UNIVERSITY OF GOTHENBURG

DEPARTMENT OF MEDICAL RADIATION SCIENCES, INSTITUTE OF CLINICAL SCIENCES

Evaluation of the DXA radiation environment at Sahlgrenska University Hospital

Saga Söderholm

Essay/Thesis:	30 hp
Program and/or course:	Medical Physics Programme
Level:	Second Cycle
Term/year:	Autumn 2021
Supervisors:	Patrik Sund and Charlotta Lundh
Examiner:	Magnus Båth

Abstract

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Purpose: The aims of this work were to evaluate the radiation environment in the dual-energy X-ray absorptiometry (DXA) rooms at Sahlgrenska University Hospital, estimate personnel doses, determine legal requirements for DXA personnel, examine the operators' view on radiation safety and develop material with dose information for patients and operators.

Theory: DXA is a low dose X-ray modality mainly used in osteoporosis examinations, for which it is considered the reference technique. Bone mineral density (BMD) is measured in the hip and the lumbar spine, and a typical protocol also includes a vertebral fracture assessment (VFA). The DXA operator is stationed in the same room without any shielding or protection during the scanning. With no regular dose measurements or calculations, most DXA operators do not know the amount of radiation they are exposed to, more than that the doses are low compared to other modalities. Personnel working with ionising radiation is generally classified as category A or B, depending on the amount of radiation they are at risk of being exposed to. Regarding DXA operators at Sahlgrenska University Hospital, there is a discussion on which category they should belong to. Currently, they are in category B, but another possibility is that they can be unclassified.

Method: Measurements were performed at the DXA scanners Hologic Discovery A and GE Lunar iDXA with help from an experienced DXA operator. A whole-body phantom was used, and scattered radiation was measured at different positions in the room with the instrument RaySafe 452 Radiation Survey Meter. The standard osteoporosis protocol, consisting of the examinations Hip, AP Spine and VFA, was run, while air kerma (µGy) and air kerma rate (µGy/h) was measured. Two different phantom sizes were used in the Hologic scanner. The scattered radiation during each examination was displayed as isodose lines between points with the same air kerma rate, calculated with the inverse square law. Yearly effective doses (mSv) to the operators were calculated using PCXMC 2.0 at different distances and directions in the rooms. Minimum distances in the different directions were also calculated, where the operator can be positioned and with certainty not exceeding 1 mSv in yearly effective dose. Finally, a questionnaire was given to the four DXA operators at the osteoporosis centre, with questions regarding their views on radiation safety.

Result: Effective doses at 2–3 meters from the centre of the scanner were under 1 mSv per year for both Hologic and GE operators in the two examined directions. Two meters from the GE scanner, perpendicular to the scanning direction, the yearly dose was 0.66 mSv, which was the highest value. However, in a position right next to the table, the doses were 2.8–7.3 mSv, showing that the levels of ionising radiation in a DXA room cannot be neglected. Different phantom sizes showed no clear effect on scattered radiation. The personnel survey showed that the operators feel safe, or somewhat safe, regarding the radiation in their workplace.

Populärvetenskaplig sammanfattning

DXA, eller DEXA (dual-energy X-ray absorptiometry), är en röntgenteknik med låga stråldoser som bygger på användandet av två olika fotonenergier. DXA används främst för mätning av bentäthet, vilket är centralt vid diagnosticering av osteoporos (benskörhet), men det kan också användas för analys av kroppssammansättning, som andel ben, fett och muskelmassa. DXA-scanners har använts kliniskt sedan 1980-talet. På senare år har de också blivit alltmer populära utanför vården, till exempel bland idrottare. Med ungefär 70 000 osteoporosrelaterade frakturer varje år i Sverige är DXA relativt vanligt, då det är standardundersökningen för både utredning och uppföljning av osteoporos.

Personalen som utför DXA-mätningen befinner sig i samma rum under hela undersökningen och använder inga strålskydd i form av till exempel blyförkläde eller skärmar. De sitter eller står vid ett skrivbord med en dator varifrån de styr DXA-scannern. Arbetstagare i verksamheter med joniserande strålning delas vanligtvis in i kategori A eller kategori B beroende på hur mycket strålning de riskerar att utsättas för. DXA-operatörerna på Sahlgrenska Universitetssjukhuset tillhör idag kategori B. Ett annat alternativ är att de kan räknas som okategoriserade arbetstagare inom verksamhet med joniserande strålning. Det utförs idag inga regelbundna mätningar av personaldoser vilket gör att de flesta operatörer inte har någon uppfattning om hur stor årlig stråldos de får, mer än att den är liten.

Syftet med det här arbetet var dels att utvärdera strålningsmiljön i DXA-verksamheten, uppskatta personaldoser och granska vilka lagar och regler som gäller för DXA-operatörer, dels att undersöka personalens syn på strålsäkerhet samt ta fram lättförståelig dosinformation till både personal och patienter.

Mätningar utfördes på Göteborgs universitets osteoporosforskningsavdelning på Sahlgrenska Sjukhuset i Mölndal, med de två DXA-maskinerna Hologic Discovery A och GE Lunar iDXA. Hologic och GE är de två ledande tillverkarna inom DXA. Ett helkroppsfantom scannades med de tre vanligaste protokollen som körs vid en osteoporosundersökning: Hip (en bild av ena höften och lårbenshalsen), AP Spine (en bild av de nedersta ryggkotorna framifrån) och VFA (*vertebral fracture assessment* – en sidobild av ryggraden). Strålningsnivåerna mättes under tiden med ett strålskyddsinstrument på 4–5 olika positioner runtom i rummet. Därefter räknades mätdatan om till effektiv dos, vilket är ett mått på skaderisken av strålningen där man tagit hänsyn till strålslag och olika organs strålkänslighet. Beräkningarna gjordes i mjukvaran PCXMC. Personalen antogs exponeras jämnt över hela kroppen och de beräknade doserna låg under 1 mSv per år som förväntat, givet att personalen håller avstånd till DXA-scannern. Det var däremot inte så god marginal som förväntat – en GE-operatör kunde komma upp i en årlig effektiv dos på närmare 0,7 mSv på två meters avstånd rakt ut från scannern. Och om operatören i stället skulle sitta precis bredvid scannern när undersökningarna kördes skulle de komma upp i så höga årsdoser att de hade hamnat i kategori B (1–6 mSv – Hologic) respektive kategori A (6–20 mSv – GE). Som exempel måste personal i kategori A genomgå en medicinsk undersökning varje år för att säkerställa att man är lämplig för arbetet, och strålningsnivåer i lokalerna måste mätas och dokumenteras. Utifrån mätresultaten togs även minimiavstånd fram i de olika riktningarna runt scannern, där operatören med säkerhet kan vara positionerad utan att överskrida 1 mSv i årsdos. Vidare undersöktes om patientstorlek påverkade den spridda strålningen i rummet. Det gjordes genom att bygga på tillägg runt buken och överkroppen så att det människolika fantomet gick från ett *body mass index* (BMI) på 18 till BMI 40. Enligt mätningarna påverkades den spridda strålningen inte nämnvärt av olika patientstorlekar.

En annan del av arbetet var att ta reda på vad DXA-operatörer själva känner kring strålsäkerheten på arbetsplatsen. En enkät med tio ja- och nejfrågor togs fram och lämnades till de fyra DXA-operatörerna som jobbar på osteoporosmottagningen på Sahlgrenska sjukhuset i Mölndal. Operatörerna hade mellan två och tjugo års erfarenhet. På frågan om de känner sig trygga angående strålsäkerheten svarade två ”ja” och två ”ja, ganska”. Majoriteten hade inte någon uppfattning om hur stor årlig stråldos de får och inte heller vart man kan vända sig med frågor som rör strålsäkerhet. Däremot tyckte de flesta att de fått tillräcklig utbildning och information gällande strålsäkerhet, och alla hade koll på vad som gäller vid graviditeter, både för personal och patienter. Två av fyra hade någon gång haft en dosimeter på sig för att mäta stråldos, varav en i samband med introduktion på arbetsplatsen och en under graviditeter.

Sammanfattningsvis kan sägas att DXA och andra lågdosmodaliteter har varit något förbisedda vad gäller strålsäkerhet. Resultaten från det här arbetet bidrar till att öka kunskapsnivån bland både DXA-personal, patienter och fysiker. De kommer också kunna användas rent praktiskt, till exempel vid installation av ny DXA-utrustning för att avgöra hur stort rum som behövs och hur man bör placera scannern och operatörsstationen för minsta möjliga personalstråldos.

Table of content

Populärvetenskaplig sammanfattning iii
Abbreviations 1
  Radiation safety laws and constitutions 2
  Aims 3
Background and theory 3
  Physical principles 4
  Technical specifications 5
Methods 6
  Hologic Discovery A 7
  GE Lunar iDXA 7
  Isodose lines 9
  Personnel dose calculations 9
  Minimum distances 11
  Personnel survey 11
Results 12
  Scattered radiation in the examination rooms 12
  Isodoses 15
  Personnel dose calculations 18
  Minimum distances 19
  Personnel survey 19
Discussion 20
  General results 20
  Laws and constitutions 21
  Pregnancy 22
  Errors and estimations 22
Conclusions 23
Acknowledgements 24
References 25
Appendix 26
  Sammanfattning för DXA-personal 26
  Patientinformation 26

Abbreviations

AP	Anterior – posterior
BMD	Bone mineral density
BMI	Body mass index
DXA, DEXA	Dual-energy X-ray absorptiometry
IVA	Instant vertebral assessment (same as VFA, used by Hologic)
LVA	Lateral vertebral assessment (same as VFA, used by GE)
ROI	Region of interest
SSM	Strålsäkerhetsmyndigheten (the Swedish Radiation Safety Authority)
SU	Sahlgrenska University Hospital
VFA	Vertebral fracture assessment

Introduction

Dual-energy X-ray absorptiometry (DXA, DEXA) is the most widely spread method for measuring bone mineral density (BMD). BMD is used to diagnose osteopenia and osteoporosis, which in turn predicts fracture risk. Dual-energy X-ray absorptiometry of the proximal femur and lumbar spine is the reference technique for this (Ellis, 2000; Karlsson, 2019).

The radiation dose to the patient from a DXA scan is low, often compared with a transatlantic flight or a day's background radiation. Since the doses are low compared to other modalities with ionising radiation, the safety, controls and education in the DXA area is often overlooked. At Sahlgrenska University Hospital (SU), no regular controls of doses to the patients or the operators are performed. Quality control of the DXA scanners is performed daily by the operators and a couple of times every year by the manufacturer. Patient doses are estimated by the manufacturers, but personnel doses are more difficult to generalise since they depend on many factors. The yearly effective dose to a DXA operator depends on the workload, their position in the room, shielding or scattering objects, patient size, scan protocols and more. Even though DXA doses are generally low, the uncertainty of the dose levels naturally causes uncertainties amongst the operators, especially if their education on ionising radiation safety is low. Another concern is how to talk to the patients about the radiation dose. The fact that the dose is very low alone is not always enough information. Concise patient information is needed, both for the patients to feel safe and for the operators to feel confident in their work. Comprehensive dose information in terms of comparing an examination with a certain flight or X days of background radiation is a good idea, as long as it is substantiated by knowledge about the actual doses. The uncertainty regarding radiation doses and safety in DXA can give rise to situations like operators not wanting to continue working when they get pregnant for example. In summary, DXA is a modality in which further dose measurements and better dose information would be very favourable, both for patients and operators.

In an osteoporosis examination, the standard protocol consists of the three examinations Hip (femur), AP Spine (lumbar spine, L1–L4) and vertebral fracture assessment (VFA – a lateral projection of the spine).

The imaging in DXA is primarily used for localisation and guidance. In AP Spine and Hip examinations, the operators use the images to position the regions of interest (ROIs) where BMD is calculated. The VFA images are used for visually detecting vertebral compressions, which can result in a falsely high BMD, but also in itself increase fracture risk (Svenska osteoporossällskapet, 2021).

Radiation safety laws and constitutions

The Swedish radiation protection law from 2018 states that it is forbidden to run a business with ionising radiation without licence (*Strålskyddslag 2018:396*, 2018). The authority that examines issues concerning permits is the Swedish Radiation Safety Authority (*Strålskyddsförordning 2018:506*, 2018). In some cases, the licence obligation can be replaced with a notification obligation (*Strålskyddslag 2018:396*, 2018). Operations that are subject to the notification obligation are for example odontological X-ray diagnostics, veterinary medical X-ray diagnostics and cabinet X-ray radiography (*Strålsäkerhetsmyndighetens Författningssamling SSMFS 2018:2*, 2018). Operations that need licence are for example radiation therapy, nuclear medicine and X-ray diagnostics (other than odontological) – where DXA is included.

In the Swedish radiation protection regulation from 2018 it is stated that for an individual person from the public, the total radiation dose from activities with ionizing radiation must not exceed an effective dose of 1 mSv per year (*Strålskyddsförordning 2018:506*, 2018). For an employee in operation with ionising radiation, the total radiation dose must not exceed 20 mSv per year (*Strålskyddsförordning 2018:506*, 2018). SSM also states in a constitution that personnel in operations with ionising radiation should be categorised based on the risk-level of the exposure of ionising radiation (*Strålsäkerhetsmyndighetens Författningssamling SSMFS 2018:1*, 2018).

An employee shall be classified as category A if it is liable that they will receive a yearly effective dose that can exceed 6 mSv, and category B if the yearly effective dose can exceed 1 mSv but not 6 mSv. A third alternative is also possible, but more rarely used: personnel with the lowest risk of exposure can be non-classified. Employees in category A must undergo medical surveillance to ascertain their fitness for their task. This surveillance includes medical examination or reviews every year and the individual radiation doses must be measured, or calculated, and documented. In category B, personnel doses must be measured, calculated or assessed to ensure correct classification (*Strålsäkerhetsmyndighetens Författningssamling SSMFS 2018:1*, 2018).

For DXA operators, and workers in other low dose modalities, the classification for exposed workers is not obvious. Currently the DXA operators at SU are in category B, but the classification is a subject for discussion.

A space where an employee can receive more than 6 mSv per year must constitute a controlled area, and a space where an employee can receive 1–6 mSv per year must constitute a protected area. Controlled and protected areas must be marked with information on the type of area and warning symbols for ionising radiation. In controlled and protected areas, radiation and activity levels must be known by measurement, calculation or assessment (*Strålsäkerhetsmyndighetens Författningssamling SSMFS 2018:1*, 2018).

If an employee who works in an operation with ionising radiation gets pregnant, it is important that this is reported to the employer as soon as possible. The employer is then obliged to offer assignments so that the equivalent dose to the fetus is as small as possible, and does not exceed 1 mSv, during the rest of the pregnancy (*Strålskyddslag 2018:396*, 2018). If the pregnant employee asks for it, the employer must offer assignments so that the radiation exposure of the employee does not exceed the limits of the general public, in other words, a yearly maximum of 1 mSv in effective dose, an equivalent dose of 15 mSv to the lens of the eye or an equivalent dose of 20 mSv to the skin (averaged over 1 cm^2 irrespective of the size of the exposed area) (*Strålskyddsförordning 2018:506*, 2018).

Aims

The aims of this work were:

- Evaluation of the radiation environment in the DXA rooms and estimation of personnel doses.
- Determination of the legal requirements for DXA personnel.
- Examination of the operators' view on radiation safety.
- Development of accessible material with dose information, both for patients and operators.

Background and theory

Single photon absorptiometry for quantifying bone mass was introduced in the early 1960s. During the following decades, dual-energy X-ray absorptiometry was developed, and in 1987 the first DXA scanners were clinically available (Blake & Fogelman, 2007). Furthermore, dual-energy X-ray techniques are also applied in body composition examinations and industrial radiography, for example in the security industry to detect high-Z materials (Chen et al., 2007). The use of DXA for body composition assessments has increased in recent years. Providing both whole-body bone mineral content, fat mass and lean mass, but also regional body composition, DXA is popular amongst athletes, healthcare practitioners and sports scientists (Slater et al., 2017).

Physical principles

DXA is based on the concept of basis material decomposition. In X-ray imaging, three quantities of the irradiated material determine the attenuation of X-rays: the atomic number, the density and the thickness of the object (Firsching et al., 2011). In a projection image, these quantities cannot be distinguished. This can be demonstrated with an example from industrial radiography. Diamond has a low atomic number and high density, while kimberlite, the host material of diamond, has a higher effective atomic number and lower density. Consequently, they can cause the same attenuation and the fractions of the materials cannot be distinguished. However, attenuation coefficients are energy dependent. Using two different photon energies, a compound material can be decomposed into two different basis materials for which the areal densities (g/cm^2) can be determined. In a bone density scan, these two basis materials are bone and soft tissue. Thus, the areal bone density can be determined (Blake & Fogelman, 2010). In a body composition scan, the components are either fat and lean mass, or, if bone is present, bone and soft tissue. This is because a dual technique cannot solve for three components. So, in bone-containing pixels fat and lean mass are grouped together as soft tissue.

Thus, DXA was developed to solve the density of two materials when physical measurements of the materials, such as thickness, are unknown. DXA for bone densitometry and body composition is based on three fundamental assumptions: 1. Transmission of X-rays through the body within two energy windows can be accurately described by a mono exponential attenuation process, 2. Individual image pixels of the human body can be described as a two-component system that can be either bone and soft tissue or fat and lean mass, and 3. The X-ray properties and soft tissue composition in bone-containing pixels can be predicted using the nearby nonbone pixels. (*IAEA HUMAN HEALTH SERIES PUBLICATIONS*, 2010, p. 20).

The attenuation of X-rays passing through a compound of N different materials (such as bone and soft tissue) is described by the equation

$$I = I_0 \, e^{-\sum_{i=1}^{N} \left(\frac{\mu}{\rho}\right)_i \sigma_i}, \qquad (1)$$

where I_0 is the unattenuated X-ray intensity, $\left(\frac{\mu}{\rho}\right)_i$ (cm^2/g) is the mass attenuation coefficient for material i, and σ_i (g/cm^2) is the areal mass density for material i.

For one higher energy X-ray beam (H) and one lower (L), passing through bone (b) and soft tissue (s), Equation (1) results in the two equations

$$I^L = I_0 e^{-\left[\left(\frac{\mu}{\rho}\right)_s^L \sigma_s + \left(\frac{\mu}{\rho}\right)_b^L \sigma_b\right]} \qquad (2)$$

and

$$I^H = I_0 e^{-\left[\left(\frac{\mu}{\rho}\right)_s^H \sigma_s + \left(\frac{\mu}{\rho}\right)_b^H \sigma_b\right]}. \qquad (3)$$

Solving Equations (2) and (3) simultaneously for σ_b and inserting the definition of the R value for soft tissue, $R_s = \left(\frac{\mu}{\rho}\right)_s^L \Big/ \left(\frac{\mu}{\rho}\right)_s^H$, leads to the equation for areal bone density:

$$\sigma_b = \frac{R_s \ln\left(\frac{I^H}{I_0^H}\right) - \ln\left(\frac{I^L}{I_0^L}\right)}{\left(\frac{\mu}{\rho}\right)_b^L - \left(\frac{\mu}{\rho}\right)_b^H R_s} = BMD, \qquad (4)$$

where the I/I_0 terms are directly measured and the μ/ρ terms are the known mass attenuation coefficients for bone. R_s is measured in a nonbone region (accordingly with assumption number 3 above) as

$$R_s = \frac{-\ln\left(\frac{I_s^L}{I_0^L}\right)}{-\ln\left(\frac{I_s^H}{I_0^H}\right)}, \qquad (5)$$

which is derived from Equation (4) when $\sigma_b = 0$ and I is denoted I_s since all attenuation is caused by soft tissue.

Technical specifications

The dual-energy X-ray beam can be produced in two different ways, using a K-edge filter or an energy switching technique. In the filter technique, a rare-earth metal filter is used to attenuate middle energies from the X-ray spectrum, leaving higher and lower energies. The absorbed energies are energies at and just above the K-edge of the filter material. The energy switching technique uses an X-ray generator that rapidly switches between low and high tube voltage. The two leading DXA manufacturers, Hologic Inc. (Bedford, MA, USA) and GE-Lunar Inc. (Madison, WI, USA), use energy switching and K-edge filter, respectively. See Table 1 for technical specifications for the two densitometers used for the measurements. Table 2 shows exposure times and skin entrance doses stated by the manufacturers. There are three different scan modes for Hologic: array, fast and express mode, where fast and express modes yield lower doses. Here, array mode was used. The GE scanner has modes of thin, standard and thick patient size, which is automatically set by the patient's height and weight.

Table 1: Technical specifications for the two DXA scanners, Hologic Discovery A and GE Lunar iDXA.

	Hologic Discovery A	***GE Lunar iDXA***
Dual-energy X-ray technique	Switching energy	K-edge filter (Cerium)
Tube voltage	100 kV and 140 kV	100 kV (effective filtered energies: ~39 keV and ~71 keV)
Tube current	5.0 mA (Hip, AP Spine), 1.2 mA (VFA)	2.5 mA (Hip, AP Spine and VFA, for standard patient thickness)
Inherent filtration, minimum	3.7 mm Al (Aluminium)	0.9 mm Al
Beam type	Single sweep wide fan beam, see Figure 1 (right).	Multi sweep narrow fan beam, see Figure 1 (middle).
Detector	216 channel Cadmium Tungstate (CdWO4) scintillators coupled to Silicon diodes	64 channel Cadmium Telluride (CdTe) solid state crystals coupled to solid state photomultipliers
Scanner size	1.92 m × 1.17 m	2.87 m × 1.31 m
Table height	71 cm	64 cm
Maximum patient weight	204 kg	204 kg
Rotatable scanner arm	Yes	No

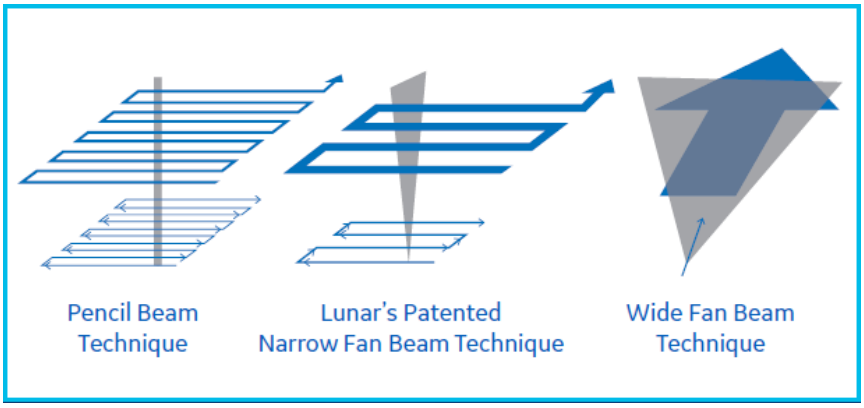

Figure 1: Three different beam techniques used in DXA: Pencil beam (used by for example Swissray), narrow fan beam (used in GE Lunar iDXA) and wide fan beam (used in Hologic Discovery). Note. From *GE Healthcare - Bone & Metabolic Health, 2019*. Copyright 2019 by General Electric Company. Reprinted with permission.

Table 2: Patient dose parameters from the manufacturers, with array mode for Hologic and standard patient thickness for GE.

	Hologic Discovery A (Array mode)	***GE Lunar iDXA*** (Standard patient thickness)
Typical exposure times	10 s (AP Spine) 10 s (Hip) 15 s (VFA)	30 s (AP Spine) 30 s (Hip) 183 s (VFA)
Approx. skin entrance doses	40 µGy (AP Spine) 40 µGy (Hip) 25 µGy (VFA)	146 µGy (AP Spine) 146 µGy (Hip) 329 µGy (VFA)

Methods

Measurements were performed at the osteoporosis research centre of the University of Gothenburg, located at SU Mölndal. Two densitometers were examined: Hologic Discovery A and GE Lunar iDXA. The densitometers were operated by an experienced DXA operator. A whole-body phantom (PBU-60, Kyoto Kagaku, Kyoto, Japan) was used to scatter the radiation. The instrument RaySafe 452 Radiation Survey Meter (Unfors RaySafe AB, Billdal, Sweden) was used to measure air kerma rate (µGy/h) and air kerma (µGy). RaySafe 452 uses a combination of two automatically handled sensor systems: A Geiger-Müller pancake used at low dose rates, and a cluster of silicon sensors at medium to high dose rates. The instrument was attached to a tripod at a height of 110 cm from the floor to the centre of the detection area. Measurements were performed about 130–170 cm from the centre of the table in different directions distributed around the room. Both rooms were relatively small, so larger distances were not possible. In both rooms, the scanners were located adjacent to a wall. Moreover, the GE scanner was in a corner, so measurements from the foot side of the table were not possible. With respect to this, there were five measuring points for the Hologic densitometer and four for GE. The used scan protocols were the three most common in osteoporosis examinations, namely AP Spine, Hip and VFA. VFA is also called Lateral Vertebral Assessment (LVA – by GE), and Instant Vertebral Assessment (IVA – by Hologic), but here the term VFA is used for both. In the Hologic scanner, two patient sizes were used; the phantom without additional bodyweight had a body mass index (BMI) of 18 (see Figure 2), and with the extra body plates the BMI was 40 (see Figure 3). In the GE scanner, only the thin phantom was used (see Figure 4). The length of the phantom was 165 cm for both BMIs. The idea was to get an overview of the radiation environment in the DXA rooms and investigate how the dose and dose rate varied at different positions and with different scan protocols and patient sizes.

Hologic Discovery A

The BMI 18 phantom was placed in the Hologic Discovery A densitometer, see Figure 2. Five measurement points were used, see Figure 5. The distances were measured from a reference point at the hips of the phantom. With the instrument placed at one measuring point at a time, AP Spine, Hip and VFA (IVA-HD) examinations were performed (Array mode). Air kerma rate, with a time resolution of 1 second, and total accumulated air kerma for each examination was measured and stored in Excel (Microsoft Corp., Redmond, WA, USA). The same procedure was carried out for the BMI 40 phantom in order to evaluate how patient size affect scattered radiation (see Figure 3). This was only done in the Hologic densitometer. A background radiation measurement was performed by measuring for 152 seconds in the Hologic scanning room with the densitometer turned off.

GE Lunar iDXA

The BMI 18 phantom was placed in the GE Lunar iDXA densitometer, see Figure 4. Four measuring points were used, see Figure 6 (measuring in direction 3 was not possible since there was no space). AP Spine, Hip and VFA examinations were performed. Air kerma rate and total accumulated air kerma for each examination was measured and stored in Excel. The iDXA arm is not rotatable, so for the VFA examination the patient needs to lie on the side with 90° angle in knees and hips. This position was not possible for the phantom, so the positioning used was the same as for AP Spine and Hip examinations, lying on the back. One VFA was performed with the phantom lying on the side after disassembling the arms and legs.

Due to the construction of the phantom, the positioning could not be done in a perfectly correct manner (for example, angling the legs in the right way).

Figure 2: Phantom with BMI 18 (thin) in the Hologic scanner.

Figure 3: Phantom with BMI 40 (thick) in the Hologic scanner.

Figure 4: Phantom with BMI 18 (thin) in the GE scanner.

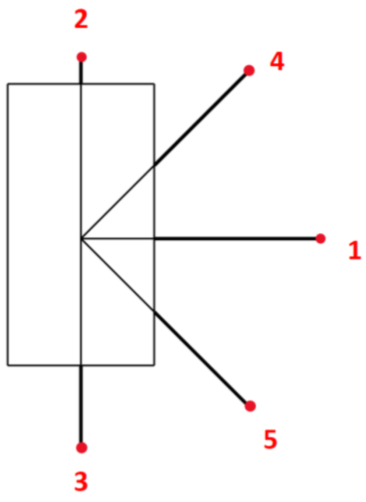

Figure 5: Measurement positions for Hologic (patient's head in direction 2). 1: 170 cm, 2: 130 cm, 3: 150 cm, 4: 170 cm and 5: 170 cm.

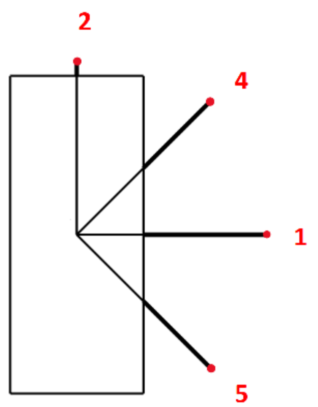

Figure 6: Measurement positions for GE (patient's head in direction 2). 1: 170 cm, 2: 155 cm, 4: 170 cm and 5: 170 cm.

The measurement data were exported to Excel from the program RaySafe View (Unfors RaySafe AB, Billdal, Sweden). DXA images were photographed from the computer screen. A mean background air kerma rate was calculated and subtracted from all other measurements. The measurements were also corrected to the actual irradiation time by removing any measurements where the radiation had not yet started. The distance to the source was corrected for the AP Spine and VFA examinations, to a point 10 cm in cranial direction from the reference point that was located at hip height of the phantom. A mean air kerma rate was calculated for each measurement. Total air kerma (µGy) was calculated by multiplying the mean air kerma rate (µGy/h) with the irradiation time (in hours).

Isodose lines

In order to visualize scattered radiation in the examination room, air kerma rate isodoses were calculated. The reference points were 100 cm, 200 cm and 300 cm from the centre of the phantom in the direction of measurement point 1, which is 90° from the table's long side. Distances were calculated with the inverse square law,

$$\frac{I_1}{I_2} = \frac{{d_2}^2}{{d_1}^2}, \qquad (6)$$

where I_1 was the measured air kerma rate at distance d_1, I_2 the isodose air kerma rate and d_2 the target distance. This was done in directions 1–5 for Hologic and 1, 2, 4 and 5 for GE. The modelling program Sketchup (Google Inc., Mountain View, CA, USA) was used for drawing the isodose lines.

Personnel dose calculations

Effective doses to the DXA operators were calculated using the dose calculation software PCXMC 2.0 (STUK, Helsinki, Finland) and Excel. PCXMC 2.0 was used to calculate a general factor to convert entrance air kerma (µGy) to effective dose (µSv) for the two beam qualities, and other calculations were done in Excel.

Five different positions around the table were examined: 200 cm and 300 cm in direction 1, 200 and 300 cm in direction 2, and 60 cm in direction 1 (corresponding to a position where a possible supporting person to the patient may sit or, in rare cases, the operator). See Figure 7 for the positions. Since the most common procedure at the osteoporosis centre is to perform Hip, AP Spine and VFA examinations, the entrance air kerma for these three examinations was summed up. Also, a 20 % extra was added to the entrance air kerma to cover the additional dose due to restarts for repositioning the patient, which are inevitable regardless of the operator's skills. The workload of an operator was assumed to be 13 examinations per day (consisting of Hip, AP Spine and VFA), 253 days per year. The parameters used in PCXMC 2.0 are shown in Table 3.

Table 3: PCXMC 2.0 parameters, used for calculating a general conversion factor from entrance air kerma (μGy) to effective dose (μSv) for the two beam qualities. Note that 'phantom' here is the operator.

Phantom height	178.6 cm
Phantom mass	73.2 kg
Age	Adult
FSD	300 cm
Beam width	50 cm
Beam height	190 cm
X_{ref}	0
Y_{ref}	0
Z_{ref}	10
Projection angle	270°
Cranio-caudal angle	0°
Max energy (MC simulation)	150 keV
Number of photons (MC simulation)	20000
Anode angle	14°
Filtration	3 mm Al + 0 mm Cu
X-ray tube potential	140 kV for Hologic and 100 kV for GE

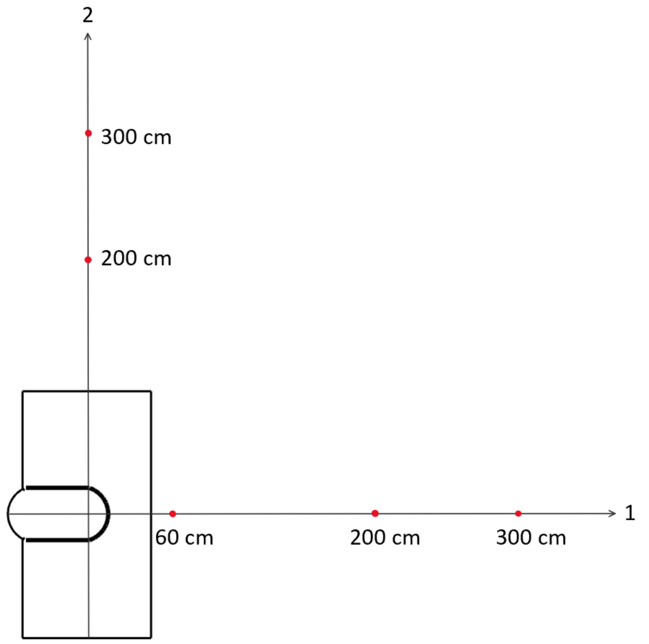

Figure 7: Positions where effective doses were calculated (same for Hologic and GE): 60 cm, 200 cm and 300 cm out from the centre (direction 1), and 200 cm and 300 cm in direction of the patient's head (direction 2).

Minimum distances

Distances from the centre of the table, where an operator would receive a yearly effective dose of 0.5 mSv, were calculated in all measured directions for Hologic and GE scanners with the thin phantom. The effective dose that corresponds to 1 µGy entrance kerma was calculated in PCXMC 2.0 for Hologic and GE X-ray fields, which was used for calculating the distance where the entrance kerma from Hip, AP Spine and VFA summed would give 0.5 mSv in yearly effective dose. Like in the personnel dose calculations, 20 % was added to the dose because of inevitable patient positioning restarts.

Personnel survey

A questionnaire with 10 questions regarding radiation safety was handed out to the four DXA operators at the osteoporosis centre at SU Mölndal. The following questions were asked:

1. How long have you been working with DXA?
2. Do you feel safe at your workplace, regarding radiation safety?
3. Do you know where to turn with questions regarding radiation safety?
4. Do you know the amount of radiation dose you get from your work every year?
5. Did you ever wear a personal dosimeter in order to measure radiation dose at your work as a DXA operator?
6. Do you think that you got enough information/education in radiation safety?
7. Do you know how to find radiation safety material on the intranet?
8. Do you often get questions from patients (regarding radiation dose or the DXA-scanner) that you are unsure about how to answer?

9. Do you know how to treat pregnant patients?
10. Do you know the routines if an operator gets pregnant?

Results

Scattered radiation in the examination rooms

The air kerma rates over time for Hip, AP Spine and VFA examinations, for Hologic and GE with thin phantom and measured at 170 cm (190 cm for Hologic VFA, due to table movement linked to the rotating scanner arm), are presented in Figure 8 – Figure 13. The Hip and AP Spine measurements were performed in direction 1, and the VFA measurements in direction 4 (due to the shielding, rotating arm in direction 1 for Hologic VFA examination). The irradiation time and total air kerma is presented in each figure. For Hip and AP Spine examinations, GE was 2–3 times faster than Hologic (considering irradiation time) and the total air kerma was about the same or slightly lower. For the VFA examination on the other hand, the irradiation time was 8 times longer, and the total air kerma 12 times higher, for GE than Hologic. Regarding the air kerma rate, a pulse pattern can be seen in the GE diagrams, mainly for AP Spine (Figure 11).

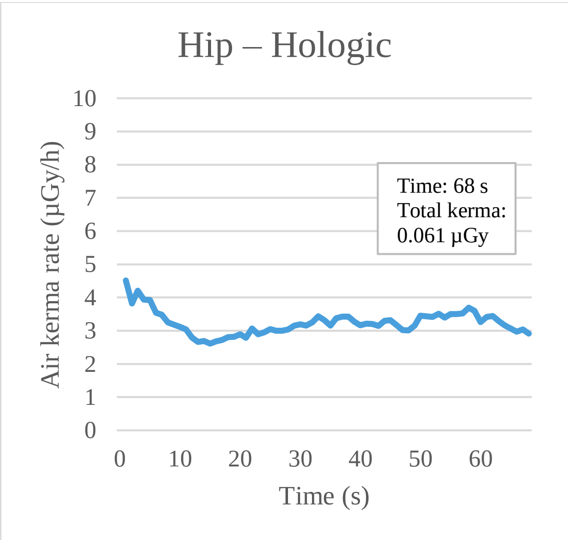

Figure 8: Air kerma rate (µGy/h) as a function of time for the Hip examination with Hologic (thin phantom). Measured at 170 cm in direction 1.

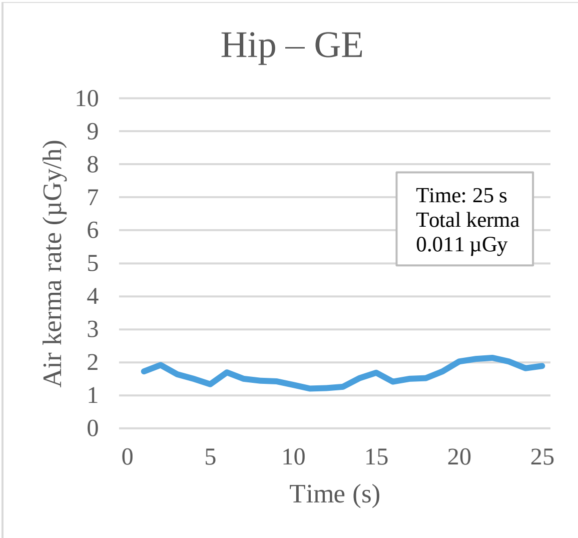

Figure 9: Air kerma rate (µGy/h) as a function of time for the Hip examination with GE (thin phantom). Measured at 170 cm in direction 1.

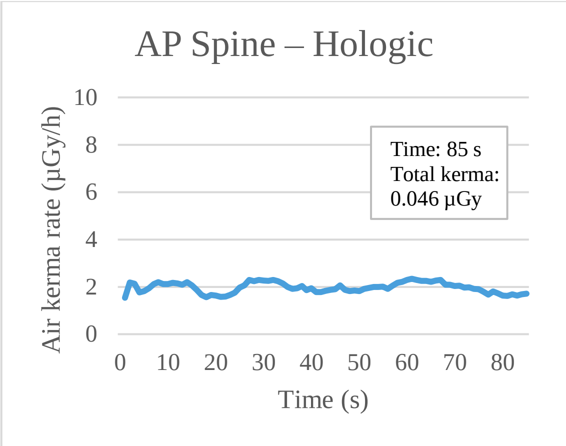

Figure 10: Air kerma rate (µGy/h) as a function of time for the AP Spine examination with Hologic (thin phantom). Measured at 170 cm in direction 1.

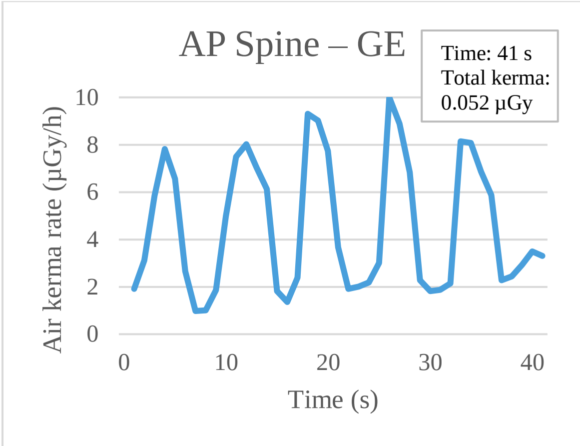

Figure 11: Air kerma rate (µGy/h) as a function of time for the AP Spine examination with GE (thin phantom). Measured at 170 cm in direction 1.

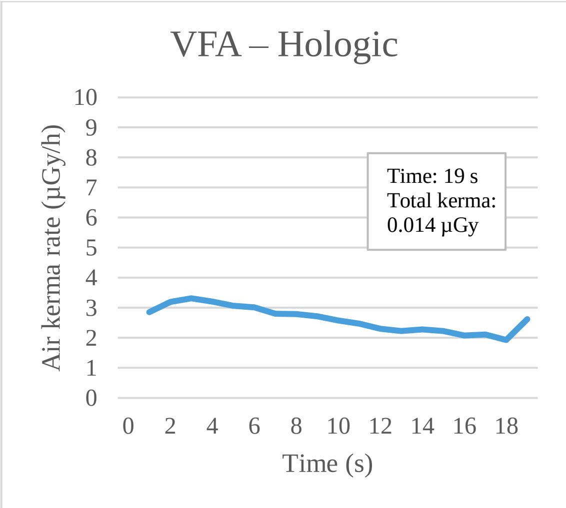

Figure 12: Air kerma rate (µGy/h) as a function of time for the VFA examination with Hologic (thin phantom). Measured at 190 cm in direction 4.

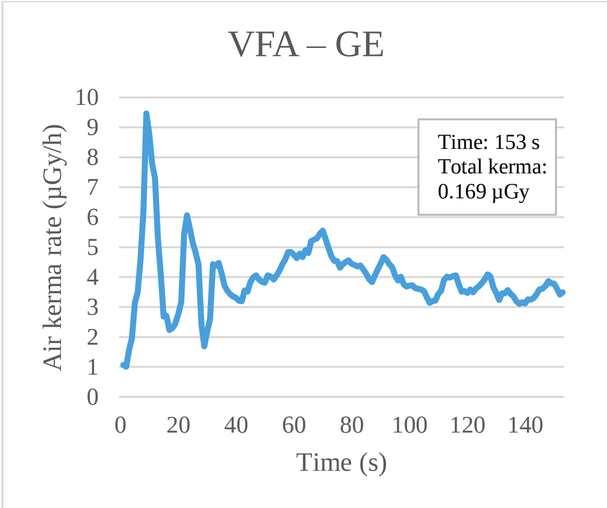

Figure 13: Air kerma rate (µGy/h) as a function of time for the VFA examination with GE (thin phantom). Measured at 170 cm in direction 4.

The VFA measurement where the arms and legs had been removed, in order to position the phantom on its side in the GE scanner, showed a total air kerma of 0.0588 µGy at 170 cm in direction 5. This compared to 0.0855 µGy for the whole-body phantom positioned on its back for the same examination. Thus, in this direction, the whole-body phantom positioned incorrectly on its back gave rise to 45 % higher scattered dose than the disassembled phantom positioned correctly on its side.

DXA images for Hip, AP Spine and VFA examinations, for Hologic and GE with thin phantom, are shown in Figure 14 – Figure 19. The images were somewhat affected by the incorrect positioning of the phantom. There are clearly visible differences between the Hologic images (Figure 14, Figure 16 and Figure 18) and the GE images (Figure 15, Figure 17 and Figure 19).

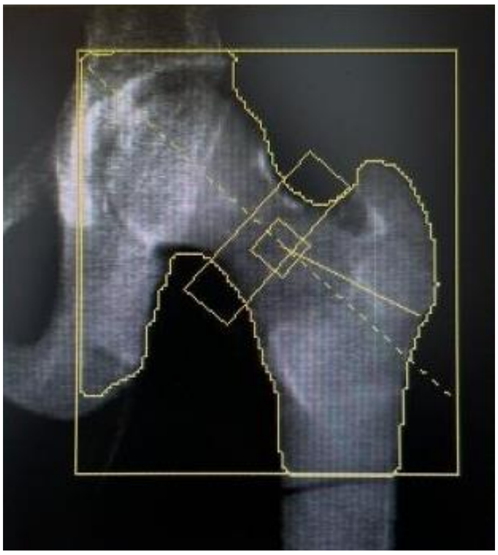

Figure 14: Hip image, Hologic (thin phantom).

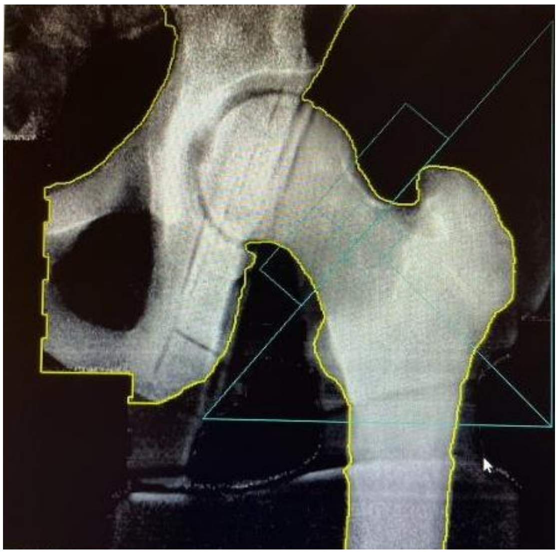

Figure 15: Hip image, GE (thin phantom).

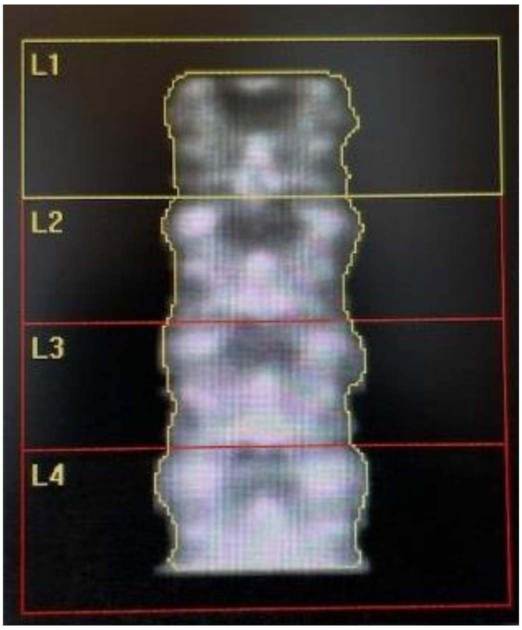

Figure 16: AP Spine image, Hologic (thin phantom).

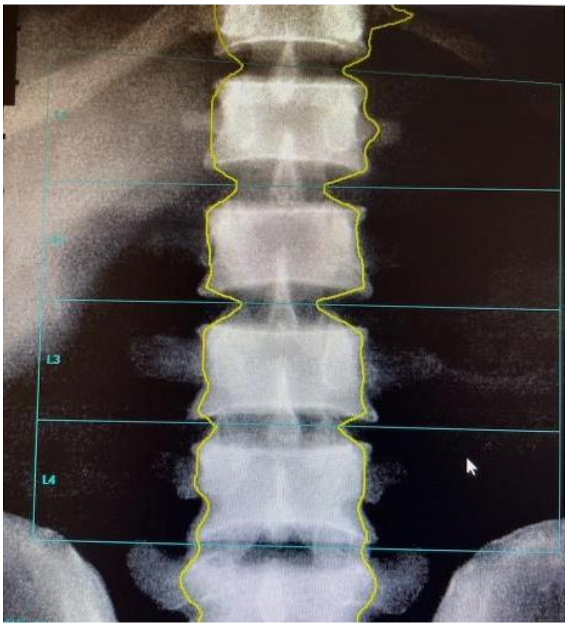

Figure 17: AP Spine image, GE (thin phantom).

Figure 18: VFA image, Hologic (thin phantom).

Figure 19: VFA image, GE (thin phantom).

Isodoses

Figure 20 – Figure 28 shows calculated isodose lines for the three standard examinations (Hip, AP Spine and VFA) for the Hologic scanner with thin and thick phantom, and the GE scanner with thin phantom. The figures show average air kerma rate for each examination, with reference points 100 cm, 200 cm and 300 cm in direction 1.

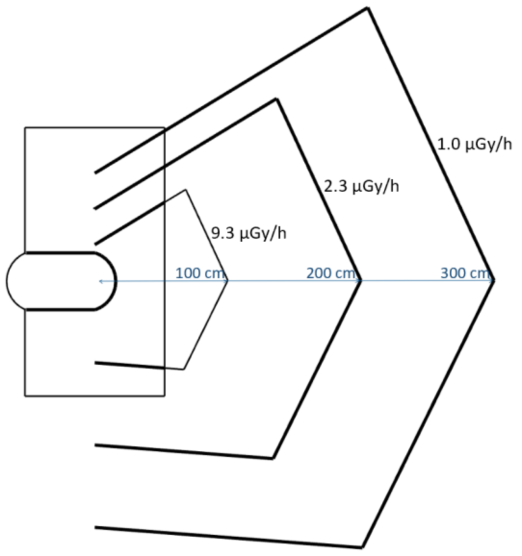

Figure 20: Hologic Hip (thin phantom).

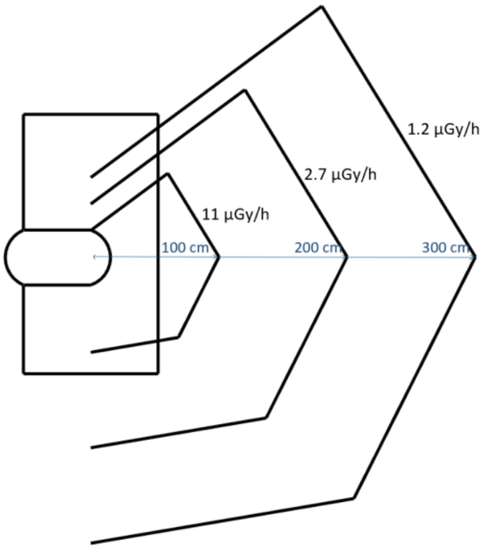

Figure 21: Hologic Hip (thick phantom).

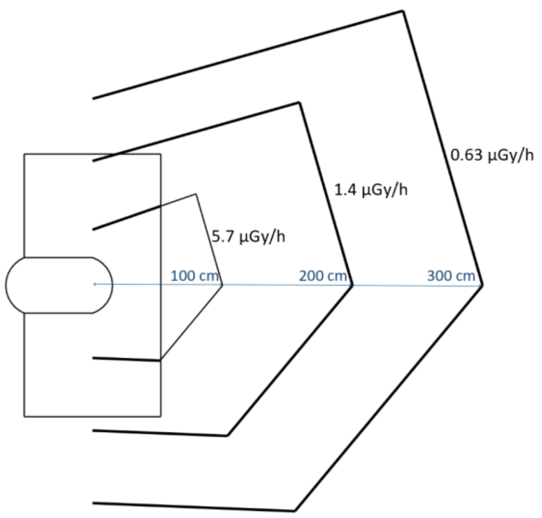

Figure 22: Hologic AP Spine (thin phantom).

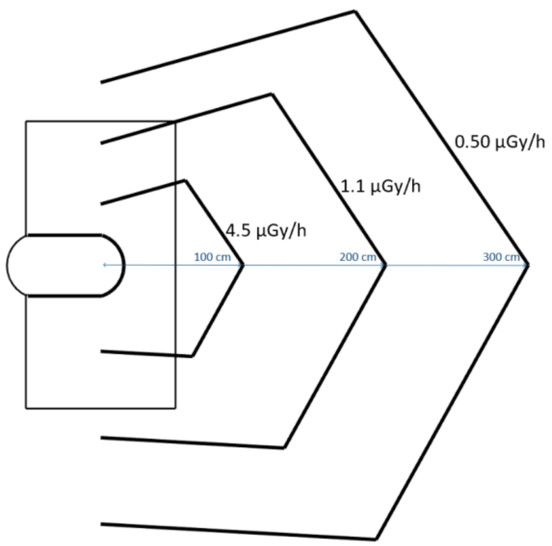

Figure 23: Hologic AP Spine (thick phantom).

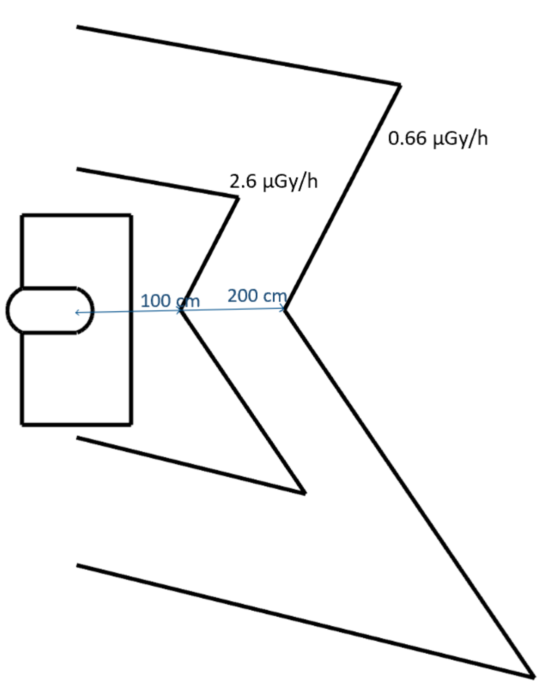

Figure 24: Hologic VFA (thin phantom).

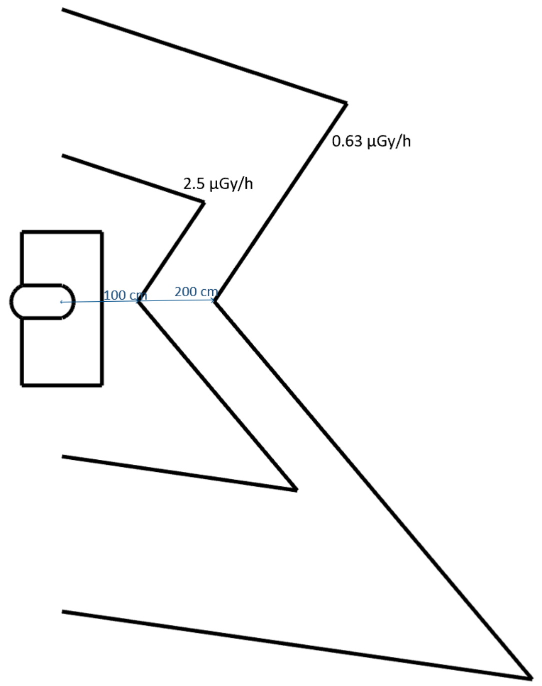

Figure 25: Hologic VFA (thick phantom).

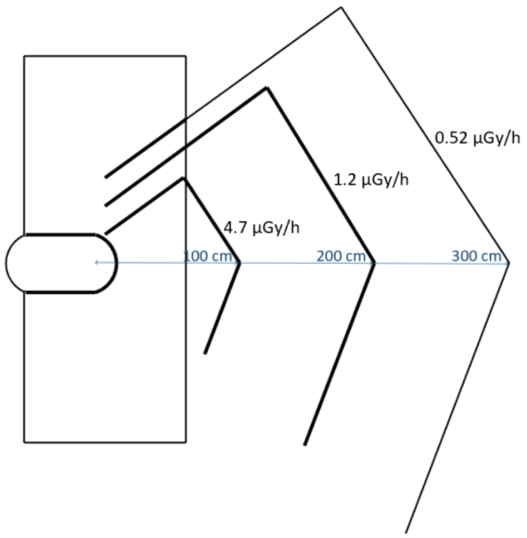

Figure 26: GE Hip (thin phantom).

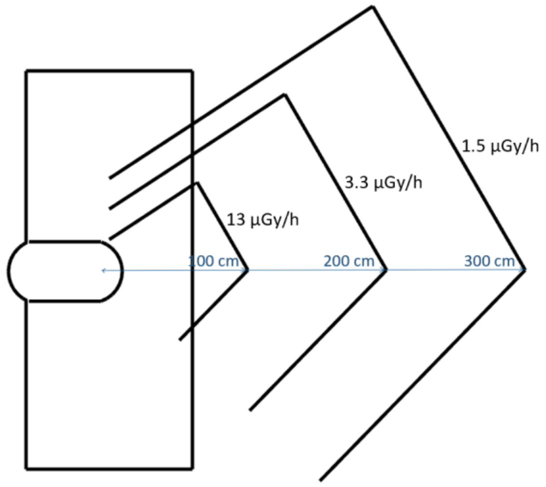

Figure 27: GE AP Spine (thin phantom).

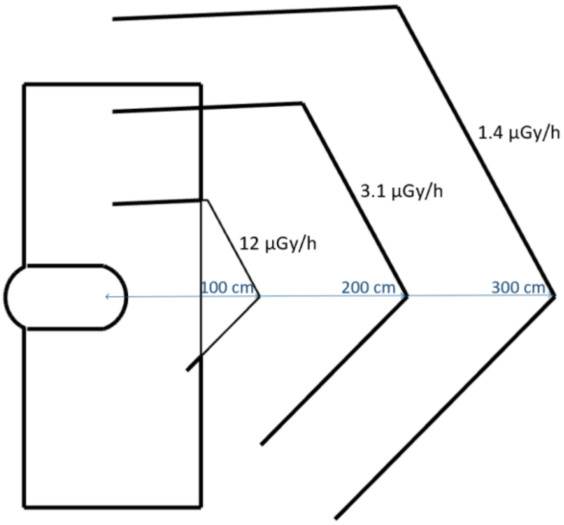

Figure 28: GE VFA (thin phantom).

Personnel dose calculations

Given that an operator performs 13 standard examinations (AP Spine, Hip and VFA and with 20 % dose addition due to restarts) per day, 253 days per year, the effective doses in the examined "operator positions" (200 cm and 300 cm) were below 1 mSv per year. The effective doses were 2.6 – 3.7 times higher for GE than Hologic in the two examined directions with the small sized phantom. Comparing the BMI 18 phantom with the BMI 40 phantom showed no clear effect on scattering doses; in direction 1 the BMI 40 phantom gave 4.5 % higher dose than the BMI 18 phantom. However, in direction 2 the BMI 40 phantom gave a 16 % lower dose (see Figure 29). In a position 60 cm from the centre in direction 1 (not shown in the figure), the yearly effective doses were 2.8 mSv for Hologic with thin phantom, 3.0 mSv for Hologic with thick phantom and 7.3 mSv for GE with thin phantom.

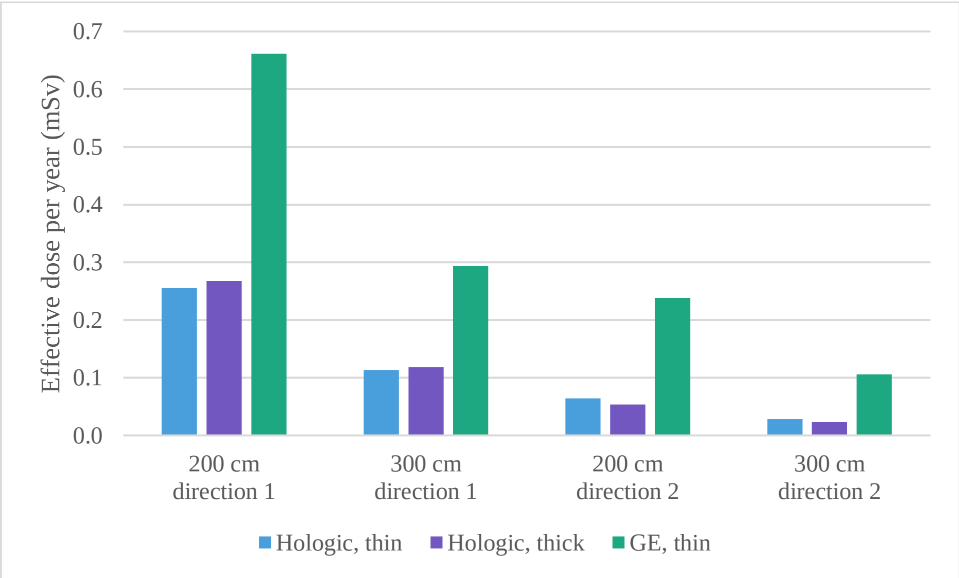

Figure 29: Yearly effective doses (mSv) at possible operator positions in the room: 200 cm and 300 cm from the centre of the table in directions 1 and 2, for examinations with Hologic with thin phantom, Hologic with thick phantom and GE with thin phantom.

Minimum distances

The distances to the source that resulted in a calculated effective dose of 0.5 mSv are presented in Table 4. The smallest distances were found in directions 2 and 3 (patient's head and foot direction) for Hologic, and direction 2 (patient's head direction) for GE, indicating least scattering in these directions. There were no measurements in direction 3 for GE.

Table 4: Minimum distances (yielding 0.5 mSv in yearly effective dose) for operator positions in the different measurement directions for Hologic and GE scanners with thin phantom.

Direction	**Min. distance (cm) Hologic**	**Min. distance (cm) GE**
1	134	222
2	60.1	125
3	85.7	–
4	145	202
5	128	160

Personnel survey

The answers to the questionnaire are summarised under each question:

1. *How long have you been working with DXA?*

   One operator had worked with DXA for 20 years, one for 9 years, one for 7 years and one for 2 years.

2. *Do you feel safe at your workplace, regarding radiation safety?*

   Two operators answered that they feel safe, two that they feel somewhat safe.

3. *Do you know where to turn with questions regarding radiation safety?*

   Two operators answered yes, and two answered no.

4. *Do you know the amount of radiation dose you get from your work every year?*

   Three operators answered no, and one answered that there should not be any radiation.

5. *Did you ever wear a personal dosimeter in order to measure radiation dose at your work as a DXA operator?*

   Two operators had never worn a dosimeter (one of them being the person with 20 years of experience). One operator had worn one when they started working. One operator had a dosimeter during two pregnancies which did not detect any radiation above background level.

6. *Do you think that you got enough information/education in radiation safety?*

   Three operators answered yes, and one "somewhat enough".

7. *Do you know how to find radiation safety material on the intranet?*

   Three answers were yes, one was “yes, probably”.

8. *Do you often get questions from patients (regarding radiation dose or the DXA-scanner) that you are unsure about how to answer?*

   One operator answered no, and one said, “not that often”. One answered that they often get questions and that they sometimes can be hard to answer. One answered that they often get questions, but they answer the questions with that the radiation is very low.

9. *Do you know how to treat pregnant patients?*

   All four operators answered yes (they do not scan pregnant patients).

10. *Do you know the routines if an operator gets pregnant?*

    All four operators answered yes. Two also said that pregnant operators get to wear a dosimeter and one said they also preferably get assigned other tasks.

In Appendix, there is an accessible summary of the results in Swedish, focusing on personnel doses, and also a brief section with patient dose information.

Discussion

General results

The magnitude of scattered radiation varied largely in different directions for both Hologic and GE. This is of importance for the DXA room configurations. Looking at the isodose lines in Figure 20 – Figure 28 it can be seen that generally the lowest dose rate was in direction 2 (patient’s head direction). Also, for Hologic (this direction could not be measured for GE), the dose rates were relatively low in direction 3 (patient’s foot direction). Generally, the highest dose rates were found in direction 1 (straight out from the table), but two isodose figures stand out from this pattern. In Figure 24 and Figure 25 the dose rate has a dip in direction 1. Due to the low dose in this direction, the isodose lines are pulled out in the other directions. This is probably caused by Hologic’s rotating scanner arm for VFA examinations, which shielded in this direction. The dose rates in this direction were about equal for thin and thick phantom, while they were higher for the thick phantom in the other directions, which may indicate shielding. More measurement points would have been needed in order to determine the actual size of the shaded area and how the isodose lines actually looked here. The minimum distances are also smallest in direction 2 for both Hologic and GE (see Table 4). In summary, when configuring a DXA room, it would probably yield the lowest dose rates – and lowest effective dose to the operator – if the operating station was positioned in the patient’s head direction from the DXA scanner. Of course, the distance to the source in different directions must also be considered.

The total scattered radiation doses, when the three standard examinations were summed, were larger for the GE densitometer in both directions 1 and 2 (see Figure 29), even though the narrow fan beam technique is supposed to give lower doses compared to wide fan beams.

The different beam techniques shown in Figure 1 can be seen in the air kerma rate plots (Figure 8 – Figure 13). With the narrow fan beam technique of GE, the field is moved back and forth over the patient with a distinct movement in axial direction in between. This is clearly seen as a pulse pattern in Figure 11.

Laws and constitutions

As an example of the importance of radiation safety work in low dose modalities, we can look at what would happen with the occupational dose for a DXA worker if they would sit right by the table, 60 cm from the centre of the patient instead of 200–300 cm, during the exposure. This is not a completely implausible scenario, as there are pictures where the operator is positioned right next to the table in brochures from both GE and Hologic. Calculated from the measurements here, this would result in yearly effective doses at 2.8 mSv for Hologic with the thin phantom, 2.9 mSv for Hologic with the thick phantom and 7.3 mSv for GE with the thin phantom (see Figure 30). In other words, the Hologic operators would receive doses that put them in category B, and the GE operators would be in category A. However, the VFA examination for GE, which contributed the most to the high doses, was associated with great uncertainties as the phantom was placed on its back instead of the correct position on its side (which was not possible). The phantom placed on its back, but without arms and legs, gave 45 % lower scattering doses. Thus, it is possible that the GE doses are strongly overestimated.

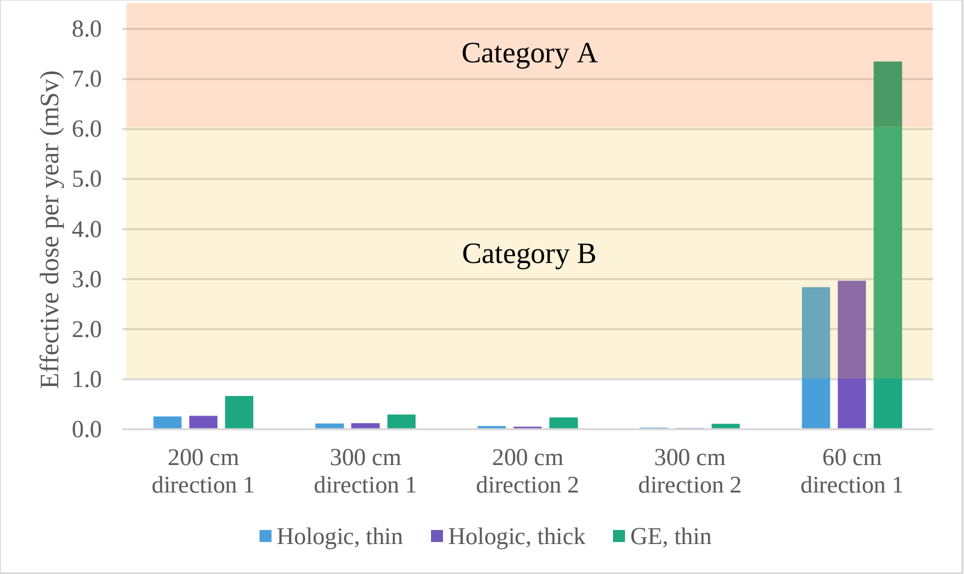

Figure 30: Yearly effective doses (mSv) at 200 cm and 300 cm from the centre of the table in directions 1 and 2, and at 60 cm in direction 1, for examinations with Hologic with thin phantom, Hologic with thick phantom and GE with thin phantom.

Regarding classification there are at least two possibilities for DXA operators. Category B, which they are in today, seems appropriate considering the dose levels. Another option is that they are unclassified, which is fully possible. All paragraphs concerning employees in operations with ionising radiation would still apply, but the specific requirements of dose measurement, room restrictions etcetera, associated with category B, would not be necessary.

Pregnancy

The results of the personnel dose measurements and calculations showed that both Hologic and GE operators receive less than 1 mSv per year at the examined positions 2–3 meters from the centre of the table. Thus, the paragraph that states that a pregnant employee is entitled to get tasks so that the effective dose does not exceed the dose limit to the public (which is 1 mSv per year) will in most cases be irrelevant for DXA operators (*Strålskyddslag 2018:396*, 2018). However, it is important that pregnant workers are instructed not to stay close to the table during examinations to ensure that the dose limit is not exceeded. But this applies for all DXA operators, not just pregnant ones.

Errors and estimations

Possible errors that have arisen from the measurements and calculations are for example that the detector was constantly positioned at one height, 110 cm from the floor. Operators are both standing and sitting. Also, the angular response of the instrument ranged from about 1.0–1.3 for angles 0° to ± 45°. Since the instrument was directed toward the source manually and the X-ray tube moved during the examinations, the shifting angular response may have affected the results. The constant height of the instrument (despite different heights of the source) together with the constant angle of the instrument during one examination (despite the moving source), also resulted in inaccuracies in the measured source-to-detector distance. The detectable energy interval of the instrument was 30 keV – 7 MeV, which means that some of the low energy photons were missed. However, it is probably the higher of the two photon energies that contributes the most to the dose, since lower energy photons cause less scattered radiation and also are attenuated in the patient to a higher degree than higher energy photons. This assumption was also made when calculating the personnel doses in PCXMC, where only the higher of the two tube voltages, 140 kV, was used for Hologic. For GE, the tube voltage is constantly 100 kV, and the Cerium filter results in effective energies at 39 keV and 71 keV. This filtering was not considered in PCXMC. Furthermore, these are parameters affecting the primary beam, not the scattered radiation which is what the operator is actually exposed to. The spectrums of the scattered radiation were unknown and also PCXMC does not take spectrums as input.

Furthermore, the field size in PCXMC was set to cover the whole body of the operator, assuming homogenous irradiation and no scattering or shielding object between the source and the operator. In reality there is most often a desk with a computer screen in between.

The personnel dose calculations were very dependent on the workload of the operators, which was estimated to 13 examinations per day, 253 days per year. This is probably an overestimation, since it is the maximum number of examinations that can be performed in a day, and no holiday or other absence from work is included. On the other hand, dose contributions from daily quality control were not included.

The BMI 40 phantom was unfortunately only scanned with Hologic, showing no clear differences in scattered radiation relative to the thin phantom. However, the Hologic and GE scanners use different scan techniques. They use different photon energies and, more importantly, GE adjusts the tube current for patient thickness. For thin patient size, the skin entrance dose is 37 µGy, while for thick patient size it is 329 µGy for an AP Spine or a Hip examination, according to dose information from GE (but for VFA the dose is the same for all three sizes). This indicates that the impact of patient thickness on scattered radiation for the GE scanner is far from neglectable and would need further measurements.

The Hologic densitometer at the osteoporosis centre is of a model called Horizon A, which is a more recent model than the Discovery A at the osteoporosis research centre, used for measurements. However, specification data from Hologic show the same skin entrance doses for Horizon A and Discovery A for the used protocols (*QDR Series X-Ray Bone Densitometers - Technical Specifications Manual*, 2013).

Finally, an important note is that the radiation source (the irradiated phantom surface) was approximated as a point source in order to be able to use the inverse square law for calculations. This approximation was motivated with the facts the beam was relatively narrow and the irradiated volume relatively small in all measurements. The source distribution was considered as a point source in the middle of the distribution.

Conclusions

- The magnitude of scattered radiation varied in different directions from the scanner, which needs to be considered when designing a DXA room. The direction with the lowest scattering dose, in general, was the direction of the patient's head. The calculated effective doses to the DXA operators were below 1 mSv per year at 2–3 meters from the centre of the table. However, at a closer distance of 60 cm, the yearly effective dose was about 2.8 mSv for Hologic operators and 7.3 mSv for GE operators. In this scenario, the operators would be in category B and A, respectively. This demonstrates the importance of radiation safety education in low dose modalities such as DXA.
- There is no legal requirement for classifying all workers in operations with ionising radiation. Since the calculated yearly effective doses at the operator positions (2–3 meters) were below 1 mSv, there is no need for the DXA operators to be in category B – they may very well be unclassified.
- The DXA operators stated that they felt safe at their workplace, in terms of radiation safety. There was no uncertainty regarding pregnancy situations, and all four operators were happy with the level of radiation safety education that they had received. However, there was a slight degree of uncertainty regarding the dose levels (naturally, since hardly any measurements had been made).
- See Appendix for an accessible summary of the results in Swedish, written specially for the DXA operators and focusing on personnel doses. In Appendix, there is also a section with patient dose information.

Acknowledgements

I wish to thank my supervisor Patrik Sund for supporting me through every step of this work, and my supervisor Charlotta Lundh for her encouragement and invaluable input. I would also like to express my gratitude to the staff at the osteoporosis centre, for giving me experience of DXA examinations in practice. A special thanks to Ulrika Hjertonsson at the osteoporosis research centre, for her time and expertise during the measurements, and for all the assistance afterwards. Thanks also to Anders Olsson at Tesika Teknik for loaning us the measurement instrument. Assistance provided by Magdalena Nilsson at Tromp Medical, and Jesper Marmstad at GE Healthcare, was greatly appreciated. Thanks also to my family and friends for always being enthusiastic and curious.

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Appendix

Sammanfattning för DXA-personal

Vid beräkning av personaldoser har jag utgått från att en operatör utför 13 undersökningar per dag, 253 dagar per år (vilket är en överskattning då ingen semester räknades in). Jag har antagit att en undersökning består av Hip, AP Spine och VFA (vertebral fracture assessment – LVA/IVA) och alltså summerat doserna från dessa för Hologic respektive GE. En uppskattning på 20 % tillägg till doserna har också gjorts, med tanke på omstarter (alltså att man behöver starta om undersökningen för att till exempel positionera om patienten). Mätningarna utfördes med Hologic Discovery A och GE Lunar iDXA, och med ett verklighetstroget helkroppsfantom i plast som ”patient”.

Vid denna typ av mätningar för dosuppskattningar måste man göra en del antaganden, och man får hantera en rad osäkerheter. Till exempel måste man känna till mätinstrumentets begränsningar. När man gör en uppskattning av effektiv dos behöver man ta hänsyn till vilka organ som bestrålas, och här antogs en jämn bestrålning över hela kroppen. Inga skyddande objekt mellan operatören och strålkällan, som datorskärm och skrivbord, räknades in. I övrigt gjordes mätningarna på Hologic Discovery A, medan de två Hologic-scannrarna på osteoporosmottagningen är av modellen Horizon A. Dock verkar stråldoserna vara lika för de undersökningarna som kördes.

De beräknade effektiva doserna till personalen, från båda scannrarna, låg under 1 millisievert (mSv) per år. Som jämförelse kan nämnas att 1–2 mSv per år är den dosnivå som en person ur allmänheten utsätts för årligen bara av att leva i samhället (radon undantaget) – det som brukar kallas för naturlig bakgrundsstrålning. Den uppskattade effektiva dosen till personalen från DXA-verksamheten mättes på två meters avstånd från bordets mitt i de två undersökta riktningarna, som var vinkelrätt ut från bordet samt i huvudändans riktning. Under 1 mSv per år innebär att personalen inte behöver kategoriseras som kategori A eller B med tillhörande krav på dosmätningar med mera. Gravid personal i kategori A och B har rätt att begära arbetsuppgifter som innebär samma exponering som allmänheten får utsättas för – alltså 1 mSv per år – vilket alltså saknar betydelse för DXA-operatörer eftersom de redan ligger under den gränsen. Det är dock viktigt att inte rutinmässigt uppehålla sig nära patienten när maskinen körs eftersom dosnivåerna då blir mycket högre.

En GE-operatör som sitter två meter rakt ut från centrum av bordet skulle enligt beräkningarna få en årlig effektiv dos på 0,66 mSv medan motsvarande siffra för Hologic var 0,26 mSv (se Figure 29). Som jämförelse ger en flygresa till New York ger ungefär 0,05 mSv, på grund av kosmisk strålning, och en vanlig mammografiundersökning ungefär 0,2 mSv.

Den spridda strålningen mättes i 4–5 olika riktningar ut från scannern (se Figure 5 – Figure 6). Minst spridd strålning uppmättes i riktningarna från bordets kortsidor. Man kan alltså sitta närmare bordets fot- och huvudända än i övriga riktningar, mätt från bordets centrum. Mätt från bordskanten blir skillnaden ännu större. Även minimiavstånd beräknades, där operatören med säkerhet kan vara positionerad utan att överskrida 1 mSv i årsdos (gränsen sattes till 0,5 mSv – se Table 4 för alla avstånd). Det ”säkra” avståndet rakt ut från bordet blev då 134 cm för Hologic och 222 cm för GE.

Patientinformation

Stråldosen vid DXA är mycket låg och jämförbar med ett par timmars flygresa eller ett par dagar av den naturliga strålning vi hela tiden utsätts för från rymden och marken. Riskerna med strålningen från en DXA-undersökning är mycket små, medan nyttan med undersökningen är mycket stor då den kan bidra med att till exempel upptäcka benskörhet i tid. Vinsten i att undersökningen kan leda till rätt diagnostik och behandling är alltså mycket större än de eventuella riskerna som den lilla extra stråldosen innebär.