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Reducing CT radiation exposure with organ effective modulation: A retrospective clinical study

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ABSTRACT

Objective: To evaluate the effect of Organ Effective Modulation (OEM) on objective and subjective image quality as well as the radiation dose needed for thoracoabdominal computed tomography (CT).
Method: This retrospective study included 196 consecutive patients who were referred to our institution for enhanced thoracoabdominal CT on a specific scanner. Patients were divided into two groups: those for whom OEM was used and those for whom it was not used. For the non-OEM group, the tube current was controlled with an angular-longitudinal modulation technique. All CT examinations were performed with adaptive iterative dose reduction with 3D processing (AIDR-3D). The radiation dose was compared between the two groups. Objective image noise was measured in several regions at the thoracic and abdominal level. Subjective image quality was assessed by two radiologists for image noise, artifacts, sharpness, and overall diagnostic acceptability at the chest, abdomen, and pelvis.
Results: The $CTDI_{vol}$ was 8.3% lower in the OEM group and high-BMI patients tended to have higher dose reductions. Image noise was not significantly different at the thoracic level, except for the ventral air space, which showed more noise in the OEM group. At the abdominal level, the OEM group showed less noise in every region, only demonstrating a significant difference in the posterior segment of the right hepatic lobe. Subjective image quality assessment indicated more artifacts in the thoracic ventral air space in the OEM group, whereas all other items including the overall diagnostic acceptability showed no statistical differences between the two groups.
Conclusion: OEM can reduce the radiation dose by approximately 8% without affecting the diagnostic acceptability of the image compared to angular-longitudinal modulation, especially in patients with a high BMI.

1. Introduction

Use of computed tomography (CT) has dramatically increased over the past two decades. As a result, the estimated annual effective dose from medical radiation exposure per individual in the United States has increased about six-fold, from 0.53 mSv in 1980 to 3.0 mSv in 2006 [1]. This increasing radiation exposure has raised concerns about the potential increase in radiation-induced carcinoma [2–4]. Therefore, it is important for radiologists to be aware of dose-reduction techniques for CT scanners.

Tube current is one of the key scanning parameters for adjusting the radiation dose in CT. It can be adjusted manually or using an automatic exposure control (AEC) technique. There are three types of tube current modulation: x-y axis (angular) modulation, z axis (longitudinal) modulation, and x-y-z axis (angular-longitudinal) modulation. Of these, x-y-z axis modulation is the most comprehensive approach [5,6].

Organ Effective Modulation (OEM) is a type of organ-based AEC [7] that has recently been introduced by Toshiba Medical Systems Corporation, Tochigi, Japan. It combines an x-y-z modulation technique with anterior-posterior asymmetric modulation that reduces radiation exposure of the anterior part of the patient by up to 60%.

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This technique reduces radiation to radiosensitive organs of the anterior part of the patient such as the lens of the eye, thyroid, and breasts. To the best of our knowledge, no study has assessed the clinical performance of OEM. Thus, in this retrospective study, we evaluated the effects of OEM on objective and subjective image quality and the radiation dose necessary for thoracoabdominal CT.

2. Materials and methods

This study was approved by the Research Ethics Committee of our institution as a retrospective data analysis of a medical imaging diagnosis; the requirement for informed consent to participate in this study was waived by the committee.

2.1. Subjects

The medical records of 196 consecutive patients who were referred for enhanced thoracoabdominal CT on a specific scanner during a 4-week period between March and April 2014 were retrospectively examined. Until March 2014, CT was performed without OEM (i.e., the tube current was controlled using x-y-z axis modulation). Thus, the non-OEM group consisted of patients scanned during the last two weeks of this month. After OEM became available in April 2014, all CT scans at our institution were performed using the OEM algorithm. The OEM group, therefore, consisted of patients scanned during the first two weeks of this month. Their heights and body weights were recorded from their medical records to calculate body mass index (BMI). BMI was calculated using the following formula: weight in kilograms divided by height in meters squared.

2.2. OEM technique

OEM is a new x-y-z modulation technique aimed at reducing the radiation dose to radiosensitive organs of the anterior part of the patient, such as the lens of the eye, thyroid, and breasts. In this technique, the tube current is decreased by up to 60% from the maximum tube current (which is usually achieved by lateral projection but may differ between patients) within an angular range of 180 degrees. The decrease in the tube current starts from lateral projection, the highest decrease is achieved at anterior-posterior projection, and the decrease decays to a normal level at contralateral projection. During the remainder of the 180-degree angular range, the tube current is not altered (i.e., it remains equal to x-y-z modulation). As a consequence, OEM can reduce the radiation dose to the anterior part of the body without increasing the radiation dose to the dorsal part of the body. As with the x-y-z modulation technique, OEM has a lower limit of 80 mA for maintaining image quality. If the calculated tube current is below 80 mA, radiation exposure is controlled by z axis modulation alone.

There are two major differences between OEM and the former type of organ-based AEC [7]. The first is that OEM has a wider tube current angle of decrease (180 degrees for OEM and 120 degrees for the former type of AEC). The second concerns the tube current of the posterior part of the body. In the former type of organ-based AEC, the tube current for the posterior part is increased to maintain a total tube current exposure time product over 360 degrees, while the tube current for the posterior part does not change in OEM.

2.3. CT data acquisition

All CT examinations were performed using a 80-detector-row helical CT (Aquilion Prime, Toshiba Medical Systems Corporation, Tokyo, Japan) at the following settings: detector collimation 80×0.5 mm, rotation time 0.5 s, pitch factor 0.812, voltage 120 kVp, and slice thickness 5 mm. For the non-OEM group, the tube current was determined by x-y-z axis modulation adjustable with AEC, and for the OEM group, the tube current was determined using OEM. All CT examinations were performed using adaptive iterative dose reduction with 3D processing (AIRD 3D), which is an algorithm that reduces image noise and artifacts. Of the four types of algorithms in AIDR 3D, we used mild AIDR. We set our reference standard deviation to 13.

All patients were given an injection of nonionic contrast material at a dose of 2 mL/kg of body weight to a maximum dose of 100 mL using a power injector (Dual Shot GX; Nemotokyorindou, Tokyo, Japan) with an injection duration of 60 s. Iohexol (Ominpaque 350; Daiichi Sankyo, Tokyo, Japan) was administered to patients who weighed less than 60 kg, and iopamidol (Iopamiron 370; Bayer, Osaka, Japan) was administered to patients who weighed 60 kg or more. Thoracoabdominal enhanced CT was performed 90 s after the injection.

2.4. Radiation dose

The radiation dose delivered to each patient was monitored using a volume CT dose index ($CTDI_{vol}$) and total milliampere value (total mAs), which were calculated using the CT scanner and automatically saved to a dose report on a picture archiving and communication system.

2.5. Objective image noise analysis

Image noise level was measured using a circular region of interest (ROI) (10–15 mm in diameter). Objective image noise was obtained as the standard deviation (SD) of the ROI. At the thoracic level, ROIs were set in the ventral air space (e.g., the gas in front of the thorax), pectoralis major muscle, and trachea at the level of the lung apex and in the ascending and descending aorta at the carina. At the abdominal level, ROIs were set in the ventral air space (e.g., the gas in front of the abdomen), lateral segment of the left hepatic

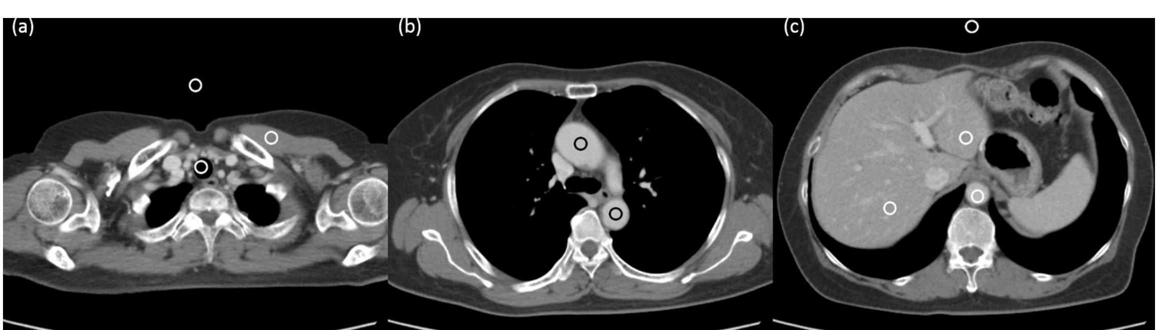

Fig. 1. ROIs used for subjective analyses of image quality: (a) at the level of the lung apex, (b) at the carina, and (c) at the umbilical portion of the left portal vein.