Predicting sagittal deformity after surgery for intramedullary tumors

Clinical article

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Object. Spinal deformity after surgery for intramedullary tumors is a potentially serious complication that may require subsequent fusion. The aim of this study was to determine whether there were risk factors that could be used to predict postoperative sagittal deformity.

Methods. The authors conducted a retrospective study of patients harboring an intramedullary tumor who had undergone surgery at a single center between 1985 and 2011. The main outcome of interest was the difference, at the last follow-up, between post- and preoperative measures of the Cobb angle formed by the superior and inferior limits of the laminectomy (ΔCobb).

Results. Sixty-three patients were eligible for inclusion in the study. The mean sagittal deformity, measured as described above, was 15.9° (range 0°–77°) at a mean follow-up of 85.4 months (range 4–240 months). Univariate analysis showed increased sagittal deformity in patients 30 years old or younger (21.9° vs 13.7°, p = 0.04), undergoing a laminectomy involving 4 or more levels (19.3° vs 12.1°, p = 0.04), and undergoing a laminectomy that included a spinal junction (20.8° vs 12.4°, p = 0.02). Multivariate analysis showed that only age (p = 0.01) and the number of spinal levels involved in the laminectomy (p = 0.014) were significant and independent predictors of postoperative sagittal deformity. The linear regression equation drawn from this model allows one to quantitatively predict sagittal deformity for any follow-up time point after surgery.

Conclusions. Authors of this study developed a statistical tool that could be used to plan surgery and follow-up as regards the risk of sagittal spinal deformity in patients undergoing surgery for intramedullary tumors. (http://thejns.org/doi/abs/10.3171/2014.5.SPINE13886)

Key Words • sagittal deformity • laminectomy • intramedullary tumor • oncology

Spinal deformity is a well-documented complication after surgery involving a multilevel laminectomy.4 Postoperative kyphosis has been reported to occur in 10%–14% of surgeries for cervical spondylotic myelopathy.11 Risk factors associated with postlaminectomy sagittal deformity are pediatric patient age,2,10,12 number of spinal levels involved in the laminectomy,5 preoperative kyphosis,6 arthrectomy,7 inclusion of a spinal junction in the laminectomy,6 adjuvant radiotherapy,7,5 and surgical reintervention.1

The issue of sagittal spinal deformity is all the more relevant after surgery for intramedullary tumors given that many of the above-mentioned risk factors (young age, extensive laminectomy, adjuvant radiation therapy, subsequent surgery) are inherent to such procedures in which the main focus is often tumor control. However, spinal deformity can also burden the functional outcome, even if the tumor is properly controlled. It is therefore important to be able to assess the risk of sagittal spinal deformity following surgery for intramedullary tumors, to inform the patient and carefully plan the surgery and follow-up.

Several approaches have been proposed to decrease the risk of postlaminectomy spinal deformity. Although contradictory results have been published,7 laminoplasty has not proved to be clearly effective, both in degenerative5 and tumoral10 conditions. In particular, McGirt et al.8 have shown in a retrospective cohort of 238 patients, including 102 with an intramedullary tumor, a similar incidence of sagittal deformity for laminectomy (12%) and laminoplasty (9.9%, p = 0.728). Although concomitant osteosynthesis does decrease the risk of deformity, it also involves serious potential pitfalls:2 increased risk of neurovascular damage and operative time, infectious and mechanical complications, imaging artifacts that can impede tumor follow-up, and adjacent-segment syndromes.

The aim of this study was to quantitatively assess
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the prognostic value of potential risk factors for sagittal spinal deformity following surgery for intramedullary tumors. Such knowledge could then be useful to plan follow-up and complementary stabilization procedures.

Methods

We conducted a retrospective cohort study of patients who had undergone surgery for an intramedullary tumor at a single institution (Department of Neurosurgery, University Hospital Bicêtre, Paris) between 1985 and 2011. Patients eligible for inclusion had complete clinical data and at least 1 imaging study (radiography, CT, or MRI) in the sagittal plane before and after surgery.

For each patient, we measured the Cobb angle at the upper and lower limit of the laminectomy on the preoperative and the last available follow-up image. By convention, the angle was negative when measuring a kyphosis and positive when measuring a lordosis. The absolute difference between pre- and postoperative Cobb angles, noted as ∆Cobb, was the main end point for sagittal deformity (Fig. 1). Radiographs had been obtained every time the surgeon detected a significant deformity (∆Cobb > 15°). In these cases, ∆Cobb was calculated by comparing preoperative and postoperative (upright) radiographs. Otherwise, ∆Cobb was calculated by comparing preoperative and postoperative (supine) MR images.

Other variables of interest included potential risk factors for postoperative deformity: patient age and sex, pre- and postoperative McCormick Scale scores, preoperative motor deficit, tumor histology, presence of an intratumoral cyst, preoperative kyphosis, spinal segment and number of levels included in the laminectomy, adjuvant radiation therapy, subsequent surgery, and length of follow-up.

Statistical analysis was conducted in a 3-step process using the SPSS Statistics software v20.0 (IBM): 1) descriptive analysis of baseline characteristics; 2) univariate analysis of baseline characteristics; 2) univariate comparison of ∆Cobb between those variables (t-test or 1-way ANOVA for categorical data, Pearson correlation for continuous data); and 3) multivariate linear regression model including variables for which the ∆Cobb was found to be significantly different in the univariate analysis. All results were considered statistically significant for a p value < 0.05.

Results

During this period, 80 consecutive cases with intramedullary tumors had been admitted. Among these cases were 63 patients who met the study inclusion criteria (Table 1). The average follow-up was 85.4 months (range 4–240 months). Mean patient age was 39.2 years (range 16–67 years), with 46% males (29 of 63) and 58% females (34 of 63) who had a preoperative motor deficit. There were 26 (41.3%) ependymomas, 22 (34.9%) astrocytomas, and 15 (23.8%) hemangioblastomas. Most tumors were located in the cervical spine (50.8%) and included a cystic component in 63.5% of the cases. A preoperative kyphosis was found in 33.3% of patients. The average extent of the laminectomy was 4.32 levels (range 2–10 levels), and the surgery included a spinal junction in 41.3% of the cases. Laminctomies included removal of the spinous processes and ligaments over the entire length of the tumor but were strictly limited to the lamina. Facet joint capsules were preserved in all cases, and no facetectomy, even a partial one, was performed in any case. Bone erosion due to the tumor itself was not observed in any of the patients. The ∆Cobb was measured on upright radiographs in 27 patients having a ∆Cobb > 15° (mean 28.6° ± 12.3°) and was otherwise measured on supine MR images (mean 6.3° ± 4.7°). The mean ∆Cobb, calculated as previously described, was 15.9° (range 0°–77°).

Results of the univariate analysis comparing sagittal spinal deformity between potential risk factors (Table 2) showed that the mean ∆Cobb was similar whether the laminectomy was performed in the cervical spine (15.2°) or thoracic spine (14.3°, p = 0.81). However, if the laminectomy encompassed a spinal junction, the mean sagittal deformity was significantly increased (20.8° vs 12.4°, p = 0.02), in particular, if it concerned the cervicothoracic junction (30.9° vs 3° for thoracolumbar junction, p = 0.01). There was also a significant effect of the spinal segment on the mean ∆Cobb (p = 0.004), with sagittal deformity 2-fold greater than that for cervicothoracic tumors (mean ∆Cobb 30.87°, 8 patients) than for tumors of other segments (cervical 15.2°, 32 patients; thoracic 14.3°, 15 patients; thoracolumbar 3°, 6 patients; lumbar 17°, 2 patients). Although sagittal deformity was greater for patients who had undergone a secondary surgery (mean ∆Cobb 23.6°, 9 patients) than for those who had not (mean ∆Cobb 14.6°, 54 patients), this result did not reach statistical significance (p = 0.08), probably because of the small number of patients in the former group.

Moreover, the extent of the laminectomy and the age of the patient also significantly correlated with the risk of postoperative sagittal deformity (R = +0.39, p = 0.002 and R = −0.35, p = 0.005, respectively). Indeed, the ∆Cobb was significantly greater when the laminectomy included...
4 or more levels (19.3° vs 12.1°, \( p = 0.04 \)) and when the patient was 30 years old or younger (21.9° vs 13.7°, \( p = 0.04 \)). Postoperative neurological deterioration, as evidenced by a decrease in the McCormick Scale score, was not associated with deformity (\( p = 0.624 \)). Lastly, the length of follow-up was strongly associated with the risk for sagittal spinal deformity (\( R = +0.29, \ p = 0.02 \)).

Multivariate analysis using a linear regression model (Table 3), including the risk factors significantly associated with sagittal spinal deformity in univariate analysis, showed that only the age of the patient (coefficient = \( -0.30, \ 95\% \ CI \ -0.61 \ to \ 0.09, \ p = 0.01 \)) and the extent of the laminectomy (coefficient = 0.31, 95% CI 0.48–4.05, \( p = 0.014 \)) were independent predictors of the risk for sagittal spinal deformity after surgery for an intramedullary tumor. As evidenced by the linear regression graph (Fig. 2), the younger the patient and the more extensive the laminectomy, the greater the sagittal deformity.

Lastly, we wondered whether it was possible to quantitatively predict the extent of the expected sagittal deformity according to the potential risk factors evidenced in our analysis, that is, patient age, extent of the laminectomy, inclusion of a junction zone in the laminectomy, and length of follow-up. The linear regression model showed that \( \Delta \text{Cobb} = 15.689 + (-0.348 \times \text{age}) + (2.267 \times \text{extent}) + (2.777 \times \text{inclusion of junction}) + (0.024 \times \text{length of follow-up}) \), where age is expressed in years, extent is the number of levels in the laminectomy, inclusion of junction is a binary (1/0) variable, and the follow-up is expressed in months. With such a simple equation, it is possible to calculate the risk for sagittal deformity at a given follow-up for any patient undergoing surgery for an intramedullary tumor.

**Discussion**

Our aim in the present study was to determine whether we could find risk factors for sagittal spinal deformity following surgery for intramedullary tumors. Our first finding was that sagittal deformity is a real issue for these patients: indeed, 35% (22 of 63) of patients presented with a sagittal deformity of 20° or more at the last radiological follow-up. Postoperative neurological deterioration, as evidenced by a decrease in the McCormick Scale score, was not associated with deformity (\( p = 0.624 \)). Lastly, the length of follow-up was strongly associated with the risk for sagittal spinal deformity (\( R = +0.29, \ p = 0.02 \)).

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Besides the usual limitations given the retrospective nature of this study, the main drawback of our analysis is that it is based on a unique radiological parameter.
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TABLE 2: Univariate analysis comparing mean sagittal deformity for potential risk factors

<table>
<thead>
<tr>
<th>Factor</th>
<th>ΔCobb</th>
<th>p Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>sex: M/F</td>
<td>14.8°/16.7°</td>
<td>0.60</td>
</tr>
<tr>
<td>motor deficit: Y/N</td>
<td>15.9°/15.8°</td>
<td>0.99</td>
</tr>
<tr>
<td>cyst: Y/N</td>
<td>17.8°/12.5°</td>
<td>0.15</td>
</tr>
<tr>
<td>kyphosis: Y/N</td>
<td>17.1°/15.3°</td>
<td>0.63</td>
</tr>
<tr>
<td>junction: Y/N</td>
<td>20.8°/12.4°</td>
<td>0.02†</td>
</tr>
<tr>
<td>total removal: Y/N</td>
<td>15.3°/18.2°</td>
<td>0.54</td>
</tr>
<tr>
<td>radiotherapy: Y/N</td>
<td>19.9°/15.2</td>
<td>0.36</td>
</tr>
<tr>
<td>secondary surgery: Y/N</td>
<td>23.6°/14.6°</td>
<td>0.08</td>
</tr>
<tr>
<td>postop McCormick Scale score: 1/2/3/4</td>
<td>14.1°/16.0°/10.6°/26.9°</td>
<td>0.12</td>
</tr>
<tr>
<td>spinal segment: cervical/cervicothoracic/thoracic/thoracolumbar/lumbar</td>
<td>15.2°/30.9°/14.3°/3/17°</td>
<td>0.004†</td>
</tr>
<tr>
<td>histology: astrocytoma/ependymoma/hemangioblastoma</td>
<td>20.2°/12.3°/15.7°</td>
<td>0.16</td>
</tr>
<tr>
<td>postop McCormick Scale score: 1/2/3/4</td>
<td>13.7°/16.1°/13.6°/31°</td>
<td>0.29</td>
</tr>
<tr>
<td>levels of laminectomy: 2–3≥4</td>
<td>12.1°/19.3°</td>
<td>0.04†</td>
</tr>
<tr>
<td>age: ≤30/&gt;30</td>
<td>21.9°/13.7°</td>
<td>0.04†</td>
</tr>
</tbody>
</table>

* Statistical test was applied according to the type of variable: Student t-test was used if the categorical variable was dichotomized, whereas 1-way ANOVA was used if there were ≥3 categorical variables.
† Statistically significant.

(DΔCobb), which does not take into account the functional consequences of such deformity (pain, quality of life, neurological status). The fact that the ΔCobb was measured on upright radiographs for patients showing a significant deformity and on supine MRI otherwise does imply some heterogeneity in our data. However, statistical comparison using a 1-way ANOVA showed no significant difference between the 2 groups in terms of factors that were not associated with the ΔCobb (apart from the rate of secondary surgeries, which was expected since radiographs were systematically obtained preoperatively). Therefore, we believe that, although sagittal deformity may have been underestimated in patients who did not have postoperative radiographs, this fact did not bias our analysis and interpretation in a systematic manner.

Sagittal deformity was 2-fold greater for patients with cervicothoracic tumors (mean ΔCobb 30.87°, 8 patients) than for those with tumors of other segments (cervical 15.2°, thoracic 14.3, thoracolumbar 3°, lumbar 17°, p = 0.004). This result is in accordance with those in other studies,4,5 which focused on cervical and cervicothoracic deformations. It would have been interesting to conduct a statistical analysis on this particular subgroup, but given the small number of patients due to the low incidence of

![Fig. 2. Regression plots between postoperative sagittal deformity and independent prognostic factors revealed in the linear regression model: age of the patient (left) and extent of the laminectomy (right).]
spinal cord tumors, such an analysis would not have been methodologically relevant.

Moreover, one could argue that we did not take into account supra- or sublaminectomy deformity or scoliosis. No patient had to undergo a secondary surgery specifically for spinal stabilization, even though sagittal deformity was sometimes quantitatively significant. Notably, this conservative management differs from what has been reported in other studies, in particular, the one by Sciubba et al.,\textsuperscript{11} in which the authors reported, at 25 months of follow-up, secondary osteosynthesis in 33\% of patients (4 of 12) with intradural (intra- and extramedullary) tumors treated with laminectomy over 3 or more spine levels. Our linear regression model allows for quantitative calculation of the expected sagittal deformity for a given patient based on age, extent of the laminectomy, inclusion of a spinal junction, and length of follow-up. For instance, one can predict that a 20-year-old patient with an intramedullary tumor treated with a laminectomy over 4 spinal levels, without encompassing a spinal junction, can expect to present with a sagittal deformity of 22° (ΔCobb) at 10 years after surgery. Although it is hard to predict whether or not a given statistical deformity will have functional consequences, such information is nevertheless very helpful in planning the follow-up and better informing the patient.

Using the statistically significant linear correlation between the duration of follow-up and the extent of sagittal deformity (p = 0.02), we made the methodological assumption that the progression of sagittal deformity was linear over time. However, as can be observed from the widespread distributions in Fig. 2, there was some variability among the patients. Thus, we emphasize that, although methodologically correct, this linear model only provides a tool to help surgeons in their decision making and does not negate individual variability.

Given the statistical nature of this work, we suggest that the decision to perform stabilization within the same procedure as the tumor removal should not be made on the sole basis of this quantitative tool. Indeed, postoperative spinal deformity in patients with an intramedullary tumor can have a mechanical or neurological origin, and often both. Therefore, in the 1st year after surgery, in patients with a high risk of sagittal deformity based on preoperative quantitative assessment, a careful follow-up should allow early detection of those needing surgical stabilization.

Lastly, the natural history of intramedullary tumors must be taken into account: For instance, a secondary surgery for a recurrent tumor might also provide an opportunity to perform a stabilization procedure at the same time. Moreover, careful MRI after a first surgery should not be hindered by osteosynthesis material. Cases of intramedullary tumors associated with a significant preoperative spinal deformity may also require concomitant osteosynthesis. Our predictive tool, therefore, does not apply in such cases.

### Conclusions

The present study showed the independent predictive value of patient age and extent of laminectomy in sagittal spinal deformity after surgery for an intramedullary tumor. The simple equation drawn from our series of 63 patients, with a mean follow-up of more than 7 years, allows any surgeon to estimate the mean sagittal deformity for a given patient. We believe that such a tool could prove useful for informing patients and planning a careful follow-up for those at risk.

### Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Parker, Knafo. Acquisition of data: Parker. Analysis and interpretation of data: Knafo, Court. Drafting the article: Knafo. 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: Parker. Statistical analysis: Knafo. Study supervision: Parker.

### References


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**TABLE 3: Multivariate analysis using a linear regression model, including risk factors significant in a univariate analysis**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Standardized Coefficient</th>
<th>Partial Correlation Coefficient</th>
<th>95% CI p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>15.689</td>
<td>−0.348</td>
<td>−0.61 to 0.09</td>
</tr>
<tr>
<td>Patient age</td>
<td>−0.348</td>
<td>−0.30</td>
<td>−0.61 to 0.09</td>
</tr>
<tr>
<td>Extent of laminectomy</td>
<td>2.267</td>
<td>0.31</td>
<td>0.48 to 4.05</td>
</tr>
<tr>
<td>Spinal junction included in laminectomy</td>
<td>2.777</td>
<td>0.10</td>
<td>−4.38 to 9.93</td>
</tr>
<tr>
<td>Length of follow-up</td>
<td>0.034</td>
<td>0.151</td>
<td>−0.02 to 0.09</td>
</tr>
</tbody>
</table>

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