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Original research

Comparison of ferromagnetic induction and bipolar electrosurgery and suction in corticotomies in pig cerebrum

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HIGHLIGHTS

- Ferromagnetic induction caused less cerebral tissue damage than bipolar electrocautery.
- Ferromagnetic induction also caused less haemorrhage than bipolar electrocautery.
- The ferromagnetic induction surgical tool may avoid limitations of standard techniques.

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ABSTRACT

Introduction: The effects of newer energy-based surgical dissection and coagulation modalities on cerebral tissue have not been investigated. Several instruments have been developed to address the limitations of traditional electrosurgical instruments in the nervous system. We compared the effects of standard bipolar electrocautery and suction (BPS) with those of a new ferromagnetic induction (FMI) device in corticotomies of pig cerebral tissue as assessed by magnetic resonance imaging (MRI) and histological analysis.

Methods: Three adult pigs underwent bilateral corticotomies (3 cm long $\times$ 1 cm deep) using both FMI and BPS. The acute cerebral tissue edema created by each method was measured on coronal volumetric T2-weighted MRI sequences immediately after surgery. A lateral thermal "damage index" was calculated by dividing the width of the visible T2 tissue edema by the measured depth. The radiographic damage indices with each method were compared statistically. Histological analysis of each incision was conducted to compare the extent of tissue damage.

Results: MRI showed that the mean radiographic damage index of each corticotomy was significantly lower with the FMI (0.30 $\pm$ 0.02 (0.28–0.32)) than with the BPS method (0.54 $\pm$ 0.11 (0.42–0.64)) ($p = 0.02$). Histological analysis suggested a correlation with the radiographic findings as the FMI tissue samples demonstrated less adjacent tissue damage than BPS.

Conclusions: FMI appeared to cause less adjacent tissue damage than the BPS method in pig cerebral tissue based on quantitative radiographic and qualitative histological analysis. Future studies are needed to investigate the clinical implications of energy-based surgical dissection on cerebral tissue.

1. Introduction

In 1928, Dr. Harvey Cushing published a revolutionary paper that described electrosurgical coagulation as a means for successfully facilitating surgeries that were previously impossible because of the risk of excessive blood loss [1,2]. The first bipolar electrosurgical device was introduced in 1937 but was not commercially available until the 1950s [3]. The use of bipolar electrosurgery has resulted in better surgical hemostasis and dissection of fine tissue when compared with use of a traditional scalpel [4–6].

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Fig. 1. The FMwand ferromagnetic induction device for surgical dissection and coagulation.

Nevertheless, concerns about the harmful effects of electrosurgery and lateral thermal damage (LTD) have been raised [5–7]. LTD from standard electrosurgical instruments may cause delayed wound healing, increased inflammation, and scarring. Intraoperative use may result in diminished tissue strength, electrical shock, obscuration of the surgical field by smoke, and increased rates of bacteremia or death [5–7]. Use of traditional electrosurgical coagulation has been limited in the nervous system because of the potential for thermal injury to neuronal structures, the stimulation/movement of innervated structure(s), brain/neuronal edema, myelin sheath disruption, and axonal rupture [7,8].

Several energy-based surgical tools based on ultrasound, radiofrequency, laser, and other technologies have been developed to address these limitations. Nonetheless, these technologies have inherent limitations for resection of brain tumors [9].

A novel technology based on ferromagnetic induction (FMI) has been developed to address the limitations of other energy based surgical technologies. The FMwand (Domain Surgical, Inc., Salt Lake City, Utah) combines a 4- to 10-μm-thick ferromagnetic alloy on a tungsten loop to generate sufficient heat to incise and seal tissue (Fig. 1). Ferromagnetic surgical technology works by creating heat by passing a high-frequency electrical current through the ferromagnetic alloy loop (a coated tungsten loop) in the tip of the handpiece. This, in turn, causes a rapidly alternating magnetic field that generates heat in the ferromagnetic alloy tip, while the current returns to the ground as it runs through the handpiece. The process creates a rapid heat "on" effect without passing current through the tissue. Heating occurs at the surface of the loop and does not elicit a neuromuscular stimulatory effect.

We compared the FMwand and traditional bipolar coagulation and suction (BPS) techniques for making corticotomies in swine brain tissue. We hypothesized that there would be less adjacent tissue damage (ATD) seen with the FMwand than with the BPS technique under controlled conditions.

2. Methods

2.1. Surgical procedure

The experimental animal protocol was approved and monitored by the Institutional Animal Care and Use Committee at our institution. Parallel corticotomies were conducted in both cerebral hemispheres of three adult swine using FMwand and BPS. The incisions were 3 cm in length and 1 cm deep with each modality in opposite hemispheres. All incisions were performed by the same surgeon.

2.2. Radiology

An immediate brain magnetic resonance imaging (MRI) scan (3-T) was obtained. Three different sequences were obtained, including T1, short tau inversion recovery (STIR), and volumetric T2. The extent of cerebral tissue edema (seen as increased hyperintense signal on coronal volumetric T2 images) caused by each incision was measured by a radiologist blinded to incision method. A "damage index" was calculated for each brain incision by dividing the width of the maximum tissue edema by its depth. Statistical significance was evaluated using a Student's t-test (significance $p < 0.05$).

2.3. Histology

Each pig was euthanized after the MRI, and tissue slices were prepared in a plane perpendicular to the midpoint of each experimental incision. The samples were fixed in formalin, stained with hematoxylin and eosin, and analyzed for the extent of ATD by a pathologist blinded to incision method. Each incision was compared qualitatively to evaluate the extent of histological tissue damage.

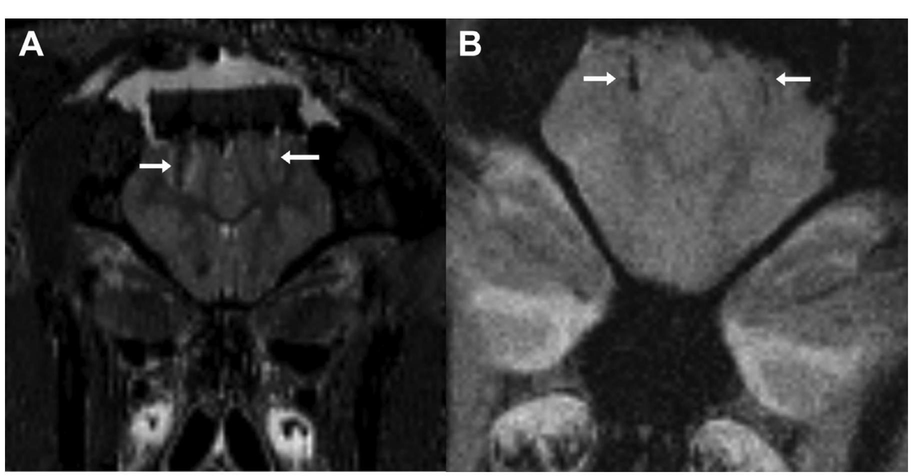

Fig. 2. (A) Volumetric coronal T2-weighted MR image demonstrating the increased cerebral tissue edema seen with the BPS (left) compared with the FMI (right) after corticotomy in rat cerebrum. (B) Coronal gradient recalled echo sequence demonstrating increased blood products in the BPS corticotomy (left) compared with the FMI corticotomy (right).