MrTEEmothy® - Optimal CT scans quality

To be able to select a CT scan for MrTEEmothy, the following quality issues must be met:

- completeness and uniformity of the images acquired during all phases of the heart cycle,
- appropriate image and scene sizes,
- appropriate contrasting,
- proper selection of reconstruction kernels.
- no artifacts,
- no significant quality loss features using Dose Care systems.

Completeness and uniformity of images acquired during all (usually 10) phases of the heart cycle.

Multiphase scans are performed based on synchronization with the ECG signal. Acquisition is performed for one or several heart cycles, and reconstruction is performed offline. The reconstruction can include subsequent phases which usually have a fixed time interval. Reconstructions are made every 10% (10 frames) and every 5% (20 frames). Sometimes the system duplicates the first frame as the last - then there are 11 or 21 frames. This last frame is identical to the first one and is not necessary for simulation.

Requirements:
for simulation, it is necessary that subsequent frames (heart phases) contain exactly the same volume of the patient's body, with the same resolution of slices (pixel spacing), their number per frame and position in the body (axis).

Appropriate image and scene sizes

The standard resolution of CT slices (pixel spacing) is about 0.35-0.4 mm. The value of image density (increment) should be comparable. Higher density can always be reduced. Good quality CT usually contains about 300+ slice images per heart beat phase.

The CT scene should contain the whole heart and partly: big vessels, lungs, sternum and vertebral column. The majority of oesophagus should also be included, from the distal trachea level to the diaphragmatic level.

The best size of CT slices is of 512x512.

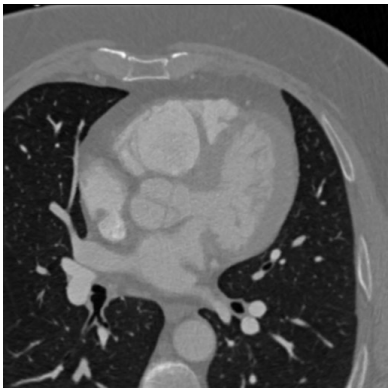
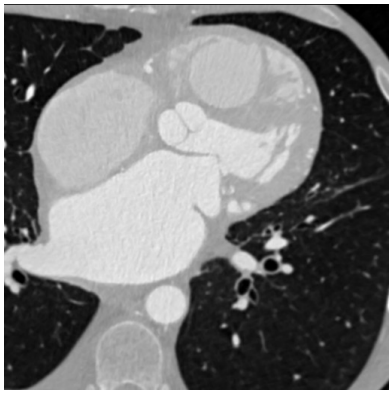
Adequate contrast

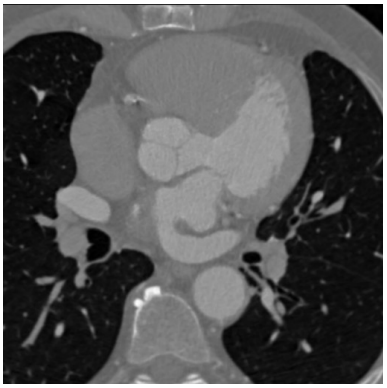
The heart should be properly contrasted.
The contrast should ideally fill both the left and right heart cavities. If only left or only right heart is filled with contrast during acquisition, only those cavities / valves will be properly visible during simulation.

Due to mixing of the contrasted blood flowing from the superior vena cava and uncontrasted blood flowing from inferior vena cava the right atrium and right ventricle may be non-uniformly contrasted. This can be

avoided by injecting the contrast to both the ulnar and femoral veins but such an approach is not a standard CT scan and may only be considered if perfect imaging of the right heart is medically indicated.

Below are some pictures that are well contrasted and poorly contrasted.

		
well contrasted		

		
poor distinction between the cardiac cavities and heart muscle	wery noisy	good contrast of the left heart, poor contrast of the right heart
poorly contrasted		

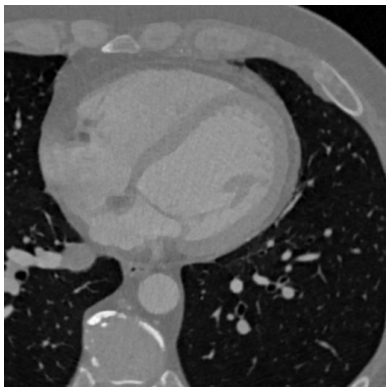
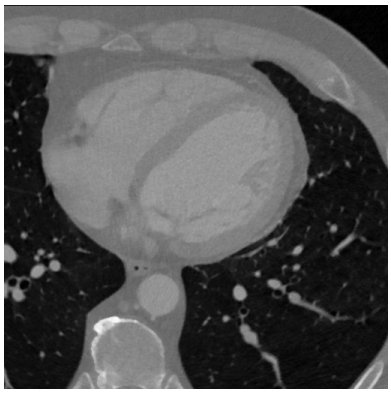
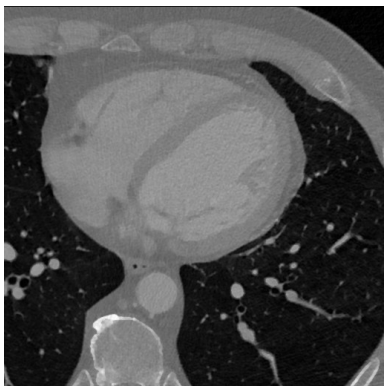
Reconstruction kernels

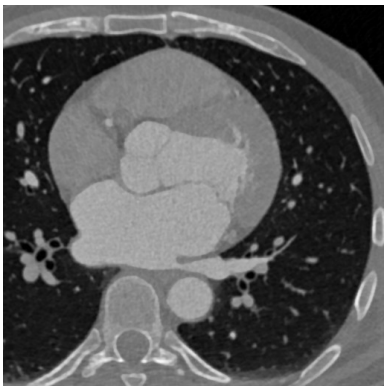
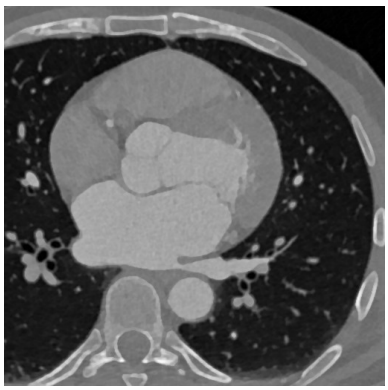
SIEMENS

Different kernels reconstruction can be chosen for reconstruction. „Soft" kernels are used to visualize soft and hard tissues – „hard" kernels more accurately visualize the bones (edges). Soft kernels show tissues smoothly, hard – create more noise. Depending on the scanner, different techniques (under different names) are available:

https://www.aapm.org/meetings/2010CTS/documents/1530_McCollough_Converting_Across_Scanner_Models_04-29-2010.pdf

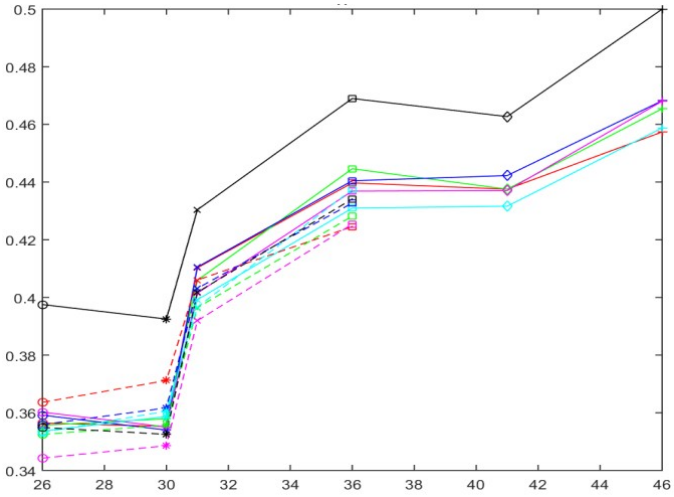
In case of the Siemens device, the kernels are defined in the order from soft to hard: b26, b30, b31, b36, b41, b46, ... In addition, the SAFIRE function can be used, which smoothes the soft tissues. Then the kernels are named I26, I30, I31 ... and have additional information about the SAFIRE function parameter ([1-5]), i.e. I26f3, I31f5, where the default value is 3.

		
I30f3	**I36f3**	**I46f3**
sample images for different kernels		

	
I26f3	**I26f5**
sample images for different SAFIRE values	

Preliminary results of experimental evaluation showed that the optimal kernel for reconstruction for simulation purposes is I30f3, the kernel B26 is also good.

Description of noise measurements, is shown below:



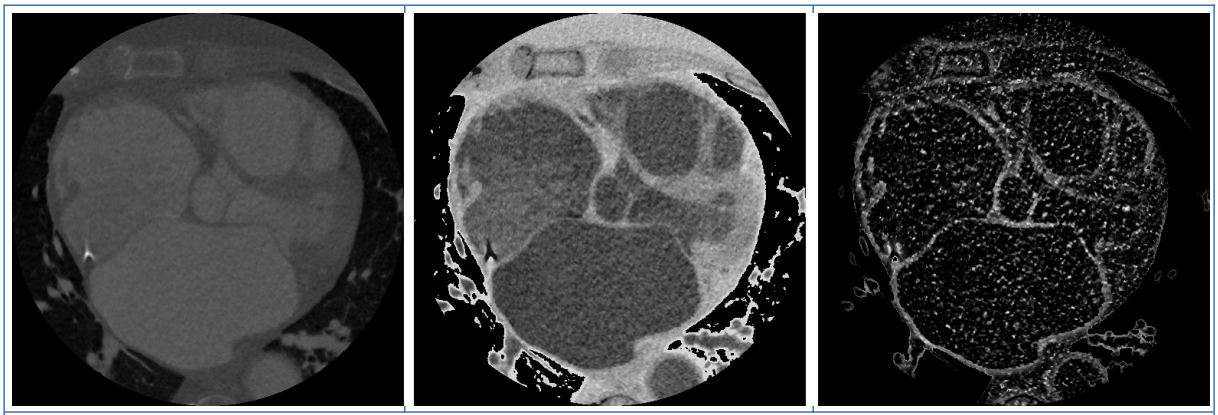
(fig. By K. Nurzyska)

TOSHIBA

In case of the Toshiba equipment, the kernels are designated with the names FC03, FC04, FC05, ... FC08 and FC13 .. FC18.

The segmentation of the heart cavities and valve leaflets is much more accurate, faster and easier when there is less noise, so the FC03 kernel or smaller is recommended. The difference between FC03 and FC05 is shown below.

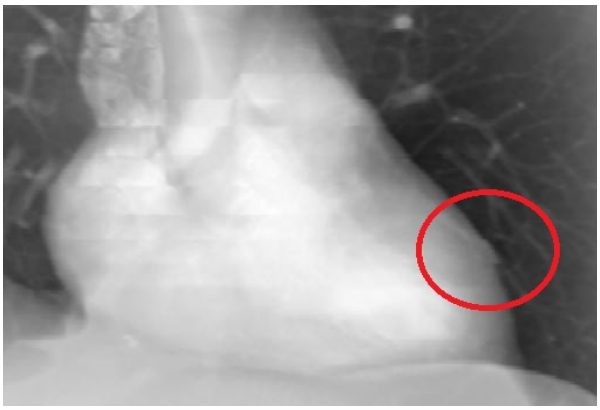
FC03

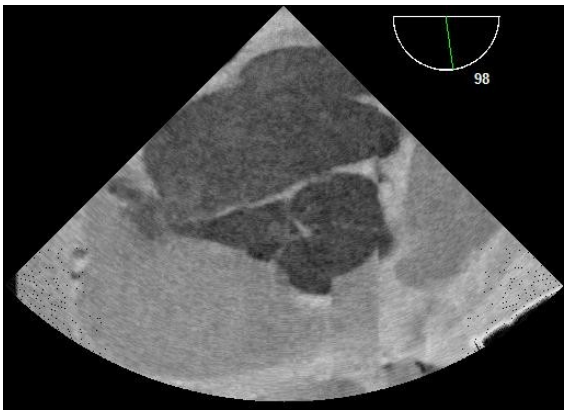


FC05

Artifacts

Correct carrying out of the simulation is hindered by artifacts that may appear in the CT set. Examples are provided below.





Patient's motion artifacts

Helical CT artifacts for metal elements

Quality in Dose Care systems

Some systems limit the radiation dose in selected phases of the heart. This can cause a limitation of CT image quality. The following example of a CT set shows this issue, having satisfactory quality of 50% - 80% phases.