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Research article

Noise reduction angiographic imaging technology reduces radiation dose during bronchial artery embolization

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ABSTRACT

Purpose: Comparison of radiation doses in patients undergoing angiographic bronchial artery embolization (BAE) before and after a noise reduction imaging technology upgrade.

Methods: We performed a retrospective study of 70 patients undergoing BAE. Procedures were performed before (n = 32) and after (n = 38) the technology upgrade containing additional filters and improved image-processing. Cumulative air kerma (AK), cumulative dose area product (DAP), number of exposure frames, total fluoroscopy time and amount of contrast agent were recorded. Mean values were calculated and compared using two-tailed *t*-tests. DSA image quality was assessed independently by two blinded readers and compared using the Wilcoxon signed-rank test.

Results: Using the new technology resulted in a significant reduction of 59% in DAP (149.2 (103.1–279.1) vs. 54.8 (38.2–100.7) Gy*cm^2, $p < 0.001$) and a significant reduction of 60% for AK (1.3 (0.6-1.9) vs. 0.5 (0.3-0.9) Gy, $p < 0.001$) in comparison to procedures before the upgrade. There was no significant difference between the number of exposure frames in both groups (251 ± 181 vs. 254 ± 133 frames, p = 0.07), time of fluoroscopy (28.8 (18.5-50.4) vs. 28.1 (23.3–38.7) min, p = 0.73), or the amount of contrast agent used (139.5 ± 70.8 vs. 163.1 ± 63.1 ml, p = 0.11). No significant difference regarding image quality could be detected (3 (2,3) vs. 3 (2–4), p = 0.64).

Conclusions: The new angiographic noise reduction technology significantly decreases the radiation dose during bronchial artery embolization without compromising image quality or increasing time of fluoroscopy or contrast volume.

1. Introduction

Massive hemoptysis is a potentially life-threatening pulmonary emergency [1]. Patients with chronic inflammatory lung diseases such as tuberculosis, sarcoidosis and cystic fibrosis develop hypertrophied and fragile bronchial arteries that may lead to hemoptysis. Surgical intervention is hazardous and often impossible in these patients with diffuse parenchymal lung disease [1]. Angiographic bronchial artery embolization (BAE) has proven to be an effective treatment for the control of bleeding [2].

However, angiographic BAE is associated with the risks of ionizing radiation and iodinated contrast agents [3]. Difficult anatomic conditions due to previous thoracic surgery, previous embolizations, or anatomical variants of bronchial artery origins may increase the required radiation dose and amount of contrast agent [4,5]. The total cumulative dose for a single BAE intervention ranges from 0.2–2.7 Gy [6]. However, recurrent bleeding-rates of 10–55% [7,8] require repeated BAE interventions, further increasing the cumulative radiation dose.

In order to reduce the radiation burden [9–11], various dose reduction techniques for angiographic procedures have been established [12,13]. Recent noise reduction imaging technologies allow for reduced radiation doses, while maintaining adequate image quality. Recently, the image-processing technology upgrade AlluraClarity (Philips Healthcare, Best, The Netherlands) for noise reduction of angiographic systems has been introduced [14]. However, the degree of dose reduction varies and depends on the area of the body examined [15,17]. The dose reduction ranges from 43% for cardiac electrophysiological interventions to 83% for iliac angiography [14,16]. Up to now, the dose reduction potential of the AlluraClarity update has not been assessed in

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patients undergoing BAE. The aim of our study was therefore to compare radiation doses in patients undergoing angiographic BAE before and after the noise reduction imaging technology upgrade.

2. Materials and methods

2.1. Study design and patient demographics

The local institutional review board approved our retrospective single-center study and waived the requirement for informed consent. The single-center study was performed at our university medical center [BLINDED FOR REVIEW]. Between 03/2012 and 10/2016 a total of 91 BAE have been performed at our department using an Allura FD20 angiographic system (Philips Healthcare, Best, Netherlands). The image-processing system was upgraded in June 2014 from Allura Xper FD20 to AlluraClarity FD20 (Philips Healthcare, Best, Netherlands). We excluded 10 patients with repeated BAE after a relapse (11%), avoiding a statistical bias regarding age and weight. Furthermore we excluded 11 patients requiring complex procedures such as occlusion of multiple vessels and included 70 patients with BAE procedures treating a single bleeding lesion. 25 patients (35%) were referred to our department with relevant hemoptysis of a known cystic fibrosis, 21 patients (30%) with an oncologic history, 9 patients (12%) after a thoracic operation and 15 patients (21%) of unknown cause (e.g. infection) from the emergency room. The AlluraClarity cohort (study group) consisted of 38 consecutive patients that underwent BAE between 06/2014 and 10/2016 after the AlluraClarity upgrade. The Allura Xper cohort (control group) consisted of 32 consecutive patients that underwent BAE between 03/2012 and 05/2014 before the upgrade. Patient's demographics are shown in Table 1.

2.2. Imaging systems

The AlluraClarity noise reduction technology includes real-time image processing-algorithms, optimized hardware and adjusted acquisition parameters per body area [14]. Regarding thoracic fluoroscopy specific parameter changes include a lowered pulse width (7.0 vs. 3.5 ms) and reduced focal spot size (0.7 vs. 0.4 mm) using AlluraClarity compared to Allura Xper. During DSA AlluraClarity employs additional 1.0 mm aluminum and 0.1 mm copper filters. Besides the hardware changes, AlluraClarity involves real-time motion compensation, spatial and temporal noise reduction and image enhancement as described before [15]. These algorithms reduce motion artefacts and improve edge imaging at the same time. Therefore further dose reduction can be achieved maintaining sufficient diagnostic image quality.

2.3. Bronchial artery embolization (BAE)

BAE is a standardized procedure at our institution that has been performed in all cases by board certified radiologists with 2–20 years of experience in interventional radiology. After placing a 5F-Pigtail catheter (Tempo, Cordis, USA) in the distal aortic arch, thoracic overview images were acquired using DSA in anterior-posterior, left anterior oblique (LAO) and right anterior oblique (RAO) orientation. DSA was performed using a mechanical iodine contrast agent injection of 30 ml and a flow rate of 20 ml/sec (Imeron 300, Bracco, Italy). Ostia of bronchial arteries were probed selectively with a 5F-Mikaelsson catheter (Impress, Merit Medical, USA) or 4F- or 5F-Sidewinder catheter (Radifocus, Terumo, Japan). Ostia of the hemorrhage-feeding vessel were identified using a 5–6 ml manual injection of contrast agent and DSA. Thereafter a 3F-microcatheter (Maestro, Merit Medical, USA) was placed in the hemorrhage feeding bronchial artery. Embolization was performed with polyvinyl alcohol (PVA) particles (Contour 350-500 µm, Boston Scientific, USA) and/or microcoils (Interlock IDC, Boston Scientific, USA). After embolization further DSA runs were performed to confirm termination of bleeding. Details of this procedure have been described elsewhere [1–3].

Table 1
Patient demographics.

Patient characteristics	Allura Xper	AlluraClarity	p-value
Number of patients	32	38	
Female	18 (56%)	20 (52%)	
Age	51.1 ± 16.7	53.7 ± 17.8	0.32
Body mass index (kg/m^2)	22.1 ± 2.5	23.0 ± 1.8	0.08

Note − Data presented as mean ± standard deviation; * = significant.

2.4. Radiation dose measurement and documentation

The deterministic effect of radiation is associated with the patient's entrance dose, measured as air kerma (AK) [18]. AK describes the energy transferred from radiation to the specified mass of air measured in Gray (Gy). Stochastic effects are reflected by the dose area product (DAP). DAP is defined as the absorbed dose of an irradiated area, expressed as Gy*cm^2 and measured by an ionization chamber placed beyond the X-ray collimators [19]. Radiation Dose Structured Reports (RDSR) before and after the technology upgrade were automatically created after each procedure and transferred into the Picture Archiving and Communication System (PACS) [20]. RDSR contain the cumulative AK, DAP, total fluoroscopy time and number of exposure frames. The total amount of contrast agent of each procedure was extracted from the documented list of material usage.

2.5. Image quality assessment

Two radiologists, each with 3 years of experience in interventional radiology independently performed a qualitative DSA image analysis. Randomized DSA images of the regional bronchial arteries before embolization were assessed. The readers were blinded to the imaging technology. Window and image settings were maintained as default settings. The two readers determined separately the visibility of bronchial arteries using a four-point Likert scale [17]: 4 = excellent, clear visualization of small distal bronchial arteries; 3 = good, visualization of subsegmental arteries; 2 = fair, visualization of segmental arteries; 1 = acceptable, visualization only of the proximal bronchial artery ostium.

2.6. Statistical analysis

Results of AK, DAP, fluoroscopy times, age and BMI were compared using two-tailed *t*-tests. Likert scale variables with non-Gaussian distribution were compared using a Wilcoxon-Mann-Whitney test. For inter-rater reliability Cohen's weighted kappa was calculated. P-values < 0.05 were considered statistically significant. Statistical analyses were performed with Quick Calcs 2015 (Graphpad Software, La Jolla, CA) and SPSS 22.0 (IBM Corp., Armonk, NY).

3. Results

3.1. BAE procedures

There was no significant difference between the Allura Xper (n = 32) and AlluraClarity (n = 38) group regarding age and BMI (Table 1). There was also no significant difference between the Allura Xper and AlluraClarity group regarding fluoroscopy time (28.8 vs. 28.1 min, p = 0.73), number of exposure frames (251 vs. 254 frames, p = 0.07), and the amount of contrast agent (139.5 vs. 163.1 ml, p = 0.11) as shown in Table 2.