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Correct Patient Centering Increases Image Quality without Concomitant Increase of Radiation Dose during Adult Intracranial Computed Tomography

Hussain Almohiy, PhD[a], Emadeldin Mohamed Mukhtar Alasar, BSc[a] and Charbel Saade, PhD[ab*]

[a] *Department of Radiological Sciences, College of Applied Medical Sciences, King Khalid University, Abha, Saudi Arabia*
[b] *Department of Diagnostic Radiology, American University of Beirut Medical Center, Beirut, Lebanon*

ABSTRACT

Purpose: To evaluate the impact of patient centering and radiation dose during intracranial computed tomography (ICT) on quantitative and qualitative image quality.

Materials and methods: A total of 500 consecutive patients who underwent ICT were retrospectively reviewed using a 128-slice CT scanner (Definition AS+, Siemens, Germany). Patients were subjected in equal numbers to one of two positioning protocols: group A, poorly centered; and group B involved accurate centering before imaging. Gray-white matter (GWM) conspicuity, contrast-to-noise ratio (CNR), and signal-to-noise ratio (SNR) in each group were calculated. Qualitative image quality in terms of GWM differentiation, distinctness of posterior fossa contents, and overall diagnostic acceptability were evaluated by 2 neuroradiologists. The dose length product, CNR, SNR, and noise were measured between each group and data generated were compared using Mann–Whitney *U* nonparametric statistics. Visual grading characteristic and Kappa analyses were performed.

Results: The mean noise index was significantly lower in group B (2.61 ± 0.29) compared with A (2.66 ± 0.21; $P < .02$). The mean attenuation of GWM, SNR, and CNR in the frontal lobe (A, 1:0.77, 0.84, 8.70 ± 1.36; and B, 1:0.65, 0.85, 15.32 ± 1.21; $P < .02$), occipital lobe (A, 1:1.10, 1.18, 10.79±2.11; and B, 1:0.94, 0.64, 14.41 ± 3.09; $P < .04$), and cerebellum (A, 1:0.79, 0.90, 12.56 ± 4.08; and B, 1:0.82, 0.87, 14.07 ± 2.28; $P < .04$) were significantly higher in group B compared with A, while the globus pallidus, caudate nucleus, and optic track in the basal ganglia demonstrated no difference in each group ($P > .05$). Mean dose length product demonstrated no significance between each group (A, 1312.03 ± 133.92; B, 1298.11 ± 130.61). The qualitative analyses demonstrated significant increases in visual grading characteristic for each reader ($P < .02$) and interobserver agreement was significantly increased in protocol B (k = 0.81) compared with A (k = 0.62).

Conclusions: Correct patient centering increases the CNR and SNR in both GWM in the left and right hemispheres of the brain during ICT.

RÉSUMÉ

Objet : Évaluer l'effet du centrage du patient et de la dose de rayonnement durant la tomodensitométrie intracrânienne (ICT) sur la qualité quantitative et qualitative de l'image.

Matériel et méthodologie : 500 patients consécutifs ayant fait l'objet d'une CTI ont fait l'objet d'un examen rétrospectif au moyen d'un appareil de TDM à 128 coupes (Definition AS+, Siemens, Allemagne). Les patients ont été soumis, en nombre égal, à deux protocoles de positionnement: Groupe A, mal centré; Groupe B, avec un centrage précis avant l'imagerie. La perceptibilité de la matière grise-blanche (GWM) et le rapport signal-bruit (SNR) ont été calculés dans chaque groupe. La qualité qualitative de l'image en termes de différenciation GWM, de distinction du contenu de la fosse postérieure et l'acceptabilité diagnostique générale a été évaluée par deux neuroradiologistes. Le produit de longueur de dose (DLP), le CNR, le SNR et le bruit ont été mesurés entre les deux groupes et les données générées ont été comparées en utilisant les statistiques non paramétriques du test U de Mann-Whitney. Des analyses de caractéristiques de notation visuelle (VGC) et des analyses kappa ont été effectuées.

Résultats : L'indice de bruit moyen était significativement plus bas dans le groupe B (2,61 ± 0,29) que dans le groupe A (2,66 ± 0,21) (p<0,02). L'atténuation moyenne des paramètres GWM, SNR et CNR dans le lobe frontal (A; 1:0,77, 0,84, 8,70 ± 1,36 and B; 1:0,65,0,85, 15,32 ± 1,21) (p<0.02), le lobe occipital

* Corresponding author: Charbel Saade, PhD, Department of Diagnostic Radiology, American University of Beirut Medical Center, PO Box 11-0236, Riad El-Solh, Beirut 1107, Lebanon.

E-mail address: Charbel.saade@aub.edu.lb (C. Saade).

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(A; 1:1,10, 1,18, 10,79 ± 2,11, et B; 1:0, 94, 0, 64, 14, 41 ± 3,09) (p <0,04), et le cervelet (A; 1:0,79, 0,90, 12, 56 ± 4,08 et B; 1:0, 82, 0,87, 14,07 ± 2,28) (p<0,04) était significativement plus élevée dans le groupe B comparativement au groupe A, tandis que le pallidum, le noyau caudé et la voie optique du ganglion basal ne montraient aucune différence entre les groupes (p>0,05). Le DLP moyen ne montre pas de différence significative entre les groupes (A: 1312,03 ± 133,92, B: 1298,11 ± 130,61). Les analyses qualitatives montrent une augmentation significative du VCG pour chaque lecteur (p<0,02) et l'accord entre les observateur était significativement plus élevé dans le protocole B (k=0,81) comparativement au protocole A (k=0,62).

Conclusion : Un bon centrage du patient augmente le CNR et le SNR de la GWM dans les hémisphères droit et gauche du cerveau durant l'ICT.

Introduction

Computed tomography (CT) has become a mainstream tool in the diagnosis of intracranial head trauma. Its high speed and submillimeter spatial resolution has enabled this technology to be widely available in the emergency setting, and its use has increased sharply. However, radiation exposure caused by medical imaging demonstrates an association with an increase in lifetime cancer risk [1–3].

Radiographers and radiologists are responsible for the administration of radiation dose following the "as low as reasonably achievable" principle. Radiographers are required to optimize CT parameters to produce optimal image quality during intracranial computed tomography (ICT). Diagnostic reference level (DRL) is one of the references for optimizing radiation exposure. DRL has been used in medical imaging to indicate whether, in routine conditions, the patient dose of administered activity from a specific procedure is unusually high or low for that particular procedure [4]. DRL studies in adults [5–10] and pediatric [5, 10–13] populations have been widely reported. For both adult and pediatric imaging, optimal centering requires the head to be positioned at the isocenter of the gantry so, as the tube rotates, the photons reaching the detector are uniform in nature, providing uniform image quality on both sides of the brain hemisphere. However, a recent study [14] revealed a skin surface dose penalty of up to 140% with a mean dose penalty of 33%, assuming that tube current is increased to compensate for the increased noise due to off-centering, resulting in poor image quality.

The radiologist's responsibility [7–12, 15, 16] is to determine the following: whether optimal CT has been performed; optimal gray-white matter (GWM) differentiation; proper cupping correction; good soft-tissue discrimination; accurate, reliable Hounsfield Units (HU) calibration; high spatial resolution and modulation transfer function and artifact-free posterior fossa and skull base.

The aggressive reduction of radiation dose may potentially result in substantial loss of image quality—such as GWM, increased signal-to-noise ratio (SNR), and reduced contrast-to-noise ratio (CNR)—highlighting the need for radiologists and technologists to optimize CT protocols in an effort to balance image quality and radiation dose [17]. Image quality differences during neuroradiologic applications differ immensely. Most of the previously published articles have considered qualitative image quality [18]. In addition, age, gender, and head diameter may be related to differences in cranial bone density, which can potentially affect the visualization of GWM when using tube current modulation. The aims of this study were to evaluate the radiation dose of adult head CT examinations and the impact of patient centering of the same (performed at three different radiologic sites at the same institution) with quantitative and qualitative image, performed with conventional, commercially available multiple detector computed tomography equipment.

Materials and Methods

Study Population

The institutional review board approved this study, and written informed consent was waived since all studies were clinically indicated, and patient data were evaluated anonymously. Between February 2013 and January 2014, 500 consecutive patients were retrospectively reviewed (mean age 77 ± 11.2 years, range 55–99 years, 249 male, 251 female) and included in this study (Table 1). Patient demographics were equally distributed: group A, poorly centered; and group B involved accurate centering before imaging. Patients were referred from the requesting physician for a head CT after clinical assessment.

CT Data Acquisition

All CT examinations were obtained using a 128-slice single-source CT scanner (Siemens definition AS+, Siemens, Germany). Image acquisition parameters of the standard protocol included a collimation of 40 × 0.6 mm (acquisition slice thickness 0.75 mm), pitch of 0.55, rotation time of 1.0 s, tube voltage of 120 kV, and tube current of 320 mA.

CT Data Reconstruction

Head CT examinations in both study groups were reconstructed using manufacture-based mathematical algorithms

Table 1
Patient Demographics

Parameter	Patient demographics
Male	249
Female	251
Age (y)	77 ± 11.2
Height (cm)	171 ± 12
Weight (kg)	78 ± 9
BMI (kg/m^2)	25.6 ± 5.5

Note, data are mean ± standard deviation.
BMI, body mass index.