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Radiation dose reduction during transjugular intrahepatic portosystemic shunt implantation using a new imaging technology

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ABSTRACT

Objective: To compare patient radiation dose in patients undergoing transjugular intrahepatic portosystemic shunt (TIPS) implantation before and after an imaging-processing technology upgrade.
Methods: In our retrospective single-center-study, cumulative air kerma (AK), cumulative dose area product (DAP), total fluoroscopy time and contrast agent were collected from an age- and BMI-matched collective of 108 patients undergoing TIPS implantation. 54 procedures were performed before and 54 after the technology upgrade. Mean values were calculated and compared using two-tailed *t*-tests. Two blinded, independent readers assessed DSA image quality using a four-rank likert scale and the Wilcoxcon test.
Results: The new technology demonstrated a significant reduction of 57% of mean DAP (402.8 vs. 173.3 Gycm^2, $p < 0.001$) and a significant reduction of 58% of mean AK (1.7 vs. 0.7 Gy, $p < 0.001$) compared to the precursor technology. Time of fluoroscopy (26.4 vs. 27.8 min, $p = 0.45$) and amount of contrast agent (109.4 vs. 114.9 ml, $p = 0.62$) did not differ significantly between the two groups. The DSA image quality of the new technology was not inferior (2.66 vs. 2.77, $p = 0.56$).
Conclusions: In our study the new imaging technology halved radiation dose in patients undergoing TIPS maintaining sufficient image quality without a significant increase in radiation time or contrast consumption.

1. Introduction

Diagnostic and interventional procedures have steadily increased over the last decades [1]. Therefore the ALARA (as low as reasonable achievable) principle concerning radiation exposure becomes more and more relevant [2]. Radiation exposure during fluoroscopy or digital subtraction angiography (DSA) is associated with deterministic radiation injuries and stochastic effects with increased cancer-risk and genetic alterations [3–7]. These risks are especially relevant for young and obese patients, undergoing repeated and complex procedures [8]. Increased amounts of scattered radiation may even concern operating staff as well [1].

Patient and operator radiation doses during angiographic interventions have been intensively observed over the past decades [9]. Various concepts of reasonable dose reduction techniques for angiographic procedures have been established [10,11].

Image-processing technologies have been introduced offering adjusted image acquisition parameters and tools for real-time image-processing, maintaining sufficient image quality at significantly reduced levels of radiation [12–14]. The Philips AlluraClarity image-processing technology is currently available and has recently replaced Allura Xper at our department.

Implantation of transjugular intrahepatic portosystemic shunt (TIPS) is a complex angiographic procedure performed in selected patients with severe symptoms of portal hypertension [15,16]. Major parts of the procedure are performed with fluoroscopy, DSA, and injection of contrast agent [17]. Fluoroscopy time, number of DSA runs and amount of contrast agent used depend upon the individual complexity of the procedure and the interventionalist's expertise [18]. Complex TIPS interventions may include additional

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Table 1
Patient demographics in study group and control group.

Characteristic	Control group Allura Xper	Study group AlluraClarity	p-value
Number of patients	54	54	
female male	12 (22%)	17 (31%)	
	42 (78%)	37 (69%)	
Age	57 ± 11	57 ± 11	0.91
Body mass index (kg/m^2)	25 ± 3	25 ± 3	0.95
Complex interventions (%)	10 (18%)	8 (15%)	0.87

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

procedures like liver biopsies, embolization of varices or deal with difficult anatomic conditions, e.g. liver-transplants [19–21]. TIPS implantation is a challenging interventional procedure involving relevant amounts of radiation exposure for patient and staff, especially in terms of repetitive procedures and obesity [22]. Therefore high radiation doses are applied during TIPS-procedures, ranging from 150 to 360 Gy*cm^2 [22,23]. Against the background of the growing demand for interventional procedures we believe optimised technologies of imaging acquisition and processing will become a crucial element for minimising radiation dose [24,25].

Reducing the relatively high radiation dose during TIPS-implantation is highly desirable. Recently the image-processing technology AlluraClarity (Philips Healthcare, Best, The Netherlands) for angiographic systems has been introduced. This technology has been reported to achieve a substantial dose reduction in several clinical areas [12–14]. We aimed to assess the radiation dose reduction by comparing radiation doses of the established Philips Allura Xper technology with the new Philips AlluraClarity in patients undergoing TIPS implantation.

2. Methods and materials

2.1. Study design and patient demographics

This retrospective single-center study was performed at [BLINDED FOR REVIEW].

Between 03/2013 and 08/2015 a total of 229 successful TIPS-procedures have been performed at our department using an Allura FD20 angiographic system (Philips Healthcare, Best, Netherlands). The image-processing software was upgraded from Allura Xper to AlluraClarity (both: Philips Healthcare, Best, Netherlands) in June 2014 [13]. In our study we did only include patients undergoing their first "de novo" TIPS implantation (n = 181) and excluded TIPS revisions (n = 48). The AlluraClarity cohort (study group) was identified first and consisted of 54 consecutive patients that underwent TIPS between 06/2014 – 08/2015. Afterwards we identified consecutive age and BMI matched patients that underwent TIPS between 03/2013 – 05/2014 before technology upgrade for the Allura Xper cohort (n = 54, control group). 73 patients that did not match age and BMI were excluded. Patient's demographics are shown in Table 1. There was no significant difference between the study and the control group regarding age (p = 0.91) or BMI (p = 0.95). However, some procedures did include an additional liver biopsy or embolization of varices, considered as complex interventions, equally distributed in both cohorts (p = 0.87).

This study has received approval from the ethical review committee.

2.2. Imaging systems

The AlluraClarity technology includes new hardware, improved acquisition parameters and improved image-processing algorithms depending on the field of use. Parameter changes regarding abdominal fluoroscopy settings include a reduced pulse width (7.0 vs. 3.5 ms) and a reduced focal spot size (0.7 vs. 0.4 mm) for AlluraClarity compared to Allura Xper. DSA AlluraClarity uses additional filters of 1.0 mm aluminium (Al) and 0.1 mm copper (Cu). These changes between Allura Xper and AlluraClarity have been tested in Phantom-studies [13]. AlluraClarity also involves real-time motion compensation, noise reduction and image enhancement, leading to improved image quality. These improvements allow further dose reduction while keeping sufficient image quality [14–16].

2.3. TIPS-implantation

TIPS-implantation at our institution is a highly standardized procedure and has been performed in all cases by board certified radiologists with 2 to14 years of experience. Percutaneous access was obtained via the right internal jugular vein and the right hepatic vein was cannulated. The position and patency of the portal vein was confirmed by wedging a catheter into a hepatic vein tributary and injecting iodinated contrast medium to retrogradely opacify the portal vein. A 15G Ross needle (Ross Modified Colapinto, Cook Medical, Bloomington, IN, USA) was then introduced in the right liver vein over a stiff 0.035-inch guide wire (Amplatz Stiff, Boston Scientific, Marlborough, MA, USA) to create the trans hepatic passage in the portal vein under fluoroscopic and ultrasound guidance under fluoroscopy and ultrasound guidance. Next a 0.035-inch guide wire (Radifocus, Terumo Interventional Systems, Tokyo, Japan) was introduced through the Ross needle into the portal vein branch maintaining the trans hepatic passage followed by a 5F catheter placed into the superior mesenteric vein. At this point venography and portal pressure measurements were performed. The tract was then dilated with a 8 mm balloon (Mustang, Boston Scientific, Marlborough, MA, USA) before inserting a 10F TIPS sheath (8–10 mm Viatorr, W. L. Gore, Newark, USA). The TIPS-stent was dilated with the same 8 mm balloon as mentioned above. Lastly, trans-TIPS venography and pressure measurements were repeated for calculation of post-TIPS portosystemic pressure gradients [17–19].

2.4. Radiation dose measurement and documentation

The deterministic impact of radiation is associated with the patient's entrance dose, measured as Air Kerma (AK) in Gray (Gy) [26]. Stochastic effects can be 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 [26,27]. Radiation Dose

Table 2
Procedure parameters of Allura Xper and AlluraClarity during TIPS-implantation. (Data presented as mean ± standard deviation; * = significant).

Parameters	Allura Xper	AlluraClarity	p-value
Cumulative DAP (Gy*cm^2)	402.8 ± 239.7	173.3 ± 137.2	<0.001*
Cumulative AK (Gy)	1.7 ± 1.1	0.7 ± 0.5	<0.001*
Time of fluoroscopy (min)	26.4 ± 16.3	27.8 ± 18.4	0.45
Contrast agent (ml)	109.4 ± 43.1	114.9 ± 62.6	0.62

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