Occupational Radiation Exposure from Fluoroscopically Guided Percutaneous Transhepatic Biliary Procedures

John Stratakis, MSc, John Damilakis, PhD, Adam Hatzidakis, MD, Nicholas Theocharopoulos, MSc, and Nicholas Gourtsoyiannis, MD

PURPOSE: The aim of this study was to determine occupational dose levels for projections commonly used in fluoroscopically guided percutaneous transhepatic biliary (PTB) drainage and stent placement procedures.

METHODS: Exposure data from 71 consecutive PTB examinations were analyzed to determine average examination parameters for biliary drainage and stent placement procedures. An anthropomorphic phantom was exposed at three projections common in PTB interventions according to the actual geometric parameters recorded in the patient study. Scattered air-kerma dose rates were measured for neck, waist, and gonad levels at various sites in the interventional radiology laboratory. To produce technique- and instrumentation-independent data, dose rate values were converted to dose-area product (DAP)–normalized air-kerma values. In addition, sets of thermoluminescent dosimetry crystals were placed in both hands of the interventional radiologist to monitor doses during all PTB procedures.

RESULTS: Isodose maps of DAP-normalized air-kerma doses in the interventional laboratory for projections commonly used in PTB procedures are presented. To facilitate effective dose estimation, normalized dosimetric data at the interventional radiologist's position are presented for left and right access drainage procedures, metallic stent placement only, and drainage and metallic stent placement in one-session procedures with and without under-couch shielding. Doses to the hands of interventional radiologists are presented for left and right transhepatic biliary access and metallic stent placement.

CONCLUSIONS: Body level–specific normalized air-kerma distributions from commonly used projections in PTB procedures may be useful to accurately quantify dose, maximum workloads, and possible radiogenic risks delivered to medical personnel working in the interventional radiology laboratory. Normalized dose data presented will enable occupational exposure estimation from other institutions.

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Abbreviations: DAP = dose-area product, LAO = left anterior oblique, PA = posterior-anterior, PTB = percutaneous transhepatic biliary, RAO = right anterior oblique, TLD = thermoluminescent dosimetry

PERCUTANEOUS transhepatic biliary (PTB) interventions are commonly performed in the interventional radiology laboratory on patients with bile duct occlusion or stenosis (1,2). Introduction of digital equipment, new techniques in image acquisition, and percutaneous biliary management have increased the number of interventional biliary procedures performed in recent years (1–4). Consequently, interventional radiologists and support personnel may be exposed to considerable levels of radiation.

Development of interventional radiology has been accompanied by significant concern for the safety of the staff involved in interventional procedures. National and regional authorized bodies have pointed out issues of interest within the optimization of radiation protection that included assessment of dose and risks of interventional laboratory personnel. Published work has mainly focused on radiation protection in various cardiologic, orthopedic, and angiographic procedures (5–7). A few previous studies have assessed radiation exposure to staff during interventional procedures (8–10). These studies have mainly concentrated on reporting an overview of entrance skin dose, dose-area product (DAP) of the procedures, and retrospectively acquired doses to body regions such as the forehead or neck. To

From the Department of Medical Physics, University of Crete, P.O. Box 2208, Iraklion, Crete GR-71003, Greece (J.S., J.D., N.T.); the Department of Natural Sciences, Technological Education Institute of Crete, Iraklion, Crete Greece (N.T.); and the Department of Radiology, University of Crete, Iraklion, Crete, Greece (A.H., N.G.) Received October 16, 2005; accepted January 23, 2006. **Address correspondence to** J.D.; E-mail: damilaki@med.uoc.gr

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our knowledge, there are no normalized occupational dosimetric data in the literature associated with projections commonly used in PTB procedures. Normalized dosimetric data incorporate a major advantage in comparison with surface or air-kerma measurements, since they constitute data independent of exposure parameters. Therefore, these data may be used from other institutions to estimate occupational exposure. Furthermore, little information is available on radiation exposure delivered to the hands during PTB procedures. These procedures can deliver high hand and finger doses compared with other methods because of the operator's close proximity to the x-ray beam and the possibility that hands may be repeatedly exposed directly to the primary beam (7).

The main objective of the current study was to provide normalized dosimetric data for projections commonly used in PTB procedures. Additionally, doses to the hands of interventional radiologists were assessed for different approaches and practice of transhepatic biliary access.

MATERIALS AND METHODS

Patient Study

During a period of 18 months, 71 patients with bile duct occlusion were treated in our interventional radiology laboratory. This study was performed in accordance with the Helsinki Declaration, and written approval was obtained from all patients. Malignant obstruction was the main indication for the intervention. A right or left approach for the PTB drainage was chosen depending on biliary anatomy and dilation of a puncture-preferred hepatic biliary duct. All procedures were performed by an experienced interventional radiologist standing on the patient's right side. Patients were separated into three groups: group 1 consisted of 35 patients on whom only biliary drainage was undertaken, group 2 consisted of 17 patients treated with biliary drainage and metallic stent placement in one session, and group 3 consisted of 19 patients treated with drainage and metallic stenting in two different fluoroscopy courses. Pulsed fluoroscopy (15 pulses per second/25 ms pulse width) with variable tube current and voltage was used. Patient data were used to determine average examination parameters for biliary drainage and stenting procedures. Accordingly, parameters for fluoroscopy and digital radiography, such as DAP measurements, field size, fluoroscopy time, and number of radiographic exposures, were recorded.

Radiographic Equipment

A floor-mounted Siemens Axiom Artis FA Angiograph (Siemens, Erlangen, Germany) with a digital fluorography C-arm assembly was used in this study. A high-output, liquid-cooled x-ray tube with a triple focus of 0.3, 0.6, and 1.0 mm, a 12-degree anode angle, and an inherent filtration of 2.5 mm Al/80kV was used. The tube housing included a collimation system and semitransparent wedge filters, which could be moved or rotated independently. The total filtration of the unit was estimated to be 5.5 mm Al. An image intensifier with a maximum circular field size of 38 cm was used. The x-ray tube was monitored by an ionization chamber incorporated in the collimation system for measuring the radiation dose in terms of cGy cm^2.

Measurements of Scattered Radiation in the Interventional Radiology Laboratory

An anthropomorphic Rando phantom (Alderson, Stanford, CA) was used to simulate the patient during fluoroscopy screening of the PTB procedure. The fluoroscopic projections typically used in PTB procedures are (i) the posterior-anterior (PA) projection, (ii) the 25-degree left posterior oblique angle for right access, and (iii) the 25-degree right posterior oblique angle for left access to the bile ducts. In the latter two projections, the names right anterior oblique (RAO) and left anterior oblique (LAO), respectively, have been assigned in accordance with the position of the image intensifier with respect to the patient. All exposures were performed with the phantom in a supine position on the fluoroscopic table, according to the actual geometric parameters used in real PTB cases assessed in this study. Exposure parameters were adjusted automatically by means of automatic exposure control. DAP rate was determined for each projection by use of the beam-on timer and the DAP meter unit readings.

For the measurement of scattered air-kerma, the area relative to the side of the fluoroscopy table occupied by interventional radiology personnel during a PTB procedure was divided into a 0.25-m grid. The x-ray tube was positioned with the aid of an experienced interventional radiologist in accordance with the Rando phantom's internal structure to simulate an actual biliary procedure. Scattered measurements were carried out using a calibrated dose rate monitor (EG&G, Berthold, Germany) capable of quantifying air-kerma rates from 0.05 μSv/hour to 10 mSv/hour. Measurements were performed at three levels relative to the floor (neck level, waist level, and gonad level) for the three projections considered in this study. Further measurements with identical exposure conditions were made to investigate the effect of a 0.5-mm lead equivalent shield attached to the long side of the table. Scattered air-kerma dose rates were converted to DAP-normalized air-kerma values by dividing the air-kerma dose rates by the DAP rate of each exposure, to obtain technique- and instrumentation-independent dosimetric data.

Verification of Air-Kerma Measurements

To compare scattered radiation produced by the Rando phantom with scattered radiation produced from real patients, air-kerma measurements were repeated for all three projections in 10 patients with anatomic characteristics similar to those of the Rando phantom. Air-kerma rates were measured at the positions usually allocated by the interventional radiologist, the interventional radiologist resident, and the assisting staff.

The Monte-Carlo-N-Particle code system (11) was also used to verify air-kerma readings in the vicinity of the fluoroscopy table. An exact representation of the actual x-ray and patient geometry was created for all PTB approaches. Diagnostic energy spectra developed by Nowotny and Hofer (12) were used in the Monte-Carlo-N-Particle input file to simulate x-ray beam and total tube filtration. Human anatomy was replicated by means of a

Table 1
Demographic Data and Average Operating Parameters of Radiation Exposures for Study Groups 1, 2, and 3 in PTB Procedures (mean values ± SD)

	Group 1*	Group 2*	Group 3*
Sex (M:F)	18:17	11:5	9:10
Age (y)	57.4 ± 12.5	62.5 ± 10.4	65.3 ± 9.1
BMI	26.2 ± 5.4	24.3 ± 4.5	26.8 ± 3.7
kV (fluoroscopy)	71.7 ± 6.1	74.3 ± 7.1	71 ± 5.1
mA (fluoroscopy)	32.2 ± 4.1	33.1 ± 4.6	30.1 ± 4.4
SSD (cm)	70 ± 2	71 ± 2	70 ± 2
kV (DR)	73.6 ± 8.8	74.8 ± 6	75 ± 5
mAs (DR)	50 ± 4	55 ± 6	50 ± 6.7
Number of radiographs	4.0 ± 3	4.5 ± 2	3.7 ± 4

* Group 1: biliary drainage only; group 2: one session biliary drainage and stenting; group 3: biliary stenting only.
Note.—BMI = body mass index; DR = digital radiography.

mathematic phantom that was constructed with BodyBuilder, a commercially available package (White Rock Science, White Rock, NM). The mathematic phantom created by BodyBuilder represented an adult human body 1.73 m in height and 71 kg in weight. Composition of the human body was modeled by assigning skeletal, soft tissue, or lung material to corresponding tissues (13,14). Air-kerma values normalized to DAP were calculated for the positions occupied by the interventional radiology personnel. Calculations were repeated for the PA, LAO, and RAO projections used in PTB procedures. Each Monte Carlo run simulated the deposition of approximately 50 million photons originating from the x-ray source. At that stage, the mathematic detectors (tallies) had converged to a relative error of less than 1%.

Calculation of Occupational Doses

With use of conversion coefficients provided by the International Commission for Radiation Protection, the face-level air-kerma measurements were converted to eye lens dose and superficial dose equivalent H_s^{face}, that is, the dose delivered to soft tissues at a depth of 0.07 mm, related to the dose received by the skin of the face (15). Likewise, the neck-level air-kerma measurements were converted to superficial dose $H_s^{neck,}$ and the waist level measurements were converted to deep dose $H_p^{waist,}$ corresponding to doses delivered to soft tissues at a depth of 10 cm (15). The effect of a 0.5-mm lead-equivalent protective apron to the values of H_p^{waist} was derived with use of broad-beam transmission data in lead for scattered radiation produced at diagnostic energies provided by Rawlings et al (16). The corresponding Hp and Hs values were used for calculation of the effective dose of the interventional radiologist with the additional protection of a thyroid collar shield according to the method proposed by Niklason et al (17).

Radiation exposure to the hands caused by scatter radiation was measured by use of calibrated LiF (TLD-200) crystals in thermoluminescent dosimetry (TLD) holding rings worn by the interventional radiologist during each procedure. All PTB procedures were performed without the use of protective gloves or spectacles. Crystals were calibrated with use of the same beam quality at the same C-arm unit used for the procedures, and they were read immediately after irradiation. TLD crystals located at the bases of the little finger on both hands have been reported to provide a reasonable estimate of dose to the exposed area of the hands (18,19).

Statistical Analysis

Statistical analysis was performed with MedCalc statistical software (Medcal, Belgium). A Kolmogorov-Smirnoff test verified that patient data followed a normal distribution. Analysis of variance was used to examine whether statistically significant differences existed between data from the three study groups. Linear regression analysis was used to test for relationships between variables. Results are stated as mean values ± 1 SD. A *P* value $< .05$ was considered to represent significance.

RESULTS

Demographic data and average operating parameters of radiation exposures recorded for study groups 1, 2, and 3 are presented in **Table 1**. There were no statistically significant differences between the three study groups. **Table 2** summarizes average DAP values recorded for fluoroscopy and digital radiography associated with biliary drainage and stenting. Left and right access, biliary drainage only, metallic stenting only, and drainage and metallic stenting in one session were considered. DAP values emanating from left access procedures were observed to be higher than right access PTB procedures. The majority of digital radiographs were taken with small C-arm angulations; therefore, DAP associated with radiographs are presented without a PA or LAO or RAO orientation. Left-access PTB procedures involved PA and RAO projection, requiring an average of 79% and 21% of total fluoroscopic time, respectively. A right-access PTB procedure involved a combination of LAO and PA projections requiring an average of 80 and 20% of procedure fluoroscopic time, respectively. Average fluoroscopy times for drainage and stenting in one session appeared to be smaller than the summation of average times related to separate sessions for drainage and stenting interventions (**Table 2**).

Figure 1 shows spatial distribution of DAP-normalized scattered air kerma doses (μGy per 1,000 cGy cm^2) at the neck, waist, and genital level of interventional radiology staff for PA, LAO, and RAO projections without under-couch protective shielding. **Figure 2** shows corresponding DAP-normalized scattered air kerma measurements with under-couch protective shielding. Normalized air kerma readings at the interventional radiologist's position for the PA, RAO, and LAO projections, are presented in **Table 3**. When protective shields are used, doses for all measured levels and projections were considerably reduced

Table 2
Average DAP Values (cGy cm²) for Fluoroscopy and Digital Radiography Associated with PTB Procedures

	Group 1		Group 2		Group 3	
	RA	LA	RA	LA	RA	LA
Projections	PA/LAO	RAO /PA	PA/LAO	RAO /PA	PA/LAO	RAO /PA
Average Fluoro (DAP)	1550/390	1670/440	1940/460	2060/490	1315/350	1440/360
Average DR (DAP)	300.4		274.8		325.8	
Average Time (min)	7.8		10.95		5.7	

Left and right access, drainage only, metallic stenting only, and drainage and metallic stenting in one session are presented. A RA-PTB uses a PA-LAO combination, whereas a LA-PTB uses a PA-RAO combination. A PTB stenting procedure is the second step of a two-session intervention, following a singe drainage procedure.
Note.—RA = right access; LA = left access.

(**Table 3**). For the LAO projection, air-kerma rates to the interventional radiologist appeared slightly elevated at the waist and neck level in comparison with the RAO projection. Air-kerma rates at the neck level were lower than those at the waist, because the radiologist's waist is closer to the source of scatter when the radiologist is standing adjacent to the patient.

Differences between air-kerma rates measured with the Rando phantom and those with real patients as the scattering source were less than 10%. Differences between air-kerma calculations performed with Monte Carlo techniques and air-kerma values from direct measurements were as much as 17%.

In **Table 4**, normalized dosimetric data concerning eye lens, face skin, and effective dose to the interventional radiologist wearing a 0.5-mm lead-equivalent apron are shown. Data are provided with and without the removable flexible under-couch protective shield of 0.5-mm lead equivalent thickness. Additionally, air-kerma values for the three positions along the vertical direction are quoted.

An overview of the dose data gauged by TLD crystals attached to the hands of the interventional radiologist is shown in **Table 5**. Doses to the left hand of the radiologist exceeded doses to the right hand in two-step procedures. Specifically, this effect was most notable in left access procedures because of the position of the hands on the left liver side of the patient. **Figure 3** shows doses for the left hand and right hand of the radiologist for all biliary procedures, plotted against DAP. A linear regression fit to the data is depicted. The correlation coefficients were 0.844 and 0.695 for the left and right hands, respectively.

DISCUSSION

Interventional radiology offers a cost-effective, nonsurgical, minimally invasive approach to several diagnostic and therapeutic interventions, diminishing hospitalization and discomfort to patients and decreasing morbidity of surgical procedures. However, interventional procedures have been reported to impart some of the highest doses to patients and staff from medical radiographs (20). Even if interventional radiology personnel are exposed to a small fraction of the radiation received by the patient, they still can collect a significant dose because of the increasing number of procedures taking place in an interventional radiology laboratory (20,21). European and national legislation has implemented requirements to optimize medical procedures involving high doses to patients and staff (22–25).

Occupational exposure from interventional radiology is higher than that from other fluoroscopy examinations (20). Moreover, exposure in the interventional radiology laboratory may not uniformly decrease with distance and may vary widely with beam angulation, staff positioning, and shielding. The head, neck, and unprotected extremities may be exposed to relatively high doses (20). Using projection-specific dosimetric data (**Figs 1 and 2**), operators may select positions that allow them to properly perform the interventional procedure and at the same time decrease their dose.

The annual effective dose limit that has been proposed by radiation protection authorities is 50 mSv (25,26). The annual limits to the skin, the lens of the eye, and the extremities are 500 mSv, 150 mSv and 500 mSv, respectively. Readings from personal dosimeters may provide an estimate of radiation exposure received by individual workers over a specified period of time. However, it is known that doses measured by these dosimeters do not represent effective dose. Therefore, maximum permissible workloads and radiogenic risks cannot be estimated from dosimeter readings. Two-monitor algorithms have been proposed that yield effective dose estimates in good agreement with experimental data (7,17). However, it is not common practice for staff working in interventional radiology laboratories to wear two dosimeters for personal dose monitoring. Isodose maps of DAP-normalized air-kerma doses at neck, waist, and gonad levels from all projections (**Figs 1 and 2**) can be used to accurately anticipate staff effective doses from PTB procedures in any interventional radiology laboratory according to the method of two dosimeters proposed by Niklason et al (17). To facilitate effective dose estimation, ready-to-use normalized effective doses for the radiologist's position are presented in **Table 4**. Effective dose can be calculated by simply multiplying normalized data by the total DAP value of the procedure. A single left-access PTB drainage procedure requiring 1,500 cGy cm² of total fluoroscopy and digital radiography results in an

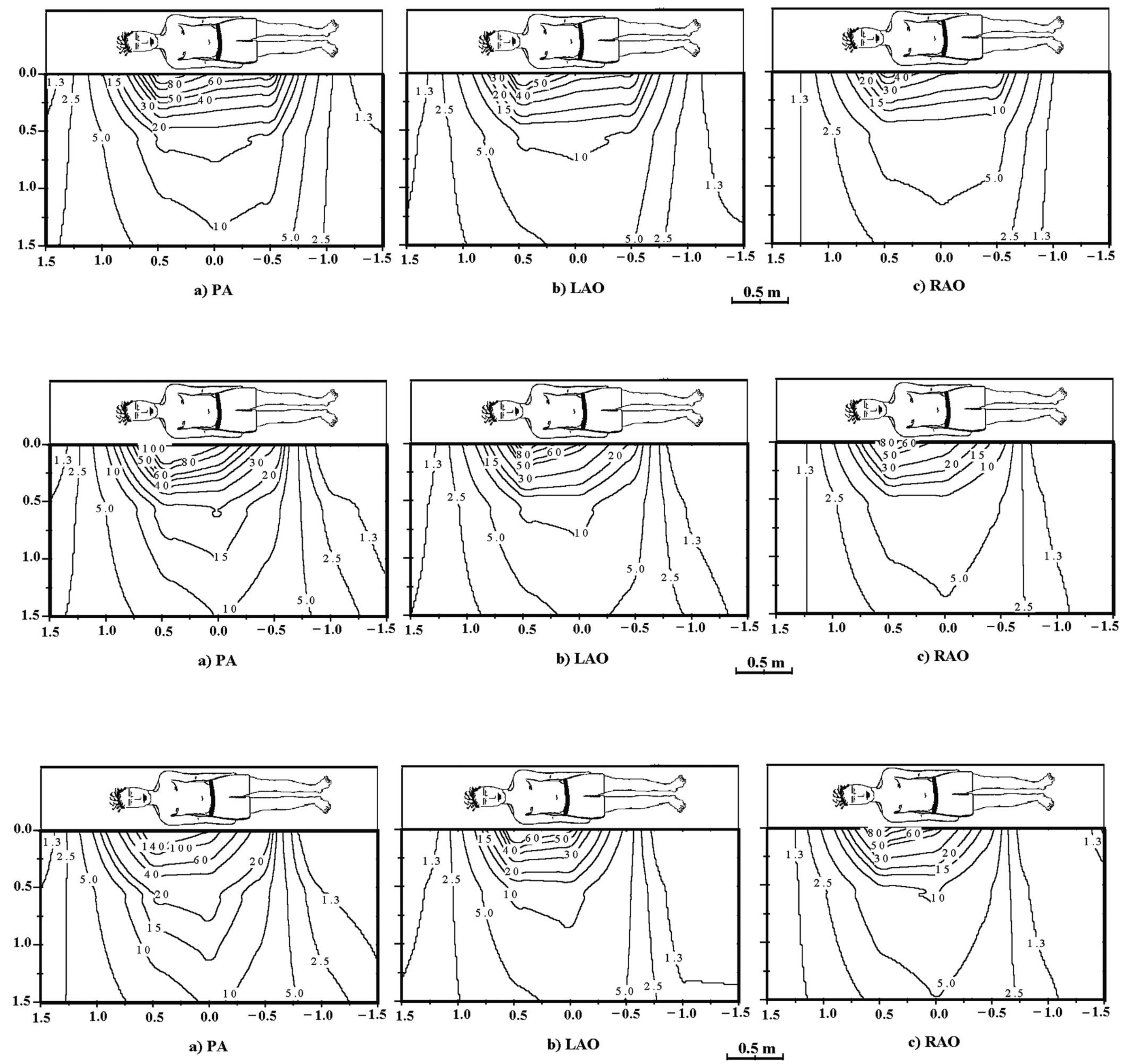

Figure 1. Spatial distribution of DAP-normalized air kerma doses (nGy/cGy cm^2) at operator's neck, waist, and gonad levels from PA **(a)**, LAO **(b)**, and RAO **(c)** projections without under-couch protective shielding. Row 1 represents distribution for the neck level, and rows 2 and 3 represent distributions for the waist and gonad levels, respectively.

effective dose of 9.3 μSv to a nonshielded worker. A right-access PTB drainage delivers 7.5 μSv to a nonshielded operator. A combined biliary drainage and stenting procedure requiring 2500 cGy cm^2 dispenses an effective dose of 12.5 μSv and 15.5 μSv to the radiologist performing a right- or a left-access approach, respectively. Accordingly, a left-access combined PTB procedure requiring 2,500 cGy cm^2 results in a 0.2-mSv abdominal surface dose for an unshielded pregnant interventional radiologist. This value decreases to 0.03 mSv for an unshielded operator when a 0.5-mm lead-equivalent under-couch shield is used. This is an important finding: an under-couch shield can significantly reduce exposure to interventional radiology personnel, especially at the gonad level.

Results of the present study indicate that maximum permissible workloads in PTB procedures should be estimated by use of the lenses as the critical organ (**Table 5**). Considering

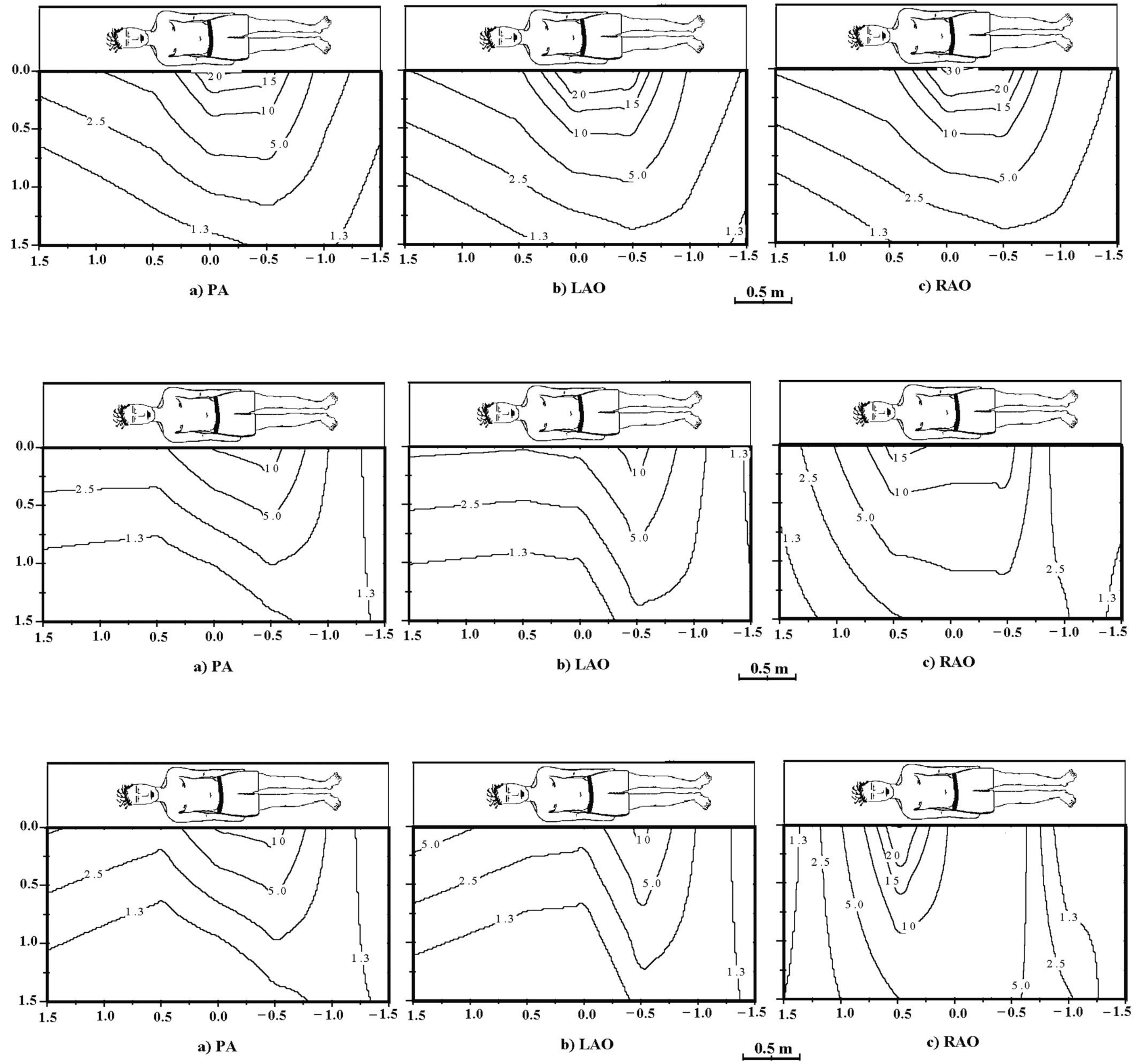

Figure 2. Spatial distribution of DAP-normalized air kerma doses (nGy/cGy cm^2) at operator's neck, waist, and gonad levels from PA **(a)**, LAO **(b)**, and RAO **(c)** projections with under-couch protective shielding. Row 1 represents distribution for the neck level, and rows 2 and 3 represent distributions for the waist and gonad levels, respectively.

150 mSv as the annual dose limit to the lens of a classified worker, and assuming a total DAP of a biliary drainage or stenting session of 1,500 cGy cm^2, an interventional radiologist could perform approximately 98 procedures per month without an under-couch protective shield. If a combined biliary and stenting procedure of 2,000 cGy cm^2 is taken into consideration, an interventional radiologist could perform approximately 74 combined procedures per month. If an under-couch protective shield is used, these numbers increase to 208 and 156 procedures, respectively. Although these workloads appear relatively high, substantial dose elevations may appear with regard to patient cooperation and applied technique. Additionally, patient size and technical aspects such as use of continuous rather than pulsed fluoroscopy, low x-ray tube filtration, and a large number of acquisitions may increase patient and staff doses and decrease maximum permissible workloads.

Moreover, maximum workloads can be determined for employees participating in more than one type of

Table 3
Normalized Air-Kerma Readings (μGy/1000 cGy cm^2) at the Interventional Radiologist's Position for Projections Commonly Used in PTB Procedures with and without Under-Couch Shielding

	PA	LAO	RAO
Without under-couch shielding			
Upper (neck level)	72	47	32
Middle (waist level)	100	58	44
Lower (genital level)	135	63	62
With under-couch shielding			
Upper (neck level)	21	30	33
Middle (waist level)	10	6	14
Lower (genital level)	10	4	9

Table 4
Normalized Dosimetric Data (μGy/1,000 cGy cm^2) at Interventional Radiologist's Position for Left- and Right-Access PTB Procedures

	Left Access	Right Access
Air-kerma (neck level)	24 (64)	28 (52)
Air-kerma (waist level)	11 (89)	9 (67)
Air-kerma (gonad level)	10 (121)	5 (78)
Eye lens dose (μGy/1000 cGy cm^2)	32 (85)	40 (69)
Face skin dose (μGy/1000 cGy cm^2)	34 (90)	35 (73)
Effective dose (μSv)	2.2 (6.2)	2.5 (5.0)

Numbers in parenthesis represent dose values obtained without under-couch shielding. Effective dose was calculated with the use of a 0.5-mm lead-equivalent apron and a 0.5-mm lead collar shield.

procedure. In this case, the dose should be anticipated separately for each type of procedure performed by the employee in the interventional radiology laboratory. Subsequently, the maximum permissible workload can be determined, taking into consideration the anticipated dose and the expected frequency of each type of procedure.

Workers who are exposed to radiation have the right to be informed of doses and risks emanating from any procedures performed. Effective dose data allow accurate estimation of radiation-induced risks from PTB procedures performed in an interventional radiology laboratory. Fatal cancer risks and radiation-induced hereditary effects can be determined by multiplying effective dose or gonadal doses by appropriate risk factors proposed by international radiation protection authorities (26,27).

Dose data presented in this study may also be useful for young workers of childbearing age and pregnant employees working in the interventional radiology laboratory. The ICRP has recommended that the unborn child of a pregnant employee should be protected by the application of supplementary equivalent dose limit of 2 mSv to the surface of the woman's abdomen for the entire pregnancy (28). Dose data presented in this study may be useful for retrospective determination of abdominal surface dose of a pregnant employee working in the interventional radiology laboratory during the first weeks after conception, when she is usually unaware of her pregnancy. Furthermore, using the curves presented in **Figures 1 and 2**, young women of childbearing age and pregnant staff may also select a zone of low abdominal exposure for minimization of radiation dose.

Doses to the hands without lead rubber protection were measured with TLD ring monitors. Interventional radiologists often find that lead rubber gloves interfere with tactile sensation, especially if fine-needle manipulation is required. Rings located at the base of little finger provide a reasonable estimate of dose to the hands, because the distance from the tips to the base is small owing to the clenched arrangement of the hand when they are handling catheters and stents. Larger inconsistencies are to be expected for the hand doses because hands are closer to the scattering source and dose is significantly dependent on operator's technique. This occurs commonly in biliary procedures in which the left hand remains close to the site of catheter access throughout the drainage or stenting procedure. A significant correlation ($P < .0001$) was observed between dose data for the left and right hands and total DAP of the procedures.

This study has its limitations. Interventional radiology personnel may participate in more than one type of procedure; therefore, maximum permissible workloads and risks should be anticipated separately for each interventional radiology procedure. However, normalized data are not available for all projections involved in procedures performed in the interventional radiology laboratory. Another limitation is that air-kerma measurements were carried out at specific heights from the floor representing neck, waist, and gonad levels of an average-height individual. However, the use of DAP normalized dose distributions to estimate radiation burden is the most realistic approach to the issue of occupational exposure during fluoroscopically guided PTB procedures. Aprons and under-couch shielding might offer effective radiation protection for workers involved in interventional radiology procedures. However, other radioprotective devices, such as ceiling-suspended or floor-mounted screens or shields, can also be used in PTB procedures. In these cases, a conservative approach is to use data produced in this study without the presence of protective shields to estimate the upper range of radiation doses to workers. This calculation will result in a conservative overestimate of the actual dose.

CONCLUSIONS

Normalized dose data presented in this study enable institutions to accurately quantify radiation doses, permissible workloads, and radiogenic risks delivered to medical personnel

Table 5
Dosimetric Data (mGy) for the Left and Right Hand of the Operator during Left-Access and Right-Access PTB Interventions

	Group 1		Group 2		Group 3	
	LA	RA	LA	RA	LA	RA
Dose						
Left hand (SD)	0.138 (0.12)	0.721 (0.99)	0.590 (0.13)	0.424 (0.12)	0.420 (0.3)	0.136 (0.26)
Right hand (SD)	0.047 (0.03)	0.284 (0.3)	0.601 (0.04)	0.842 (0.05)	0.070 (0.05)	0.042 (0.77)

Note.—LA = left access; RA = right access; SD = standard deviation.

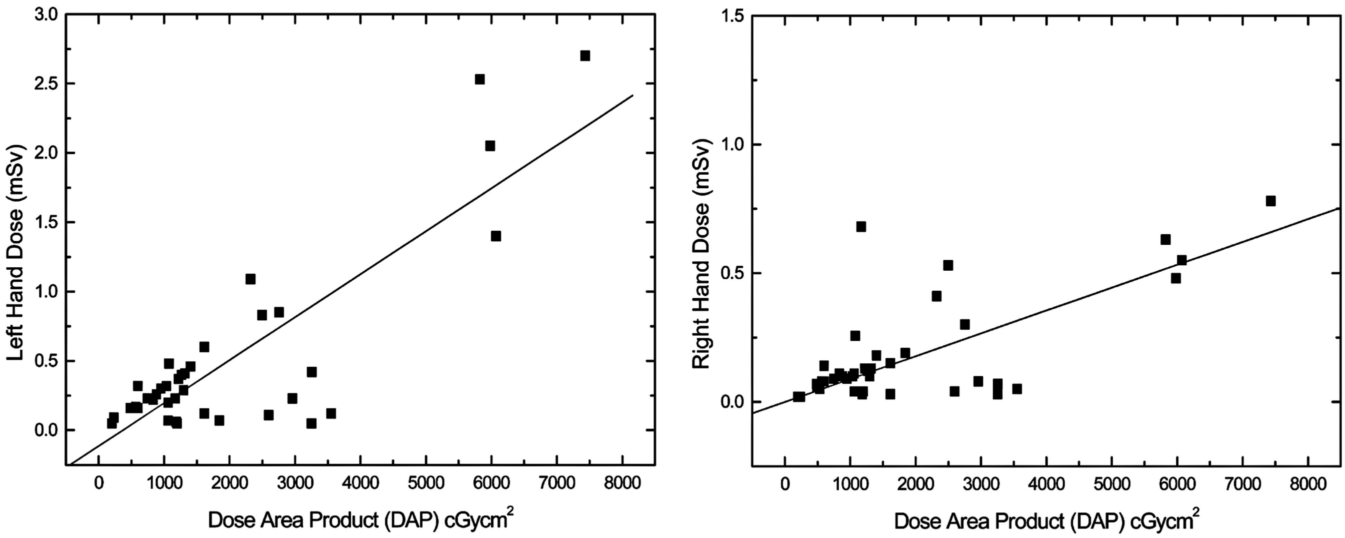

Figure 3. Hand dose plotted against DAP for all PTB procedures in the current study.

during PTB procedures. Using body level–specific normalized dose distributions, operators may select positions that allow them to properly perform the PTB procedure and at the same time decrease their dose. Our results indicate that the use of radioprotective under-couch shielding dramatically lowers occupational exposure, especially at the abdominal level. This information may be also useful for pregnant personnel working in interventional radiology laboratories. Hand doses derived from this study were found to be low. Doses to the left hand of the radiologist were larger than doses to the right hand. This may be attributed to the left hand's proximity to the patient.

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