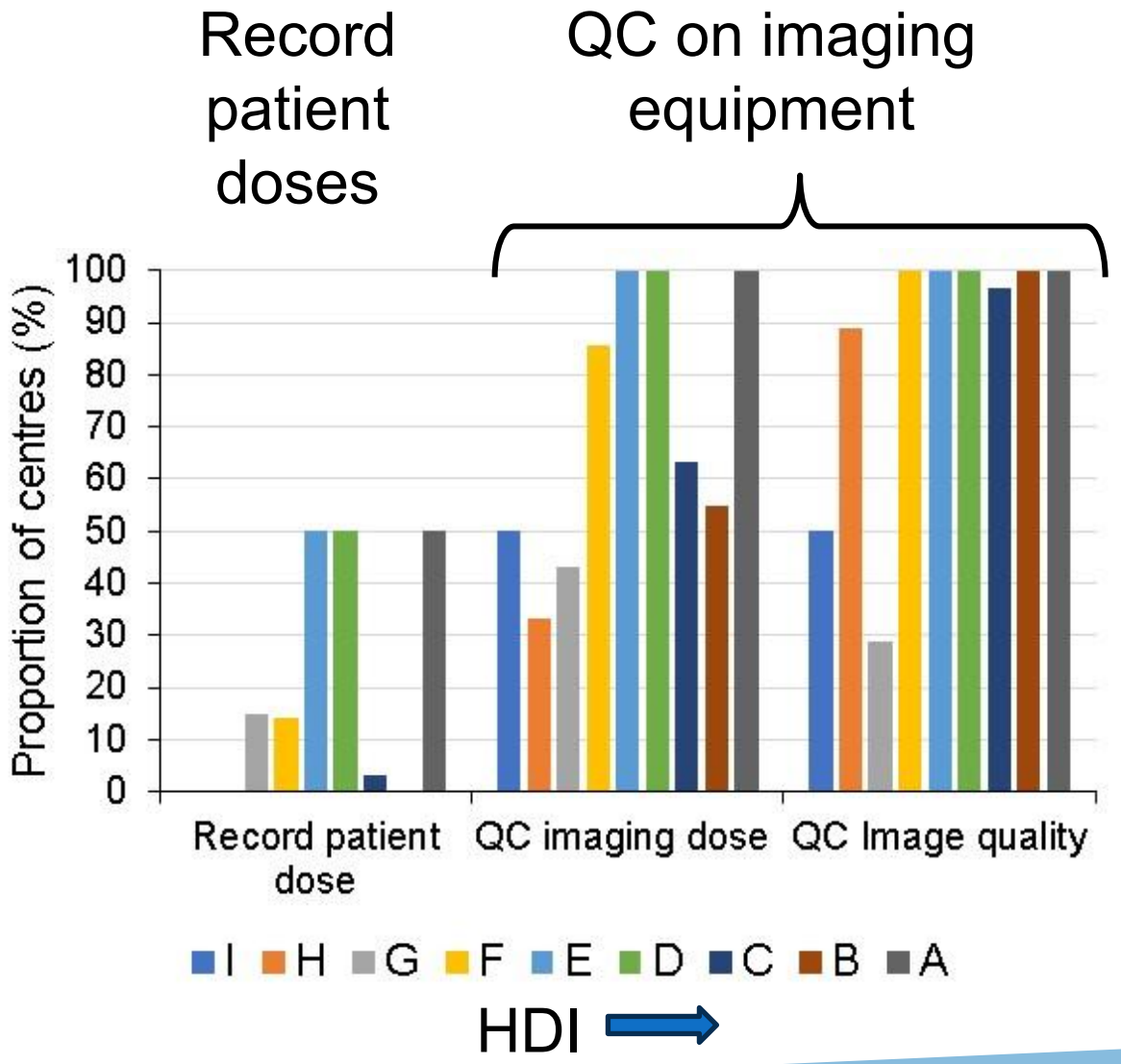
No dose information provided or recorded by most treatment platforms during IGRT

5 Radiation doses from imaging and Quality Assurance

- Optimisation of radiological protection requires a knowledge of patient doses
- 50% of European RT centres recorded patient doses
- <10% of RT centres in other parts of the world record recorded patient doses

QA

- Most centres in higher HDI countries measure image quality during QC tests, but many do not measure dose quantities
- Centres in countries with lower HDIs do not have tools to measure imaging doses



Quality Assurance

Frequency

- The frequency tended to decline with the HDI of the country
- QC tests were not performed at all on imaging equipment in some centres in the two African countries

Guidance

- National guidelines
- AAPM Task Group reports, ACR guidelines
- Vendors guidance
- Instructions linked to performance evaluation tools

Quality Assurance

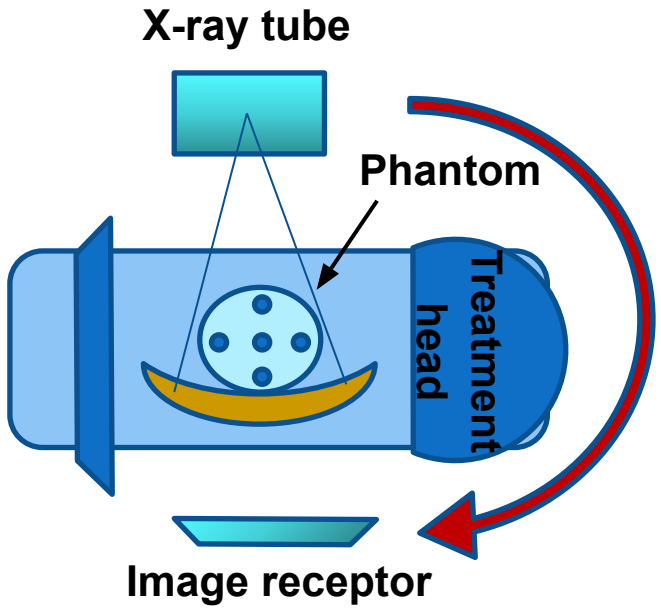
Who is performing QA?

- Different healthcare staff groups with medical physicists making up the largest proportion some being trained diagnostic physicists and others therapy physicists adapting their skills.
- Some RT centres also reported that tests were carried out by third party companies or equipment engineers, and not by medical physicists or radiographers within the RT centre.
- The amount of performance testing appears to be generally increasing with a number of RT centres commenting on changes they were introducing currently or planning for the near future.

Lack of optimisation of imaging RT

REASONS

- Many CBCT units do not display a dose quantity
- Current techniques for measuring doses from CBCT are complex and require imaging specialist equipment
- RT physicists need the training, practical experience, technical equipment, guidance for imaging dose optimization in IGRT – and also time!



Summary

IGRT has become the standard of care in EBRT in the majority of countries

- Most RT centres use radiologic images for verification in 75%-100% of treatments
- Cone beam CT is the main IGRT modality in high- and middle-income countries
- These countries frequently image at every fraction
- Most centres use vendors protocols with limited optimisation
- Fewer than 50% of RT centres record patient doses from imaging

Next steps

- **TG-116 decided to focus on the management CBCT dose**
- **Evaluate current dose measurement methods for CBCT**
  - Impractical methods
- **Develop a practical dose measurement method for Radiotherapy Centers**
  - Topic of session 12 presentation “ICRP TG-116 CBCT dosimetry project”
- **Include the method in TG-116 report recommendations**

Radiological protection aspects of imaging in radiotherapy

ICRP

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Annex

A. IMAGING TECHNIQUES USED IN RADIATION THERAPY
B. CONE BEAM CT DOSIMETRY
C. ERRORS IN TREATMENT INVOLVING THE APPLICATION OF IMAGING

ICRP TG116
Mentee Project 2

Measurement of CBCT imaging dose

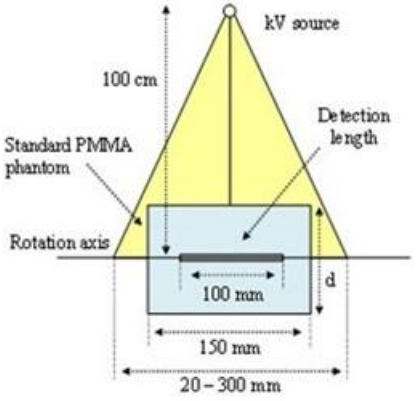
Few radiotherapy centres:

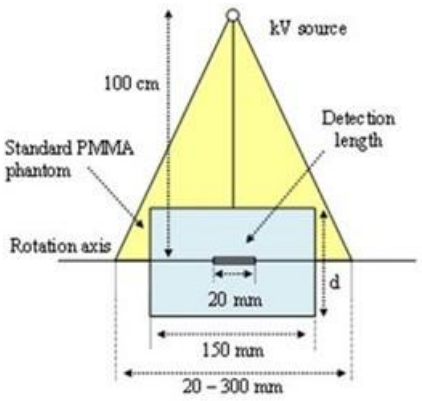
- Measure CBCT doses
- Have methods which could be use to measure CBCT dose

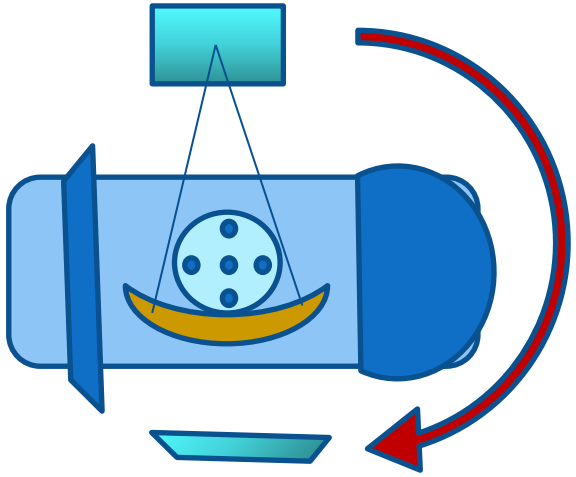
Countries participating

Europe and N. Africa	Rest of the World
Germany, Portugal	Australasia, USA, UAE
Serbia. Cyprus, Algeria	Saudi Arabia, Malaysia
	Colombia, Iraq

Project: Determine feasibility of measurement of the CBCT dose with a wide beam used in the clinic using a 150 mm CT phantom and chamber (100 mm and/or 0.6 cc).







Spreadsheets prepared for data collection