Use of an ultrasonic osteotome device in spine surgery: experience from the first 128 patients

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Abstract

Introduction The ultrasonic BoneScalpel is a tissue-specific device that allows the surgeon to make precise osteotomies while protecting collateral or adjacent soft tissue structures. The device is comprised of a blunt ultrasonic blade that oscillates at over 22,500 cycles/s with an imperceptible microscopic amplitude. The recurring impacts pulverize the noncompliant crystalline structure resulting in a precise cut. The more compliant adjacent soft tissue is not affected by the ultrasonic oscillation. The purpose of this study is to report the experience and safety of using this ultrasonic osteotome device in a variety of spine surgeries.

Methods Data were retrospectively collected from medical charts and surgical reports for each surgery in which the ultrasonic scalpel was used to perform any type of osteotomy (facetectomy, laminotomy, laminectomy, en bloc resection, Smith Petersen osteotomy, pedicle subtraction osteotomy, etc.). The majority of patients had spinal stenosis, degenerative or adolescent scoliosis, pseudoarthrosis, adjacent segment degeneration, and spondylolisthesis et al. Intra-operative complications were also recorded.

Results A total of 128 consecutive patients (73 female, 55 male) beginning with our first case experience were included in this study. The mean age of the patients was 58 years (range 12–85 years). Eighty patients (62.5 %) had previous spine surgery and/or spinal deformity. The

ultrasonic scalpel was used at all levels of the spine and the average levels operated on each patient were 5. The mean operation time (skin to skin) was 4.3 h and the mean blood loss was 425.4 ml. In all cases, the ultrasonic scalpel was used to create the needed osteotomies to facilitate the surgical procedure without any percussion on the spinal column or injury to the underlying nerves. There was a noticeable absence of bleeding from the cut end of the bone consistent with the ultrasonic application. There were 11 instances of dural injuries (8.6 %) and two of which were directly associated with the use of ultrasonic device. In no procedure was the use of the ultrasonic scalpel abandoned for use of another instrument due to difficulty in using the device or failure to achieve the desired osteotomy.

Conclusions Overall, the ultrasonic scalpel was safe and performed as desired when used as a bone cutting device to facilitate osteotomies in a variety of spine surgeries. However, caution should be taken to avoid potential thermal injury and dural tear. If used properly, this device may decrease the risk of soft tissue injury associated with the use of high speed burrs and oscillating saws during spine surgery.

Keywords Ultrasonic scalpel · Spine surgery · Osteotomy · Safety · Dural injury

Introduction

Various osteotomy techniques, such as facetectomy, laminotomy, laminectomy, en bloc resection, Smith Petersen osteotomy and pedicle subtraction osteotomy have been widely used in spine surgeries. Successfully performing these procedures is critical to achieve adequate spinal decompression and optimal deformity correction which

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will ultimately lead to better clinical outcome. However, these osteotomy procedures are technically demanding and the traditional surgical tools such as high-speed drills, rotating burrs and threadwire saws carry a risk of durotomy and neural injury with inappropriate handling [1, 2].

Recently, a novel ultrasonic osteotome device (BoneScalpel, Misonix, USA) has been introduced into the surgical field [3, 4]. This is a low-frequency ultrasonic device that selectively cuts dense mineralized tissue like bone while theoretically causing little damage to the surrounding soft tissues. The device is comprised of a blunt ultrasonic blade that oscillates at over 22,500 cycles/s with an excursion ranging from 35 to 300 μm depending on amplitude setting and blade geometry. The recurring impacts pulverize the non compliant crystalline structure resulting in a precise cut. The more compliant adjacent soft tissue is theoretically not affected by the ultrasonic oscillation. The purpose of this study was to report on the experience and safety of using this ultrasonic osteotome device in a variety of spine surgeries.

Materials and Methods

We conducted a retrospective review of 128 consecutive patients who underwent spine surgeries with the use of the ultrasonic BoneScalpel (beginning with our first case experience) from October 2010 to July 2012. Patient's age, gender, diagnosis and surgical procedure were documented. Total levels operated, surgical time, blood loss and intra-operative dural and nerve injuries were obtained from medical records. All cases were performed at the same hospital by a single surgeon. The majority of patients had spinal stenosis, degenerative or idiopathic scoliosis, pseudoarthrosis, adjacent segment degeneration, and spondylolisthesis et al. Intra-operatively, various osteotomies (facetectomy, laminotomy, laminectomy, en bloc resection, Smith Petersen osteotomy, pedicle subtraction osteotomy, etc.) were carefully performed using the ultrasonic device together with pituitaries, curettes, rongeurs and osteotomes. The ultrasonic scalpel was used to facilitate straight line osteotomies through the pars interarticularis, through the lamina, through the base of the pedicle, through the vertebral body and through the facet joint surfaces.

Results

A total of 128 consecutive patients (73 female, 55 male) were included in this study. The mean age of the patients at surgery was 58 years (range 12–85 years). Eighty patients (62.5 %) had previous spine surgery and/or spinal deformity (scoliosis and/or kyphosis). The patients' primary

Table 1 The primary diagnosis of the study patients

Primary diagnosis	Cases
Spinal stenosis	24
Degenerative scoliosis	15
Pseudoarthrosis	15
Adjacent segment degeneration	11
Idiopathic scoliosis	11
Degenerative spondylolisthesis	10
Disc herniation	9
Flat back syndrome	7
Metastatic spine tumor	5
Vertebral compression fracture	3
Congenital scoliosis	2
Kyphosis	2
Loosened hardware	2
Sacral fracture	2
Scheuermann's kyphosis	2
Spinal spondylosis	2
Primary spinal tumor	3
Multiple myeloma	1
Epidural hematoma	1
Pseudoarticulation	1
Total cases	128

Table 2 Peri-operative outcome of the surgeries

Average levels operated/patient	5 levels
Mean operative time (skin to skin)	4.3 h
Mean blood loss	425.4 ml
Complications associated with the ultrasonic device	2

diagnosis is summarized in Table 1. The ultrasonic scalpel was used at all levels of the spine and the average levels operated on each patient was 5. The mean operative time (skin to skin) was 4.3 h and the mean blood loss was 425.4 ml (Table 2). In all cases, the ultrasonic scalpel was used successfully to create the needed osteotomies to facilitate the surgical procedure without any percussion on the spinal column or injury to the underlying nerves. There was a noticeable absence of bleeding from the cut end of the bone consistent with the ultrasonic application (Figs. 1, 2) which coagulates the interstices of the marrow while it cuts.

In this series, a total of 11 dural injuries (8.6 %) were encountered, two of which were directly associated with the use of the ultrasonic scalpel. The first case was a 3 mm dural thermal injury which resulted from the overheating of the local tissue by the scalpel blade sitting in one position. This was over sewn with a watertight closure. The second dural injury occurred in a revision case where the dura was adherent and partially ossified. As the osteotomy was

Fig. 1 Intraoperative images showing the use of ultrasonic scalpel during (a, b) and after (c) osteotomies in a revision kyphosis surgery

created and the bone peeled off, the dura was torn in the lateral recess of the epidural canal. This was repaired primarily with a dural patch. However, the patient developed positional headaches, nausea and vomiting postoperatively. A MRI scan at 1 month postoperative showed a large complex fluid collection in the posterior paraspinal soft

Fig. 2 Intraoperative images showing the ultrasonic scalpel creating facetectomies (a) and the completed facetectomies (b) for a scoliosis patient

tissues from T12 to S1. The patient underwent a revision surgery to repair the pseudomeningocele and she recovered well from the revision surgery and reported significant improvement with pain and posture.

Discussion

Bone removal (facetectomy, laminotomy, laminectomy, en bloc resection, Smith Petersen osteotomy, pedicle subtraction osteotomy, etc.) is an essential step in spine surgeries which can sometimes be challenging. Traditional osteotomy instruments such as high-speed drills, rotating burs and threadwire saws can produce considerable vibration and torque intra-operatively. In addition, manual osteotomes require malleting, which is accompanied by the risk of plunging into the soft tissues of the epidural space. Some reports have showed that there is an increased risk of durotomy and neural injury especially when performing osteotomy in a deep area, in a narrow surgical field, or in a revision situation [1, 2, 5].

The use of ultrasonic vibration for the cutting of bone was developed several decades ago [6, 7]. However, it was only in the last several years that the tools and technique have been adopted in the surgical field, especially for oral and maxillofacial surgeries. Some studies have shown that these ultrasonic instruments can decrease the risk of damage to surrounding soft tissues and critical structures such as nerves and vessels, especially during osteotomy

procedures [8, 9]. The ultrasonic scalpel used in this report has a long, narrow blade with a cutting surface ranging from 10 to 20 mm in length and 0.5–1.0 mm in width. The device allows for bone dissection along a narrow cutting blade which vibrates longitudinally at high frequency. The surgeon can create narrow bone cuts with minimal bone debris and destruction. As soft tissue has greater elastic properties than osseous structures, it can thus withstand high amounts of impact energy which help to create a well-controlled environment for bone removal and minimize the risk of dural and neural injury [4].

In this study, we reported our experience with 128 consecutive spine surgeries with the use of the ultrasonic scalpel. The majority of the patients had previous spine surgeries and/or spinal deformity. In all cases, the ultrasonic scalpel was successfully used to create the needed osteotomies with high precision to facilitate the surgical procedure without percussion on the spinal column or injury to the underlying nerves. We found that one of the major advantages (although difficult to objectively quantify) of this ultrasonic device is the reduction of bleeding which helps to create and maintain visibility in the surgical field. Sanborn et al. [4] also reported that there is a notable reduction in osseous bleeding in the ultrasonic scalpel group compared with the traditional technique in an ovine model which may attribute to a local hemostatic effect. We have noticed that by virtue of the precision and ease of control (oscillation versus rotation) the efficiency of the surgery has improved. As a result those often technically challenging osteotomy procedures can now be performed in less time with the ultrasonic scalpel. Others have already reported that utilization of the ultrasonic device can significantly shorten the time required for the removal of the lamina compared to the use of traditional instruments in the ovine model [4]. The ultrasonic scalpel uses a narrow blade with a self-irrigating system that provides lubrication and cooling into the cutting cavity and limits the risk of mechanical and thermal injury [4]. However, we did encounter one incident of dural tear from the overheating of the local tissue by the scalpel blade sitting in one position. It is imperative that the surgeon continue to move the device and not let it bind in one position.

A total of 11 dural injuries (8.6 %) occurred in this case series. Since majority of the patients had previous spine surgery and/or spinal deformity, this dural injury rate is comparable with previous reports [10]. Notably, we have a second dural injury which is directly associated with the ultrasonic scalpel. The patient developed pseudomeningocele postoperatively which eventually led to a revision surgery. Thus, surgeons should pay special attention to the risk of dural injury while using the ultrasonic device especially under challenging conditions such as revision

spine surgeries where the dura may be adherent to bone or partially ossified.

Overall, the results of this study are comparable with a previous report in which the authors compared laminectomies using traditional instruments, and traditional instruments with the ultrasonic scalpel in an ovine model. They found that the incidence of durotomies in the control group and the experimental groups was comparable (one in each group). The single dural injury in the experimental group happened during the first surgery which was the first time for the surgeon to use this device in vivo [4]. This report and our data both support that there is a learning curve to safely using this novel device. We suggest that surgeons who are new to this technique use particular care to avoid local temperature increases from the frictional effects. Generous irrigation should be applied to achieve effective cooling.

There are limitations in this study. We present a retrospective case series review and there is no control group. As there are many other surgical tools used together with the ultrasonic scalpel during the surgery, it is difficult to evaluate the exact benefits of this osteotome device. Well-designed controlled studies can potentially be carried out in animal models [4]. Future efforts could also be made to evaluate if the use of this ultrasonic device can lead to improved clinical outcome in the patients who had spine surgeries.

In conclusion, our case series showed that an ultrasonic scalpel can be safely used to facilitate osteotomies in a variety of spine surgeries. However, caution should be taken to avoid the potential thermal injury and dural tear. If used properly, this device may decrease the risk of soft tissue injury associated with the use of high speed burrs and oscillating saws during spine surgeries.

Conflict of interest The authors declare that there is no direct conflict of interest associated with this manuscript.

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