Patient Radiation Dose Reduction during Transarterial Chemoembolization Using a Novel X-Ray Imaging Platform

Ryan Kohlbrenner, MD, K. Pallav Kolli, MD, Andrew G. Taylor, MD, PhD, Maureen P. Kohi, MD, Nicholas Fidelman, MD, Jeanne M. LaBerge, MD, Robert K. Kerlan, MD, Vishal K. Agarwal, MD, Evan D. Lehrman, MD, Sujal Nanavati, MD, David E. Avrin, MD, and Robert Gould, DSc

ABSTRACT

Purpose: To evaluate radiation dose reduction in patients undergoing transarterial chemoembolization with the use of a new image acquisition and processing platform.

Materials and Methods: Radiation-dose data were obtained from 176 consecutive chemoembolization procedures in 135 patients performed in a single angiography suite. From January 2013 through October 2013, 85 procedures were performed by using our institution's standard fluoroscopic settings. After upgrading the x-ray fluoroscopy system with an image acquisition and processing platform designed to reduce image noise and reduce skin entrance dose, 91 chemoembolization procedures were performed from November 2013 through December 2014. Cumulative dose–area product (CDAP), cumulative air kerma (CAK), and total fluoroscopy time were recorded for each procedure. Image quality was assessed by three interventional radiologists blinded to the x-ray acquisition platform used.

Results: Patient radiation dose indicators were significantly lower for chemoembolization procedures performed with the novel imaging platform. Mean CDAP decreased from 3,033.2 $dGy \cdot cm^2$ (range, 600.3–9,404.1 $dGy \cdot cm^2$) to 1,640.1 $dGy \cdot cm^2$ (range, 278.6–6,779.9 $dGy \cdot cm^2$; 45.9% reduction; $P < .00001$). Mean CAK decreased from 1,445.4 mGy (range, 303.6–5,233.7 mGy) to 971.7 mGy (range, 144.2–3,512.0 mGy; 32.8% reduction; $P < .0001$). A 20.3% increase in mean total fluoroscopy time was noted after upgrading the imaging platform, but blinded analysis of the image quality revealed no significant degradation.

Conclusions: Although a small increase in fluoroscopy time was observed, a significant reduction in patient radiation dose was achieved by using the optimized imaging platform, without image quality degradation.

ABBREVIATIONS

AP = anteroposterior, CAK = cumulative air kerma, CDAP = cumulative dose–area product, DSA = digital subtraction angiography, FOV = field of view

Diagnostic and therapeutic procedures in interventional radiology routinely result in the exposure of patients to ionizing radiation (1–3). Cognizance of the potential deterministic and stochastic effects of cumulative radiation exposure to patients and interventionalists is therefore important (4,5). Although modern x-ray angiographic equipment allows modification of imaging parameters to reduce radiation exposure, image quality must be maintained to complete each procedure safely, efficiently, and effectively.

A new image acquisition and processing platform (AlluraClarity; Philips, Best, The Netherlands) has been shown to reduce patient radiation dose in various body interventional and neurointerventional procedures (6–9). This platform employs an advanced noise-reduction algorithm and optimized system settings, including increased beam filtration, to reduce the incident radiation required to produce a digital image of diagnostic quality. In addition to demonstrating a decrease in

From the Department of Radiology, University of California, San Francisco, 505 Parnassus Ave., M-391, San Francisco, CA 94143. Received March 28, 2015; final revision received June 7, 2015; accepted June 11, 2015. **Address correspondence to** R.K; E-mail: ryan.kohlbrenner@ucsf.edu

K.P.K. and R.G. receive partial salary support from Philips (Best, The Netherlands). None of the other authors have identified a conflict of interest.

J Vasc Interv Radiol 2015; 26:1331–1338

http://dx.doi.org/10.1016/j.jvir.2015.06.016

radiation exposure, previous studies (8–12) have also shown no appreciable degradation of overall image quality during these interventions in human and animal models.

Transarterial chemoembolization for hepatocellular carcinoma routinely involves prolonged fluoroscopy time and numerous angiographic images. We hypothesized that the optimized imaging platform would result in substantial reduction in radiation exposure to patients. The purpose of this investigation was to quantify the radiation exposure reduction to patients undergoing transarterial chemoembolization at our institution with the use of the AlluraClarity platform.

MATERIALS AND METHODS

This study was approved by our institutional review board, with waiver of informed consent. We retrospectively identified 176 consecutive transarterial chemoembolization procedures for hepatocellular carcinoma performed from January 2013 until December 2014. Procedures performed for treatment of metastatic disease were excluded.

Cohorts and Imaging Techniques

All chemoembolization procedures in this study were performed in the same angiographic suite with the use of a single-plane flat-panel detector angiography system (AlluraXper FD20; Philips). The initial group consisted of procedures performed by one of 10 attending operators between January 1, 2013, and October 30, 2013 (referred to as the reference group). During this period of time, our institution's standard settings (Allura Xper "Eco" settings) were routinely used for image acquisition and processing during chemoembolization. The system settings were characterized by a typical tube voltage of 80 kVp using only inherent filtration, a 0.7-mm focal spot, and a detector dose of 1.9 μGy per frame for a large–field-of-view (FOV) digital subtraction angiography (DSA) acquisition of 30 × 38 cm. Subsequent to November 5, 2013, all chemoembolization procedures performed in this angiography suite employed a new image acquisition and processing platform (referred to as the study group). This system uses proprietary image-processing algorithms, beam filtration, and control hardware adjustments to reduce the entrance dose to the patient while maintaining or reducing image noise. The study system settings were characterized by a typical tube voltage of 80 kVp using supplemental copper (0.1 mm) and aluminum (1.0 mm) filtration, a 0.7-mm focal spot, and a detector dose of 1.0 μGy per frame for large-FOV DSA acquisitions. Study group procedures were performed by one of 10 attending operators; nine of these operators also performed procedures in the reference group.

Dose Assessment

For each chemoembolization procedure, the cumulative air kerma (CAK) and cumulative dose–area product (CDAP) were defined as the two primary patient radiation dose metrics. Inherently, both parameters included radiation from standard fluoroscopy, DSA, and cone-beam computed tomography (CT). Acquisition parameters associated with each procedure included the number of exposures and total fluoroscopy time. These data were obtained retrospectively by querying the DoseWatch software database (GE Medical, Little Chalfont, United Kingdom) and sorting by procedure type and time period. The units used in this database for CAK and CDAP were milligrays and decigray centimeters squared, respectively. Total fluoroscopy time was measured in seconds. Total number of exposures was defined as the sum of digital photospot images, DSA frames, and individual cone-beam CT projections obtained during the procedure.

Demographics

Patient demographic data, including age and sex, were gathered for each group. Patient size was also compared between the cohorts, as several studies of angiographic procedures have demonstrated an increase in dose–area product with increasing patient size (13–15). As patient body mass index measurements were not available, the anteroposterior (AP) thickness of each patient was assessed by using measurements obtained from a diagnostic abdominal CT or magnetic resonance (MR) imaging scan that was temporally related to the chemoembolization procedure included in the analysis. As most fluoroscopic and angiographic images are obtained in the upper abdomen during chemoembolization, measurements of AP thickness were made in the midline abdomen at the level of the portal vein bifurcation on axial images. Measurements were performed manually on a 2-megapixel picture archiving and communication system monitor and were rounded to the nearest millimeter. Measurements on CT images used the thinnest reconstructions available; those made on MR images used a thin-slice two-dimensional sequence free of noticeable artifact. The mean difference in time between the cross-sectional study and the chemoembolization procedure was 41.5 days (range, 1–330 d). In two instances, cross-sectional imaging within 180 days of chemoembolization was no longer available at the time of retrospective analysis, and more remote studies were used (193 and 330 d from chemoembolization).

Subjective Image Quality Assessment

Thirty of the 176 procedures were randomly selected for subjective image quality analysis: 15 on the reference system and 15 on the study system. Image quality was scored by three interventional radiologists unfamiliar with the imaging platform upgrade. Three image series in each procedure were graded from 0 to 4 by each reviewer on a standard 2-megapixel picture archiving and communication system monitor. The scoring system