COMPARISON OF DOSE RECEIVED DURING BREAST CANCER DIAGNOSIS PERFORMED BY USING TWO DIFFERENT IMAGING MODALITIES: CONTRAST-ENHANCED SPECTRAL MAMMOGRAPHY AND FULL-FIELD DIGITAL MAMMOGRAPHY*

K. Kisielewicz[a,†], K. Rawojć[b], M. Tulik[a], A. Dziubińska[a]
L. Mazur[a], B. Kiełtyka[c], J. Łukaszewska[a]
D. Najberg-Pierzchała[a], M. Gądek[a], E. Łuczyńska[a]
Z. Woś[a], J. Miszczyk[d], S. Heinze[a], A. Dziecichowicz[a]

[a]Centre of Oncology, Maria Skłodowska-Curie Memorial Institute
Kraków Branch, Poland
[b]University Hospital in Kraków, Department of Endocrinology
Nuclear Medicine Unit, Poland
[c]M. Smoluchowski Institute of Physics, Jagiellonian University
Kraków, Poland
[d]H. Niewodniczański Institute of Nuclear Physics Polish Academy of Sciences
Kraków, Poland

(Received November 18, 2019)

Breast cancer (BC) is strongly related to woman age. 95% of all BC cases affect women over 40 years of age. Mammography and ultrasound are the main diagnostic tools. Women with suspicious changes are referred to additional examination *i.e.* Magnetic Resonance Imaging (MRI). High progress in the development of new mammography devices *i.e.* new flat panel detectors, compression paddles, spectral modes and new type of X-ray tubes gives a variety of new diagnostic modules available for clinical use. The aim of this study was to compare doses given to the patients during full-field digital mammography with doses obtained from dual-energy contrast-enhanced spectral mammography (CESM). The comparison of entrance surface air kerma (ESAK) and average glandular dose (AGD) values for both options are discussed in the paper. Our preliminary data show that CESM might be a new diagnostic tool allowing an accurate detection of malignant breast lesions, giving results similar to those received from

* Presented at the 3$^{\rm rd}$ Jagiellonian Symposium on Fundamental and Applied Subatomic Physics, Kraków, Poland, June 23–28, 2019.
† Corresponding author: `z5kisiel@cyf-kr.edu.pl`

MRI. However, due to higher levels of radiation exposure during CESM, one should take risk factor into account. Each method has its own benefits with respect to specific applications which are further discussed.

DOI:10.5506/APhysPolB.51.339

1. Introduction

Breast cancer (BC) is the predominant women malignancy resulting in one out of three cancer-related deaths in highly developed countries. It was clearly shown that a significant reduction in BC-specific mortality was associated with an introduction of screening programs [1]. Full-field digital mammography (FFDM) with the use of high-resolution digital modality combined with iodinated contrast agents is a common imaging approach used in BC lesion studies. However, a conventional FFDM has some limitations in terms of its sensitivity, especially in patients with dense breast tissue [2]. Patients, for whom MG study does not give a clear answer, or is impossible to interpret, are most frequently diagnosed further by contrast-enhanced breast magnetic resonance imaging (MRI). MRI is currently regarded as the most sensitive BC detection technique. On the other hand, it is limited by lower availability and higher costs, moreover, the probability of false positive cases is higher than in other imaging techniques [3]. Dual-energy contrast-enhanced spectral mammography (CESM) is a new imaging modality. Due to the specific imaging protocol which consists of two images, using low and high energy, of both breasts acquired after a single administration of contrast agent, additional information about a pathological neovascularization (angiogenesis) in the breast tissue might be obtained [4–7].

Maria Skłodowska-Curie Memorial Cancer Center and Institute of Oncology, Kraków Branch, Poland, has been equipped with a digital mammography device allowing dual-energy CESM acquisitions since 2012. Firstly, conventional MG and CESM in 152 preoperative women were compared. Findings were evaluated with respect to the performed histopathology. A significant correlation between the degree of lesion enhancement in CESM and malignancy — the stronger then enhancement, the higher the probability of malignancy [8]. Quantitative analysis of enhancement levels in CESM can distinguish between invasive and benign or *in situ* lesion [8]. CESM sensitivity, specificity and accuracy were 100% *vs.* 91%; 41% *vs.* 15%; and 80% *vs.* 65% for FFDM, respectively. In conclusion, it was stated that CESM may provide higher sensitivity for BC detection and greater diagnostic accuracy than conventional FFDM [9]. The goal of the next step was to compare CESM and breast MRI with histopathological results. Above all, sensitivity was 100% with CESM and 93% with breast MRI. Accuracy was 79% for CESM *vs.* 73% for breast MRI [10]. Better accuracy, specificity, and false-positive rate of CESM in breast cancer detection than MRI [11] was observed. Contrast-enhanced spectral mammography displayed a good correlation with histopathology in assessing the lesion size of breast cancer, which is consistent with MRI [11]. The glandular tissue is highly sensitive to X-ray exposure. Therefore, on the basis of defined average glandular dose (AGD) value, the risk of cancer induction during an examination should be estimated. The aim of the study was to quantitatively assess the exposure level increase after CESM system installation at Maria Skłodowska-Curie Memorial Cancer Center and Institute of Oncology, Kraków Branch, Poland, and compare it to patient's exposure after FFDM which was performed at the same institution for the same female patients.

2. Material and methods

In the study, 482 consecutive women (mean age: 53.3 ± 12.1 yrs, min age: 25 yrs, max age: 86 yrs) diagnosed with screening mammography between 2011 and 2014 were retrospectively enrolled. The first group of 250 patients was examined using a FFDM unit, GE Senographe Essential. The second group of 232 patients were examined using the same digital mammography device developed by GE Healthcare with the option of dual-energy CESM acquisition (SenoBright®) [12]. A total of four X-rays, two of each breast, were taken for a screening mammogram. A detailed description of FFDM and CESM diagnostic procedures performed at our Institute has been presented in previous publications [9, 10]. Permission No. OIL/KBL/17/2018 from Bioethical Committee at the Regional Medical Commission in Kraków was given for this project.

CESM acquisition consisted of two images in two view orientations (craniocaudal, CC, and mediolateral oblique, MLO) for each breast were automatically collected: a low-energy acquisition at 21–31 kVp and 44–138 mAs (with molybdenum/rhodium and rhodium/rhodium filters) and a high-energy acquisition at 30–49 kVp and 77–179 mAs (with molybdenum/copper or rhodium/copper filters). Exposure settings depended on breast thickness and density. For every projection, an entrance surface air kerma (ESAK) and average glandular dose (AGD) were determined. Values of ESAK and AGD are provided by the diagnostic unit automatically. Verification measurements of automatically provided ESAK and AGD were performed according to the European Reference Organisation for Quality Assured Breast Screening and Diagnostic Services (EUREF) and the formula

$$\mathrm{AGD} = \mathrm{ESAK} \times g \times s\,, \tag{1}$$

where g — glandularity conversion coefficients, s — spectral correction factor.

All measurements were done in reference point (which is defined 45 mm from a patient chest wall) using RTI semiconductor dosemeter calibrated in terms of air kerma and PMMA breast phantom slabs. For each patient exposure, glandularity conversion coefficients were interpolated for each breast thickness and HVL. The proper spectral correction factor for the selected target/filtration combination was also chosen. The type of distribution was examined for the collected data due to proper statistical analysis.

3. Results

Obtained results were grouped according to compressed breast thickness: less than 23 mm; 28–32 mm; 33–42 mm; 43–52 mm; 53–62 mm; 63–72 mm. Changes is ESAK values in both examined groups of patients (diagnosed by FFDM and by CESM, respectively) are presented in the Fig. 1 (top) and

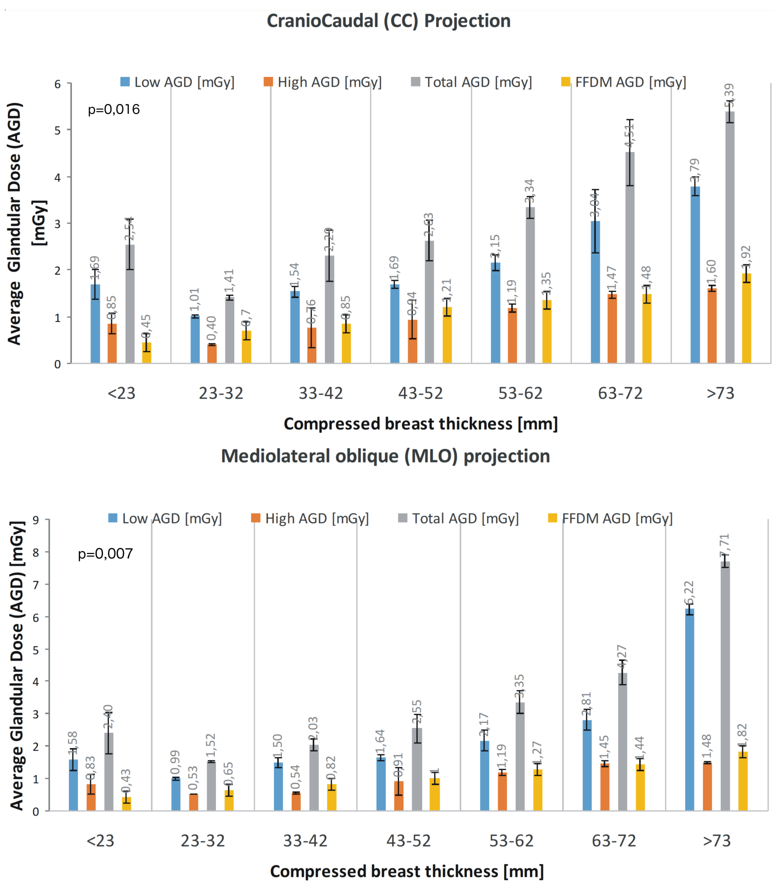

Fig. 1. AGD for CESM and FFDM mammography: (top) CC Projection, (bottom) MLO Projection.

(bottom). For digital unit, AGD — compressed breast thickness relationship represents a linear trend. The slope was defined during flat panel calibration. Relative expanded uncertainty of AGD (for $k = 1$) equals 7%.

The collected data are in accordance with one-tailed Student's t-distribution. For average glandular dose comparison for CESM and FFDM, statistical t-test was used. Comparing the AGD for CESM *vs.* FFDM for CC projection: calculated t-value is 3.656 which determine p-value to be equal 0.016.

For MLO projection: t-value is 2.877, p-value is 0.007. The difference between two distributions of AGD is significant at defined significance level: 0.05 for CC and MLO projections.

Comparing AGD values in CESM between CC and MLO projections, the differences are not statistically significant ($t = 0.287$, $p = 0.389$) for 0.05 significance level.

4. Discussion and conclusions

The low-energy part of CESM acquisition is much higher comparing with conventional FFDM in terms of radiation dose received by patients. Aside from that, the high-energy part was estimated to be approximately 20% of the dose of one conventional mammogram [5]. For the newest generation of CESM devices, it was reported that for the mean breast thickness of 56 mm, the AGD was 2.65 mGy per image (values between 1.07–4.76 with standard deviation of 0.78 mGy) [13]. In that study, a high-energy acquisitions account for 25% of the total dose with an average AGD of 0.65 mGy (values between 0.24–0.83 with standard deviation of 0.23 mGy) *vs.* 2.00 mGy (values between 0.84–3.74 with standard deviation of 0.58 mGy) for low-energy acquisitions. For our group of patients and for an average breast thickness of 45 mm (43–52 mm), median AGD is 6.6 mGy (values of AGD for a low-energy acquisition and high-energy acquisition were equal to 5.1 mGy and 1.5 mGy, respectively) for CESM compared to 1.2 mGy for FFDM. Moving up to 72 mm average breast thickness, AGD for CESM is nearly 7.5 times higher than for FFDM — medians of 12 mGy and 1.6 mGy, respectively.

One should not forget about using proper exposure conditions and examination doses ensuring that doses higher than necessary are not delivered to acquire diagnostic mammograms. Observed better accuracy, specificity, and false-positive rate of CESM in breast cancer detection than for MRI [11], a shorter waiting time comparing with MRI should be considered in terms of increased AGD in CESM.

Spectral mammography plays also an important role in delineating tumor size and extension [14]. Each method has its own benefits regarding its adequate application.

REFERENCES

[1] L. Tabár *et al.*, *Radiology* **260**, 658 (2011).
[2] E.D. Pisano *et al.*, *New Engl. J. Med.* **353**, 1773 (2005).
[3] M.S. Jochelson *et al.*, *Radiology* **266**, 743 (2013).
[4] J.M. Lewin, P.K. Isaacs, V. Vance, F.J. Larke, *Radiology* **229**, 261 (2003).
[5] C. Dromain *et al.*, *Eur. Radiol.* **21**, 565 (2011).
[6] M.B.I. Lobbes *et al.*, *Eur. Radiol.* **24**, 1668 (2014).
[7] E.M. Fallenberg *et al.*, *Eur. Radiol.* **24**, 256 (2014).
[8] W. Rudnicki *et al.*, *Eur. Radiol.* **29**, 6220 (2019).
[9] E. Luczyńska *et al.*, *Korean J. Radiol.* **15**, 689 (2014).
[10] E. Łuczyńska *et al.*, *Med. Sci. Monit.* **21**, 1358 (2015).
[11] D. Xing *et al.*, L, *J. Comput. Assist. Tomogr.* **43**, 245 (2019).
[12] M. Daniaux *et al.*, *Arch. Gynecol. Obstet.* **292**, 739 (2015).
[13] E.M. Fallenberg *et al.*, *Breast Cancer Res. Treat.* **146**, 371 (2014).
[14] R. Wessam *et al.*, *Brit. J. Radiol.* **92**, 20180245 (2019).