Safety of spinal decompression using an ultrasonic bone curette compared with a high-speed drill: outcomes in 337 patients

Clinical article

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Object. Unintended durotomies are a common complication of spine surgery and are often correlated with increased postoperative morbidity. Recently, ultrasonic bone curettes have been introduced in spine surgery as a possible alternative to the conventional high-speed drill, offering the potential for greater bone-cutting precision and less damage to surrounding soft tissues. To date, however, few studies have investigated the safety and efficacy of the ultrasonic bone curette in reducing the rates of incidental durotomy compared with the high-speed drill.

Methods. The authors retrospectively reviewed the records of 337 consecutive patients who underwent posterior cervical or thoracic decompression at a single institution between January 2009 and September 2011. Preoperative pathologies, the location and extent of spinal decompression, and the use of an ultrasonic bone curette versus the high-speed drill were noted. The rates of incidental durotomy, as well as hospital length of stay (LOS) and perioperative outcomes, were compared between patients who were treated using the ultrasonic bone curette and those treated using a high-speed drill.

Results. Among 88 patients who were treated using an ultrasonic bone curette and 249 who were treated using a high-speed drill, 5 (5.7%) and 9 (3.6%) patients had an unintentional durotomy, respectively. This finding was not statistically significant (p = 0.40). No patients in either cohort experienced statistically higher rates of perioperative complications, although patients treated using an ultrasonic bone curette tended to have a longer hospital LOS. This difference may be attributed to the fact that this series contained a statistically higher number of metastatic tumor cases (p < 0.0001) in the ultrasonic bone curette cohort, likely increasing the LOS for that patient population. In 13 patients, the dural defect was repaired intraoperatively. No patients who experienced an incidental durotomy had new-onset or permanent neurological deficits postoperatively.

Conclusions. The safety and efficacy of ultrasonic bone curettes in spine surgery has not been well established. This study shows that the ultrasonic bone curette has a similar safety profile compared with the high-speed drill, although both are capable of causing iatrogenic dural tears during spine surgery.

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Key Words • cervical • thoracic • dural tear • durotomy • cerebrospinal fluid leak • complication • ultrasonic bone curette • high-speed drill

Unintended durotomies are a common complication of spine surgery, with reported incidences in the literature ranging from 0% to as high as 35%.1,5,29,50 This variability is a function of not only the type and complexity of spinal procedure involved, but also the fact that most studies are small and retrospective in nature, usually limited to case series from a single-surgeon or a single-institution experience.1,2,4,9,10,12,14,15,16,25-27,29,39,40,43,45,47,48,50 Management of incidental durotomies usually requires intraoperative surgical revision with or without fibrin glue or graft placement, or postoperative flat bed rest with or without subarachnoid drain placement.1,13,29,21,22,26,34,42-44,48 Despite these measures, however, complications resulting from dural tears may develop. These complications

Abbreviations used in this paper: IQR = interquartile range; LOS = length of stay.

Dr. M. Bydon and Mr. Xu contributed equally to this work.
include CSF leak or fistula, meningitis, arachnoiditis, spinal epidural abscess, pseudomeningoceles, intraspinal hemorrhage or subdural hematoma, low-pressure headache, acquired Chiari malformation, sensory and motor dysfunction and pain due to associated nerve root injury, or delayed nerve root entrapment.\textsuperscript{15,37,27,29,36,51}

In light of these potential complications, multiple efforts have been made to implement a safer bone curette system compared with the standard of care, the use of a high-speed drill. To this end, ultrasonic vibrations used in piezoelectric surgery have gained the most traction. First introduced in the 1950s, piezoelectric surgery has found widespread acceptance and use in the performance of osteotomies in the fields of dentistry and oral and maxillofacial surgery, reducing the risk of damage to surrounding soft tissues and important structures such as nerves, blood vessels, and mucosa.\textsuperscript{6,20,23,24,32,33} In neurosurgery, ultrasonic aspirators have been used to remove soft-tissue tumors such as meningiomas and vestibular schwannomas.\textsuperscript{32}

More recently within the past few years, ultrasonic bone curettes have been adapted to perform not only endoscopic bone removal over the skull base, but also laminectomies of the spinal column.\textsuperscript{6–8,24,28,32,33,38,41,46} In a sequence of case series and technical notes, the Sonopet UST-2001 (Miwatec Co., Ltd.) has been shown to be a versatile, safe, and efficient method for bone removal within spine surgery.\textsuperscript{6,20,23,24,32,33} Nonetheless, the time-consuming nature of the Sonopet necessitated its suggested combined usage with the conventional high-speed drill when removing large amounts of bone—for example, in the lumbar spine—or when dissecting complicated ossified lesions within the spinal architecture. To date, the primary outcome delineating the efficacy of ultrasonic bone curettes in reducing the rate of incidental durotomies remains unclear.

To better understand the benefits and potential drawbacks of ultrasonic bone curette use in spine surgery, we describe our experience using the BoneScalpel (Misonix, Inc.), an ultrasonic bone curette optimized for orthopedics and neurosurgery applications in bone dissection, sculpting, and removal. We compare the incidence of unintentional durotomy and the outcomes of patients treated with the BoneScalpel to those treated using a conventional high-speed drill.

**Methods**

**Patient Selection**

We reviewed patient data for all patients undergoing surgical management of spinal pathologies between January 2009 and September 2011 at Johns Hopkins Hospital and the Johns Hopkins Bayview Medical Center. The study was approved by the institutional review board. Patients included in this study were those who had undergone posterior cervical and/or thoracic decompression with or without instrumented fusion for extradural pathologies. We excluded cases involving intradural pathology because treatment of these pathologies by definition necessitates durotomy and intradural exploration. We also excluded lumbar pathology because the thicker lamina in the caudal spine often precluded the effective use of an ultrasonic bone curette. The cases reported in this study include metastatic tumors, osteomyelitis and discitis, hematoma, and degenerative disease of the spine. In total, we report a series of 337 cases in which either the BoneScalpel or the high-speed drill was used. The level of each lesion was recorded from operative notes, and the presence of degenerative spinal conditions such as scoliosis, degenerative disc disease, and spondylolisthesis was verified with radiographic images. Operative reports were reviewed for classification of surgical procedures into either cases utilizing the BoneScalpel or cases utilizing the high-speed bone drill. Incidental dural tears or intraoperative CSF leakage attributed to these 2 surgical instruments were identified using operative reports. Perioperative and postoperative outcomes were ascertained via clinic notes and telephone calls.

**Operative Technique**

In all cases of dural tears using the high-speed drill, the actual tearing mechanism was due to the Kerrison punch. We continue to classify these cases under the high-speed drill category as the use of the drill necessitates extensive use of the Kerrison punch as well. For patients experiencing dural tears via the ultrasonic bone curette, the dural lesion was due to the curette itself, not from accessory instruments used during the operation. In comparison with tears created by the high-speed drill, ultrasonic curette tears tended to be more linear in quality. They also tended to be lateral in location and cranio-caudal in orientation. These features are consistent with tears directly anterior to the area targeted by the ultrasonic curette.

**Statistical Analysis**

Preoperative and intraoperative variables were compared between the treatment cohort (patients who underwent a decompression using the BoneScalpel) and the control group (patients who underwent a decompression using the conventional high-speed drill) using a Student t-test for continuous normal data, and the chi-square test or Fisher exact test for categorical data. Data analysis was performed using Prism 5 (GraphPad Software, Inc.). Statistical significance was defined as a p value < 0.05.

**Results**

A total of 337 patients underwent surgical treatment for cervical or thoracic spinal pathology requiring posterior decompression with or without instrumented fusion. Of the 337 patients, 187 were male, and the mean age was 60.4 ± 16.2 years (Table I). The BoneScalpel was used in 88 patients, and the high-speed drill in 249. Among these patients, the average age was 59.7 ± 18.7 years in the BoneScalpel cohort and 60.6 ± 12.9 years in the high-speed drill group. This was not statistically different (p = 0.62). In the BoneScalpel treatment group, 49 patients (55.7%) were male, while 138 (55.4%) were male in the high-speed drill group (p = 0.97). In total, we excluded 50 patients due to intradural pathology: 35 for intradural...
tumors, 14 for Chiari malformation or arachnoid cyst, and 1 for an arteriovenous fistula.

Of 337 patients, 234 (69.4%) were treated for degenerative disease (Table 1). Of these 234 patients, 45 (51.1%) were treated with the BoneScalpel and 189 (75.9%) with the conventional high-speed drill, a statistically significant difference (p < 0.0001). Thirty-seven patients (11.0%) were treated for metastatic tumors; of these 37 patients, 24 (27.3%) were in the BoneScalpel group and 13 (5.2%) were in the control group, also a statistically significant difference (p < 0.0001). The number of patients in each group treated for a traumatic origin, primary extradural tumors of the spine, osteomyelitis, epidural hematomas, and epidural abscesses were not significantly different.

Of the 337 patients, 132 (39.2%) had pathology located exclusively in the cervical spine, 71 (21.1%) in the thoracic spine, and 134 (39.8%) in the cervicothoracic spine (Table 2). Of these 337 patients, the BoneScalpel was used to treat 29 patients (33.0%) who had cervical spine pathology, 23 (26.1%) who required operation of the thoracic spine, and 36 (40.9%) who were operated on at the cervicothoracic junction. In the high-speed drill cohort, 103 patients (41.4%) had spinal disease limited to the cervical region, 48 (19.3%) underwent surgery at the thoracic spine, and 98 (39.3%) required treatment across the cervicothoracic junction. There were no statistically significant differences between treatment cohorts as a function of spinal pathology location.

In the entire cohort, 276 patients (81.9%) underwent spinal decompression between 1 and 3 vertebral levels, 59 (17.5%) underwent decompression between 4 and 6 vertebral levels, and 2 (0.6%) had more than 6 spinal levels decompressed (Table 2). The BoneScalpel was used in 70 patients (82.7%) who had 1–3 levels decompressed, 41 (16.5%) had 4–6 spinal levels decompressed, and in no patients who required more than 6 levels of decompression. In the high-speed drill cohort, 206 patients (82.7%) had 1–3 vertebral levels decompressed, 41 (16.5%) had 4–6 spinal levels decompressed, and 2 (0.8%) required more than 6 levels of spinal decompression. There were no statistically significant differences in spinal levels involved between patients treated with the BoneScalpel or conventional high-speed drill.

Among the 337 patients who received posterior cervical or thoracic spinal decompression, 14 (4.2%) experienced intraoperative incidental durotomy (Table 2). Five patients (5.7%) who had unintended durotomy were treated with the BoneScalpel, and 9 (3.6%) were treated using the high-speed drill. This difference was not statistically significant (p = 0.40). Patients who underwent de-

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total</th>
<th>BoneScalpel</th>
<th>High-Speed Drill</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>location (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cervical</td>
<td>132 (39.2)</td>
<td>29 (33.0)</td>
<td>103 (41.4)</td>
<td>0.1647</td>
</tr>
<tr>
<td>thoracic</td>
<td>71 (21.1)</td>
<td>23 (26.1)</td>
<td>48 (19.3)</td>
<td>0.1750</td>
</tr>
<tr>
<td>cervicothoracic</td>
<td>134 (39.8)</td>
<td>36 (40.9)</td>
<td>98 (39.3)</td>
<td>0.7982</td>
</tr>
<tr>
<td>levels involved (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–3</td>
<td>276 (81.9)</td>
<td>70 (79.5)</td>
<td>206 (82.7)</td>
<td>0.5047</td>
</tr>
<tr>
<td>4–6</td>
<td>59 (17.5)</td>
<td>18 (20.5)</td>
<td>41 (16.5)</td>
<td>0.3974</td>
</tr>
<tr>
<td>&gt;6</td>
<td>2 (0.6)</td>
<td>0</td>
<td>2 (0.8)</td>
<td>0.3991</td>
</tr>
<tr>
<td>incidental durotomy (%)</td>
<td>14 (4.2)</td>
<td>5 (5.7)</td>
<td>9 (3.6)</td>
<td>0.4035</td>
</tr>
<tr>
<td>median LOS in days (IQR)</td>
<td>6 (4–9)</td>
<td>6 (4–10)</td>
<td>5 (4–8)</td>
<td>0.003</td>
</tr>
</tbody>
</table>
compression using the BoneScalpel experienced a longer hospitalization course than those who received the high-speed drill (p = 0.003). Thus, patients who experienced the BoneScalpel had a median hospital LOS of 6 days (IQR 4–10 days), whereas those who received the high-speed drill had a median hospitalization length of 5 days (IQR 4–8 days). This significant difference may be attributed to the fact that our series contained a statistically higher number of metastatic tumor cases (p < 0.0001) in the BoneScalpel cohort, likely increasing the LOS for that patient population.

In 13 patients, the dural defect was repaired intraoperatively and none of these patients required any additional treatment. However, in 1 case in which decompression was necessitated by a metastatic thoracic extradural lesion (Case 6, Table 3), the patient’s postoperative course was complicated by a pulmonary embolism and methicillin-resistant *Staphylococcus aureus* empyema. After a second operation for dural defect repair and lumbar drain placement, the patient subsequently recovered without any additional complications.

**Discussion**

The literature on iatrogenic dural tears during spine surgery is sparse, and the factors that predispose patients to intraoperative unintentional durotomy remain ambiguous. While some studies have implicated the patient’s age, sex, revision surgery, invasiveness of procedure, surgeon experience, and presence of complicating conditions as potential risk factors for durotomy, most of these conclusions have been drawn from small retrospective studies. Recently, Baker et al. published a prospective analysis of 1745 patients who underwent spine surgery and found that age, lumbar surgery, revision surgery, and increased surgical invasiveness were significant risk factors of unintended durotomy. This is consistent with the Williams et al. prospective study of the Scoliosis Research Society spinal database comprising 108,478 cases, which also found the highest risks for durotomy among the elderly, those with revision surgeries, and those with degenerative causes for spine surgery. In Ruban and O’Toole’s case-controlled analysis of 563 patients treated using minimally invasive spine surgery, risk factors identified for durotomy included prior spine surgery at the index level and operation in the lumbar spine region, suggesting that these risk factors are independent of an open versus a minimally invasive technique and more likely due to spinal anatomy.

Consistent with the findings of Baker et al., patients in our cohort experiencing durotomy were also older (61.1 ± 11.9 years) than those who did not (58.5 ± 15.0 years), although this was not statistically significant (p = 0.51). Moreover, consistent with the results of the study of Williams et al., patients who experienced incidental durotomy in our study were most likely to have received surgery for degenerative disease (11 of 14 patients, 78.6%). Furthermore, the 14 patients who had unintended durotomy in our analysis also experienced the highest levels of surgical invasiveness as rated by the scale of Mirza et al. used in the analysis of Williams et al. The surgical invasiveness for these 14 patients includes multilevel spinal decompression with instrumented fusion in all patients (100%), as well as additional discectomy, corpectomy, and/or cage/bone graft placement procedures in 7 (50%; Table 3). Of note, although the risks of incidental

**TABLE 3: Characteristics of all patients treated with the BoneScalpel or high-speed drill who experienced intraoperative incidental durotomy**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Treatment</th>
<th>Diagnosis</th>
<th>Level of Pathology</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>70, F</td>
<td>BoneScalpel</td>
<td>degenerative disease</td>
<td>C3–6</td>
<td>laminectomy, facetectomy, foraminotomy, instrumented fusion</td>
</tr>
<tr>
<td>2</td>
<td>44, F</td>
<td>BoneScalpel</td>
<td>degenerative disease</td>
<td>C3–6</td>
<td>laminectomy, instrumented fusion</td>
</tr>
<tr>
<td>3</td>
<td>61, M</td>
<td>BoneScalpel</td>
<td>degenerative disease</td>
<td>C3–7</td>
<td>laminectomy, instrumented fusion</td>
</tr>
<tr>
<td>4</td>
<td>60, M</td>
<td>BoneScalpel</td>
<td>degenerative disease</td>
<td>T10–12</td>
<td>laminectomy, facetectomy, discectomy, graft placement, instrumented fusion</td>
</tr>
<tr>
<td>5</td>
<td>78, M</td>
<td>BoneScalpel</td>
<td>chordoma</td>
<td>C2–5</td>
<td>laminectomy, facetectomy, rhizotomy, graft placement, instrumented fusion</td>
</tr>
<tr>
<td>6</td>
<td>55, M</td>
<td>high-speed drill</td>
<td>metastatic follicular thyroid carcinoma</td>
<td>T2–8</td>
<td>laminectomy, facetectomy, corpectomy, rhizotomy, graft, instrumented fusion</td>
</tr>
<tr>
<td>7</td>
<td>47, F</td>
<td>high-speed drill</td>
<td>degenerative disease</td>
<td>C4–6</td>
<td>laminectomy, foraminotomy, instrumented fusion</td>
</tr>
<tr>
<td>8</td>
<td>47, M</td>
<td>high-speed drill</td>
<td>epidural tumor</td>
<td>T7–12</td>
<td>laminectomy, corpectomy, rhizotomy, instrumented fusion</td>
</tr>
<tr>
<td>9</td>
<td>72, F</td>
<td>high-speed drill</td>
<td>degenerative disease</td>
<td>T9–11</td>
<td>revision surgery, laminectomy, facetectomy, rhizotomy, corpectomy, graft placement, instrumented fusion</td>
</tr>
<tr>
<td>10</td>
<td>72, F</td>
<td>high-speed drill</td>
<td>degenerative disease</td>
<td>C4–7</td>
<td>laminectomy, facetectomy, foraminotomy, instrumented fusion</td>
</tr>
<tr>
<td>11</td>
<td>60, M</td>
<td>high-speed drill</td>
<td>degenerative disease</td>
<td>T7–11</td>
<td>laminectomy, facetectomy, foraminotomy, discectomy, instrumented fusion</td>
</tr>
<tr>
<td>12</td>
<td>61, M</td>
<td>high-speed drill</td>
<td>degenerative disease</td>
<td>C3–7</td>
<td>laminectomy, instrumented fusion</td>
</tr>
<tr>
<td>13</td>
<td>49, M</td>
<td>high-speed drill</td>
<td>degenerative disease</td>
<td>C3–7</td>
<td>laminectomy, instrumented fusion</td>
</tr>
<tr>
<td>14</td>
<td>80, F</td>
<td>high-speed drill</td>
<td>degenerative disease</td>
<td>T10–12</td>
<td>laminectomy, facetectomy, discectomy, instrumented fusion</td>
</tr>
</tbody>
</table>
Incidental durotomies are a well-known complication of spine surgery. In this study, we conducted a retrospective analysis of 337 patients who underwent posterior decompression of the cervical or thoracic spine using either the ultrasonic bone curette BoneScalpel or the conventional high-speed drill. To our knowledge, this is one of the first studies in the literature to investigate the relative risk for iatrogenic dural tears for an ultrasonic bone curette compared with the conventional high-speed drill in reducing incidental durotomy rates. However, as the rate of adoption of ultrasonic bone curettes in spine surgery continues to increase, patient sample sizes will, by definition, be small until rates of usage among spinal surgeons reach greater levels.

In addition, because we represent an academic teaching hospital, surgeon experience may be a potential biasing factor. Four of 6 attending physicians had patients who experienced durotomy in both the high-speed drill and BoneScalpel cohorts. No attending physician was overrepresented in either patient cohort, with or without durotomies. Separately, we must acknowledge that at our institution, patients were more likely to have been treated using the BoneScalpel if they presented with metastatic tumor (p = 0.003) was influenced by the overrepresentation of patients with metastatic tumor burden in that patient cohort. Nevertheless, limiting the analysis to only the degenerative cohort or the metastatic tumor cohort continues to reveal no statistical benefit for the ultrasonic bone curette in reduction of unintended durotomy compared with the high-speed drill (Table 4). Therefore, additional studies involving multiple institutions and those that are prospective in design may help further clarify the relative risks of incidental durotomy that accompany the utilization of ultrasonic bone curettes versus the high-speed drill in spine surgery.

Conclusions
pared with the high-speed drill. Among 88 patients who underwent a decompression using the BoneScalpel and 249 who underwent decompression using the high-speed drill, 5 (5.7%) and 9 (3.6%) patients experienced an unintended durotomy, respectively (p = 0.40). No patients in either cohort experienced statistically higher rates of perioperative complications, although patients treated using the BoneScalpel had a longer length of hospitalization compared with high-speed drill controls. We believe this difference may be attributed to the fact that our retrospective series contained a statistically higher number of meta-

dynamic tumor cases (p < 0.0001) in the BoneScalpel cohort, likely increasing the LOS for that patient population. No patients who experienced an incidental durotomy had new-onset or permanent neurological deficits postoperatively. Thus, we find that the BoneScalpel is at least as safe and efficacious as the conventional high-speed drill. Nonetheless, both instruments should be used cautiously to avoid unintended entrance into the thecal sac.

Disclosures

Dr. A. Bydon is the recipient of a non-study related research grant from DePuy Spine. He serves on the clinical advisory board of MedImmune, LLC. Dr. Gokaslan is the recipient of research grants from DePuy, AO North America, AO Spine, the Neurosurgery Research and Education Foundation, and the Orthopaedic Research and Education Foundation; and holds stock in Spinal Kinetics and US Spine. Dr. Witham is the recipient of a research grant from Eli Lilly. Dr. Scuibba has received non-study related research support from DePuy, and has consulting relationships with Medtronic, NuVasive, Globus, and DePuy. Dr. Jallo has received a pediatric fellowship grant from Medtronic.

Author contributions to the study and manuscript preparation include the following. Concept and design: A. Bydon, M Bydon, Gokaslan. Acquisition of data: M. Bydon, Xu, Papadimitriou. Analysis and interpretation of data: M. Bydon, Xu. Drafting the article: Xu, Papadimitriou. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: A. Bydon. Statistical analysis: A. Bydon, M. Bydon, Xu. Administrative/technical/material support: A. Bydon. Study supervision: A. Bydon, M. Bydon, Xu.

References


TABLE 4: Incidental durotomy in patients treated using the BoneScalpel or high-speed drill, analyzed separately according to degenerative or metastatic disease origins

<table>
<thead>
<tr>
<th>Incidence of Durotomy</th>
<th>Total</th>
<th>BoneScalpel</th>
<th>High-Speed Drill</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>in degenerative disease (%)</td>
<td>11 (4.7)</td>
<td>4/45 (8.9)</td>
<td>7/189 (3.7)</td>
<td>0.2296</td>
</tr>
<tr>
<td>in metastatic tumors (%)</td>
<td>3/37 (8.1)</td>
<td>1/24 (4.2)</td>
<td>2/13 (15.4)</td>
<td>0.2777</td>
</tr>
</tbody>
</table>
Safety and efficacy of an ultrasonic bone curette


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