Cardiac CT
Chapter 1

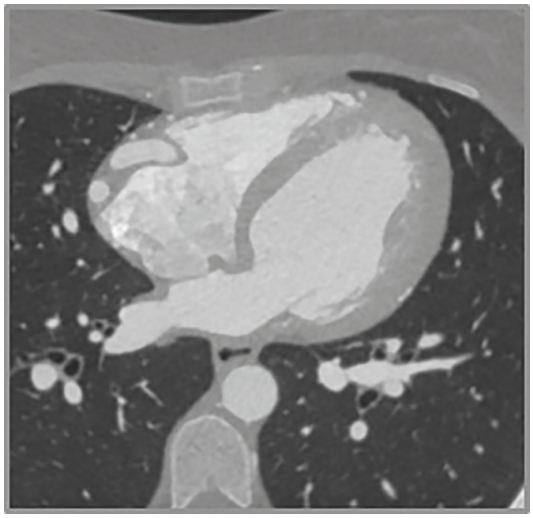
GENERAL PRINCIPLES OF CT

Ronak Rajani

General principles of CT

RECOGNIZING THE BENEFITS OF COMPUTED TOMOGRAPHY (CT)

With a standard chest x-ray, three-dimensional data is represented as a two-dimensional image. Computed tomography (CT) provides three-dimensional imaging free of superimposed structures, with an equal resolution throughout each plane. CT literally translates to computer drawings and reconstructions of an image of thin cross sections of the body.

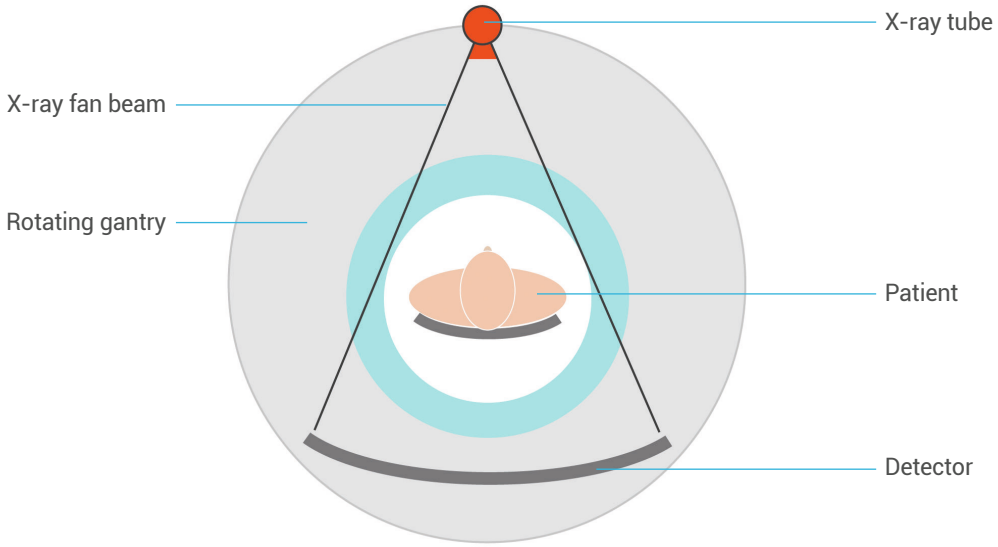


General principles of CT

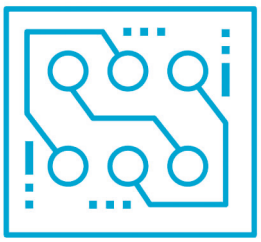
DECONSTRUCTING THE MACHINE

A CT scanner is made up of three main components:

1. The gantry



2. The data acquisition system

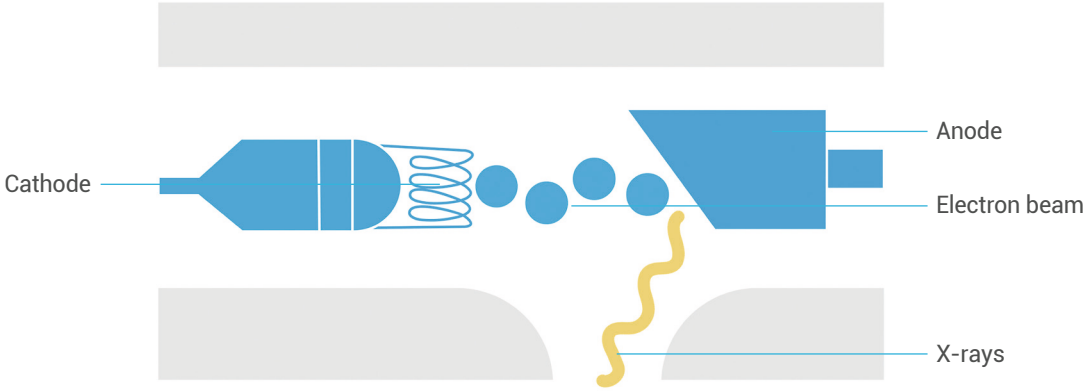


3. The console

The x-ray tube generates x-rays that pass through a flat filter and a bowtie filter. The flat filter is designed to absorb low energy x-rays that contribute to patient exposure, but do not reach the detector or contribute to image formation. The bowtie filter enables x-ray beam sharpening. Both filters are designed to provide an effective means to improve radiation dose, by better utilizing and absorbing off axis x-rays. Once the x-rays pass through the filters they reach a pre-patient collimator, which defines the x-ray beam size and helps to reduce radiation dose. The x-rays pass through the patient and are picked up by a detector. The detector transforms the x-ray energy into light energy and then into electrical current. The data acquisition system converts the analog data into digital data and sends the output to the workstations, where the CT scan may be visualized. The console represents the control station for the CT scanner and the contrast pump, as well as being the workstation for the clinician.

General principles of CT

APPLYING PHYSICS



What is an x-ray?

X-rays are photons of electromagnetic radiation that are produced when a target of heavy metal is struck by electrons travelling at high-speed.

How does an x-ray tube work?

In the x-ray tube there is a cathode, which contains a hot filament that glows like a hot light bulb and an anode opposite this. Electrons are boiled off the hot cathode filament and accelerated by the anode voltage to hit the tungsten target. This gives off heat and also x-rays.

What is kVp and mA?

The kVp represents the peak voltage that is applied across the x-ray tube; this determines the highest x-ray energy.

The tube current reflects the rate of electron flow, from the cathode to the anode, and is measured in milliamperes (mA). The mAs is the number of milliamperes per second of exposure time.

What does attenuation mean?

X-ray attenuation refers to the absorption and scatter of x-rays as they pass through tissue. For example, 100 x-rays are generated from the x-ray tube before they enter a patient, as they pass through the patient some x-rays are absorbed and scattered. This leaves only 40 x-rays emerging. The incident intensity then represents 100; the transmitted intensity is 40 and the attenuated x-rays 60. CT, in essence, is measuring the attenuation.

How do CT detectors work?

As the x-rays reach the detector the photon energy hits a scintillation crystal, which turns the energy into a light signal. A photodiode then converts this into electrical current. The data acquisition system converts this current from an analog to digital form and the data can then be processed for workstation use.

What does the CT image represent?

It represents the range of attenuation values for each tissue the x-rays have passed through. The data is displayed as Hounsfield unit value in a pixel, which represents the Hounsfield unit for the voxel (cube of data).

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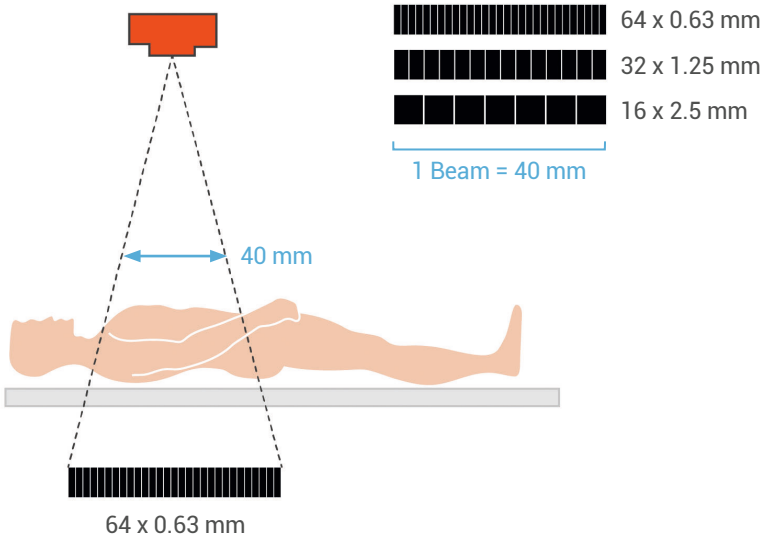
SPEAKING THE LANGUAGE OF COMPUTED TOMOGRAPHY

Detector configuration

The detector configuration determines how the detectors are arranged.



Temporal resolution

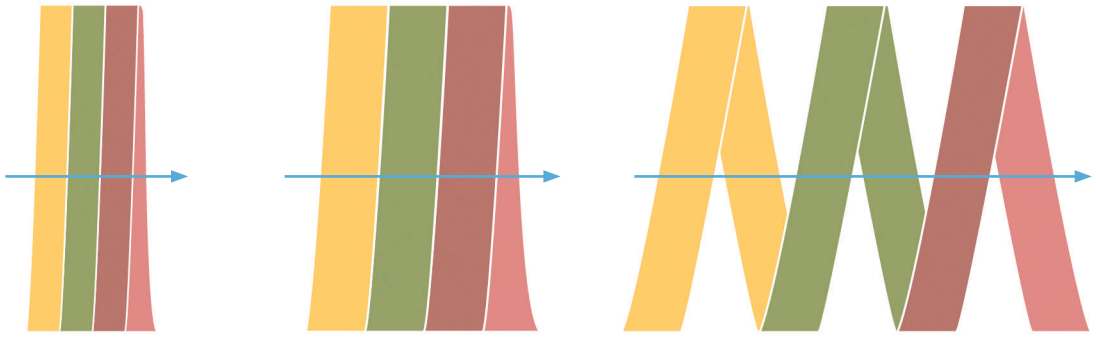
The temporal resolution is the time it takes for an x-ray tube to acquire a cross-sectional image. It is typically half of the gantry rotation time for a single x-ray tube scanner and a quarter of the gantry rotation time for a dual-source scanner.

$$\frac{\text{Time for tube to rotate 360 degrees}}{2}$$

$$\frac{\text{Time for tube to rotate 360 degrees}}{4}$$

The pitch

The pitch is the amount of table travel in one gantry rotation divided by the total thickness of the slices. For typical cardiac CT, a pitch of < 1 is required to ensure no gaps in the data occur, when trying to evaluate small structures.



Pitch < 1 Pitch = 1 Pitch > 1

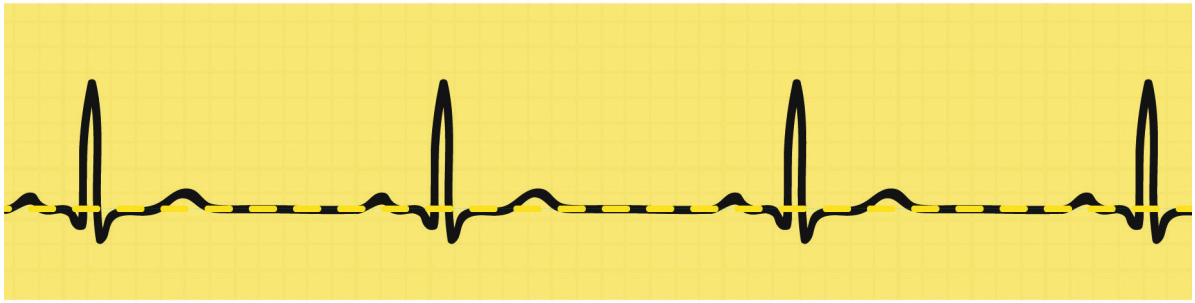
$$\text{Pitch} = \frac{\text{table travel in 1 gantry rotation}}{\text{total thickness of slices}}$$

General principles of CT

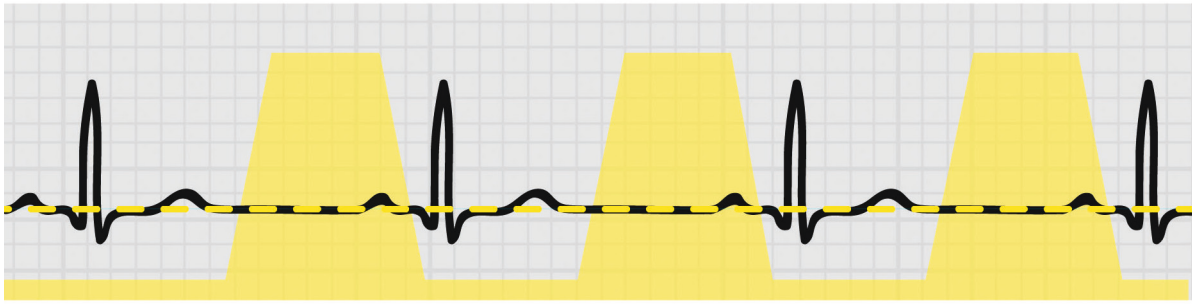
MASTERING THE DIFFERENT CORONARY CT SCANNING MODES

There are a variety of different scan modes that can be used for cardiac CT; these are displayed below in order of highest radiation dose first. Retrospective scans involve scanning the entire cardiac cycle, then reconstructing the specific phase or phases required. This mode enables functional and cine imaging. Prospective ECG-gated scans monitor the R wave and only turn the tube current on at the pre-selected phase of interest. These scans have the lowest radiation dose and do not generally permit functional imaging. The lower the resting heart rate (< 65 bpm), the more flexibility there is in scan modes.

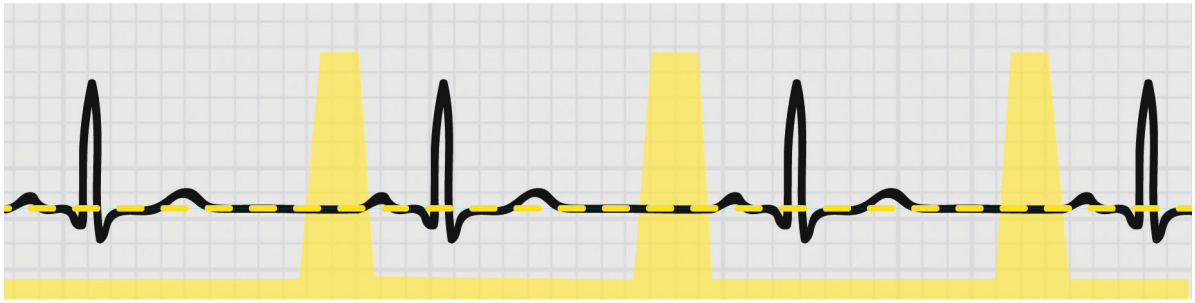
Retrospective ECG-gated helical



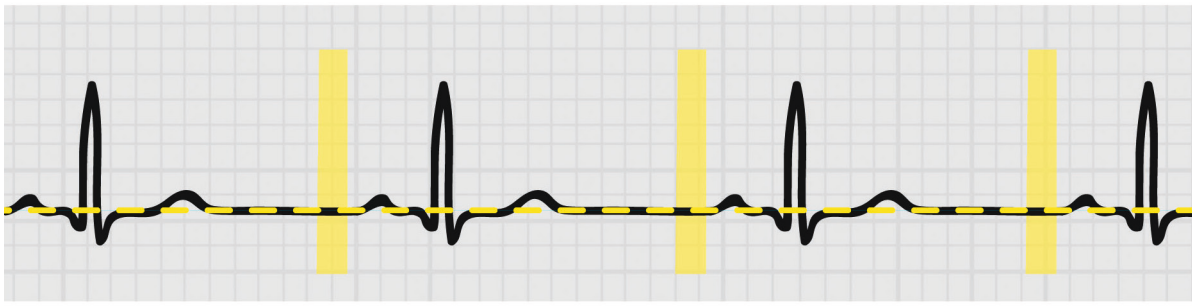
Retrospective ECG-gated helical—with dose modulation



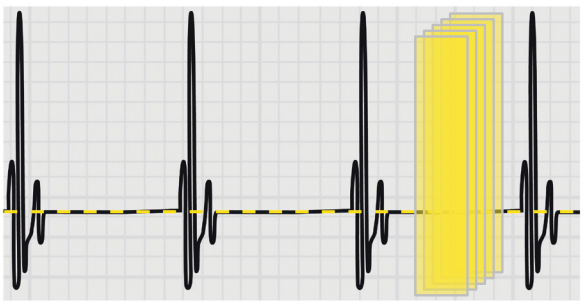
Retrospective ECG-gated helical—with aggressive dose modulation



Prospective ECG-gated axial scan—with and without padding



Prospective high pitched ECG-gated scanning—on dual source scanners



READING LIST

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