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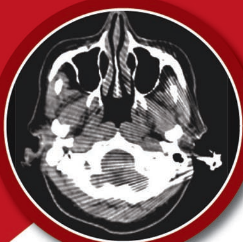
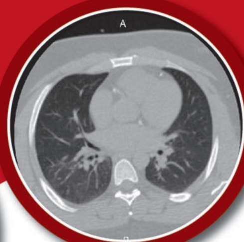
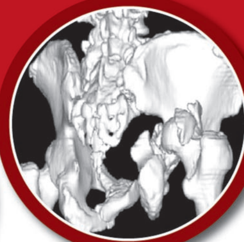






Karthikeyan's

Step by Step®
CT Scan

Revised by
Sachin Khanduri

2nd Edition

JAYPEE

Contents

Chapter 10

Recent Advances in Computed Tomography

INTRODUCTION

Since the first usage of this technology in 1972, computed tomography has made a few notable advances. In recent years, several advancements have been achieved like extreme multi-detectors CT, iterative reconstruction analog, dual energy CT, cone beam CT, portable CT and phase contrast CT which has significantly enhanced diagnostic capabilities.

HARDWARE

Modern CT scanners typically utilize liquid coolant, hot cathode, and high-capacity X-ray tubes featuring a copper-backed tungsten target. Advances in technology have addressed issues related to target temperature, heat accumulation, and heat dissipation. The reduction in scan times has significantly increased the anode capacity, by up to five times, which eliminates the need for cooling pauses during procedures and scans.

CONE-BEAM COMPUTED TOMOGRAPHY SCANNER

Cone-beam CT (CBCT) scanners are compact, affordable systems that deliver low radiation doses and are specifically designed for imaging the maxillofacial region. This technology represents a major advancement in dentistry, revolutionizing dental diagnostics by enabling the transition from 2-dimensional to 3-dimensional imaging.

Principle of CBCT (Fig. 10.1)

A new and emerging technology involves the use of a rotatory gantry for imaging, with an X-ray source and detector attached to it. This technology employs a 2-dimensional detector system, allowing it to produce comprehensive volumetric data in a single gantry rotation, as opposed to the conventional CT, which uses a single-dimensional approach. Unlike the conventional CT scanner that utilizes a fan beam geometry, the cone-beam CT scanner employs a divergent X-ray forming a cone.

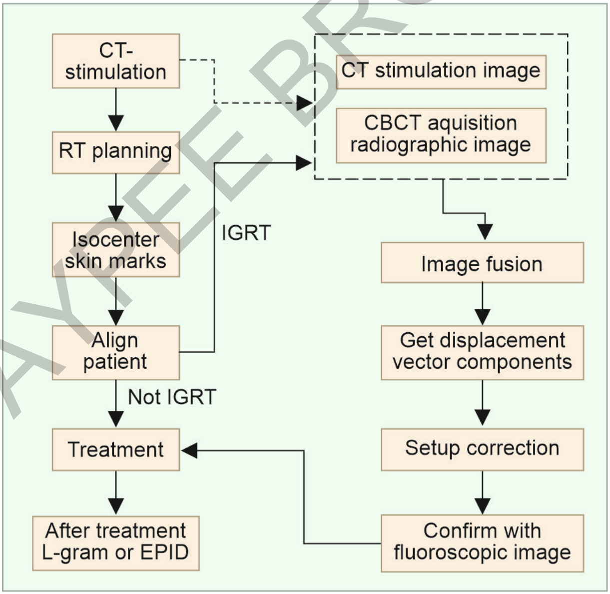


Fig. 10.1: Principle of CBCT.

Components of CBCT Image Production

Components of CBCT image production are:

- Acquisition configuration
- Image detection
- Image reconstruction
- Image display

The X-ray source and detector rotate around a fixed rotation fulcrum located at the center of the target area. Throughout this rotation, numerous sequential planar projection images of the field of view (FOV) are captured, either completing a full arc or a partial arc.

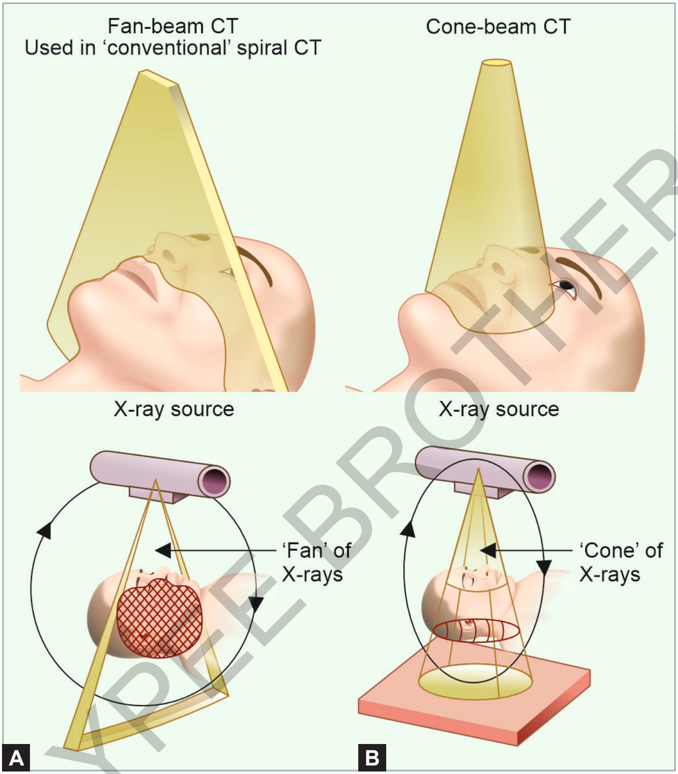
The field of view in imaging is primarily influenced by the size and shape of the detector, the geometry of the beam projection, and the ability to collimate the beam. In cone-beam computed tomography **(Fig. 10.2)**, the resolution is largely determined by the individual volume elements, or voxels, generated from the volumetric dataset. The dimensions of these voxels are dictated by the pixel size on the area detector, in contrast to conventional CT, where the voxel size is influenced by slice thickness **(Tables 10.1 and 10.2)**

Cone-beam CT scanner provides two data products:

1. Volumetric image data from the scan.
2. Image report generated by the operator.

Table 10.1: Comparison of CBCT and fan beam CT.

	Fan-beam CT (single axial)	***Cone-beam CT***
CT generation	3rd	3rd
X-ray beam shape	Fan-beam	Cone-beam
Detector type	X-axis only	X and Y-axis
Volume acquisition requirements	Multiple gantry rotations	Single gantry rotation (potentially)
Examination speed	Fast	Fastest



Figs. 10.2: (A) Fan-beam CT; (B) Cone-beam CT.

All of these images are saved in digital imaging and communication in medicine (DICOM) format.

Cone-beam exposure provides a radiation dose to the patient higher than other imaging procedure in dentistry; hence the as low as reasonably achievable (ALARA) principle must always be applied.

Table 10.2: Advantages and drawbacks of CBCT.

Advantages of CBCT	*Drawbacks of CBCT*
• Rapid scan time • Limitation of the X-ray to the target • Reduced patient radiation dose • It offers images with high contrast and is especially effective for visualizing the bony structures of the craniofacial region	• Larger FOVs in CBCT reduce image quality due to increased noise and decreased contrast resolution caused by scattered radiation • Artefacts: – X-ray beam artefacts, e.g., beam hardening – Scanner-related artefacts – Motion artefacts – Cone-beam-related artefacts—partial volume averaging, under-sampling and cone-beam effect • Image noise • Poor soft-tissue contrast

HELICAL AND MULTISLICE COMPUTED TOMOGRAPHY

HELICAL COMPUTED TOMOGRAPH (FIG. 10.3)

Helical scanning involves continuous rotation of the X-ray tube while the patient is moved through the rotating X-ray beam plane by the couch. Slip ring technology, introduced in 1980 with three rings, enables continuous energization of the X-ray tube and continuous data collection. This setup allows reconstruction of images at any desired z-axis position.

Slip rings **(Figs. 10.4A and B)** are electromechanical devices facilitating the transmission of electricity and signals between rotating and stationary components, allowing for faster rotation (5 s/rotation) and more than 360 degrees of movement. They use brushes made of silver graphite alloy to maintain contact and transmit power to the gantry. Slip rings are crucial in spiral CT or multislice CT, enabling continuous gantry rotation. It eliminates the reliance on

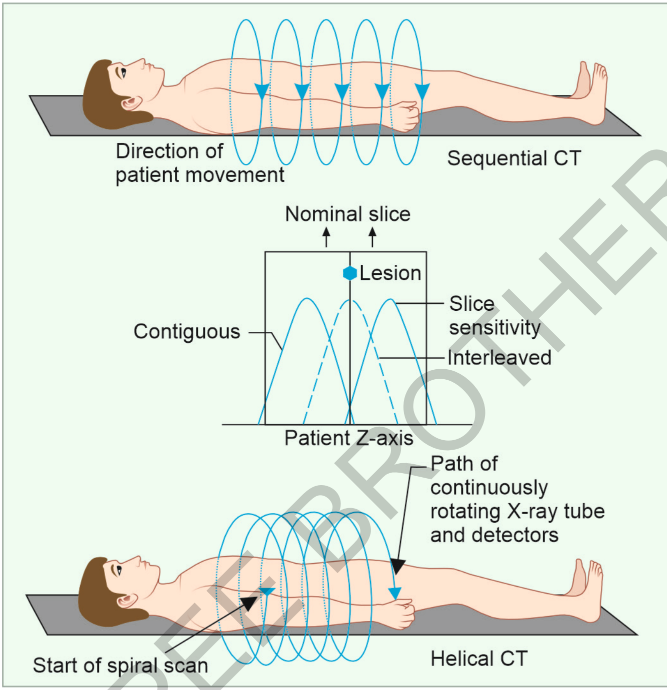
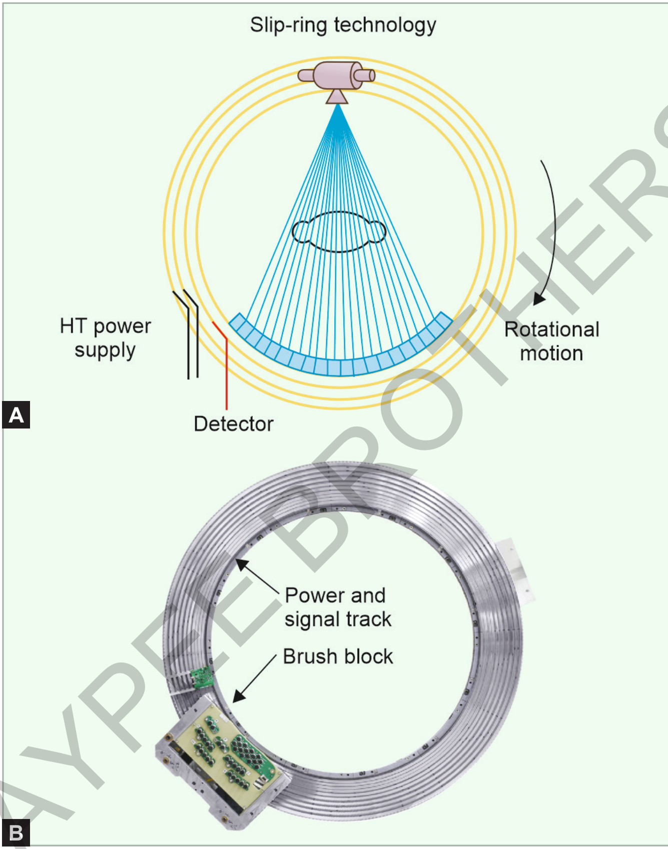


Fig. 10.3: Principle of helical CT (schematic).

electrical cables that can restrict continuous rotation. Helical or spiral or volume scanning, introduced for clinical use in 1990, involves simultaneous movement of both the X-ray tube and the couch. This method ensures continuous data acquisition as the couch moves, capturing complete volume data in a single exposure. The X-ray source follows a helical path during the scan.

In helical scanning, the X-ray tube rotates continuously, and the couch moves the patient through the plane of rotating X-ray beam.



Figs. 10.4A and B: (A) Schematic representation of a slip ring; (B) Slip ring.

- Using a slip ring technology, the tube is energized continuously, and data are collected continuously.
- Image can be reconstructed at any desired z-axis position along the patient.

MULTIDETECTOR COMPUTED TOMOGRAPHY (FIG. 10.5)

Multidetector computed tomography (MDCT) is an advanced imaging technique used in medical diagnostics. It employs multiple rows of detectors to capture detailed cross-sectional images of the body. MDCT provides high-resolution images that aid in the detection and characterization of various conditions, including injuries, tumors, and vascular abnormalities **(Table 10.3)**. By rotating around the patient, the MDCT scanner gathers data from different angles, allowing for precise reconstruction of internal structures. This technology is crucial in modern medicine for its ability to offer comprehensive diagnostic information swiftly and accurately.

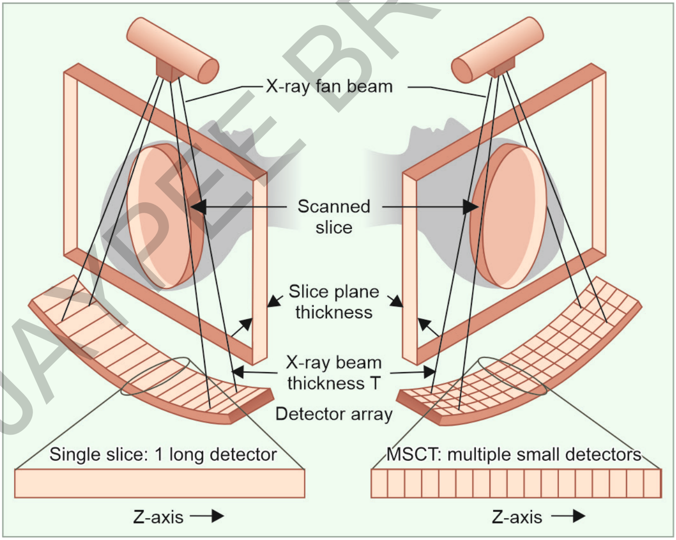


Fig. 10.5: Schematic representation of the single slice CT (left) and multislice CT (right).

Table 10.3: Advantages of MDCT.

◆ **Shorter scan duration:** – Reduced movement artifacts – Children – Trauma patients – Acutely ill or dyspneic patients – Multiplanar reformations ◆ **Improved contrast enhanced scans:** – Well-defined phase of contrast enhancement – Reduced contrast volume for computed tomography angiography (CTA) – More homogeneous enhancement	◆ **Longer scan ranges CTA:** – Aorta and peripheral runoff – Thoracoabdominal aorta – Carotids from arch to intracerebral circulation ◆ **Trauma:** Full spine examinations ◆ **Thinner sections:** – Near isotropic imaging (any application) – Arbitrary imaging planes – Multiplanar reformations – 3-dimensional rendering

Principle

Unlike conventional and helical CT scanners, which use linear arrays of detector elements, multidetector computed tomography utilizes two-dimensional arrays of detector elements. This innovation enables MDCT scanners to capture multiple slices or sections simultaneously, significantly enhancing the speed of image acquisition. This technology represents a substantial advancement in CT imaging by allowing for faster and more efficient scanning, thereby improving diagnostic capabilities across various medical conditions.

During a multidetector computed tomography scan, a rotating X-ray tube acquires multiple images in sequence. Patients are required to remain still on a table for about

5–15 minutes, depending on the area of interest being scanned. The table moves through a gantry. X-ray detectors capture images of the internal structures of the body as X-rays pass through. These images are then transmitted to a computer, which reconstructs them on a screen for review by a technologist. The technologist assesses the image quality and prepares the results for the radiologist's examination and interpretation.

Multislice systems offer superior spatial resolution in both axial and longitudinal directions by acquiring numerous thin slices rapidly. This capability enables swift imaging of large tissue volumes with adjustable slice thickness, crucial in scenarios where patient motion is a concern. Additionally, these systems optimize X-ray tube usage, thanks to their quick rotation times and extensive volume coverage, enhancing image quality while minimizing artifacts.

Certain MDCT studies necessitate the use of an oral contrast agent to improve image clarity of the body. Patients will receive specific instructions if their examination requires them to consume a preparation containing contrast (barium sulfate) beforehand. Alternatively, other studies may utilize an intravenous (IV) contrast agent such as iodixanol and iopamidol to enhance image quality. Studies may require administration of IV and oral contrast both simultaneously.

DETECTOR PITCH (FIG. 10.6)

Pitch (P) is a term used in helical CT with two terminologies depending on whether single slice or multislice CT scanners are used.

Single Slice CT

The term **detector pitch** is the table distance traveled in one 360° gantry rotation divided by beam collimation.

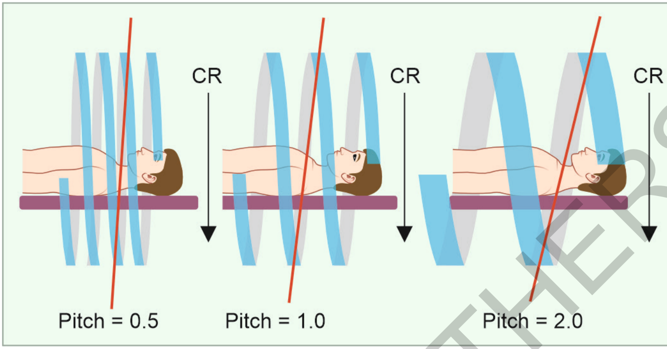


Fig. 10.6: Schematic representation of pitch of CT.

For example, if the table traveled 5 mm in one rotation and the beam collimation was 5 mm, then pitch equals 5 mm/5 mm = 1.0.

Choice of pitch affects both image quality and patient dose:

- P = 1.0: X-ray beams are contiguous for adjacent rotations.
- P >1.0: X-ray beams are not contiguous for adjacent rotations, i.e., there are gaps in the X-ray helix, but the full volume is still irradiated, only with fewer projections per rotation.
- P <1.0: there is X-ray beam overlap, i.e., a volume of tissue is irradiated more than once per scan.

Thus, a pitch >1.0 results in decreased patient dose but also decreased image quality (fewer projections are obtained, resulting in a lower signal-to-noise ratio). A pitch of <1.0 results in better image quality but a higher patient dose.

Multislice CT

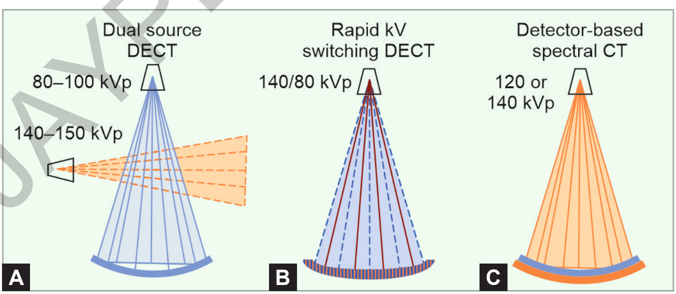
Beam pitch is defined as table distance traveled in one 360° gantry rotation divided by the total thickness of all simultaneously acquired slices.

DUAL ENERGY COMPUTED TOMOGRAPHY (FIGS. 10.7A TO C)

Dual energy CT (DECT) represents a significant advancement in modern medical imaging, enhancing the modality's capabilities. It utilizes both conventional X-ray and a secondary, lower-energy X-ray to capture images, providing DECT with distinct advantages over conventional CT scans across various medical tests and procedures.

Principle

Single energy CT (SECT) uses a single polychromatic X-ray beam emitted from one source and detected by a single detector. Dual source DECT (dsDECT) involves two X-ray tubes and two detectors for simultaneous dual-energy acquisition and processing **(Fig. 10.7A)**. Single source DECT (ssDECT) employs a single X-ray tube that rapidly switches between low and high energies, with a single detector registering information from both energies in quick succession **(Fig. 10.7B)**. Detector-based spectral CT utilizes a single X-ray tube with full-dose



Figs. 10.7A to C: Schematic representation of working of: (A) Dual source dual energy CT (dsDECT); (B) Single source dual energy CT (ssDECT); (C) Detector-based spectral CT.

Karthikeyan's
Step by Step® CT Scan

This book is an essential resource for medical students, postgraduate residents, and clinicians who wish to reference computed tomography (CT) scan literature in a concise and easily understandable format. It presents a clear and comprehensive guide to CT, making complex concepts accessible to readers at all levels of experience.

Key features of the book include:

- *Concise and Accessible Text:* Written in a straightforward language, the book simplifies CT concepts, making it ideal for both quick reference and in-depth study.
- *Comprehensive Coverage:* The book covers key aspects of CT, including:
  - History and development of CT, with a focus on the basics of X-rays and the evolution of CT technology through its various generations.
  - Technical parameters, such as patient positioning, slice thickness, and detector configurations.
  - Image acquisition protocols for different clinical applications.
  - Postprocessing techniques to enhance diagnostic quality.
  - CT contrast issues and radiation dose management for improved safety.
  - Recent advances including multidetector computed tomography (MDCT) and electron beam tomography (EBT).
- *High-quality Images:* The text is enriched with clear, high-resolution images to support understanding of key concepts.
- *Logical Organization:* Well-structured chapters allow readers to find specific topics and grasp important concepts easily.

In summary, Step-by-Step CT offers a well-structured, concise, and practical approach to understanding CT imaging. With its comprehensive coverage of core topics and recent advancements like MDCT and EBT, this book is an invaluable tool for medical students, postgraduate residents, and clinicians seeking to enhance their knowledge and expertise in CT.

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