ARTICLE IN PRESS

Physica Medica xxx (2015) 1–10

Contents lists available at ScienceDirect

Physica Medica

journal homepage: http://www.physicamedica.com

Original paper

Optimization of dose and image quality of paediatric cardiac catheterization procedure

Lukmanda Evan Lubis [a,*], Ika Bayuadi [a], Supriyanto Ardjo Pawiro [a], Kwan-Hoong Ng [b], Hilde Bosmans [c], Djarwani Soeharso Soejoko [a]

[a] Department of Physics, Faculty of Mathematics and Natural Sciences, University of Indonesia, 16424, Depok, Indonesia
[b] Department of Biomedical Imaging, Faculty of Medicine, University of Malaya, 50603, Kuala Lumpur, Malaysia
[c] Department of Imaging & Pathology, Catholic University of Leuven, 3000, Leuven, Belgium

ARTICLE INFO

Article history:
Received 19 February 2015
Received in revised form 24 April 2015
Accepted 14 May 2015
Available online xxx

Keywords:
Cardiac catheterization
Dose
Figure of merit
Image quality
Optimization
Paediatric

ABSTRACT

The purpose of this study is to quantify the quality of the available imaging modes for various iodine-based contrast agent concentration in paediatric cardiology. The figure of merit (FOM) was defined as the squared signal to noise ratio divided by a patient dose related parameter. An in house constructed phantom simulated a series of vessel segments with iodine concentrations from 10% or 30 mg/cc to 16% or 48 mg/cc of iodine in a blood plasma solution, all within the dimensional constraints of a paediatric patient. The phantom also used test inserts of tin (Sn). Measurements of Entrance Surface Air Kerma (ESAK) and exit dose rate were performed along with calculations of the signal-to-noise ratio (SNR) of all the objects. A first result showed that it was favourable to employ low dose fluoroscopy mode and lower frame rate modes in cine acquisition if dynamic information is not critical. Normal fluoroscopy dose mode provided a considerably higher dose level (in comparison to low dose mode) with only a slight improvement in SNR. Higher frame rate cine modes should be used however when the clinical situation dictates so. This work also found that tin should not be intended as iodine replacement material for research purposes due to the mismatching SNR, particularly on small vessel sizes.

© 2015 Associazione Italiana di Fisica Medica. Published by Elsevier Ltd. All rights reserved.

Introduction

Contrast-enhanced, fluoroscopically-guided interventions are the most common technique to both diagnose and treat cardiac conditions. Due to technological advancements, the technique is becoming a standard clinical procedure worldwide. To ensure clinical goals being achieved, complicated techniques with lengthy duration are often required [1,2], making cardiac interventional procedures the highest X-ray dose exam [3]. Also in paediatric cardiology, however, patient and staff doses should be “as low as reasonably achievable” (ALARA) [4].

Image quality is generated by means of iodine based contrast agents injected in the major arteries. Ideally it is worked at the lowest dose level compatible with just sufficient image quality. This optimal clinical working point is determined by the operational characteristics of the fluoroscopic device. For paediatric cases, optimization is even more stringent than in adults. Young patients are in their initial growth period, with high cell proliferation rate and, therefore, face more risk to DNA damage due to radiation [5]. Moreover, radiation exposure to children below the age of 15 years is two to three times more likely to induce cancer (averaged over all cancer types) than those to adults at the age of 45 years [6].

Whereas adult patients are normally undergoing catheterization procedures for acquired cardiac conditions, paediatric patients suffer from congenital cardiac diseases that often require subsequent investigation. It is not uncommon that a single paediatric patient undergoes up to 10 catheterizations before reaching adulthood [7]. In addition, the small arterial vessel size of young patients makes it a challenge to complete the procedures in due time [8]. Optimization is particularly important.

The peak tube voltage (kVp) is adjusted towards patient thickness during the procedures by the automatic exposure control (AEC) system. Previous works showed that the kVp has a direct impact on both patient dose and image quality and it is therefore often the first parameter being optimized in dedicated investigations [4,5]. The tube current (mA) is typically governed by manufacturer-predefined dose levels (i.e. modes) which are

* Corresponding author.
E-mail address: lukmanda.evan@sci.ui.ac.id (L.E. Lubis).

http://dx.doi.org/10.1016/j.ejmp.2015.05.011
1120-1797/© 2015 Associazione Italiana di Fisica Medica. Published by Elsevier Ltd. All rights reserved.

Please cite this article in press as: Lubis LE, et al., Optimization of dose and image quality of paediatric cardiac catheterization procedure, Physica Medica (2015), http://dx.doi.org/10.1016/j.ejmp.2015.05.011

selected at the start and further applied during the procedure as a function of the required image quality level. Optimization in the cath lab includes, next to kVp and mA, also the concentration of iodine-based contrast agents.

In order to study the combined effect of all these parameters, a single figure of merit, expressing the overall quality, is preferred. We propose to use the squared signal to noise ratio divided by ESAK.

Materials and methods

A Philips Allura Xper FD10 (Philips Medical System, Best, the Netherlands), in use in the Invasive Cardiology Department (Pertamina Central Hospital, Jakarta, Indonesia), was utilized during the whole work. The device was equipped with a 25 cm × 25 cm flat-panel detector system. Pixel size was 184 × 184 μm and 15 to 30 frames were acquired per second. The device was equipped with an MRC-GS 0508 x-ray tube and a voltage ranging from 40 to 125 kV. The maximum tube load was limited to 1250 mA at 80 kV. A performance check on the x-ray unit was performed in accordance with AAPM Report No. 70 [9] prior to the study.

PMMA slabs each of 2.5 cm thickness and with a FOV (Field of View) of 25 cm × 25 cm were used to simulate patients. A foil of 99.98% Sn (tin) of 127 μm thickness was obtained from Sigma–Aldrich chemicals. Tin was selected for its K-edge similarity with iodine [10] and was used to represent the 100% iodine concentration.

Omnipaque Iohexol (GE Healthcare, Shanghai, China) with iodine concentration of 300 mgI/cc was used in this study. The contrast agent was mixed with blood plasma in different concentrations to mimic the clinical situation. Actual blood plasma, obtained from the Indonesian Red Cross (Jakarta representative), was used as solvent for the iodine-based contrast agent. It was selected for its blood fluid property without leaving stains on the phantom.

An in-house phantom and additional PMMA plates were used to simulate patients. In the in-house phantom of 5 cm thickness (Fig. 1), twenty cylinders, representing vessels with five diameters (8 mm, 6 mm, 4 mm, 2 mm, and 1 mm), were drilled 4 cm deep into the PMMA at fixed evenly spaced distances. Homogenous stacks of PMMA were put such that the dedicated stack with the cylindrical holes was in the middle of the slab. Each 'vessel' diameter was drilled multiple times to allow the study of iodine-based contrast medium with a series of concentrations. We matched the weight data released by the Indonesian Ministry of Health [11] with the data of our patients. Our paediatric cases are typically 3.5 kg, corresponding to a PMMA thickness of 9.3 cm for the PA projections, see Appendix I [12]. Technical factors endorsed the use of 10 cm thickness for simulating patients. Therefore, a pair of PMMA slabs of each 2.5 cm thick were used to sandwich the in-house phantom in order to achieve the matching thickness. The high purity Sn foil was cut following the sizes of the artificial vessels and vessel like strips were placed in the phantom.

Preparation

As administration of iodine-based contrast agents are limited to no less than 1 cc/kg body mass [13] and the typical body masses for Indonesian paediatric patients aged 0–59 months are between 2.5 and 4 kg [11], the iodine-based contrast agent quantity in the blood plasma solvent for simulating the clinical situation in this work was chosen accordingly. The solvent-combining procedure was performed in the Faculty of Pharmacy, University of Indonesia, using a laboratory-class blood-handling protocol. The resulting concentrations of iodine-based contrast agent in blood plasma, as enlisted on Table 1, were injected into the artificial vessels of the in-house phantom to simulate iodine contrast agents in cardiac arteries.

Experimental arrangements

The overall geometry was set in accordance with typical clinical use. Figure 2 shows how the gantry and phantoms were set in position. The commonly-used postero-anterior position was applied, with minimum distance between the phantom and the FPD (Flat Panel Detector) surface. Measured distances between tube focus to FPD and focus to phantom entrance layer were 87 cm and 75 cm, respectively. To mimic the existing clinical situation in the facility, the anti-scatter grid was present during all exposures.

A pair of 2.5 cm-thick PMMA slabs was positioned on and below the in-house phantom to obtain a total of 10 cm thickness in accordance with typical paediatric patient thickness. Two dosimeters were used to measure incidence dose at the one hand and dose with backscatter at the other hand.

Imaging parameters

The exposures were made under the operation of the AEC for fluoroscopic and cine acquisition modes. In fluoroscopic mode, there exist three dose modes (low, normal, and high), while cine modes were available in two pulse-rates (15 and 30 fps). In the cine modes, there exist post-acquisition filtration algorithms (displayed as 'low contrast' and 'high contrast' modes) that did not influence the radiological parameters. Table 2 lists the exposure parameters for each mode as chosen by the AEC for the 10 cm-thick object.

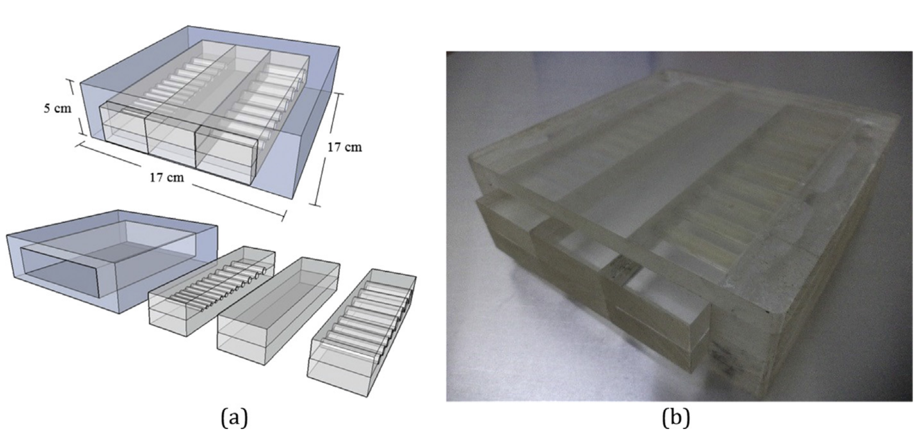

Figure 1. (a) Design and (b) actual photograph of the in-house phantom.

Please cite this article in press as: Lubis LE, et al., Optimization of dose and image quality of paediatric cardiac catheterization procedure, Physica Medica (2015), http://dx.doi.org/10.1016/j.ejmp.2015.05.011

Download English Version:

https://daneshyari.com/en/article/10732089

Download Persian Version:

https://daneshyari.com/article/10732089

Daneshyari.com