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Managing Patient Dose in Multi-Detector Computed Tomography (MDCT)

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Abstract—Computed tomography (CT) technology has changed considerably in recent years with the introduction of increasing numbers of multiple detector arrays. There are several parameters specific to multi-detector computed tomography (MDCT) scanners that increase or decrease patient dose systematically compared to older single detector computed tomography (SDCT) scanners. This document briefly reviews the MDCT technology, radiation dose in MDCT, including differences from SDCT and factors that affect dose, radiation risks, and the responsibilities for patient dose management. The document recommends that users need to understand the relationship between patient dose and image quality and be aware that image quality in CT is often higher than that necessary for diagnostic confidence. Automatic exposure control (AEC) does not totally free the operator from selection of scan parameters, and awareness of individual systems is important. Scanning protocols cannot simply be transferred between scanners from different manufacturers and should be determined for each MDCT. If the image quality is appropriately specified by the user, and suited to the clinical task, there will be a reduction in patient dose for most patients. Understanding of some parameters is not intuitive and the selection of image quality parameter values in AEC systems is not straightforward. Examples of some clinical situations have been included to demonstrate dose management, e.g. CT examinations of the chest, the heart for coronary calcium quantification and non-invasive coronary angiography, colonography, the urinary tract, children, pregnant patients, trauma cases, and CT guided interventions. CT is increasingly being used to replace conventional x-ray studies and it is important that patient dose is given careful consideration, particularly with repeated or multiple examinations.

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Guest Editorial

BENEFITS AND COSTS, AN ETERNAL BALANCE

This ICRP *Publication* on managing the dose the patient receives in the era of multi-detector computed tomography (MDCT) is very timely. Not all workers involved in CT fully appreciate the specific parameters in MDCT which increase or decrease the dose imparted to patients compared with the original single slice CT machines. The various technological options, including automatic exposure control, are well covered in this report. Each institution must agree on various protocols to allow the production of diagnostically adequate images at reasonable radiation cost. Thus the report emphasises that image policy should be specified by the users and appropriately suited to the clinical task. For certain clinical conditions (e.g., the detection of lung nodules) there can be considerable savings in radiation with virtually no detriment to patient care. Similarly requests for imaging in paediatric practice and in pregnancy can be handled with marked dose reduction. Recently it has been shown that in CT colonography, there may be good grounds for not worrying too much about tiny lesions (Pickhardt et al., 2007); this may allow lower-dose protocols to be adopted with more confidence.

CT has become the pre-eminent method of examining patients with ionising radiation. Because of the versatility provided by newer multi-detector CT systems, it is fast replacing the clinical examination of the patient. For example, in the acute abdomen there is increasing evidence that the plain abdominal radiograph can be safely discarded and the whole triage of the patients now often depend on the CT findings (discharge, admit, observe, surgery – see Ng et al., 2002). So fast is the growth of CT that around 75 million CTs are performed annually in the USA for a total population of around 300 million. CT has virtually replaced the IVU, the barium enema, and much diagnostic angiography. In years to come it is possible that even the chest x-ray for a patient with dyspnoea may be replaced by low-dose CT.

Radiologists are de-skilling in the interpretation of CXRs; the lateral view is now performed much less commonly with nearly all patients with equivocal findings on a PA CXR being referred on for CT. CT is even needed when the CXR is definitely abnormal in order to clarify the nature of those abnormalities. Furthermore the image quality of the scout view/scannogram/digitally acquired radiograph is challenging the image quality of certain aspects of the CXR (lung bases, bones, etc.). Thus, for all these reasons, a review reminding everyone in the health care industry of the radiation issues is pertinent.

Many workers have shown the disproportionate radiation burden to the community from CT compared with the relatively low number of procedures performed. And this is particularly true in paediatric practice. Thus every time a child or young or pregnant patient is referred, one should think about whether the clinical question could be satisfactorily answered by a technique which avoids ionising radiation. We should be using US and MR whenever possible in children. In adult practice we should avoid lumbar spine CT; one exception is bone mineral quantification although such measurements can also be obtained at a much lower dose by techniques such as DEXA.

Even when CT is the optimal investigation for the clinical problem and recommended by guidelines (RCR, 2007), there are many tricks of the trade which can reduce dose. It has become widely appreciated that an un-enhanced series is not indicate for the majority of body CT examinations; perfusion studies and CT urography are obvious exceptions to this rule. Any technique that requires un-enhanced, early arterial, late arterial, early portal, late portal, and delayed imaging can lead to an enormous radiation dose (Dixon and Goldstone, 2002). Thus such repeat sequences should only be used in exceptional circumstances. Indeed nearly all clinical questions can usually be answered by two sequences at most.

Whilst it is possible to reduce the radiation dose to certain specific questions (such as the lung nodule identification alluded to above), it is controversial whether initial **diagnostic** CT examinations, where the diagnosis may be unknown, should be performed with reduced dose parameters. One of the inherent advantages of CT is that a full data set is obtained, providing full information about a range of tissues (bones, muscles, internal organs etc). This data set can be re-interrogated at a future date to answer specific questions which may emerge during a patient's hospital admission.

For example, even if the initial clinical question was for 'lung parenchyma for possible sarcoidosis', it may turn out that the patient has a possible underlying malignancy, in which case close interrogation of the bones would also be needed. Bone texture would not be all that well demonstrated on a low-dose chest examination. This concept of obtaining the maximum possible information during any **initial** CT examination has been adopted by many departments. The CT data set is an information bank which can be interrogated at many different settings at a later date.

Indeed, if the all the raw data are saved, one can re-analyse at high special algorithm for high resolution images in order to demonstrate fine detail of the lung or sagittal images of the thoracic spine and vertebral canal. If the initial investigation is comprehensive, it may very well save a repeat CT and other investigation, some of which might involve ionising radiation. In the example of the patient with 'query sarcoidosis', who turns out to have a malignancy, an NM skeletal scintigram may be avoided if the bones have been comprehensively examined by CT. Such arguments are further extended by radiology centres that promote 'whole body' CT screening. Despite the high radiation dose such examinations appear to be on the increase, even though many counsel against widespread screening for asymptomatic patients (Dixon, 2004). It will be interesting to see how whole body MR screening competes with CT screening in the future.

This paper also highlights the need for additional training for all workers involved in CT. This should include the correct education of medical students about the dose implications of CT. It necessitates the continual education of clinicians requesting CT examinations. But, above all, there should be extensive and ongoing training for the CT technicians/radiographers who control the CT examination parameters. While those responsible for an institution will happily pay several hundreds of thousands of dollars/euros for a new CT machine, those same individuals are often very reluctant to invest much in radiographic training and continuing medical education, or in medical physics support to monitor the radiation aspects of CT.

In short it is an honour to write an accompanying editorial to this review. I very much hope that at least the summary points are read by the appropriate administrators.

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CONTENTS

SUMMARY POINTS	9
GLOSSARY	11
1. MDCT TECHNOLOGY	17
1.1. Background	17
1.2. Introduction to MDCT technology	18
1.3. Differences between SDCT and MDCT	19
1.4. Upcoming developments	22
1.5. What is the motivation for this report?	22
1.6. References for Chapter 1	23
2. RADIATION DOSE IN MDCT	27
2.1. Introduction	27
2.2. Are doses in MDCT different and if so, why?	27
2.3. What are the considerations for users switching over from SDCT to MDCT?	29
2.3.1. Factors that can increase dose in MDCT	29
2.3.2. Factors that can decrease dose in MDCT	30
2.4. Dose surveys and diagnostic reference levels	30
2.5. Perspective on radiation risks	32
2.5.1. Deterministic risk	32
2.5.2. Stochastic risk	34
2.6. Responsibilities for patient dose management	34
2.7. References for Chapter 2	35
3. WHAT CONSIDERATIONS AND ACTIONS AFFECT PATIENT DOSE?	39
3.1. Compromise between dose and image quality	39
3.1.1. General descriptors of image quality	39
3.1.2. Different imaging tasks require different levels of quality	40
3.2. Equipment and protocol issues affecting patient dose	41
3.2.1. Overbeaming	41
3.2.2. Overranging	42
3.2.3. Image thickness	43
3.3. Operator choices that affect patient dose	45
3.3.1. Scanner model and manufacturer	45
3.3.2. Tube current (mA) and tube current–exposure time product (mAs)	46
3.3.3. Image quality selection paradigms	50
3.3.4. Temporal mA modulation	53
3.4. Tube voltage (kVp)	53
3.5. Pitch, beam collimation, and slice width	54
3.6. Scan coverage and indication	54

3.7.	System software: Image reconstruction, noise reduction, and metal artefact reduction algorithms	55
3.8.	Modification of scan acquisition and reconstruction parameters	55
3.9.	References for Chapter 3	56
4.	DOSE MANAGEMENT IN CLINICAL PRACTICE.....	59
4.1.	Justification of examination	59
4.2.	Training issues.....	60
4.3.	Techniques and doses for particular CT examinations	61
4.3.1.	Chest CT.....	61
4.3.2.	CT for coronary calcium quantification and non-invasive coronary angiography	63
4.3.3.	CT colonography.....	65
4.3.4.	CT for trauma	65
4.3.5.	CT of the urinary tract.....	66
4.3.6.	CT-guided interventions	67
4.3.7.	CT in children.....	67
4.3.8.	CT of the pregnant patient.....	68
4.4.	Future directions	69
4.5.	References for Chapter 4	70
APPENDIX A.	HOW TO DESCRIBE DOSE IN CT.....	73
A.1.	Computed tomography dose index (CTDI).....	73
A.2.	Dose length product (DLP)	75
A.3.	Organ dose and effective dose	75
A.4.	Dose estimation tools.....	76
A.5.	Developments in CT dosimetry	76
A.6.	References for Annex A.....	78

PREFACE

Over the years, the International Commission on Radiological Protection (ICRP), referred to below as ‘the Commission’, has issued many reports providing advice on radiological protection and safety in medicine. Its *Publication 73* is a general overview of the area. These reports summarise the general principles of radiological protection and provide advice on the application of those principles to the various uses of ionising radiation in medicine and biomedical research.

Most of those earlier reports are of a general nature. More recently, the Commission has focused on addressing some more specific situations where difficulties have been observed. A series of such reports was initiated at the Commission’s meeting in Oxford, United Kingdom, in September 1997. On the recommendation of ICRP Committee 3, the Commission has established a number of Task Groups to produce reports on topical issues in medical radiation protection. The Commission tries to ensure that reports on such problem areas are written in a style which is accessible to those who may be directly concerned with these issues in their daily work, and that every effort is taken to ensure wide circulation of such reports.

Several such reports have already appeared in print as ICRP *Publications 84, 85, 86, 87, 93, 94, 97, 98*, and *Supporting Guidance 2*. The present report continues this series of concise and focused documents, and several further such advisory reports are being prepared.

ICRP *Publication 87*, published in 2000, dealt with ‘Managing Patient Dose in Computed Tomography’. In that report, multi-detector CT was mentioned in passing in a couple of sentences, but the technique was developing and there was little experience of dose management with MDCT. By 2005, the situation had changed entirely, MDCT was rapidly replacing ‘conventional’ CT equipment, and at the Commission’s meeting in Bern, Switzerland, in September 2005, a Task Group on dose management in multi-detector computed tomography was launched. Its terms of reference were to consider the rapid increase of this new and faster technique and the ensuing new clinical applications, and to discuss parameters specific to MDCT that systematically increase or decrease patient dose. The Task Group was requested to complete its report rapidly.

The membership of the Task Group was as follows:

M.M. Rehani (Chair)	M. Kalra	C. McCollough
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Corresponding members were:

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The membership of Committee 3 during the period of preparation of this report was: