Høgskulen på Vestlandet

BRA330 - Bacheloroppgave

BRA330

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Kandidatnr.:	312

Informasjon fra deltaker

Antall ord *:	8021		
Egenerklæring *:	Ja	**Inneholder besvarelsen konfidensiell materiale?:**	Nei
Jeg bekrefter at jeg har registrert oppgavetittelen på norsk og engelsk i StudentWeb og vet at denne vil stå på vitnemålet mitt *:	Ja		

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Nei

BACHELOR'S THESIS

A Quantitative Analysis of the Impact of a CT Simulation Tool on Radiography Students' Learning

En kvantitativ analyse av effekten av en CT simulator på studenters kunnskaper

Candidate number 312

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Abstrakt

Innledning: Bakgrunnen for denne studien er den økte bruken av computertomografi (CT) som undersøkelsesmetode. De siste 20 årene har bruken av CT i de nordiske landene økt betraktelig, og utgjorde i 2012 50-80% av totaldosen til befolkningen fra medisinsk avbildning (NRPA, 2012). For pasienten innebærer CT en langt høyere stråledose enn ved konvensjonell røntgen, og det er dermed ønskelig at man holder stråledosen så lav som mulig samtidig som man oppnår god bildekvalitet. For å oppnå denne optimaliserte strålebruken er det viktig at radiografer innehar tilstrekkelige kunnskaper om hvordan ulike parametere ved CT påvirker både bildekvaliteten og stråledosen som pasienten får, slik at stråledosene som gis ikke er høyere enn det som er rimelig. En databasert CT-simulator kan potensielt bidra til økte kunnskaper om prinsipper innen CT for å kunne optimalisere undersøkelsene som blir gjort. Målet med denne studien er å kartlegge hvordan bruk av en CT-simulator vil påvirke studenters kunnskaper om stråledose og bildekvalitet innen CT.

Metode: Data i denne studien ble samlet inn ved hjelp av spørreskjemaer som deltakerne fylte ut før og etter intervensjonen. Intervensjonen i dette tilfellet var bruk av en CT-simulator på datamaskin. Det samme spørreskjemaet ble delt ut før og etter intervensjonen, for å kartlegge effekten av intervensjonen. Samtidig som de brukte CT-simulatoren skulle deltakere følge et oppgavehefte knyttet til CT-simulatoren. Deltakere ble også bedt om å oppgi hvor lang tid de brukte på å følge oppgaveheftet, maksimalt 45 minutter. For å analysere dataen ble det benyttet statistiske metoder som t-test og korrelasjonstester.

Funn: Det ble funnet en statistisk signifikant forbedring av studentenes kunnskaper som følge av bruk av CT-simulatoren. Videre ble det ikke funnet signifikant korrelasjon mellom studenters erfaringer med CT, tid brukt på intervensjonsoppgavene og forbedring i resultatene. Resultatene i denne studien gir et godt grunnlag for videre undersøking av hvordan databasert simulering kan benyttes i radiografien som et effektivt læringsverktøy.

Abstract

Introduction: The background to this study is the increasing use of computed tomography (CT) as a patient examination method in clinical practice. In the last 20 years, the use of CT in the Nordic countries has increased considerably, and in 2012 represented 50-80% of the total dose to the population from medical imaging (NRPA, 2012). Patients are subjected to a much higher radiation dose from CT than from conventional X-rays, and it is therefore desirable to reduce the radiation dose as much as possible whilst also maintaining a high image quality. In order to achieve this optimised radiation use, it is essential that radiographers are fully conversant with how different parameters of CT affect both the image quality and the radiation dose that the patient receives, thereby ensuring that the radiation doses given do not exceed what is considered appropriate. A computer-based CT simulation tool can potentially help to increase students' knowledge of the principles of CT with a view to optimising patient examinations. The aim of this study is to map the extent to which using a CT simulation tool impacts on radiography students' knowledge of radiation dose and image quality within CT.

Method: The data in this study were collected using questionnaires completed by participants before and after the intervention. The intervention in this case was the use of a computer-based CT simulation tool. The same questionnaire was used before and after the intervention in order to map the impact of the intervention. Whilst using the CT simulation tool, participants were also asked to follow an intervention task paper associated with the tool. Participants were also asked to specify how long they spent following the intervention task paper, up to a maximum of 45 minutes. In order to analyse the data, statistical methods such as t-tests and correlation tests were used.

Findings: A statistically significant improvement was found in the students' knowledge as a result of using the CT simulation tool, although this was shown to decrease over time. Furthermore, no significant correlation was found between students' level of experience in CT, time spent on the intervention tasks and the improvement in results. The results of this study provide a good basis for further research on how computer-based simulation can be used in radiography as an effective learning tool.

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1 Introduction

This paper is my bachelor's dissertation in my final year of study of Radiography at the Western Norway University of Applied Sciences. I have chosen to explore how students' knowledge of CT radiation doses and image quality can be affected by using a CT simulation tool, because I believe that this is a highly relevant topic to the field. This dissertation is submitted in accordance with the Western Norway University of Applied Sciences' regulations. I confirm that this is all my own work, and that where quotes or citations have been made, they are appropriately referenced.

1.1 Background

The background for the topic of this dissertation is the increased use of ionising radiation in diagnostic imaging, specifically within computed tomography (CT). Over the past 20 years, the use of CT in the Nordic countries has increased considerably. In 2012, CT scans alone made up 50–80% of the total radiation dose to the population from medical imaging (The Nordic Radiation Protection co-operation, 2012). This has raised concerns about the potential side effects on patients, particularly with regard to radiation-induced cancer and death (Faggioni et al., 2016). In terms of radiation dose, CT involves a significantly higher dose than that of conventional x-ray examinations. Epidemiological and empirical evidence links CT-associated radiation exposure to an increased risk of radiation-induced cancer (Power et al., 2016). It is therefore desirable to minimise the dose as much as is reasonable, while still maintaining good image quality. ALARA – as low as reasonably achievable – refers to the concept of giving as little radiation as is reasonable without compromising on the image quality (NRPA, 2018). Because the risk associated with radiation doses in CT is greater than zero, it is evident that reducing radiation doses in CT must continue to be a high priority in the CT community, especially in light of the aforementioned increase in the number of CT examinations that are performed on a yearly basis. ALARA is therefore an important concept that healthcare professionals should endeavour to adhere to in all radiological examinations involving radiation doses, and particularly in relation to CT.

In order to reduce the radiation dose received by patients from CT examinations, there are two main principles to follow, the first one being to ensure that all examinations are duly justified for the individual patients. Radiologists and referring doctors share the major responsibility of directing patients to the most appropriate imaging modality for the required diagnostic examination. The second principle to follow is that of the aforementioned ALARA. This entails optimising all the technical aspects of the examination in order to achieve a satisfactory level of image quality whilst maintaining as low a radiation dose as possible (McCollough et al., 2009). Thus, radiographers must possess sufficient knowledge and skills to be able to follow this principle.

The Norwegian Regulations on Radiation Protection and the Use of Radiation state that “The undertaking shall ensure optimisation of the medical use of radiation. Optimisation includes inter alia choice of method, apparatus and equipment, work procedures, assessment of radiation dose and dose distribution to the patient, image quality and the effect of therapy” (Radiation Protection Regulations, 2017, §40). In order to achieve this optimised use of radiation in which radiation doses do not exceed what is considered reasonable and image quality is adequate, it is vital that those performing the examinations, i.e. radiographers, possess sufficient knowledge of how CT parameters affect the image quality and the radiation dose that the patient receives. This dissertation will therefore attempt to assess the extent to which use of a CT simulation tool affects radiography students’ knowledge regarding image quality and radiation dose in CT. The intention is to give an indication of whether or not it would be beneficial to implement such a simulation tool in the radiography study programme in the future.

1.2 Relevance to the field

Computer-based simulation is relatively new in the field of radiography education but the little research that exists shows that it is beneficial to increasing students’ knowledge (Stowe et al., 2018). CT simulation is therefore part of this evolution in the use of computer-based simulation, and as such can play an important role in the development of future study programmes.

With regard to the relevance of the subject to the field of radiography, this study could be considered highly relevant. This is because the study observes how a CT simulation tool affects students' knowledge, with the aim of implementing such a tool in radiography study programmes at some point in the future. It is also desirable to develop the radiography education in relation to knowledge about CT parameters in order to give newly qualified radiographers a good starting point when they start working, and to ensure they have the knowledge to optimise CT scans in terms of image quality and radiation doses. The ultimate goal is to improve the outcome for the patient, both in terms of radiation dose received and image quality.

1.3 Objective

The aim of this study is to assess how the use of a CT simulator – with adjustable parameters including kilovolts, milliamperes and slice thickness – will affect radiography students' knowledge regarding CT parameters and image quality. Gaining a better understanding of this would help inform how computer-based simulation technologies can be used effectively in teaching and learning.

With the previous paragraphs in mind, the following research question has been formulated: To what extent will use of a CT simulator impact on radiography students' knowledge about image quality and radiation doses?

Furthermore, there are other factors within this topic that are of interest, such as how the participants perform on the questionnaire one week after the intervention compared to one day after the intervention. As will be discussed, previous literature suggests that memory fades over time. This indicates that the expected outcome in this study is that the results may decline on the second post-test compared to the first one.

1.4 Outline

This dissertation consists of six chapters. The first chapter contains the introduction to the study, the objective and hypotheses. The subsequent chapters deal with previous literature and methodology, and this is followed by a presentation of the findings, discussion and conclusion.

1.5 CT principles

The theory presented in this section was found in literature from the radiography syllabus and library online search function at the Western Norway University of Applied Sciences.

During CT scans, the values of the exposure parameters vary, and it is essential to understand the effects that these parameters have on the image quality and the radiation dose when altered. In addition to the device-related measures for reducing radiation exposure such as automatic exposure control, for which the manufacturer is responsible, there is also a set of user-related measures that further affect the image quality and the applied radiation dose (Buzug, 2008, p. 493).

One of the measurements used for image quality is noise, which is often measured as the standard deviation within a set region of interest. In order to reduce the noise that appears in a CT scan, one option is to increase the mAs value for the scan. However, if all other factors are maintained, the radiation dose will increase linearly with the mAs value. Hence, a doubled mAs value results in the radiation dose being doubled (McNitt-Gray, 2006). Furthermore, at a constant X-ray tube current, the dose increases linearly with the acquisition time. However, the mAs product is always to be considered as a total, meaning that at a constant dose the acquisition time can be reduced while simultaneously increasing the tube current. This will not affect the image noise but can reduce the likelihood of motion artefacts occurring during short acquisition times (Buzug, 2008, p. 499).

When the tube voltage (kV) is increased, the efficiency of the X-ray tube is improved as well as the penetration of the radiation being increased. A greater penetration results in a decrease in the image contrast. However, this is compensated for by the improved quantum statistics. Therefore, the general image quality is improved but at the expense of a higher dose being given to the patient (Buzug, 2008, p. 500; McNitt-Gray, 2006).

Slice thickness is another factor that can be selected prior to performing a CT scan, and can usually be adjusted from 1 millimetre up to 10 millimetres with the help of a collimator on the tube side of the scanner. Thus, the slice thickness does not affect the radiation dose if the same area is to be measured. The benefit of a thinner slice sequence is the reduction of so-called partial volume artefacts – due to averaging different tissues' attenuation values – as well as stair-step artefacts occurring in the sagittal or coronal reformatting of the image. The drawback of finer collimation is that fewer X-ray photons will reach the detector, resulting in an increase in the image noise. In order to maintain the level of image quality, the mAs product, and subsequently the dose, must be increased inversely proportional to the slice thickness (Romans, 2011, p. 366; Buzug, 2008, p. 500; McNitt-Gray, 2006).

The presented variance in the radiation dose and image quality, depending on the selected parameters, shows the importance of understanding how to manipulate the exposure parameters to maintain a low dose whilst also achieving a satisfactory image quality.

2 Previous literature

2.1 Reported knowledge among radiographers and students

Radiographers as healthcare professionals are the ones responsible for administering CT radiation doses to patients. Thus, it is essential that they possess enough knowledge and skills regarding how specific scan parameters affect image quality and patient doses in CT (Healy et al, 2017). Kada (2012) reports that knowledge regarding radiation doses and risks of ionising radiation is poor among final year radiography students in Norway, and this applies to all six of the radiography institutions in Norway. Only six of the 122 students in Kada's study achieved a score of at least 50% in the questionnaire on radiation issues. It is also reported that junior radiologists, medical students and radiography students have a limited awareness of radiation protection, specifically concerning real radiation doses of daily radiological examinations (Faggioni et al., 2016).

Poor knowledge of diagnostic reference values and order of organ sensitivity was reported by Rawashdeh et al. among radiographers in Jordan (2018). Good general knowledge was however reported regarding the correlation between each exposure parameter and the resulting image quality. Limited awareness of real radiation doses received in radiological examinations has also been demonstrated, and it is suggested that more teaching is needed in radiation safety (Faggioni et al., 2016). The limited awareness indicates that radiographers are unaware of the radiation doses each of the organs receive during a CT scan, and highlights a need for CT radiographers to undertake more training focused on radiation exposures in CT (Rawashdeh et al., 2018).

2.2 Simulation, simulators and active learning

Despite diagnostic radiography also requiring technical knowledge and practical skills, the use of virtual simulation using computer programs is less established in diagnostic radiography than in radiotherapy. Practical exercises in the traditional manner requires close supervision of the students and involves radiation, as opposed to using a computer program where no radiation is required and the need for supervision is subsequently reduced. A computer-based simulation program would therefore likely increase the amount of time that students are able to repeatedly practice the basic skills used in diagnostic radiography (Shiner, 2018).

Active learning is defined by Collins and O’Brien (2003, p. 5) as “The process of having students engage in some activity that forces them to reflect upon ideas and how they are using those ideas.” The core element of active learning thus entails direct participation in learning activities such as collecting information, discussion and problem solving, as opposed to passively listening to a teacher. As part of this learning process, students need to assess their own skill and knowledge levels on an ongoing basis by reflecting on how they have tackled the learning activities. Furthermore, it is widely agreed that the most lasting learning stems from direct interaction with, for example, intellectual and physical environments (Edwards, Kemp, & Page, 2014; Nesin, 2012; NMSA, 2010).

In a previous study, Stowe et al. (2018) aimed to assess the effectiveness of using a CT simulation tool on student radiographer learning, with specific regard to the correlation between CT scan parameters, patient dose and image quality. The study was a student project in the OPTIMAX research school and used the same CT simulation tool as is used in this study. Participants in the study were radiography students from six different countries. There was a quality control group and an intervention group. Both groups completed a pre-test questionnaire and a post-test questionnaire, with the intervention group using the CT simulation tool in between the two tests. The results showed significant improvement in the intervention group and no improvement with the quality control group (Stowe et al., 2018).

Using computer-based simulators as a learning method has been shown to have a positive effect on knowledge improvement, and it is also reported to raise students' motivation (Gambari et al., 2014; Kleinert et al., 2015). Unlike static classroom settings, virtual learning environments can stimulate active learning through students exploring activities that emulate real-life scenarios. Furthermore, participating in a virtual world can be an enjoyable experience for the learner, and provides an opportunity for self-teaching whilst fostering independent problem solving. However, it is important to understand that the educator must also be properly trained in how to use the simulation tool in order to be able to implement it effectively in learning situations (Hansen, 2008).

2.3 Potential factors affecting the outcome

The decay theory suggests that memory fades over time, meaning that information is less available for later retrieval as time passes (Berman, 2009). A study showed that students who revise the course material many times within a short space of time perform better on an immediate test than students who revise the course material several times at longer intervals.

However, in a delayed test, students who revised the course material with longer intervals in between vastly outperformed the students who studied intensively over a short period of time (Rawson & Kintsch, 2005, p. 79).

Furthermore, students' motivation affects the energy and effort put into a given task. Students' motivation also impacts on the persistence shown in activities (Csikszentmihalyi, 2014, p. 180). This implies that students who are lacking in motivation may have a lower threshold for giving up on a question and resorting to guesswork.

This section has shown that recent studies have focused on knowledge regarding radiation doses and exposures among radiographers and radiography students. As mentioned, the knowledge within various topics relating to radiation doses is reported to be poor among radiography students. This suggests a need for more learning in these topics, preferably as an integral part of the study programme as this is the students' main source of knowledge on such areas. Other studies have focused on using computer-based simulators and active learning as different ways of learning. These methods have proved successful in other medical fields, such as in surgical oncology, where immersive patient simulators are used (Kleinert et al., 2015).

However, few studies have combined the two to focus on both improving knowledge of radiation doses and image quality in CT using a simulator for learning. This research paper will therefore focus on using simulation and active learning, in the shape of a CT simulation tool, to improve students' knowledge on radiation doses and image quality in CT specifically. In addition, factors that could affect the impact of such an intervention tool will also be discussed.

3 Method

The choice of method is dependent on the research question (Dalland, 2014, p. 112). The methodological choices made in this study are explained in this chapter.

3.1 Quantitative method

Quantitative research is defined by Aliaga and Gunderson (referred to in Muijs, 2011, p. 1) as "explaining phenomena by collecting numerical data that are analysed using mathematically based methods (in particular statistics)". A quantitative approach typically starts with a specific theory, which leads to formulated hypotheses that are later measured quantitatively and analysed using statistical procedures (Holton & Burnett, 2005, p. 30).

In this study, quantitative methods will be utilised to assess the effect that a CT simulator has on students' knowledge regarding radiation dose and image quality in computed tomography. Hypotheses will also be formulated to provide clarity and focus on the research question in this study. Furthermore, students' results will be presented numerically in the form of incorrect or correct answers, giving zero points or one point, respectively.

3.2 Statistical sample

The participants in this study are all radiography students in their second year of study at the Western Norway University of Applied Sciences. Prior to the study, they had attended lectures and sat exams about CT principles, including radiation doses, image quality and optimisation of CT scans. Before commencing the study, permission was sought from the leader of the Department of health and functioning at the Western Norway University of Applied Sciences to conduct a study using students from this department as participants (see Appendix 6).

It is desirable that as many as possible of the students participate and consent to the use of their data in this study. In order to observe a small change, the sample size needs to be considerably larger than if a large change is sought. However, if a significant difference is shown from a small sample, this is not problematic. (Shepperd, 1999). The statistical significance in this study will be explored later on, under Section 4.

The sample group initially consisted of 37 students. Because the results in the study by Stowe et al. (2018) were validated through the use of a quality control group, there was no need to use a control group in this study. Two students were not present at the time of the pre-test and were therefore excluded, one student opted out of the study, two did not answer all questions in the surveys and could not therefore be included, and one student only completed the first study and was also therefore disregarded. In addition, some of the participants were only present at one of the post-tests and were therefore also excluded. The number of participants was therefore 22 (n=22). The table below shows the number of participants present at each of the three tests. However, only the participants who completed all three tests were included in the study.

Table 1: Number of participants present at each of the tests

	Pre-test	**Post-test 1**	**Post-test 2**
Number of participants	31	29	24

Each participant was allocated a number in addition to a different letter representing the pre-test, intervention task paper and two post-tests, respectively. This made it possible to measure results individually and anonymously, and ensured that only those who had completed all three tests were included.

3.3 Information letter

The participants in this study all gave written and informed consent. Prior to filling out the pre-test, students were given an information letter (see Appendix 1) describing the study's aim, background and what participation would entail for the individual students, in line with ethical guidelines (The Norwegian National Committees for Research Ethics, 2014). The information letter also described the CT simulation tool and how it would be used. Contact details were also given in case of any further questions about the study.

3.4 Questionnaire

The main data collection instrument used in this study is a questionnaire. Standardised questionnaires can produce quantifiable answers that help to reduce bias in the data analysis and provide a good foundation for comparisons between any future studies. Also, the repeat measurement approach chosen in this study means that the same group can be measured before and after the intervention. However, it is important that the questionnaire is designed to give answers to the research question. Having a pre-structured questionnaire can make it easier for participants to answer the questions, as they only have to select an answer as opposed to formulating their own answers and writing them down (Johannessen et al., 2010, 260-261).

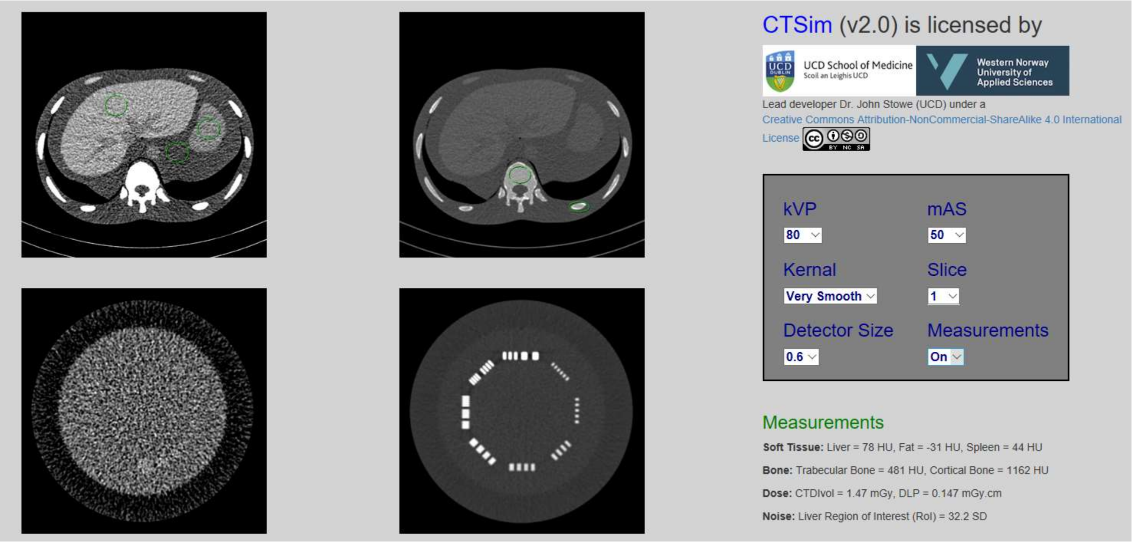
In order to collect data about radiography students' knowledge about CT a study was conducted in which students first completed a questionnaire, see Appendix 2. The source of the questionnaire and intervention task paper is a study by Stowe et al. (2018) on students' knowledge of CT doses and image quality before and after the use of the same aforementioned CT simulation tool. The questionnaire and intervention task paper were obtained with permission for use in this study. The questionnaire consists of 29 multiple choice questions, each with four alternative answers. Seven of the questions relate to radiation dose, 20 are concerned with image quality – 11 of which contain images related to the question – and two are a combination of these two topics.

The original questionnaire and intervention task paper were in English, but in order to make them more comprehensible for the students and reduce the chance of misunderstandings, they were translated from English into Norwegian. A back translation into English was also carried out in order to compare with the original for accuracy. This helped ensure that the meaning was the same in both languages. Some questions had to be changed slightly in order not to lose the intended meaning during the translation process, and one question – number 26 – was removed due to the answers being potentially confusing and unsuitable for translation.

In addition to the questions designed to test students' knowledge, the questionnaire also asked participants to indicate their level of experience, ranging from no experience to expert level in CT. This is a background variable that will be useful when analysing correlation. Also, at the end of the intervention task paper, participants were asked to specify how long they spent on the intervention task. This variable will also be used to run correlation tests.

3.5 CT simulation tool

The intervention tool used in this study is an interactive CT simulation tool developed in 2016 in a collaboration between the Western Norway University of Applied Sciences and University College Dublin (Healy et al., 2017). It was developed to enable radiography students to adjust CT parameters and see how image quality and radiation doses were affected by these changes, without using ionising radiation or performing an actual scan. The images on the interface are that of a morphological phantom (KYOTO), and a Catphan phantom to review image quality. The parameters that can be adjusted are kV, mAs, slice thickness, kernel and detector size. When parameters are adjusted, the user can see changes immediately through visualisation on the interactive display, in terms of visual image quality and calculated dose received.



CTSim (v2.0) is licensed by

Lead developer Dr. John Stowe (UCD) under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License

kVP 80

mAS 50

Kernal Very Smooth

Slice 1

Detector Size 0.6

Measurements On

Measurements

Soft Tissue: Liver = 78 HU, Fat = -31 HU, Spleen = 44 HU

Bone: Trabecular Bone = 481 HU, Cortical Bone = 1162 HU

Dose: CTDIvol = 1.47 mGy, DLP = 0.147 mGy.cm

Noise: Liver Region of Interest (RoI) = 32.2 SD

Figure 1: The CT simulation tool

3.6 Pilot study

Pilot tests are small-scale studies that are often conducted in preparation for a main study in order to assess the feasibility of the study and identify potential barriers (Ferguson & Brophy, 2017, p. 235). Therefore, the first group of participants was used for a pilot test, and improvements were subsequently made to the questionnaire, as mentioned in Section 3.4. The participants in the pilot test were all third-year radiography students. Despite two out of the five participants reporting that they would have preferred more time, all five of them completed the intervention task in under 45 minutes. Thus, 45 minutes was considered adequate time for the intervention task.

3.7 Data collection

The study was based on a pre-test-post-test design (Frey, 2018, p. 2), and entailed the completion of three surveys: one prior to the simulation, one the day after and one a week after. In order to avoid external factors influencing the results, the pre-test, intervention and post-tests were all scheduled into the participants' timetable to ensure that they would not attend any lectures on the relevant topics.

Following on from the pre-test was the intervention, where students used a CT simulation tool that is installed on the computers at Western Norway University of Applied Sciences. The students were given 45 minutes to complete a set of exercises where they could adjust the values of kV and mAs, and also the slice thickness, kernel and detector size in the CT simulation tool. The exercises included adjusting the different parameters to observe how the changes affect the image quality and the radiation dose, and this was displayed below the control panel in the simulation tool. On the intervention task paper, students were prompted to take note of their observations for their own benefit. Students were instructed not to communicate with each other during the intervention task.

A questionnaire identical to the one previously completed was then filled out the day after and a week after the intervention. The time given to complete the post-tests was 15 minutes, and all of the participants were able to complete it within this time frame. The reason for conducting two post-tests in the study was to measure how much knowledge the students had retained over time.

Although the lights were switched off and the window blinds were closed, the conditions could still be described as sub-optimal for viewing diagnostic images. However, the aim was not for the participants to describe the diagnostics in the image, but to explore the image quality in relation to scan parameters and filters. These conditions were therefore deemed acceptable.

3.8 Data analysis

After collecting the questionnaires from the participants, the results for each participant were calculated. One point was given for a correct answer, and an incorrect answer scored zero points. The results were then plotted into an Excel sheet. This was done by two people to ensure the data were plotted correctly.

In order to be able to compare the results from the tests, paired t-tests were used. A research hypothesis is usually necessary to ensure a well-developed research study (Toledo, Flikkema & Toledo-Pereyra, 2011), and as with many statistical procedures, the paired sample t-test has two competing hypotheses: the null hypothesis and the alternative hypothesis (Statistics Solutions, 2019). The null hypothesis assumes that the true mean difference between the paired samples is zero, while the alternative hypothesis assumes that the true mean difference between the paired samples is not zero. The alternative outcome can have one of several forms depending on the expected outcome. In some cases, the direction of the difference does not matter, and a two-tailed hypothesis would be used (Statistics Solutions, 2019). If the direction of the difference matters, an upper-tailed or a lower-tailed hypothesis is used, consequently with a difference that is higher or lower than zero. See the formal and mathematical definitions:

- The null hypothesis (H_0) assumes that the mean difference in test results (μ_d) is equal to zero
    - H_0: $\mu_d = 0$
- The upper-tailed alternative hypothesis (H_1) assumes that the mean difference in the test results is greater than zero
    - H_1: $\mu_d > 0$

      (Statistics Solutions, 2019)

In this study, a null hypothesis and an upper-tailed alternative hypothesis are deemed most relevant because the outcome is expected to be positive. The null hypothesis states that there is no difference in the students' knowledge regarding image quality and radiation dose after the intervention task. The upper-tailed alternative hypothesis subsequently states that there is a significantly positive impact on students' knowledge regarding image quality and radiation dose after the intervention task. The hypothesis is a predictor of the possible outcome of the study, and as such will be used to test the research question.

Paired sample t-tests are used to determine whether or not the difference between two sets of observations is null. In a paired sample t-test, each subject is measured twice, in this case before and after, giving pairs of observations (Statistics Solutions, 2019). However, in this study each subject is measured three times – before, one day after the intervention and finally one week after the intervention. Therefore, there are several pairs of observations. In this study, a repeated measures design is utilised, in the sense that the same questionnaire was completed before and after the intervention, on the same group of participants (Molenberghs, 2011, p. 1221).

Results were analysed in a paired sample t-test using the IBM SPSS statistical software version 25.0, which is widely used within academic research (Paura & Arhipova, 2015, pp. 9–14). Three pairs were considered – pre-test and the first post-test, pre-test and the second post-test, and finally the first post-test and the second post-test.

In addition to the effect that the intervention has on students' knowledge, another interesting factor to observe is a possible correlation between time spent on the intervention task, level of experience and improvement in the questionnaire results. In order to assess the correlation, a Pearson's correlation test was carried out (Mukaka, 2012, p. 69). Pearson's correlation test indicates how strongly two variables correlate (Johannessen, 2010, p. 302).

3.9 Validity and reliability

Validity refers to whether the data are representative of a general phenomenon (Johannessen et al., 2010). When it comes to validity of this study, the questions in the survey are designed to test the students' knowledge regarding image quality and radiation dose in CT, and they include content that covers a wide range of radiography course material. The survey therefore accurately measures what the study was designed to measure, and validity is therefore considered to be good. Results in this study concur with an earlier, similar study (Stowe et al., 2018), which further reinforces the validity.

Reliability refers to the accuracy of a study's data, and whether the results of the tests are consistent (Johannessen et al., 2010). The reliability and consistency of the test results were measured using Cronbach's alpha, which is a test used to estimate internal reliability. The results showed 0.75, and reliability is therefore considered to be good (Statistics Solutions, 2019).

3.10 Ethical considerations

While completing the questionnaire and using the CT simulation tool was a mandatory part of the course for the students, participating in this study was entirely voluntary. In other words, all the students who were present had to complete the pre-test, do the exercises with the CT simulation tool, and fill out the two post-tests, but they could choose if they wished to let their data be used in this study. Written consent was obtained through the questionnaires that were filled out, and those who chose not to consent were subsequently disregarded from the study. Furthermore, the questionnaires and intervention task papers were all pseudonymised to maintain anonymity throughout the study, while still permitting tracking of each individual participant's change as a result of the intervention.

All data were collected anonymously, and the leader of the Department of health and functioning at the Western Norway University of Applied Sciences granted approval to use students in this study. A test was run to assess whether there were any ethical considerations that would require the Norwegian Centres for Research Data to be notified of the study. The test indicated that no such notification was necessary.

4 Findings

In this chapter, the results of the tests performed are presented, and these are illustrated with tables and figures.

In order to compare pre and post-test results, the mean score was calculated for each of the three surveys. Paired t-tests, as described in Section 3.7, were then carried out to establish the statistical significance of the scores. By using Cronbach's alpha, reliability was measured at 0.75, which is considered to be good (Statistics Solutions, 2019).

4.1 Test results

The mean score on the pre-test – before the use of the CT simulation tool – was 18.96 points out of a possible 29. The mean score on the first post-test – the day after the use of the CT simulation tool – was 21.05 points out of a possible 29, and the mean score on the second post-test – a week after the intervention – was 20.5 out of a possible 29. These figures correspond to test scores of 65.38, 72.41 and 70.69%, respectively. The mean scores improved by 11% from the pre-test to the first post-test, and 8% from the pre-test to the second post-test.

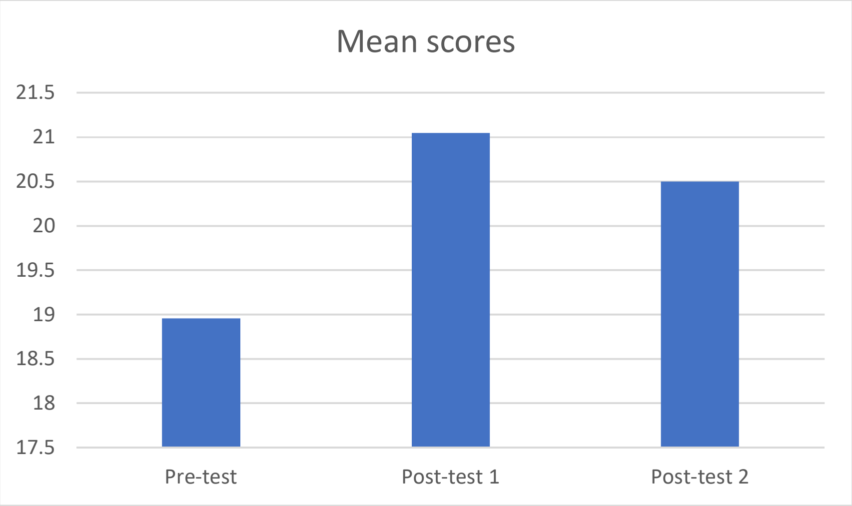


Figure 2: Mean scores of the pre-test and two post-tests (N=22)

The paired t-tests used to analyse the data from the study show that there was a statistically significant difference in the scores on the questionnaires before (M=18.96, SD=3.539) and after (M=21.05 SD=2.751 and M=20.5 SD=3.098) the use of the CT simulation tool, based on the condition that the value of p must be lower than 0.05 (p=0.05) in order for there to be a statistical significance. The p-value for the pre-test versus post-test 1 was 0.005, and the p-value for the pre-test versus post-test 2 is 0.026, see Table 2. These p-values are both lower than the p-condition. The mean difference in these tests is therefore shown to be statistically significant. The p-value of post-test 1 versus post-test 2 is 0.135, showing a statistically insignificant mean difference between the two post-tests. However, as seen in Table 2, the improvement weakens over time, with 77.27% of students showing an improvement in the first post-test compared to just 63.64% in the second post-test.

Table 2: Average scores and standard deviation in each of the tests (N=22)

	Pre-test	**Post-test 1**	**Post-test 2**	**Post–test 1 vs pre-test P-value**	**Post–test 2 vs pre-test P-value**	**Post–test1 vs post-test 2 P-value**
Average score	18.96	21.05	20.5			
Standard deviation	3.54	2.75	3.10			
				0.005	0.026	0.135

Some of the questions concerning image quality showed a low-score trend. In the pre-test, participants scored less than 0.5 points on average on several questions regarding image quality, as shown in Table 3.

Table 3: Average scores on some questions regarding image quality (N=22)

Question	**Average score pre-test**	**Average score post-test 1**	**Average score Post-test 2**
11: "The CT number (Hounsfield Unit) of fat depends on:"	0.065	0.310	0.333
14: "Why does image 2 of the test tool have increased spatial resolution?"	0.484	0.724	0.750
18: "What kernel reconstruction was applied to Image 1?"	0.290	0.655	0.792
20: "Which of the following is the most likely Hounsfield Unit of fat tissue?"	0.387	0.552	0.500
26: "The following abdomen CT slice features what window setting?"	0.484	0.655	0.708

The table below shows the tendency of a high average score on some of the questions regarding radiation dose.

Table 4: Average scores on some questions regarding radiation dose (N=22)

Question	**Average score pre-test**	**Average score post-test 1**	**Average score Post-test 2**
1: (What will happen) "If kVp is reduced while mAs held constant"	0.645	0.931	0.833
3: "What is DLP?"	0.323	0.621	0.625
21: "Does the application of a reconstruction filter (post-scan) affect dose?"	0.968	0.966	0.958

4.2 Correlation

Eight of the participants rated themselves as being comfortable with CT, 12 said they had some experience, while two reported having no experience in CT. In terms of time spent on the intervention task, 16 out of the 22 students reported to have spent the full 45 minutes, and three of them were unable to complete the intervention task due to lack of time.

A Pearson's correlation test showed there to be no significant correlation between time spent on the intervention task and results in the post-tests. The correlation test was then repeated to identify any correlation between participants who spent less than the permitted time to complete the intervention task, participants who used the full 45 minutes and participants who did not manage to complete all the tasks in the intervention task paper. There was shown to be no significant correlation between these factors.

A Pearson's correlation test was also therefore run to see if there was any correlation between students' level of experience and their score in the pre-test. The test reported no significant correlation between the two factors, with a negligible negative R-value. This indicates that students' self-reported level of experience did not affect their scores in the pre-test.

5 Discussion

This chapter will discuss the results presented in Section 4, and reflect on the findings in relation to previous research. Furthermore, the chapter will give an indication of what new insights have been found in the field of research into the CT simulation tool in students' learning.

5.1 Effect on student knowledge

The statistical significance between pre and post-testing indicates that the simulation was the factor that resulted in the change from pre to post-testing. Thus, after conducting the study and implementing the aforementioned statistical methods, it is apparent that the use of a CT simulation tool does in fact have a statistically significant positive effect on students' knowledge of how CT parameters affect image quality and radiation dose.

The results in this study concur with that of previously mentioned studies, which have found a positive impact on student learning when using computer-based simulation (Gambari et al., 2014), and more specifically a CT simulation tool (Stowe et al., 2018). However, in the study conducted by Stowe et al. (2018), participants' mean scores improved by 16.86% from the pre-test to the post-test. In comparison, participants in this study improved by 11% from the pre-test to the first post-test, showing a smaller improvement than that in the study by Stowe et al. (2018). There are many factors that could affect this result, such as the time limitations on the participants to complete the intervention task. As previously mentioned, three out of the 22 participants were unable to complete the intervention task, and 16 out of the 22 used the full 45 minutes to complete it. There is a possible added stress factor caused by the time limit given, and this could impact on the benefit gained from the intervention task, thus affecting the results. Furthermore, the pre-test results in this study scored a higher percentage than the pre-test results in the study by Stowe et al. (2018). This could be part of the reason for the smaller improvement in this study compared to the one by Stowe et al. (2018).

In the pre-test, participants scored a lower average on the questions regarding image quality than those regarding radiation dose. There was a considerable improvement in the average score on questions regarding image quality after the intervention, as seen in Table 3 in Section 4.1. This could indicate that students were less knowledgeable about image quality than radiation doses prior to the intervention, and that more training in image quality would be beneficial. Nevertheless, there is an overall significant improvement in the participants' knowledge regarding these topics as a result of using the computer-based simulation tool, which concurs with previous studies (Stowe et al., 2018; Gambari et al., 2014; Kleinert et al., 2015).

In this study, there were two hypotheses. The null hypothesis assumed that the use of a CT simulation tool would not impact on students' knowledge regarding image quality and radiation dose. Conversely, the alternative upper-tailed hypothesis assumed that the use of a CT simulation tool would have a positive impact on students' knowledge regarding these topics. The statistical analysis of the data revealed that the null hypothesis can be rejected, as it is untrue that the use of a CT simulation tool had no impact. The alternative upper-tailed hypothesis can be accepted on the basis that the average result was a positive change from the pre-tests to the post-tests.

5.2 Weakening tendency

However, despite the statistical insignificance between the two post-tests, the weakening tendency that participants showed over time correlates with the decay theory mentioned previously in Section 2.3. This suggests that further interventions are needed to increase the benefits of using a CT simulation tool. Repetition is therefore recommended as one possible solution. Repeating the simulation at intervals during the course of study would reinforce students' knowledge, thereby increasing the likelihood of long-term recall. An important factor to consider is the intervals between the interventions; sessions should be spaced out over time in order for them to have an effect on long-term recall, as reported by Rawson and Kintsch (2005, p. 79). As previously mentioned, students with intervals between their revision work scored better on a delayed test than those who studied intensively over a short period of time. The delayed test better represents the real-life situation in which the aim is for students to retain the knowledge in the long term, as opposed to immediate tests, where the knowledge is easily disregarded afterwards. Thus, repeating the interventions with intervals spread over time could increase the long-term gain of using the CT simulation tool for learning. Due to time constraints, the second post-test in this study was conducted only one week after the intervention. For future studies, a longer interval between the intervention and second post-test could be used in order to further investigate the weakening tendency.

5.3 Correlation and background variables

The background variable in this study was participants' level of experience in CT. Despite all the participants being second-year students, their self-reported level of experience varied considerably. This could partly be because they have not all had clinical placements at a CT department. In this study, no correlation was found between the participants' level of experience in CT and the results on the questionnaires. It could be considered reasonable to assume that students with a higher level of experience in CT would tend to score higher in the pre-test than those with little or no experience. However, given that the students evaluated their own experience, it is possible that some either under- or overestimated their own level of experience in CT, and that an objective measurement of their experience could skew the results in the correlation test. Furthermore, it is not known how many of the participants have experience from clinical placement at a CT department. This is also something to consider for future studies.

No significant correlation was found between spending less than 45 minutes, 45 minutes or not completing the intervention task. The insignificant negative R-value could be due to the fact that the three participants who did not complete the entire intervention task paper may not have gained as much knowledge as those who did complete it, thereby not improving as much as they potentially could have done if they had been able to complete all the exercises on the intervention task paper. The students in the pilot test were third-year students and therefore more likely to have greater experience, thereby needing less time to reflect on the questions. In contrast, the second-year students in the main study may have felt stressed by the limit time and therefore not learnt as much as they might have done with a longer time allowance. This is a factor that could be improved in further studies on this topic.

5.4 Motivation

There are a number of factors that could impact on how participants respond to the questionnaires and how they interact with the CT simulation tool. Some of these factors include their motivation, concentration and enthusiasm for their subject. Given that the questionnaire and intervention task were compulsory parts of their course, it is not easy to determine whether students were in fact motivated to learn and take away new skills from the use of the CT simulation tool. As previously mentioned, students' motivation also impacts the persistence shown in activities, and students who lack motivation could more easily give up on a question and instead guess the answer (Csikszentmihalyi, 2014, p. 180). Additionally, it is possible that less motivated students spend less time completing the intervention task and consequently do not yield the maximum benefit from the CT simulation tool. However, this was outside the scope of this study, but could be a useful area for further investigation.

With that said, previous literature states that as well as having a positive effect on knowledge improvement, using simulators as a learning tool also improves students' motivation (Kleinert et al., 2015). This could suggest that by implementing a CT simulation tool into the course and giving students the opportunity to familiarise themselves with it, students may become more motivated and susceptible to gaining new knowledge. The findings in this study concerning gaining knowledge through the use of a simulator concur with previously mentioned literature on the topic. For example, Gambari et al. (2014) report that the use of computer-based simulation improved students' academic achievements in the field of physics.

Despite the apparent overall positive impact that the intervention task had on the students, not all of the changes in results represent an improvement. Three out of the 22 participants

(13.6%) saw a negative change from the pre-test to the post-tests, while two of the participants saw no change from the pre-test to the post-tests. The standard deviation of the percentage point change from the pre-test to the first post-test was shown to be 11.9, which indicates that there is a range of differences in the results. However, there is still a majority of positively affected participants, as seen by the mean and standard deviation of the improvement to the questionnaire scores.

5.5 Strengths and weaknesses

In relation to the strengths and weaknesses of this dissertation and the study, it is important to be self-critical and review what could have been done better.

This study used a repeated measures design, meaning that the same group was tested before and after the intervention, using the same questionnaire (Molenberghs, 2011, p. 1221). However, participants did not have the opportunity to access an answer sheet, meaning that they could not simply memorise the answers for the next time they completed the test. This is considered a strength of the study since the results reflect what the students learned and were able to recall from the intervention, as opposed to how much they were able to memorise from the answer sheet.

A further strength of the study is that the findings may be applied and tested in other fields that use computer-based simulation tools (Shuttleworth & Wilson, 2008), and with larger samples can support further studies that could be generalised.

Another strength of this study could be that the repeated measures design used gives a low sampling variability (Molenberghs, 2011, p. 1221; Johannessen et al., 2010, pp. 260–261), meaning that the fact that the same students answered the same questionnaire before and after the intervention keeps things consistent. This in turn enhances the validity of the results.

The small sample size could be considered a weakness of the study, but the clear evidence from the results provides a good basis for further testing. Furthermore, the sample size has less relevance because of the statistical significance shown (Shepperd, 1999).

Another weakness of the study was the limited control over extraneous variables, such as the impact of other self-study that students may have undertaken before post-testing. Extra study may have boosted scores in the post-tests and thereby skewed results. However, reasonable steps were taken to ensure partial control in that students were not given further instruction in the relevant subjects after the pre-test and intervention. Also, the study was coordinated with their timetable in a way that ensured participants would not have any lessons or lectures on CT topics in between the pre-test, intervention task and the two post-tests.

Another factor that may have affected how the students performed in the questionnaires is whether or not they had undertaken a clinical placement at a CT department. This could have a major impact on students' knowledge and skills in CT as there is reportedly a wide gap between what is taught in the study programme and what students learn in clinical practice. (Hegerstrøm, 2018, p. 30). Also, students who have not yet had the opportunity to undertake a clinical placement in CT may not have experienced first-hand what a scan entails in real life, or how optimisation works.

In terms of correlation between time spent on the intervention and improvement in test results, the fact that not all participants were able to complete the intervention tasks could affect the result of the correlation test. Although there was an insignificant negative correlation, this could be due to the fact that some of the participants who utilised all 45 minutes were unable to complete all the tasks on the intervention task paper. This could indicate that the second-year students should have been given more time than the third-year students in the pilot test were given.

6 Conclusion

The findings in this study indicate that the use of a CT simulation tool has a significantly positive impact on students’ knowledge regarding image quality and radiation dose in CT.

This study was a direct assessment of change in student knowledge, and as such, the findings have provided evidence of the extent to which students’ knowledge of image quality and radiation dose improves following the use of a CT simulation tool. The findings in this study provide a useful basis for further investigations of how computer-based simulation can be used in radiography as an effective learning tool. Integrating such technology into the radiography curriculum can improve students’ knowledge but the weakening tendency over time suggests that it is necessary to repeat the intervention with adequate intervals so that knowledge is retained for a longer period of time. Thus, further research is needed on how long-term recall can be improved and on other factors that could improve the potential use of a CT simulation tool in learning situations. This will help achieve the ultimate goal of research in this area to optimise CT examinations for the benefit of the patient.

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8 Appendices

Appendix 1: Information letter

Forespørsel om deltakelse i studie i forbindelse med bacheloroppgave som også er en del av en større studie ved Høgskulen på Vestlandet (HVL) i samarbeid med University College of Dublin (UCD).

Kartlegging av studenters kunnskaper om CT-parametere før og etter bruk av CT-simulator

Bakgrunn og formål

Jeg er radiografstudent ved Høgskulen på Vestlandet, og i forbindelse med min bacheloroppgave vil jeg undersøke studenters kunnskaper om CT. Bakgrunnen for studien er den økte bruken av CT som undersøkelsesmetode. De siste 20 årene har bruken av CT i de nordiske landene økt betraktelig. For pasienten innebærer CT en langt høyere stråledose enn ved konvensjonell røntgen, og det er dermed ønskelig at man holder stråledosen så lav som mulig samtidig som man oppnår god bildekvalitet. (NRPA, 2012) For å kunne optimalisere stråledose og bildekvalitet i forhold til hverandre er det viktig at radiografer innehar relevant kunnskap om nettopp dette. Formålet med studien er derfor å kartlegge i hvilken grad bruk av en CT-simulator vil øke første og andre års radiografstudenters kunnskaper om hvordan ulike CT-parametere påvirker bildekvalitet og stråledose. CT-simulatoren ble utviklet av UCD og er et samarbeidsprosjekt med HVL Bergen. Simulatoren lar brukeren endre på blant annet kVp, mAs, kernel og snittykkelse.

Hva deltakelse i studien innebærer

Ved å samtykke til deltakelse i studien vil du få gjennomføre en pre-test og to post-tester med spørsmål om stråledose og bildekvalitet ved CT-undersøkelser. Oppgavesettet består av noen spørsmål om stråledoser og noen spørsmål om bildekvalitet, til sammen 29 spørsmål. Først svarer du på spørreskjemaet, deretter vil du få ta i bruk en CT-simulator på skolens datamaskiner på bildebehandlingslaboratoriene. Du vil få et oppgavehefte med instruksjoner om hva du skal gjøre. Simulatoren illustrerer hva som skjer med bildekvaliteten og stråledose når man endrer på de ulike parameterne. Etter du har brukt CT-simulatoren skal du dagen etter og etter en uke svare på samme spørsmål (post –test).

Konfidensialitet

Spørreskjemaene er anonymiserte slik at man ikke kan gjenkjenne hvem som svarer. Du vil få en kode for å kunne sammenligne pretest og posttestresultater. Studien har vært testet i Norsk samfunnsfaglig database, og trenger ikke å meldes til personvernombudet.

Frivillighet

Det er frivillig å delta i studien, og du kan når som helst trekke seg om du skulle ombestemme deg, uten å oppgi grunn. Alle opplysninger vil bli slettet dersom du trekker seg fra studien.

Dersom du har spørsmål om studien kan du kontakte meg eller min veileder på epost eller telefon.

Erica Hognestad, radiografstudent.
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Appendix 2: Questionnaire

Spørreskjema CT

Jeg samtykker til deltagelse i studien «Kartlegging av studenters kunnskaper om CT-parametere før og etter bruk av CT-simulator» (kryss av): Ja_______ Nei________

Hvor mye erfaring har du med CT? Sett ring rundt ett alternativ:

Ingen erfaring Litt erfaring Komfortabel med CT Ekspert på CT

Følgende er et spørreskjema med 29 spørsmål om CT. Vennligst svar ved å sette ring rundt svaret ditt og skrive svaret ditt (a, b, c, d) på linjen til høyre. Resultatene vil bli gradert, men vil forbli anonyme.

SPØRSMÅL: **SVAR:**

1. Hvis kVp reduseres samtidig som mAs holdes konstant:
a. Øker pasientdose (↑) ______
b. Reduseres pasientdose (↓)
c. Forblir pasientdosen den same
d. Øker bildekvaliteten (↑)

2. Endres bildekvaliteten hvis mAs dobles i CT?
a. Ja, den øker subjektivt (↑) ______
b. Ja, den reduseres subjektivt (↓)
c. Nei, den forblir den samme
d. Ja, bildekvaliteten dobles

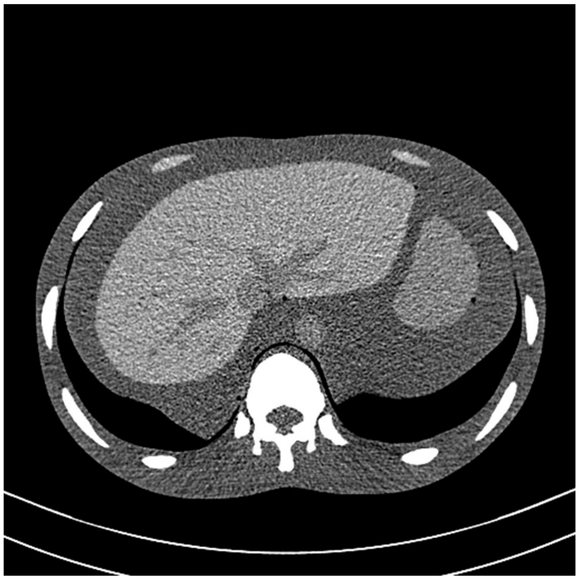
3. Hva er DLP?
a. Doserate ______
b. "Patient exposure"
c. Doserate og "patient exposure"
d. "Noise index"

4. Hva er romlig oppløsning i CT?
a. Evne til å skille objekter fra bakgrunnen ______
b. Evne til å registrere hendelser som forekommer innen kort tid
c. Evne til å skille objekter av en viss størrelse plassert nært hverandre
d. Evne til å detektere eller bruke alle røntgenfotoner som kommer ut av pasienten

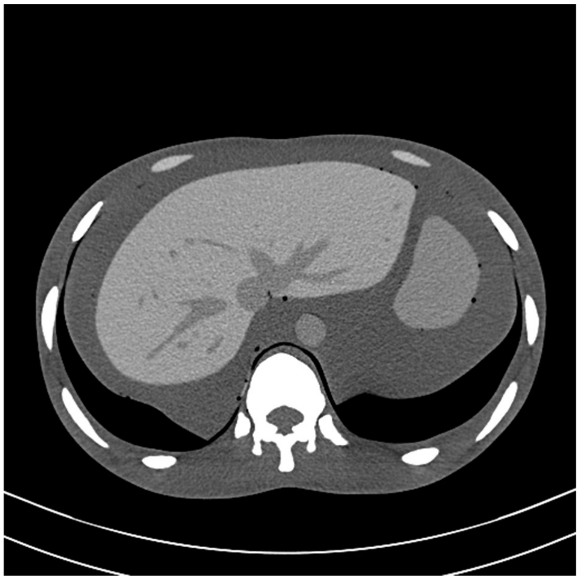
5. Hvilken faktor påvirker ikke kontrastoppløsning?

a. Snittykkelse ______
b. mA
c. Kernel
d. Anatomisk plan

6. Bildene under har lik snittykkelse. Hvilket bilde har redusert støy, og hvorfor?



Bilde 1



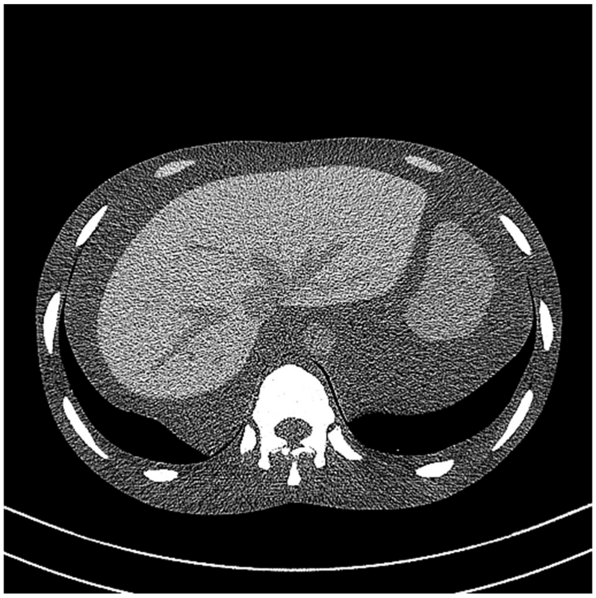
Bilde 2

a. Bilde 1; pga redusert mAs (↓) ______
b. Bilde 1; pga økt kVp (↑)
c. Bilde 2; pga økt mAs (↑)
d. Bilde 2; pga redusert kVp (↓)

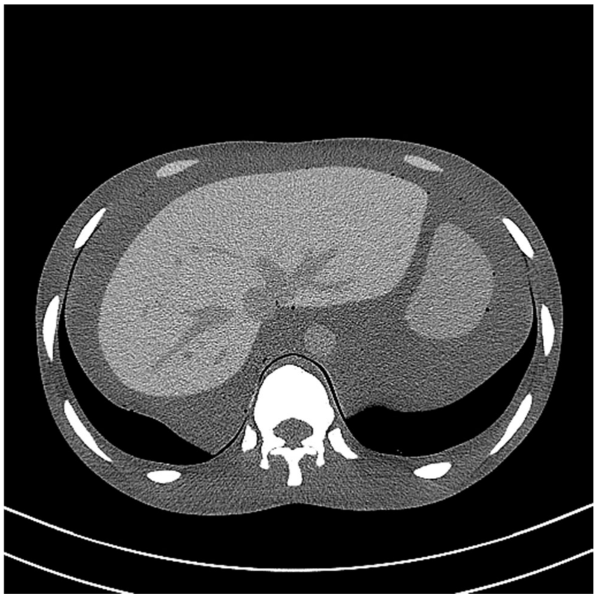
7. Bruk av skarp kernel tillater bedre romlig oppløsning, men en ulempe er:

a. Økt pasientdose (↑) ______
b. Økt støy i bildet (↑)
c. Lysere bilde
d. Mørkere bilde

8. Bilde 2 har høyere CTDIvol-dose i mGy. Hvilken endring i skannparametere kan være årsaken til denne forskjellen?



Bilde 1



Bilde 2

a. Redusert mAs (↓) ______
b. Økt snittykkelse (↑)
c. Bruk av et skarpere rekonstruksjonsfilter
d. Økt kVp (↑)

9. Hvilket av følgende resultater skyldes økt snittykkelse?

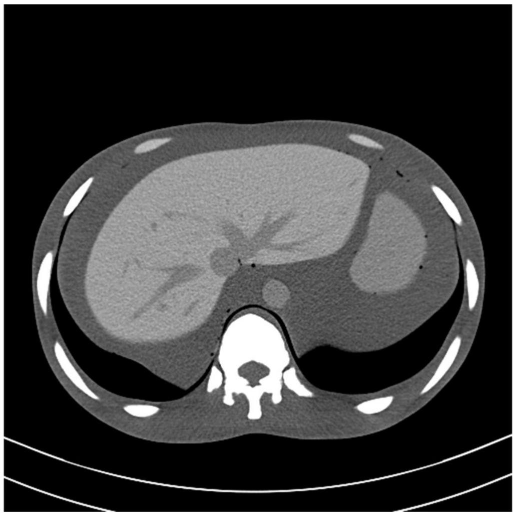
a. Redusert støy (↓) i leveren ______
b. Økt støy (↑) i milten
c. Et mer “kornete” bilde
d. Økt støy (↑) i fettvev

10. Reduksjon av kVp (↓) på CT er fordelaktig fordi:
a. Penetrasjonsevnen til strålene forbedres ______
b. Det gir økt kontrast i vev (↑)
c. Det gir mindre synlige metallgjenstander
d. Skanntid reduseres

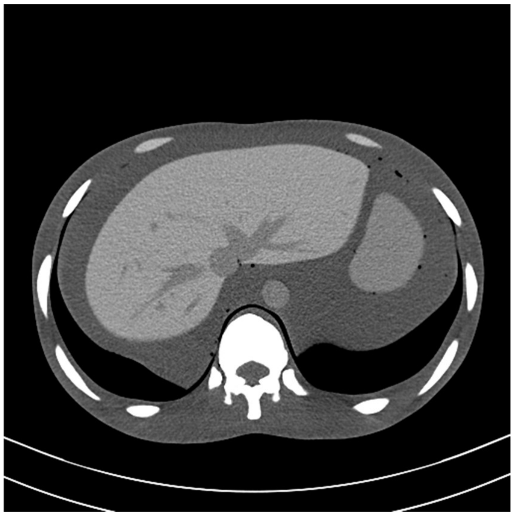
11. CT-tallet (Hounsfield Unit) i fett avhenger av:
a. kV ______
b. mAs
c. Rekonstruksjonsalgoritme
d. Ingenting, det er konstant

12. Hvilket av de følgende bildene har størst snittykkelse? Alle andre parametere er like.

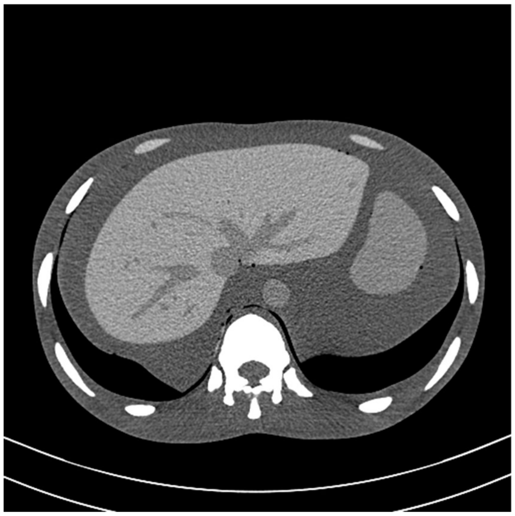
Bilde 1



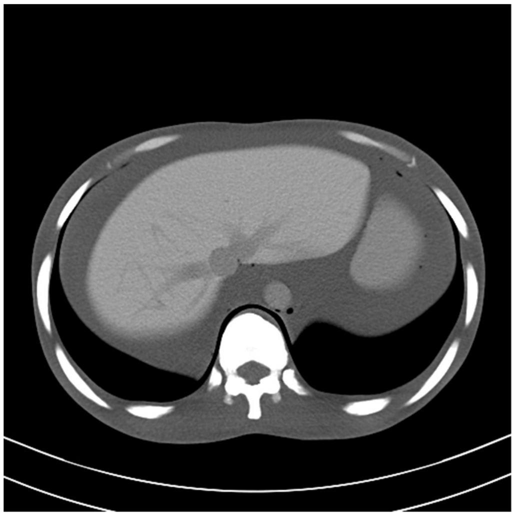
Bilde 2



Bilde 3



Bilde 4



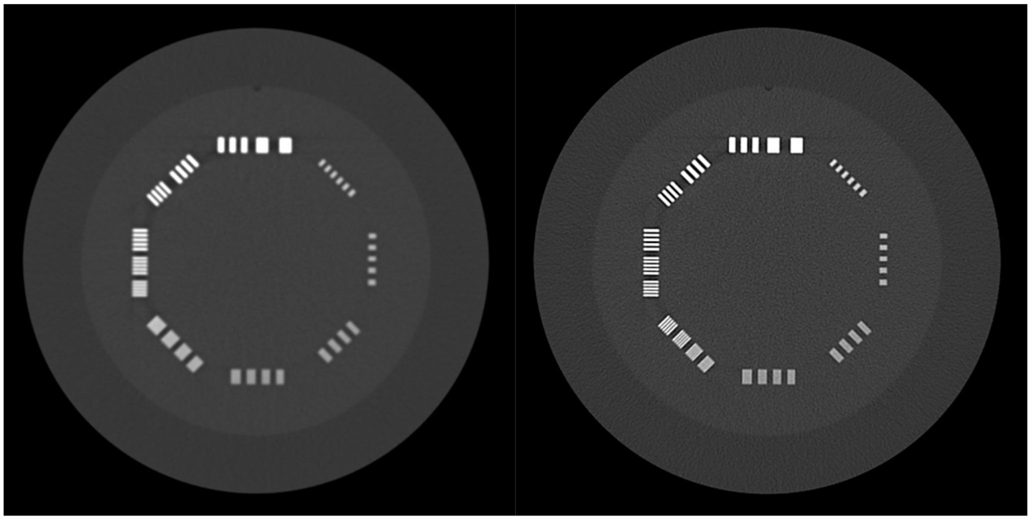
a. Bilde 1 ______
b. Bilde 2
c. Bilde 3
d. Bilde 4

13. Hva er CTDIvol?

a. Gjennomsnittsdose i et snitt ______
b. “Patient exposure”
c. Doserate
d. Noise index

14. Hvorfor har bilde 2 av catphanfantomet økt romlig oppløsning (↑)?

Bilde 1 Bilde 2



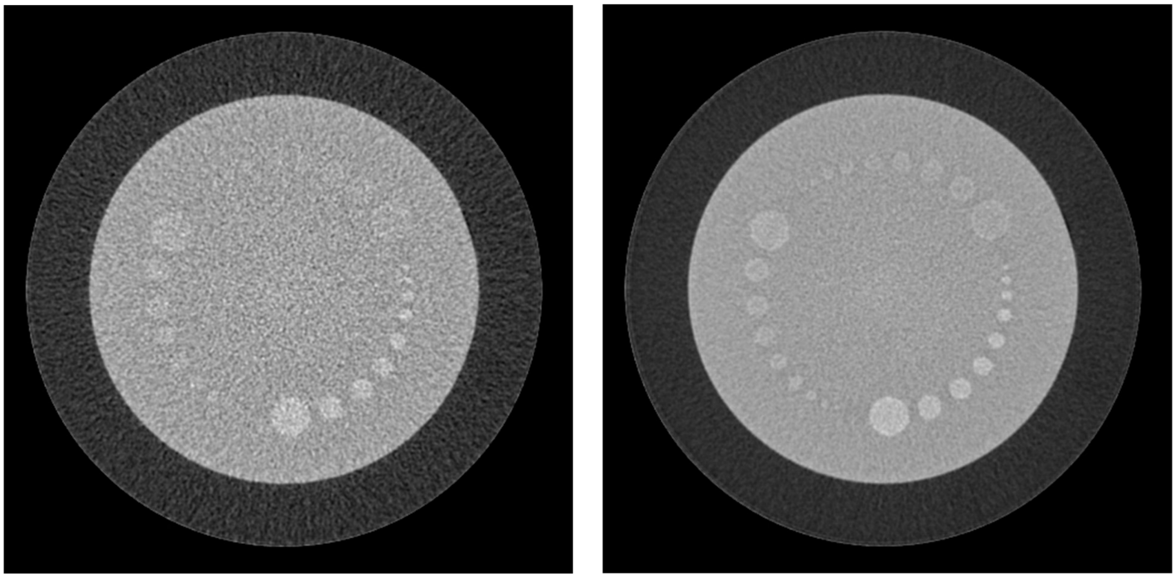
a. “Very sharp” kernelrekonstruksjon ______
b. “Very smooth” kernelrekonstruksjon
c. Økning av kVp (↑)
d. Økning av mAs (↑)

15. Hva er den mest sannsynlige verdien på Houndsfield Units i kortikalbein i følgende bilde?

a. 1000 HU ______
b. 200 HU
c. 0 HU
d. -1000 HU

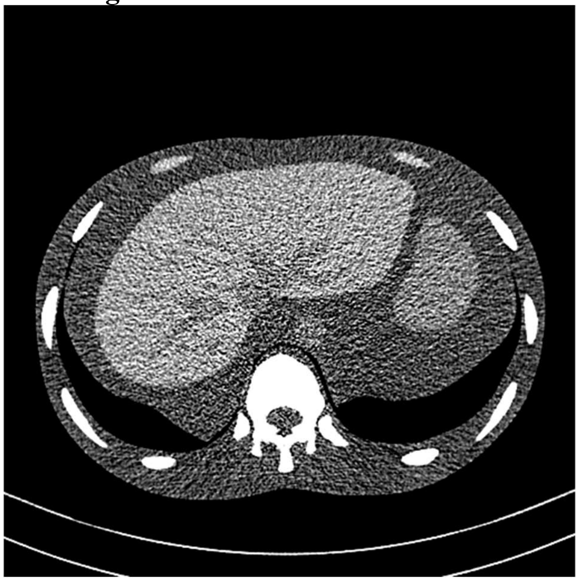
16. Hva er årsaken til forbedret kontrastoppløsning (lavkontrast) i Bilde 2?

Bilde 1 Bilde 2



a. Økt mAs (↑) ______
b. Redusert mAs (↓)
c. Tynnere snitt
d. Redusert stråledose (↓)

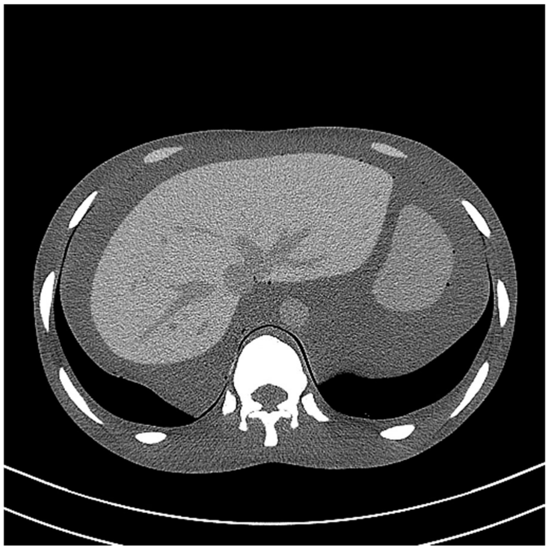
17. Hva er den mest sannsynlige kombinasjonen av tekniske faktorer (skannparametere) brukt i følgende bilde?



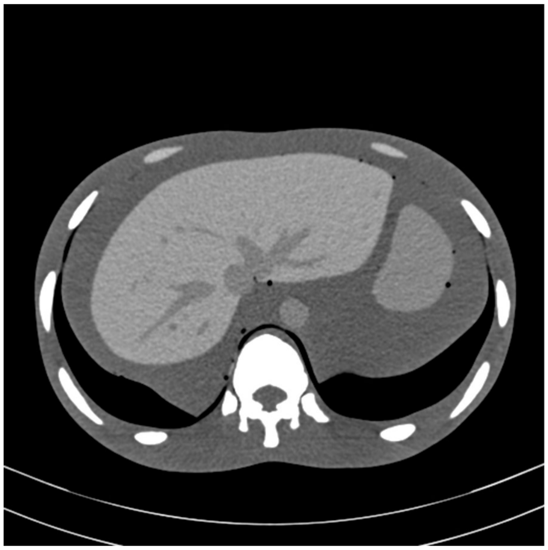
a. 30 kVp, 15 mAs ______
b. 80 kVp, 50 mAs
c. 130 kVp, 200 mAs
d. 150 kVp, 500 mAs

18. Hvilken kernel ble brukt i bilde 1?

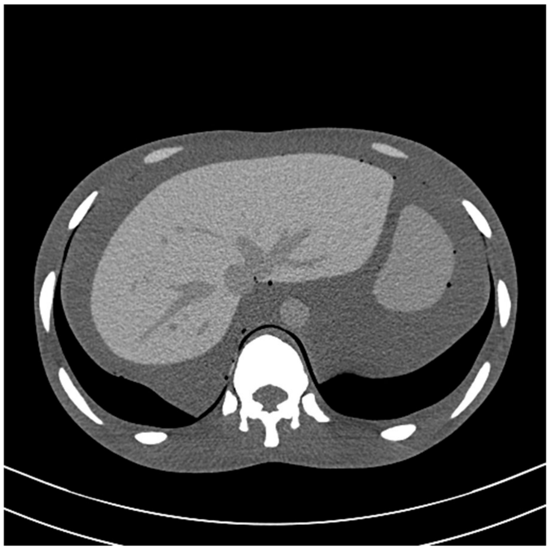
Bilde 1



Bilde 2



Bilde 3



a. "Very smooth" rekonstruksjon ______
b. Standard rekonstruksjon
c. "Very sharp" rekonstruksjon
d. Ingen

19. Hvilke tekniske faktorer vil gi høyest pasientdose (mGy)?

a. 80 kVp, 50 mAs ______
b. 110 kVp, 100 mAs
c. 130 kVp, 200 mAs
d. 110 kVp, 400 mAs

20. Hvilken av de følgende er den mest sannsynlige Houndsfield Unit-verdien i fettvev?
a. -500 HU ______
b. -20 HU
c. 500 HU
d. 1000 HU

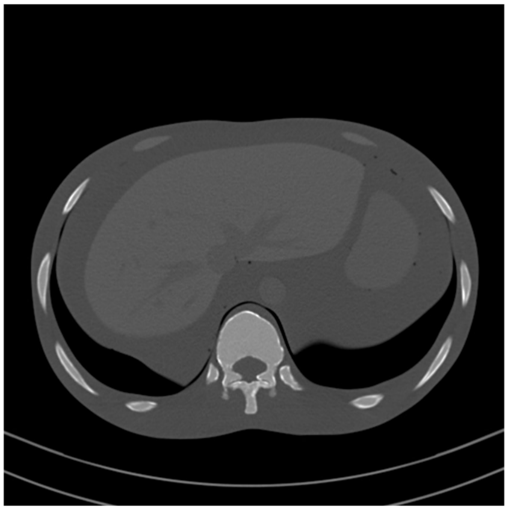
21. Påvirker bruken av et rekonstruksjonsfilter (post-skann) dosen?
a. Alltid ______
b. Aldri
c. Kun ved en jevn (“smooth”) kernel
d. Kun ved en veldig skarp kernel

22. For et CT-skann velges faktorer som kV, mAs og snittykkelse:
a. Før skannet ______
b. Etter skannet
c. Under skannet
d. Aldri, disse faktorene er alltid konstante

23. Hvilket av følgende er ikke et primært skannparameter?
a. Rørspenning ______
b. Rørstrøm
c. Skanntid
d. Kernel

24. Hvilke av følgende er sant?
a. Støy reduseres (↓) med økende kVp (↑) ______
b. Støy øker (↑) med økende kVp (↑)
c. Stråledose reduseres (↓) med økende kVp og mAs (↑)
d. Stråledose er konstant med økende kVp og mAs (↑)

25. Hvilke parametere ble sannsynligvis valgt for følgende bilde?



a. 30 kV, 50 mAs ______
b. 110 kV, 200 mAs
c. 250 kV, 500 mAs
d. 400 kV, 400 mAs

26. Hvilken «window»-innstilling har følgende CT abdomen?

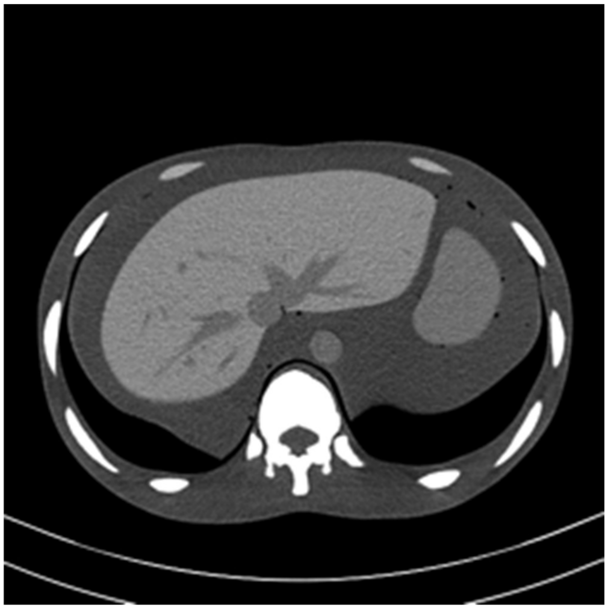
a. “Water window” ______
b. “Soft tissue window”
c. “Bone window”
d. “Air window”

27. Hvilken faktor påvirker ikke romlig oppløsning?

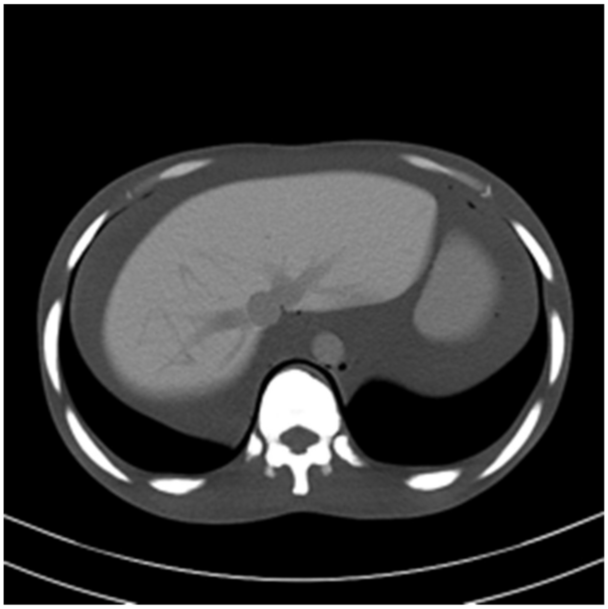
a. Kernel ______
b. mA
c. Snittykkelse
d. Pasientbevegelse

28. Hvilket bilde har nedsatt skarphet (↓) og hvorfor?

Bilde 1



Bilde 2



a. Bilde 1; pga tynnere snitt ______
b. Bilde 1; pga tykkere snitt
c. Bilde 2; pga tynnere snitt
d. Bilde 2; pga tykkere snitt

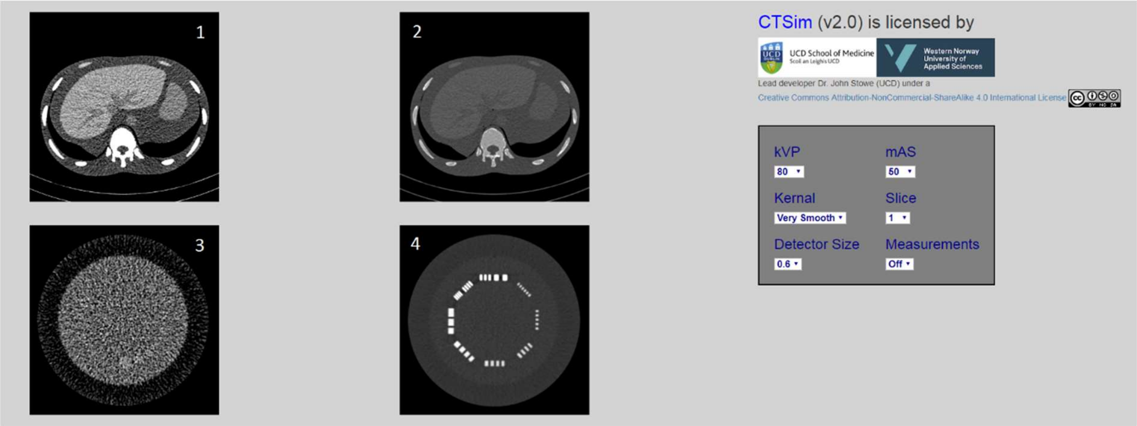
29. «CT image enhancement» brukes for å:
a. Forbedre form og kanter for bedre bildekvalitet ______
b. Redusere støy
c. Alle de ovennenvte
d. Ingen av de ovennevnte

Appendix 3: Intervention task paper

Bruk av CT-simulator

Hvordan bruke CT-simulatorverktøyet:

<u>Grunnleggende om verktøyet:</u>



CTSim (v2.0) is licensed by

Lead developer Dr. John Stowe (UCD) under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License

kVP: 80
mAS: 50
Kernal: Very Smooth
Slice: 1
Detector Size: 0.6
Measurements: Off

Du ser fire bilder på skjermen.

1. Øverst til venstre:	CT-snitt av et abdomenfantom med bløtvevsvindu
2. Øverst til høyre:	CT-snitt av et abdomenfantom med beinvindu
3. Nederst til venstre:	CT-snitt av et kontrastoppløsningsfantom
4. Nederst til høyre:	CT-snitt av et catphanfantom

På høyre side av skjermen kan du se justerbare parametere.

- kVP: er et skannparameter, kan kun endres før skannet
- mAS: er et skannparameter, kan kun endres før skannet
- Kernal: er et rekonstruksjonsparameter, glatter ut kanter eller gjør kanter skarpere
- Slice (snitt): snittykkelsen i millimeter. Må velges før skann og kan kun gjøres tykkere i postprosessering.
- Detector size (detektorstørrelse): ikke en del av leksjonen. Merk at snittykkelsen må være større enn detektorstørrelsen.
- Measurements (målinger): hvis du skrur dem på kan du se:
  - **CTDIvol** i mGy representerer dosen i et snitt (**gjennomsnittsdose i et snitt**).
  - **DLP (Dose-lengde-Produkt** i mGy.cm er dose gitt til pasient (**Patient exposure**).
  - Støy, definert som standardavvik, kun målt i leveren. Jo større den er, desto mer støy er det.

Bruk av verktøyet:

Først beholdes målingene avslått.

Startparametere er kVp: 80, mAs: 50, kernel: very smooth, snittykkelse: 1

1. Hvis du øker kVp og beholder resten av parameterne som de er, hvilke forandringer ser du i bildene? Kan du forklare disse forandringene?

2. Sett kVp tilbake til 80 og begynn å endre på mAs. Hva slags endringer ser du nå? Kan du forklare det du ser?

3. Sett mAs tilbake til 50 og endre på kernel. Hva ser du nå? Forklar det du ser.

4. Sett kernel tilbake til “very smooth” og begynn å endre på snittykkelsen. Ser du noen forskjeller?

Bildekvalitet:

Kontrastoppløsning (lav kontrast) er evnen til å skille to gråtoner som er veldig like. I kontrastoppløsningsfantomet (bilde 3) kan du telle antall sirkler du ser.

1. Hvis du ser på bildene og endrer parameterne, hvilken kombinasjon gir best kontrastoppløsning? Prøv å forklare det du ser, skriv det ned og noter hvilke parametere du brukte.

kVP	mAS	kernel	snittykkelse

Romlig oppløsning er evnen til å skille veldig små objekter som ligger nært hverandre. I romlig oppløsning-fantomet (bilde 4) kan du telle linjene du ser.

2. Fortsett å se på bildene og endre på parameterne. Hvilken kombinasjon gir den beste romlige oppløsningen? Prøv å forklare hva du ser, og skriv ned hvilke parametere du brukte.

kVP	mAS	kernel	snittykkelse

Slå på målingene. Observer hvordan HU-verdien endres i de neste trinnene.

3. Lek med parameterne.
Hvordan påvirker støyen hva du ser?

Hvordan påvirker det kontrastoppløsningen (lavkontrast)?

Hvordan påvirker det romlig oppløsning?

Hvordan påvirker det bildet av abdomen?

Dose:

Se på dosen i DLP.

Gå tilbake til parameterne du synes ga best kontrastoppløsning.

1. Hvordan påvirker parameterne dosen sammenlignet med startparameterne (kVp: 80, mAs: 50, kernel: very smooth, snitt: 1)?

2. Var dette som forventet?

○ Ja ○ Nei

Hvorfor?

3. Forsøk å endre på parameterne du synes ga best kontrastoppløsning. Kan du endre dem slik at kontrastoppløsningen forblir den samme mens dosen reduseres?

Bruk nå parameterne du fant for best romlig oppløsning.

1. Hvordan påvirker parameterne dosen sammenlignet med startparametrene (kVp:80, mAs: 50, kernel: very smooth, snitt: 1)?

2. Var dette som forventet?

○ Ja ○ Nei

Hvorfor?

3. Forsøk å endre på parameterne du synes ga best romlig oppløsning. Kan du endre dem slik at den romlige oppløsningen forblir den samme mens dosen reduseres?

Dose og bildekvalitet:

Prøv å redusere både støy og dose i det beste bildet for kontrastoppløsning du fant.

1. Kunne du gjøre det?

○ Ja ○ Nei

Bruk disse parameterne: kVP: 110, mAs: 250, kernel: standard, snittykkelse: 4mm

DLP= 7.81 mGy.cm

Prøv nå å redusere støyen og behold dosen nært denne DLP-en. Skriv ned hvilke parametre du fant.

kVP	mAS	kernel	snittykkelse

Bruk disse parameterne: kVP: 110, mAS: 250, kernel: standard, snittykkelse: 4

SD = 8.6

Prøv nå å redusere dosen og behold støyen nært dette standardavviket (SD). Skriv ned hvilke parametere du fant.

kVP	mAS	kernel	snittykkelse

Konklusjon:

Hva er dine konklusjoner om skannparametere og påvirkningen på bildekvalitet og pasientdose?

Kommentarer:

Hvor lang tid brukte du på å fullføre dette?

……………………..minutter

Var det nok tid?

○ ja ○ nei

Ville du hatt mer tid?

○ ja ○ nei

Synes du oppgaven var lett, passe eller vanskelig?

○ lett

○ passe

○ vanskelig

Har du noen kommentarer til forbedring?

Vennligst ikke snakk med andre studenter om denne oppgaven.

Appendix 4: Questionnaire in English

Name: ________________________________
University: ____________________________
How many years is your program? _____________
What year of study have you most recently completed? ______________

How much CT experience do you have? Please circle one:

No experience
Some experience Comfortable with CT
Expert with CT

The following is a questionnaire of 30 questions on Computed Tomography (CT).
Please answer each question by circling your answer *and* writing your selection on the rightmost line.
Results will be graded, but all scores will remain <u>anonymous</u>.

QUESTIONS:	**ANSWER:**

1. If kVp is reduced (↓) while mAs is held constant:

a. Patient dose is increased (↑) ______
b. Patient dose is decreased (↓)
c. Patient dose remains the same
d. Image quality increases (↑)

2. In CT, does image quality change if mAs is doubled?

a. Yes; it increases subjectively (↑) ______
b. Yes; it decreases subjectively (↓)
c. No; it stays the same
d. Yes; the image quality is doubled

3. What is DLP?

a. Dose rate ______
b. Patient exposure
c. Dose rate and patient exposure
d. Noise index

4. What is spatial resolution in CT?

a. Ability to differentiate objects from background ______
b. Ability to record events occurring within a short duration
c. Ability to resolve or distinguish objects of a certain size placed near each other
d. Ability to detect or use all x-ray photons exiting the patient

5. Which factor does <u>not</u> affect contrast resolution?

a. Slice thickness ______
b. mA
c. Kernals
d. Anatomical plane

6. With slice thickness constant, which image acquired has reduced noise, and why?

Image 1

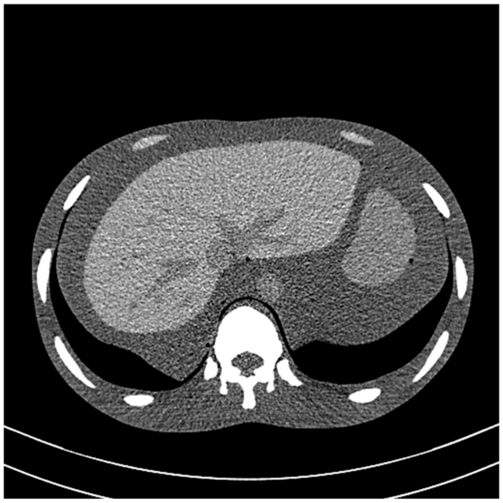
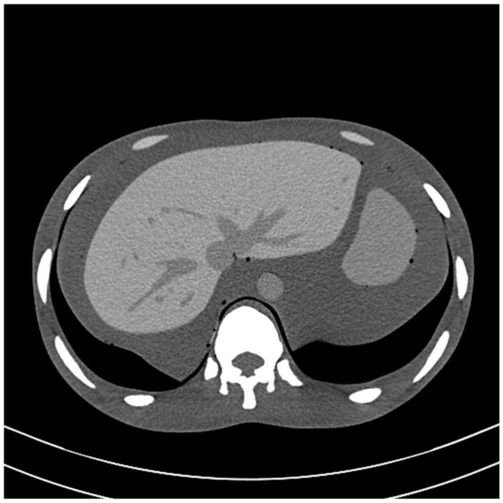


Image 2



a. Image 1; due to decreased mAs (↓) ______
b. Image 1; due to increased kVp (↑)
c. Image 2; due to increased mAs (↑)
d. Image 2; due to decreased kVp (↓)

7. While using sharp kernels allows for better spatial resolution, a disadvantage is:

a. Increased patient dose (↑) ______
b. Increased image noise (↑)
c. A brighter image
d. A darker image

8. Image 2 has a higher CTDIvol dose in mGy. What change in scan parameters could account for this difference?

Image 1

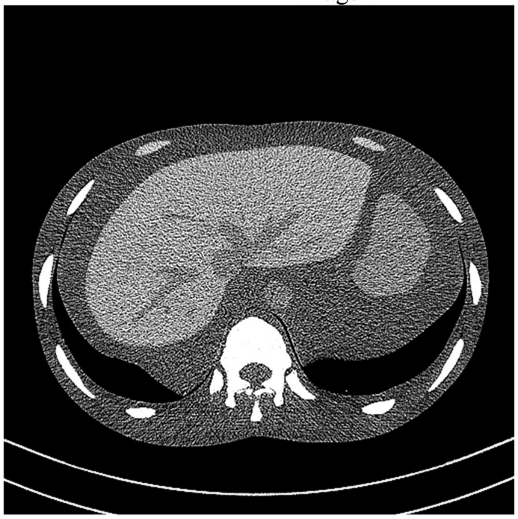
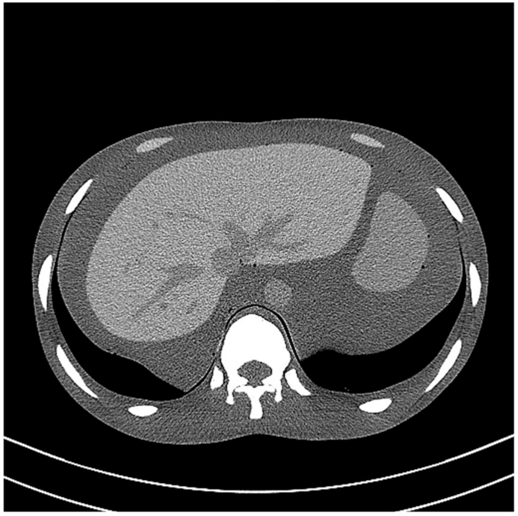


Image 2



a. Decreased mAs (↓)

______

b. Increased slice thickness (↑)
c. Using a higher resolution reconstruction filter
d. Increased kVp (↑)

9. Which of the following results from increasing slice thickness (↑)?

a. Decreased noise (↓) in the liver ______
b. Increased noise (↑) in the spleen
c. A more "grainy" image
d. Increased noise (↑) in fat tissue

10. Decreasing kVp (↓) in CT is advantageous because:

a. X-ray penetration improves ______
b. Increased tissue contrast (↑)
c. Less noticeable metal artefacts
d. Scan times are reduced

11. The CT number (Hounsfield Unit) of fat depends on:

a. kV ______
b. mAs
c. Reconstructive algorithm
d. Nothing, it is constant

12. Which of the following images features the largest slice thickness?

Image 1

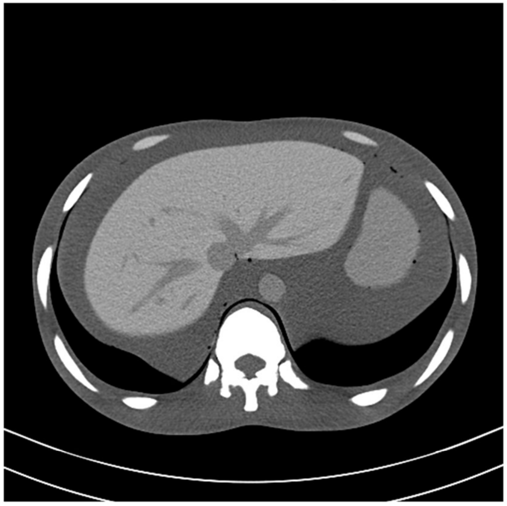


Image 2

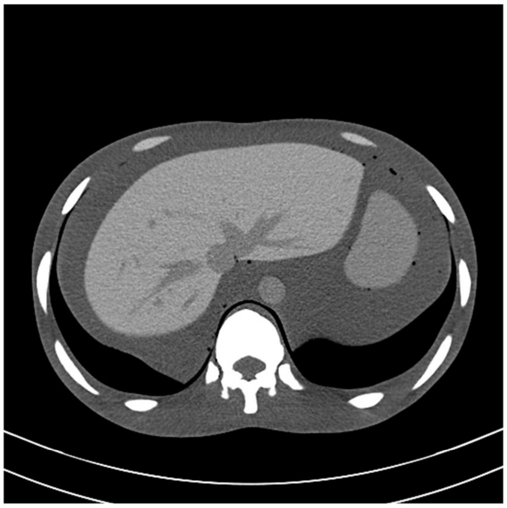


Image 3

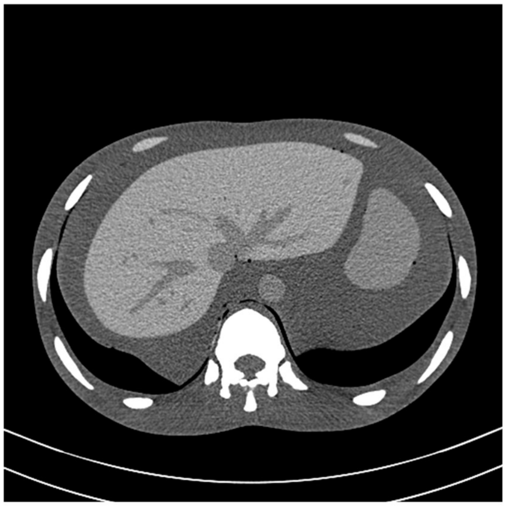
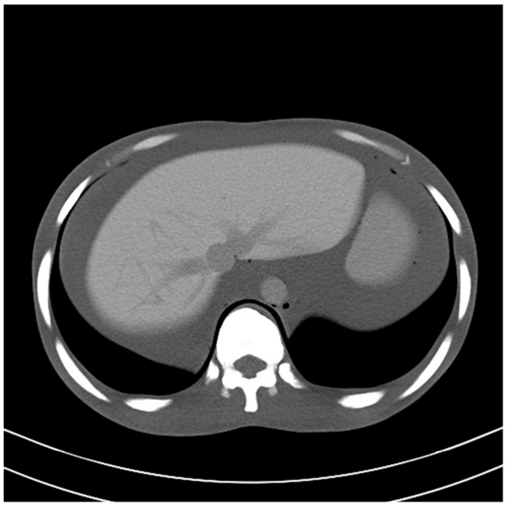


Image 4



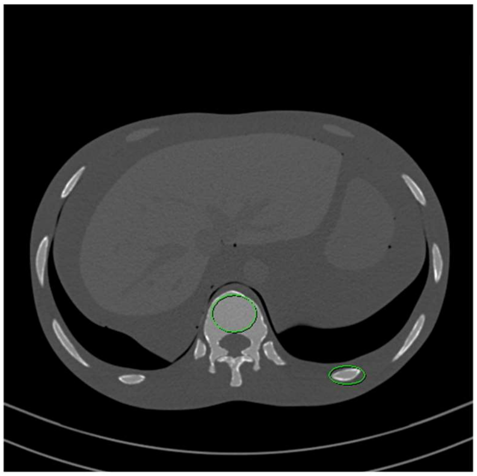
a. Image 1 _______
b. Image 2
c. Image 3
d. Image 4

13. What is CTDIvol?
a. Dose rate and patient exposure _______
b. Patient exposure
c. Dose rate
d. Noise index

14. Why does Image 2 of the CT test tool have increased spatial resolution (↑)?

a. Very sharp kernel reconstruction applied ______
b. Very smooth kernel reconstruction applied
c. Increase in kVp (↑)
d. Increase in mAs (↑)

15. What is the most likely measurement for Hounsfield Units of cortical bone in the following image?



a. 1000 HU ______
b. 200 HU
c. 0 HU
d. -1000 HU

16. What is the reason for improved contrast resolution in Image 2?

Image 1

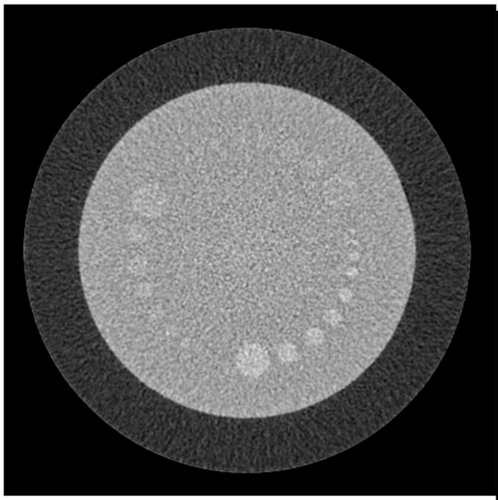
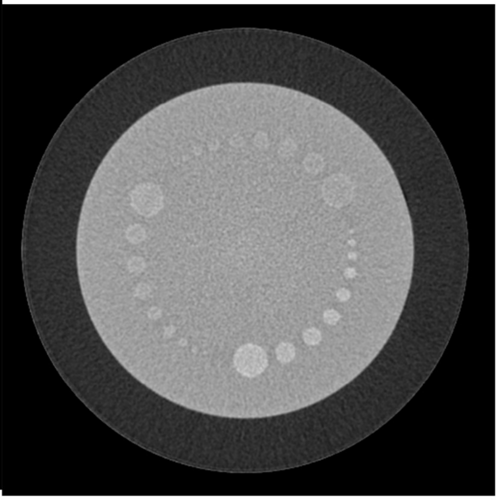
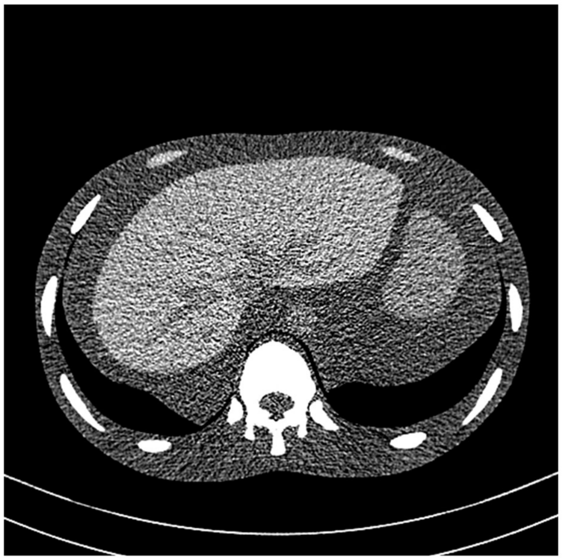


Image 2



a. Increased mAs (↑)
b. Decreased mAs (↓) ______
c. Thinner slice thickness applied
d. Decreased radiation dose (↓)

17. What is the most likely set of technical factors applied in the following image?



a. 30 kVp, 15 mAs ______
b. 80 kVp, 50 mAs
c. 130 kVp, 200 mAs
d. 150 kVp, 500 mAs

18. What kernel reconstruction was applied to Image 1?

Image 1

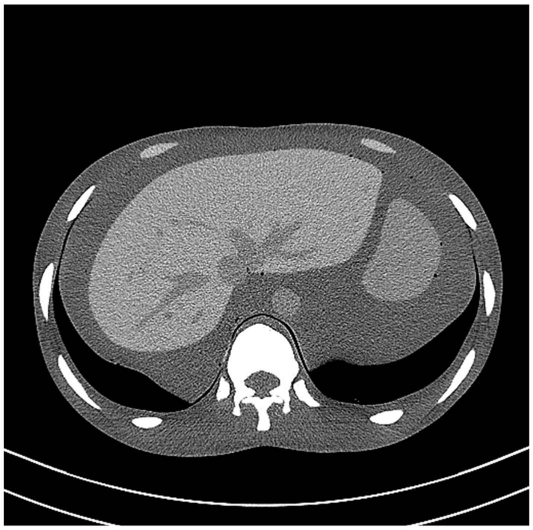


Image 2

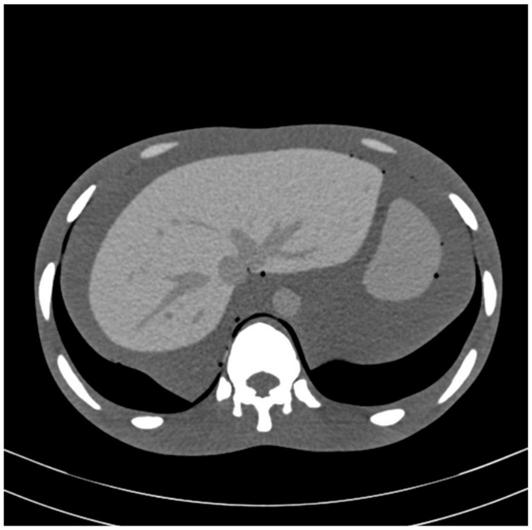
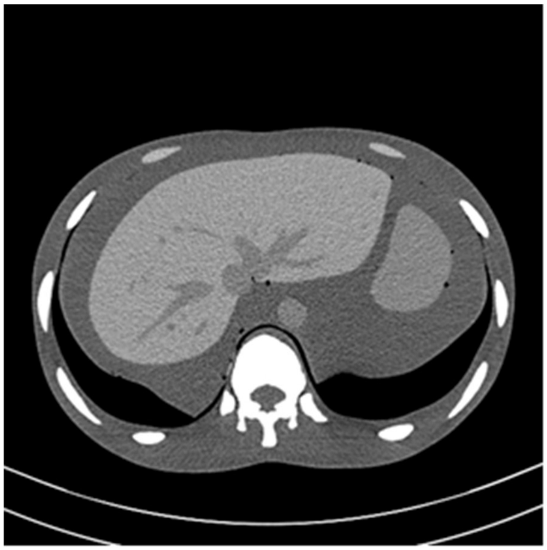


Image 3



a. Very smooth reconstruction ______
b. Standard reconstruction
c. Very sharp reconstruction
d. None

19. What technical factors would result in the highest patient dose (mGy)?

a. 80 kVp, 50 mAs ______
b. 110 kVp, 100 mAs
c. 130 kVp, 200 mAs
d. 110 kVp, 400 mAs

20. Which of the following is the most likely Hounsfield Unit of fat tissue?

a. -500 HU ______
b. -20 HU
c. 500 HU
d. 1000 HU

21. Does the application of a reconstructive filter (post-scan) affect dose?

a. Always ______
b. Never
c. Only with a smooth kernel
d. Only with a very sharp kernel

22. For a CT scan, factors such as kV, mAs, and acquisition slice thickness are selected:

a. Before the scan ______
b. After the scan
c. During the scan
d. Never; these factors are always constant

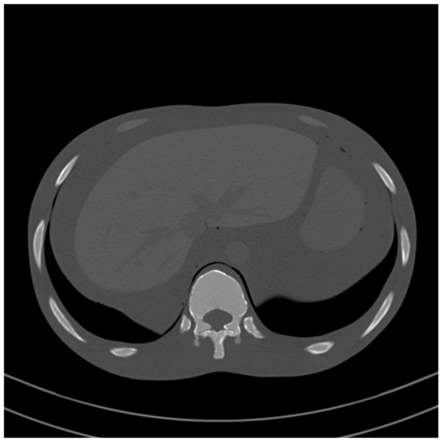
23. Which of the following is <u>not</u> a primary scan parameter?

a. Tube voltage ______
b. Tube current
c. Scan time
d. Kernels

24. Which of the following is true?

a. Image noise decreases (↓) with increasing kVp (↑) ______
b. Image noise increases (↑) with increasing kVp (↑)
c. Radiation dose decreases (↓) with increasing kVp and mAs (↑)
d. Radiation dose is constant with increasing kVp and mAs (↑)

25. What parameters were likely selected for the following image?



a. 30 kV, 50 mAs ______
b. 110 kV, 200 mAs
c. 250 kV, 500 mAs
d. 400 kV, 400 mAs

26. Which of the following is <u>true</u>?

a. Radiation dose increases linearly (↑) with scan time. ______
b. There is a simple relationship between voltage and radiation dose.
c. Radiation dose decreases (↓) when thinner acquisition slices are selected.
d. Radiation dose decreases linearly (↓) with increasing mA value (↑).

27. The following abdomen CT slice features what window setting?

a. Water window setting ______
b. Soft tissue window setting
c. Bone window setting
d. Air window setting

28. Which factor does <u>not</u> affect spatial resolution?

a. Kernals ______
b. mA
c. Slice thickness
d. Patient motion

29. Which image has decreased detail (↓) and why?

Image 1

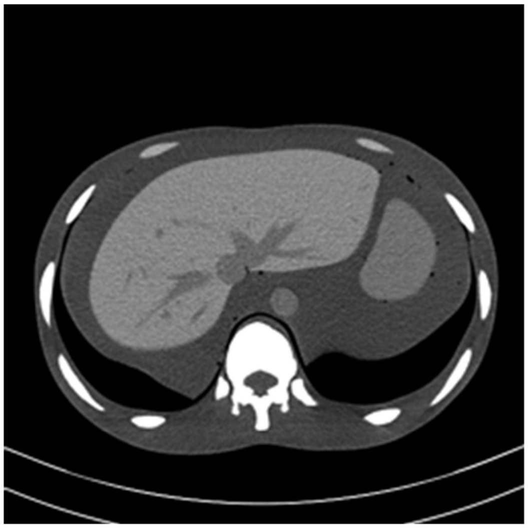
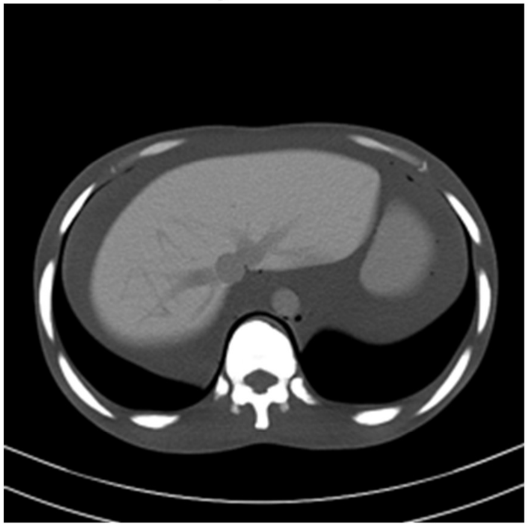


Image 2



a. Image 1; due to smaller acquisition slice thickness ______
b. Image 1; due to larger acquisition slice thickness
c. Image 2; due to smaller acquisition slice thickness
d. Image 2; due to larger acquisition slice thickness

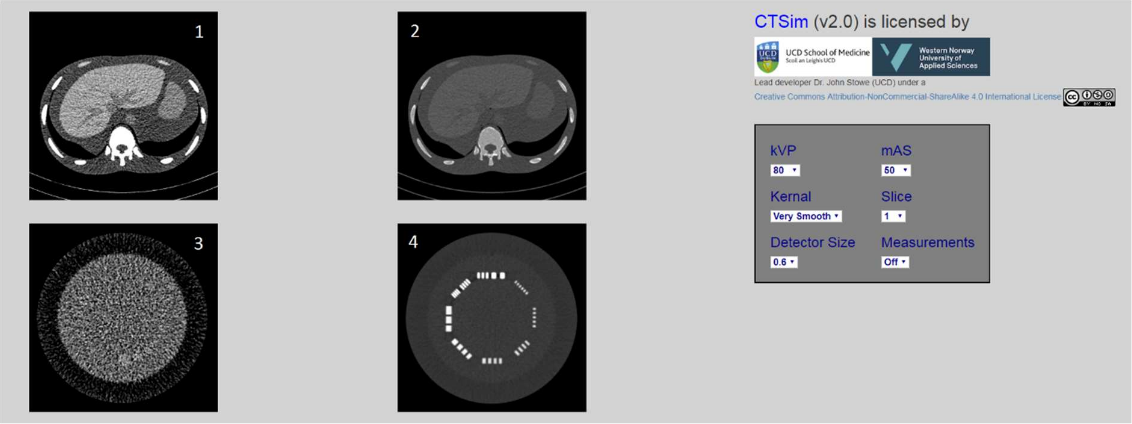
30. CT image enhancement is used to:

a. Enhance shape and edge for improved image quality ______
b. Reduce image noise
c. All of the above
d. None of the above

Appendix 5: Intervention task paper in English

How to use the CT simulation tool

Basics about the tool:



CTSim (v2.0) is licensed by

Lead developer Dr. John Stowe (UCD) under a

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kVP: 80

mAS: 50

Kernal: Very Smooth

Slice: 1

Detector Size: 0.6

Measurements: Off

You can see four pictures on the screen.

1. Top left: CT slice of an abdomen phantom with a soft tissue window setting
2. Top right: CT slice of an abdomen phantom with a bone tissue window setting
3. Bottom left: CT slice of a contrast resolution phantom
4. Bottom right: CT slice of a spatial resolution phantom

On the right part of the screen, you can see adjustable parameters.

- kVP: it is a scan parameter, only adjustable prior to scan.
- mAS: it is a scan parameter, only adjustable prior to scan.
- Kernal: it is a reconstruction parameter, it sharpens or smooth out edges.
- Slice: it is the acquisition slice thickness in millimetres. It must be chosen before scan and can then only be made thicker in post-processing.
- Detector size: not part of the lesson. Just note that the slice thickness has to be bigger than the detector size.
- Measurements: if you switch them on, you can see:
  - HU in different regions of interests (RoI). Zero is water.
  - The **CTDIvol** in mGy represents the dose received in 1 centimetre (i.e. **dose rate**).

- **DLP** in mGy.cm which is the dose received by the patient (i.e. **patient exposure**).
- Noise, defined as standard deviation, only measured in the liver. The bigger it is, the more noise there is.

Using the Tool:

First, keep the measurements switched off.

Start parameters are at kVP: 80, mAS: 50, kernal: very smooth, slice: 1

1. If you increase the kVP and keep the rest of the parameters the same. What changes do you see in the pictures? Can you explain the changes?

2. Put kVP back at 80 and start changing the mAS. What are the changes now? Can you explain what you see?

3. Put mAS back at 50 and change the kernel. What can you see now? Explain what you see.

4. Set the kernal back to very smooth and start changing the slice thickness. Do you see any differences?

Image Quality:

Contrast resolution is the ability to distinguish two shades of grey that are similar but not the same. In the contrast resolution phantom (image 3) you can count the circles you see.

1. Looking at the pictures and changing the parameters, what combination gives the best contrast resolution?

   Try to explain what you see, write this down and write down what parameters you used.

kVP	mAS	kernal	slice

Spatial resolution is the ability to distinguish very small objects that are close to each other, in the spatial resolution phantom (image 4) you can count the lines you see.

2. Still looking at the pictures and changing the parameters, what combination gives the best spatial resolution?

Try to explain what you see, write this down and write down what parameters you used.

kVP	mAS	kernal	slice

Now turn on the measurements. During the next steps, take a look at how the HU change.

3. Play with the parameters. How does the noise affect what you see?

How does it affect contrast resolution?

How does it affect spatial resolution?

How does it affect the picture of the abdomen?

Dose:

Look at the dose in DLP.

Go back to the parameters you found for the best contrast resolution.

1. How do the parameters affect the dose compared to the start parameters (kVp:80, mAs: 50, kernal: very smooth, slice: 1)?

2. Was this what you expected?

○ yes ○ no

Why?

3. Can you adjust the best parameters for contrast resolution you found so the contrast resolution stays the same, but the dose decreases?

Now use the parameters for the best spatial resolution you found.

1. How do the parameters affect the dose compared to the start parameters (kVp:80, mAs: 50, kernal: very smooth, slice: 1)?

2. Was this what you expected?

○ yes ○ no

Why?

3. Can you adjust the best parameters for spatial resolution you found so the spatial resolution stays the same, but the dose decreases?

Dose and Image Quality:

Try to reduce both the noise and the dose in the best image for contrast resolution you found.

1. Were you able to do it?

○ yes ○ no

Use these parameters: kVP: 110, mAS: 250, kernal: standard, Slice: 4

DLP= 7.81 mGy.cm

Now try to reduce the noise and keep the dose close to this DLP. Write down what parameters you found.

kVP	mAS	kernal	slice

Use these parameters: kVP: 110, mAS: 250, kernal: standard, Slice: 4

SD = 8.6

Now try to reduce the dose and keep the noise close to this SD. Write down what parameters you found.

kVP	mAS	kernal	slice

Conclusion:

What are your conclusions about scan parameters and the influence on image quality and patient dose?

Comments:

How much time did you use to complete this?

……………………..minutes

Was it enough?

○ yes ○ no

Would you have liked to have more time?

○ yes ○ no

Did you find the task easy, normal, or difficult?

○ easy

○ normal

○ difficult

Do you have any comments to help us improve?

PLEASE DO NOT TALK ABOUT THIS TASK WITH OTHER GROUPS!

Appendix 6: Request for permission

Forespørsel om bruk av studenter i bacheloroppgave

Bakgrunn og formål

Jeg er radiografstudent ved HVL, og i forbindelse med min bacheloroppgave vil jeg undersøke studenters kunnskaper om CT før og etter bruk av en CT-simulator. Bakgrunnen for studien er den økte bruken av CT som undersøkelsesmetode. De siste 20 årene har bruken av CT i de nordiske landene økt betraktelig. For pasienten innebærer CT en langt høyere stråledose enn ved konvensjonell røntgen, og det er dermed ønskelig at man holder stråledosen så lav som mulig samtidig som man oppnår god bildekvalitet. (The Nordic Radiation Protection co-operation, 2012 For å kunne optimalisere stråledose og bildekvalitet i forhold til hverandre er det viktig at radiografer innehar relevant kunnskap om nettopp dette. Formålet med studien er derfor å kartlegge i hvilken grad bruk av en CT-simulator vil øke tredje- og andreårs (R16 og R17) radiografstudenters kunnskaper om hvordan ulike CT-parametere påvirker bildekvalitet og stråledose. CT-simulatoren ble utviklet ved University College Dublin og er et samarbeidsprosjekt med Høgskulen på Vestlandet (HVL) her i Bergen. Simulatoren lar brukeren endre på blant annet kVp, mAs, kernel og snittykkelse.

Hva deltakelse i studien innebærer

Ved å samtykke til deltakelse i studien vil studenter få gjennomføre en pre-test og en post-test med spørsmål om stråledose og bildekvalitet ved CT-undersøkelser. Testen tar omtrent 15 minutter å svare på. Mellom disse to testene vil studentene ta i bruk en CT-simulator på HVLs datamaskiner på bildebehandlingslaboratoriene. Studentene får 45 minutter til dette, og skal følge instruksjoner i et oppgavehefte. Simulatoren illustrerer hva som skjer med bildekvaliteten når man endrer på de ulike parameterne, samt hva som skjer med stråledosen ved de samme endringene.

Studentene informeres muntlig om prosjektet, og får utdelt et samtykkeskjema. Studentene samtykker ved å krysse av på spørreskjemaet.

Konfidensialitet

Spørreskjemaene som studentene får utdelt vil være anonymiserte slik at man ikke kan gjenkjenne de ulike studentenes svar. Studentene vil få en kode for å kunne sammenligne pretest og posttestresultater.

Frivillighet

Det er frivillig for studenter å delta i studien, og man kan når som helst trekke seg om man skulle ombestemme seg, uten å oppgi grunn. Alle opplysninger vil bli slettet dersom man trekker seg fra studien.

Jeg har tatt NSDs test for meldeplikt, og prosjektet mitt trenger i følge denne ikke å meldes.

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