

CaSO_4 (Dy) THERMOLUMINESCENT DOSIMETERS FOR THE DETERMINATION OF GONADAL DOSES

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Thermoluminescent dosimeters can be regarded as almost ideal point detectors. Accurate measurements of the absorbed dose can be performed. The dosimeters are easily introduced into a patient and dose distributions in or near organs of interest are obtained.

At the moment several thermoluminescent dosimetry systems are available on the market. Some of these systems were reviewed previously (HASMAN & GROOTHEDDE). In our hospital a Teledyne 7300 reader is available and both LiF and CaSO_4 (Dy) discs embedded in a teflon matrix are used. The LiF phosphors have the advantage of being almost tissue equivalent, whereas CaSO_4 (Dy) suffers from the fact that it is highly energy dependent (Fig. 1). However, its sensitivity is about thirty times larger than that of LiF at cobalt energy. An investigation was started on the female gonadal dose as compared to the delivered skin dose. Since in most surveys the gonadal dose is rather low due to shielding of parts of the body, a very sensitive dosimeter was wanted enabling a read-out of 1 mR with reasonable accuracy. The high sensitivity LiF dosimeters from Harshaw are known to be able to measure an exposure of 5 mR with some accuracy, whereas CaSO_4 (Dy) dosimeters are able to measure 1 mR with at least the same accuracy. The investigation was started on the actual energy dependence of CaSO_4 (Dy) in radiation beams with peak potentials varying from 50 to 150 kV.

Submitted for publication 21 February 1974.

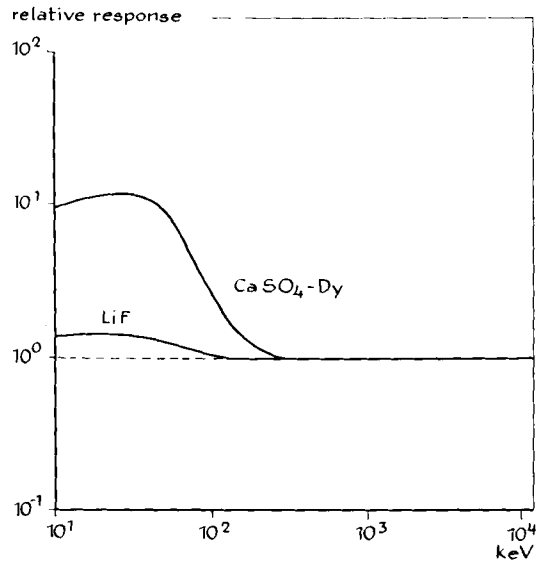


Fig. 1. The energy dependence of CaSO_4 (Dy) and LiF dosimeters relative to water.

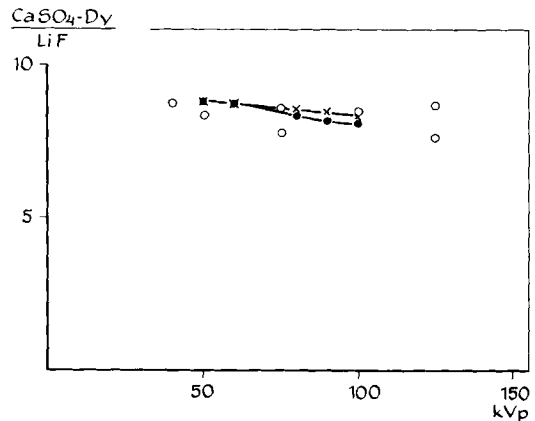


Fig. 2. Comparison of CaSO_4 (Dy) output with LiF output as a function of peak potential. The direct beam data have been calculated and measured. $\circ$ measured, $\times$ direct beam calculated, $\bullet$ scattered beam calculated.

Measurements have been performed with CaSO_4 (Dy) and LiF, and the ratio between the outputs was determined as a function of peak potentials.

Some results obtained with the CaSO_4 (Dy) discs at urography are also reported. In the last section a conclusion on the usefulness of CaSO_4 (Dy) discs is given.

TLD measurements. The energy dependence of CaSO_4 (Dy) has been determined with two roentgen machines. Results have been obtained using a Philips Standard DLX with a Rotalix 0-75/125 diagnostic tube (total inherent filtration 1 mm Al). Additional measurements were performed with the Philips RT 250 deep therapy unit, having a higher filtration.

In the first place the energy response of CaSO_4 (Dy) and LiF dosimeters has been

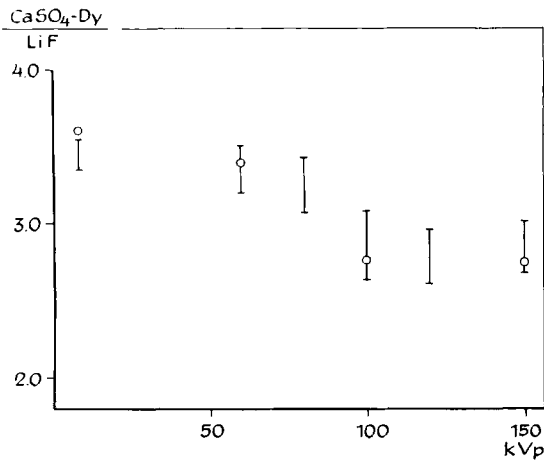


Fig. 3. The ratio in response of CaSO₄ (Dy) relative to LiF for the direct and scattered beam as a function of peak potential. Filter 0.5 mm Al, O scattered beam, I direct beam.

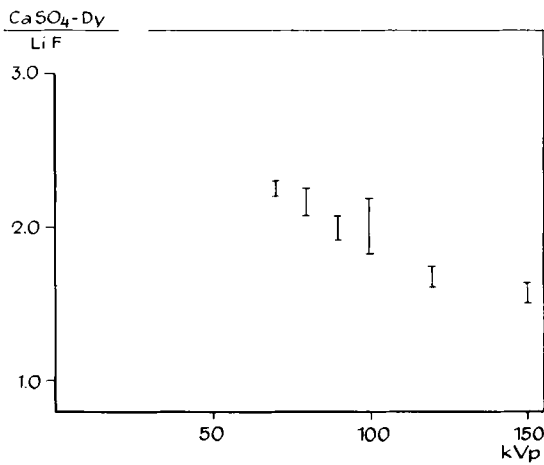


Fig. 4. The ratio in response of CaSO₄ (Dy) relative to LiF for a heavy filtered beam. Filter 1.0 mm Cu + 1.0 mm Al.

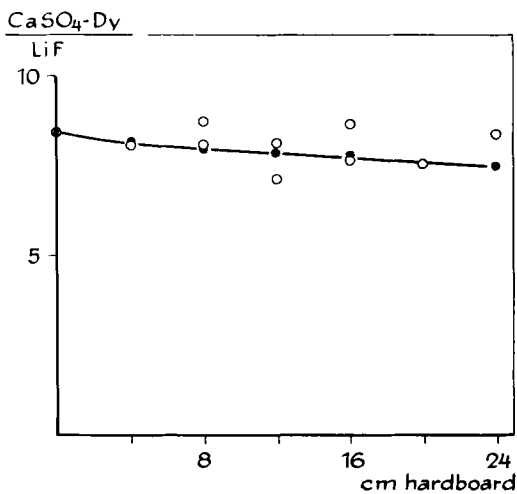


Fig. 5. Comparison of CaSO₄ (Dy) output with LiF output for different thickness of the hard board phantom. O measured (100 kV; 0.5 mm Al), ● calculated (90 kV).

Table 1
Dependence of LiF output from peak potential

0.5 mm Al; RT 250		1 mm Cu + 1 mm Al; RT 250	
kV	LiF output/mR	kV	LiF output/mR
60	1.4	60	1.2
80	1.4	80	1.3
100	1.4	100	1.3
120	1.4	120	1.2
150	1.2	150	1.2

measured. The dosimeters were placed in the direct beam produced by the Rotalix tube. Since the spectral distribution of the direct beam and a scattered beam (90°) was known the measured results could be compared with calculated values. As could be expected the energy dependences are the same (Fig. 2). Two important results are clear from measurement and calculations: (a) the energy dependence of the CaSO_4 (Dy) dosimeters is rather small in this case, (b) measurements in the direct beam will give a similar energy dependence as measurements in scattered beams.

These results may be explained by the fact that the contribution of low energy photons to the total spectrum is rather high due to the low filtration.

Therefore, since the energy response of CaSO_4 (Dy) for energies less than 60 keV is rather uniform, only a small energy dependence can be expected for beams with low filtration and not too high peak potential. The similarity in primary and scattered spectra was shown by WAGGENER et coll. (1973) also for higher filtrations. Since the inherent filtration of the diagnostic unit is rather low and cannot be considered as representative for most diagnostic units, additional experiments have been performed on a RT 250 deep therapy unit. The inherent filtration of this unit varies from 1.5 mm Al at 50 kV to 2.5 mm Al at 250 kV. In most of the experiments 0.5 mm Al was added. In Fig. 3 the ratio of the response of CaSO_4 (Dy) relative to LiF is shown as a function of energy for a moderately filtered beam. Again the ratio varies over the energy range but the output from the CaSO_4 (Dy) discs does not vary more than $\pm 10\%$ over the potential range when compared with LiF. Using a heavier filtration of 1 mm Al and 1 mm Cu the decrease in the ratio is more significant but the effective energy dependence of CaSO_4 (Dy) is still within $\pm 15\%$ as compared to LiF for the potentials considered (Fig. 4). The ratio between the CaSO_4 (Dy) and LiF responses is also measured for scattered radiation and compared with the corresponding ratio for the primary beam. Also in this case (Fig. 4) both values lie close together over the whole potential range considered.

As a last experiment the response of the CaSO_4 (Dy) and LiF discs behind a variable thickness of hard board has been measured (RT 250, 0.5 mm Al additional filtration, 100 kV), and compared with results calculated from the known spectra. Calculation and measurement agree within the experimental error (Fig. 5).

Table 2
Gonadal exposure in mR delivered during urography

Case	kV	mAs	No. of photos	Size	Gonadal dose in mR
1	70	97	5	35 × 43	24
			6	24 × 30	
2	80	214	5	35 × 43	34
			10	24 × 30	
3	72	146	1	35 × 43	9
4	70	146	4	35 × 43	23
			3	24 × 30	
5	70	97	4	35 × 43	7
			3	24 × 30	
6	70	146	3	35 × 43	25
			2	24 × 30	
7	70	91	4	35 × 43	72
			3	24 × 30	
			3	18 × 24	
8	70	65	4	35 × 43	36
			3	24 × 30	
9	74	146	3	35 × 43	21
			2	24 × 30	
			1	18 × 24	
10	80	86	3	35 × 43	8
			2	24 × 30	
			1	18 × 24	
11	70	146	2	35 × 43	36
			3	24 × 30	
			3	13 × 18	
12	75	146	3	35 × 43	17
			2	24 × 30	
13	72	146	2	35 × 43	36
			2	24 × 30	
			2	18 × 24	
14	68	146	5	35 × 43	49
			2	24 × 30	
			2	18 × 24	
15	70	146	5	35 × 43	61
16	75	146	3	35 × 43	26
			2	24 × 30	
17	80	344	5	35 × 43	80
			5	24 × 30	
18	85	312	5	35 × 43	83
			5	24 × 30	
19	72	91	3	35 × 43	34
			4	24 × 30	
20	72	103	3	35 × 43	37
			1	24 × 30	
			1	18 × 24	

In Table 1 the LiF output is compared with the output of an ionization chamber (ionisation chamber type 37480 of the Philips universal dosimetry system) to see whether the LiF dosimeters would still have some energy dependence. Values of the LiF output per mR are given for two filtrations as a function of peak potential. The sensitivity of the LiF dosimeters is somewhat less for the heavier filtration (Table 1). Nevertheless, the energy dependence is hardly noticeable for a given filtration and therefore it could be concluded that the LiF dosimeters could be used as a reference dosimeter instead of the ionization chamber for the comparison with the CaSO_4 (Dy) dosimeters.

The gonadal dose has been determined in 20 male patients undergoing urography. The gonads were shielded by lead to reduce the gonadal dose. That this is effective can be seen by comparing the mean gonadal dose published here with other values quoted in the literature (on the average 900 mR per examination, BEENTJES, as compared to 36 mR in our case).

Since the energy response varies maximally $\pm 10\%$, no attempt has been made to determine the ratio of the responses of LiF and CaSO_4 (Dy) in the primary beam each time. The output of CaSO_4 (Dy) has thus been directly converted to mR using a once measured conversion factor. In Table 2 the results are tabulated together with information on the tube potential, mAs values and field dimensions. An average gonadal dose of 36 mR was obtained.

Conclusions. Although the energy dependence of CaSO_4 (Dy) dosimeters is well-known these dosimeters can be used with a fair accuracy over a tube potential range varying from 50 to 150 kV, when the beam is not too heavily filtered. It appears that the response of the CaSO_4 (Dy) dosimeters varies only $\pm 10\%$ as compared with the LiF response, whereas the sensitivity of the CaSO_4 (Dy) dosimeters is much higher.

SUMMARY

For the measurement of gonadal doses sensitive dosimeters are necessary. Since CaSO_4 (Dy) thermoluminescent dosimeters are very sensitive the energy dependence has been measured as compared to LiF in the tube potential region between 50 and 150 kV. Moreover the output of the LiF dosimeters was compared with the results of ionization chamber measurements. Although the energy dependence of CaSO_4 (Dy) is well-known the actual dependence on the potential appears to be within $\pm 10\%$ for moderately filtered beams in the region from 50 to 150 kV.

ZUSAMMENFASSUNG

Zur Messung von Gonaden-Dosen sind empfindliche Dosimeter notwendig. Da CaSO_4 (Dy) Thermolumineszenz-Dosimeter sehr empfindlich sind, wurde die Energieabhängigkeit, verglichen mit LiF, bei Röhrensparnungen im Bereich von 50 und 150 kV gemessen. Darüberhinaus wurden die Ausschläge der LiF Dosimeter mit den Ergebnissen von Ionisations-Kammermessungen verglichen. Obwohl die Energieabhängigkeit von CaSO_4 (Dy) gut bekannt ist, scheint die aktuelle Abhängigkeit von der Spannung für mässig filtrierte Strahlen im Bereich von 50 bis 150 kV innerhalb von $\pm 10\%$ zu liegen.

RÉSUMÉ

Les mesures des doses aux gonades nécessitent des dosimètres sensibles. Etant donné que les dosimètres thermoluminescents au CaSO₄ (Dy) sont très sensibles, on a mesuré leur dépendance à l'égard de l'énergie par comparaison au LiF dans l'intervalle de différences de potentiel du tube entre 50 et 150 kV. De plus le débit des dosimètres LiF a été comparé avec le résultat des mesures faites avec des chambres d'ionisation. Bien que la dépendance à l'égard de l'énergie du CaSO₄ (Dy) soit bien connue, la dépendance réelle à l'égard du potentiel paraît être dans un intervalle de $\pm 10\%$ pour des faisceaux modérément filtrés dans le domaine de 50 à 150 kV.

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