Optimized Imaging of the Postoperative Spine

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KEYWORDS

• Spine • Spine hardware • Postoperative spine • Dual energy • MR imaging • CT

KEY POINTS

- Few tasks in imaging are more challenging than that of optimizing evaluations of the instrumented spine.
- Applying these fundamental principles to postoperative spine computed tomography and magnetic resonance examinations will mitigate the challenges associated with metal implants and significantly improve image quality and consistency.
- Newer and soon-to-be-available imaging enhancements should provide improved visualization of tissues and hardware as multispectral imaging sequences continue to develop.

INTRODUCTION

There are few imaging tasks more challenging to the radiologist than optimizing evaluations of the instrumented spine as there is significant artifact induced by implanted metal devices on both magnetic resonance (MR) imaging and computed tomography (CT). MR imaging artifacts are mainly caused by volume magnetic susceptibility mismatch between metal devices and tissue. In CT, the issues are beam hardening and streak (BHS) artifacts. The purpose of this article is to describe the critical techniques for MR and CT imaging of the postoperative spine, focusing on key technical factor adjustments; the value of innovations, such as dual energy CT (DECT); and new MR techniques, such as metal artifact reduction and chemical shift imaging.

CT

Fundamental Factors

CT is a quick and effective imaging tool for the evaluation of the spine in postoperative patients and is commonly obtained to demonstrate the position of surgical hardware with respect to the adjacent bone, nerves, spinal canal, and vessels. CT is best suited to assess for hardware complications, such as malpositioning, disruption, and mechanical loosening, as well as to demonstrate cortical and trabecular bone continuity at fusion sites.[1] In addition, in those patients with recurrent symptoms who have contraindications to MR imaging, CT provides the sole cross-sectional imaging option. Although CT is effective in evaluating the postoperative spine, there are challenges posed by BHS artifacts associated with metallic hardware. Metal-related attenuation of the x-ray beam manifests as dark and bright bands that reduce the integrity of visualization of the hardware as well as the surrounding bone and soft tissues.[2] The artifact depends on both fixed and modifiable variables. Fixed variables are related to the hardware itself and include metal composition (increased density, increased artifact) and geometry (increased thickness, increased beam attenuation). Modifiable variables are generally related to the CT acquisition parameters and

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include x-ray kilovolt peak (kVp), x-ray tube current, pitch, and image reconstruction parameters (**Table 1**).[1]

KVP

One of the most important modifiable variables is the x-ray kilovolt value. Increasing the x-ray kVp decreases x-ray beam attenuation from metal, thereby reducing artifact. The radiation dose is directly affected by an increase in kVp from 120 to 140, producing an approximately 40% increase in the dose to patients. Appropriate reduction in tube current (milliamps per second) compensates for the increase, maintaining the radiation dose. In general, a 15% increase in kVp should be accommodated by a 50% decrease in mAs. Note that as low contrast detectability is inversely related to the kVp used, there is a small tradeoff in image sensitivity with increases in kVp.

ITERATIVE RECONSTRUCTION

The use of iterative reconstruction (IR) techniques, ubiquitous on modern scanners, reduces the dose required to obtain an appropriately low noise image. The ability of IR to recognize and then remove noise has a modest positive impact on the artifacts produced by metal hardware (**Fig. 1**). Newer model-based IR techniques have an even greater impact on artifact reduction (**Fig. 2**).

SLICE THICKNESS

The most important scanning parameter with respect to the degree of beam hardening artifact is the acquisition slice profile (**Fig. 3**). With a multichannel CT system, the minimum possible thickness should be fed to each imaging channel, as the benefit of the thinner acquisition voxels will be manifest in the in-plane, reformatted, and 3-dimensional (3D) images even if thicker slices are used for interpretive purposes. With increasing helical pitch (defined as table distance traveled per 360° rotation/total collimated width of the x-ray beam), slice profiles broaden; thus, minimum pitch values should be used. Techniques such as in-plane and through-plane oversampling lead to a reduction in effective voxel sizes and minimized artifact.

Table 1
Managing BHS artifact

CT	Managing Beam Hardening Artifact
X-ray kVp	High kVp (110–120 kVp)
Image reconstruction algorithm	Model-based iterative reconstruction
Acquisition slice profile	Minimize voxel size High definition, oversampling
Dual energy	Dual source, single-source rapid voltage switching, single-source layered (sandwich) detector, sequential acquisition (spin-spin)

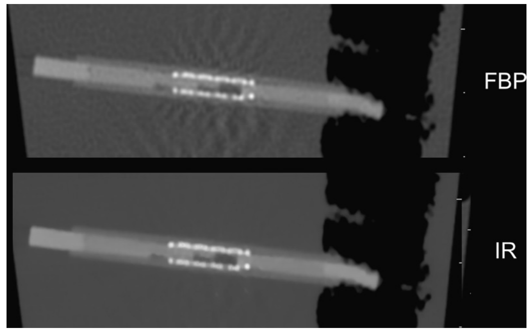

Fig. 1. Value of IR. Note the reduction of structured noise and artifact with the use of IR versus filtered back projection (FBP).

ADVANCED TECHNIQUES

DECT

Methods

Although the potential benefits have been known for some time, DECT has only recently become commercially available and practical over the last decade.[3] There are several commercially available methods for DECT,[4] including dual-source, single-source rapid voltage switching, single-source layered (also known as *sandwich*) detector, as well as sequential acquisition (spin-spin) (**Fig. 4**). Quantum counting detectors may be available in the future. Each method has advantages and disadvantages regarding spectral contrast and dose efficiency.[5]

Dual Source Imaging

Siemens Medical Corporation developed the first commercial dual-source approach based on 2 orthogonally mounted x-ray sources, which simultaneously expose a set of detectors (Somatom Definition Flash and Force). The second x-ray source is a smaller detector and, thus, has a relatively smaller field of view depending on the scanner model (see **Fig. 4**).[6]