Improved Imaging of the Cervico-Thoracic Junction in Computed Tomography

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INTRODUCTION

The advent of the multislice CT scanner in 1999 offered expanded capacity, speed, and an increase in accuracy 8-times over the single slice CT scanner. Today’s equipment, with 64 times more test area, has shortened test time and offered higher resolution.1,3 Despite the development of new and advanced techniques in CT equipment, more noise has increased as a result of the introduction of shading artifacts. The CT image contrast is lowered and ultimately, there is a deterioration of image quality.4,5 Shading artifacts are divided by type. There is the “cup” artifact generated in cases of scanning homogeneous materials, such as phantom water because the images appear unevenly in a cup pattern. Another type is the streak artifact observed in a streak pattern generated between two highly dense materials.

Methods to reduce such artifacts include reduction of beam hardening artifacts by physically filtering the X-ray beam, shortening of X-ray exposure,7,8 expressing by expansion of the CT number area,9 linear/polynomial interpolation that has been used from the early period of CT development,10,11 iterating reconstruction,12-14 and image processing on a single image.14,15

It is known that if the cervical spine has trauma and injury, it is difficult to examine the cervico-thoracic junction by general X-ray radiography.16 Therefore, in the 1980s, the swimmers technique was introduced to examine the cervico-thoracic junction.17,18

Purpose: To reduce beam hardening artifacts caused by the shoulder joint, we explored new and unique methods to improve the quality of images, such as varying the injection site and changing the position of patients (swimmers position).

Materials and Methods: Fifth-four patients underwent neck CT examinations performed in routine and swimmers position and with a 64-slice MDCT scanner in spiral scanning. To examine the difference due to the injection sites of contrast material, subjects were divided into right- and left-side groups. For the evaluation of images, we carried out a subjective and objective assessment based on radiologists’ ratings and noise measurement. Results: Images of the lower neck in the swimmers position exhibited less hardening and streak artifacts. The subjective and objective evaluations showed that the swimmers position received higher rating by radiologists and had lower noise level than that of routine position. The swimmers position was the most effective for the diagnosis of the cervico-thoracic junction area. As for the injection site, we obtained better images by an injection of contrast material in the right arm than in the left.

Conclusion: CT examination of the lower neck in the swimmers position may improve the quality of image and the effectiveness of diagnosis. The injection of a contrast material to the right side rather than the left side reduced foreign body artifacts.

Key Words: Cervico-thoracic junction, computed tomography, artifacts, swimmers position
In CT examination, abundant noises are similarly, developed on the image of the lower neck and the thoracic inlet because of beam hardening artifacts. Therefore, we explored the potential to decrease such beam hardening artifacts and streak artifacts that may be generated because of the shoulder joint methods. We searched for the improvement of the quality of images by varying scanning parameters, injection sites, and beam collimation as well as changing of the position of patients.

MATERIALS AND METHODS

Fifth-four patients (24 males, 30 females) who underwent neck CT test were examined under routine position (both arms were lowered) and swimmers position in a supine position (one arm was raised over the head), as shown in Fig. 1. Patients were divided in two groups matched for age and gender. Patients in the swimmers position group were able to raise one arm over the head freely; that is, there were no patients suffering from severe arthritis, traffic accident, or trauma. The distribution of patients with respect to age and gender in each group is summarized in Table 1.

CT examinations were performed with a 64-slice MDCT scanner (Brilliance 64, Philips, Cleveland, USA) and obtained in the craniocaudal direction. Patients were scanned in the supine position after deep inspiration. In the CT examination, a spiral mode was selected. A 130 mL contrast material was injected at a rate of 3.5 mL/sec using an 18 G needle. Scan delay time (the time taken to obtain first image) was 70 sec. To assess the difference due to the injection site, they were divided into the right and left groups. The scanning parameters, including 120 kVp, 250 mAs, and 0.75 sec rotation time, and 0.671 pitches, were used. The computed tomography dose index (CTDI) with the above scanning parameter was 14.7 mGy. Although 1-mm-thick contiguous transverse CT scans of the entire neck were used for clinical purposes, the image was reconstructed on 3-mm-thick transverse CT scans for the assessment.

For the evaluation of images, cases in the routine position were considered to be 3 points (fair), which was the standard. Cases evaluated in the swimmers position were classified from 1 point (bad) to 5 points (excellent), and evaluated by a radiologist. The objective assessment of noise was obtained by measuring the standard deviation of pixel values in a homogeneous region at the spinal cord, the body of first thoracic spine, and

![Fig. 1. Topography of the neck in the routine position (Left) and swimmers position (Right).](image)

| Table 1. The Distribution of Patients with Respect to Ages and Gender in Both Groups |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
| Gender                     | Age (yrs)       |                 |                 |                 |
|                           | 1 - 20 | 21 - 40 | 41 - 60 | 61 - 80 |
| Male                       | 2      | 5       | 3       | 2       |
| Female                     | 2      | 6       | 6       | 1       |
the scalene muscle, as shown in Fig. 2. The objective noise was defined as the standard deviation of the measured density. A circular region of interest (ROI) was selected differently as $0.28 \pm 0.20\, \text{cm}^2$ at the spinal cord, $0.57 \pm 0.30\, \text{cm}^2$ at the body of first thoracic spine, and $0.31 \pm 0.20\, \text{cm}^2$ at the scalene muscle. The ROI was selected 3 times with a slightly different area on a respective part to increase the reliability of the noise measurement.

**RESULTS**

The clinical test was performed by varying the position of patients (routine and swimmers position), injection site of the contrast material, and beam collimation to reduce beam hardening artifacts and streak artifacts that might be generated in the lower neck and the cervico-thoracic junction area due to the shoulder joint. The following subjective and objective results were obtained from the radiologists’ rate and the noise assessment, respectively.

1. In comparison with the cases examined in the routine position, 8 patients (29.6%) had 5 points (excellent), 17 patients (63%) had 4 points (good), and 2 patients (7.4%) had 3 points (fair). As shown Fig. 3, beam hardening artifacts and streak

![Fig. 2. The selected region used to assess CT number and noise, namely, the spinal cord, body of the first thoracic spine, and scalene muscle.](image1)

![Fig. 3. Images of the sthenic (left) and hypersthenic (right) in (A) the routine position and (B) swimmers position. The streak artifacts (arrow indicated) shown in Figure (A) disappeared in the swimmers position in both cases.](image2)
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Fig. 4. CT number and noise assessment at the spinal cord, body of first thoracic spine, and scalene muscle. The shaded area represents a tolerable CT number; that is, Hounsfield units in the respective body tissues and fluids.

Fig. 5. Comparison of images according to injection site (left: right arm injection; right: left arm injection). The right figure shows artifacts that originated from the slow blood flow rate that resulted in acute curvature of the left subclavian vein.

artifacts that might be generated in the cervico-thoracic junction area were noticeably decreased.

Fig. 4 represents CT number and noise at respective body tissues and fluids according to age. As shown in the figures, the swimmers position had a lower noise level than the routine position in all cases and showed a similar standard CT number for respective body tissues and fluids. Noise levels of the spinal cord and scalene muscle at routine positions were the same or half of the standard CT number of the respective body tissues and fluids.

2. Regarding the injection sites, 30 patients (55.6%) among 54 subject patients in the routine position, were injected on their right side and 24 patients (44.4%) were injected on the left. Among patients injected on the right, 14 (46.7%) had 5 points (excellent), 12 patients (40%) had 4 points (good), and 4 patients (13.3%) had 3 points (fair). In patients injected on the left side, 8 (33.3%) had 5 points, 8 (33.3%) had 4 points, and 8 (33.3%) had 3 points. The results confirmed that the artifacts generated during the contrast material passing through the left subclavian artery or vein resulted in its acute curvature due to the slow blood flow rate. Artifacts generated in the lower neck area were decreased more by an injection to the right side than an injection to the left side (Fig. 5).
DISCUSSION

It is difficult to clearly examine the cervico-thoracic junction area.\textsuperscript{16} Compared with it however, CT could provide improved accuracy in the diagnosis in the lower neck area.\textsuperscript{21} Beam hardening artifacts and streak artifacts that may be generated during neck CT examination on the lower neck area are important causes of the deterioration of images. In general, the swimmers position for X-ray radiography, was introduced in 1980, to examine the cervico-thoracic junction area for the first time.\textsuperscript{17,18} Subsequently, it has been reported that the accuracy of the diagnosis of the cervico-thoracic junction was greatly improved.\textsuperscript{18} Similarly, such efforts have been made to improve the images of the lower neck area during the neck CT examination by using the swimmers position in supine.

As described in the present results, in comparison with the cases examined in a routine position, beam hardening artifacts and streak artifacts in the lower neck area were decreased in the case of the swimmers neck CT; nonetheless, we encountered with several unexpected problems. First, if one arm was raised over the head, the head moved unconsciously in the direction of the raised arm. Thus, we required complete caution to maintain the same position until the completion of the examination. Second, the examination with the swimmers position was not feasible for cases whose movement was uncomfortable after surgery and patients who could not raise an arm due to severe trauma or traffic accident. Third, due to the raised arm, two shoulder joints of the swimmers position became asymmetric. Consequently, this position generated distortion of images (Fig. 6).

Artifacts were generated in the cerebellum due to the raised arm. As shown in Fig. 7, streak artifacts were not generated in the cerebellum in the routine position.

In summary, the clinical test was performed by
varying the position of patients (routine and swimmers position), the injection site of contrast material, and the beam collimation to reduce beam hardening artifacts and streak artifacts that may be generated in the lower neck area and the cervico-thoracic junction. We obtained the following conclusions.

For the diagnosis of the lower neck by CT examination in the swimmers position, the quality of images and the efficacy of diagnosis, especially at the cervico-thoracic junction area, were drastically improved in both subjective and objective evaluations in spite of several disadvantages such as breaking of symmetry, limitation of patients, and generation of streak artifacts in the cerebellum.

As for injection site, better images were obtained by the injection of a contrast material on the right side rather than the left.

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