The importance of medical staff placement in CT examination rooms

A study of the scattered radiation doses in CT examination rooms in Da Nang, Vietnam.

MAIN FIELD: Radiography
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Summary

“The importance of medical staff placement in CT examination rooms”

Background: Vietnam is a developing country and is in the process of improving its healthcare system. The increasing CT-examinations means higher radiation doses on the radiological clinics and entails the importance of protection from ionizing radiation.

The Purpose of this study was to study the scattered radiation doses in an examination-room when performing computed tomography (CT) examinations and to do observations in hospitals concerning how medical staff relate to radiation protection in Vietnam.

Method: The study was an experimental study with a quantitative approach involving measurements and observations in Da Nang, Vietnam. An electronic dosimeter was used to measure the radiation doses during a thorax routine CT-protocol for adults on a thoracic phantom. Visits at a radiological clinic were performed to observe staff placement and relation to radiation during exposure.

Result: Observations showed no major differences in staff radiation safety in CT between the oncology hospital in Da Nang and Swedish hospitals. The measurement results showed that the highest radiation dose was close and in front of the CT gantry (96 µGy) and the lowest dose on the side of the CT scanner (0,42 µGy). The measurements also showed that no radiation got through the lead shield surrounding the CT room.

Conclusion: The radiation dose is dependent to the distance and direction to the radiation source. Standing on the sides of the CT scanner is the safest place from radiation exposure for the medical staff that stays in the CT room.

Keywords: Ionizing radiation, radiation protection, radiography, radiographer, dosimetry
Sammanfattning

"Vikten av placering för medicinsk personal i CT-undersökningsrum"

Bakgrund: Vietnam är ett utvecklingsland och är i färd med att förbättra vården. De ökande CT-undersökningarna innebär ökade stråldoser på radiologiska kliniker och där av större behov av skydd mot joniserande stråling.

Syftet med denna studie var att studera de spridda stråldoserna i ett undersökningsrum under datortomografi-undersökningar (CT) och att utföra observationer på sjukhus rörande hur medicinsk personal hänför sig till strålskydd i Vietnam.


Resultat: Observationerna visade att det inte finns några större skillnader mellan onkologiska sjukhuset i Da Nang och svenska sjukhus när det gäller strålsäkerhet för personal vid CT. Mätresultaten visade att den högsta stråldosen var nära, framför CT-gantry (96 μGy) och den lägsta stråldosen var på sidan av CT-maskinen (0,42 μGy). De mätningar som gjordes utanför CT rummet visade också att ingen strålning gick igenom blyskyddet runt CT-rummet.

Slutsats: Stråldoserna är beroende av avståndet och riktningen till strålkällan. Att stå vid sidorna om CT-scanners är den säkraste platsen för att undvika strålningsexponering för personal som stannar inne i undersökningsrummet.

Nyckelord: Joniserande strålning, strålskydd, radiografi, röntgensjuksköterska, dosimetri
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Introduction

During the last 15-years the number of computed tomography (CT) examinations has almost tripled. It now contributes to more than 60% of the total collective dose from x-ray examinations (Ploussi & Efstathopoulos, 2016). Medical staff, both non-radiological and radiological, often need to stay in the scanning room to support patients during CT examinations (Heilmaier et al., 2016). There are many reasons why medical staff has to stay in the CT room during scanning, for example to comfort patients with anxiety or to monitor patients in need of intensive care (Mori, Koshida, Ishigamori & Matsubara, 2014). Because of the increasing amount of CT examinations, it is important that the medical staff, both non-radiological and radiological, knows about the risks of radiation and how to be as safe as possible when you have to stay in the examination room. This thesis focus on the radiation safety and radiation awareness among medical staff in Vietnam and the main purpose is to study how the radiation is scattered in the CT room. A similar study was made in Switzerland to show the staff where they should place themselves to get the least amount of radiation in the CT room. The study in Switzerland was very appreciated among the staff and helped them to increase radiation awareness (Heilmaier et al., 2016). Hopes are that this thesis can be helpful to the Vietnamese staff and can be used as a guide for staff placement in the CT room.
Background

Vietnam

Vietnam is located in Southeast Asia with a population of over 84 million people. The capital is Hanoi and the biggest city is Ho Chi-Minh city. The currency is Dong. Vietnam is known for their food, history and beautiful nature (Vietnamportalen, 2017).

Vietnam has in a quarter-century transformed from a poor agricultural nation to a lower middle-income country where industry and services account for the biggest part of the economy. It has occurred in parallel with the transformation from a planned economy to a market economy. The rapid growth has been accompanied by a major reduction of poverty (Landguiden, 2015).

Vietnam has developed in various areas since the 1990s and today they generally provide good quality healthcare. The child mortality has decreased significantly and the average life expectancy is 73 years. Improvement of the current healthcare service is an important part of reforms being made in Vietnam (InterNations, 2014).

Medical care in Vietnam is shared between the public and private sectors. Most people living in Vietnam currently have to pay for some or all health services out of their own pocket, especially if they visit the better equipped private clinics. The new Law on Health Insurance aims to provide a more equitable healthcare system. As a developing country, Vietnam is in the process of improving its healthcare system and has made great efforts in implementing health financing reforms (Angloinfo, 2016).

Radiation doses

Radiation doses can be measured in a number of ways. The different ways of measuring radiation dose are:

**Absorbed dose** is used to assess the potential for biochemical changes in specific tissues. Absorbed dose is the concentration of radiation energy deposited in tissue as a result of an
exposure to ionizing radiation. X-rays can penetrate deep into the body and deposit energy in internal organs. Absorbed dose describes the intensity of the energy deposited in any small amount of tissue located anywhere in the body. The unit for measuring the absorbed dose is called Gray (Gy), which is defined as Joules/kg.

**Equivalent dose** is an amount that takes the damaging properties of different types of radiation into account. Absorbed dose tells us the energy deposit in a small volume of tissue. Equivalent dose addresses the impact that the type of radiation has on that tissue. There are different types of radiation but all electromagnetic radiation used in X-ray diagnostic medicine has the same lower-harm potential, compared to different kinds of particle radiation with higher linear energy transfer. This means that the absorbed dose and the equivalent dose are numerically the same, only the units are different. For diagnostic radiation, the equivalent dose is normally measured in milliSievert (mSv) = the absorbed dose in mGy.

**Effective dose** is a calculated value, measured in mSv, that take three factors in account:

- The absorbed dose to all organs of the body.
- The relative harm level of the radiation.
- The sensitivities of each organ to radiation.

The quantity of effective dose helps us take into account sensitivity. Different parts of the body have different sensitivity to radiation. For example the head is less sensitive than the chest. This is because the brain tissue is less sensitive to radiation then for example lung tissue. Effective dose relates to the overall long-term risk to a person from a procedure and is useful for comparing risks from different procedures.

The absorbed dose and equivalent dose can be used to assess short-term risk to tissues. If the diagnostic examinations are properly performed, there will be no short-term effects from the radiation exposure. The most important dose quantity for patients is effective dose because it allows for simple comparison of long-term risks (Radiology info, 2011).
Radiation risks

Upon exposure to radiation there is a risk of the induction of cancer. At low irradiation, the probability of getting cancer by radiation is very small. The likelihood though increases with increasing radiation dose.

The natural background radiation from cosmic rays and radioactive substances in our environment and in the body gives an annual dose of about 1 mSv (the radiation dose from radon, 0.8 mSv/year is not included). The average radiation dose per person (including medical radiation and radon) is 3 mSv/year (Swedish radiation safety authority, 2011). The probability that the natural radiation causes cell changes that lead to cancer later in life is estimated to be 0.005 percent, or roughly 1 case in 20,000 people per year. This probability is so low that it cannot be detected by epidemiological investigation. It infers the assumed probability figure by observing the cancer probability in much higher radiation doses for many years. For a normal population the given risk of radiation-induced cellular changes that lead to cancer later in life is 5 percent per Sievert (Sv). From these data, it is then assumed that the probability decreases linearly proportional to the lower dose (Swedish radiation safety authority, 2011).

In a study from *Saudi Journal of Biological Sciences*, one wanted to measure the biological risks of radiation to patients in computed tomography angiography (CTA) procedures. 152 adult patients with clinical indications were involved, 84 men and 68 women. The angiographic procedures that were made included cerebral, chest, abdomen, pelvis and limb procedures. They were performed on a 64-slice CT scanner from Toshiba Sensation Aquilion 64, Japan. A constant voltage potential was used for the CTA procedures, 120 kV. The tube current-time (mAs) differed per procedure and was ranged from 100 to 250 mAs. The dose length product, DLP (mGy·cm), was used to estimate the organ-equivalent dose using software provided by the National Radiological Protection Board and patient exposure parameters. To get the overall cancer risk per procedure one multiplied the effective dose with the risk coefficients. The result of the study showed that the highest radiation dose per CTA procedure involved cerebral CTAs. The highest effective dose involved pelvic CTAs. The trunk includes the most radiosensitive organs with tissue weighting factors and so that can explain this finding. The lower limb procedures had the lowest dose values (Alkhorayef, Babikir, Alrushoud, Al-Mohammed & Sulieman, 2017).
The same study showed that the risks for males and females differed in procedures. Risks in CT abdomen were similar for both males and females and they both also had a high radio sensitivity in the thyroid. Otherwise, females have three special organs with high carcinogenic radio sensitivity. These involve breast, uterus and ovary. Males on the other hand, have one organ with high sensitivity, which is testis. The study showed that the uterus and ovaries were exposed to the highest radiation dose compared to other organs. The breast that is a high radiosensitive organ has the highest equivalent dose for chest procedures and has the highest cancer probability compared to the uterus (Alkhorayef, Babikir, Alrushoud, Al-Mohammed & Sulieman, 2017). Because of these findings, CT procedures that are performed on the chest and abdomen in especially girls and young females need to be carefully justified to decrease the radiation doses.

Another radiosensitive organ in both men and women is the lens of the eye. Too much radiation can affect it with opacities and visual impairment, cataracts (International Atomic Energy Agency, 2013). In the study from Saudi journal of biological sciences the lens received 41.2 mSv per cerebral CTA procedure and this value is lower compared to previous studies. Unfortunately, a threshold was not justified and this could lead to unnecessarily high radiation dose. In light of this information, the lens of the eye dose during CTA and other imaging procedures should be reassessed and rigorous justification of the procedures is needed. In a cancer risk point of view the current study showed that the patient cancer risk is one cancer case per 1000 CTA chest procedures and three per 1000 CTA abdomen procedures. The least risk for CTA procedures is thyroid cancer (Alkhorayef, Babikir, Alrushoud, Al-Mohammed & Sulieman, 2017).

In general, the patient radiation dose is proportional to the tube current–exposure time product (mAs). Many other factors also affect the radiation dose from the CTAs. These factors include beam energy, rotation or exposure time, slice thickness, pitch and dose reduction techniques. The progress in CT technology is therefore important to follow to decrease the dose values to the patients as much as possible. The cancer effect has though no threshold. Any radiation dose can cause cancer or genetic mutations because any DNA damage can initiate loss of cell division control. Therefore, radiation protection against ionizing radiation is crucial to the dose received in CTA procedures, regardless of the quantity, and is highly relevant. Moreover, other alternatives should be considered, such as magnetic resonance imaging.
(MRI) to decrease the biological risks in patients (Alkhorayef, Babikir, Alrushoud, Al-Mohammed & Sulieman, 2017).

Medical staff and radiation

Medical staff, both non-radiological and radiological staff, often need to stay in the scanning room to support patients during CT examinations (Heilmaier et al., 2016). The reasons why medical staff need to stay in the room are many, for example to relieve anxiety in patients or to take care of a trauma patient who is in need of intensive care while performing the CT-examination (Mori, Koshida, Ischigamori & Matsubara, 2014). Studies have shown that non-radiological medical staff have insufficient knowledge when it comes to risk of radiation to patients associated with CT (Jin Hee L. et al., 2015). Non-radiological professionals have the least knowledge of the risk of radiation but they still, at times remain in the scanning room during examinations because they need to take care of the patient at the same time (Heilmaier et al., 2016). Non-radiological professionals have less knowledge of CT and how the radiation is spread in the scanning room. A study in Switzerland where radiation doses were measured in different places of the scanning room, a so-called “traffic light system” was developed for the medical staff to relate to. They put coloured stickers on the floor with the colours red, orange and green. Green was the best place to stand on to get the least radiation exposure and red was the worst place. The traffic light system was appreciated by the medical staff and especially by the non-radiological professionals who could look at the floor to see where they should stand to get the least dose (Heilmaier et al., 2016).

Safety

Correct protection and safety is an extremely important concept in radiology departments in hospitals. During the last 15-years period the number of CT examinations has almost tripled. It now contributes to more than 60% of the total collective dose from x-ray examinations (Ploussi & Efstathopoulos, 2016). Because of these increasing numbers, it is extremely important for both radiological professionals and other medical staff to have the knowledge about protection from the ionizing radiation. It is important for the radiological staff to decrease the doses for the patients as much as possible but also for themselves, especially because of the daily exposure of radiation for the radiographers. The increasing use of higher dose procedures such as CT-examinations means that the safety and health risks are much
higher for the staff who work with radiation on a daily basis. In a study from Greece the conclusion of the radiation safety was to implement "Radiation protection culture”, or "RPC”, in x-ray departments. RPC stands for the combination of knowledge, beliefs and practices related to the radiation safety. Insufficient knowledge and lack of collaboration are the most significant barriers in the implementation of RPC. With a richer knowledge about risks with radiation and also collaboration among medical staff there might be a much more enlightened issue. Both among radiographers and other medical staff at the hospital who also might be in need to stay in the examination room with the patient during the examination for some reason (Ploussi & Efstathopoulos, 2016). To enlighten where the best place with minimum radiation is in the room by this study, this may help all medical staff involved to maximum their health safety.

The radiographer and the profession

Radiography is the main area for radiographers and is built on science and proven experience. Radiographer’s work along six different core components; person-centred care, collaboration in teams, evidence-based care, improvement and quality, safe care and informatics. The main area of radiography is also the understanding of interactions between care environment, technique and the human being. The interaction between patients in all ages and their care need is also a big part in the radiography. As a radiographer, you meet all kinds of people but mostly during a short moment under specific circumstances. During these short occasions the radiographers work along four ground principles that is the principle of respect and self-determination, not to harm, to do good and the principle of justice. As the radiographer work independently they have the responsibility to make the best of the examination (Örnberg & Andersson, 2012).

Radiographers in Sweden work along a principle called “ALARA”. The meaning of ALARA is “As Low As Reasonably Achievable” and stands in this case for the radiation dose that is used during an examination. ALARA is used for the safety of the patient so that he or she will get the least radiation exposure and still a good image quality for the doctors to diagnose (Health physics society, 2017).

It is also important for the radiographer to work as a team-member. In one hospital it is usually around 20-40 radiographers that work together in one clinic and they also work
together with nurses, assistant nurses and doctors. Sometimes they also need to work together with emergency staff during emergencies and nurses from different sections of the hospital. Therefore, it is very important for the radiographer to have the ability to work along with other people, even if they work independent in the profession. Education is also a centred part in the profession. As the radiographers work together, they will teach and help each other and other co-workers to give and to get more experience and knowledge. They can also supervise and assess students during their education (Örnberg & Andersson, 2012).

Quantitative studies

This study has a quantitative approach, which means that the method is based on studying structured data that can be quantified in numbers or categories. With the use of quantitative research, the researcher wants to measure something in different ways. These methods can involve for example experiments, observations or surveys. A main part in quantitative studies is replication. It means that a study can be performed several times but still obtain the same result. Another important part is reliability and validity, which describes if the method is reliable and if what was to be measured really has been measured (Backman, 2008). The reliability and validity of this study is discusses below the method discussion.

Rationale

The topic of radiation doses and protection associated with CT is not easily found in studies or articles made in Vietnam. Therefore this topic is rather unexplored and to study this is highly relevant to establish some guidelines for the medical staff to relate to when remaining in the scanning room to avoid scattered radiation. In addition, as the numbers of CT examinations is increasing the medical staff is also increasing the risk of radiation exposure on a daily basis (Ploussi & Efstathopoulos, 2016). Therefore, a study similar to the one in Switzerland (Heilmaier, Mayor, Zuber, Fodor & Weishaupt, 2016) would contribute to raise awareness of the scattered radiation in CT-rooms among vietnamese non-radiological medical staff and how to protect one another against it.
**Purpose**

The main purpose was to study the scattered radiation doses in an examination-room when performing CT-examinations and to do observations in hospitals concerning how medical staff relates to radiation protection in Vietnam.

**Question at issue**

What does the radiation pattern in a CT-room look like? Where should the staff place themselves while nursing the patient in order to minimize radiation exposure?

**Material and method**

This study was an experimental study with a quantitative approach, involving measurements and observations in Da Nang, Vietnam.

**Observations**

Visits to an oncological hospital in Da Nang were performed to visit the radiology department and observe how the staff protected themselves against radiation when they were present in the examination room. The observations were performed in the beginning of the study during three days. The staff at the radiology department was observed and talked to about their work with radiation. The objective of the observations was to see if there are any major differences between Vietnam and Sweden when it comes to working with CT-radiation and also to observe how the medical staff were working and placing themselves in relation to the exposure of radiation. The observations were also going to show how often the medical staff stayed in the examination room during the radiation exposure. During the observations, the authors had a few question at issues for themselves concerning the medical staff and radiation exposure. The issues were concerning; how does the medical staff, both radiographers and non-radiographers, relate to radiation inside the CT-examination room? How do the medical staff protect themselves from radiation exposure if they have to stay in the CT-examination room? Does the CT-room contain lead shields or lead walls? How often does medical staff stay inside the CT-examination room during radiation exposure?
These questions at issue were guidelines for the authors to know what to look for during the observations. After the observations, the issues were discussed and presented below the discussion and result in this study.

Thanks to the observations it was clearer on which places the electronic dosimeter needed to be placed on for the measurement study to get the most realistic result and how many places it needed to measure.

**Pilot-study**

Before the actual study a pilot-study was performed. The pilot-study was performed in the same clinic, with the same protocol and the same phantom as the actual study to figure out which spots in the CT-room was relevant for the study. The same dosimeter, as during the actual study, was also used during the pilot-study. All the same 17 places as in the actual study were also measured in the pilot-study and also some other places to compare if other places were necessary. More than one measurement were made on a few places and showed that the dosimeter showed a small difference between every measurement. Therefore, the authors decided to measure three times on each place later in the actual study. The results from the pilot-study were not used in the actual study and are not presented in the result below.

**Dosimetry**

An electronic dosimeter was used to measure radiation doses in different places in the examination-room. Before the study, the electronic dosimeter was tested at the hospital Ryhov in Jönköping, Sweden to make sure that the radiation dose result was going to be reliable. Dosimeters are devices used to measure an absorbed dose of ionizing radiation (Gilman, 2004). The dosimeter that was used in the study is called “Unfors EDD-30”. It is an electronic personal dosimeter (EPD) and consists of a small sensor on a cable connected to a display unit. The sensor can measure the dose and dose rate to a specific part of the body, i.e. to eyes, hands, feet, etc. Total exposure time is also measured. The EPD has a dose range of 10 nGy - 9999 Gy and measures gamma, beta and ionizing radiation. The dosimeter has a 94% accuracy (Nor-dax, n.d.). When the sensor and display unit have been positioned and the instrument turned on, dose is accumulated and alarms are triggered when selected dose or
dose rate limits are exceeded. For the measurements at the clinic the dosimeter was set to “FREE”, which means that it measures radiation without dose limit and without taking any specific body parts in to account.

**Measurements**

The measurements were performed on the ionizing radiation from a CT-machine used for training students in a radiological student-clinic at the university in Da Nang, Vietnam. The examination that was performed for the measurements was Thoracic CT. This was because of the availability of phantoms at the student clinic in Da Nang. There was only one thoracic phantom at the clinic and it was used as “the patient” during the examinations and measurements. The thoracic phantom is an accurate life-size anatomical model of a human torso excluding arms, head and lower extremities. The soft tissue substitute material and synthetic bones have x-ray absorption rates very close to those of human tissues (Kiyoshi & Norihisa, 2012). The protocol of the thorax that was used was the most common in the clinic. This was to get a reliable and relevant result in the study. The protocol used for the measurements was a thoracic routine CT-protocol for adults. The parameters from the CT protocol are shown down below in Table 1.

*Table 1. Parameters from the thoracic routine CT protocol used in the study.*

<table>
<thead>
<tr>
<th>CT Protocol:</th>
<th>l_ToraxRoutine (Adult)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topogram time (s):</td>
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</tr>
<tr>
<td>Thor. Routine time (s):</td>
<td>3+22 (3=delay time)</td>
</tr>
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<td>Table height (cm):</td>
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</tr>
<tr>
<td>FOV:</td>
<td>300</td>
</tr>
<tr>
<td>Eff. mAs (mean):</td>
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</tr>
<tr>
<td>Slice thickness (mm):</td>
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</tr>
<tr>
<td>Pitch:</td>
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</tr>
</tbody>
</table>

The measurements were performed on a 2-slice CT-machine from Siemens called SOMATOM SPIRIT-M-CT-160 from 2009. The radiation doses were measured by the dosimeter in 17 different places in the CT examination-room. 14 of the measurements were
made inside the CT-room and 3 were made outside the room. These three places was outside of two lead doors and a lead window to measure if any radiation got through. The 14 other measurements inside the CT-room was scattered along the walls and also along the CT-machine to get an overview in the room and which factors that affected the radiation dose.

On each place in the CT-room that a radiation measurement was made, three examinations were performed so that three measurements could be provided. This was to get a mean of the radiation dose for each place. Otherwise, the doses would show a small difference between each measurement according to the pilot study. The mean was therefore the most reliable result. It was calculated by subtracting the three readings and then dividing the total sum of the number of measurements (here three). The collected information was then analysed and compared to find out where in the examination room the most and the least radiation dose was obtained.

The dosimeter was placed on a real size skeleton from the clinic to get a realistic placement as if it was a real person standing in the room. The dosimeter is equipped with a sensor on a cable connected to a display unit. This sensor was taped to the skeleton in the same height as the middle of the CT gantry which was on a height of 94 cm above the floor. This placement was in height with symphysis pubis on the skeleton, which is in the front of pelvis in between of the pubic bones (os pubis).

Analysis

After the measurements, a ratio scale was used to describe the readings and also a summery map was presented over the examination room showing the results of the study. The radiation doses that were developed during the measurements are presented in Table 2 below the result. The table presents the mean from all three measurements on each place and also the standard deviation. To get the standard deviation an equation was used, \(\sqrt{\frac{\sum(x-m)^2}{n}}\). The radiation doses are presented in micro Gray (\(\mu\)Gy) which was the unit that the dosimeter measured in during the measurements. The summary map shows the radiation doses scattered over the room and can be used as a recommendation for the medical staff, showing them where they can place themselves in the room to be exposed by as low radiation dose as possible. This is to increase radiation safety among the staff. The map is presented down below in Picture 2 in the result section. The statistics of radiation doses and the observations were then compared.
and a conclusion was made in order to suggest improvements regarding radiation safety for the staff.

**Article research**

To find articles involving the main issue of the study, PubMed was used. Some of the keywords that were used during the search was; radiological staff placement, staff placement in CT examination rooms, radiographers and radiation, radiation protection among radiological staff, radiation doses and CT, radiation doses in CT examination rooms. Some articles were found in English but no one was about about Vietnam. The only articles about staff placement in CT examination rooms or radiation doses in CT rooms that were found was in Vietnamese and the authors had no possibility to translate those articles.

**Ethical considerations**

The radiation measurements were performed during thoracic CT examinations of a phantom and therefore no selection of participants was used. In a similar study made in Switzerland, participating people were placed around the CT-machine during the radiation exposures. The participants had to use lead aprons for their safety and a dosimeter each to measure the radiation dose during the exposure of radiation (Heilmaier et al., 2016). In the current study in Vietnam however, no selection was used. The electronic dosimeter was merely placed on a real size skeleton in the CT-room on places medical staff most likely would stand on during examinations. This was to increase safety for other persons and make the time more efficient. No ethical considerations was then involved during the measurement study because of the lack of population. Only if unauthorized persons in the campus observed the study their safety was considered so that no one got exposed by unnecessary radiation during the measurements. In these cases, the authors always made sure that the lead door to the CT-room was closed during the examinations and radiation exposure and that no one was left in the CT-room.

During the observations at the oncological hospital in Da Nang there were more ethical considerations. The hospital manager gave an oral approval before the observations took place. The patients and medical staff were also informed about the study during the field studies for their safety and security.
Below Appendix 2, an ethical review is attached. The authors and Swedish supervisor made it before the study began.

**Swedish occupational code**

The personal information concerning patients’ integrity and anonymity was kept confidential. During the field studies, the authors conformed to the Swedish occupational code. This code is a standard thinking and implementation among all radiographers in Sweden so that patients can feel safe concerning their integrity, information and anonymity during their hospital stay. This Swedish occupational code is called “Yrkesetiska kodén för röntgensjuksköterskor” in Swedish (Vårdförbundet & Svensk förening för röntgensjuksköterskor [SFR], 2008). Information about the Vietnamese culture was also received, especially about what is appropriate for students in field studies in hospitals in Vietnam. After the observations, the collected data was handled with confidentiality and no personal information was spread outward the study work.

Besides the occupational code there are also four main demands in research ethics in Sweden; the information requirement, the consent requirement, the confidentiality and use requirement. These main demands have to be followed by all staff that works in hospitals in Sweden to protect patients. The meaning of these demands is that information will be provided to the patient about their care and the patient has the rights to determine their own involvement in the investigation. Any personal data involving the investigation must be stored in such a way that unauthorized persons cannot take advantages of them. Finally, the fourth main demand requires that the personal data collected from the investigation may be used only for research purposes (Vetenskapsrådet, 2002). The authors also followed these demands during the data collections and observations in the study.

Care ethics are also included in the Swedish health care and a big part of education in health care. There are some ground principals that always are included when taking care of a patient. It is the autonomy, same as in the four main demands, which means that the patient has the right to self-determination in their participation in the investigation. Another principal is the right of justice, that every human has the same rights of medical care whether its gender, race,
ability or function. These care ethics also tells you to do good and not to harm. In Swedish health care universities, these care ethics are taught (Läkare med gränser, 2017).

Result

Observations

The result of the observations showed that the medical staff in Da Nang were really meticulous about leaving the CT-room during the examination to avoid unnecessary radiation exposure and the CT-room was surrounded by lead walls and lead glass to protect the staff from radiation. The CT-rooms were also equipped with lead aprons if the staff needed to stay in the scanning-room during radiation exposure. The observations also showed that there are no major differences between the oncology hospital in Da Nang and Swedish hospitals when it comes to staff radiation safety in CT. The one thing that differed from the hospitals in Skövde and Kalmar in Sweden was that during punctures the doctor did not stay in the examination-room while scanning in Vietnam. They scanned and choose the location for the puncture and then the doctor did the procedure without looking at a screen in the CT-room as they do in Skövde and Kalmar. This means that the doctor in Vietnam will be exposed to less radiation, because the part with real time scanning while performing the puncture is precluded.

Measurements

The results from the measurements are presented in Table 2. The table shows the mean and the standard deviation from all three measurements on each place. The radiation doses are presented in micro Gray (µGy). The table also shows a column with place numbers which stands for the 17 different measurement-places. The map (Picture 1) below shows the numbers scattered over the CT room meaning where the measurements took place. How the radiation doses where scattered in the CT examination room is also presented in a colour map below in Picture 2. The map shows a colour schedule from the highest to the lowest radiation dose. The highest dose is presented in a dark red colour and the lowest dose in white. The map is scaled to its proper place where the measurements took place in Da Nang, Vietnam.
The table under Appendix 1 below appendices shows all three measurement doses on all 17 places in the CT-room and also the mean result of each place.

The measurements from this study shows that the highest radiation dose is in front of the CT gantry standing beside the patient bed, place number 10 and 13 in the table 2. The lowest radiation dose was presented on the sides of the CT gantry, in place 9 and 14. The measurement results also shows that the distance from the radiation source in the CT room affects the radiation exposure. The radiation dose on the farthest places from the CT gantry was place 6 and 7 and had the second least radiation dose after place 9 and 14. These places where around 300 cm from the CT gantry.

The measurements that were performed outside the CT room all showed a radiation dose of 0.0 µGy, which showed that the lead doors and lead window was exceptionally secure for radiation exposure. No radiation got threw the lead shield.
Table 2. The scattered radiation dose mean results & standard deviation measured in the CT examination room.

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<th>Place nr</th>
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<th>STD.deviation (µGy)</th>
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</table>
Picture 1. The scattered measurement places in the CT examination room.
Picture 2. Colour map over the scattered radiation dose results in the CT-room, presented in micro Gray.
Discussion

Method discussion

The examination that was going to be used at first for the study was abdominal CT, because of the high dose rate during that examination. The phantom though that was available in the student clinic in Da Nang was a thoracic phantom and therefore this was used for the measurements during the examinations. The examination that was going to be performed then had to be changed into a thoracic CT-scan. Because of the change, the protocol that was used was a routine thorax-protocol for adults. This protocol was the most common in the clinic and relevant for the study, although an abdominal CT would likely give higher radiation dose values at the specific points (Swedish radiation safety authority, 2010).

Reliability & Validity

Reliability means that it is possible to redo the study in the same way that was described in the method of the study and get the same result. Validity means measuring what is meant to be measured and to be using the right instrument for the study (Patel, & Davidsson, 2011). The reliability in this study is high because it is easy to redo the measurements with the same CT-machine, same protocol, same dosimeter and the same placement of the dosimeter. The factors that adversely affects the reliability is the size of the examination room, phantom size and the placement of the CT-machine. These factors can differ from different hospitals. To get the same result as in this study, the room has to have the same size and interior layout. The same phantom was used for all the measurements in this study instead of a real patient so that the size of the patient would not affect the scattering of radiation. Using a dosimeter was the best way to measure radiation in this study and the dosimeter was tested by a medical physicist before the measurements, which adds to the validity and reliability. The instructions to the dosimeter say that it has a 94% accuracy, which can decrease the reliability and validity (Nor-dax, n.d.). Therefore, three measurements were performed on each measurement place in this study so that no value was completely different and did not match the other values. This method increased the reliability and validity.
Result discussion

The result in this study showed that the parameters that affected the radiation dose exposure the most was avoidance of the field radius of the radiation inside the CT examination-room and the distance to the radiation field. The absolute least radiation dose was exposed on the sides of the CT machine. This is because of the avoidance of the radiation field radius. According to this study the radiation from the CT gantry is spread as a V from both the front and the back. Therefore if you stand on the sides of the machine, the radiation field does not hit you as much as if you stand in front of the CT machine or in the back of it. There are though always some scattered radiation in the whole CT room and impossible to avoid radiation exposure fully without lead shield. The best possible way to avoid radiation exposure is therefore to stay outside of the CT room during the examinations. When the medical staff need to stay inside the CT examination room during radiation exposure one can think of some guidelines. These occasions can be during examinations for example trauma patients or intensive care patients (ICU patients) when the patients need help, support or just a watching eye so that everything is ok.

Radiation doses

The maximum dose that is allowed to medical staff over 18 years is 100 mSv/5 year. This is measured as whole body effective dose. The maximum dose in one year is 50 mSv. To students under 18 years the maximum dose is 6 mSv/year. The maximum dose to the lens of the eye is 20 mSv/year (Linköpings universitet, 2015). To be able to reach the limit values of whole body exposure (20 mSv/year) the staff has to stay in the room during 209 examinations of the thorax in one year without lead apron. This is based on the highest radiation measurement in this report (96,03 µGy) next to the gantry (place 13). The medical staff in Vietnam used lead aprons when they needed to stay in the room, which means that the radiation to the whole body is decreased by 96% (Challa, Warren, Danak & Bates, 2009). To reach the limit values of whole body exposure with lead apron, the staff has to stay in the room during 5000 examinations of the thorax in one year. This shows that the risk of reaching the limit value is very small. To reach the limit values for equivalent radiation dose to the lens of the eye, the staff has to stay in the room during 209 examinations of the thorax. Lead aprons only protect the body so the eyes are still exposed by the full dose of radiation. This means that the eyes are the part of the body that will reach the limit value the fastest. If the
staff has to stay in the room during many different examinations with more radiation than the thorax protocol, it may be good to use lead glasses to protect the eyes from unnecessary radiation. Real-time qualitative display of radiation exposure may be a good way to increase awareness among the staff and therefore reduce radiation dose. The staff has a real-time view over the dose that they are exposed by and therefore try to avoid unnecessary radiation exposure (Baumann et al, 2015).

**Radiation protection - guidelines**

The guidelines that the medical staff can think of when they stay in the CT room are to avoid the radiation field during radiation exposure. They can stay close to the patient for as long as no sequences on the CT scanner are running. As soon as the sequences are running the medical staff can move and stand on the side of the CT machine to avoid high radiation exposure. This small move is only a mere meter and the medical staff can still talk to the patient if needed. The small movement can maybe seem unnecessary but it means a lot for the radiation exposure that decreases from 96.03 µGy to 0.423 µGy (according to the measurements in this study) and therefore a decrease of 227 times. These guidelines are also supported in the study from Switzerland (Heilmaier et al., 2016).

Another guideline for the medical staff is to use the distance in the examination room if possible. The farther distance from the radiation source (the CT machine in this case) the more decrease of radiation exposure. If the medical staff do not have the possibility to stand on the side of the CT machine, they can move back to a place along the wall that is the farthest from the CT gantry. This will also decrease the radiation exposure, not as much as on the side of the CT but it will decrease with about 84 times according to this study. In addition, the distance from the top of the CT patient bed to the end of the bed is a distance of 220 cm in this study. The place in the end of the bed shows a dose of 2,865 µGy, which is about 34 times less radiation dose than the highest dose on the top of the bed close to the gantry. In summary, small movements away from the radiation source makes big differences in the dose values.

However, if the patient has lots of tubes or maybe feel nauseated and needs a vomit bag and support nearby the medical staff might have to stay close. In this case the best way for the medical staff to avoid unnecessary radiation exposure is to wear a lead apron. This will
protect the most radiation sensitive parts of the person standing that close to the radiation field.

There are many different kinds of radiation protections for medical staff working with radiation, both lead based and non-lead based. These radiation protection methods can be useful in occasions when medical staff need to stay in the examination room or when radiological staff are performing interventional radiological examinations (IR). During the IR the radiological staff stays in the examination room during the examination and will therefore be exposed by much radiation if they do not protect themselves (The Society of Interventional Radiology, 2017).

**Lead-based protection**

Some of the lead-based protection methods are lead aprons, lead glasses, table-attached lead-drapery, floor-based lead shields, roof-attached lead glass and a lead protective suit. The lead protective suit is a whole body lead suit that covers the body down to the ankles, out on the arm and has an attached head shield. Some lead-based covers were tested in an article from *Journal of interventional cardiology* where the authors measured how much a lead apron reduced radiation doses to the radiological staff. Using a 1,0 mm leaded overlapping personal gown showed a result of 96 % radiation dose reduction. They also measured doses using a 0,75 mm leaded glasses and got a result of 67 % reduced exposure to the left eye. In the study the authors also describes the radiation reduction by using the 0,5 mm roof-attached lead glass. This lead shield reduced the radiation dose to the eye by 86 %. A 0,5 mm floor-based lead glass reduced radiation dose to the radiologist by 81 % when using it in combination with both lead apron and thyroid lead shield (Challa, Warren, Danak & Bates, 2009). A lead protective suit called SPRPS was tested in an article from *Baylor university medical center proceedings*. The suit provided a 1,0 mm lead apron down to the ankles and out on the arms and a 0,5 mm lead head shield. The study was made when the radiologist where standing at the patients head, side and pelvis. The results showed that the radiation dose to the eye of the radiologist where reduced from 781 µSv to 2 µSv (87,5 %) when standing by the head of the patient. Standing by the side reduced the dose from 479 µSv to 3 µSv (99 %) and by the pelvis it reduced from 412 µSv to 9 µSv (98 %). The study showed that exposure was 99 % lower when using the SPRPS in all positions (Ray, Mohammad, Taylor, Cura & Savage, 2013). These two studies shows that lead aprons and lead shields have a big impact on the
radiation doses and is therefore important to use inside of the examination room during radiation exposure.

**Non-lead based protection**

The non-lead based protection methods are experienced staff, information, distance to the radiation field, automatic contrast syringe and microphone outside of the examination room so that the medical staff can hear and talk to the patient without entering the room during radiation exposure (Gustavsson & Lindgren, 2014). These methods make it easier for the medical staff to leave the room and still have the possibility to keep an eye on the patient and have control over the situation and still don’t get exposed to any radiation.

**Protection versus experience**

In a Swedish study, the authors compared different radiation protection methods. The result showed that the most effective radiation protection during IR was the lead protective suit called SPRPS and for the eyes, the floor-based lead glass. Even though the study showed that both the lead protective suit and the floor-based lead glass is the most effective protection, it may not be the best protection method for the patients and the staffs’ well being. The suit is more heavy than lead aprons and might feel scary for the patient and the floor-based lead glass decreases the proximity and connection to the patient for the medical staff (Gustavsson & Lindgren, 2014). Flexible lead aprons, thyroid shield, good knowledge and experience about radiation protection might therefore be a more effective radiation protection method for the radiological staff.

**Increasing use of CT**

Despite the various dose reduction approaches that has been established in recent years (2007-2014), the doses per X-ray procedure has only been slightly reduced (Brix, Griebel, Nekolla, Schegerer, 2017). The mean effective dose to German inhabitants increased from approximately 1,4 mSv in 2007 to 1,6 mSv in 2014, mainly due to the increasing frequency of CT examinations (Brix et al, 2017). Even though the machines and protocols get better at reducing radiation, the increasing amount of CT examinations still adds to the increasing
radiation exposure to patients. The increasing amount of CT examinations also contributes to more radiation to medical staff. It is important that doctors outside the radiological department justifies the examination and really consider whether X-ray examination is necessary or if there is any other way to diagnose the patient without using radiation. This is an important step in the work to reduce radiation to both patients and staff (Brix et al, 2017).

New research

A study from China is investigating the radiation dose and image quality for iterative reconstruction combined with the CARE kV technique in chest-computed tomography scanning for physical examination. A total of 130 patients who underwent chest CT scanning were randomly chosen. The quality reference value was set as 80 mAs. The patients were randomly divided into groups according to the scanning scheme. Sixty patients underwent a chest scan with 100kV using the CARE kV technique and SAFFIRE reconstruction and the other 70 patients underwent chest scanning with 120 kV. The mean CT value, image noise, and signal-to-noise ratio of the apex of the lung, the level of the descending aorta bifurcation of the trachea, and the middle area of the left atrium were measured. Two radiologists evaluated the image quality on a 5-point scale and the results of the two groups were compared. The CT dose index of the volume (CTDvol), dose length product (DLP), and effective dose (ED) were compared. The results showed that all images for both groups satisfied the diagnosis requirement. There was no statistical difference in the image quality between the two methods. The results also showed that CTDvol, DLP, and ED were lower in the experimental group than the control group. This means that the patients received less radiation dose in the experimental group than the control group. The CARE kV technique combined with iterative reconstruction for chest CT scanning for physical examination could reduce the radiation dosage and improve CT image quality, which has a potential clinical value for imaging the thorax (Gao Y., Li ZL., Yang B., Yang YY., Zhao W, 2017). This new technique contributes to lowering the radiation dose to the patient, which in the end means that the radiation dose to the staff also is reduced. This could be a good technique to use in the future to reduce radiation to both patients and staff.

Reflections
It was hard to find information and research from Vietnam about radiation and radiation to staff while getting background information to the study. Before we went to Vietnam, we did not know much about how they work at hospitals or how the radiation safety was. The lack of information and research was one of the main reasons why we wanted to write about radiation to staff in Vietnam. Research about radiation to patients during different x-ray examinations is very common and we think that the information about radiation to staff are just as important. The staff is risking to get exposed by radiation on a daily basis during their work. This is also a big reason why we wanted to do this study, to enlighten the radiation exposure to the medical staff.

The observations were only made in one hospital in Vietnam for three days so the result does not represent CT-radiation safety throughout Vietnam. The observations were only a small part of this thesis that lead to better knowledge about the workflow and how they worked with radiation. Visits to more hospitals and weeks of observations at each hospital needs to be made to cover CT-radiation safety in all of Vietnam. Although, the observations we did before collecting the data gave us more insight in the workflow and showed us how the radiation awareness was in a real working environment. We have learned that the workflow and the radiation safety in Vietnam and Sweden are very similar and that the staff is very aware of the importance of radiation protection.

Before the study, we found some similar studies from other countries including Switzerland. Therefore, we had some knowledge before we started the measurements in Vietnam about how the radiation is scattered in a CT room. Although we did not let this information affect our measurements. We also did not know what kind of CT scanner we were going to work with and study in Vietnam. Therefore, we used many different places in the CT room to measure so that we got a scattered result over the whole CT room. Our results in this study though showed a similar result to the previous studies we found.

**Conclusion**

The conclusion of this study is that the radiation dose in the CT examination room is dependent to the distance and direction to the radiation source, here the CT scanner. The best
guideline that the medical staff can think of when they stay in the CT room is to avoid the radiation field during radiation exposure. The longer distance from the CT scanner, the lower radiation dose exposure. Also in an opposite direction to the radiation exposure one gets the least radiation dose exposure, which is on the sides of the CT scanner. Therefore, standing on the sides of the CT scanner is the best way for medical staff to stay safe from unnecessary radiation exposure.

The measurements inside of the CT examination room showed that there is no place in the room that escapes radiation exposure completely. Therefore, radiological staff and other medical staff working in the CT should strive not to stay in the CT room during examinations. For their own safety, they should at least wear lead aprons or other lead shields during radiation exposure if possible. The colour map (picture 2) in this study is just a guideline to all medical staff that for some reason needs to stay in the CT examination room during radiation exposure. The map gives the medical staff information about how the radiation dose is scattered in the CT room and can help them in their work to be safe from radiation.

The observations at the oncology hospital in Da Nang showed that the staff was really meticulous about leaving the room during CT-examinations. All staff had knowledge about the importance of leaving the room while the radiation was on. If they had to stay in the room they had lead aprons that they could use. The doctor did not stay in the CT-room during scanning while performing biopsy punctures. They did the punctures without real-time scanning, which differs from the hospitals in Kalmar and Skövde. The staff at the oncology hospital in Da Nang have radiation awareness and a safe way of working with radiation.

The result from this study could be a help and guideline for all staff that works in radiological clinics at hospitals in both Vietnam and Sweden. Therefore, this report will be sent to the oncology hospital and University of Medical Technology and Pharmacy in Da Nang, Vietnam. Swedish hospitals that is in need of this kind of information can also take part of the report.
References

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DOI: https://doi.org/10.1007/s00117-017-0242-y

DOI: 10.1111/j.1540-8183.2009.00433.x

DOI: 10.1097/MD.0000000000006175


DOI: 10.1055/s-0041-110450


DOI: https://doi.org/10.15441/ceem.14.019


Appendix 1. *The scattered radiation dose results measured in the CT examination room.*

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Appendix 2. Ethical review in Swedish.

EGENGRANSKNING VID EXAMENSARBETEN

Examensarbets titel: The importance of medical staff placement in CT examination rooms

Student/student: Frida Nelson & Fredrik Palm
Handledare: Pär Sandström

1. Kan projektet innebära någon eller några av följande nackdelar för deltagaren (patient, försöksperson, informant)?
   a/ Medicinsk risk
   b/ Smärta
   c/ Hot mot personlig integritet
   d/ Annat obelag

2. Kan det garanteras att deltagarna inte kan identifieras i resultatredovisningen?

3. Är deltagandet i projektet frivilligt?

4. Kan en deltagare när som helst och utan angivande av skäl avbryta sitt deltagande?

5. Innebär studien att personregister upprättas - om ja - vem ansvarar för registret och till vem är registratet?

6. Hur är den skriftliga informationen utformad?
   - Inga deltagare kommer användas därför inget svar på dessa frågor.
   a/ Beskriv projektförras att deltagarna förstår dess uppgift och syfte. (Inga fickuttryck, klar svenska)
   b/ Framgär det att vården eller andra insatser inte påverkas av beslut om att medverka eller avstå från medverkan?
   c/ Framgär det att vården eller andra insatser inte påverkas om deltagaren avbryter sin medverkan?

7. Erbjuds försökspersonerna att ta del av forskningsresultatet?

Ovanstående frågor är noga penetrerade och sanningsenligt besvarade.

Jönköping den 17/2-17
Frida Nelson

Frederik Palm

Pär Sandström

Student/student
Handledare
Special thanks to our supervisors Pär Sandström in Sweden for the support and to Dr Dung in Vietnam for all the help and hospitality during our visit. We would also like to thank Hans Johansson at Ryhov hospital for the help with the dosimeter.