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Original paper

Organ and effective doses from paediatric interventional cardiology procedures in Chile

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ABSTRACT

The aim of this study was to present the results of organ and effective doses for paediatric patients for different types of interventional cardiology procedures for age and weight groups, derived from a patient dosimetry pilot programme carried out in Chile, under the auspices of the International Atomic Energy Agency.

Over seven years, a retrospective collection of demographic and patient dose data was obtained: age, gender, weight, height, number of cine series, total number of cine frames, fluoroscopy time, dose-area product (DAP) and cumulative dose at patient entrance reference point. Monte Carlo software was used to calculate organ and effective doses.

1506 procedures were divided into four age and seven weight groups. Organ doses (median values) for diagnostic and therapeutic procedures were: active bone marrow 0.90 and 0.64 mGy; heart 1.99 and 1.46 mGy; lungs 3.56 and 2.59 mGy; thyroid 1.27 and 0.83; and breast (in the case of females) 1.78 and 1.36 mGy. The ranges for effective doses (median values) and weight bands were 1.2–3.9 mSv for diagnostic procedures and 1.0–2.5 mSv for therapeutic procedures. The resulting conversion factors (median values) to estimate effective dose from DAP (in mSv/Gy.cm2) were: 1.70; 0.89; 0.58; and 0.40, for age groups of <1 year, 1–<5 years, 5–<10 years and 10–<16 years, respectively.

The obtained set of dose values will enable comparisons with other imaging procedures (comparing the same age bands) for justification and optimization purposes.

1. Introduction

Millions of children around the world with congenital and acquired heart disease undergo interventional cardiology procedures [1]. This situation undoubtedly provides tremendous benefits. However, there are also well-recognized risks to ionizing radiation [2]. It is therefore appropriate to identify organ doses in order to adequately assess risk and benefit for the justification and optimization of these procedures and to guide efforts in radiological protection.

Radiation exposure during paediatric interventional cardiology (PIC) procedures is one of the main issues to consider, because children have immature and still-developing organ and tissue structures and are hence more sensitive to ionizing radiation. These factors, as well as the potentially longer lifespan of these children, may significantly increase lifetime cancer risk [3–7].

According to the International Commission on Radiological Units (ICRU), the basic physical quantity used in radiological protection for stochastic effects such as cancer and heritable effects is the absorbed dose averaged over an organ or tissue [8]. Organ doses cannot be measured directly in patients undergoing interventional cardiac procedures. Nonetheless, they can be calculated to a reasonable approximation using the Monte Carlo calculation methods, provided that sufficient data are available on the X-ray examination technique [9].

Only a few studies have been published reporting organ doses to patients during PIC procedures [10–15]. Harbron et al. [16] report data from 36 studies performed between 2000 and March 2016 concerning paediatric doses during these procedures. However, papers reporting organ doses for different kind of procedures, age groups and patient weights are still non-existent for paediatric cardiology in the regions of Latin America and the Caribbean.

Therefore, the goal of this study was to determine organ doses in the most irradiated organs and effective doses for eleven common types of PIC procedures carried out in the largest paediatric

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hospital in Chile, categorized into age groups and patient weight bands. This work is part of a pilot program on patient dosimetry carried out under the auspices of the International Atomic Energy Agency (IAEA). Organ doses may be useful for justification and optimization of interventional procedures and for some epidemiological studies. These results will contribute to the evaluation of the paediatric population doses derived from PIC procedures in the regions of Latin America and the Caribbean for the UNSCEAR surveys. Effective doses may be of interest, as suggested by the ICRP, for comparing the relative radiation risk from different imaging procedures and for comparing the use of similar technologies and procedures in different hospitals and countries as well as the use of different imaging technologies for the same medical pathology, provided that the reference patient or patient populations are similar with regard to age and sex [8].

2. Materials and methods

The more familiar quantity of dose-area product (DAP) is used in medicine, equivalent to air kerma-area product (KAP) [9]. The cumulative dose (CD) quantity referred to in the standard IEC 60601-2-43 edition 2.0 [17] is equivalent to the incident air kerma (IAK) without backscatter at the patient entrance reference point, used to estimate skin dose. However, none of these dosimetric quantities can directly allow estimations of stochastic radiation risks and potential tissue reactions [8,18].

It should also be noted that the use of the CD display at the X-ray system for paediatrics may produce significant differences from the real skin dose values depending on patient thickness. The CD is calculated at 15 cm down from the isocentre, and in paediatrics patient skin may be at a shorter distance. Differences between the IAK reported by the X-ray system and the entrance surface air kerma (ESAK) measured by the authors and reported in a previous paper ranged from −25 to −45% (with larger differences for smaller children) [19].

The data presented in this paper have been obtained at the Luis Calvo Mackenna Hospital in Chile using the dose indicators values from the last seven years. This paediatric cardiovascular service has a cardiac laboratory with a biplane X-ray system (Siemens Axiom Artis BC, Siemens Inc., Erlangen, Germany) equipped with image intensifiers, with specific imaging protocols for paediatric procedures and with a properly calibrated ionization transmission chamber integrated into the collimator housing to measure DAP values [20,21]. This paediatric hospital was selected due to being the largest in Chile, responsible for approximately 50% (about 200 interventional procedures per year) of all PIC procedures nationwide. In Chile, the number of PIC procedures per million inhabitants and year ranges from 40 to 80 [22].

Data were collected over a seven-year period from January 2008 to December 2015. Despite DICOM radiation dose structured reporting not yet being enabled for the system in use, it was possible to extract the relevant data from the patient dose reports produced by the Siemens X-ray system at the end of each procedure. Patient dosimetric quantities were corrected with the appropriate calibration factor (0.81) for the frontal C-arm (derived from the table and mattress attenuation measured for the X-ray beam qualities in the system used). No correction factor was necessary for the lateral C-arm. The data collected for each procedure were: procedure type; age; gender, weight; height; DAP and CD (without the correction due to patient thickness); total number of cine images; and fluoroscopy time. Additional technical details are available in the dose reports produced by the X-ray system at the end of the procedures (see Fig. 1; C-arm angulations, kVp, mA, pulse time, added filtration, and so forth).

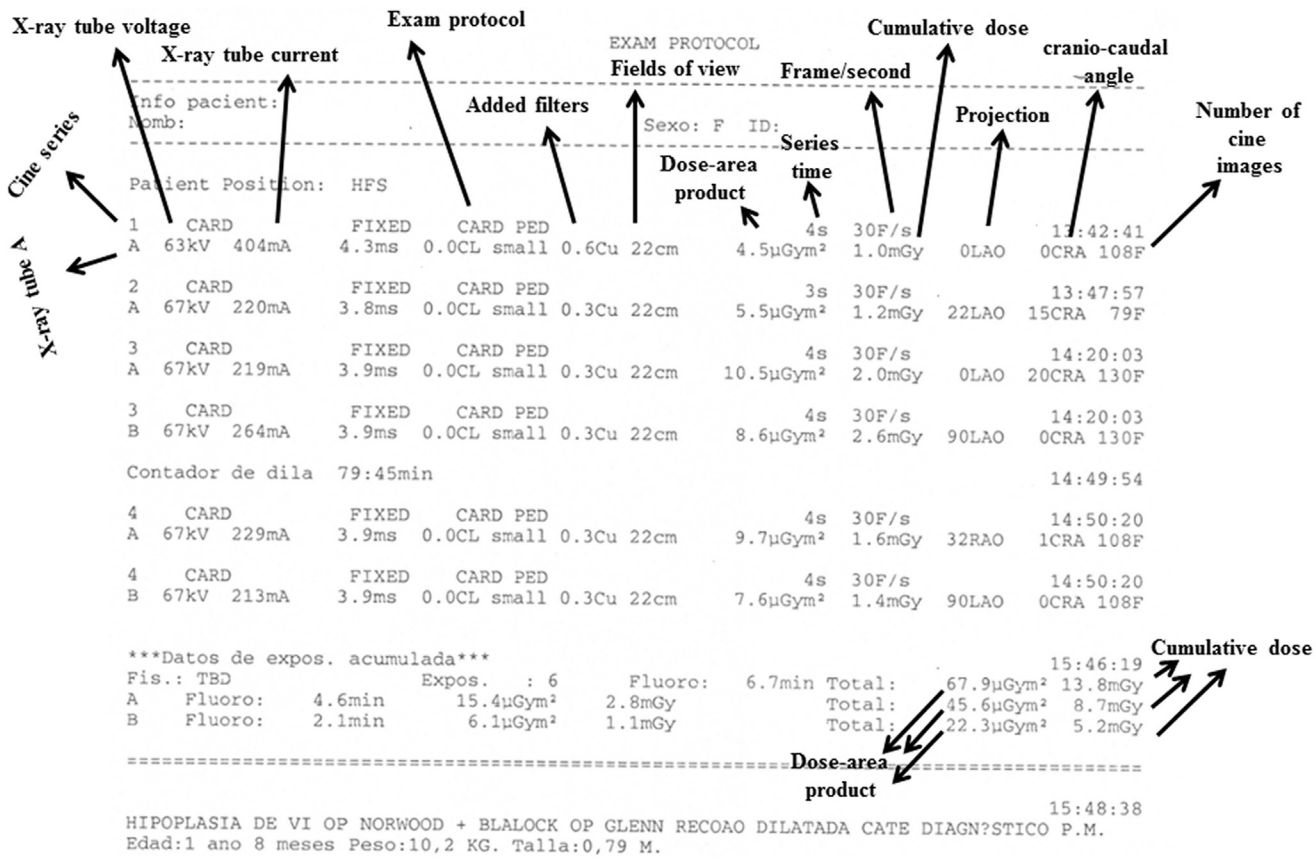

Fig. 1. Patient dose report from the X-ray system used.

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