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Whole tumour first-pass perfusion using a low-dose method with 64-section multidetector row computed tomography in oesophageal squamous cell carcinoma

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ABSTRACT

Purpose: To propose a low-dose method at tube current-time product of 50 mAs for whole tumour first-pass perfusion of oesophageal squamous cell carcinoma using 64-section multidetector row computed tomography (MDCT), and to assess the original image quality and accuracy of perfusion parameters.
Materials and methods: Fifty-nine consecutive patients with confirmed oesophageal squamous cell carcinomas were enrolled into our study, and underwent whole tumour first-pass perfusion scan with 64-section MDCT at 50 mAs. Image data were statistically reviewed focusing on original image quality demonstrated by image-quality scores and signal-to-noise (S/N) ratios; and perfusion parameters including perfusion (PF, in ml/min/ml), peak enhanced density (PED, in HU), time to peak (TTP, in seconds) and blood volume (BV, in ml/100 g) for the tumour. To test the interobserver agreement of perfusion measurements, perfusion analyses were repeatedly performed.
Results: Original image-quality scores were 4.71 ± 0.49 whereas S/N ratios were 5.21 ± 2.05, and the scores were correlated with the S/N ratios ($r = 0.465$, $p < 0.0001$). Mean values for PF, PED, TTP and BV of the tumour were 33.27 ± 24.15 ml/min/ml, 24.06 ± 9.87 HU, 29.42 ± 8.61 s, and 12.45 ± 12.22 ml/100 g, respectively. Intraclass correlation coefficient between the replicated measurements of each perfusion parameter was greater than 0.99, and mean difference of the replicated measurements of each parameter was close to zero.
Conclusion: Whole tumour first-pass perfusion with 64-section MDCT at low-dose radiation could be reproducible to assess microcirculation in oesophageal squamous cell carcinoma without compromising subjective original image quality of the tumour.

1. Introduction

Neovascularization within oesophageal squamous cell carcinoma provides a conduit for the tumour growth, and for the capabilities of distant metastasis. Better demonstrating of the tumour's angiogenic behavior is urgent for effective prevention of the angiogenesis. Computed tomography (CT) perfusion, as a non-invasive technique to capture physiological parameters reflecting the vasculature within tumours in vivo [1], allowed us to detect the neovascularization in oesophageal tumour [2–5]. Clinically, blood volume can be used as a valuable perfusion parameter for evaluating the tumour vascularity within oesophageal squamous cell carcinomas, as was demonstrated by Chen et al. [2,3].

However, all the published perfusion studies of oesophageal tumour have classically been reported to be achieved with CT at 100 mAs to evaluate the tumour vascularity [2–5], and this technique is currently limited by the radiation dose. According to the principle of ALARA (as low as reasonably achievable) suggested by the International Commission of Radiological Protection [6,7], it is urgent to reduce radiation dose in perfusion CT. The most common method used to reduce radiation dose in thoracic CT is to lower tube current-time product during the CT scanning. Due to radiation dose proportional to tube current-time product at constant tube voltage and slice thickness, we chose half (50 mAs) of tube current-time product used for classical perfusion study in

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Table 1
Image-quality scoring system.

Mediastinal image contrast	5	4	3	2	1
Mediastinal image noise	5	4	3	2	1
Visually sharp reproduction of thickened oesophageal wall	5	4	3	2	1
Visually sharp reproduction of the necrotic area of the oesophageal tumour	5	4	3	2	1
Visually sharp reproduction of aorta (excluding motion artifact)	5	4	3	2	1
Visually sharp reproduction of heart (excluding cardiac motion artifact)	5	4	3	2	1

Quality was assessed for each component of the image using the following 5-point scale: 5, excellent; 4, very good; 3, adequate; 2, suboptimal; 1, worst.

this low-dose perfusion study. To our knowledge, however, there were no reports regarding whole tumour perfusion of oesophageal tumour with multidetector row computed tomography (MDCT) at low-dose radiation. Thus, the aim of our study was to propose a low-dose method at 50 mAs in whole tumour first-pass perfusion of oesophageal squamous cell carcinoma with 64-section MDCT, and to assess the original image quality and accuracy of perfusion parameters.

2. Materials and methods

2.1. Patients

Ethical approval was obtained from the institutional review board of our hospital, and each patient gave written informed consent prior to the study. Patients were enrolled into our study if oesophageal squamous cell carcinomas were initially confirmed by endoscopic biopsy, the mass were clearly shown on CT scan images, and the coverage of the tumour along *z*-axis was not more than 10 cm. Patients were excluded from the present study when they had renal impairment or contrast allergy, or had already received cancer-related therapy.

Between February 2007 and January 2008, 59 consecutive patients (52 men, 7 women; mean age, 61.1 years; age range, 41–81 years) with oesophageal squamous cell carcinoma, who met the inclusion criteria and agreed to participate in the study, formed the cohort. In this cohort, the tumours were located in the lower thoracic portion of esophagus, both the midthoracic and lower thoracic portion, the midthoracic portion, both the upper thoracic and midthoracic portion, and the upper thoracic portion in 21, 14, 19, 2 and 3 patients, respectively. The mean patient size along *z*-axis, patient weight and thoracic anteroposterior diameter was 166.21 ± 5.18 cm, 53.73 ± 8.76 kg, and 21.38 ± 3.46 cm, respectively. And the mean coverage of the tumour along *z*-axis was 40.75 ± 17.95 mm. All patients underwent low-dose CT perfusion imaging at 50 mAs, which is half of the standard tube current-time product for thoracic CT examinations at our institution. In this cohort, 34 patients without contraindications to surgery had tumour resection for therapy, and they were reconfirmed by postoperative pathology. The remaining with contraindications to surgery received chemoradiotherapy.

2.2. Imaging

Patients were scanned using a 64-section MDCT scanner (Philips Brilliance 64, Philips Medical System, Best, the Netherlands). Prior to the CT image acquisition, 200–400 ml water was used immediately as oral oesophageal negative contrast material. A 19-gauge cannula (B. Braun, Melsungen, AG, Germany) was placed into an antecubital fossa vein before the patient lay supine on the scanner table. An initial non-enhanced breath-hold helical scan was obtained using the following parameters: 120 kV; 100 mAs; table feed, 110 mm/s; rotation time, 0.4 s; collimation, 32 mm × 1.25 mm; scanning field of view (SFOV), 350 mm; and matrix, 512 mm × 512 mm. This scan was used to plan the subsequent perfusion study. Based on the coverage of the tumour, a 10-cm tumour region of interest (ROI) encompassing the entire visible tumour was selected for the cine imaging by an experienced radiologic associate professor (the first author with 12 years of experience in thoracoabdominal radiology).

Using a pump injector (MEORAO-Stellant, MEORAO Company, Germany), 50 ml iodinated contrast medium (Ultravist 300, Iopamidol, Schering, Germany) containing 300 mg of iodine per ml was administered as a bolus into the antecubital fossa vein at the rate of 6–7 ml/s. Five seconds after the start of the bolus injection, dynamic CT acquisition encompassing the entire visible tumour was commenced to allow the spiral acquisition of baseline non-enhanced images. In detail, the dynamic study consisted of a total of 12 helical acquisitions including an initial spiral scan at 1.55 s with table moving forward, followed by 11 consecutive scanning series each composed by a temporal sampling interval of 3.31 s with table moving backward and a spiral scan identical with the previous scan. The parameters were used for the dynamic scan as follows: 120 kV; 50 mAs; table speed, 110 mm/s; rotation time, 0.4 s; collimation, 32 mm × 1.25 mm; SFOV, 350 mm; and matrix 512 mm × 512 mm. Total dynamic acquisition time was 55 s. During the dynamic acquisitions, patients were asked to breathe quietly to minimize the movement of esophagus. The dynamic images were reconstructed with 5-mm section thickness using a standard reconstruction algorithm at a mediastinal window width of 350 HU and a window level of 40 HU. In each patient, a total of 240 images obtained from 12 dynamic CT scans with a 5-mm thickness were defined as "original images", and were transferred to an image processing workstation (Extended Brilliance Workstation, Philips Medical System) to be written on disks for the subsequent perfusion measurements.

In order to stage oesophageal carcinoma, especially in the depiction of lymph nodes or distant metastasis for appropriate medical treatment, the dynamic examination was followed with a routine enhanced thoracic or thoracicoabdominal CT examination shortly after the completion of intravenous injection of 50–70 ml of ultravist, respectively.

2.3. Image qualitative analysis

The original images on the disks were transferred to the previous image processing workstation for image qualitative analysis. Because acceptable-quality original images were required for the accuracy of subsequent perfusion analysis, the quality of these images was initially assessed. Among the 12 dynamic CT scans, the original images obtained in fifth scan were randomly selected for the image qualitative analysis. The qualitative analysis of the randomized images was subjectively performed independently by an experienced radiologic associate professor (Reviewer #1, the first author with 12 years of experience in thoracoabdominal radiology) and an experienced radiologist (Reviewer #2, the third author with 11 years of experience in radiology) focusing on the image quality of thickened oesophageal wall and the input artery (descending aorta) for subsequent perfusion analysis. Objective criteria used to evaluate the image quality were the ability to see the differentiation of soft-tissue structures within fat on mediastinal windows [8]. The original images (Fig. 1) were assessed on a 5-point scale (1, worst; 2, suboptimal; 3, adequate; 4, very good; 5, excellent) according to