Evaluation of Metallic Artifacts Caused by Nonpenetrating Titanium Clips in Postoperative Neuroimaging

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BACKGROUND: **Nonpenetrating titanium clips create no suture holes and thereby reduce cerebrospinal fluid leakage after dural closure. However, no data exist regarding metallic artifacts caused by these clips during postoperative neuroimaging. We aimed to evaluate clip-related artifacts on postoperative magnetic resonance (MR) images of 17 patients who underwent spinal surgery.**

METHODS: **A phantom study evaluated the size of metallic artifacts, and a clinical study evaluated the quality of postoperative spinal MR images. Both 1.5-T studies used T1-weighted and T2-weighted fast spin echo sequences. The phantom study compared clip and artifact size for 10 clips. Artifacts were defined as signal voids surrounded by high signal amplitude that followed the clip shape. In the clinical study, 2 neurosurgeons assessed 22 images from 17 patients of the spinal cord, cauda equina, and paravertebral muscles adjacent to the nonpenetrating titanium clips, using 5-point scales.**

RESULTS: **Mean metallic artifact sizes were 4.82 $\pm$ 0.16 mm (T1) and 4.66 $\pm$ 0.25 mm (T2; $P < 0.001$ vs. control). The former and latter were respectively 207% and 200% larger than the clip size. Both readers graded spinal cord and paravertebral muscles images as 3 or 4, indicating very good image quality regardless of clip-related artifacts, with excellent interobserver agreement ($\kappa = 0.99$ and 0.98, respectively).**

CONCLUSIONS: **Metallic artifacts caused by nonpenetrating titanium clips were 200% larger than the actual clip but did not affect spinal cord and extradural tissue visualization. The use of these clips for closing the spinal dura mater does not alter postoperative radiologic evaluation quality.**

INTRODUCTION

Postoperative cerebrospinal fluid (CSF) leakage is a major complication of spinal surgery, and its prevention is crucial, particularly after surgery for spinal intradural lesions. Several sealing materials have been proposed as adjuncts for dural closure to minimize the potential for adverse events, such as infection, and to decrease the risk of pseudomeningocele formation. However, CSF leakage is not always prevented during these procedures. Compared with the intracranial region, the spinal region offers a narrower operative field and a thinner and more fragile dura mater[1,2]; therefore, meticulous dural suturing may be impossible after intradural procedures.

The nonpenetrating titanium clip has been designed to achieve faultless vascular anastomoses. This clip does not create any suture holes and has been successfully used in peripheral arterial bypass surgery.[3-8] Its use was approved by the U.S. Food and Drug Administration for vascular anastomosis and reconstruction in December 1993 and for dural closure in 1996 (Figure 1).

We have previously reported the usefulness of nonpenetrating titanium clips for dural closure in spinal surgery on the basis of data from both in vitro and clinical studies.[1] A significant difference was apparent between expanded polytetra fluoroethylene (ePTFE) sutures and nonpenetrating titanium clips in terms of the water pressure that could be tolerated by

Key words
- Cerebrospinal fluid leakage
- Dural closure
- Magnetic resonance imaging
- Metallic artifacts
- Nonpenetrating clips
- Spinal surgery

Abbreviations and Acronyms
CSF: Cerebrospinal fluid
ePTFE: Expanded polytetrafluoroethylene
MR: Magnetic resonance

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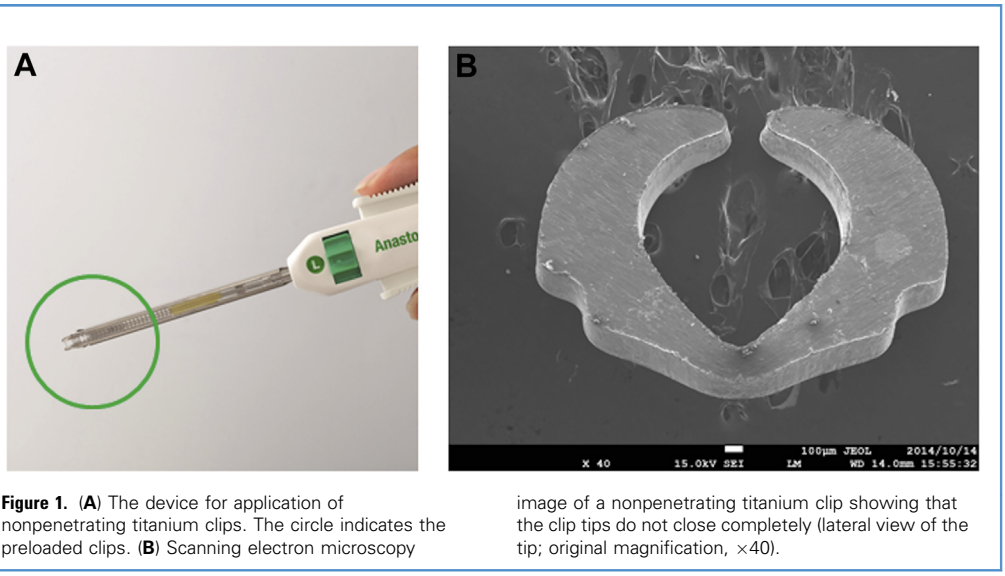

Figure 1. (**A**) The device for application of nonpenetrating titanium clips. The circle indicates the preloaded clips. (**B**) Scanning electron microscopy image of a nonpenetrating titanium clip showing that the clip tips do not close completely (lateral view of the tip; original magnification, ×40).

sutured ePTFE sheets, with the latter tolerating 1508% greater leakage pressure than the former. Moreover, these clips do not close completely (Figure 1) and therefore make no suture holes. Regarding CSF leakage patterns, the nonpenetrating titanium clips did not make any suture holes in the ePTFE sheet and fluid leakage occurred between the clips, whereas fluid leakage was associated with the pressure increase that occurred at the suture holes made by the ePTFE sutures. Of 31 patients who underwent spinal intradural procedures using nonpenetrating titanium clips, 1 (3.2%) experienced CSF leakage postoperatively. No other complications (eg, allergic reactions, adhesions, or infections) were encountered.

On the other hand, because these clips are made of titanium alloy, they may cause mechanical artifacts on postoperative magnetic resonance (MR) images. This situation may complicate follow-up, particularly in cases of intradural tumorous lesions. Animal studies have shown significantly less inflammation, a lesser extent of foreign body reactions, and fewer meningoneural adhesions with the use of nonpenetrating titanium clips compared with the use of penetrating needles and sutures for dural plasty.[9]

However, no experimental and clinical studies have evaluated metallic artifacts caused by nonpenetrating titanium clips in postoperative neuroimaging. Therefore, in the present study, we evaluated the mechanical artifacts associated with nonpenetrating titanium clips on postoperative MR images using a simple model that mimicked spinal surgery. In addition, we present our surgical experience with these clips in 17 consecutive patients. To the best of our knowledge, this is the first experimental study evaluating such artifacts.

METHODS

Nonpenetrating Titanium Clips

Nonpenetrating titanium clips (VCS [Vascular Closure System] [LeMaitre Vascular Inc., Burlington, Massachusetts, USA]) are manufactured for the reconstruction of tubular organs, including peripheral arteries and veins. The technical and biological advantages of nonpenetrating titanium clips have been described previously.[3-6,8] Scanning electron microscopy showed incomplete closure of the tips; consequently, no suture holes were created (Figure 1). We measured 10 nonpenetrating titanium clips using a Mitutoyo digimatic outside micrometer (Mitutoyo Corp., Kawasaki, Japan) and found a mean size of 2.33 ± 0.0065 mm, which was used as control for comparison with the size of artifacts on MR sequences.

Data Acquisition

Phantom and clinical studies were performed using a 1.5-T MR imaging unit (Optima MR450w [GE Medical Systems, Milwaukee, Wisconsin, USA]). All MR imaging studies involved the acquisition of T1-weighted and T2-weighted fast-spin echo sequences. Table 1 summarizes the imaging parameters for all MR sequences used at our institute for imaging the spinal region.

Table 1. Parameters Used for the Different Magnetic Resonance Imaging Sequences

	T1-Weighted Fast-Spin Echo	T2-Weighted Fast-Spin Echo
Repetition time (milliseconds)	450	5465
Echo time (milliseconds)	8.9	97.2
Band width (kHz)	31.2	31.2
Field of view (mm)	180	180
Section thickness (mm)	3	3
Matrix	512 × 512	512 × 512

All phantom sequences were obtained in the coronal plane, and all clinical study sequences were obtained in the axial and sagittal planes.