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Effect of an arm traction device on image quality and radiation exposure during neck computed tomography

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ABSTRACT

Objective: To retrospectively determine the effect of an arm traction device on image quality and radiation exposure during a neck computed tomography (CT) scan.
Materials and methods: Standard neck CT examinations with an automatic tube current modulation technique were compared for two groups (intervention group: patients with an arm traction device, $n = 45$; control group: no particular positioning optimization, $n = 45$). Image quality was the primary outcome and was assessed using image noise and the streak artifact. The secondary outcome was radiation exposure, which was measured by the volume CT dose index ($CTDI_{vol}$) and dose-length product. Potential confounders, including the effective diameter of the neck and scan length, were also assessed.
Results: Image noise and the streak artifact at the lower neck and the supraclavicular fossa were significantly improved in the intervention group compared with the control group ($p < 0.001$). There was a significant decrease in the $CTDI_{vol}$ in the intervention group versus the control group ($p = 0.042$). DLP showed a tendency toward a decrease in the intervention group that was non-significant ($p = 0.106$). The effective diameter and scan length showed no statistical difference between the two groups.
Conclusion: An arm traction device improves the image quality in the lower neck and the supraclavicular fossa during a neck CT. Application of this device also reduces the tendency for radiation exposure.

1. Introduction

The computed tomography (CT) image quality in the lower neck is frequently reduced by a streak artifact from the shoulder girdle and contrast media lingering on the subclavian vein. CT image quality improvement strategies can involve trade-offs, including factors that increase the radiation dosage or manufacturing costs in the relation to CT hardware or software improvements [1–4]. One method for image quality improvement without the need to increase the radiation exposure is optimization of the patient position (e.g., using a method of moving the shoulder downward during a CT scan of the neck region) [5,6]. Prior authors have used a pulling device or CT table strap and demonstrated an improved image quality of the spinal cord or the supraclavicular area without increasing the radiation dose [5,6]. Techniques developed by CT manufacturers, including automatic tube current modulation and iterative reconstruction, become increasingly applied for routine CT examinations of the neck since they have demonstrated an improvement in the image quality without increasing the radiation exposure [7–9]. However, a strategy using both an arm traction device and an automatic tube current modulation technique has not been evaluated for neck CT. The purpose of this study was to retrospectively determine whether there is an additive effect on image quality and radiation exposure in a CT of the neck region by employing an arm traction device along with automatic tube current modulation.

2. Materials and methods

Our retrospective study protocol was reviewed and approved by the institutional review board of our hospital. Written informed consent to undergo the CT protocol was obtained from all patients before each examination.

Abbreviations: CT, computed tomography; FOV, field of view; PACS, picture archive and communications system; SD, standard deviation; ROI, region of interest; IJV, internal jugular vein; SCM, sternocleidomastoid; CV, costovertebral; DLP, dose-length product; CTDIvol, volume CT dose index; SSDE, size-specific-dose-estimate.

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2.1. Study patients

The intervention group included patients who consented to using the arm traction device during a neck CT scan among cases that had been randomly selected from April to May 2013. All of the enrolled patients met the following criteria: older than 18 years of age; able to follow commands and cooperate with the use of the arm traction device; no previous history of surgery or radiation therapy to the neck; and no vascular or bony medical instruments such as a central line or a metallic plate in the upper arms or the shoulder. Using these criteria, 45 patients were finally enrolled in the intervention group. For comparison, 45 patients were randomly selected from a series who satisfied the same inclusion criteria for the intervention group other than application of the traction device and were enrolled into the control group during the same period.

2.2. CT protocol and analysis

Patients in both the control and intervention groups were positioned on the CT table with the shoulders lowered as much as possible according to the standard imaging protocol. A radiological technologist gave further instructions regarding lowering of the shoulders and maintaining that position throughout the scan. The custom-made arm traction device was used in the intervention group and was placed and secured by the radiological technologist (Fig. 1).

All patients underwent a CT examination on one of several commercially available CT systems with multi-detector capability ranging from 64 to 128 channels (Siemens Medical Solutions, Erlangen, Germany). The technique was varied according to the system used, but most sessions were performed with 128-channel imaging systems. Typical imaging variables were as follows: 120 kV; 200 effective mAs; axial scan mode; display field of view (FOV), 22 cm; large-body scan FOV, 50 cm; pitch of 1; gantry rotation time of 0.5 seconds; detector collimation of 128 × 0.6 mm; and 3-mm axial reconstructed section thickness with a soft-tissue algorithm. Real-time automatic tube current modulation software (CareDose4D; Siemens Medical Solutions, Erlangen, Germany) was used to regulate the tube current, depending on the patient's anatomy. Images were obtained from the upper margin of the frontal sinus through the top of the aortic arch 70 seconds following the administration of 140 mL of intravenous iopamidol (Isovue-370; Bracco Diagnostics Inc., Princeton, NJ, USA) at a rate of 2.5 mL/s. Radiologic images were reviewed using a picture archive and communications system (PACS).

One neuroradiologist who had 4 years of dedicated head and neck experience assessed the image noise by calculation of the standard deviation (SD) of the CT values in Hounsfield units (HUs) for pixels in a standard 0.5–1 cm^2 square region of interest (ROI). CT values were measured at the mid- and lower neck levels contralateral to the side of intravenous contrast media administration. The ROIs were placed on the internal jugular vein (IJV) and sternocleidomastoid (SCM) muscle at the level of the cricoid cartilage (mid-neck) and the thyroid gland and IJV at the level of the 1st costovertebral (CV) joint (lower neck).

Another neuroradiologist who had 14 years of experience performed axial CT image analysis on the PACS screen and was blind to whether the arm traction device was being used or not as the scanning parameters were removed from the PACS screen. All image assessment was performed using a standard soft-tissue window/level setting (windows: 300/level: 35). The degree of streak artifact in the supraclavicular fossa was evaluated and scored as follows: 1, no or minimal artifact with no image obscuration; 2, mild artifact causing partial obscuration of subcutaneous fat or skin without diagnostic interference; and 3, severe artifact causing obscuration of deep cervical structures with diagnostic interference. The supraclavicular fossa was defined on each axial scan when any portion of the clavicle was identified on one side of the neck [10].

Radiation exposure was evaluated by the dose-length product (DLP) and volume CT dose index ($CTDI_{vol}$). Potential confounders, including the effective diameter of the neck and scan length, were also assessed. The effective diameter of the neck was calculated on an axial CT image at the level of the upper margin of the tracheal cartilage using the following equation: effective diameter = $\sqrt{\text{the anteroposterior diameter} \times \text{the transverse diameter}}$ [11]. The total scan length was assessed for each patient by multiplying the total number of axial images acquired by the section thickness.

2.3. Outcomes measures

The primary outcome measure for the investigation was the CT image quality measured by image noise in the mid- and lower neck levels and measured by the streak artifact in the supraclavicular fossa. The secondary outcome measure included the radiation exposure, measured by $CTDI_{vol}$ and DLP.

2.4. Statistical analysis

Data are presented as means and standard deviations for continuous variables and as the number of subjects for categorical variables. The Student's *t*-test was used to analyze the difference between the two groups with respect to image noise, DLP, $CTDI_{vol}$, effective diameter, and scan length. The Mann–Whitney nonparametric test and Fisher's exact test were used to compare the streak artifact levels between the groups. All statistical analyses were performed using MedCalc version 15.0 statistical software (MedCalc Software, Mariakerke, Belgium), with a *p*-value of 0.05 considered statistically significant.

3. Results

Demographic characteristics, image quality, and radiation exposure in all patients are presented in Table 1. There was no difference in the sex ratio or mean age between the two study groups. Objective evaluations of image quality based on the assessment of image noise showed that the intervention group demonstrated statistically better CT image quality than the control group in the lower neck (1st CV joint level; $p < 0.001$) but no difference in the mid-neck (cricoid cartilage level). Noise reduction was achieved in 45% of the mean SD (from 15.5 to 8.6 HU) at the IJV and 51% (from 18.4 to 9.0 HU) at the thyroid gland in the lower neck. The subjective evaluation of the streak artifact in the supraclavicular fossa showed a statistical difference between the intervention and control groups (mean score of 1.3 versus 1.9; $p < 0.001$). A score of 3 showing diagnostic interference was significantly more frequent in the control group compared to the intervention group (13.3%, 6/45 versus 0%, 0/45; $p = 0.026$). A statistically significant decrease in radiation exposure was observed in $CTDI_{vol}$ in the intervention group compared with the control group ($p = 0.042$). DLP showed a tendency toward a decrease in the intervention group that was non-significant ($p = 0.106$). The effective diameter and scan length showed no statistical difference between the two groups (Fig. 2).

4. Discussion

We retrospectively assessed the effect of an arm traction device combined with automatic tube current modulation on the image quality and radiation exposure level for a neck CT. This application reduced the image noise in the lower neck and the streak artifact in the supraclavicular fossa. Additionally, we found a tendency toward