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Impact of low dose settings on radiation exposure during pediatric fluoroscopic guided interventions

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ABSTRACT

Purpose: To evaluate the effects of lowering the detector entrance exposure in children undergoing interventional radiology procedures.
Materials and Methods: The study retrospectively investigated radiation dose levels in pediatric patients aged 0–18 years before (n = 39) and after (n = 26) lowering detector entrance dose, undergoing embolization of peripheral Arteriovenous malformations, Portal Vein Interventions or Percutaneous Transhepatic Cholangio Drainage (PTCD) between 2014 and 2017. Patient characteristics, fluoroscopy time, protocols used as well as resulting Skin Dose and Dose Area Product (DAP) were compared in each cohort. Image quality was assessed by two independent readers.
Results: The two patient cohorts did not differ in terms of patient demographics. Similarly, fluoroscopy time did not differ before and after implementation of the low dose settings. An overall reduction of skin dose of 75.1% for AVM embolizations, 80.5% for Portal Vein Interventions and 85.3% for PTCD placement was observed. The DAP decrease was 82.5% for AVM embolizations, 72.2% for Portal Vein Interventions and 79.8% for PTCD placement. Image quality was generally considered to be good with an insignificant difference between pre and post implementation of the low dose approach and good agreement between the two readers. Manual inroom-switching to higher dose levels was possible, however this was not performed more frequently after implementation of the low dose settings.
Conclusion: Lowering the detector entrance dose in pediatric interventional radiology procedures results in a significant decrease of the radiation dose burden.

1. Introduction

The number of pediatric interventional procedures is continuously increasing. At the same time, surgery keeps pushing the limits such as in pediatric liver transplantation, requiring interventional radiology support to manage associated complications. Additionally, paradigm shifts have placed interventional radiology as the treatment option of choice, e.g. in case of vascular malformations. Associated with the increase in pediatric interventional radiology procedures comes an increase in radiation exposure to the pediatric patient population and thus the ALARA principle (as low as reasonably achievable) is becoming increasingly important. A comprehensive report investigating the use of interventional procedures in 20 countries, including developing countries, has emphasized the need to promote radiation safety precautions especially for pediatric patients [1].

While robust data about fluoroscopy dose metrics has been collected in adults [2–4], most of the knowledge regarding pediatric fluoroscopy dose metrics during interventional procedures is obtained from cardiac catheterization procedures as well as neuroradiological interventions [5,6]. Only recently, comprehensive data on pediatric radiation doses have been reported and reference levels for pediatric interventional procedures have been suggested [7]. However, only little is known regarding radiation dose in pediatric interventional procedures of the abdomen and extremities. Multiple efforts to improve radiation safety

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and to adhere to the ALARA principle have been reported in the literature, including the 'Image Gently, Step Lightly' campaign, launched in 2009 [8,9]. Since then, increasing effort to reduce fluoroscopy dose metrics during pediatric interventional procedures has been made. Recently the first direct measurements of effective dose levels using pediatric anthropomorphic Rando-Alderson phantoms for abdominal interventional procedures have been published [10]. Further modification of preset parameter settings in a dedicated pediatric fluoroscopy program allowed for an additional reduction of the effective dose, up to 27% for the fluoroscopy mode and up to 63% for digital subtraction angiography [10]. This suggested that significant lowering of patient exposure can be reached, which has to be further explored in vivo.

The purpose of the current study was therefore to compare patient dose exposure in a pediatric patient population before and after optimization of preset parameters. Aim was to prove that reduction of the detector entrance dose, as previously investigated in a phantom setup, leads to a significant reduction of the skin entrance dose as well as the dose area product during interventional procedures in different pediatric patient populations, without impairment of image quality.

2. Material and methods

2.1. Patients

Ethics committee waived the need for approval due to the retrospective character of the study. The study was conducted according to the Declaration of Helsinki.

In order to compare radiation fluoroscopy dose metrics, both the skin dose as well as the dose area product (DAP) were compared in two pediatric patient populations undergoing interventional procedures, before and after adjustment of the detector entrance dose. Patients prior to modification of the detector entrance dose were included from March 2013 to April 2015, the recruitment period after adjustment of the preset parameter settings ranged from May 2015 to February 2017. Three subgroups of patients were analyzed: Patients undergoing embolization of arteriovenous malformations of the extremities (AVM), patients undergoing portal vein interventions as well as patients undergoing initial placement of Percutaneous Transhepatic Cholangio Drainage (PTCD) following split liver (living donor) transplantation (Table 1).

2.2. Angiography equipment

Both fluoroscopic and angiographic acquisitions were performed on an Artis zee biplane angiography unit (Siemens Healthcare GmbH, Forchheim, Germany), equipped with a state-of-the-art flat panel detector (30 cm × 40 cm).

2.3. Interventional procedures

All interventional procedures were performed under general anesthesia.

Treatments of arteriovenous malformations of the upper arm, forearm, upper and lower leg were performed using ethylene vinyl alcohol copolymer (Onyx, Medtronic) predominantly via transartrial approaches. However, in some cases due to complex anatomy additional direct puncture of high-flow malformations had to be performed to bring the embolization agent to the target. Embolizations were performed using both the antegrade and retrograde plug and push technique via multiple microcatheter positions applying catheters with detachable tips, as previously described [11]. Collimation was limited to the region of interest where the embolization was performed.

Portal vein interventions included both portal vein recanalization in hepatic transplant recipients by Percutaneous Transluminal Angioplasty (PTA) including stent placement, if required. Segment II and III from living donors were used as orthotopic transplant grafts, rendering an aberrant anatomy compared to the regular pediatric liver. Additionally, occlusion/embolization of porto-systemic shunts in Abernethy malformations were investigated. Those were performed either through a transhepatic or transjugular approach (or both). Access to the portal system was routinely gained via ultrasound guided puncture and subsequently fluoroscopy and DSA was used for image guidance.

Percutaneous Transhepatic Cholangio Drainage (PTCD) procedures were performed for biliary drainage in hepatic transplant recipients following living donor split liver transplantation and associated biliary strictures. Similarly, access to the biliary system was obtained via ultrasound guided puncture and subsequent navigation was performed by fluoroscopy and DSA guidance. Crossing of biliary strictures was performed using various 4 French catheters with placement of Locking-Loop drains of various size.

All treatments were performed by either one of two different operators with 23 and 11 years of experience in pediatric interventional radiology, who did not change during the course of the study.

Table 1
Dose parameters.

	Fluoroscopy		DSA acquisitions	
Dose parameters	Preset parameters	Modified parameters	Preset parameters	Modified parameters
Tube Voltage (kV)	70	70	66	66
Entr. Dose (nGy/pulse)	29	18	1200	540
Frame/sec	7.5	7.5	2	2

2.4. Acquisition protocols

All procedures were performed routinely in a monoplanar manner, however when required in complex anatomical situations, the biplane mode was applied. The fluoroscopy/DSA unit used in this study allowed for three different preset parameter settings in fluoroscopy mode (triplet) per exam set with continuously increasing radiation dose. Routinely, procedures were commenced using the lowest setting, and if required due to impaired image quality, switching to higher dose settings in a stepwise manner could be performed on the inroom-display by the operator. A remote connection to the manufacturer allowed for exact retrospective tracking of the operator's performance, e.g. protocol used, fluoroscopy time as well as tube and detector parameters. Similarly, each switch to higher dose settings was recorded.

Collimation was performed as narrow as possible to the region of interest. Scatter grids were removed for all children < 15 kg body weight as well as for peripheral interventions of the extremities.

Modification of preset parameter settings was performed adjusting the detector entrance dose (see Table 1). In a previously reported phantom study these modifications led to a reduction of the effective dose of up to 27% for fluoroscopy and up to 63% for DSA [10]. Automatic Exposure Control (AEC), which performs automatic adaption of tube current and voltage, exposure time, focal spot and filtration, was routinely applied.

Protocol used for the particular intervention, patient demographics, fluoroscopy time as well as resulting Skin Dose and Dose Area Product were compared between the two cohorts.

2.5. Data analysis and statistics

Skin entrance dose as well as dose area product were compared before (pre) and after (post) adjustment of preset parameters settings in