

An OSL-based dosimeter for exposure control verification in x-ray mammography imaging systems

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INTRODUCTION

Verifying that the output exposure of an x-ray mammography imaging system is within established control limits is an important component of programs designed to ensure patient safety.

To address this need, LANDAUER has developed a compact easy-to-use dosimeter that utilizes optically stimulated luminescent (OSL) technology to facilitate quality control in x-ray mammography, and thereby provide a cost-effective solution for secondary or more frequent monitoring of mammography system output exposure levels.

OBJECTIVES

The purpose of this study was to characterize the performance of the Mammography OSL dosimeter relative to an earlier TLD-based mammography dosimeter and independently, using a variety of x-ray mammography systems utilizing a range of technologies including screen-film mammography and digital mammography.

METHODS

The active detection element of the dosimeter is a strip of OSL material comprised of $Al_2O_3:C$ suspended in a binder material. The strip is 3 mm wide, 0.13 mm thick and 30 mm long and is encapsulated in a light-tight plastic enclosure with exterior dimensions of 10 mm wide, 5.4 mm thick and 54 mm long (as shown in Figure 1).



Figure 1 - Mammo OSLD

Embedded in the plastic outer case are overlying filtration segments corresponding to 0 mm, 0.2 mm, 0.4 mm and 0.6 mm AL.

The Mammography OSL dosimeter was positioned at the surface of the quality control phantom used in the American College of Radiology's breast accreditation program, beneath the compression paddle edge nearest to the chest wall (Figure 2) and exposed at the designated representative clinical technique using each of the mammography imaging systems evaluated. Five dosimeters were evaluated for each system tested to assess reproducibility in readings.

For each of the mammography imaging systems evaluated, using the same representative technique and exposure settings employed when irradiating the dosimeters, either a Keithley Triad Model 35050A ion chamber (independent OSLD measurements) or a Radcal 10X-6M (TLD vs OSLD measurements) was used to measure the x-ray beam half-value layer (HVL) and the entrance surface exposure surface (ESE). In all ESE measurements, the ion chamber was positioned per the ACR recommended technique at the side of the phantom. For HVL measurements the ion chamber was placed at 6 cm from the edge of the chest wall with the compression paddle at its maximum vertical height and the ion chamber positioned vertically between the surface of the detector cover and paddle.

System	#	Technology
Siemens Novation DR	2	DR
Hologic Selenia Dimensions	2	DR
GE Senographie Essential	2	DR
GE 2000D	1	DR
Lorad M-IV / FUJI	1	SF -> CR
GE Instrumentarium Diamond	1	SF -> CR
GE Instrumentarium Performa	1	SF

Table 1 - X-ray mammography imaging systems (SF: screen-film, CR: computed radiography, DR: digital radiography)

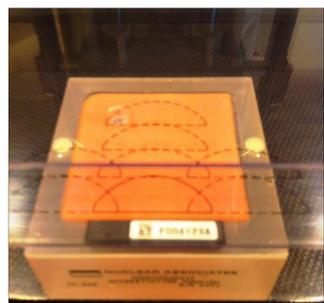


Figure 2 - Mammo OSLD positioned on phantom

The OSL mammography dosimeter strips were readout using an automated OSL reader whose absolute exposure response had been previously established by reading calibration strips exposed to a reference standard M30 x-ray spectrum (HVL = 0.36 mm AL). The resulting test dosimeter strip exposure profile was evaluated using regions of interest corresponding to the location of each filtered segment of the strip to compute an estimate of the x-ray beam half-value layer (HVL) and entrance surface exposure (ESE or E_o) using the expression shown in Equation 1:

METHODS (Continued)

$$HVL_{calc} = \frac{t_b \cdot \ln(2 \cdot \frac{E_a}{E_o}) - t_a \cdot \ln(2 \cdot \frac{E_b}{E_o})}{\ln(\frac{E_a}{E_b})} \quad \text{Eq (1)}$$

The computed HVL, known kVp and target/filter combination were then used to compute an exposure-to-dose conversion factor (DCF) for 50-50 breast composition from published data provided by the manufacturers. An estimate of the average glandular dose (AGD) was then computed by multiplying the entrance exposure estimate by the appropriate exposure-to-dose conversion factor shown in Equation 2:

$$AGD_{calc} = E_o \cdot DCF_{INTERP} \quad \text{Eq (2)}$$

RESULTS

The performance of the Mammography OSL dosimeter was evaluated relative to TLD dosimeters using a GE 2000D system and then subsequently verified using a variety of x-ray mammography systems including screen-film (SF), computed radiography (CR) and direct digital radiography (DR) (See Table).

A comparison of the HVL and AGD results obtained for the GE 2000D system demonstrated that TLD and OSLD measurements were comparable. A comparison of OSLD to ion chamber measurements for target/filter combinations Mo-Mo, Mo-Rh and Rh-Rh showed agreement within 4%, 7% and 10%, respectively, whereas HVL measurements showed an average agreement within 2%, 2% and 5%, respectively.

For the independent comparison, five repeat measures of HVL, ESE and AGD obtained for each system using the mammography OSL dosimeter were highly reproducible, with a coefficient of variation of <5%. Results obtained with the dosimeter offset laterally ± 0.5 , ± 1.0 and ± 2 cm yielded results with a coefficient of variation within 5%, demonstrating that the dosimeter is also not sensitive to small errors in placement. The average of HVL measurements obtained using the dosimeter, agreed to within 10% of that obtained using the ion chamber but individual measurements showed as much as a 20% difference, depending on target/filter combination. The average Entrance Surface Exposure (ESE) from which AGD is derived, obtained using the Mammography OSL dosimeter, agreed with that obtained using an ionization detector within 10%-30% for all system evaluated.

DISCUSSION

The performance of the Mammography OSL dosimeter evaluated using conventional mammography systems and x-ray spectra, i.e. those systems employing target filter combinations such as Mo-Mo, Mo-Rh and Rh-Rh, demonstrated excellent consistency with ion chamber measurements when all factors are taken into account. For those mammography systems based on digital radiography for which newer more penetrating target/filter combinations such as W/Rh are utilized, the AGD results could be as much as 30% higher compared with ion chamber measurements, suggesting there is potential to further optimize the dosimeter performance using these systems by employing a strip reader calibration correction that takes into account beam quality effects.

CONCLUSIONS

The LANDAUER mammography TLD dosimetry system has historically provided consistent measurement of half-value layer, entrance surface exposure and average glandular dose for characterizing the performance of conventional mammography imaging systems. The results of this early evaluation of a new OSLD-based dosimeter demonstrate comparable or better performance, indicating the usefulness of Mammography OSLD for: (1) measurement of the performance of a mammography imaging system as part of a regular quality control program, and (2) remote audits of machine output exposure levels conducted in compliance with national regulatory requirements.

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