Cervical spondyloitic myelopathy is a progressive, degenerative disease and the most common cause of spinal cord dysfunction worldwide. Narrowing of the spinal canal is caused by disc protrusion, ossification of the posterior longitudinal ligament, thickening of the ligamentum flavum, or osteophytes, and leads to compression of the cervical spinal cord and nerve roots. Depending on the severity of the disease, symptoms can include neck pain, loss of hand dexterity, gait difficulties, and impotence. Over time, progressive CSM may lead to tetraparesis or tetraplegia.

Previous studies have demonstrated that CSM can severely reduce a patient’s health-related quality of life. Patients with CSM are often treated surgically to halt or reverse the progression of myelopathic symptoms. Surgical intervention has been shown to significantly improve functional status, decrease neurological symptoms, and reduce overall pain.

Despite the frequent clinical occurrence of CSM and the widespread use of surgery for this condition, the cost-effectiveness of this intervention has not been previously assessed. We therefore sought to address this knowledge gap through a cost-utility analysis.
gap. This study reports the results of a cost-utility analysis of surgical intervention for the treatment of CSM at a single Canadian institution. Further, we compare the cost utility of CSM surgery to that of other common medical interventions.

**Methods**

**Study Design**

Between January 2006 and September 2007, patients entering treatment for CSM in the Division of Neurosurgery in the Toronto Western Hospital of the University Health Network were prospectively recruited for this study, which was part of a larger multicenter AOSpine North America CSM study examining the outcomes of surgical treatment of CSM. The research ethics board governing Toronto Western Hospital approved the study, and all patients gave their informed consent in writing.

Ninety-three patients undergoing surgery for symptomatic CSM were enrolled in the study and were followed up for 24 months. Symptomatic CSM was defined as experiencing one or more of the following symptoms: numb or clumsy hands, impairment of gait, bilateral arm paresthesia, Lhermitte phenomenon, and weakness. Furthermore, the patient had to demonstrate one or more of the following: corticospinal distribution motor deficits, atrophy of hand intrinsic muscles, hyperreflexia, a positive Hoffman sign, upgoing plantar responses, lower-limb spasticity, or a broad-based unstable gait. Patients were excluded from the study if they had asymptomatic cervical cord compression, if they had undergone previous surgery for CSM or were not referred for surgical consultation or if they had concomitant symptomatic lumbar stenosis, an active infection, neoplastic disease, rheumatoid arthritis, or ankylosing spondylitis.

Table 1 describes patient demographic characteristics. Of the 93 participants, 10 (11%) withdrew before study completion, 13 (14%) did not complete follow-up, and 70 (75%) completed the required 24-month follow-up.

**Outcome Measures**

The effectiveness of the intervention was evaluated by measuring the change in utilities using SF-6D utility values derived from SF-36v2 scores. The SF-36v2 has been proven to be valid and reliable in patients with CSM. The SF-6D is a health state classification measure that is based on 7 of the 8 domains of the SF-36v2 questionnaire, combining physical functioning, emotional and physical role participation, social functioning, bodily pain, mental health, and vitality. The SF-6D describes 18,000 health states. These are accompanied by a set of standard gamble–derived preference weights obtained from a sample of the general population. The preference weights range from 0.0 (worst health state) to 1.0 (best health state) and are used in cost-utility analyses.

Patients were asked to complete the SF-36v2 questionnaire before treatment and at 6, 12, and 24 months following surgery. The SF-6D health utility gains were derived from the entire multicenter study sample by calculating the difference between baseline and 12-month follow-up values. Of the 278 patients enrolled in the multicenter study, 17 withdrew consent and 1 died of an unrelated cause prior to 12 months' follow-up. Follow-up data were available for 222 (85.4%) of the 260 eligible patients. The SF-6D utilities at the Toronto site were consistent with the utilities in the overall CSM–North America study. A 10-year horizon with 3% discounting was applied to health utilities to determine the number of QALYs gained by the intervention. A QALY provides an estimate of the number of months or years of a reasonable quality of life a patient can expect to gain from treatment. For example, if the patient’s health state was 0.6 before treatment and 0.8 after treatment, the annual gain is 0.2 QALYs.

Health outcomes were also evaluated using the Neck Disability Index, the mJOA scale, and a modified version of the Nurick Scale. The original Nurick Scale is a 6-grade system (0–5) that does not include a classification for asymptomatic patients. Our modified version is a 7-grade scale (0–6), where Grade 0 represents no root or cord symptoms and Grades 1–6 are equivalent to Grades 0–5 of the original Nurick scale.

**Medical Costs**

Direct medical costs of treatment for each patient comprised hospital inpatient costs and physician reimbursement costs obtained from the hospital’s Case-Costing Database and from the Ontario Schedule of Benefits for Physician Services (Table 2). Direct medical costs comprised all inpatient services provided in the 24 months following surgery, including ward costs, medication, instrumentation, and in-hospital services and procedural costs, as well as any treatment for peri- and postoperative complications including reoperations occurring within 24 months following the index surgery. Outpatient costs consisted of pre- and postoperative MRI studies and 3 follow-up visits, which were completed as per protocol and reflect the standard of care at Toronto Western Hospital. Postoperative MRI is used to ascertain the adequacy of decompression after surgery. Indirect costs, such as disability losses and foregone productivity, were not included. Also not included were costs of loss of quality of life.
Cost-effectiveness of surgery for cervical spondylotic myelopathy

The mean estimated value (± SD) for the direct costs of medical treatment was CaD $21,066 ± $14,759 (range CaD $14,494–$148,197). The range in surgery costs was due to different types of surgical approaches, emergency surgeries with after-hours premiums, and/or the inclusion of a second surgery within 24 months of the primary surgery.

The estimated cost-utility ratio was CaD $32,916 per QALY. The sensitivity analysis showed a range of $27,326–$40,988 per QALY gained, based on a 20% variation in utility values.

Discussion

Our analysis suggests that surgical treatment for CSM is a cost-effective intervention by conventional standards. The cost-utility ratio for CSM surgeries is CaD $32,916/ QALY, which is below WHO benchmarks that suggest that programs be considered highly cost-effective if life years are purchased at a cost of less than gross domestic product per capita, which was US $45,110 (CaD $46,012 by midyear exchange rate in 2008). Table 4 lists the cost utility of other accepted surgeries, indicating that the cost per QALY gained for CSM surgery falls within the range of surgical procedures deemed to be cost-effective.

Cervical spondylotic myelopathy often affects people over the age of 50 years, and as our population ages, the frequency of surgeries in cases of CSM is expected to rise. This study demonstrates that surgical decompression and fusion can induce a clinically relevant improvement of health-related quality of life in patients with CSM, findings which are consistent with earlier CSM studies. Previous CSM studies have also demonstrated that symptoms rarely improve with conservative management of CSM. In patients with CSM that is left untreated, symptoms often worsen, and a subgroup of patients may even progress to tetraplegia. Strengths of this study include the use of prospectively accrued data, a large sample size, the use of a validated outcome measure, and a thorough analysis of all direct medical costs. In addition, the demographics of the participants at our center were very similar to participants at all other 11 study centers in the US. Cost-effectiveness

### TABLE 3: Changes in neurological severity and functional and health outcomes in the entire multicenter sample (n = 222)*

<table>
<thead>
<tr>
<th>Outcome Measure (score range)</th>
<th>Mean Score</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>mJOA (0–18)</td>
<td>Baseline</td>
<td>12 Mos</td>
</tr>
<tr>
<td>13.01 ± 2.63</td>
<td>15.74 ± 2.52</td>
<td>2.74 ± 2.94</td>
</tr>
<tr>
<td>modified Nurick Scale (0–6)†</td>
<td>3.11 ± 0.96</td>
<td>1.51 ± 1.48</td>
</tr>
<tr>
<td>Neck Disability Index (0–100)</td>
<td>41.76 ± 21.03</td>
<td>30.39 ± 22.94</td>
</tr>
<tr>
<td>SF-36v2</td>
<td>PCS (0–100)</td>
<td>36.60 ± 9.67</td>
</tr>
<tr>
<td></td>
<td>MCS (0–100)</td>
<td>40.09 ± 10.87</td>
</tr>
<tr>
<td></td>
<td>SF-6D (0–1)</td>
<td>0.575 ± 0.131</td>
</tr>
</tbody>
</table>

* MCS = Mental Component Summary; PCS = Physical Component Summary.
† Includes a classification for patients with no root or cord symptoms (see Methods).

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### Statistical Analysis

The cost-effectiveness of the surgery was analyzed from the perspective of health care payers. Dividing the mean cost of treatment by the mean number of QALYs gained provides an estimate of cost utility measured in cost per QALY. A sensitivity analysis was performed by varying utility values by 20%. Data analysis was generated using SAS/STAT software, version 9.2 of the SAS System for Windows (SAS Institute, Inc.).

### Results

Patients exhibited significant improvement in all measured health outcomes at 12 months following surgery (Table 3). The SF-6D utilities improved significantly by a mean of 0.0734 (95% CI 0.0557–0.0912, p < 0.01) at 12 months and remained unchanged at 24 months. Patients experienced a mean discounted gain of 0.64 QALYs over the 10-year period.

### TABLE 2: Direct costs of medical treatment for surgical decompression in patients with symptomatic CSM

<table>
<thead>
<tr>
<th>Item Billed</th>
<th>Average Cost (CaD $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>clinic</td>
<td></td>
</tr>
<tr>
<td>special surgical consultation</td>
<td>144.75</td>
</tr>
<tr>
<td>preadmission surgery admission unit</td>
<td>182.56</td>
</tr>
<tr>
<td>follow-up visits (including radiography)</td>
<td>364.92</td>
</tr>
<tr>
<td>imaging</td>
<td></td>
</tr>
<tr>
<td>preop MRI</td>
<td>262.95</td>
</tr>
<tr>
<td>postop MRI</td>
<td>262.95</td>
</tr>
<tr>
<td>procedure</td>
<td></td>
</tr>
<tr>
<td>spine surgeon billing</td>
<td>3,393.56</td>
</tr>
<tr>
<td>anesthesia billing</td>
<td>1,220.71</td>
</tr>
<tr>
<td>inpatient costs*</td>
<td>15,234.04</td>
</tr>
<tr>
<td>total</td>
<td>21,066.44</td>
</tr>
</tbody>
</table>

* Inpatient costs include cost of hospital room, food, medications, implants, laboratory testing, and administration for index surgery and any rehospitalization.
analyses have some inherent methodological limitations, including the assumptions made in deriving QALYs from health outcomes. While there is a debate over the use of EQ-5D (developed by the EuroQol Group) versus SF-6D utility values, this study uses SF-6D values to calculate QALYs gained, which is a validated approach in cost-utility analyses. In choosing a 10-year horizon for health outcomes, we have assumed that the benefits of surgery remain 10 years postoperatively, an assumption that is supported by anecdotal rather than empirical evidence. To further address this issue, we have discounted utilities by 3%, effectively reducing the value of long-term gains.

Additional limitations of this study include an incomplete analysis of all costs associated with CSM surgery. Costs were calculated from the health care payers’ perspective and therefore include only reimbursements for direct hospital treatment. While the reimbursements are not necessarily the same as the costs for provided treatment, our approach follows similar methodology to other cost-utility analyses. Furthermore, we did not compare the costs of surgical versus conservative treatments and have not subtracted the avoided costs of conservative disease management. Thus it is possible that surgical treatment is more cost-effective than our results suggest.

Our cost data reflect costs in the Canadian health care system. The extent to which these data apply in other countries depends on the actual costs of similar services.

Conclusions
Surgical intervention for patients with CSM leads to significant improvement in health utilities measured by SF-6D preference-based utility scores. The cost per QALY gained is within the range of values considered cost-effective. Allocation of hospital resources should focus on creating awareness of this condition at the primary care level, allowing for rapid triage, imaging, assessment, and treatment.

Disclosure
This study was sponsored by AOSpine North America, a 501(c) nonprofit corporation. Author contributions to the study and manuscript preparation include the following: Conception and design: Fehlings, Massicotte. Acquisition of data: all authors. Analysis and interpretation of data: Fehlings, Jha, Hewson, Kopjar, Kalsi-Ryan. Drafting the article: Jha, Hewson. 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: Fehlings. Statistical analysis: Kopjar. Study supervision: Fehlings.

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