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PATIENT SURFACE DOSES IN COMPUTERIZED TOMOGRAPHY EXAMINATIONS

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INTRODUCTION

The diagnostic value of computerized tomography has increased due to very rapid technical advances in both equipment and techniques [1,2]. When the CT scanners were introduced, a significant problem for the specification of the radiation dose imparted to the patient undergoing CT examination has been created. In CT, the conditions of exposure are quite different from those in conventional X-ray imaging. CT procedure involves the continuous tomography of thin layers. Some of these layers touch each other while others overlap. The radiation doses received by patients can vary considerably. In addition to the radiation from the collimated primary beam, patients are exposed to significant scattered doses in unpredictable amounts.

Every effort should be made to keep these doses to a reasonable minimum, without sacrificing the image quality. The aims of this work were to determine the surface doses delivered to various organs of patients during various computerized tomography examinations (head, thorax, kidney, abdomen and pelvis). Particular attention was directed to the precise determination of doses received by the eyes (during CT of head) and gonads (during CT of pelvis and lower abdomen) since these organs can be near or even in the primary X-ray beam.

MATERIALS AND METHODS

Selected TL dosemeters were used for all dose measurements. These are the most frequently used devices for dose measurements in computerized tomography [3-8]. For the measurements of the distribution of surface doses during computerized tomography, LiF:Mg, Ti TL dosemeters (manufactured at the Institute for Nuclear Physics, Krakow, Poland) and TLD-700 (Harshaw) were emplyed. During the measurement of the patient doses, all TL dosemeters were placed in pairs of two in rubber holders 3 mm thick. Only TL dosemeters for the eye lens were wrapped in dark foil, without rubber holders.

Reading was performed on a TOLEDO 654 reader (Pitman/Winten). The energy dependence and other characteristics of the dosemeters used have been described in previous publications [9,10].

Computerized tomography was performed using two quite different CT units: (i) The first CT unit was SOMATOM DR-H (manufactured by Siemens), version HC-1, third generation. This equipment was installed in 1987 at the University Hospital "Dubrava", Zagreb, where measurements on 71 patients were performed; (ii) The second CT unit used in this study was SCT-4500TE (manufactured by Shimadzu). The equipment was installed in 1994 at the University Hospital "Merkur", Zagreb, where measurements on 24 patients were performed.

RESULTS AND DISCUSSION

During various computerized tomography examinations, surface radiation doses received by 95 patients were measured (i) in the primary X-ray beam region and (ii) outside of the primary X-ray beam (mostly scattered radiation).

According to the literature, the absorbed doses received by the organs vary considerably from one CT scanner to another [1-3,6]. These differences may be due to the differences in the size of the focus, the effective atomic number of the target material, quality of the filter materials and so on [3].

During computerized tomography of the whole abdomen, surface radiation doses received by 10 patients (2 groups of 5 on each machine) were measured in the primary beam at the upper, middle and lower section of the examined organ and for eye, thyroid and chest, as well as for the right and left gonads. The averaged results for all patients of any one unit are given in Table 1. The doses measured in the primary X-ray beam at the examined organ are the maximum surface doses received by a patient during CT of the whole abdomen. Using SOMATOM DR-H equipment surface radiation doses received by the whole abdomen ranged from 8 to 47 mGy, while using SCT-4500TE unit surface doses renged from 15 to 58 my.

Similar doses in the primary beam were measured during CT examination of other organs. The surface dose during CT examination of upper abdomen varied from 7 to 54 mGy for SOMATOM DR-H unit, and from 17 to 56 mGy for SCT-4500TE unit. During CT of kidney the surface doses varied from 17 to 71 mGy for SOMATOM DR-H unit, and from 29 to 85 mGy for SCT-4500TE unit. The surface radiation dose during CT examination of thorax and pelvis were measured using only SOMATOM DR-H equipment. The maximum surface dose was 24.59 mGy during CT of thorax and 74.16 mGy during CT of pelvis.

The doses absorbed by different organs during the diagnostic CT examination depend on the technical parameters such as the number of scans, the thickness of scans, scan times, couch increment, tube voltage, total mAs and other characteristics of the equipment, as well as on the type and severity of illness. Clinical parameters, such as patient size and composition and patient cooperation with regard to control and motion, also influence the dose and image quality.

All our measurements were performed on actual patients. This must be borne in mind, especially when considering doses received in the primary beam, since the slightest movement during tomography (e. g. the blink during CT of the brain) can significantly affect the dose. Furthermore, the beam angle in the case of actual patients is always adjusted to the optimum diagnostic requirements; this can contribute significantly to the total dose of scattered radiation[1,6] as well as to the dose in the primary beam.

The absorbed dose for a given examination in computerized tomography varies by a factor of 3 in New Zealand, and a factor of 5 in Sweden and in the United Kingdom[2]. In Japan, the effective dose equivalent for the same examination varies by a factor of 3.5, depending on CT scanner unit[2,3]. All these dose were measured mostly on a hypothetical average adult (phantom), although actual patients can vary significantly. In this study, the surface dose measured on actual patients undergoing the same examination varied by a factor between 2 and 6. At the same time, the number of scans and the total mAs with actual patients varied by a factor of 2 for the same examination. There were no significant differences between two different CT systems.

The surface radiation doses outside of primary beam received by the eyes, thyroid, and chest, as well as the left and right gonads during CT examination, involving a narrow, highly collimated X-ray beam directed exclusively to the examined areas, result from scattered radiation. The ratio of the minimum to the maximum of the measured surface doses from scattered radiation varies by a factor of 2 to 7. This is understandable if we consider the following: (i) these doses originated from scattered radiation, which varied according to the position, size and shape of patients' bodies; (ii) among the 95 patients were little children (approximately 7 years of age), as well as both very thin and very corpulent adults; therefore, the distance of the primary X-ray beam from the organ being measured for dose received significantly varied from one patients to antoher, (iii) the number of scans varied by a factor of 2.6 (from 13 to 34); (iv) the total mAs also varied by a factor of approximately 2.

During CT examination of pelvis and lower abdomen the gonads can be found near or even in the primary X-ray beam. The surface dose received by gonads results from both scattered and direct radiation. The surface dose to gonads during CT examination of whole abdomen varied from 11 up to 40 mGy; during CT of pelvis the doses to gonads were from 20 to 43 mGy. Taking into account the high tissue weighting factor for gonads (0.20) this fact can create a serious radiation protection problem and special attention has to be directed to both, the justification of the procedure, as well as to carefull planning of the examination procedure (optimization of radiation protection).

CT unit	SOMATOM DR-H (Siemens)		SCT-4500TE (Shimadzu)	
Tube voltage (kV)	125		120	
No. of scans	27-30		21-33	
Scan thickness (mm)	8		10	
Scan time (sec.)	7		4.5	
mAs	8500-9300		8200-12600	
No. of patients	5		5	
Surface dose (mGy) on	Lowest value	Highest value	Lowest value	Highest value
In primary beam - upper part of examined organ				
Front	8.36	40.70	20.77	58.30
Right side	11.14	47.24	15.81	46.43
Back	10.46	42.12	20.92	53.80
Left side	9.41	41.28	39.65	56.10
In primary beam - middle part of examined organ				
Front	27.49	47.57	31.13	51.08
Right side	10.97	31.30	10.66	45.91
Back	10.55	28.53	17.44	46.83
Left side	10.45	43.54	15.08	54.46
In primary beam - lower part of examined organ				
Right side	9.41	40.84	0.25	1.84
Left side	10.33	47.09	0.34	1.05
Outside of primary beam				
Base of nose (eye)	0.20	0.46	0.13	0.43
Thyroid	0.45	1.04	0.56	1.45
Chest	0.76	5.48	1.89	8.41
Right gonad	15.23	37.98	0.61	1.61
Left gonad	11.23	39.14	0.64	1.87

Table 1: Distribution of surface radiation doses (mGy) received by various organsduring **whole abdomen CT examination** by 2 different scanners.

CONCLUSION

The distribution of surface radiation doses received by patients during CT examination can be successfully measured using TL dosemeters. In this study, the srface dose measured on several patients undergoing the same examination varied by a factor ranging from 2 to 6. There were no significant differences between two different CT systems. Since computerized tomography is an increasingly common diagnostic procedure, and sine various equipment is used, such measurements should be performed for all equipment. This would provide the following benefits; (i) facilitate the control of CT equipment; (ii) identify equipment requiring additional safety measures; (iii) facilitate patients risk assessment; and (iv) aid in directing efforts towards reducing the total radiation doses. From the point of view of radiation protection of patiens, an optimum procedure for CT examination should be decided by considering not only the image quality but also the absorbed dose resulting from CT examination. One of the main objectives in CT examination is to obtain an optimum image quality with a minimum radiation dose. In attempting to reduce the dose, it is important to realise that this is not only possible by technical improvement, but is even more effective by careful advance planning of the examination and by reducing the number of slices.

ICRP 60 suggests the introduction of the concept of dose constraints also in the medical field, so that both dose calculations and dose measurements should equally serve to establish the reference values as a criterion of good radiological practice [12]. International Basic Safety Standards [13] suggest for diagnostic radiology, including computerized tomography examinations, wide scale quality surveys, which include entrance surface doses. This study is in accordance with these international recommendations. Several European countries are at present collaborating on the development of the quality assurance measures to reduce the variability in doses from comparable computerized tomography examinations [2].

LITERATURE

1. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). *Sources, Effects and Risks of Ionizing Radiation.* 1988 Report to the General Assembly, with Annexes (New York: UN) (1988).
2. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). *Sources and Effects of Ionizing Radiation.* UNSCEAR 1993 Report to the General Assembly, with Scientific Annexes (New York: UN) (1993).
3. Nishizawa, K., Maruyama, T., Takayama, M., Okada, M., Hachiya, J. and Furuya, Y. *Determinations of Organ Doses and Effective Dose Equivalents from Computed Tomographic Examination.* Br. J. Radiol. **64**, 20-28 (1991).
4. Huda, W. and Sandison, G.A. *CT Dosimetry and Risk Estimates.* Radiat. Prot. Dosim. **12**, 241-249 (1985).
5. Yalcintas, M.G. and Nalcioglu, O. *A Method for Dose Determination in Computerized Tomography.* Health Physics **37**, 543-548 (1979).
6. Shope, T.B., Morgan, T.J., Showalter, C.K., Pentlow, K.S., Rothenberg, L.N., White, D.R. and Speller, R.D. *Radiation Dosimetry Survey of Computed Tomography Systems from Ten Manufacturers.* Br. J. Radiol. **55**, 60-69 (1982).
7. Faulkner, K. and Moores, B.M. *Scattered Radiation Distributions around Computed Tomography Scanners and the Associated Radiation Hazard to Personnel.* Br. J. Radiol. **55**, 70-74 (1982).
8. Fearon, T. and Vucich, J. *Normalized Pediatric Organ-Absorbed Doses from CT Examinations.* AJR **148**, 171-174 (1987).
9. Ranogajec-Komor, M. and Osvay, M. *Dosimetric Characteristics of Different TL Phosphors.* Radiat. Prot. Dosim. **17**, 379-384 (1986).
10. Ranogajec-Komor, M., Muhiy-Ed-Din, F., Milković, Đ. and Vekić, B. *Thermoluminescence Characteristics of Various Detectors for X Ray Diagnostic Measurements.* Radiat. Prot. Dosim. **47**, 529-534 (1993).
11. Vekić, B., Duvnjak, N. and Ranogajec-Komor, M. *Determination of Patient Surface Doses from Computerized Tomography Examination of Head.* Proc. Austrian-Italian-Hungarian Radiation Protection Symposium: Radiation Protection in neighbouring countries in Central Europe, Obergurgl/Tyrol, 28-30. April 1993., N. Vana, A. Hafner (Editors), Vienna, 193-196 (1994).
12. ICRP Publication 60. 1990 *Recommendations of the International Commission on Radiological Protection.* Pergamon Press, Oxford (1991).
13. IAEA . *International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources.* Interim Edition, Safety Series No. 115-1, International Atomic Energy Agency, Vienna (1994).