

# IMAGE GUIDANCE DOSES IN RADIOTHERAPY

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# IMAGING DOSE

ALARA requires that imaging dose is managed and optimised

Imaging dose presents an increased risk for paediatric patients

- Increased effective dose
- Increased radiosensitivity
- Longer remaining life span

*Hence ...*

image  
gently®



The Image Gently Alliance



Australian Government

Australian Radiation Protection  
and Nuclear Safety Agency

## Fact Sheet

### CT Imaging and Children

CT imaging (CT scanning) is an important medical diagnostic technique that is used on adults and children of all ages.



The Royal Australian and New Zealand  
College of Radiologists\*

Recommendations for Imaging in Children in Non-Dedicated Paediatric Centres

# RADIATION THERAPY

In radiation therapy, this often isn't prioritised. Imaging dose is much less than therapeutic dose; and so benefits of optimisation are reduced.

There have been few efforts to establish dose reference levels, as in diagnostic imaging.

Investigators that have implemented DRLs (using dose length product or dose index volume, CTDIvol) have noted large variations between centres.

European Commission have recommended dose inter-comparison programmes between radiotherapy centres (not DRLs) should be applied.

# RADIATION THERAPY

Dose optimisation in radiation therapy is most important in image-guided techniques, where imaging is more frequent.

This imaging significantly reduces errors and allows more conformal treatments; so there is plenty of justification for exposure.

But the obligation to optimise exposure remains.

AAPM Task Group 180 published a report on image guidance doses.

It is intended to supplement the report of AAPM Task Group 75, on the same topic.

## The management of imaging dose during image-guided radiotherapy: Report of the AAPM Task Group 75

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## Image guidance doses delivered during radiotherapy: Quantification, management, and reduction: Report of the AAPM Therapy Physics Committee Task Group 180

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# AAPM TG180

Should we be worried?

AAPM TG180 notes a single image acquisition using kV energies can deliver a dose of 0.1–5.0 cGy to the patient depending on the imaging modality.

A kV-CBCT procedures employed for pelvic imaging can add a cumulative dose of 1–3% of the prescription dose during the course of treatment.

Dose variations as small as 5% may lead to real variations in both tumor response and the risk of morbidity.

ICRP life time probability of inducing fatal cancer is  $5 \times 10^{-5}$  per mSv.

TG75 provides an example of a 30 year old woman with daily imaging over 30 fractions: 8.2 mSv effective dose per CT – 246 mSv total, which is a 1.2% probability of radiation-induced cancer.

# THERAPEUTIC DOSE OUTSIDE THE FIELD

TG75 recommended that the community investigate the calculation of effective dose from the primary and scattered therapy beam so that imaging and therapy dose can be properly compared.

Some authors have established doses and risks of secondary cancer due to peripheral radiation based on models.

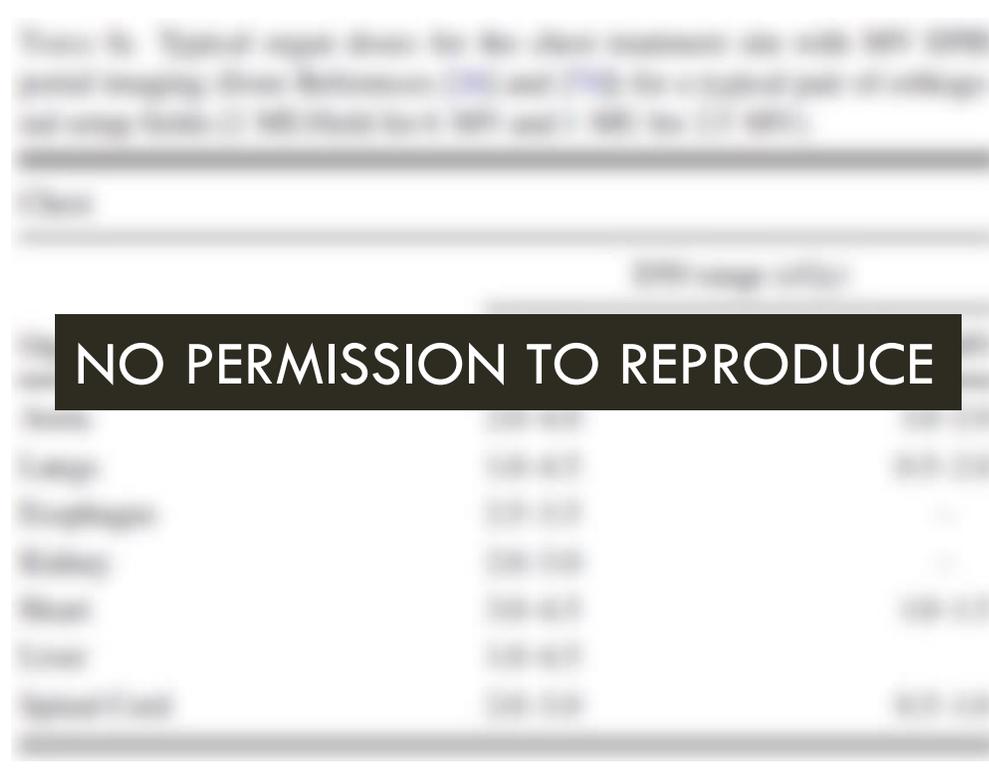
Followill et al. (1997) suggested whole-body equivalent doses per Gy for a 6 MV beam was 8 mSv – minimum of 0.4% cancer risk based on NCRP data.

Kry et al. (2005) suggested maximum risk of fatal secondary malignancy was 1.7% for 3DCRT and 2.1% for 10 MV IMRT.

Ruben et al. (2008) suggested risks between 0.5% and 2% depending on technique (3DCRT/IMRT), region, and risk model.

Uselmann & Thomadsen (2015) estimated mean effective dose to non-target organs of radiotherapy patient population as 298 mSv (using ICRP 60).

# PORTAL IMAGING, TG180



# CONE BEAM CT, TG180

Table 1. Typical values for the cone beam CT system TG180. The values are given in the units indicated in the table. The values are given in the units indicated in the table. The values are given in the units indicated in the table.

Parameter	Value		Parameter	Value	
	Unit	Value		Unit	Value
Beam diameter	mm	180	Beam diameter	mm	180
Beam length	mm	180	Beam length	mm	180
Beam width	mm	180	Beam width	mm	180

NO PERMISSION TO REPRODUCE

Parameter	Value		Parameter	Value	
	Unit	Value		Unit	Value
Beam diameter	mm	180	Beam diameter	mm	180
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Table 2. Typical values for the cone beam CT system TG180. The values are given in the units indicated in the table. The values are given in the units indicated in the table. The values are given in the units indicated in the table.

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# QUESTIONS

1. What image guidance are you using in the department? What energies are used?
2. Have you measured or calculated beam quality or dose for that imaging system? How was that measured or calculated? In-air / in-phantom?
3. Has it been checked since acceptance? How often is it checked?
4. Have any local protocols been developed to optimise / reduce the imaging dose?
5. How many images might be acquired with that system per fraction?
6. Is any imaging dose reported or accounted for? If so, is it patient- or nonpatient-specific? Is any in-vivo dose verification performed?

**PRESENTATIONS FROM  
NANCY, STEVE & TANYA**

# TASK GROUP RECOMMENDATIONS

# RECOMMENDATIONS, TG-75

1. In all IGRT treatments, compile a complete picture of all of the imaging procedures to be used before, during, and after treatment;
2. Identify those image-guidance steps that can potentially be accomplished without the use of ionizing radiation;
3. Configure the image acquisition systems to eliminate dose outside the required FOVs;
4. Plan the imaging technique to be consistent with the image quality and information needed for the treatment decision being made;

# RECOMMENDATIONS, TG-75

5. After arriving at an IGRT imaging scenario that eliminates un-needed dose and optimizes the required exposure, use the resources of this report to estimate the total effective imaging dose, from all sources, that the patient will receive;
6. Evaluate the total dose patient-by-patient using guide-lines for estimating stochastic and deterministic risk, with the understanding that the diagnostic imaging community relies on judgment rather than prescription in assessing individual exposure risk.

# RECOMMENDATIONS, TG-180

1. Reduce the imaging field size as much as possible. This will reduce the volume of irradiated tissue surrounding the target. Reducing the cranial-caudal extent of kV CBCT scans can also significantly reduce the integral as well as scattered dose in the volume
2. During patient setup for MV portal images, minimize the imaging field size without removing reference structures needed for patient alignment. For images acquired for documenting delivery, select “image during treatment” to avoid adding additional dose to the patient.

# RECOMMENDATIONS (TG-180)

3. For Tomotherapy units, select MVCT scan pitch parameters that balance imaging dose with clinical need (i.e. patient positioning or adaptive planning). The imaging dose differs significantly when different pitch parameters are selected.
4. For MV-CBCT, select a patient-specific MV imaging protocol and restrict the imaging field of view (FOV). The imaging dose can be reduced if bony anatomy rather than soft tissue is used for treatment localization. Note that the degree of dose reduction possible will depend upon the image quality requirements of the clinicians.

# RECOMMENDATIONS (TG-180)

5. When deciding between 2D radiographs or 3D volumetric images, consider the image requirements. As ALARA is the guiding principle, consider 2D if two planar orthogonal kV images are sufficient for the task. The organ doses from image guidance can be reduced by a factor of 10 using 2D kV imaging compared to 3D kV-CBCT.
6. Optimize imaging parameters (e.g., kVp, mAs) and select appropriate manufacturer-provided default clinical protocols (pelvis, abdomen, thorax, head and neck) for different normal adult body sites. In the case of pediatric patients with a small body size, default low-dose protocols for a head and neck kV-CBCT scan can be used to image a pelvic site. This reduces imaging dose by a factor of 2–3 without compromising the image quality.

# RECOMMENDATIONS (TG-180)

7. The kV-CBCT scan protocols that use partial rotation provide the opportunity to selectively avoid irradiating superficial organs. The technique can be used to dramatically reduce the dose to the eyes; or the bladder or rectum.
8. Since the beam exit dose is only a few percent of the entry dose for kV x rays, the beam directions used for orthogonal planar images can be selected to minimize dose to critical organs.
9. Consider the use of full bow tie filters when acquiring planar kV images. Bow tie filters can significantly reduce skin dose and dose to organs at risk.

# OTHER RECOMMENDATIONS & QUESTIONS

TG-180 recommends [dose] consistency checks should be performed annually and after each system upgrade.

European Commission have recommended dose inter-comparison programmes between radiotherapy centres (not DRLs) should be applied.

1. Do you object to any of these recommendations?
2. Any comments on possible implementation in your clinical department?
3. Any additional recommendations to make?

# WORKSHOP SESSIONS



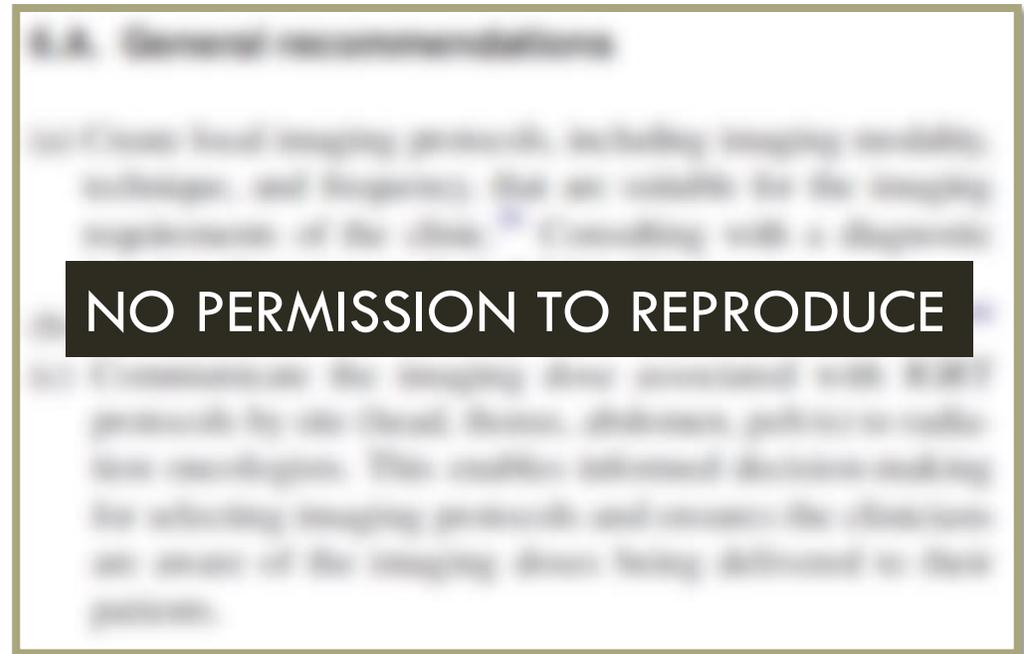
# CASE 1: DEVELOP PROCEDURE

Draft a procedure for **measuring, optimising** and/or **quality assurance** of imaging dose in your radiation oncology department.

How might you **justify** imaging dose?

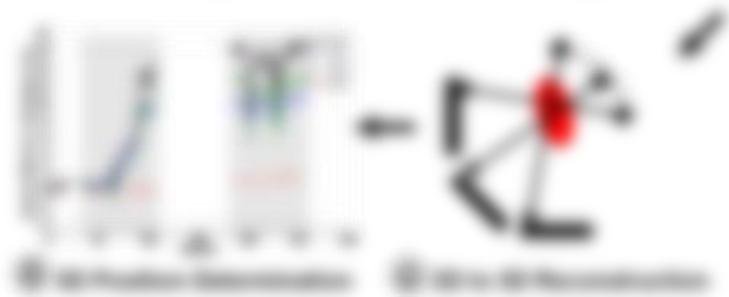
What **reporting** should you perform?

Point form notes, to be shared with the group.



# CASE 2: KILOVOLTAGE INTRAFRACTION MONITORING

Case: clinicians want MLC-tracking system for prostate and lung SABR, specifically KIM



First clinical use of KIM for prostate featured:

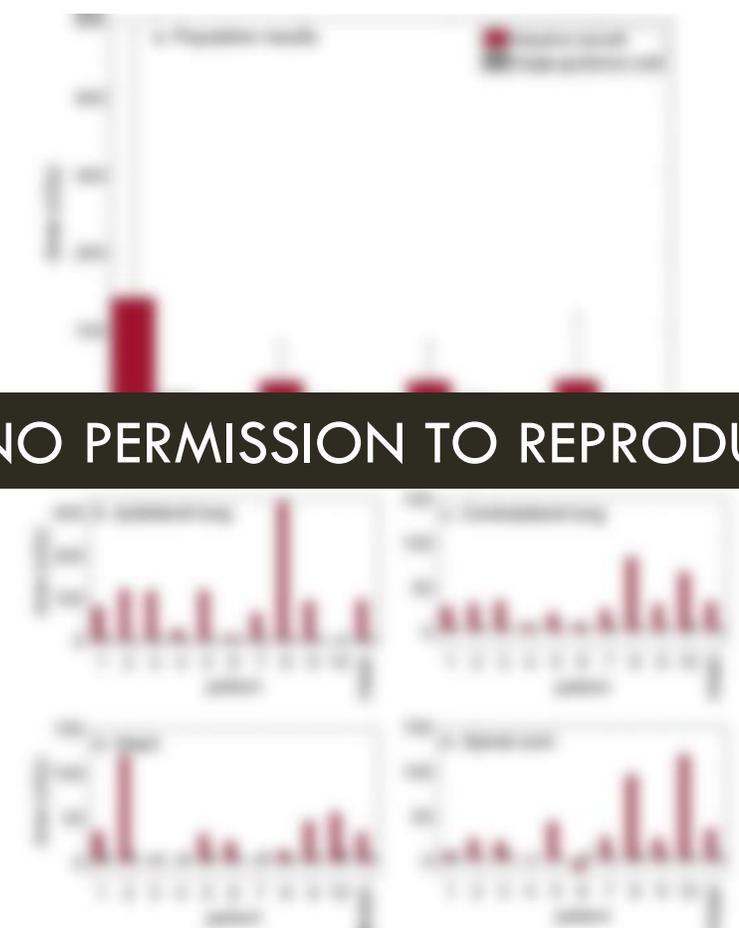
- Pre-treatment  $120^\circ$  kV arc
- Continuous imaging at 10 Hz, with 125 kVp, 80 mA, 13 ms and a field size of  $6 \times 6$  cm<sup>2</sup>.

How might you **estimate, measure, report, justify** and **optimise** the imaging dose delivered?

# CASE 2: KILOVOLTAGE INTRAFRACTION MONITORING

Lung SABR application:

- 10 mAs and 125 kVp, 5 Hz
- Field size was  $15 \times 15 \text{ cm}^2$
- VMAT deliveries of 60-350 s in length
- Mean doses of 12.2 cGy (ips. lung), 5.6 cGy (cont. lung), 8 cGy (heart), 6.5 cGy (spinal cord) over treatment.
- Less than extra dose due to potential larger treatment volumes.



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