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Metallic Postoperative Artifacts on Cervical MR

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Summary: Spectroscopy of cervical diskectomy specimens obtained from sheep demonstrated that metallic susceptibility artifacts are produced by microscopic amounts of nickel, copper, and zinc. Sufficient quantities of metals to produce artifacts are deposited only by contact of metal drill bits and suction tips. If these instruments do not come in contact during surgery, susceptibility artifacts are not observed.

Index terms: Magnetic resonance, artifacts; Diskectomy, percutaneous; Spine, intervertebral disks

In as many as 5% of patients who have MR examinations after cervical diskectomy, metallic artifact obscures the operative site and precludes evaluation of the thecal sac and its contents (1). The purpose of this study is to determine the cause of these artifacts.

Methods

Twenty-seven cervical disk spaces in sheep were imaged in a water bath at 1.5 T using T1 spin-echo (400/13/1, TR/TE/excitations) and gradient-recalled (450/15/1, 15° flip angle) sequences. Subsequently, diskectomy using a standard surgical drill (Midas Rex, Fort Worth, TX) was performed on 22 disks. In 11 interspaces, a metal surgical suction tip was allowed to contact the bit briefly; in the other 11 spaces, the two instruments were separate throughout the procedure. The remaining five disks were left unoperated. After diskectomy, the specimens were rescanned and plain films of the specimens also obtained.

The disk spaces were then graded for signal intensity on a 0 to 3 scale by one author unaware of which disks had been operated on and the technique of diskectomy. A score of 3 indicated that a disk had unchanged signal intensity; a score of 2 meant that one third or less of the disk had diminished signal compared with the first magnetic resonance (MR) scan; a score of 1 meant that between one and two thirds of the disk had diminished signal. Disks with low signal in over two thirds of the interspace received a score of 0.

After the disks had been graded for signal intensity, four of the interspaces operated on with momentary contact of the suction tip with the drill and four operated on without contact, as well as seven areas remote from the operated areas, were analyzed by energy dispersive x-ray fluorescence spectroscopy (EDXRFS) using a Tracor model 5050 spectrometer (Mountain View, CA). Qualitative identification of elements present in a sample is determined by the energy of characteristic peaks in the spectrum; quantitative information can be derived from the intensity of the peaks (2, 3).

Results

The plain radiographs obtained before and after discectomy showed no metal particles.

All disks had high signal intensity on preoperative MR (Fig. 1A). The five control (unoperated) disks had scores of 3 on the postoperative MR. All operated disks had diminished scores (signal intensity) after surgery, but the reduction was much more in the disks operated on with momentary suction-tip-to-drill-bit contact (Fig. 1B).

X-ray fluorescence spectroscopy of the four intervertebral disks operated on without suction-tip-to-drill-bit contact as well as the seven areas remote from the diskectomy sites revealed only trace amounts of nickel (0.00 to 0.07 mg per 100 gm of tissue), zinc (0.35 to 0.57 mg/100 gm), and copper (0.01 to 0.14 mg/100 gm). Examination of two of the four disks that had been operated on with drill-bit-to-suction-tip contact demonstrated markedly higher amounts of nickel (0.16 to 0.43 mg/100 gm), zinc (0.77 to 1.23 mg/100 gm), and copper (0.34 to 0.70 mg/100 gm) (see Figs. 2A and 2B). All spectra revealed the expected peaks for calcium, strontium, potassium, and phosphorus. Iron levels were low and similar for all 15 areas examined (0.08 to 0.11 mg/100 gm).

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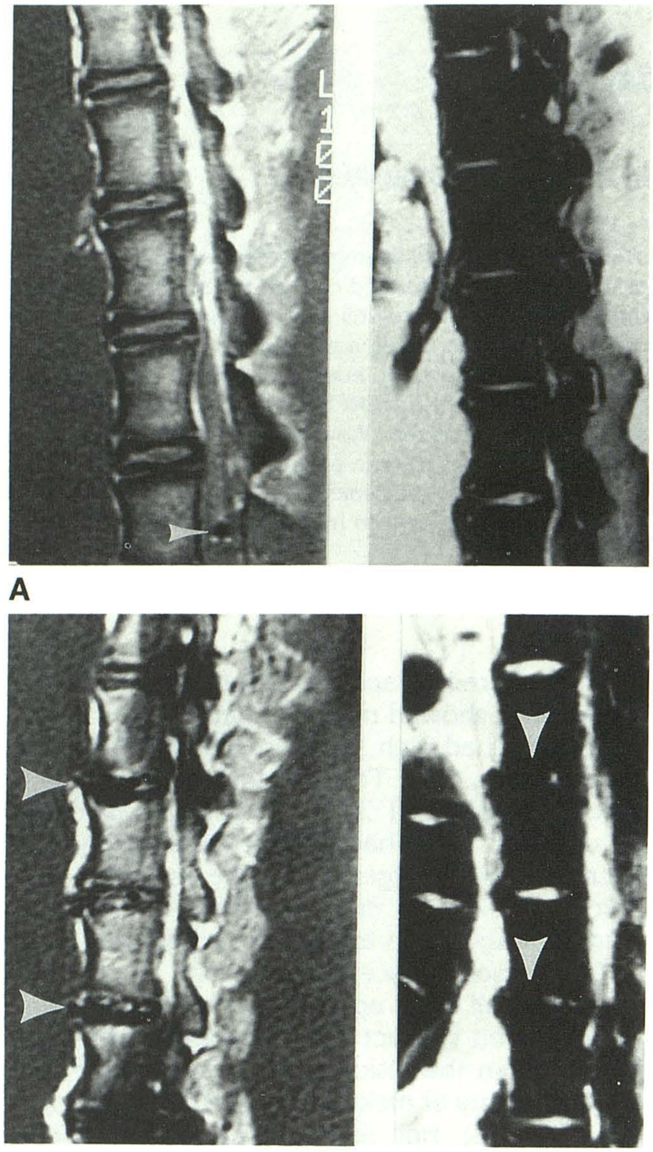


A

B

Fig. 1. *A*, These images show a specimen prior to diskectomy. The spin-echo T1 (400/13/1, TR/TE/excitations) examinations on the left and the gradient-echo study (450/15/1, 15° flip angle) is on the right. Note that the disks are of uniform high signal intensity. The metal artifact in the spinal canal (*arrowhead*) is from specimen removal.

B, This postoperative examination (spin-echo T1 on the left and gradient-echo on the right) shows diminished signal in the disks, especially in those disks operated on with drill-to-suction-tip contact (*white arrowheads*).

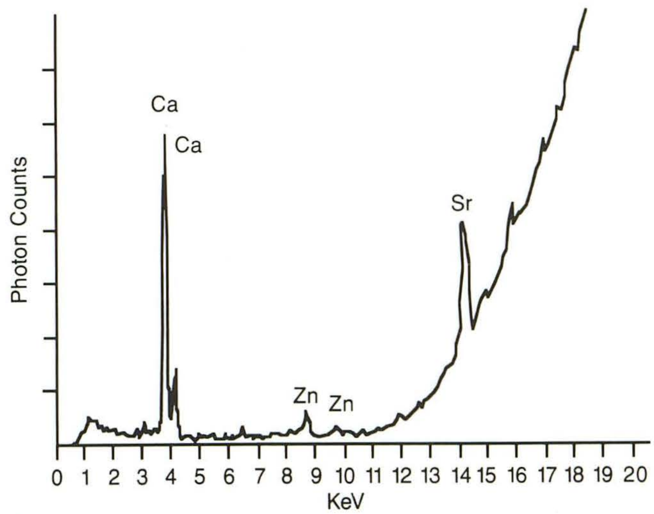
Paired Student *t* test was used to compare signal intensity scores in each disk before and after surgery. *T* values of 5.41 and 5.97 for the disks operated on with instrument contact and examined by T1-weighted spin-echo and gradient-recalled sequences, respectively, were obtained. These are statistically significant at the *P* = .01 level. For the disks operated on without instrument contact, the comparison of pre- and postoperative scores revealed *t* values that were not statistically significant (2.0 and 3.0 for T1 and gradient-recalled images, respectively).

Discussion

Previous authors have noted the existence of metal artifacts in patients after cervical diskectomy (1, 4, 5). Heindel and colleagues (6) drilled two holes in pig femurs, briefly touching the instruments in one procedure but not the other. They found that metallic artifact occurred in only the hole in which the instruments had touched, and after finding iron particles around that hole by histologic staining concluded that the artifact was caused by ferromagnetic particles (6). Indeed, this may well have been the case, as they report that their instruments were untempered and contained 70% iron.

This study demonstrates that nickel, zinc, and copper, in addition to iron, can produce significant metallic artifact at clinically used field strengths. As the spectroscopic data show, MR signal decreases as the quantities of nickel, zinc, and copper increase. Thus, elimination of ferromagnetic compounds from surgical instruments may not improve postoperative image quality. Rather, what is important is that the drill bit used for cervical diskectomy not come in contact with other metallic instruments during surgery. It is significant that artifacts were not produced by the tempered steel bit alone, even though trace amounts of nickel and zinc can be demonstrated spectroscopically. Apparently, minute particles of metal are deposited during diskectomy when the disk, and probably more so when the harder endplates and peridisk osteophytes are drilled out; however, the effect of these fragments does not appear significant from an imaging standpoint.

It should be noted that the metal artifacts seen in human postoperative examinations are larger than those demonstrated in this study. This is most likely because of the more extensive drilling, with associated increased chance of prolonged metal-to-metal contact, which is needed in patients to remove degenerative periarticular osteophytes and bone. In clinical practice, one can reduce metal artifacts by reducing TE as much as possible. Currently, images can be obtained at TEs as short as 7 or 8 msec. This improves gradient-echo imaging by diminishing the time



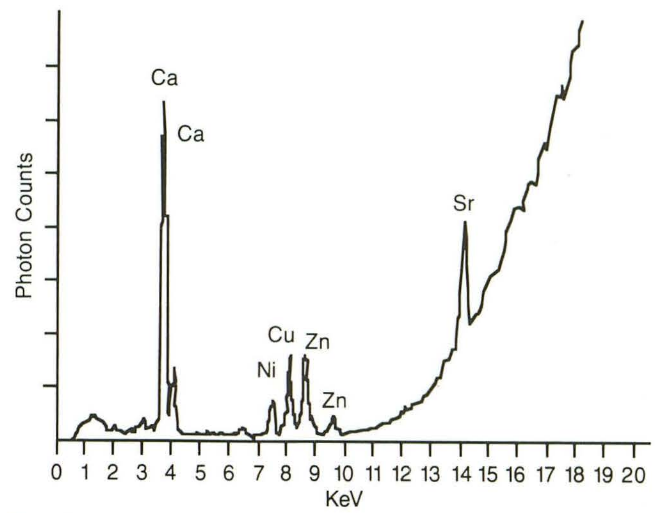


Fig. 2. *A*, This spectrum is from a disk operated on without instrument contact. This is similar to spectra from unoperated areas (data not shown). Zinc = 0.35 mg/100 gm of tissue.

B, This spectrum is from an operated disk where drill bit and suction tip were in contact. Note the presence of elevated amounts of nickel (Ni = 0.43 mg/100 gm of tissue), zinc (Zn = 0.77 mg) and copper (Cu = 0.77 mg).

available for local field inhomogeneity-induced spin dephasing prior to image formation. Additionally, diminishing TE usually improves both gradient and spin-echo images because the higher gradient strengths required produce greater changes in frequency across each voxel, the effect of which is to make the frequency shift attributable to metal-induced metal susceptibility effects proportionally less. The drawback of this technique, aside from the higher gradient strengths required, is the decrease in signal-to-noise ratio which occurs because the increased gradient strengths result in increased signal bandwidth, the signal-to-noise ratio being proportional to the inverse of the square root of the bandwidth.

In summary, metallic artifacts after cervical diskectomy are caused by minute particles produced in sufficient quantities to affect MR images only by contact of metallic instruments. The suction tip itself does not necessarily need to contain iron, because nickel, copper, and zinc alone produce sufficient susceptibility artifact to produce artifact. Drilling itself does not produce the metallic artifacts visible on MR, although microerosions from drill bits may deposit tiny amounts of metal in the operative site which can be detected spectroscopically. The quality of MR status after cervical diskectomy could be improved and the need for postoperative cervical CT myelography diminished if suction tips made of plastic were employed, if metallic suction tips were assiduously prohibited from touching the drill during surgery, and, possibly, if TE were reduced to 7 or 8 msec.

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