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Radiation exposure to patients and examiners during endoscopic retrograde cholangiopancreatography procedures

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► ***Short report***

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ABSTRACT

Background: Endoscopic retrograde cholangiopancreatography (ERCP) is now widely used in the diagnosis and treatment of gastrointestinal tract disorders. A large number of X-ray fluoroscopy and digital radiographs make ERCP as an interventional radiological procedure. In this study, patients' and examiner's entrance skin doses (ESDs) were measured during diagnosis and treatment procedures and patients' effective dose (ED) were calculated. ***Materials and Methods:*** Thermoluminescent dosimeters (TLDs) and dose area product meter (DAP) were used to measure ESDs of 30 patients and examiner and calculate patients' ED. Besides, to assess the effectiveness of an extra lead shield in decreasing examiner's ESDs, a lead cover was wrapped around the X-ray tube. The data were analyzed with IBM SPSS Statistics version 16 software. ***Results:*** The mean DAP and fluoroscopy time (FT) of the diagnostic procedure were 4.09 Gy.cm^2 and 32.4 s while those of the therapeutic procedure were 7.60 Gy.cm^2 and 76.2 s. The strong linear correlation between DAP and FT was observed for the therapeutic procedures but the diagnostic ones. The patients' mean EDs of diagnostic procedure (1.21±0.52 mSv) and therapeutic one (2.25±1.72 mSv) were calculated. Moreover, the shielding cover around the X-ray tube decreased ESDs of the organs of interest except gonads. ***Conclusions:*** The results reveal that therapeutic ERCP procedure imposes a greater radiation dose compared to diagnostic ERCP one. However, the doses of the patient and the examiner depend highly on examiner's experience, technical skills and knowledge in radiation protection. The results suggest that attempts to reduce radiation doses should be made.

***Keywords**: ERCP, effective dose, radiation exposure, entrance skin dose.*

INTRODUCTION

ERCP is a commonly used procedure for diagnosis and treatment of gastrointestinal tract disorders. Although this procedure has advantages, patients and examiners are exposed to primary and scattered X-ray for a relatively long time [1].

During the ERCP procedure, patients usually receive heterogeneous dose distributions; thereby to evaluate the net benefit of the procedure, the more appropriate indicators of patient dose are entrance skin doses (ESDs) and effective dose(ED)[2]. Besides, the examiners standing near the patients to conduct the procedure may receive radiation dose. This dose may be very low. However, no radiation dose can be considered safe due to the cumulative effect and high workload [3].

ESDs were measured directly with thermoluminescent dosimeters (TLDs) [4, 5] or ion chamber [6] and indirectly with dose area product meter (DAP) [7]. Moreover, ED in this procedure can be calculated using DAP measurements and a conversion coefficient [8].

It should be noted that patients would benefit the examination despite radiation exposure, but they should be protected towards unnecessary doses. On the other hand, the staffs who perform the procedures routinely receive the additional doses during the procedures. Therefore, radiation protection of staffs is as important as that of patients. Several studies have been conducted to evaluate the occupational exposures and investigated the effects of shielding to dose reduction of the staffs [9, 10].

Despite the fact that ERCP procedures, in general, may impose a relatively high risk to patients and staffs, a few researchers have investigated the incurred doses and potentially harmful effects. Also, the small number of studies have been carried out in developing countries such as Iran.

The present study aims to (i) measure ESDs and calculate ED of patients, (ii) measure ESDs of examiner's organs of interest (hands, thyroid and gonads) due to diagnostic and therapeutic ERCP procedures and (iii) assess the effectiveness of the shielding cover around the X-ray tube to reduce occupational exposure at a teaching hospital in Mashhad-Iran.

MATERIALS AND METHODS

Patient dose management

Thirty patients participated in this study at a teaching hospital in Mashhad-Iran. The 20 out of them underwent diagnostic procedures and the rest underwent therapeutic procedures. The ethics and research committee approved the study and written consent was obtained from all patients. To measure ESDs of patients' organs of interest (thyroid, gonads, and lens of the eyes), two TLDs (TLD-100H, LiF: Mg, Cu, P) were placed on subjects' skin at the organs of interest.

After ERCP procedures were conducted by APELEM X-ray unit (APX HF III model), the exposed TLDs were read by a Harshaw 3500 manual TLD reader. According to the simple model suggested by Duggan et al., to derive energy response correction factors for LiF: Mg, Cu, P in diagnostic and interventional radiology, a correction factor of 1 is applied in the present study[11]. Besides, during the conduction of the ERCP procedure, a DAP meter (Gammex-RMI) was attached to the X-ray unit. DAP value and fluoroscopy time (FT) were subsequently recorded so as to be employed later.

It should be noted that prior to irradiation, TLDs were calibrated according to the international protocols for the range of energies used in the study. TLD chips were placed inside thin plastic sachets to be protected from physical and chemical damages. Each set of dosimeters were accompanied by four blanks, these were treated exactly as the dosimeters used for patients and examiner; but were not exposed. The mean dose of blanks was taken as background for irradiated TLDs. Patients' characteristics and ERCP data are shown in table 1.

In order to calculate patients' EDs, DAP and a conversion coefficient (ED to DAP ratio of phantom) were required. The conversion coefficient was determined using a male Rando phantom (radiology support devices, Inc, California, USA). To obtain ED and DAP value for the phantom, 60 TLDs were inserted in organs and tissues defined by ICRP-103 [2]. ERCP was performed on the phantom, in the same position of the patients, with FT of 168s. Phantom's ED was determined by equation 1:

$$ED_{Phantom} = \Sigma_T W_T D_T \quad (1)$$

Where W_T and D_T are tissue weighing factor and mean absorbed dose of organ T of the phantom, respectively. To obtain D_T, it is necessary to combine the cross-sectional anatomical data with experimentally determined dose distributions within the phantom. For a measured dose distribution, the absorbed organ dose D_T can be derived as follows:

$$D_T = \Sigma_i f_i \text{ (organ)} \times D_i \quad (2)$$

Where f_i is a fraction of organ T and D_i is the absorbed dose of fraction f_i located within slice i (for each organ, $\Sigma_i f_i = 1$). Finally, the EDs of the patients were calculated from the following equation (3):

$$ED_{Patient}(Sv) = DAP_{patient}(Gy.m^2) \times \left(\frac{ED(Sv)}{DAP(Gy.m^2)}\right)_{phantom} \quad (3)$$

Examiner dose management

One experienced endoscopist performed all procedures. ESDs of the examiner's organs of interest (the lens of eyes, thyroid, gonads and hands) were measured by two TLDs, for each organ, which were placed under the lead thyroid shield and apron (for thyroid and gonads). The mean value of two TLDs in each position was considered for both the patients and the examiner.

The estimate of the shielding effect on dose reduction

In order to assess the effect of lead shielding cover wrapped around the X-ray tube, ERCP was carried out when the Rando phantom was placed beside the patient's couch at nearly the same position where the examiner normally stands. Then phantom's ESDs were measured by TLDs with and without the shielding cover. The organs of interest were the lens of the eyes, thyroid, and gonads.

All statistical analysis was performed in IBM SPSS Statistics version 16 software.

Table 1. Patients' body characteristics

Procedure	No.	Gender		Age (Year)
		Male (%)	Female (%)	
Diagnostic ERCP	20	25	75	52.4±16.9
Therapeutic ERCP	10	40	60	79.5±4.4

RESULTS

ESD measurements of the examiner's and the patients' organs of interest were performed. Details of ESDs of both groups were presented in table 2. According to table 2, ESDs of the patients were higher than those of the examiner in both procedures as can be expected.

There is a significant statistical difference between diagnostic and therapeutic procedures regarding DAP (P-value=0.031) and FT (P-value=0.003). There is no correlation between DAP and FT of the diagnostic procedure although a strong correlation between those (R^2 =0.9) was observed for the therapeutic one.

The result of the dose measurements of the Rando phantom was showed in table 3. In the study, FT and DAP of the phantom was 168 s and 0.705 Gy.cm^2, respectively. Therefore, using organs' weighting factors defined in ICRP 103, the phantom's ED and the conversion coefficient were obtained as 0.21mSv and 0.297 mSv/Gy.cm^2, respectively.

The acquired DAP values of the patients varied widely (0.88-7.00 Gy.cm^2 for diagnostic procedures and 2.22-17.53 Gy.cm^2 for therapeutic ones). Having the patient's DAP and the conversion coefficient, the patients' ED were calculated from the equation 3. The mean calculated patients' ED in diagnostic and therapeutic procedures were 1.21±0.52 mSv and 2.25±1.72 mSv, respectively.

The organ doses of the phantom with / without lead shielding cover of X-ray tube were demonstrated in table 4. As can be seen from the table, shielding decreased the dose of the thyroid by approximately 70% and the dose of the lens of the eyes by approximately 30%. In contrast, the dose of the gonads increased by approximately 155% when using shielding.

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Table 2. Mean ESDs in diagnostic and therapeutic ERCP procedures.

Procedure	TLD position	Number of patients	Examiners' mean ESDs (mGy)	Patients' mean ESDs (mGy)
Diagnostic	Thyroid	20	0.024 (0.017-0.036)	0.031 (0.026-0.036)
	Lens of the eyes	20	0.024 (0.020-0.029)	0.028 (0.022-0.033)
	Gonads	20	0.025 (0.021-0.031)	0.065 (0.031-0.095)
	Right hand	20	0.024 (0.019-0.031)	-
	Left hand	20	0.027 (0.020-0.038)	-
Therapeutic	Thyroid	10	0.032 (0.020-0.052)	0.039 (0.020-0.058)
	Lens of the eyes	10	0.031 (0.020-0.040)	0.035 (0.016-0.049)
	Gonads	10	0.035 (0.020-0.059)	0.051 (0.023-0.086)
	Right hand	10	0.039 (0.027-0.054)	-
	Left hand	10	0.037 (0.018-0.075)	-

Table 3. Dose measurements of the Rando phantom for D_T of organs and tissues defined by ICRP-103 (2, 16)during ERCP.

Organ T	D_T(mGy)	Organ T	D_T (mGy)
Gonads	0.034	Liver	1.428
Bone marrow	0.322	Esophagus	0.393
Colon	0.093	Thyroid	0.048
Lung	0.208	Skin	1.064
Stomach	0.298	The remaining organs	0.076
Bladder	0.046	ED of the phantom	0.21(mSv)

Table 4. ESDs of the phantom with /without the lead shield wrapped around the X-ray tube.

TLD position	ESD with the lead shield (mGy)	ESD without the lead shield (mGy)
Thyroid	0.022	0.071
Lens of the eyes	0.033	0.047
Gonads	0.056	0.022

DISCUSSION

In the past few years, ERCP procedures have been increasingly used. Subsequently, the research area of radiation protection in this examination has attracted more interests. Compared to other studies, the mean FT, DAP and ED were much lower in this study (mean FT: 32.4 s, mean DAP: 4.09Gy. cm^2, mean ED: 1.21±0.52 mSv for diagnostic ERCP and mean FT: 76.2s, mean DAP: 7.06Gy. cm^2, mean ED: 2.25±1.72 mSv for therapeutic ERCP) [6, 8, 12, 13] (detailed information provided as Appendix A). The differences may result from advanced equipment, operating methods or the experience which the examiners had.

It is evident that patient gonads received a relatively higher dose in both procedures (table. 2).This is due to the fact that the patient's gonads, females in particular, are closer to the radiation field and were not shielded. Thus, more efficient protection is essential. Also, the examiner's ESDs of organs of interest were much lower in comparison to other studies [6, 14, 15]. This difference may be due to several factors such as the lower FT compared to other study, proper shielding and safety culture (detailed information provided as Appendix B).

Covering the X-ray tube with a lead shield decreased the leakage radiation and hence the examiner's ESDs, however, this conclusion is not true for gonads. Although it is unexpected, in practice, these values have been obtained and we are sure these are correct. The possible explanation is that the leaded cloth shields laterally scattered radiation, but could increase forward scattered radiation.

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Appendix A. Comparison of mean DAP, FT, and ED of patients from ERCP.

Study	Diagnostic ERCP			Therapeutic ERCP		
	DAP (Gy. cm^2)	FT (s)	ED (msv)	DAP (Gy. cm^2)	FT (s)	ED (msv)
Sukko et.al. (8)	-	-	-	5.15	144	1
Larkinet et.al. (13)	13.5	138	3.1	66.8	630	12
Tsalafoutas et.al. (12)	13.7	186	2.9	41.8	360	8.7
Buls et.al.(6)	-	-	-	49.9	360	9.9
This study	4.09	32.4	1.21	7.60	76.2	2.25

Appendix B. Examiner's mean ESDs of the organs of interest during ERCP.

Study	Hand (mGy)	Thyroid (mGy)	Lens of the eye (mGy)
Buls *et al.*[6]	0.44	0.30	0.34
Germanaud *et al.* [15]	-	0.10	0.13
Cohen RV[14]	-	2.05	1.67
This study	0.04	0.03	0.03

CONCLUSION

ESDs and EDs of both procedures were lower than those reported in the literature. Patients' and staffs' doses depended on the nature of the examination according to the results. Nevertheless, patients' gonad dose is relatively and unexpectedly high, which is needed better protection. Improvement of radiation protection may result in a reduction in ESDs and EDs of both group. Additional studies are required to be carried out in order to establish national dose reference levels (DRLs) to patients and examiner's ED during ERCP procedures in Iran.

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