

Computed Tomography Its History and Technology

Innovations For People

The initial use of computed tomography (CT) for applications in radiological diagnostics during the seventies sparked a revolution in the field of medical engineering. And even throughout the eighties, a CT examination lost little of its special and exclusive character. In the meantime, however, times have changed. Today computed tomography represents a perfectly natural and established technology which has advanced to become an indispensable and integral component of routine work in clinics and medical practices.

The following brochure will give you insights into the history of computed tomography as well as its present status. Nevertheless, this is an on-going development process. And Siemens will continue to consistently extend its leading position in CT technology. With you. For you. And for your patients.

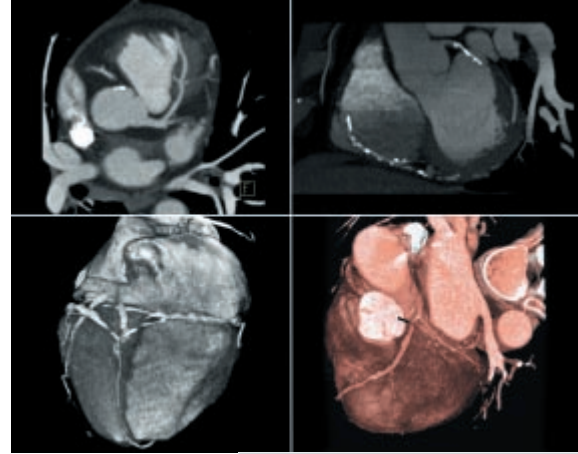
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Historical Outline

The invention of computed tomography is considered to be the greatest innovation in the field of radiology since the discovery of X-rays. This cross-sectional imaging technique provided diagnostic radiology with better insight into the pathogenesis of the body, thereby increasing the chances of recovery. In 1979, G.N. Hounsfield and A.M. Cormack were awarded the Nobel Prize in medicine for the invention of CT.

Today, CT is one of the most important methods of radiological diagnosis. It delivers non-superimposed, cross-sectional images of the body, which can show smaller contrast differences than conventional X-ray images. This allows better visualization of specific differently structured soft-tissue regions, for example, which could otherwise not be visualized satisfactorily.

Since the introduction of spiral CT in the nineties, computed tomography has seen a constant succession of innovations. The development of slipping technology allowed for a continuously rotating gantry – the prerequisite for spiral CT. The first spiral CT scanner was a Siemens SOMATOM Plus system. Today this technology is widely used.



11/08/1895

Discovery of X-ray radiation

Discoverer: The physicist and later nobel prize winner Wilhelm Conrad Roentgen (1845–1923), dean at the Julius Maximilian University of Wuerzburg and holder of the chair of physics



1896

F.H. Williams

F.H. Williams succeeds in taking the first chest X-ray in Boston, and Carl Schleussner develops the first silver bromide coated photographic X-ray plates in Frankfurt a. Main, Germany

Diagnostic results can now be archived; until then, fluorescent screens resulting in high radiation exposure had been used

1903

E.A.O. Pasche

E.A.O. Pasche builds a collimator for suppressing scattered radiation

Radiation protection for all parties involved for the first time; until then, both patients and physicians always had to face the "bare" X-ray tube

1913

Gustav Bucky

William D. Coolidge

Gustav Bucky develops the scattered radiation grid in Berlin, Germany

The engineer William D. Coolidge builds the first high-vacuum hot-cathode tube in Massachusetts, USA

Image quality is improved by eliminating scattered radiation before it strikes the X-ray film. Performance and durability of X-ray tubes greatly enhanced

M i l e s t o n e s i n t h e H i s t o r y o f C T

X-ray image of his wife's hand

1930/31

Allesandro Vallebona

Bernard Ziedses
des Plantes

Allesandro Vallebona develops stratigraphy, thus paving the way for tomography

Not long after, Bernard Ziedses des Plantes develops planigraphy, thereby further refining the tomographic technique and creating geometrically perfect images for the first time

To some extent this helped overcome the disadvantage of superimposition in the two-dimensional display of three-dimensional objects where relevant structural information can be lost; the required planigraphic depth had to be guessed

1972

Godfrey N. Hounsfield

In London, Godfrey N. Hounsfield's development of computed tomography marks the beginning of a new era in diagnostic imaging

With the aid of computed tomography it was possible for the first time to produce non-superimposed images of an object slice. Using so-called convolvers, digitized scan data are reconstructed into an image of a slice plane



1974

SIRETOM

Instant image
reconstruction

First CT system from a medical equipment manufacturer

SIRETOM CT system



1976

SOMATOM

OPTI X-ray tube with high heat capacity: 1.0 MHU

5 s scan time

Whole body CT

1978

SOMATOM 2

ECG-synchronized CT image

512 x 512 display matrix

1981/82

SOMATOM DR3

512 x 512 reconstruction matrix

50 cm FOV (display field); graphically selectable and continuously variable

3 s scan time for a full 360° rotation

1 mm slice width

0.5 mm high-contrast resolution

OPTI X-ray tube with 1.35 MHU

Automatic scanning (AutoScan)

Graphically specified scan range

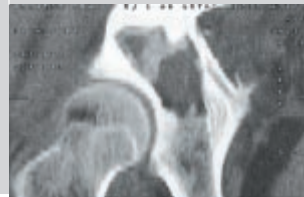
1983/84

SOMATOM DRH

± 25° gantry tilt angle
70 cm gantry opening

OPTI X-ray tube with 1.75 MHU

Integrated MPR function (Multi Planar Reformatting)



Coronales MPR, Femurkopf/Azetabulum, SOMATOM DRH



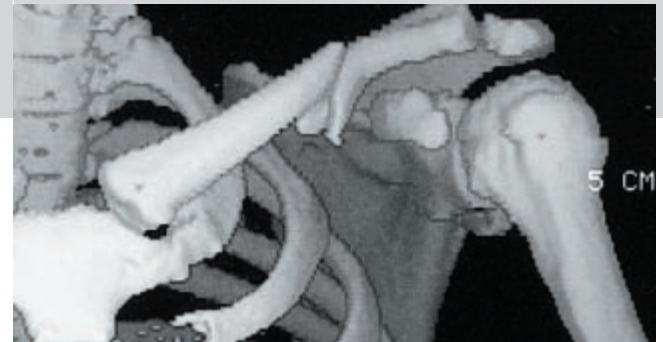
3D Oberflächendarstellung Schlüsselbeinfraktur, SOMATOM DRH

1985/86

SOMATOM CR

Modern applications: DYNAMIC CT and 3D with MPR and SSD (Shaded Surface Display)

3D Shaded Surface Display (SSD)



1987/88

SOMATOM Plus

1 s/360° slipping technology

Continuous rotation of tube and detector

Shorter examination times

Increased patient comfort

DURA X-ray tube with 4.3 MHU

40 kW DURA generator

Integrated gantry cooling: Heat exchanger

1024 x 1024 display and documentation matrix

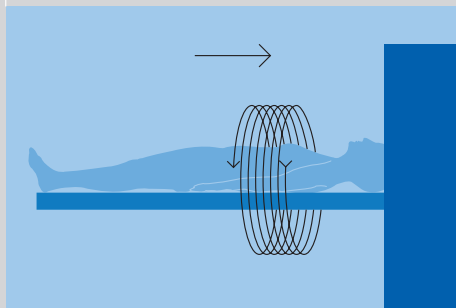
Real-time MPR

Selection of five slice thicknesses (1–10 mm)

1989

First spiral CT scanner in routine operation

Continuous volume measurement
Data acquisition during one breath hold
24 s/24 cm continuous volume acquisition



Spiral CT acquisition with continuous tabletop feed



Left: 3D Shaded Surface Display of the lung, high-resolution, spiral CT

Right: Spiral CT, lung, high-resolution, 2 mm, SOMATOM Plus

1990

SOMATOM Plus-S

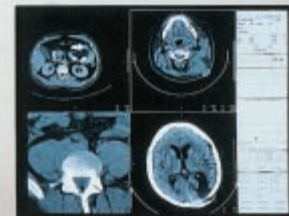
32 s continuous SPIRAL scan
QUANTILLARC 3 detector

1991

SOMATOM AR

Intuitive, mouse-controlled Windows™ user interface

Compact slipping scanner
Monitor with 4-quadrant display (512² ea.) for multitasking
High-efficiency QUANTILLARC 4 detector



Intuitive Windows™ user interface, mouse-controlled



SOMATOM AR

1992

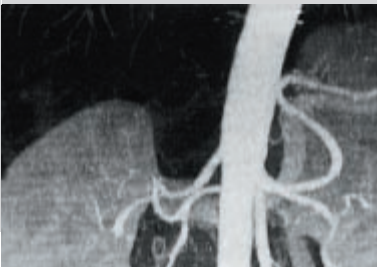
Integrated CT-Angiography

DURA-S X-ray tube with 4.3 MHU

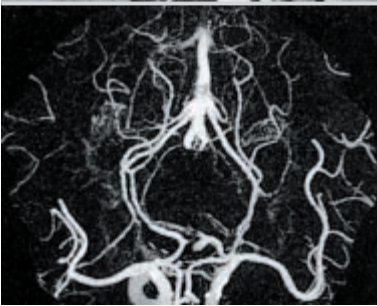
Prospective and retrospective overlapping SPIRAL reconstruction

SPIRAL XP: 40 s (pitch variable from 1:1 to 2:1)

Maximum Intensity Projection (MIP) and Minimum Intensity Projection (MinIP) incl. editing function for CTA



CT-Angio (MIP) of the renal arteries, SOMATOM Plus-S



CT-Angio (MIP) of the circle of Willis, SOMATOM Plus-S

1994

SOMATOM Plus 4

Subsecond spiral CT

Larger volumes acquired faster, shorter breath hold, increased patient comfort, improved thin-slice resolution

0.75 s scan time for a full 360° rotation, 0.5 s for a quick scan

100 s/130 cm multiple spiral acquisition with 1:1 pitch

Selection of six-slice thicknesses (1–10 mm)

± 30° remote-controlled gantry tilt

QUANTILLARC 6 inert gas detector

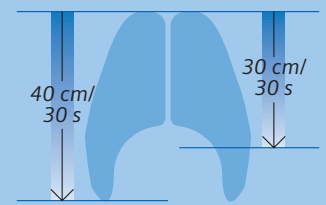
40–55 kW modularly upgradeable DURA generator

DURA X-ray tube with 5.3 MHU



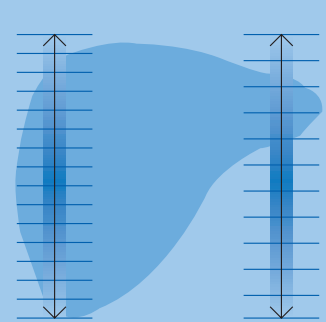
Subsecond spiral CT, long MPR, abdomen/pelvis, SOMATOM Plus 4

0,75 s SPIRAL 1,0 s SPIRAL



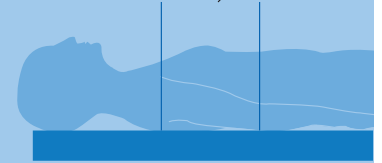
More volume in the same time

0.75 s SPIRAL 1.0 s SPIRAL



Improved thin-slice resolution

22 s → 0.75 s SPIRAL



30 s → 1.0 s SPIRAL

The same volume in less time

Advantages of subsecond SPIRAL scans

1996/97

Lightning UFC™

UFC Ultra Fast Ceramic Detector

Same image quality with significantly reduced radiation dose

Improved MPR – coronal/sagittal/oblique

Real-time image display (1 image/rotation)

Volume Rendering Technique (VRT)

1998

SOMATOM Volume Zoom

Multislice spiral scanning with 4 slices per rotation

Fastest rotation time of 0.5 s

Virtually isotropic resolution

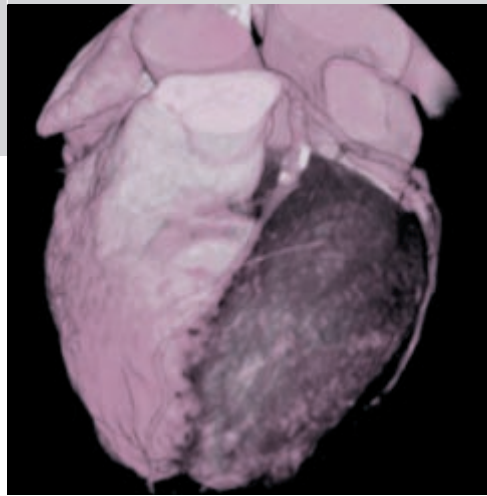
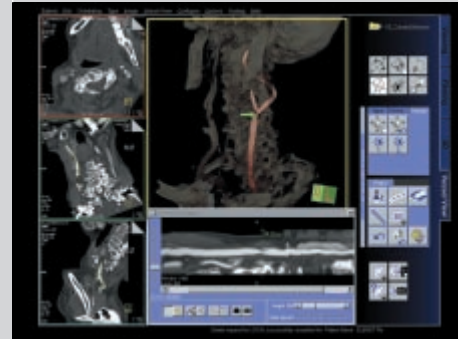
HeartView CT: First use of Cardio CT in routine operation, temporal resolution of up to 125 ms

SureView™: Reconstruction algorithm for multislice spiral scanning

1999

syngo software

Intuitive user interface for all medical applications and products



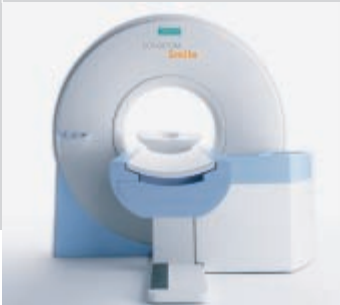
2000

SOMATOM Smile

Designed to be the smallest and most cost-effective spiral CT scanner

Plug-and-play installation

Do-it-yourself application training and service concept supported by interactive CD-ROMs



2001

CARE Dose

Dose modulation for reduced radiation



2002

SOMATOM Sensation 16

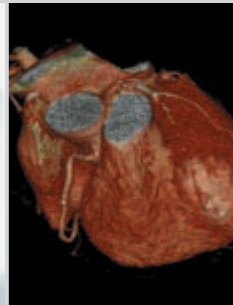
Multislice scanning with 16 slices per rotation

Isotropic resolution of up to 0.6 mm

Routine submillimeter slices (16 x 0.75 mm)

Cardio CT with extremely high image quality – temporal resolution of up to 105 ms with HeartView CT

Reconstruction algorithm with cone beam correction

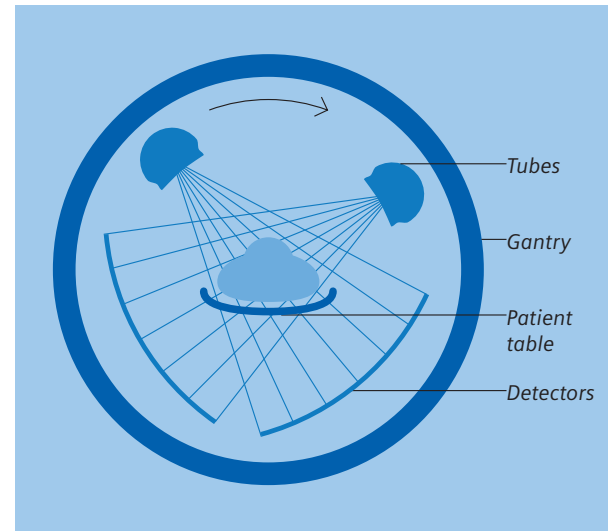


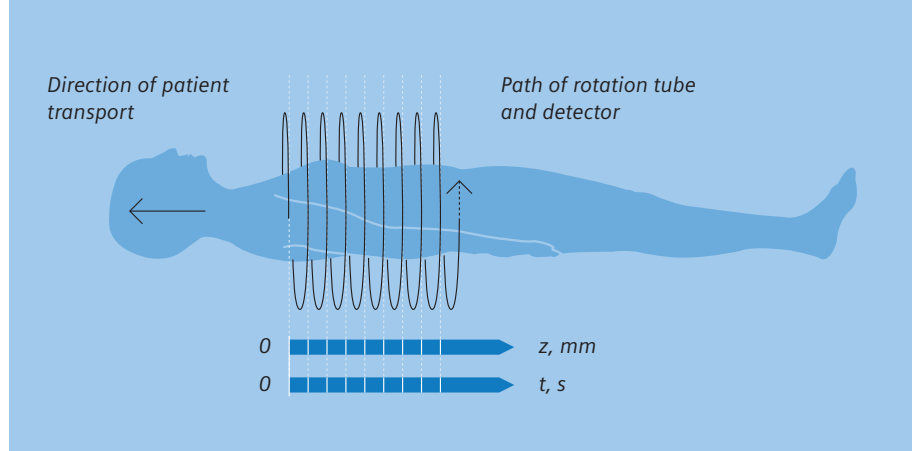
State of the Art

Sequential CT

A cross-sectional image is produced by scanning a transverse slice of the body from different angular positions while the tube and detector rotate 360° around the patient with the table being stationary. The image is reconstructed from the resulting projection data.

If the patient moves during the acquisition, the data obtained from the different angular positions are no longer consistent. The image is degraded by motion artifacts and may be of limited diagnostic value. The tomographic technique is suitable only to a limited extent for the diagnosis of anatomical regions with automatic functions such as the heart or the lung.





Spiral CT

Spiral CT is often referred to as “volume scanning”. This implies a clear differentiation from conventional CT and the tomographic technique used there. Spiral CT uses a different scanning principle. Unlike in sequential CT, the patient on the table is moved continuously through the scan field in the z direction while the gantry performs multiple 360° rotations in the same direction. The X-ray thus traces a spiral around the body and produces a data volume. This volume is created from a multitude of three-dimensional picture elements, i.e. voxels.

The table movement in the z direction during the acquisition will naturally generate inconsistent sets of data, causing every image reconstructed directly from a volume data set to be degraded by artifacts. However, special reconstruction principles – interpolation techniques which generate a planar set of data for each table position – produce artifact-free images. Thus it is possible to reconstruct individual slices from a large data volume by overlapping reconstructions as often as required.

Software applications enable the clinical use of spiral CT even for regions which are subject to involuntary movements.

Setup of a CT System

A CT system comprises several components.

These basically include:

- The scanning unit, i.e. the gantry, with tube and detector system
- The patient table
- The image processor for image reconstruction
- The console

The console represents the man-machine interface and is designed to be multifunctional. It is the control unit for all examination procedures, and is also used to evaluate the examination results. To enhance the workflow, Siemens has developed a double console capable of performing both functions at the same time.



Scanning unit (gantry)

A CT scanning system consists of an X-ray unit, which functions as a transmitter, and a data acquisition unit, which functions as a receiver. In commercial CT systems these two components are housed in a ring-shaped unit called the gantry.



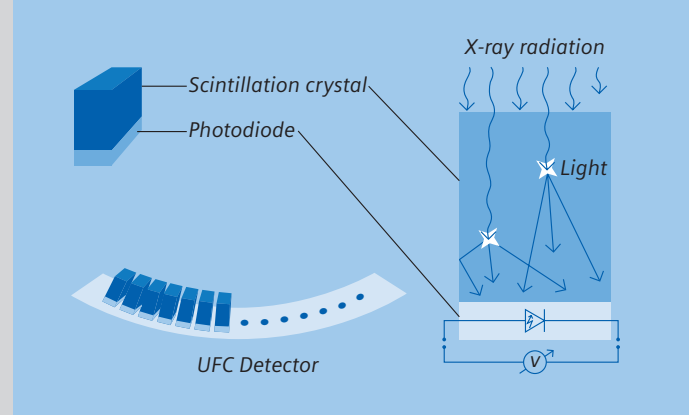
X-ray components

- Tube

Manufacturers of CT systems use X-ray tubes with variable focal spot sizes. This makes sense, because volumes for which good low-contrast resolution is essential need to be scanned with a large focal spot and high power, whereas high resolution images with thin slices require a small focal spot. Tubes used in modern CT scanners have a power rating of 20–60 kW at voltages of 80 to 140 kV. The systems can, however, be operated at maximum power for a limited time only. These limits are defined by the properties of the anode and the generator. To prevent overloading of the X-ray tube, the power must be reduced for long scans. The development of multi-row detector systems has practically excluded this limitation, since these detector systems make much more efficient use of the available tube power.

- Shielding

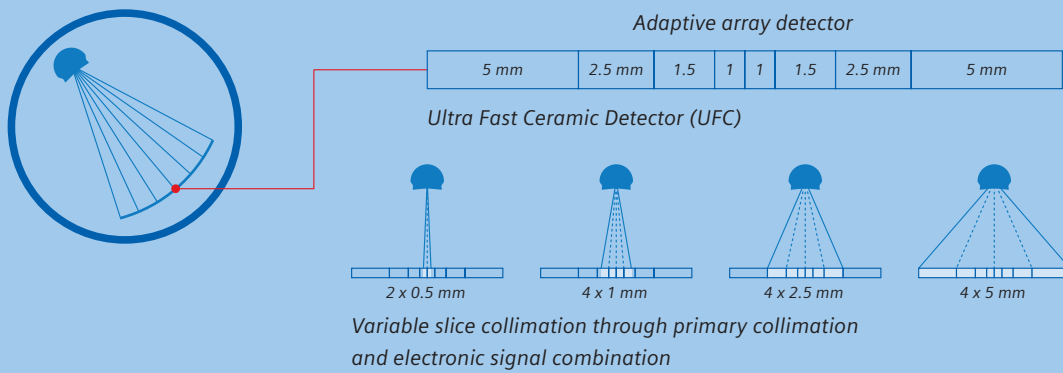
Each CT scanner is equipped with grids, collimators and filters to provide shielding against scattered radiation, to define the scan slice and to absorb the low-energy portion of the X-ray spectrum. In this way, both the patient and the examiner are protected.



Data acquisition components

- Detector

The detector system plays a special role in the interaction of the CT components. It converts the incident X-rays of varying intensity to electric signals. These analog signals are amplified by downstream electronic components and converted to digital pulses. Over time, certain materials have proven very effective in the utilization of X-rays. For example, Siemens uses UFC (Ultra Fast Ceramic) Detectors which, due to their excellent material properties, dramatically improve image quality.



- Multi-row detector

Multi-row detectors utilize radiation delivered from the X-ray tube more efficiently than single-row detectors. By simultaneously scanning several slices, the scan time can be reduced significantly or the smallest details can be scanned within practicable scan times. In the adaptive array detectors used by Siemens, the rows inside the detector are very narrow, becoming wider as you move toward its outer edges in the z direction (longitudinal axis of the body). A combination of collimation and electronic interconnection provides considerable flexibility in the selection of slice thicknesses. At the same time the space required by the detector septa, and therefore the unused space, is minimized.

Scanner Parameters

Collimation

The radiation beam emitted by the X-ray tube is shaped using special diaphragms also referred to as “collimators”. A distinction can be made between two types of collimators. The source collimator is located directly in front of the radiation source – i.e. the X-ray tube. It reduces the radiation beam to form the maximum required fan beam, thus also determining the emitted dose.

The detector collimator, which is positioned directly in front of the detectors, is primarily used to shield the detector against scattered radiation, thus preventing image artifacts. The collimation and focal size determine the quality of the slice profile.

From the data volume from a multislice scanner images can be reconstructed with slice thickness equal to or larger than the detector collimation. For example, a 5 mm collimation allows images to be reconstructed with a slice thickness of 5 mm or more. The widest range of possibilities in the selection of collimation and reconstructed slice thicknesses is offered in spiral CT using multidetector systems.



Increment

The increment determines the distance between images reconstructed from a data volume. If an appropriate increment is used, overlapping images can be reconstructed. In sequential CT, overlapping images are obtained only if the table feed between two sequences is smaller than the collimated slice thickness. This, however, increases the patient dose.

In spiral CT the increment is freely selectable as a reconstruction parameter, i.e. by selecting the increment the user can retrospectively and freely determine the degree of overlap without increasing the dose. Overlapping reconstructions offer the advantage of better image quality due to lower noise and easier and more accurate diagnosis of small structures.

An illustrative example: A 100 mm range was acquired in the spiral mode with 10 mm collimation. After the acquisition, slices of 10 mm thickness can be reconstructed at any point of this range. If an increment of 10 mm is used, contiguous slices of 10 mm thickness are reconstructed every 10 mm. (see figure 1).

If an increment of 5 mm is used, slices of 10 mm thickness are reconstructed every 5 mm. The slices overlap by 50%. With an appropriate increment an overlap of 90% can be achieved. Modern CT systems allow the reconstruction of slices with arbitrary increments (see figure 2). A clinical useful overlap is 30%–50%.

Figure 1

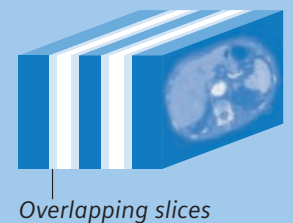
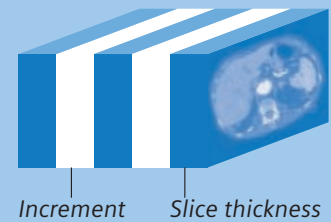
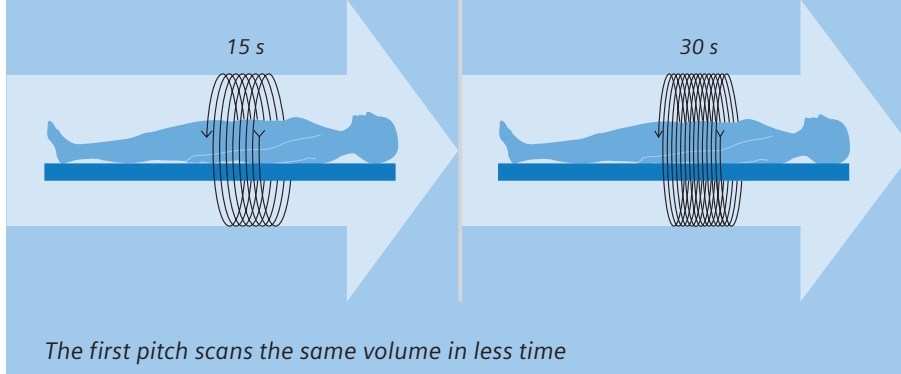


Figure 2



Pitch

An important factor in spiral scanning is the table feed per rotation. The larger the table feed, the faster (i.e. with fewer rotations) a body region can be scanned. However, if the table feed is too large, image quality will be impaired. In this context the term "pitch" is used. For single-row systems the definition

pitch = table feed per rotation/collimation

is generally accepted. Experience has shown that a good image quality can be obtained with a pitch between 1 and 2. It should also be noted that the dose can be significantly reduced in single-row systems if a pitch factor > 1 is applied. In the context of multi-row systems, pitch cannot yet be defined clearly. The ambiguity involved becomes apparent in the following example (SOMATOM Sensation 4):

Collimation 4×2.5 mm, table feed 10 mm

First possibility: pitch = $10 \text{ mm} / 4 \times 2.5 \text{ mm} = 1$

Second possibility: pitch = $10 \text{ mm} / 2.5 \text{ mm} = 4$

To avoid misunderstandings, we use "feed per rotation" rather than "pitch" on the user interface.

Rotation time

Rotation time is the time interval needed for a complete 360° rotation of the tube-detector system around the patient. It affects the spiral scan length and thus the coverage of the scan range during a certain period of time. Ultra modern CT systems require only 0.4 seconds for one rotation. A short rotation time has the following advantages:

- A longer spiral scan can be acquired in the same scan time
- The same volume and the same slice thickness can be scanned in less time
- Motion artifacts are eliminated
- Savings on contrast media through shorter examination times
- Reduced patient discomfort, since less contrast medium is required

For shorter examination times or fast acquisition of large anatomical regions a subsecond rotation time is recommended. This applies especially, for instance, to constantly moving organs such as the heart.



mAs

The mAs value (e.g. 100 mAs) is the product of the tube current (e.g. 200 mA) and the rotation time (e.g. 0.5 s).

In multi-row CT systems we simplify this equation by using what is commonly called “effective mAs”. This is the product of the tube current and the exposure time for one slice (rotation x collimation/feed per rotation).

The selected mAs and tube voltage determine the dose. The mAs value selected depends on the type of examination. Higher mAs values reduce the image noise, thus improving the detectability of lower contrasts. For visualizations of soft tissue, i.e. regions of low contrast, a higher dose and larger slice thickness are required. The abdomen and brain are typical regions of soft-tissue contrast. Visualizations of bones or the lungs, i.e. regions of high contrast, as well as contrast studies of vessels require lower doses and thinner slices.



Siemens CT scanners also feature the CARE Dose technical measures package (CARE = Combined Applications to Reduce Exposure), which was developed to reduce patient exposure to radiation. This package guarantees shorter examination times, the lowest possible exposure to radiation, and images of excellent quality.

Ultra modern computer technology “monitors” the patient during the entire examination period. During each rotation, the radiation is continuously measured and modulated according to the current attenuation level. CARE Dose thus makes it possible to vary the radiation dose depending on the patient’s anatomy and thus reduce it by as much as 56%.

Scanner parameters determine the image quality. Optimal performance of spiral CT systems can be achieved only with an optimal combination of parameters.

Image Generation

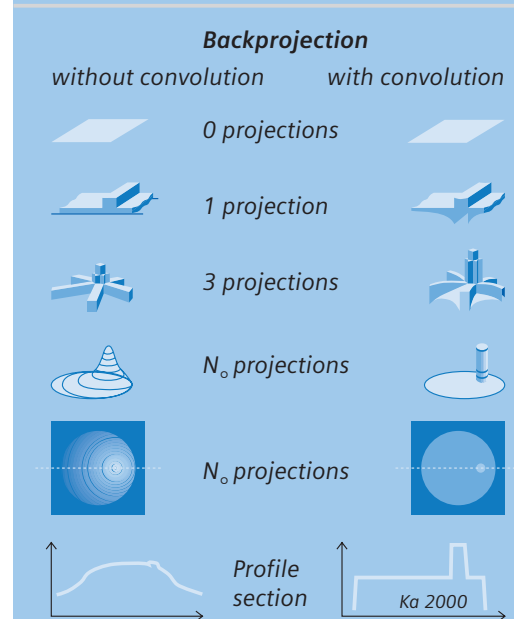
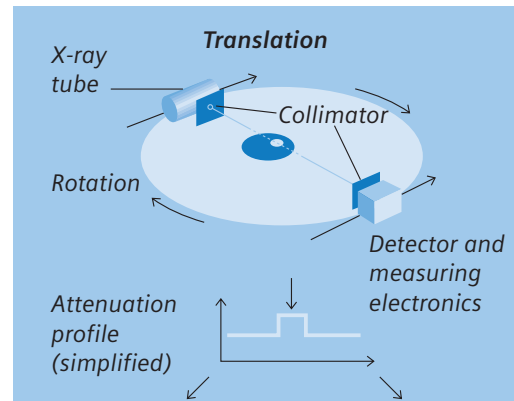
A CT image is produced

Acquisition:

In the simplest case, the object (here a round cylinder) is linearly scanned by a thin, needle-like beam. This produces a sort of shadow image (referred to as "attenuation profile" or "projection"), which is recorded by the detector and the image processor. Following further rotation of the tube and the detector by a small angle, the object is once again linearly scanned from another direction, thus producing a second shadow image. This procedure is repeated several times until the object has been scanned for a 180° rotation.

Display:

The various attenuation profiles are further processed in the image processor. In the case of simple backprojection, each attenuation profile in the scanning direction is added up in the image memory. This results in a blurred image due to the disadvantage of this simple backprojection, i.e. each object not only contributes to its own display, but also influences the image as a whole. This already becomes visible after 3 projections. To avoid this problem, each attenuation profile is subjected to a mathematical high-pass filter (also referred to as "kernel") prior to the backprojection. This produces overshoot and undershoot at the edges of the object. The mathematical operation is referred to as "convolution". The convolved attenuation profiles are then added up in the image memory to produce a sharp image.





Lung window



Soft-tissue window

What does a CT image show?

The CT image does not show these μ values directly, but the CT numbers according to Hounsfield:

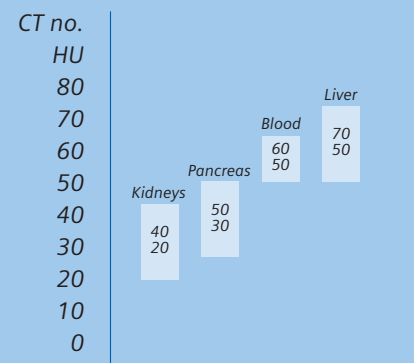
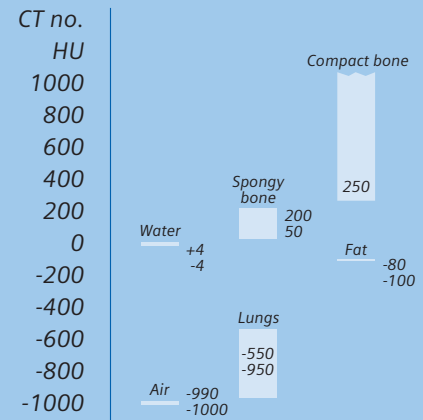
$$\text{CT number} = 1000 (\mu - \mu_{\text{water}}) / \mu_{\text{water}}$$

CT numbers are measured in HU = Hounsfield units. The CT number of water and air is defined as 0 HU and -1000 HU respectively; this scale has no limit in the positive range of values. Medical scanners typically work in a range of -1024 HU to +3071 HU.

Windowing

In the CT image, density values are represented as gray scale values. However, since the human eye can discern only approx. 80 gray scale values, not all possible density values can be displayed in discernible shades of gray. For this reason, the density range of diagnostic relevance is assigned the whole range of discernible gray values. This process is called windowing.

To set the window, it is first defined which CT number the central gray scale value is to be assigned to. By setting the window width, it is then defined which CT numbers above and below the central gray value can still be discriminated by varying shades of gray, with black representing tissue of the lowest density and white representing tissue of the highest density.



The Hounsfield scale

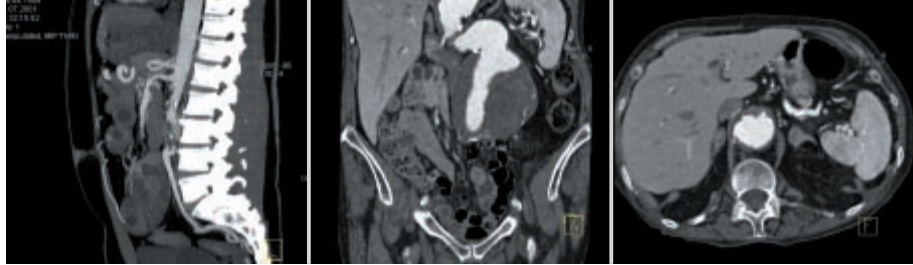
Image Evaluation and Image Processing

The first obvious results of any CT examination are the axial cross-sectional images. Since these images are already available in digital form on a storage medium, they can be processed immediately by the processor. The evaluation of geometrical parameters such as distance, area, angle and volume as well as density measurements are part of clinical routine today. The tissue density is determined using the CT number averaged over a defined evaluation area, the so-called Region Of Interest (ROI). Geometrical parameters can be defined more accurately than in conventional radiography, since the problems of superimposition and distortion do not exist in CT.

Examples of 2D post processing capabilities offered by modern CT systems:

- Display of the CT numbers of arbitrary pixels in the image
- Display of the CT number profiles along arbitrary intervals in the image
- Zoom and shift of image segments
- Filtering of images
- Addition, subtraction or other possibilities of image overlapping

The terms “two-dimensional” (2D) and “three-dimensional” (3D) refer to the image content. Views showing entire volumes are referred to as “3D displays”.



sagittal

coronary

transversal

Two-dimensional displays

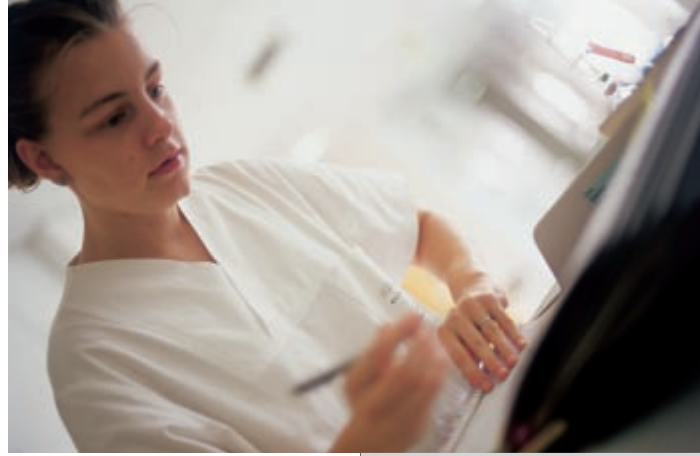
CT mainly uses the transverse plane as the imaging plane. Therefore, views of other orientations usually have to be reconstructed from the original images. This is done by **M**ulti **P**lanar **R**eformation (MPR).

With MPR, a series of axial images are combined to form a stack. By aligning the same columns and rows of all images of a series, the computer reconstructs contiguous images for any arbitrary plane. The examiner can then interactively page through these images, using the mouse for example, and evaluate them (iMPR). By paging forwards and backwards, he finds the image which most clearly shows the anatomical and pathological detail of interest. 4-quadrant displays with axial, sagittal, coronary, and oblique slice orientation are standard today and provide a good overview.

An extension of the MPR technique allows the interactive combination of thin slices into slices (slabs) of any thickness. This technique is used for better visualization of structures, such as vessels, which extend across several slices. This technique has become known as Sliding-Thin-Slab (STS).

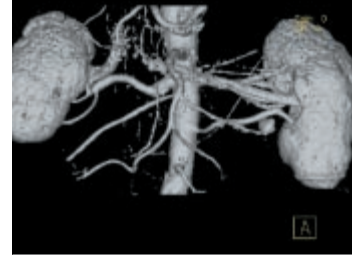
Advantages of two-dimensional displays

- Direct, accurate display of CT numbers
- Easy orientation in the volume
- Unambiguous interpretation of image values
- Interactive evaluation on the monitor
- Basis for 3D images



Three-dimensional displays

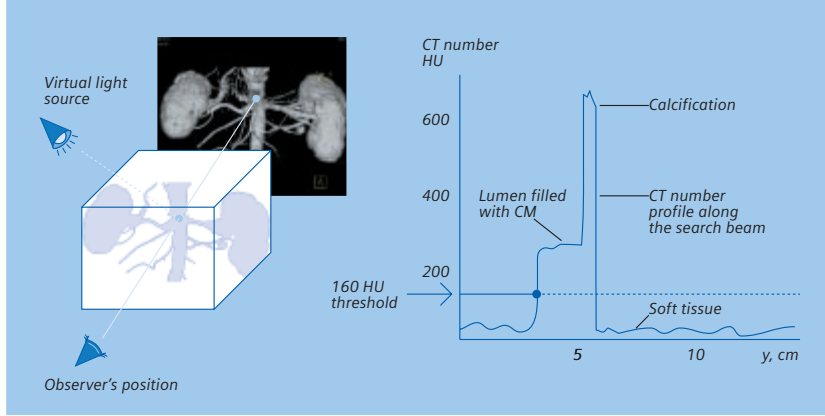
For 3D visualizations the position and viewing direction with respect to the volume of interest must be indicated. Along this viewing direction through the data volume a spatial image is reconstructed from the CT numbers pixel by pixel. Such virtual views are especially suitable for structures which clearly stand out against their surrounding area, such as the skeletal system or contrast-filled vessels.



*Shaded Surface
Display (SSD)*



*Maximum Intensity
Projection (MIP)*

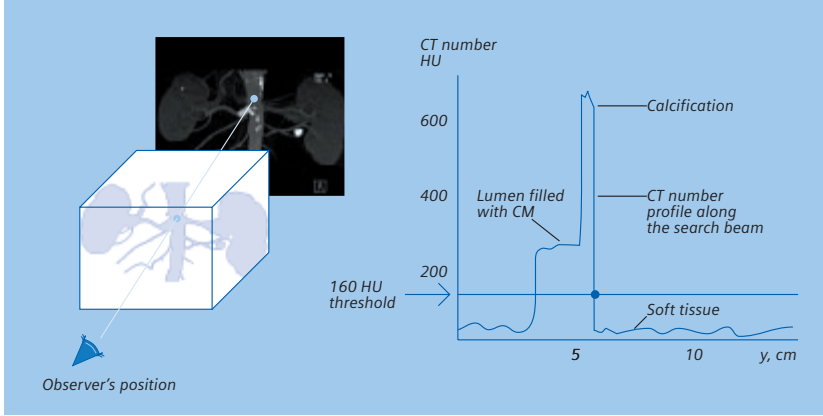


- **Shaded Surface Display (SSD)**

For threshold based surface displays a CT number, e.g. 150 HU, is predefined as a threshold. All pixels, i.e. voxels, which exceed this threshold value contribute to the result image. From the viewer's position these are all those pixels along each beam which first exceed the threshold. The surface is then reconstructed from the totality of pixels and illuminated by an artificial light source to create a shading effect (Surface Shaded Display, SSD). The shading effect intensifies the depth impression for the viewer. With this technique, however, the original density information from the CT numbers is lost.

With SSD it must be noted that the gray scale values are no longer related to the original density of the structures. For example, if several structures which exceed the threshold value are superimposed in the viewing direction, only the structure closest to the front surface of the monitor is displayed. This also applies if the structures behind it have considerably higher CT numbers.

It also needs to be taken into account that SSD displays always depend on the threshold value selected. For example, the display of vascular stenoses can be distorted by selecting an inappropriate threshold. If the threshold value is increased, a higher degree of stenosis results, if it is decreased, stenoses may be obscured. In this way calcifications and contrast medium in the vessels can no longer be differentiated. Therefore, SSD images are hardly suitable for diagnosis. They are, however, used to document results or for 3D displays.

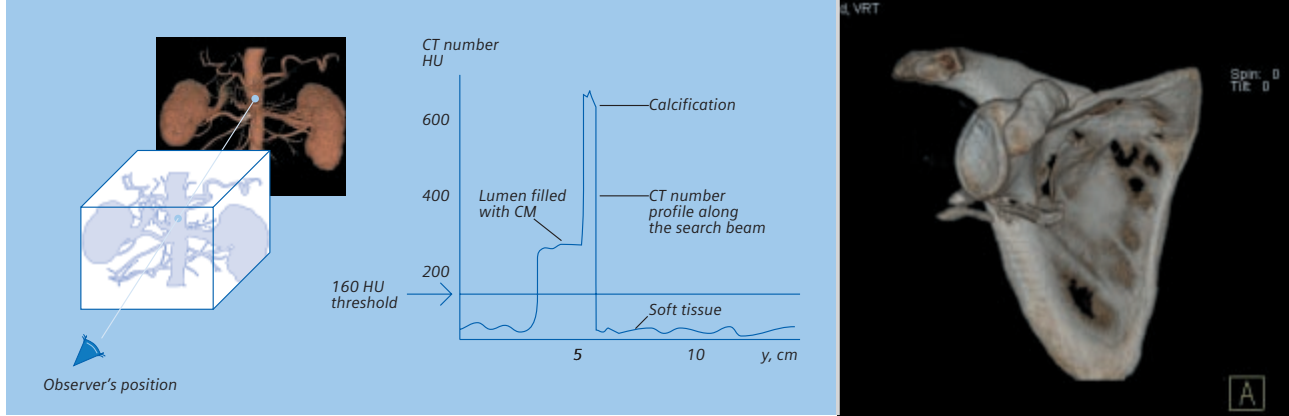


- **Maximum Intensity Projection (MIP)**

Maximum Intensity Projections (MIP) are based on the voxels with the highest density, i.e. CT number. Along a virtual beam extending from the viewer through the 3D image volume, the voxel with the highest density value is displayed in the resulting MIP image. Each MIP image is therefore a 2D projection image. Running several MIP images in fast sequence can create a realistic spatial impression. For this, an image series is created by varying the viewing angle in small steps.

In contrast to SSD, with this technique a minimum of density information is retained. Moreover, the projection is always a combination of those voxels from the entire volume that have the highest density, irrespective of whether these voxels are located further towards the front or the back of the image. Unlike in SSD images, calcifications and contrast medium are clearly differentiated in MIP images.

Alternative to the MIP image, it is also possible to display pixels with the lowest intensity in the projection image. These images are called MiniIP images. They are used to display structures such as the bronchial tree.



- **Volume Rendering Technique (VRT)**

Volume Rendering Technique (VRT) refers to the process of reconstructing a 3D model from a 2D image stack. VR techniques go beyond SSD and MIP techniques in their basic approach and performance. They are not limited to a certain threshold or maximum density value. Instead, all density values along a virtual beam which have a suitable weighting can contribute to the result image. In contrast to MIP and SSD, the entire Hounsfield scale can be included in VRT. Each CT number is assigned an opacity and color via freely selectable and interactively modifiable transfer functions. This makes it possible to simultaneously display an extremely wide variety of tissue structures of various density or HU value in a single volume data set.

- **Virtual endoscopy (VE)**

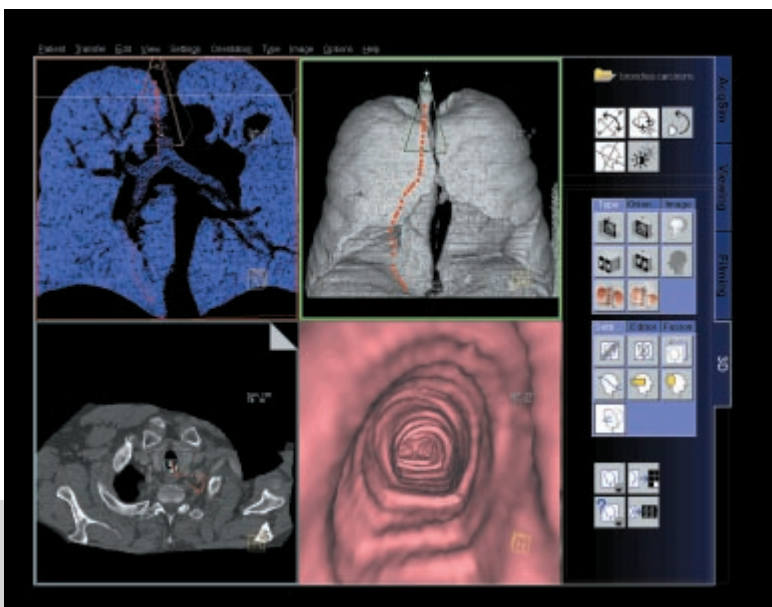
A special type of VRT is perspective Volume Rendering (pVR), which is used mainly to generate virtual endoscopic views. This technique is used to obtain a perspective view of the display region.

Virtual endoscopy is mainly used for anatomical cavities: These include, for example, the bronchial tree, large vessels, the colon and paranasal sinuses. But VE is also used for areas not directly accessible for conventional endoscopy, such as the cisternae of the brain or the gastrointestinal region.

When the endoscope is inserted in a cavity displayed with the perspective Volume Rendering Technique, this gives the user the impression of “flying through” the displayed region (virtual flight).

Advantages of three-dimensional displays

- Realistic display of volumes
- Presentation of the entire volume in one single image
- Improved recognition of diagnostically relevant details
- Helpful for more precise surgical planning
- CT image data as a basis for three-dimensional models
- Possible free rotation of 3D objects



Clinical Use of CT

CT in general clinical use

The use of spiral CT has significantly shortened scan times compared to sequential CT. This is of great advantage when examining patients who, due to the nature of their illness, are unable to cooperate. Motion artifacts caused by different respiratory conditions during the acquisition are reduced considerably, because in spiral CT the entire volume is scanned faster and without gaps. Multiple scans due to breathing during the acquisition are no longer necessary. The patient dose is therefore reduced.

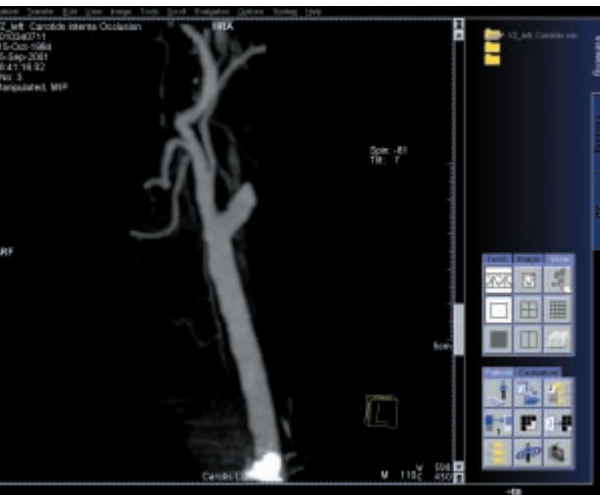
Advantages of spiral CT in clinical use

- Complete coverage of organs in a single respiratory position
- Short scan times (resulting in fewer motion artifacts and a lower contrast medium requirement)
- Additional diagnostic information due to improved resolution (thinner slices) and 3D visualization in routine operation
- Special cost-effective applications based on spiral CT



CT-Angiography (CTA)

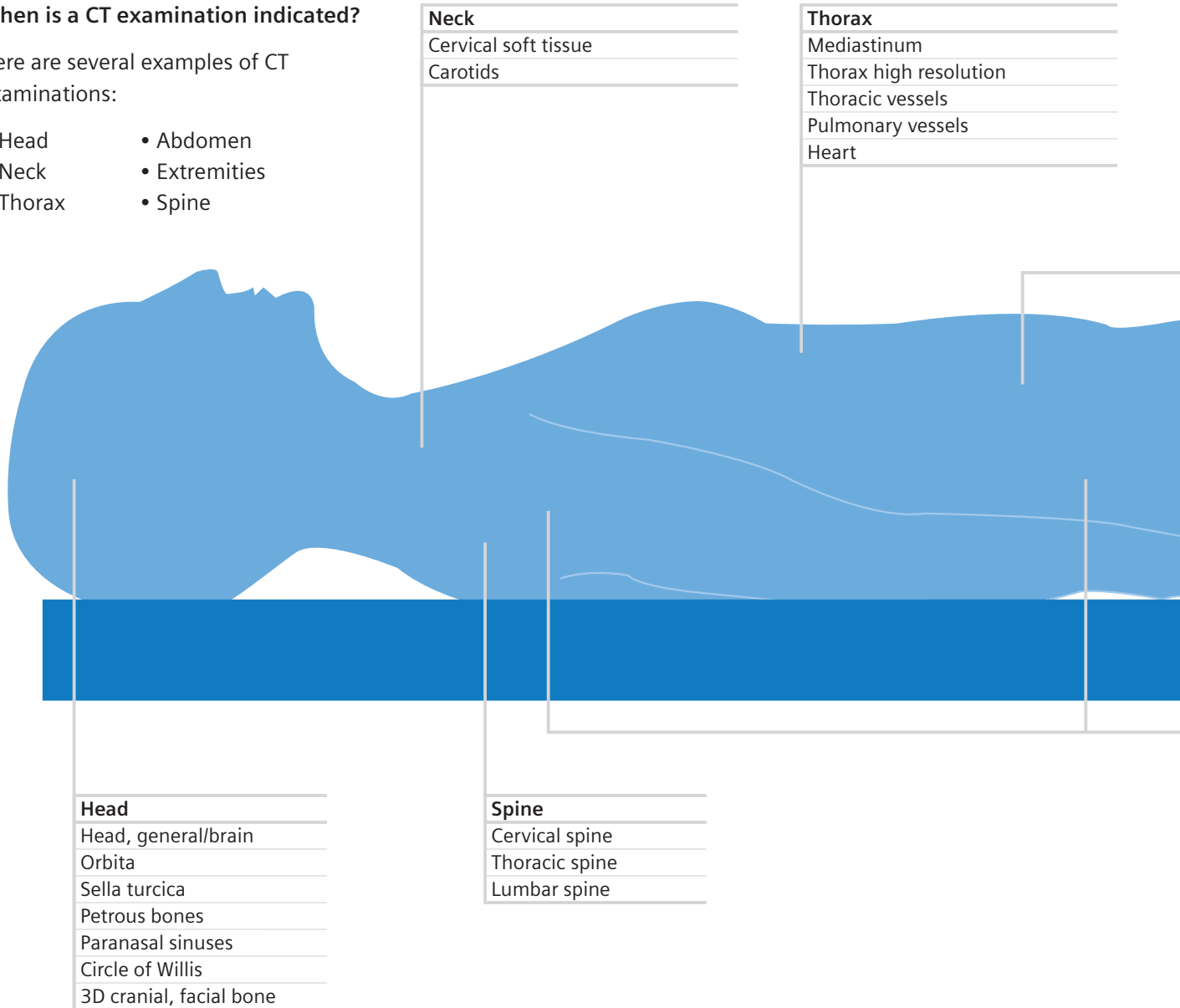
CT-Angiography (CTA) enables the display of vascular structures aided by injections of contrast medium. The introduction of the multislice scanner has made it possible to display the entire vascular system with maximum contrast enhancement in extremely short scan times. Image post processing enables good display of the entire vascular system. Even small vascular exits and origins (branches) and embolisms or dissection membranes can be displayed. The physician can retrospectively select any projection and generate three-dimensional images, e.g. for surgical planning.



When is a CT examination indicated?

Here are several examples of CT examinations:

- Head
- Neck
- Thorax
- Abdomen
- Extremities
- Spine



Abdomen/pelvis

Liver

CT-Arteriopography (CTAP)

Pancreas

Kidneys, biphasic

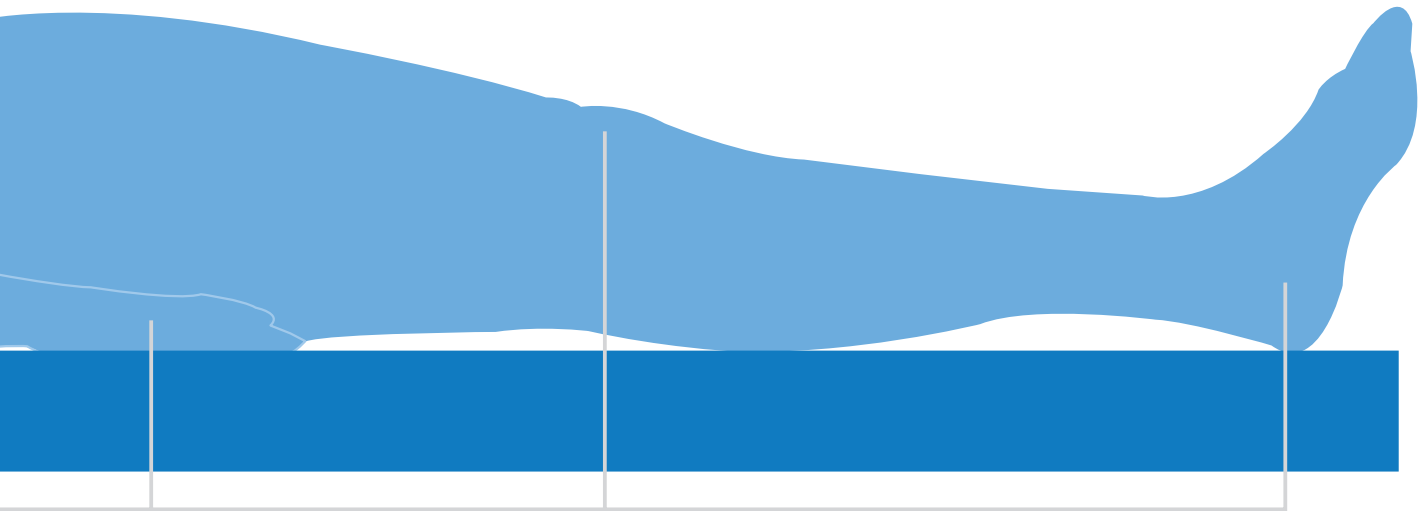
Adrenal glands

Renal arteries

Abdominal vessels

Small pelvis

Vessels, pelvic/lower extremity



Extremities

Shoulder joint

Hip joint

Wrist bone

Knee joint

Foot

The information in this document contains general descriptions of technical possibilities which do not necessarily apply to each individual case. Any performance features individually required must therefore be stipulated upon conclusion of the relevant agreement.

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