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Choice of tube extremity for emission of the lowest radiation dose in pediatric patients

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ABSTRACT

Aims: To compare the dosage of radiation the thyroid and gonad glands receive in pediatric patients undergoing chest X-rays, in distinct positions, towards the goal of developing of an X-ray tube positioning protocol.
Methods: A randomized controlled clinical trial was carried out in the Pediatric Intensive Care Unit (PICU) at the Institute of Cardiology/University Foundation of Cardiology of Rio Grande do Sul, Brazil from June 2014 to September 2016. Patients were divided into two groups. One group was positioned with the thyroid gland facing the **anode** end of an X-ray tube, and in the other group the thyroid gland faced the **cathode** end. Radiographs were evaluated by five observers, following criteria recommended by the Commission of the European Communities (CEC).
Results: Forty-eight pediatric patients, with a mean age of 2.0 ± 1.3 years, participated in this study. Based on the evaluation of 48 images, it was determined that the thyroid and gonad glands facing the cathode were exposed to 13.3 ± 3.1 μGy and 13.5 ± 4.1 μGy of radiation, respectively ($p = 0.008$). Additionally, the thyroid and gonad glands facing the anode were exposed to 11.7 ± 3.1 μGy and 12.7 ± 3.1 μGy of radiation, respectively ($p = 0.007$). The mean input dose in the center of the chest was 20.8 ± 9.6 μGy in both positions.
Discussion: The proximity of the thyroid gland to the cathode end of the X-ray tube appears to be related to the dosage of ionizing radiation. Adverse effects associated with exposure to ionizing radiation could be minimized by positioning the thyroid gland to the **anodic** end of the X-ray tube.
Conclusion: Patients should be placed facing the anode end of the X-ray tube when taking thoracic X-rays, in order to reduce radiation exposure to the thyroid and gonad glands.
ClinicalTrials.gov Identifier: NCT02925936.

1. Introduction

Radiological imaging is an extremely valuable diagnostic tool used in pediatrics. Pediatric radiographic chest examinations are commonly used as an accompaniment in congenital heart disease (CHD) related surgical correction procedures, potentially exposing the patients to high levels of radiation [1, 2].

Due to the satisfactory results and low costs, the chest radiography scan is accepted worldwide as an accurate diagnostic method [2]. However, since the developing cells of young patients are particularly radiosensitive, pediatric radiographic examinations need to be performed with greater attention and precision.

With regards to CHD, an accurate diagnosis is essential for a successful treatment and outcome, and several techniques have been utilized. Transthoracic echocardiography (TTE) is a simple and non-invasive technique, but lacks the ability to clearly visualize the malformations of the great vessels. Cardioangiography (CAG) is the gold standard for CHD diagnosis; however, it is an invasive procedure. Multi-slice spiral CT is another non-invasive exam; however, the radiation dose and contrast media-related adverse reactions pose significant risks to children. With pediatric patients, they require the highest quality imaging techniques, so that exams do not need to be repeated [4]. Thus, a great deal of attention has been focused on developing protocols that minimize ionizing radiation exposure [3].

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It is well known that radiation, used in procedures for the diagnosis and/or treatment of diseases and complications, may also cause cancer [5]. In fact, one of the main consequences of X-ray radiographs, among young people, is the substantial radiation exposure to the thyroid gland, which may lead to thyroid cancer [6]. Monte et al. showed that about 10% of neoplasms usually occur in people younger than 21 years old, which represents 3% of all childhood neoplasms. Thus, the carcinogenic effect of radiation is particularly concerning in prepubertal individuals [7]. Worldwide trends indicate that medical radiation exposure has been increasing, due to cardiological procedures, and particularly in cases involving CHD [5].

In recent years, the deleterious effects of radiation exposure have been addressed, and greater attention has been given to the dosage used when taking radiographic images. The Commission of the European Communities (CEC) has developed quality criteria, suggesting the need to develop specific measurements for pediatric patients. The criteria focus on the quality of the images by using, as a rule, the most common exams in pediatric radiographic scanning, as well as the reference values for the Dose Area Product (DAP), which is also known as the Entrance Skin/Surface Dose (ESD) [8].

In 1998, the Brazilian National Health Care Surveillance Agency (ANVISA) published Ordinance N. 453, establishing radiological protection guidelines in Brazil. However, these guidelines were only aimed at adult patients. As a consequence, the pediatric dosage references were only related to adult dosages, without actually referring to the appropriate dosage for children [9].

With the increase in the number of available technologies in radiology, it is imperative that the techniques chosen expose the patients to minimal doses of radiation when performing radiographic exams, without losing the pattern quality needed for proper and accurate diagnosis [10, 11].

Thus, the objective of this study was to compare the dosage of radiation exposed to the thyroid and gonad glands of pediatric patients undergoing chest radiographies in distinct positions, so as to develop a standardized protocol that reduces radiation exposure, in these patients.

2. Methods

A randomized controlled clinical trial was developed and conducted from June 2014 to September 2016.

2.1. Population and place of study

After randomization, 48 patients aged 0 to 4 years old were included in the study (Fig. 1). The individuals were divided into two groups (24 for the **anode** end position and 24 for the **cathode** end position). Routine exams were performed at the request of the cardiologist. Data were collected from patients admitted to the Pediatric Intensive Care Unit (PICU) at the Institute of Cardiology/University Foundation of Cardiology (IC-FUC) of Rio Grande do Sul, Brazil.

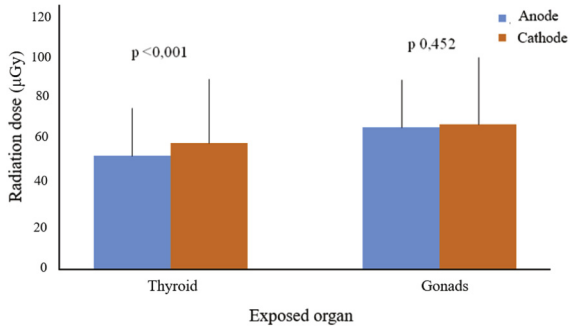

Fig. 1. Comparison of radiation dosages in the thyroid gland and gonads, at two X-ray tube positions.

2.2. Sample

According to the *Evaluation of dose patterns in pediatric radiology* [12], sample calculations considered differences significant when there was a significance level of ≤5%, with 80% of power with a standard deviation of 0.026 for the Dose Area Product (DAP) or Entrance Skin/Surface Doses (ESDs) in μGy, and an expected difference of 0.01 in mGy. The total number of subjects was 48, and 48 radio-photographic images were analyzed.

2.3. Inclusion criteria

The subjects who were included in the trial at the Pediatric Intensive Care Unit (PICU) had to be undergoing cardiac surgery at the IC/FUC of Rio Grande do Sul, were considered infants with an age of 0 (minimum age) to 4 years (maximum age), and had a chest X-ray exam requested by doctors.

2.4. Exclusion criteria

The individuals not admitted for the trial were pediatric patients with scans that failed to comply with the technical quality criteria for diagnostic radiographic images proposed by the CEC, as evaluated by the radiologist responsible for that exam report [8].

2.5. Ethical considerations

The study was designed in accordance with the International Ethical Guidelines for Biomedical Research Involving Human Subjects, Resolution N. 466/12. The project was approved by Research Ethics Committees (RECs) at IC/FUC of Rio Grande do Sul, under the number 4769/12 and was registered at ClinicalTrials.gov (NCT02925936).

2.6. Logistics

After being properly informed about the study, caregivers signed an Informed Consent Form. The variables evaluated in this study included: focal-receptor image distances, thickness of the thorax, as well as radiation exposure to the thorax, thyroid gland and gonad glands. Sociodemographic and clinical characteristics of each subject were also evaluated, and included weight and height for Body Mass Index (BMI) calculations, so as to determine if the children would be considered low weight.

The subjects were selected from pediatric patients in the Pediatric Intensive Care Unit of the IC/FUC of Rio Grande do Sul, who were administered an in bed chest X-ray exam. Twenty-four patients were radiographed with the **cathode** end of the X-ray tube facing the region to be studied (control) and the others were radiographed with the **anode** end facing the region to be evaluated (intervention).

The radiological imaging was performed by the researcher and four radiology professionals, and the exams were carried out using an in bed anteroposterior (AP) view, with a central ray oriented towards the center of the thorax at the nipple line [10]. A portable Shimadzu X-ray instrument, with 500 mA of current, was used for data collection [11]. Radiological imaging resulting from AP incidences fulfilled the criteria recommended by European Commission [8]. For the AP projections the following criteria were taken into consideration: symmetrical reproduction of thorax without rotation or basculation, reproduction of the costal grid above the diaphragm, clear reproduction of pulmonary vascularization (mainly in the periphery), clear reproduction of the trachea and proximal segment of the bronchi, clear view reproduction of the diaphragm and cost-phrenic angles, clear reproduction of the heart and aorta, visualization of the retrocardiac region of the lungs