Patient Doses from Noncardiac Diagnostic and Therapeutic Interventional Procedures

Ioannis A. Tsalafoutas, PhD, Helen Goni, PhD, Petros N. Maniatis, MD, Paris Pappas, MD, Nick Bouzas, MD, and George Tzortzis, MD

PURPOSE: To determine the patient doses during noncardiac diagnostic and therapeutic interventional procedures carried out in a dedicated angiographic unit.

MATERIALS AND METHODS: For 1,214 interventional procedures, the technique type, dose–area product (DAP), cumulative dose (CD), and fluoroscopy time were recorded. These procedures were classified into 23 categories (10 diagnostic and 13 therapeutic) that included nine to 259 patients each. For each category, descriptive statistical analysis was used to determine the characteristics of DAP, CD, and fluoroscopy time distributions. The statistical significance of the differences observed between categories in terms of DAP was assessed.

RESULTS: For the 23 categories studied, the median DAP values ranged from 0.2 to 176.8 Gycm ^{2}. In comparison with the literature, the mean and median DAP values in this study were within reported ranges for eight categories, greater for three, and less for six, whereas for the remaining six categories no relevant data were found in the literature.

CONCLUSIONS: Overall, the results of this survey indicate that the techniques used by the interventionalists, the operation skills of radiation technologists, and the performance of the x-ray unit present no obvious deficiencies in terms of patient radiation protection. However, for those procedures in which lower DAP values were found in the literature, it should be further investigated whether patient doses could be reduced without degradation of the diagnostic and therapeutic outcomes.

J Vasc Interv Radiol 2006; 17:1489–1498

Abbreviations: CD = cumulative dose, DAP = dose–area product, ESD = entrance skin dose

DURING the past 20 years the number of interventional radiology procedures has increased as a result of the diagnostic accuracy and therapeutic efficacy achieved with minimally invasive techniques (1). During this time, the technical advances of angiographic x-ray systems combined with the development of new devices and techniques for intervention have also contributed to the increase in the variety and complexity of these procedures.

One disadvantage of interventional radiology is that it involves ionizing radiation and can therefore cause significant patient radiation doses, as has been reported in several studies concerning a wide range of interventional radiology procedures (2–19). Indeed, many interventional radiology procedures require prolonged fluoroscopy times and the acquisition of many images, both of which contribute to increased exposure to patients and medical staff. As an immediate consequence, reports concerning the occurrence of deterministic effects in patients undergoing interventional procedures have steadily increased since the early 1990s (1). Acute skin reactions like erythema or epilation may require a skin dose of at least 2 Gy (the threshold for the onset of transient erythema in sensitive patients), but unfortunately doses of this magnitude are not considered uncommon for some complicated interventional radiology procedures. Even when the skin doses are below the threshold of 2 Gy, the stochastic effects of ionizing radiation are always of concern.

To estimate the risk related to the adverse effects of ionizing radiation, the effective dose is considered as the most suitable dosimetric quantity (20). The effective dose takes into account the doses received by all radiation-sensitive organs and is weighted for the sensitivity of each of them. Because the information required for the precise determination of effective dose is not available in clinical practice, effective dose is estimated indirectly on the basis of easy-to-measure dosimet-

From the Medical Physics Department (I.A.T.), Agios Savvas Hospital; Medical Physics Unit (H.G.) and Radiology Department (P.P., N.B., G.T.), "Laiko" Hospital; and Computed Tomography Department (P.N.M.), "Konstantopoulio-Agia Olga" Hospital, Athens, Greece. Received February 2, 2006; revision requested May 15; final revision received June 1; and accepted June 5, 2006. **Address correspondence to** I.A.T., 158 Kolokotroni, 162 31, Byronas, Athens, Greece; E-mail: j_tsalas@hotmail.com

None of the authors have identified a conflict of interest.

DOI: 10.1097/01.RVI.0000233526.17393.E4

ric quantities and appropriate conversion coefficients that have been determined for specific radiographic projections, or even for complete examinations, through detailed analysis of each examination procedure and the use of Monte Carlo techniques (21).

According to the National Protocol for Patient Dose Measurements in Diagnostic Radiology (22), the most appropriate quantity for examinations involving fluoroscopy and changes in the anatomic area irradiated is the dose–area product (DAP). In the same report (22), other dosimetric quantities like the entrance skin dose (ESD) and the entrance surface air kerma are also proposed for the measurement or estimation of patient dose. The interventional radiologic procedures always involve fluoroscopy as well as changes in the anatomic area, the x-ray field size, and the focus-to-skin distance, and therefore the DAP is the most appropriate quantity for patient dose monitoring. However, because many interventional radiologic procedures are associated with high skin doses, knowledge of the peak skin dose (PSD) is also required.

The precise determination of PSD is a difficult task that cannot be accomplished without use of several thermoluminescent dosimeters, radiochromic films, or specialized skin dose mapping software (4). Such equipment is not always available; therefore, a reasonable alternative is the measurement of cumulative dose (CD), defined as the air kerma at a reference distance from the focus (3,4). It should be noted that CD and DAP indicators are currently required for all International Electrotechnical Commission 60601–2-43–compliant interventional fluoroscopes (23). The CD may give a good estimate of PSD, provided that the x-ray entrance surface does not change significantly during the examination. When this is not the case, the CD may significantly overestimate the actual PSD, as reported by Miller et al (4). However, the knowledge of CD is always useful, because as long as it remains below 2 Gy, it is certain that the threshold for the onset of deterministic effects has not been exceeded except in cases in which the focus-to-skin distance is shorter than that usually assumed (~65 cm). When the CD is greater than 2 Gy, the procedure has to be further analyzed in terms of anatomic coverage to assess whether there is a high probability that the PSD has exceeded the threshold. Therefore, it can be decided whether follow-up of a specific patient for radiation injuries is required and whether the use of specialized equipment is necessary in procedures of this type to determine the actual PSD.

This article presents the results of a survey concerning the patient doses during noncardiac interventional procedures that have been performed by radiologists with a dedicated angiographic unit during approximately 16 months. Diagnostic and therapeutic interventional procedures were monitored, and each was classified in fairly broad categories. The survey data were analyzed and compared with other data available in the literature.

Table 1
Description of the Diagnostic Interventional Procedures Studied

Code	Description
D-1	DSA of the abdominal aorta, iliac, femoral, popliteal arteries with its trifurcations and arteries of the legs bilaterally
D-2	DSA of abdominal aorta and superselective DSA of renal arteries
D-3	DSA of the abdominal aorta, iliac, femoral, popliteal arteries with its trifurcations and arteries of the legs bilaterally and superselective DSA of renal arteries (ie, combination of D-1 and D-2)
D-4	Superselective DSA of common carotid and vertebral arteries with carotid bifurcations and intracranial branches in face and profile projections
D-5	Phlebography of the iliac veins and inferior vena cava
D-6	Superselective DSA of hepatic, splenic, and superior and inferior mesenteric arteries
D-7	Percutaneous cholangiography
D-8	DSA of abdominal aorta, iliac, femoral, popliteal arteries with trifurcations and arteries of the legs bilaterally; and superselective DSA of common carotid and vertebral arteries with carotid bifurcations and intracranial branches in the face and profile projections (ie, combination of D-1 and D-4)
D-9	DSA of celiac trunk and its branches (hepatic, left gastric, and splenic arteries)
D-10	DSA of aortic arch with its great branches (brachiocephalic, carotid, and vertebral arteries)

Note.—DSA = digital subtraction angiography.

Table 2
Description of the Therapeutic Interventional Procedures Studied

Code	Description
T-1a	Replacement of nephrostomy tube
T-1b	Nephrostomy ipsilaterally or bilaterally
T-1c	Removal of nephrostomy tube
T-2	Percutaneous cholangiography and stent implantation
T-3	Percutaneous balloon angioplasty of iliac arteries
T-4	Percutaneous balloon angioplasty and stent implantation (one, two or more vessels) of iliac, femoral, or renal arteries
T-5	Superselective embolization of different arteries
T-6	Nephrostomy and ureteral stent implantation of transplant kidney
T-7	Stent implantation of jugular or subclavian vein
T-8	Percutaneous balloon angioplasty of superficial femoral artery
T-9	Implantation of filter in the inferior vena cava
T-10	Percutaneous balloon angioplasty of renal arteries
T-11	Percutaneous balloon angioplasty and stent implantation of the subclavian artery