TA5 – Radiation Protection in Medicine

Mammographic Dose Survey in the Czech Republic

Novak Leos[1], Rada Jiri[2]

(1) National Radiation Protection Institute, Prague, Czech Republic
(2) National Radiation Protection Institute, Ostrava, Czech Republic

Introduction

At present, it is generally accepted that the average dose to the glandular tissue is the most reasonable dose descriptor in mammography with regard to the risk of breast cancer induced by ionizing radiation [1]. It is advantageous to use the quantity mean glandular dose MGD for setting of diagnostic reference levels (DRL) as well, although the quantity is not directly measurable as it is the case of DRL quantities for other imaging modalities. The reason is that a directly measurable quantity suitable for mammography, incident air kerma K_i, depends a lot on a beam quality. The influence of the beam quality (expressed by tube voltage, half value layer and combination of anode/filter material) is already included in calculation of mean glandular dose. To assess a radiation burden of patients due to mammography at a national level a representative dose survey is needed to carry out. Such a study provides statistically significant dose data for setting of the national diagnostic reference levels. National Radiation Protection Institute is performing the study in the Czech Republic since the year 2005.

Materials and methods

A mammographic dose survey performed in the Czech Republic is based on evaluation of mean glandular dose for cranio-caudal (CC) and medio-lateral oblique (MLO) view, which are the standard mammographic projections. The study started in the year 2005. Aims of the study are to establish new diagnostic reference levels with regards to compressed breast thickness, to analyze influence of different X-ray machine types, image receptors and imaging techniques on doses to patients. Current DRLs, given by Czech legislation [2], were adopted from European Commission recommendation for digital mammography [3]. The calculation of MGD is based on a formalism suggested by Dance [4, 5] and accepted by European Commission in their recommendations [1, 3]. Mean glandular dose is computed from incident air kerma K_i (kerma free in air at a surface of a compressed breast without backscatter) using tabulated conversion coefficients according to equation 1. Values of the conversion coefficients depend on a breast thickness, beam quality and patient age.

$$MGD = K_i \cdot g \cdot c \cdot s \qquad \textit{(eq. 1)}$$

K_i *incident air kerma (mGy)*

g *tissue dose conversion coefficient converting incident air kerma to mean glandular dose for Mo/Mo combination of anode/filter material and 50% breast glandularity (mGy/mGy)*

c *breast composition correction coefficient for another than 50% breast glandularity and a given patient age group*

s *spectral correction factor for another than Mo/Mo combination of anode/filter material*

These coefficients were calculated using Monte Carlo simulation of radiation transport through a mathematical phantom of a human breast. The values of the conversion coefficients could be found in the original papers by Dance [4, 5] and in the EC recommendations [1, 3] as well. For a Mo/Al combination of anode/filter material (present in a Planmed Sophie X-ray unit) a spectral correction factor was not given in the original work. The same value as for the Mo/Mo combination is used in that case.

To obtain a value of incident air kerma for each patient and projection, exposure parameters are collected from mammographic centers from their reports. At each workplace, data are commonly collected for 50 patients undergoing indicated examination and also for 50 different patients undergoing mammographic screening, in case the workplace is a screening center. Exposure parameters are recorded for right/left breast and CC/MLO projection separately. For each patient a value of high voltage, anode/filter material, projection, compressed breast thickness, product of exposure time and tube current and patient age is reported. Additionally, X-ray set characteristics are received from regular quality control (QC) measurements. From protocols of the QC measurements, a value of radiation yield, half value layer HVL and focus - breast support distance is reported. The incident air kerma K_i is calculated according to equation 2.

$$K_i = Y(100).Q.\left(\frac{100}{FSD - l}\right)^2 \qquad \textit{(eq. 2)}$$

Y(100) *radiation yield measured at a distance 100 cm from a focus (mGy/mAs)*

Q *product of exposure time and tube current (mAs)*

FSD *focus-breast support distance (cm)*

l *compressed breast thickness (cm)*

Radiation yield and HVL are measured only for some setting of high voltage during the QC tests. To cover a whole range of applied voltage during clinical exams, interpolation is made between the measured values of radiation yield and HVL. In the original papers by Dance, the conversion factors were tabulated with a step of 1 cm for breast thickness and with a step of 0,05 mm Al for HVL. For an improved precision of the calculation, the conversion factors are interpolated to obtain values with a step of 1 mm for breast thickness and of 0,01 mm Al for HVL. The calculation is made by MS Access relational database macro developed by Young [6].

Before the calculations, the exposure data are inspected for mistakes caused by wrong transcription of the data from mammograms. In this particular case, individual outlying values are removed. In general, a

relationship between compressed breast thickness and a corresponding value of mAs is checked. Sometimes the data correlate very well as it can be seen at figure 1. However, workplaces with misleading data occur as well as it is shown at figure 2. It is believed, that such the data indicate a problem with automatic exposure control circuit (AEC). Unfortunately a follow-up of such a workplace is not possible, because the dose survey is performed by National Radiation Protection Institute, which is not a regulatory body. This problem could be solved in a future by inclusion of the survey into topics covered by a clinical audit performed by Ministry of Health.

Results and discussion

There are 114 mammographic workplaces in the Czech Republic, 57 of them are screening centers. There are 150 registered/licensed X-ray units among these workplaces. However, not all of them are still in clinical use. Most frequently used X-ray units in the Czech Republic are Alpha RT (13 %), Planmed Sophie (12 %), Senographe DMR (11 %), Performa MGF 110 (10 %) and Mammograf CH 22S (10 %).

Figure 1: A correct dependence of mAs on a breast thickness

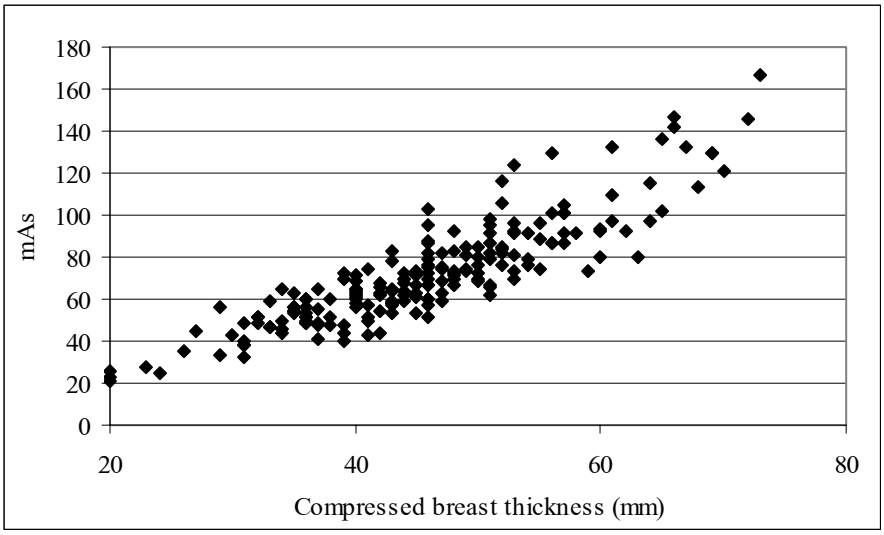
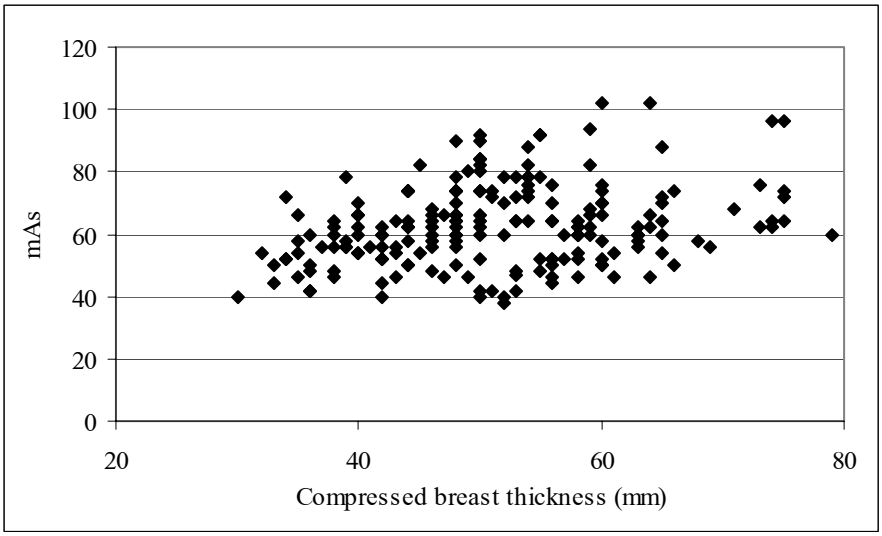


Figure 2: Dependence of mAs on a breast thickness indicating a problem with AEC



Currently, patient exposure data are collected for about 2300 patients from 24 workplaces located in central and eastern part of the Czech Republic, 16 of these workplaces are screening centers. The following results are related entirely to CC projection. Average compressed breast thickness, used X-ray machine type and minimal, maximal and average values of MGD from surveyed workplaces are summarized in table 1. No explicit relationship between average breast thickness and average value of MGD is obvious from the data. It is caused mainly by different performance of given X-ray machine models when setting the exposure parameters for a given breast thickness and by differences in an imaging process. These relationships will be further studied after a collection of larger amount of data.

Table 1: Summary of MGD results for surveyed workplaces

Workplace	X-ray machine model	Mean glandular dose (mGy)			Average breast thickness (mm)
		minimal	maximal	average	
1	Alpha RT	0,35	2,62	1,01	51,6
2	Alpha RT	0,66	3,60	1,17	55,0
3	Alpha RT	0,57	3,85	1,43	58,6
4	Diamond MGX 2000	0,61	6,78	1,81	54,0
5	LORAD M-IV	0,34	3,38	1,50	54,2
6	MAM CH 22S	0,77	6,24	2,54	50,4
7	Mammodiagnost	0,87	4,85	1,98	47,8
8	Mammomat 3000 Nova	0,24	1,63	0,70	45,5
9	MGU 10A	0,80	3,53	1,55	48,5
10	Performa MGF - 110	0,45	2,98	1,62	48,0
11	Performa MGF - 110	0,45	4,00	1,30	54,5
12	Senographe 2000D	0,86	2,67	1,67	52,2
13	Senographe 800T	0,79	4,54	1,94	50,9
14	Senographe DMR	0,79	3,43	1,80	48,3
15	Senographe DMR	0,61	2,99	1,52	46,2
16	Senographe DMR+	0,47	3,98	1,38	50,8
17	Senographe DMR+	0,13	4,65	1,43	55,8

18	*Senographe DMR+*	*0,44*	*2,12*	*1,01*	*42,5*
19	*Senographe DMR+*	*0,45*	*2,04*	*1,10*	*45,1*
20	*Senographe DMR+*	*0,49*	*2,28*	*1,24*	*47,0*
21	*Senographe DMR+*	*0,37*	*2,78*	*1,30*	*47,1*
22	*Sophie*	*0,49*	*4,28*	*1,51*	*54,1*
23	*Sophie*	*0,24*	*4,46*	*1,65*	*51,4*
24	*Sophie*	*0,24*	*1,97*	*1,06*	*48,7*

The third quartiles of mean glandular dose distributions were determined from the preliminary results too. Values of the third quartiles were compared with DRL recommended by EC [3]. Separate distributions were made for breast thicknesses in a range 19-23 mm, 30-34 mm, 43-47 mm, 51-55 mm, 58-62 mm and 73-77 mm. These intervals were chosen to correspond with a breast thicknesses equivalent to thicknesses of PMMA, for which the DRLs in EC document were stated. For all of the breast thickness categories, the third quartile was lower than achievable value of MGD recommended by EC, except the breast thicknesses of 2,1 and 3,2 cm. The data are summarized in table 2. Value of the third quartile for the largest breasts is missing, since too few cases occur in that range.

Table 2: Recommended DRL by EC and third quartiles obtained from the survey in the Czech Republic (CR)

PMMA thickness (mm)	*Equivalent breast thickness (mm)*	*Relevant range (mm)*	*EC recommendation [3]*		*3rd quartile in CR (mGy)*
			MGD acceptable	*MGD achievable*	
20	*21*	*19-23*	*0,8*	*0,6*	*0,9*
30	*32*	*30-34*	*1,3*	*1,0*	*1,2*
40	*45*	*43-47*	*2,0*	*1,6*	*1,4*
45	*53*	*51-55*	*2,5*	*2,0*	*1,7*
50	*60*	*58-62*	*3,3*	*2,6*	*2,0*
60	*75*	*73-77*	*5,0*	*4,0*	*2,7*
70	*90*	*88-92*	*7,3*	*5,8*	*-*

Most relevant are the data for the range of compressed breast thickness 51-55 mm, since a mean value of compressed breast thickness is 50,3 mm in the Czech Republic. This result shows that a proper thickness of PMMA phantom used for QC measurements is 45 mm, which is the reference thickness given in the EC documents as well. Whole distribution of compressed breast thickness is shown in figure 3 and a whole MGD distribution for the most frequent breast thicknesses is shown in figure 4.

Figure 3: Compressed breast thickness distribution for a CC view

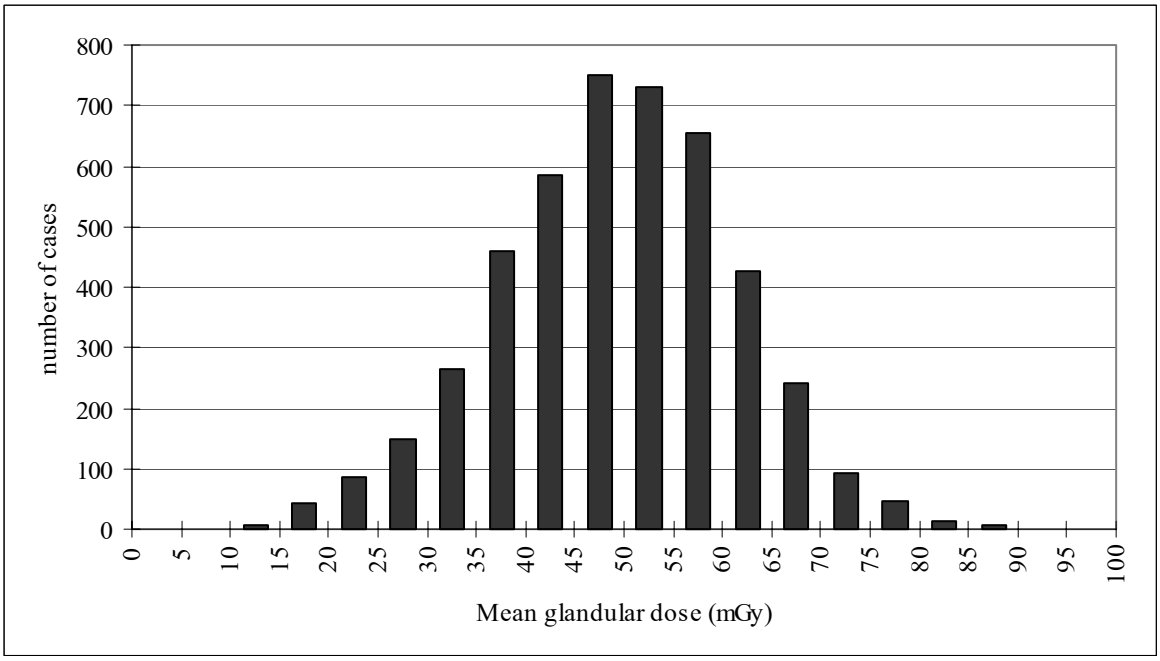
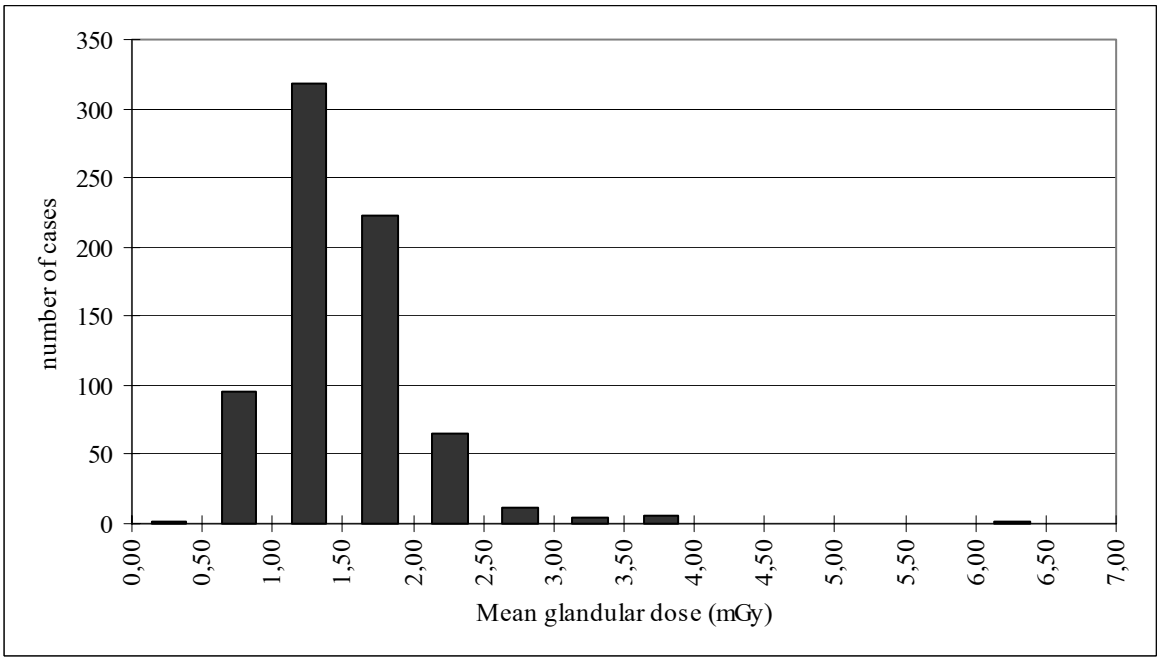


Figure 4: Mean glandular dose distribution for CC view for a breast thickness 51-55 mm



Conclusions

On a basis of presented data, it could be concluded, that the situation in the Czech Republic with respect to patient doses in mammography is encouraging and that the requirements of European Commission are well fulfilled. However, it is obvious, that the obtained results can not be considered as statistically significant at the moment, because the data were

not collected from a representative sample of centers, which should observe a distribution of X-ray unit types, type of a mammographic center (screening/non screening ones) and also a locality of a center. The dose survey still continues to cover the whole Czech Republic with the main task to determine new national diagnostic reference levels and to find out optimized standards for carrying out the examinations with respect to patient doses and image quality.

References

1) *European Commission. European Protocol on Dosimetry in Mammography, EUR 16263 EN, 1996*
2) *State Office for Nuclear Safety. Decree of the SONS No. 307/2002 Coll., on Radiation Protection amended in Decree of the SONS No. 499/2005 Coll., 2005*
3) *European Commission. Addendum on Digital Mammography to Chapter 3 of the European Guidelines for Quality Assurance in Mammography Screening, 2003*
4) *Dance, D. R. Monte Carlo Calculation of Conversion Factors for the Estimation of Mean Glandular Brest Dose, Phys. Med. Biol. Vol. 35, No. 9, pp. 1211 - 1219, 1990*
5) *Dance, D. R. et al. Additional Factors for the Estimation of Mean Glandular Breast Dose Using the UK Mammography Dosimetry Protocol, Phys. Med. Biol. Vol. 45, pp. 3225 -3240, 2000*
6) *Young, K. C. Breast Dose Surveys in the NHSPSP: Software and Instruction Manual Version 2.0, NHSBSP Report 04/05, 2004*