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ORIGINAL REPORT

The utility of dual-energy CT for metal artifact reduction from intracranial clipping and coiling☆

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KEYWORDS
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Abstract
Objective: To assess the ability of dual-energy CT (DECT) to reduce metal-related artifacts in patients with clips and coils in head CT angiography, and to analyze the differences in this reduction between both type of devices.
Materials and methods: Thirteen patients (6 clips, 7 coils) were selected and retrospectively analyzed. Virtual monoenergetic images (MEI) with photon energies from 40 to 150 keV were obtained. Noise was measured at the area of maximum artifact. Subjective evaluation of streak artifact was performed by two radiologists independently. Differences between noise values in all groups were tested by using the ANOVA test. Mann−Whitney *U* test was used to compare the differences between clips and coils. Cohen's κ statistic was used to determine interobserver agreement.
Results: The lowest noise value was observed at high energy levels ($p < 0.05$). Noise was higher in the coil group than in the clip group ($p < 0.001$). Interobserver agreement was good ($\kappa = 0.72$).
Conclusions: TCED with MEI helps to minimize the artifact from clips and coils in patients who undergo head CT angiography. The reduction of the artifact is greater in patients with surgical clipping than in patients with endovascular coiling.

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PALABRAS CLAVE
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Utilidad de la tomografía computarizada de energía dual en la reducción del artefacto metálico generado por clips y *coils* intracraneales

Resumen
Objetivo: Evaluar la capacidad de la TC de energía dual (TCED) para reducir el artefacto metálico en pacientes con clips y *coils* intracraneales en estudios de angio-TC cerebral, y analizar el diferente impacto que dicha reducción tiene en función del tipo de dispositivo estudiado.
Material y métodos: Se analizaron retrospectivamente 13 pacientes (6 clips, 7 *coils*). Se obtuvieron imágenes virtuales monoenergéticas (IVM) en un rango de 40 a 150 keV. Se midió el ruido dentro del área de máximo artefacto. La evaluación subjetiva del ruido fue realizada independientemente por dos radiólogos. Las diferencias encontradas se evaluaron mediante el test ANOVA. El test Mann-Whitney se utilizó para comparar las diferencias entre clips y *coils*. Se determinó el grado de concordancia interobservador (coeficiente κ).
Resultados: El ruido fue más bajo en los niveles energéticos más altos ($p < 0,05$). El ruido fue mayor en pacientes con *coils* ($p < 0,001$). La correlación interobservador fue buena ($\kappa = 0,72$).
Conclusiones: El uso de TCED con reconstrucciones virtuales monoenergéticas ayuda a minimizar el artefacto producido por clips y *coils* intracraneales en estudios de angio-TC cerebral. La reducción del artefacto conseguida es mayor en el grupo de pacientes con clips que en el grupo de pacientes con *coils*.

Introduction

The prevalence of intracranial aneurysms in the adult population is around 2%[1] and they have been more and more diagnosed during the last few years following the boom in the use of non-invasive imaging modalities (computed tomography [CT] and magnetic resonance imaging [MRI]). The indication for its treatment depends on various factors. The direct occlusion of the aneurysmatic sac can be conducted via the endovascular route (with coils) or surgically (with clips). Then it is necessary to keep follow-up of these patients, being the MRI the modality of choice thanks to a less metal-induced susceptibility artifact, and because this imaging modality uses no ionizing radiation. However, at times, the MRI is contraindicated or cannot be conducted, and we have to choose other alternative techniques such as the CT scan or the conventional arteriography.

Metallic elements such as clips or coils within the exploratory area of CT scans can be an important cause of streak artifacts. These artifacts can block the correct visualization of the aneurysmatic sac treated and, even, the remaining arteries, which in turn is an important limitation to the diagnostic capabilities of these imaging modalities. That is why it is a priority to have tools available capable of minimizing this effect. Such artifacts are due to two (2) different mechanisms basically: the beam hardening phenomenon and the photon starvation phenomenon. The former one occurs because tissues preferably absorb low-energy photons when penetrated by polychromatic X-ray beams, that is, a beam with photons of different energy levels. This effect is even more consistent in high-attenuation regions like the bones, and when the X-ray beam penetrates structures with noticeable transitions of thickness and density. The photon starvation phenomenon takes place when X-ray beams penetrate a high-density element such as metal, that is, when the attenuation of such element is at its peak, and very few photons can penetrate it, leading to incomplete ranges of attenuation that are the cause of a false absorption halo that generates bands or images that have the appearance of ''sunbeams''.

The metallic devices (clips and coils) used to repair aneurysms in cerebral arteries cause both effects and, therefore, are a source of streak artifacts in CT scan images.[2,3]

The concept of dual-energy CT (DECT) was born during the development of the very first CT machines back in the decade of the 1970s, although in the daily practice it was used for the first time after the arrival of modern software and hardware tools.[4,5] DECT machines use two (2) different energy spectra through two (2) X-ray tubes simultaneously (dual-source CT scanner) or one singe tube (multilayer detectors where the detector can separate different energy photons from the emitted X-ray beam; and also ultrafast kilovoltage commutation where the tube can rapidly modulate the tension causing low and high-energy spectra). The main advantages of DECT are basically two. The first one being the characterization of materials based on different attenuations of the same element observed at two different energy levels (usually 80 kVp and 140 kVp). The second one is the possibility of generating virtual monoenergetic reconstructions where the image is seen as if acquired using one single-source CT scanner, that is, at a given kiloelectronvolt (keV).[5,6] As opposed to the attenuation values derived from the polychromatic