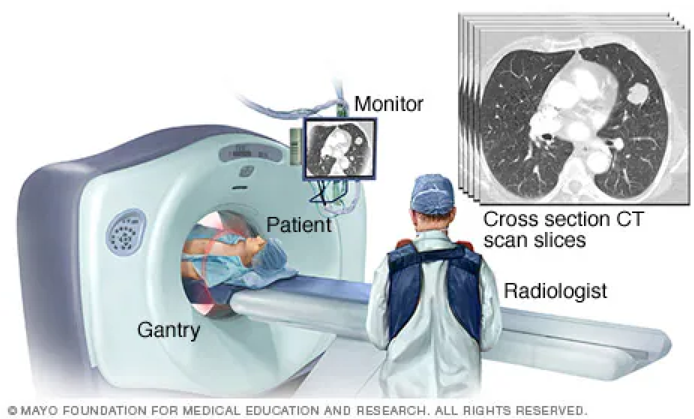
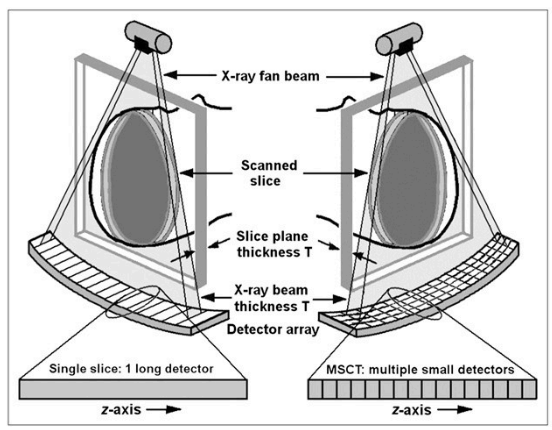
CT scans and .dicom files

How does a CT scan work?

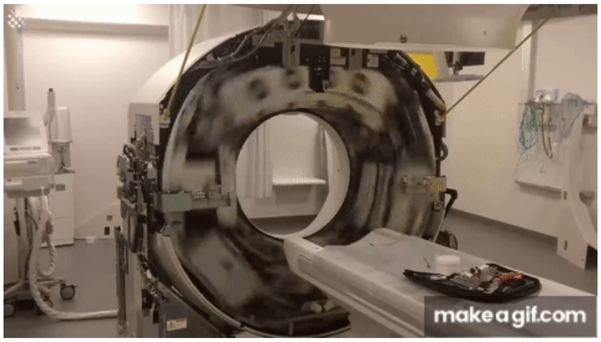


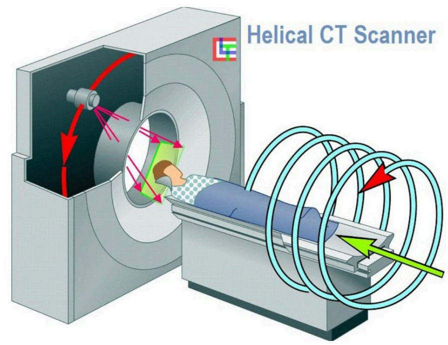


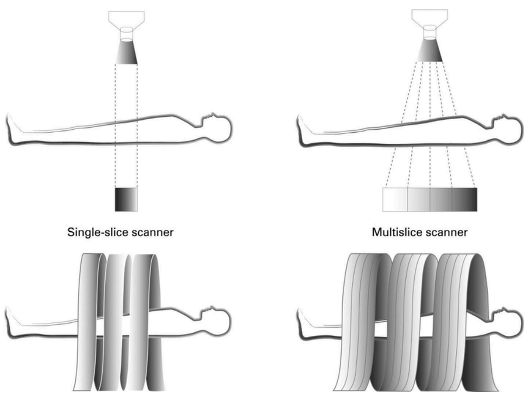
▼ **Data acquisition**

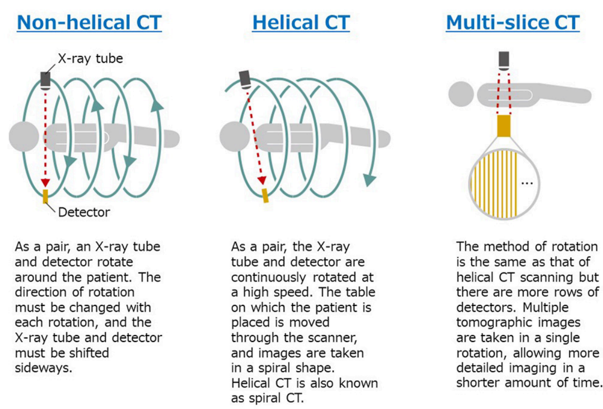
Nowadays, data are acquired in a helical (spiral) fashion as the patient moves through the rotating X-ray emitter and detector. A CT scan uses a relatively high dose of X-rays, so it is typically performed only when necessary and focused on specific areas of interest. **Whole-body CT scans**

are rarely performed due to radiation exposure concerns, unless required in cases like **severe trauma, cancer staging, or certain screening protocols**.



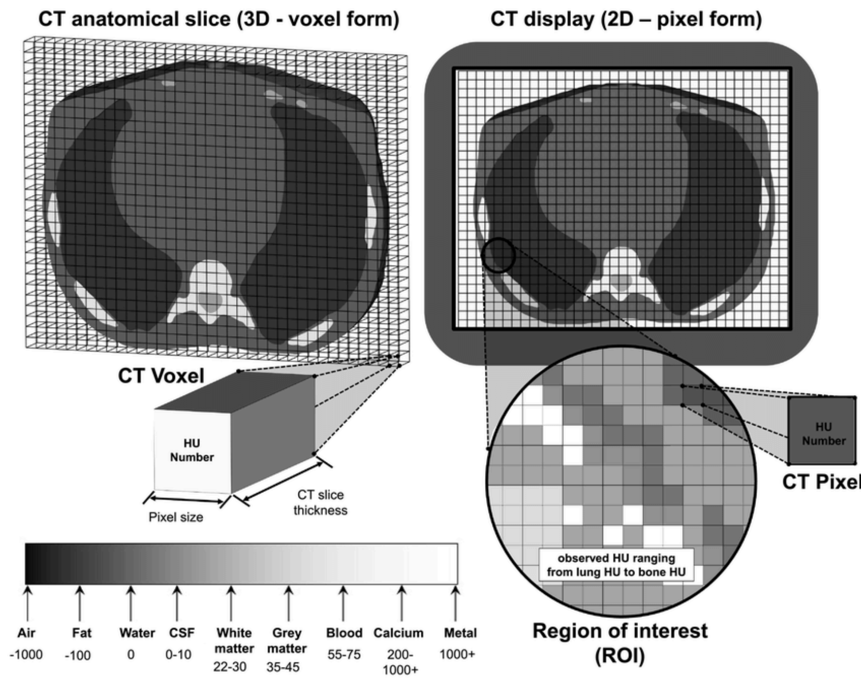






▼ Slice Thickness

CT scan slices typically range from **0.5 mm to 5 mm**, depending on the imaging protocol. High-resolution scans, such as for brain or lung imaging, often use thinner slices (0.5–1 mm), while routine body scans may use thicker slices (3–5 mm) to reduce radiation dose and scan time. Each slice can be roughly thought of as a 2d image, usually 512×512px.

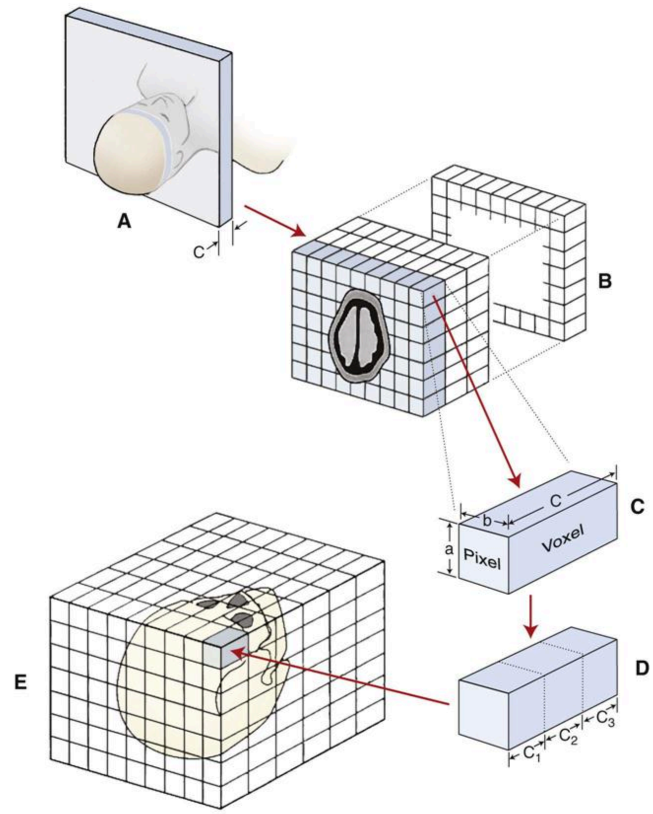


▼ **Voxel Dimensions**

A **voxel (3D pixel in a CT scan)** has three dimensions:

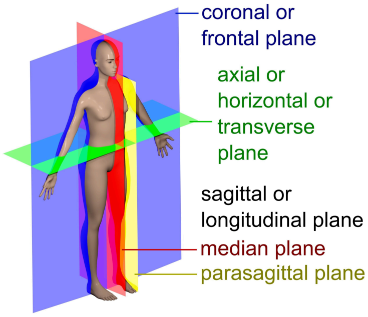
1. **In-plane resolution (x, y):** Determined by the scanner's spatial resolution and field of view, typically **0.2 to 1 mm** per pixel.
2. **Slice thickness (z):** Matches the **acquired slice thickness** (e.g., 0.5–5 mm).

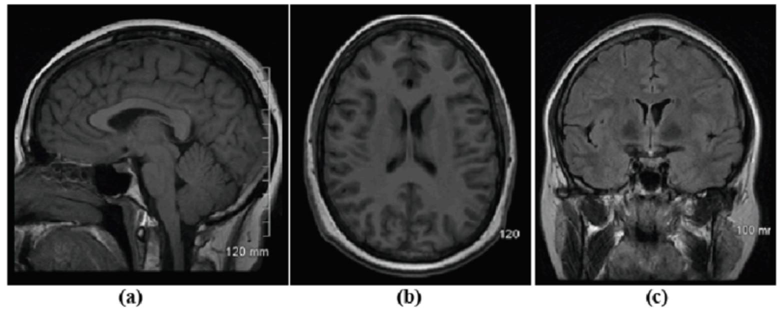
Thus, a voxel in a high-resolution CT scan could be **(0.5 mm × 0.5 mm × 0.5 mm)**, while in a lower-resolution scan, it might be **(1 mm × 1 mm × 5 mm)**.



▼ **Cool thing: slicing**

If you think of these slices as forming a **3D block of voxels**, you can re-slice this block in any direction you want. The usual types of slicing are **axial, coronal, and sagittal**, and they are used to highlight different anatomical planes of the body. The most common (**default**) format you will find is the **axial plane**, as it is the primary acquisition plane in most CT scans.





▼ Constrast vs. non-contrast CT

The same slice in a CT can "look" different. Why? CT images can appear very different depending on whether **contrast media** is used:

1. **Non-Contrast CT:**
    - Shows differences in tissue density based only on their natural X-ray attenuation.
    - Useful for detecting **calcifications, fractures, brain hemorrhages, lung nodules, or kidney stones**.
    - Structures like soft tissues (e.g., muscles, organs) may appear similar, making it harder to differentiate them.
2. **Contrast-Enhanced CT (CECT):**
    - Uses **iodine-based contrast agents**, injected intravenously or orally, to enhance blood vessels, organs, and abnormal tissues.
    - Helps differentiate between **tumors, inflammation, infection, and vascular conditions** by highlighting areas with high blood supply.
    - Contrast phases (arterial, venous, delayed) provide additional diagnostic information based on blood flow dynamics.

☝🏾 Why the Images Differ

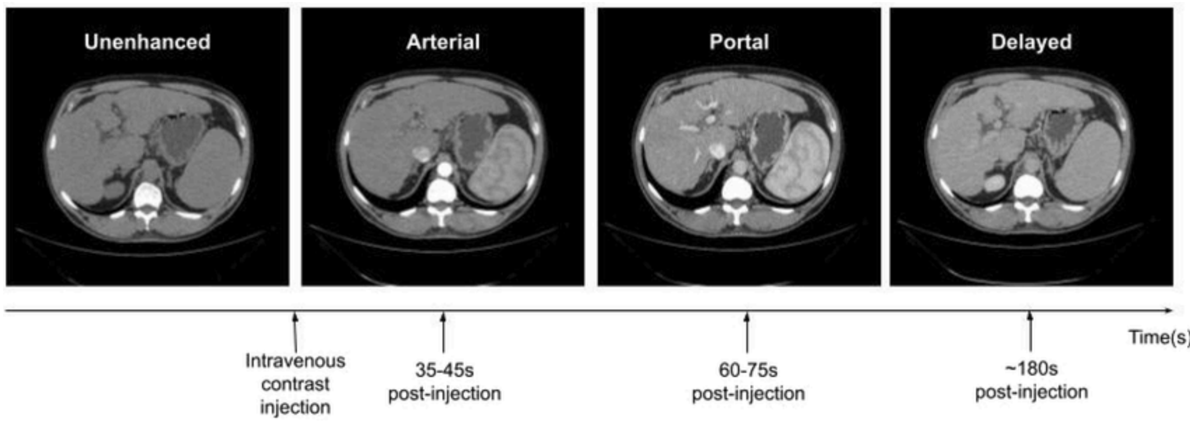
- **With contrast**, structures become more distinguishable due to differential absorption of the contrast agent.

- **Without contrast**, image contrast relies purely on native tissue densities, making some structures harder to differentiate.

☝🏽 How Contrast is Administered During a CT Scan

The contrast administration process and scan timing depend on the type of **study and protocol** being used. Here's how it typically works:

1. **Intravenous (IV) Contrast:**
    - The **contrast is injected** (often with a power injector for precise timing).
    - **Multiple scans are taken** at different time points (contrast phases):
        - **Non-contrast phase (optional):** Before contrast injection (for baseline comparison).
        - **Arterial phase:** 15-30 seconds after injection to capture arteries.
        - **Venous phase:** ~60-90 seconds after injection to see organs and veins.
        - **Delayed phase:** A few minutes later for tumors or kidney function assessment.
    - The patient **remains in the machine** while these scans are taken sequentially.
2. **Oral Contrast:**
    - The patient drinks contrast **30–90 minutes before scanning** (to allow it to coat the GI tract).
    - A **single scan** is typically performed after the contrast has moved through the system.
3. **Rectal Contrast:**
    - Administered just before scanning.
    - Usually, a **single scan** is taken after the contrast is in place.


Unenhanced
Arterial
Portal
Delayed
Time(s)
Intravenous
contrast
injection
35-45s
post-injection
60-75s
post-injection
~180s
post-injection

🪄 ...and now, you’re finally ready!

▼ Bonus pic

The `.dicom` (a.k.a. `.dcm`) data format

The data format is not exclusive to CT scans. The **DICOM (Digital Imaging and Communications in Medicine) file format** is a standardized format used for storing and transmitting medical images, such as X-rays, MRIs, and CT scans, along with associated metadata. It integrates image data with patient information, acquisition parameters, and other relevant details in a single file, enabling interoperability between different medical imaging devices and systems.

In the context of CT scans, each `.dcm` **(DICOM) file** typically corresponds to **one CT slice**. Thus, a full CT scan consists of a **series of slices** (a set of `.dcm` files), which are usually stored together in a directory when exported.

- Sample `.dcm` file:

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(0008, 0008): ImageType = ['ORIGINAL', 'PRIMARY', 'AXIAL', 'CT_SOM5 S
PI']
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917122309900000275
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(0008, 0021): SeriesDate = 20250109
(0008, 0022): AcquisitionDate = 20250109
(0008, 0023): ContentDate = 20250109
(0008, 002a): AcquisitionDateTime = 20250109182116.443000
(0008, 0030): StudyTime = 181615
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(0008, 0060): Modality = CT
(0008, 0070): Manufacturer = Siemens Healthineers
(0008, 0080): InstitutionName = Generic Hospital
(0008, 0081): InstitutionAddress = [REDACTED ADDRESS]
(0008, 0090): ReferringPhysicianName = SMITH^JOHN^^^
(0008, 0201): TimezoneOffsetFromUTC = +0100
(0008, 1010): StationName = CT123456
(0008, 1030): StudyDescription = CT Abdomen With and Without Contrast
(0008, 103e): SeriesDescription = Baseline 1.00 Br40 S3
(0008, 1040): InstitutionalDepartmentName = Pediatric Radiology
(0008, 1090): ManufacturerModelName = SOMATOM go.Top
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```

```
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ocedure Step SOP Class
  (0008, 1155) Referenced SOP Instance UID        UI: 1.3.12.2.1107.5.1.7.XXX
XXX.30000025010808150284900000047
]
(0008, 1140): ReferencedImageSequence = [
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XXX.30000025010917122309900000106
]
(0008, 3010): IrradiationEventUID = 1.3.12.2.1107.5.1.7.XXXXXX.300000250
10917122309900000098
(0010, 0010): PatientName = Patient^Anonymous
(0010, 0020): PatientID = 000000
(0010, 0030): PatientBirthDate = 19560427
(0010, 0040): PatientSex = M
(0010, 1010): PatientAge = 068Y
(0010, 1020): PatientSize = 1.65
(0010, 1030): PatientWeight = 53
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(0018, 0050): SliceThickness = 1
(0018, 0060): KVP = 90
(0018, 0090): DataCollectionDiameter = 500.700012
(0018, 1000): DeviceSerialNumber = 123456
(0018, 1020): SoftwareVersions = syngo CT VA40A
(0018, 1030): ProtocolName = Torso/Abdomen (Three-Phase)
(0018, 1100): ReconstructionDiameter = 368.85077186964
(0018, 1110): DistanceSourceToDetector = 976
(0018, 1111): DistanceSourceToPatient = 535
(0018, 1120): GantryDetectorTilt = 0
(0018, 1130): TableHeight = 124.000
(0018, 1140): RotationDirection = CW
(0018, 1150): ExposureTime = 625
(0018, 1151): XRayTubeCurrent = 286
(0018, 1152): Exposure = 179
(0018, 1160): FilterType = W1
```

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(0018, 1170): GeneratorPower = 24
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(0018, 1201): TimeOfLastCalibration = 082117.000000
(0018, 1210): ConvolutionKernel = ['Br40f', '3']
(0018, 5100): PatientPosition = FFS
(0018, 9305): RevolutionTime = 0.5
(0018, 9306): SingleCollimationWidth = 0.6
(0018, 9307): TotalCollimationWidth = 38.4
(0018, 9309): TableSpeed = 61.4
(0018, 9310): TableFeedPerRotation = 30.72
(0018, 9311): SpiralPitchFactor = 0.8
(0018, 9313): DataCollectionCenterPatient = [0.0, -124.0, 1424.792]
(0018, 9318): ReconstructionTargetCenterPatient = [0.0, -124.0, 1424.792]
(0018, 9323): ExposureModulationType = ELLIP_ZEC
(0018, 9345): CTDIvol = 7.088114681197375
(0018, 9346): CTDIPhantomTypeCodeSequence = [
  (0008, 0100) Code Value               SH: '113691'
  (0008, 0102) Coding Scheme Designator SH: 'DCM'
  (0008, 0104) Code Meaning             LO: 'IEC Body Dosimetry Phantom'
]
(0019, 0010):  = SIEMENS CT EXAM APP SHARED
(0019, 1002):  = 288
(0019, 1003):  = Br40fS3n1.:02684:0HhAAL1adA
(0020, 000d): StudyInstanceUID = 1.2.392.200036.9125.2.3.39.31.XXXXX
XXX
(0020, 000e): SeriesInstanceUID = 1.3.12.2.1107.5.1.7.XXXXXX.3000002501
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(0020, 0010): StudyID = 35713670
(0020, 0011): SeriesNumber = 2
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(0020, 0037): ImageOrientationPatient = [1, 0, 0, 0, 1, 0]
(0020, 0052): FrameOfReferenceUID = 1.3.12.2.1107.5.1.7.XXXXXX.300000
```

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(0020, 0060): Laterality =
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(0020, 1041): SliceLocation = -1424.792
(0020, 4000): ImageComments =
(0021, 0010):  = SIEMENS MED
(0021, 1011):  = [-1.136868377E-13, 0]
(0028, 0002): SamplesPerPixel = 1
(0028, 0004): PhotometricInterpretation = MONOCHROME2
(0028, 0006): PlanarConfiguration = 0
(0028, 0010): Rows = 512
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(0028, 0030): PixelSpacing = [0.72041015625, 0.72041015625]
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(0028, 0101): BitsStored = 16
(0028, 0102): HighBit = 15
(0028, 0103): PixelRepresentation = 0
(0028, 0106): SmallestImagePixelValue = 0
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(0029, 0011):  = SIEMENS CT EXAM EQUIPMENT
(0029, 0012):  = SIEMENS CSA HEADER
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(0029, 1007):  = 1000
(0029, 100d):  = FFSNONE
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```

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(0029, 1048):  = NONE
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(0029, 104f):  = Native
(0029, 1050):  = 163.0 mAs
(0029, 1051):  = First: 90.0 kV, Second:
(0029, 1052):  = First: 140.0 kV, Second:
```

```
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(0029, 1106):  = 3.62106
(0029, 1109):  = P82B
(0029, 1208):  = SOM 5
(0029, 1209):  = VA10A 971201
(0029, 1210):  = b''
(0032, 1032): RequestingPhysician = ^^^^
(0032, 1033): RequestingService = SYNCROMED
(0038, 0010): AdmissionID = 2132012
(0040, 0244): PerformedProcedureStepStartDate = 20250109
(0040, 0245): PerformedProcedureStepStartTime = 181615.904443
(0040, 0253): PerformedProcedureStepID = GR17033ac3e3944a
(0040, 0254): PerformedProcedureStepDescription = CT Chest With and
Without Contrast
(0040, 0275): RequestAttributesSequence = [
  (0008, 0050) Accession Number           SH: '0035713670'
  (0020, 000d) Study Instance UID         UI: 1.2.392.200036.9125.2.3.39.3
1.XXXXXXXX
  (0032, 1060) Requested Procedure Descript LO: 'CT Chest With and With
out Contrast'
  (0040, 0007) Scheduled Procedure Step Des LO: 'CT Chest With and Wit
hout Contrast'
  (0040, 0009) Scheduled Procedure Step ID  SH: '27549219'
  (0040, 1001) Requested Procedure ID       SH: '35713670'
]
(7fe0, 0010): PixelData = b''
```

▼ `SeriesDescription` values across multiple files

- Topogram AP 0.60 MPR Tr20 cor
- Delayed 1.00 Br40 S3
- CT Raw data
- Baseline 3.00 Br40 S3
- Delayed 3.00 Br40 S3

- Arterial 3.00 Br40 S3
- Pre-monitoring 10.00 Br36
- Patient Protocol
- Dose Report
- Venous Mediast 1.00 Br40 S3
- Venous Mediast 3.00 Br40 S3
- Baseline 1.00 Br40 S3
- FUJI Presentation State – ANNOTATIONS
- Examination Report
- Monitoring 10.00 Br36
- Arterial 1.00 Br40 S3
- FUJI Basic Text SR for HL7 Radiological Report
- Venous Lung 1.00 Bl60 S3

▼ CT scan phases

CT scan series descriptions often include terms that indicate whether contrast was used and during which phase of enhancement:

- **"Arterial phase":** Indicates that contrast was injected and images were acquired when contrast was primarily in the arteries.
- **"Venous phase":** Indicates that contrast was injected and images were acquired when contrast was primarily in the veins.
- **"Delayed phase":** Indicates contrast-enhanced imaging after a delay to visualize areas like tumors or fibrotic tissues.
- **"Baseline ":** Refers to pre-contrast (non-contrast) images—no contrast liquid was used here.

Phase	**Timing** After Contrast Injection	**Key Features**	**Best For**
Non-Contrast (Baseline)	No contrast (before injection)	Natural tissue density, no enhancement	Detecting calcifications, hemorrhages, or baseline comparisons
Arterial Phase	15–30 seconds	Contrast in **arteries**	Evaluating arteries (e.g., aorta, coronary), detecting active bleeding, hypervascular tumors
Venous (Portal Venous)	60–70 seconds	Contrast in **veins and organs**	Assessing abdominal organs (liver, kidneys), identifying hypovascular tumors, thromboembolism
Delayed	5–10 minutes	Contrast diffused into tissues	Detecting tumors (contrast retention), fibrosis, and urinary structures (ureters, bladder)
Dynamic (Perfusion/Monitoring)	Continuous imaging	Tracks real-time blood flow dynamics	Perfusion studies, blood flow assessments, or tracking contrast dynamic

▼ Kernel reconstruction techniques

What Are Reconstruction Kernels?

- CT scanners collect **raw data** during the scan, and this data is reconstructed into images using **kernels** or **algorithms**.
- A **reconstruction kernel** (also called a convolution filter) is a mathematical algorithm that determines how the raw CT data is processed to produce the final image.

- Kernels are tailored to enhance specific features of the image, such as soft tissue contrast or fine structural details, depending on the clinical need.

What Do `Br40` and `Bl60` Specifically Refer To?

1. `Br40`:

- **"Br"**: Indicates the **type of kernel** optimized for balanced imaging, often for soft tissue and structures requiring moderate detail.
- **"40"**: Refers to the **level of sharpness/noise reduction**, with 40 being balanced for **soft tissue contrast** without introducing excessive sharpness or noise.
- **Application:**
  - Suitable for soft tissues like the brain, mediastinum, or organs like the liver and kidneys.
  - Often used in phases like **arterial**, **venous**, or **delayed**, where contrast-enhanced soft tissue and vascular structures are being evaluated.

2. `Bl60`:

- **"Bl"**: Refers to a **soft tissue smoothing kernel**, often used for lung imaging.
- **"60"**: Indicates a **sharper kernel** than lower numbers like 40, making it more suitable for highlighting fine structural details.
- **Application:**
  - Common for imaging air-filled spaces like the lungs.
  - Enhances edges, which is useful for detecting small nodules, fine lung parenchyma details, or other high-contrast structures.

Practical Note:

- The **choice of kernel** depends on the **region of interest** and the **clinical question**:

- For **soft tissue and general imaging**: Use **Br40**.
- For **lungs or fine edge detail**: Use **Bl60**.

These terms might vary slightly across CT scanner manufacturers (e.g., Siemens, GE, Philips), but the general principles hold.