OPTIMISATION OF LOW DOSE COMPUTED TOMOGRAPHY PROTOCOL FOR DIAGNOSTICS OF DEVELOPMENTAL DYSPLASIA OF THE HIP USING A PHANTOM BASED NOISE SIMULATION APPROACH

Authors:

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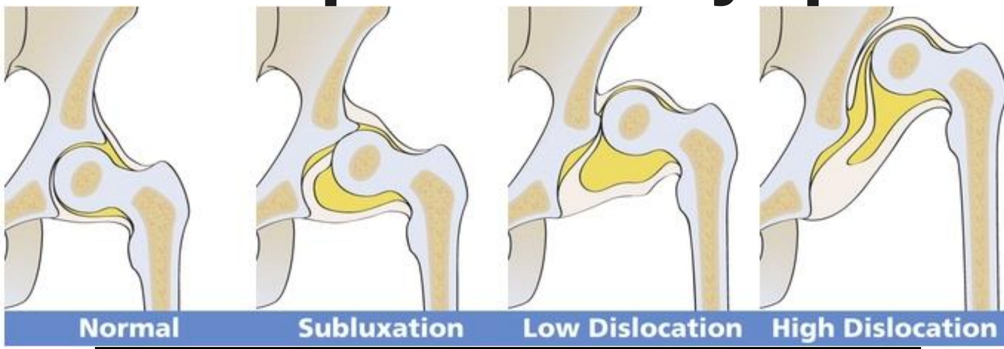
Developmental dysplasia of the hip (DDH)



Diagnostic modalities:

- ~~Functional tests, palpation~~
- ~~Ultrasound~~
- ~~Roentgenography~~
- ~~Magnetic resonance imaging~~
- Computed tomography (CT)

OPTIMISATION

Do we even need to optimise?

Image Quality based optimisation

vs

Indication based optimisation

The tasks for the work

- To identify noise affecting scanning parameters and create a phantom corresponding to the DDH case.
- To generate the reference noise samples for the DDH case.
- To construct and apply the phantom based noise simulation algorithm for images of developmental dysplasia of the hip.
- To evaluate the impact of noise on the image quality and clinical acceptability, in the simulated images.

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Materials and methods

Selection criteria:

•Same tube voltage – 120 kV.

•Slice thickness – 0.75mm.

•Reconstruction kernels B20.

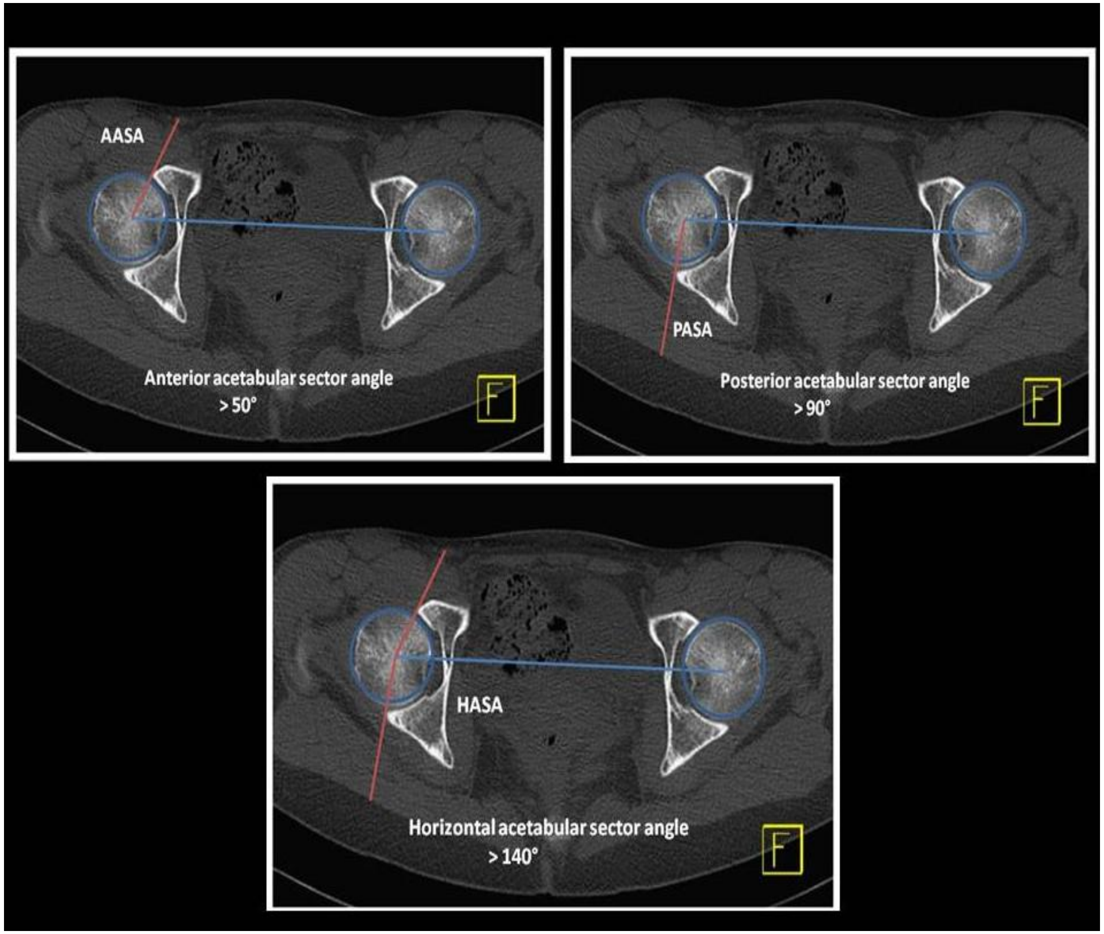
20 patient scans were chosen for the simulation.

Phantoms used

Gelatine based phantom, for noise sample generation.

Spherical phantom for noise-size dependence and plaster impact evaluations.

Image evaluation



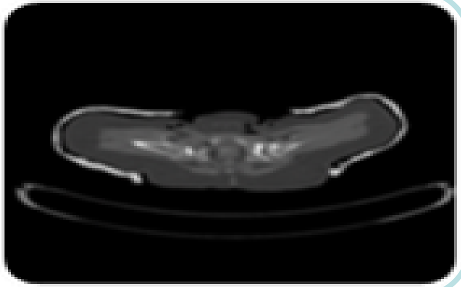
- Axial evaluation:
  - Angles between structures.
  - Reduction control.
  - Sharpness and visibility.
- 3D evaluation:
  - Evaluation of the bone positions.
  - Structure visibility.
  - Angle measurement.

Simulation

GOAL:

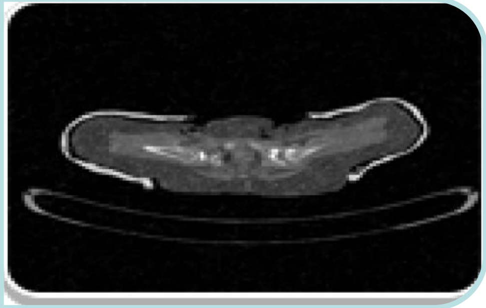
Adapting the noise sample for the individual image and combining them

Original image



Noise sample

Simulated low dose image



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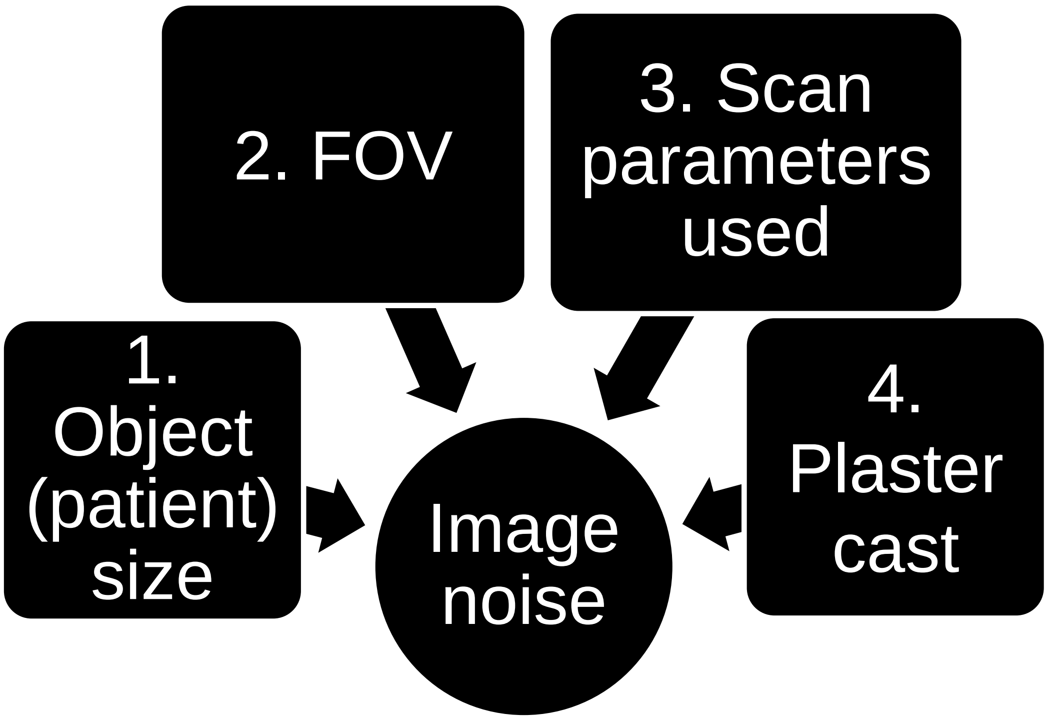
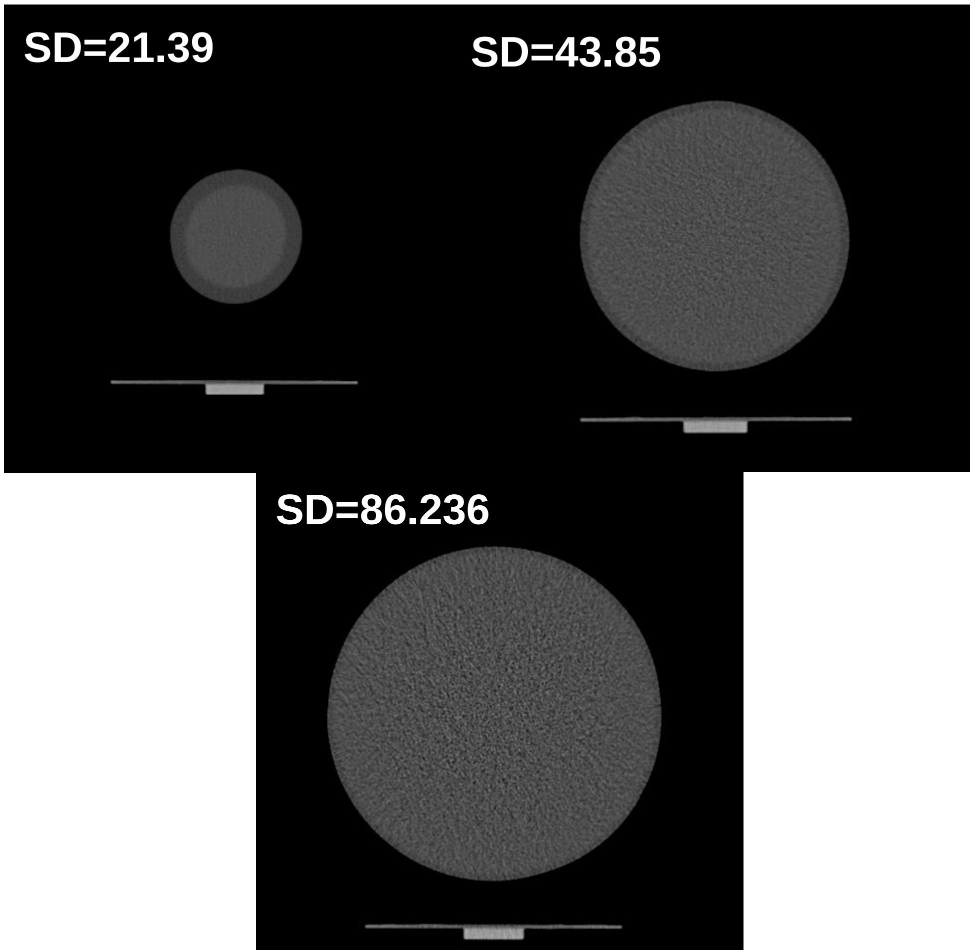
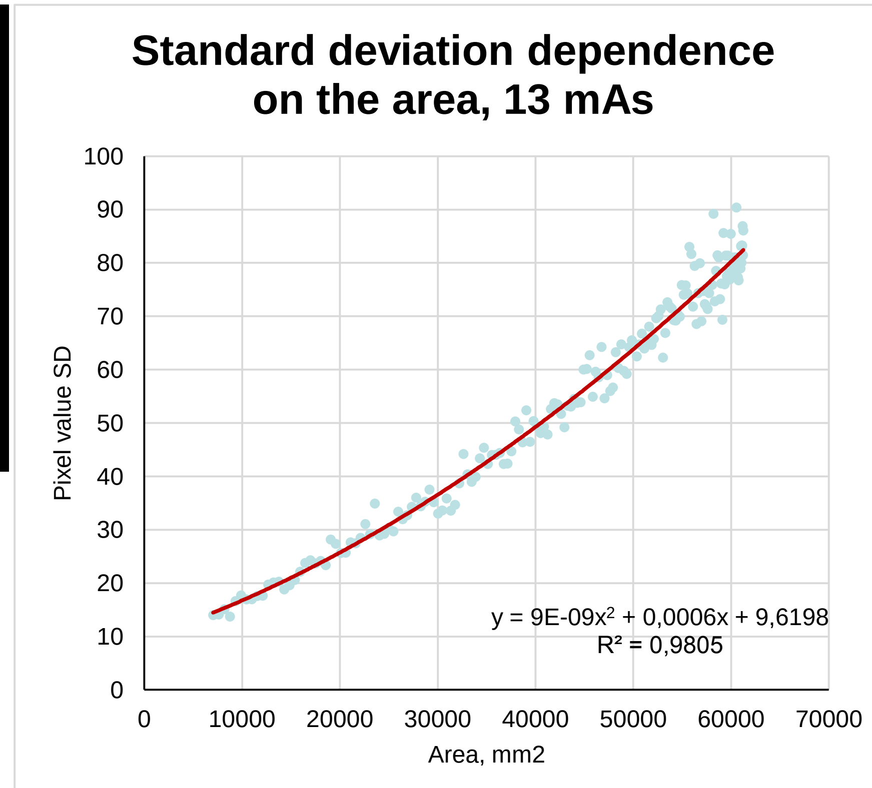
Results

Selected patient parameters in the case of DDH, most influencing the simulation and noise in the image.



1. Object Size (size-noise dependence)



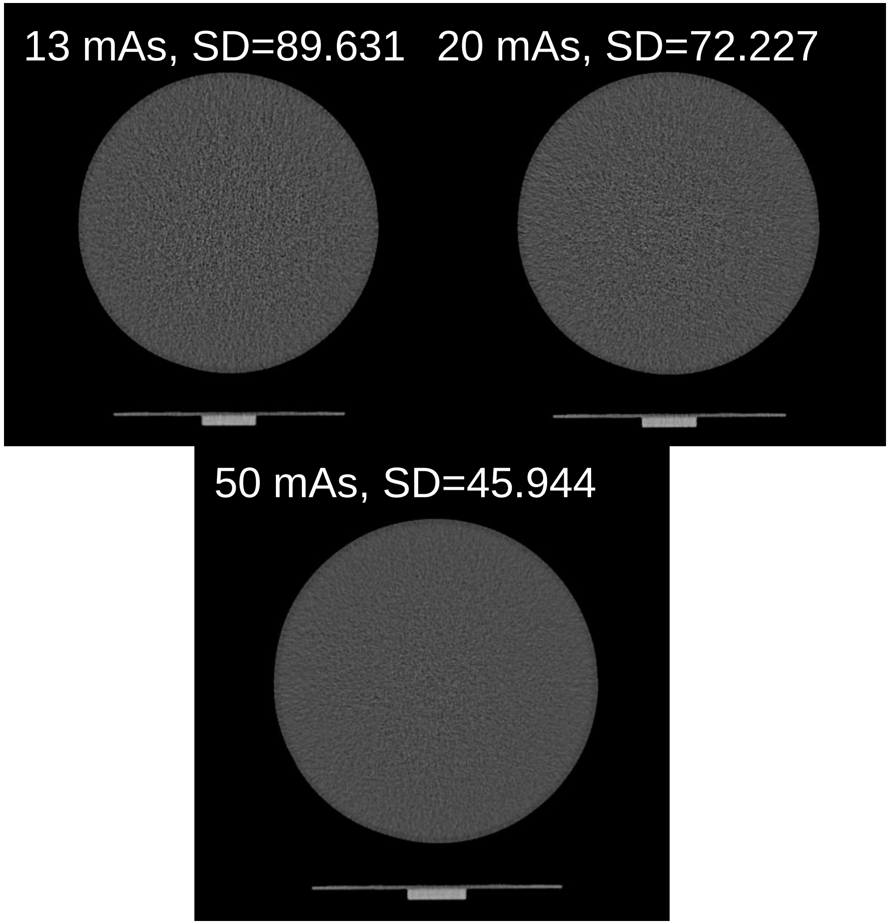


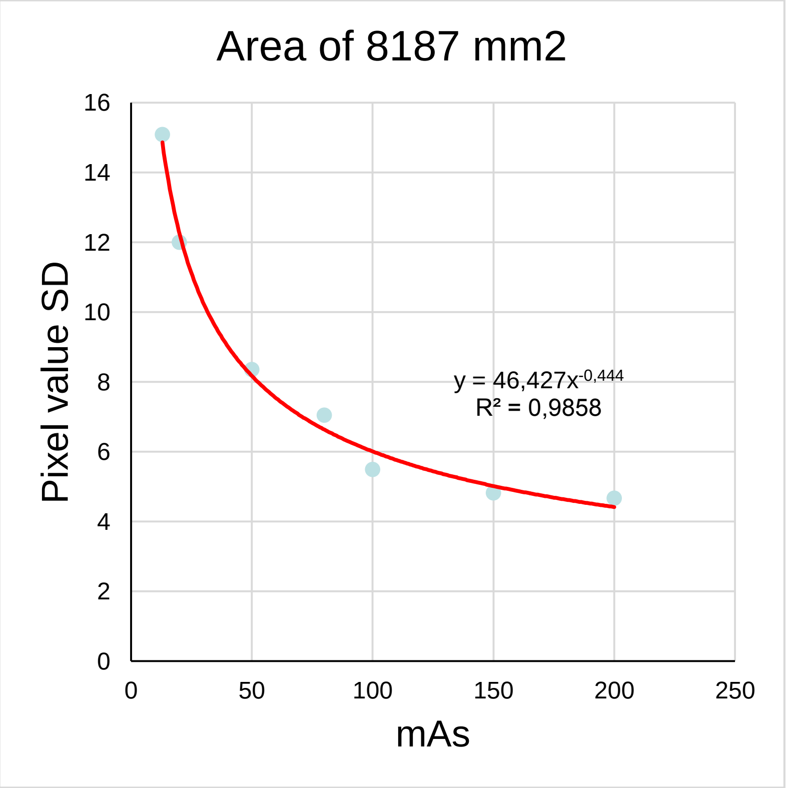
2. Field of view (FOV)

Two types of images depending on the FOV:

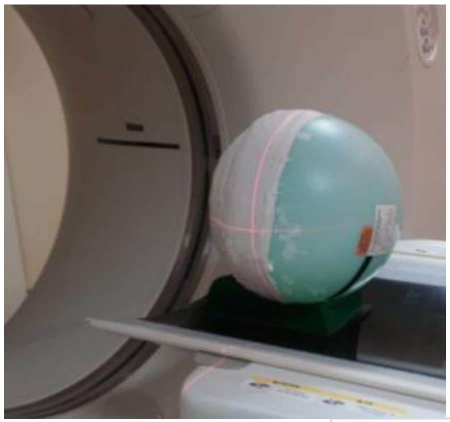
- Normal (large FOV)
- “Cropped” (small FOV)

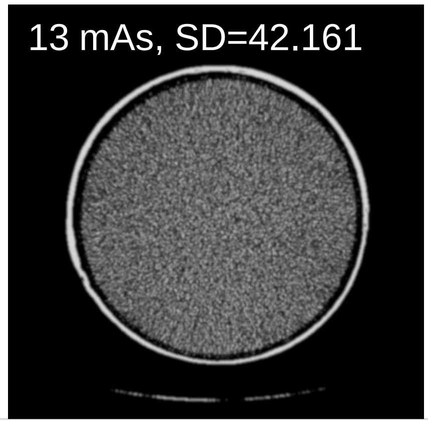
3. Scanning parameters (mAs-noise dependence)

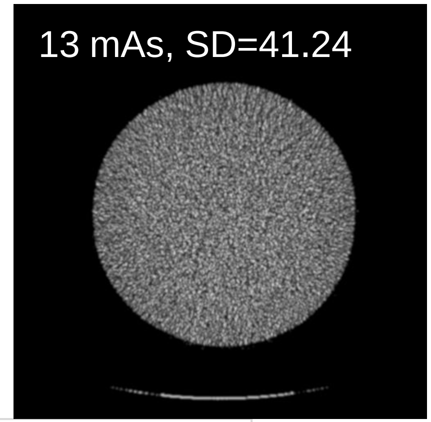


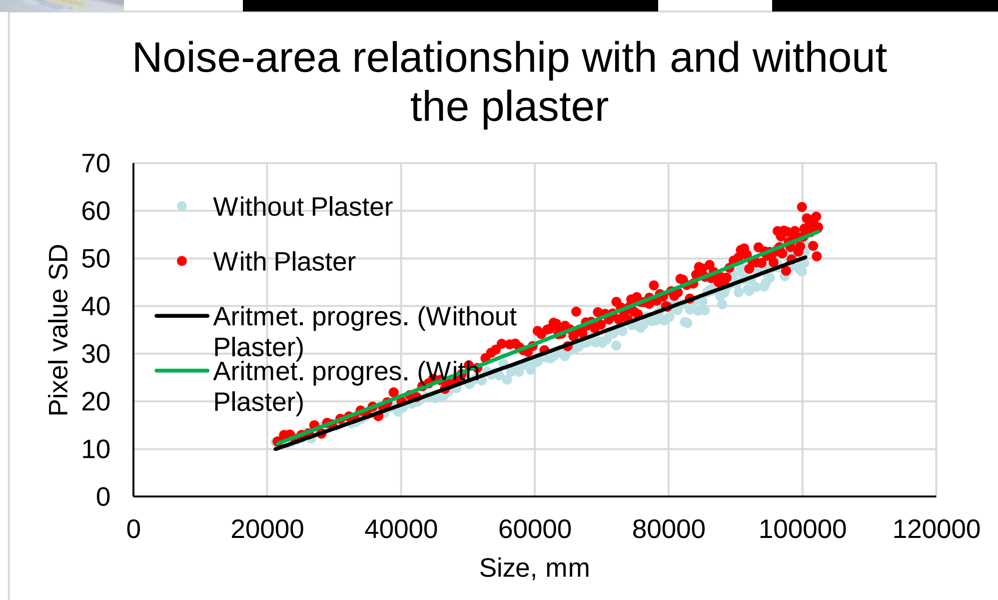


4. Plaster cast influence on noise

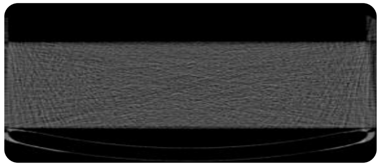




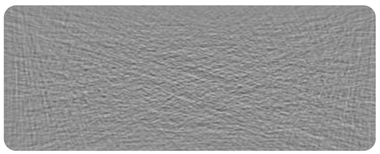




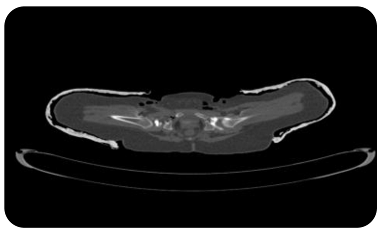
Simulation



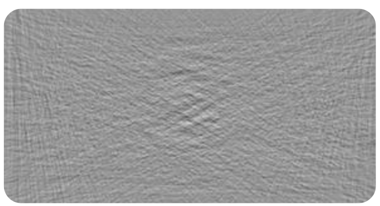
1. Gelatin phantom scans



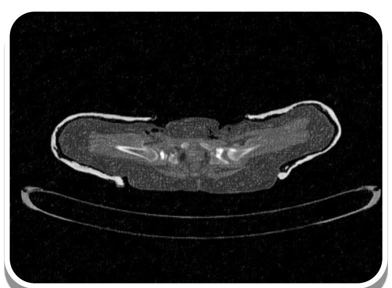
2. Reference noise sample



3. Noise parameter identification



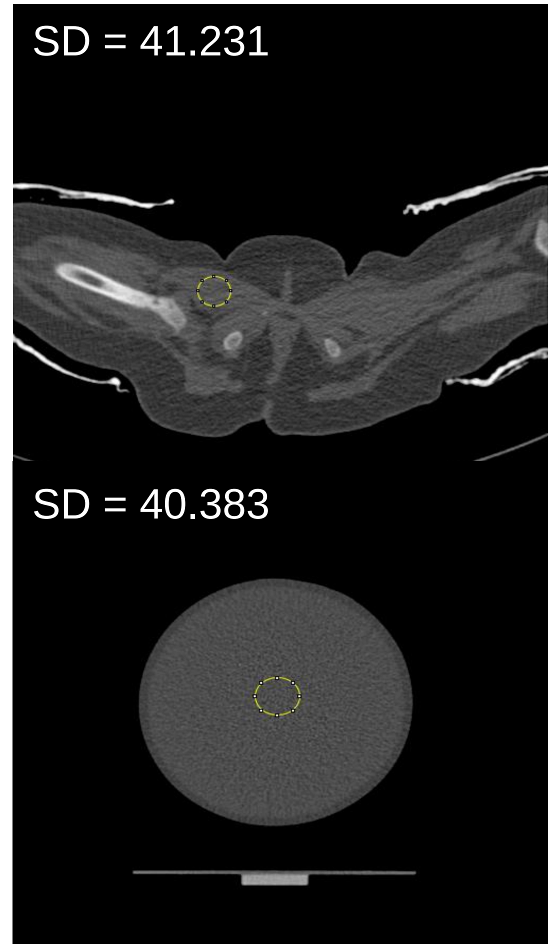
4. Noise sample modification

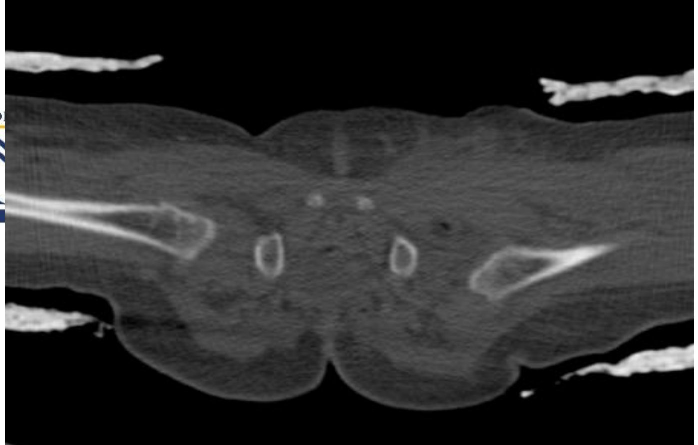


5. Combining the noise sample and the original patient image

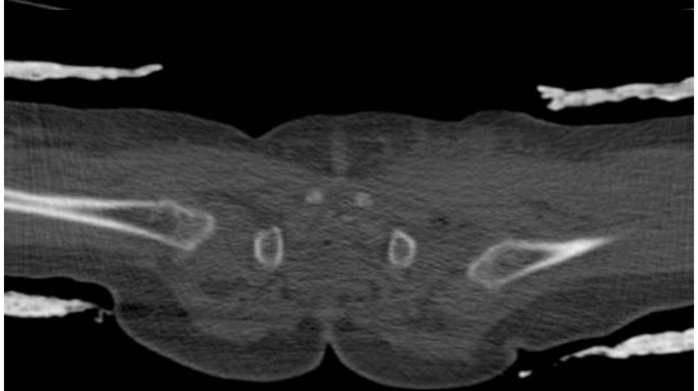
Simulation validation

The validation of whether or not the simulation was successful, was made using manual comparisons between the measured SD of various areas on the patient and the measured SD of the spherical phantom with the same area.

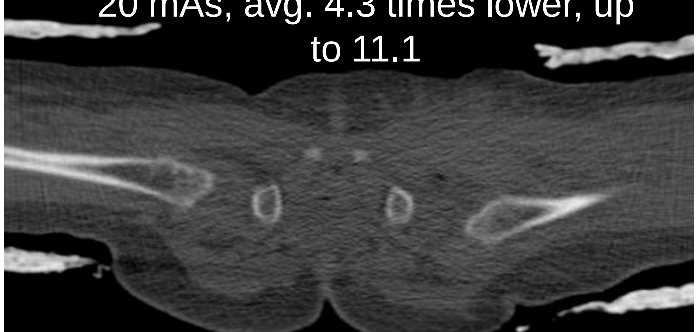




50 mAs, avg. 1.7 times lower, up to 4.4



20 mAs, avg. 4.3 times lower, up to 11.1



13 mAs, avg. 6.7 times lower, up to 17

- The 50 mAs and 20 mAs simulations had no images that received negative evaluation.
- At 13 mAs few images were evaluated as negative on image quality based criteria.

Conclusions

1. It was found that a specially constructed gelatin phantom was suitable for the phantom based simulation in the case of developmental dysplasia of the hip.
2. Analysis of the factors, that influence the noise in computed tomography images, has shown that the developed noise simulation algorithm was suitable for image noise simulation in the case of developmental dysplasia of the hip.
3. By reducing the exposure to 13 mAs, it is still possible to perform successful clinical diagnosis and achieve good postreduction control of developmental dysplasia of the hip.
4. Based on the evaluation results, the recommended CT protocol would effectively reduce the dose and the risk of cancer to the patient, in our case, on average, up to 17 times.

Recommendations

- Tube voltage – 120 kV (any lower would increase beam hardening artifacts).
- Manual mAs setting – 13 mAs.
- Reconstruction – Soft tissue filter (B20 in our case).
- Area of the scan (scan length) – only the relevant anatomical part of the pelvis, where the diagnosis is being made.

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