Review Article

3 DIMENSIONAL CT

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ABSTRACT

3 Dimensional Computed Tomography (3D CT), has proved to be an extremely useful tool in the evaluation of varied pathologies. In this article, we have attempted to briefly review the physical principles involved and to outline the technique of acquisition of 3D images.

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Introduction

Three dimensional CT (3D CT) is essentially a method of surface rendition of anatomy by means of a special computer software. The software is available in modern CT scanners as an optional package, or may be available as an auxiliary unit to be used in tandem with an existing scanner [1]. This technique has been experimentally tried since the early 1980's [2] and its use has been documented in the evaluation of craniofacial and peripheral musculoskeletal pathologies [3]. These still form the mainstay of indications for 3D CT.

BASIC PHYSICAL PRINCIPLES

3-D CT is a surface rendition. It is performed with the help of a sophisticated software programme. The procedure consists of obtaining plain axial scans of the region of interest. The computer is then provided with a carefully selected 'threshold' attenuation value. The programme scans each CT slice line by line and records the exact co-ordinates of each pixel that shows an attenuation value higher than the chosen threshold. For example if a attenuation value of +200 HU is chosen, only those pixels with an attenuation value of +200 HU or more will be included in the 3D image. These selected pixels represent voxels which are deemed to contain tissue denser than the selected threshold.

The scans are then stacked one on top of the other by the computer and adjacent selected pixels are joined to form a surface rendition. This image is then assigned a surface shading by a virtual light source. Those pixels which are close to the light source are

brightly illuminated whereas the distant ones are suitably shaded. Of course, those pixels which are perceived to be located behind another opaque pixel are not displayed on that surface image. This play of light and shadows is responsible for creating the three dimensional effect [4].

Since the selection of a pixel for incorporation into the 3D image is an all or none phenomenon, there is no grey scale differentiation perceived between the pixels chosen; they are all seen as uniformly white. This means that individual tissue differences cannot be highlighted by this technique [1]. Hence the application of 3D CT is mostly limited to the imaging of bony pathologies. On the other hand, a significant corollary of this is that low mAs, low contrast axial images can be used to generate excellent 3D images. This has a bearing on patient dose, as will be discussed later. One may sometimes attempt to display certain internal soft tissue lesions with 3D, if their Hounsfield value is sufficiently higher than surrounding structures, by selecting threshold values suitable to include the lesion. This is possible in the case of vascular pathology like AV malformation, and highly vascular or calcified tumors [5].

SCAN PARAMETERS

The scan parameters used were as follows:

k Vp: This was always 133 kVp.

mAs: We used low mAs of 190-200 as a standard for all studies.

Scan times: The scan times were kept as short as possible in order to reduce motion artifacts. Scan times of 2 sec and 2.7 sec were used as standard.

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Slice thickness: Thin overlapping slices are ideal. Hence 1 to 5 mm slice thickness with contiguous slices or overlapping slices in the region of interest were obtained.

RECONSTRUCTION PARAMETERS AND OPTIONS

REGION OF INTEREST RECONSTRUCTION: It is possible to select a small region of interest within the area scanned and to selectively reconstruct it in 3D format.

THRESHOLD VALUE: We selected a constant threshold value of +200 HU for bone renditions and -150 HU for skin. The low value for skin was chosen to highlight the interface between skin and air by reducing partial volume averaging. Selection of constant threshold values was with a view to standardization of technique for technicians as well as providing comparability in follow up.

LIGHTING: Lighting is a specialised form of post processing of the reconstructed 3D image that helps to provide the depth effect in the image. The standard display has the light source positioned as if it is directly behind the operator. This may however be moved to any point on the screen to provide the desired perspective. This option was exercised in many cases.

DISPLAY MATRIX: Both 256 x 256 and 512 x 512 display matrices are available with the programme. A 256 x 256 matrix is preferred, as the 512 x 512 matrix leads to an inordinate increase in the reconstruction time, of the order of upto five times and more [1].

DISPLAY OF IMAGES: There is a standard display of six views namely, top, bottom, left, right, front and back views. Additional views are also possible if required. This is done by presenting the 3D image as a "wire frame" on the screen, which may then be rotated in any direction to yield appropriately angled views. Once the angulation is selected, surface lighting of the image is done. It was found that round the clock views prove very helpful in traumatic bony pathology. These round the clock views may be incorporated in serial frames or a cine loop for effective display [6].

EDITING AND CUTTING: Editing refers to the process of deleting certain portions of the image from the 3D image by editing it out of the scan slices before reconstruction. This technique is extremely useful in studying joint pathology, by editing out the bony contours (as in removal of the femoral head in hip joint in order to display the acetabular articular surface) [7].

This technique is rarely used due to the time constraints in a busy department.

Cutting on the other hand, is a function that is performed after reconstruction. The superficial planes may be peeled off to reveal deeper pathology. This technique is used to demonstrate dense intracranial lesions by cutting away part of the overlying skull bones.

ARTIFACTS

It is important to understand that artifacts are common in 3D CT and with a little bit of care, most of them can be reduced, though not completely eliminated. The commonly encountered artifacts are as under:

- (a) Due to patient motion - streak artifacts
- (b) Due to thick slices- Raster lines
- (c) Due to extraneous densities - dense material on clothing, dental fillings etc. produce streaks.

The above represent artifacts of inclusion, that is, the appearance of densities where none are expected. Exclusion artifacts in the form of 'holes' may be seen in thin bones where a few pixels may show density lower than threshold due to partial volume averaging, and consequently be left out of the reconstruction. These are common in orbital roof and lamina papyracea.

ARTIFACT REDUCTION

Motion artifact is minimized by explaining the procedure to the patient and repeated firm instructions to lie absolutely still. Sedation is required in restless and very young patients. Scan times are kept as short as possible to reduce the possibility of motion. Thin slices in the region of interest reduce the Raster lines.

The head rest used in routine scanning has a high Hounsfield value (+400 HU) and can produce artifacts while visualizing the back of the skull [1]. The head rest is to be dispensed with and the patient's head directly secured to the table top. Other sources of high density streak artifacts are to be edited out of the image where they interfere with the visualization.

The problem of 'holes' is to some extent limited by taking thin sections, but for the most part, it has to be accepted as an unavoidable evil in the interest of reducing the patient dose.

ADVANTAGES OF 3D CT

The surface renditions afforded by this technique are life like and provide an excellent delineation of bony pathology. Congenital defects and fractures are well demonstrated from an infinite array of angles as

if the part were in fact being handled by the observer. The exact shape and size of fragments and bony gaps helps the surgeon immensely in planning the surgical approach.

INDICATIONS

The chief indications for 3D reconstruction are:

1. Craniofacial anomalies of congenital origin like craniostenosis and encephalocele, or traumatic origin as in facial fractures. This was illustrated well in a case of a 11 month old child with abnormal shape of the head. 3D CT of the skull revealed evidence of early fusion of the coronal and lambdoid sutures on the left side, with attendant deformity of the vault being displayed to advantage (Fig-1).
2. Musculoskeletal trauma especially fractures around the hip and knee joint. This was illustrated well in a 28 year old male patient involved in a road traffic accident. X-ray revealed fracture of the medial tibial condyle left knee. Axial CT of the knee showed depressed comminuted fracture of the medial tibial condyle with haemarthrosis on the left side. Region of interest 3 D reconstruction of the left knee not only revealed the fracture but also demonstrated the numerous fragments and their exact relationships with each other as well as the joint space (Fig-2).
3. Spinal deformity like spinal canal or foraminal stenosis, spinal tumors or fractures.
4. Peripheral bony tumours for volumetric assessment.
5. Dental reconstructive surgery [8].
6. Limited application can be found in densely enhancing soft tissue tumors by appropriate threshold selection.

LIMITATIONS

- 1 The use of this modality is limited to the representation of skin and bone. Individual soft tissues cannot be imaged as no grey scale differentiation is possible.
2. The requirement of a large number of sections imposes higher patient radiation doses and higher tube load.
3. The radiologist has to spend more time interacting with the computer console during reconstruction process. The total time taken for each patient is more, and in a busy department, this may be a constraint.
4. Artifacts are common, and can interfere with use-

Fig. 1 : Plagiocephaly, showing fusion of coronal and lambdoid sutures on the left side

Fig. 2 : Depressed comminuted fracture of medial tibial condyle.

ful information if not eliminated.

5. Most importantly, the modality is not diagnostic of etiology. It serves as an aid to treatment planning, and hence the expectations of the clinician have to be realistic while ordering 3D CT.

CONCLUSION

The application of 3D CT is to be found in bony pathology of congenital or traumatic origin. It is extremely useful in delineating the exact bony contours and offers the clinician the opportunity of planning his approach with the help of lifelike renditions of bony structures. With the successful application of this technique in our centre in such cases, and the positive response from the clinicians, it has become a routine application in the imaging work up for the indications as already considered in the foregoing discussion.

The knowledge of the specific indications as well as

the potential pitfalls in the nature of artifacts is absolutely essential for the clinician before he can refer a case for 3D CT studies. The implications of higher patient doses and effect on tube life is of cardinal importance for the imageologist in order to derive the maximum benefit from this technique.

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