3. Clinical Principles of MSCT

The Concept of Volume Acquisition

The introduction of multislice CT has resulted in a major conceptual shift in how examinations are conducted in CT. In conventional, incremental CT, an examination is built up from successive exposures at different discrete locations in the patient. Ultimately the data gathered relate to a volume of tissue but display may not be complete owing to intervals between the exposed sections. Accordingly, the inherent disadvantages of incremental CT are the inability to examine an organ or body area quickly, and the possibility of failing to detect lesions which fall between or on the edge of exposed sections.

Helical CT, and especially MSCT, has largely eradicated these problems. In helical CT the exposure is continuous while the patient is moved through the gantry and the x-ray beam describes a helix through the tissue. This generates a continuous volume of data from the beginning to the end of the exposure. This data volume is then available for analysis to provide image display.

MSCT has the advantage of acquiring volumetric data very quickly and usually within a single breath-hold. Acquisition is dependent on the beam collimation, the number of detector arrays available, the pitch and the table speed. In practice these parameters are interdependent and cannot be separated from considerations of radiation dose. These factors, together with the level of exposure, determine the quality of data contained in the target volume, most especially the ability to resolve differences in contrast.

The ability to obtain volumetric data rapidly allows examinations to be completed in a short time and greatly reduces the risk of movement misregistration. The entirety of an organ may also be examined at one phase of physiological function, for example perfusion. The technique of CT fluoroscopy represents a particular use of rapid acquisition over a small volume.

MSCT allows large target volumes to be covered with ease. It also permits multiple exposure of the same volume in multiphase studies. Both factors tend to increase examination complexity and patient dose. The temptation to exceed clinically justifiable dose levels must be resisted in practice. The issues of justification and optimisation therefore require particular attention in MSCT.

MSCT differs from incremental CT in that it conceptually separates exposure from image reconstruction. In incremental CT the collimation of the exposure beam defines the characteristics of the primary reconstructed images and constrains the possibilities of a retrospective reconstructions (reformats). In MSCT image reconstructions may be independent of the beam characteristics of the exposure used to acquire the data volume. Although in clinical practice these factors remain linked by considerations of image quality, understanding of the potential of MSCT is aided by considering them from separate viewpoints.

The Concept of Dose Level Selection

MSCT generates with a single exposure a volume of data which forms the basis for image reconstruction. As in incremental CT, the level of exposure and the quality of the image data are closely related, and affect spatial and contrast resolution in the reconstructed image. Exposure must be sufficient to yield an image which is adequate for evaluation but the radiation dose must not be higher than that needed to deliver an adequate image.

In MSCT, as in incremental CT, exposure is affected by tube current, the length of the exposure and the beam collimation, which in turn dictates spatial resolution in the z axis. However in MSCT there are additional factors which make the relationship between exposure and image quality more complex.

In helical CT dose is also affected by pitch, decreasing as pitch increases. The most significant increase occurs when pitch falls below one and there is overlap of the exposure beam. In appropriate circumstances reduction of tube current may be utilised to reduce this effect.

Compared to conventional CT, the penumbral effect at the edge of the exposure is greater in MSCT, particularly in the case of thin beam collimation. This effect is less significant in systems with a large (i.e. 8 or 16) number of detector arrays. Scatter is also relatively higher in MSCT, particularly when using wide beam collimation.

Certain practice logistics may also tend to increase absorbed dose in MSCT. Examinations frequently cover several different areas. When these include areas where high image quality is required it may be logistically convenient to obtain a single acquisition using exposure parameters appropriate to that area, so that other areas included in the target volume receive a higher dose than would have been required if they had been examined separately. Further, the ease of examination possible with MSCT may lead operators to extend target volumes unjustifiably as a precaution against repeat exposures. Finally, the volume and complexity of data created by MSCT may produce workload problems for radiologists, competing with appropriate attention to radiation protection.

As in incremental CT, quality of image data generated is dependent on the clinical requirement. For example, z axis resolution for examination of small structures is improved by thin beam collimation and low pitch, whereas examining a large target volume may require wide beam collimation and a high pitch. Both approaches contain implications influencing image noise and therefore contrast resolution in particular. In practice the clinical indication determines the nature and quality of the images required for interpretation and this in turn defines the primary image reconstruction, which usually dictates the dominant factors for the exposure.

The concept of appropriate dose level selection therefore derives from considerations which are appropriate to the clinical indication. This may be considered as the process of weighting the image towards a particular characteristic, such as contrast or spatial resolution, or speed of acquisition in the case of covering a large area or examining a restless patient in a short time.

This concept of weighting or setting an appropriate dose level to yield a dominant image characteristic does not preclude significant dose reduction. Those operating CT equipment must exercise constant awareness of the need of this. For example, a high resolution study of small structures requires thin beam collimation and a low pitch to improve z axis resolution but if the structure has high natural contrast the effect of these in increasing exposure may be counteracted by significant reduction in tube current.

MSCT holds additional potential for reducing absorbed dose. Different types of image may be reconstructed from one data acquisition without the need for second exposure. In practice the reduction of anatomincal mis-registration and other forms of movement artefact made possible by MSCT should reduce the need for repeat exposures.

The practice of MSCT must of course concur with national and international regulations and guidelines relating to dose constraint. Examinations must not be conducted unless they are clinically justified and operators must ensure that examinations are obtained with a radiation exposure that is as low as possible with regard to the clinical indication. The general principles are well established by international and national legislation and personnel have a legal responsibility to ensure that their examinations conform to dose reference levels, where these are available. However in MSCT the evidence base for constraint is as yet limited because the technique is newly developed. Those who operate MSCT equipment, therefore, need to exercise constant review of emerging evidence and to ensure that this is incorporated into their practice.

The Concept of Selective Image Reconstruction

MSCT characteristically generates a volume of data, usually of high quality. Indeed, under certain conditions of beam collimation, field of view and matrix, the voxels and spatial information contained in the volume may be isometric. These circumstances offer more choice in the selection of image reconstruction than is provided by incremental CT.

In incremental CT beam collimation and exposure usually define the parameters of the primary reconstructed image and further reconstruction is only possible within constrained limits. In MSCT the volumetric data may be used to produce axial sections of varying thickness, or images in different planes by multiplanar reformatting, or three-dimensional images produced by surface rendering, maximal intensity projection or volume rendering. Any number or combination of these images may be extracted from the data without further exposure of the patient.

The primary image reconstruction is usually made in the axial plane but this may not the primary source of diagnostic evaluation. The concept of volumetric acquisition in

helical CT makes it possible to regard axial image reconstruction as just one application of planar reconstruction within a multiplanar capacity.
This flexibility allows the radiologist to select the imaging plane and characteristics most appropriate to the clinical indication. For example, in CT angiography multiplanar reformatted images following the course of the vessel or maximal intensity projections may be more appropriate for evaluation than conventional axial sections. Software programmes available on most systems now permit a wide range of approaches to display of the original data.
A drawback of this approach is that selective reconstruction usually discards some of the information in the data volume. However it is important that all potential information from the exposure is preserved. For this reason it is usual to create for archive one set of reconstructed images which contains the maximum information available from the acquisition. These images will usually be in the axial plane and will contain the most detailed information available. These images may not be inspected as part of the diagnostic evaluation but must always be available for review in cases of difficult interpretation, or to provide information about organs or structures which may not initially be part of clinical indication. These images are referred to as the primary reconstruction (i.e. the reconstructed sections) in the practice guidelines which follow. An important characteristic of the primary reconstruction is that it frequently defines the limit of spatial resolution in the examination and the reconstruction parameters are therefore dictated by clinical indications.
The practice guidelines also give recommendations on secondary reconstruction or viewing slices. These are the images which will normally be the primary source of diagnostic evaluation and will vary according to the clinical indication. As indicated above, they may consist of images in different planes and of different slice thickness, or any combination of these. It is not obligatory to archive these images as they can be reproduced from the primary reconstruction at a later date if necessary but in practice it will frequently be found convenient to archive viewing images which are of significant importance to diagnostic evaluation. This approach adds to the significant storage capacity needed for archiving images from MSCT.

Please refer to the quality criteria as:

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European Guidelines for Multislice Computed Tomography
Funded by the European Commission
Contract number FIGM-CT2000-20078-CT-TIP
March 2004