

# Giant Petroclival Primary Intradural Chordoma: Case Report and Systematic Review of the Literature

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## Abstract

**Background** Chordomas are rare, locally aggressive neoplasms thought to arise from notochordal remnants in the axial skeleton. Primary intradural chordomas are considered to be extremely rare. In this article a giant intradural petroclival chordoma is presented, and a synthesis of the available literature is performed to measure overall survival (OS) and recurrence-free survival (RFS) and to identify prognostic factors.

**Methods** A systematic Medline review yielded 47 patients with purely intradural tumors from 38 publications including 39 chordomas, 8 cases of echordosis physaliphora, and 1 case with features of both. The 5-year OS and RFS were calculated based on the Kaplan-Meier method. Risk factors for progression or mortality were analyzed using binomial logistic regression.

**Results** Maximal tumor diameter varied from 1.5 to 6.0 cm (mean: 3.2 cm). Tumors were located predominantly in the prepontine area (66.7%). Combined 5-year Kaplan-Meier OS and RFS were 77% ± 11% and 74% ± 11%, respectively. Incomplete surgical resection, larger tumor diameter, and an elevated Ki-67 index were statistically more frequent in cases of recurrence and mortality.

**Conclusions** Based on a systematic literature review, the behavior of primary intradural chordomas may be closer to typical chordomas than was previously thought.

## Keywords

- ▶ chordoma
- ▶ notochord
- ▶ skull base neoplasms
- ▶ brainstem neoplasms

## Introduction

Chordomas are rare locally aggressive neoplasms of notochordal origin, constituting 2 to 4% of primary bone tumors.<sup>1</sup> In contrast to echordosis physaliphora (EP), which are usually small incidentally discovered rests of tissue within the clivus or retroclival space, cranial base chordomas mostly arise extradurally and produce symptoms secondary to growth and bony destruction. Rare cases of extraosseous *intradural chordoma*

have been reported and generally considered to have a more favorable prognosis relative to typical chordomas.<sup>2–4</sup> We report a case of a giant intradural chordoma lacking bony involvement. We furthermore performed a systemic review of the literature to (1) assess for clinical, histologic, and radiologic differences between intradural chordoma and EP; (2) summarize overall survival (OS) and recurrence-free survival (RFS) data; and (3) identify risk factors impacting 5-year RFS and OS in patients with intradural chordomas and EP.

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## Materials and Methods

The current study is a systematic review of the literature applying the Preferred Reporting Items for Systematic Reviews guidelines.<sup>5</sup> All studies included were case reports or small primarily retrospective case series.

### Search Strategy

A systematic electronic article search was conducted through Medline between 1974 and 2013, using the Medical Subject Heading terms *chordoma*, *eccordosis physaliphora*, *notochord*, *bone neoplasms*, and *skull base neoplasms*. Titles and abstracts were then reviewed to identify cases of intradural chordomas or eccordosis physaliphora. A manual search was also conducted from the reference lists of selected articles to identify additional studies. Of these articles, a full-text review was performed by two coauthors independently (F.A. and S.D.), applying inclusion and exclusion criteria to obtain a final group of included studies. Studies were included if (1) they reported patients with histologically confirmed intradural chordomas or eccordosis physaliphora; (2) patients were symptomatic and/or had large ( $\geq 3$  cm maximal diameter) or growing tumors; and (3) tumors were found to have bony stalk without evidence of bony destruction. Articles were excluded if (1) patients were asymptomatic and/or had small ( $< 1$  cm maximal diameter) tumors; (2) if the article was an autopsy, nonsurgical, or pure radiologic series; and (3) if the patient was treated in the era before computed tomography (CT) or magnetic resonance imaging (MRI).

### Data Collection

After a final list of articles was assembled, individual patient data were extracted and compiled on to a master database. Patient age, sex, tumor size, location, pathologic diagnosis, presenting symptoms, extent of surgical resection, adjuvant therapy, follow-up duration, recurrence, and mortality were all recorded.

### Statistical Analyses

From the compiled patient database, 5-year overall OS and RFS were calculated using the Kaplan-Meier method. Risk factors for progression or mortality were analyzed using binomial logistic regression. An assessment of risk of bias was not possible for this study. A  $p$  value  $< 0.05$  was considered to be statistically significant. Statistics were performed using IBM SPSS v.21.0 (IBM, Inc, Armonk, New York, United States).

## Results

An initial systematic Medline search yielded 416 publications. After screening based on title and abstract review and applying the previously described inclusion and exclusion criteria, there were 38 publications including 47 patients. The details of each study are tabulated in **Appendix A**, and subject demographics from the literature cases and ours (48 patients total) are summarized in **Table 1**. Patient age ranged from 9 to 76 years (mean: 42.8 years) and maximal tumor diameter varied from 1.5 to 6 cm (mean: 3.2 cm). Tumors were located

predominantly in the prepontine (66.7%) and sellar/suprasellar/hypothalamic (18.8%) areas, and the postoperative follow-up ranged from 3 weeks to 144 months (mean: 30.2 months). Pathologic diagnosis was reported as chordoma in 39 cases and eccordosis physaliphora in 8 cases. In one series of two patients in which the distinction of EP versus chordoma was not explicitly made,<sup>6</sup> the diagnosis was inferred based on the histologic description provided in the manuscript (one EP and one chordoma). In one case, histologic features of both chordoma and EP were reported.<sup>7</sup> Of 43 of 48 patients for whom extent of surgical resection was reported, 25 had complete or near-complete resection, whereas 18 had subtotal removal. Information regarding adjuvant radiation therapy was available in 41 of 48 cases. Adjuvant radiotherapy was administered in seven cases; all of these patients had undergone subtotal resections. In most cases, radiation therapy was not given (32/41 cases) or given only at recurrence (2/41 cases). None of the cases had bony involvement. In four cases, a bony stalk was observed connecting the intradural tumor to the clivus but without frank bony destruction. In the remaining cases, a bony stalk was absent. Clinical presentation varied between cases but was mainly secondary to brainstem involvement: 52.5% of patients experienced headaches, cranial nerve palsies were observed in 41.5%, and gait disturbance in 30%. Most of the cases presented with subacute to chronic symptoms, and only a few presented with acute neurologic deterioration related to tumoral hemorrhage. One case of EP presented with fatal diffuse nonaneurysmal subarachnoid hemorrhage, and another chordoma with intratumoral hemorrhage.<sup>3,8</sup>

Survival data were available for 32 of 48 patients. Based on the Kaplan-Meier survival analysis of the compiled available individual patient data, 5-year RFS was  $74\% \pm 11\%$ , and mean RFS was 112.0 months (95% confidence interval [CI]: 86.6–137.5 months) (**Fig. 1A**). The 5-year OS was  $77\% \pm 11\%$ ; excluding 30-day surgical mortality, 5-year OS was  $87\% \pm 7\%$ . Mean OS was 115.9 months (95% CI, 90.7–141.2 months) (**Fig. 1B**). The 5-year OS for patients undergoing complete resection was  $92\% \pm 8\%$ , compared with  $63\% \pm 18\%$  for those with subtotal resection ( $p = 0.00004$ ). The 5-year RFS for patients undergoing complete resection was  $83\% \pm 15\%$ , compared with  $64\% \pm 15\%$  for those with subtotal resection ( $p = 0.00290$ ). Patients who developed recurrence had a larger tumor diameter ( $4.3 \pm 0.5$  cm versus  $3.2 \pm 1.2$  cm;  $p = 0.0390$ ) and a more elevated Ki-67 index ( $6.83 \pm 1.21\%$  versus  $1.03 \pm 1.84\%$ ;  $p < 0.001$ ) compared with those who did not (**Tables 2 and 3**). Similarly, patients who died had a larger tumor diameter ( $4.8 \pm 0.8$  cm versus  $3.2 \pm 1.2$  cm;  $p = 0.039$ ) and a more elevated Ki-67 index ( $6.83 \pm 1.21\%$  versus  $1.03 \pm 1.84\%$ ;  $p < 0.001$ ) than those who survived. No other recurrence or survival-related risk factors analyzed were found to be statistically significant.

### Case Illustration

The patient is a 51-year-old right-handed man who works as a janitor. He presented with a 2-year history of balance difficulty and initially vertical diplopia, followed by diplopia in all

**Table 1** Subject demographics

No. of subjects	48 (25 males/20 females/3 not specified)
Mean age	42.8 ± 17.9 y (range: 9.0–76.0 y)
Follow-up	30.2 ± 33.0 mo (range: 0.75–144.0 mo)
Tumor location	
Prepontine	32/48 (66.7%)
Sellar/suprasellar/hypothalamic	9/48 (18.8%)
Other (cerebellar, foramen magnum, tentorial, pineal, petroclival, disseminated)	7/48 (14.6%)
Maximal tumor diameter	3.2 ± 1.3 cm (range: 1.5–6.0 cm)
Reported histology	Chordoma: 38/48 (79.2%)
	EP: 9/48 (18.8%)
	Chordoma and EP 1/48 (2.1%)
Presenting symptoms	
Cranial nerve palsy	17/41 (41.5%)
Headaches	21/40 (52.5%)
Intraventricular hemorrhage	1/40 (2.5%)
Gait disturbance	12/40 (30.0%)
Tinnitus	3/40 (7.5%)
Speech disturbance	3/40 (7.5%)
Motor weakness	7/40 (17.5%)
Memory disturbance	6/40 (15.0%)
Visual signs or symptoms	9/40 (22.5%)
Sensory symptoms	3/40 (7.5%)
Adjuvant radiation therapy	
Upfront	7/41 (17.0%)
At recurrence	2/41 (4.9%)
None	32/41 (78.0%)
Information not specified	7/48

Abbreviation: EP, ependymoma.

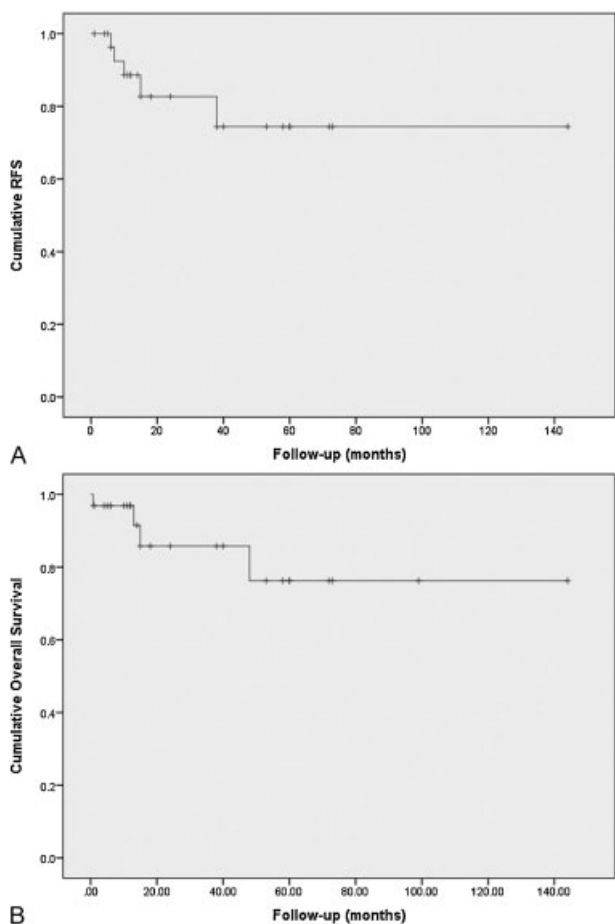
vectors. He also complained of decreased hearing and facial sensation on the left side. On examination, he had near-complete ophthalmoplegia in the left eye, as well as left ptosis and a fixed, dilated pupil. There was 20% subjective sensation in the left V1–3 dermatomes. His gait was ataxic, and he had psychomotor slowing as well as mild word-finding difficulty. He had diffuse hyperreflexia, and positive Hoffman and Babinski reflexes. There was bilateral upper and lower extremity dysmetria.

His magnetic resonance imaging (MRI) demonstrated a giant left petroclival intradural lesion extended from the jugular foramen caudally and superior to the tentorium to the parasellar space and cavernous sinus (► **Fig. 2**). A head computed tomography (CT) demonstrated a lack of any bony destruction, remodeling, or tumoral involvement. There was severe effacement of the brainstem and partial encasement of the basilar and ipsilateral vertebral arteries. The lesion appeared lobulated, hyperintense on T2, hypointense on T1, and

there was only mild heterogeneous enhancement. The preoperative differential diagnosis included atypical meningioma, schwannoma, neuroepithelial cyst, and chordoma. A preoperative CT scan did not demonstrate any bony involvement of the tumor.

### Operation

The patient underwent a left-sided posterior transpetrosal approach. Intraoperative monitoring of long tract motor- and sensory-evoked potentials, as well as brainstem auditory evoked responses and cortically evoked facial nerve motor-evoked potentials was performed. The presigmoid dura was opened from above the jugular bulb across the superior petrosal sinus and to the temporal lobe. The vein of Labbé was seen coursing posteriorly to drain into the transverse sinus. The tentorium was divided posterior to the course of the trochlear nerve. An expansile mass was seen medial to the trochlear, trigeminal and VII–VIII nerves. It was debulked and



**Fig. 1** (A) Kaplan-Meier recurrence-free survival (RFS) curve of 32 of 48 patients with primary intradural chordoma. The 5-year RFS was 74% ± 11%, and mean RFS was 112.0 months (95% confidence interval [CI], 86.6–137.5 months). (B) Kaplan-Meier overall survival (OS) curve of 32 of 48 patients with primary intradural chordoma. The 5-year OS was 77% ± 11%; excluding 30-day surgical mortality, 5-year OS was 87% ± 7%. Mean OS was 115.9 months (95% CI, 90.7–141.2 months).

mobilized without difficulty. Superiorly, the tumor was resected up to the cavernous sinus; however, the visualization offered by the approach was inadequate and a small remnant was believed to have been left behind. Medially, the tumor dissected very well off the brainstem and basilar artery. The tumor was followed into Meckel cave, which

was partially unroofed and packed with Surgicel and Tisseel following tumor removal. The remainder of the tumor was removed, and intraoperative monitoring remained pristine throughout the case.

**Pathology**

All the histologic sections examined showed the presence of a tumoral proliferation composed of cells with vacuolated cytoplasm and areas resembling cartilage (►Fig. 3). In some areas, the cells formed anastomotic cords floating in a chondroid type of matrix. Cytokeratin immunohistochemistry was strongly positive, and there was focal but definite positivity for both S-100 and brachyury. The Ki-67 index was very low (< 0.5%), with only a few positive nuclei. Final diagnosis was consistent with chordoma.

**Postoperative Course**

Postoperative MRI (►Fig. 2) demonstrated complete resection of the posterior fossa tumor with an expected small remnant within the cavernous sinus. His postoperative course was complicated by a single partial complex seizure on postoperative day 1, for which antiepileptic medication was not started, and there were no further episodes. He also developed a pseudomeningocele that resolved spontaneously without specific intervention. His ataxia, weakness, psychomotor slowing, ptosis, and diplopia all resolved postoperatively, although clinically he continues to have a trochlear nerve palsy.

At 3 months postoperatively, the patient received fractionated stereotactic radiotherapy (fSRT) with an intensity-modulated radiotherapy RAPID Arc system (Varian Medical Systems, Palo Alto, California, United States) using MRI fusion. A total dose of 52 Gy was delivered in 28 fractions. His last follow-up MRI at 12 months from surgery demonstrated no recurrence of the tumor.

**Discussion**

Luschka first described his finding of pathologic ectopic notochordal tissue at the posterior clivus in 1856.<sup>9</sup> In 1857, Virchow gave the first microscopic description and termed the lesion *echondrosis physaliphora*, believing it to be a process affecting the cartilage of the speno-occipital

**Table 2** Risk factors associated with recurrence in 32/48 patients with intradural chordoma or echordosis physaliphora

	Recurrence (n = 5)	No recurrence (n = 27)	p value
Maximal diameter, cm	4.3 ± 0.5	3.1 ± 1.3	0.010
Age, y	46.0 ± 16.4	38.2 ± 19.0	0.381
Sex	1 male/4 females	17 males/8 females	0.130
Enhancement	5 yes/0 no	18 yes/7 no	0.355
Pathology	5 chordoma/0 EP	22 chordoma / 5 EP	0.284
Bony stalk	0 yes / 5 no	3 yes/24 no	0.424
Ki-67, %	5.12 ± 3.56	1.08% ± 1.88	0.004

Abbreviation: EP, echordosis physaliphora.

**Table 3** Risk factors associated with overall survival in 32/48 patients with intradural chordoma or echordosis physaliphora

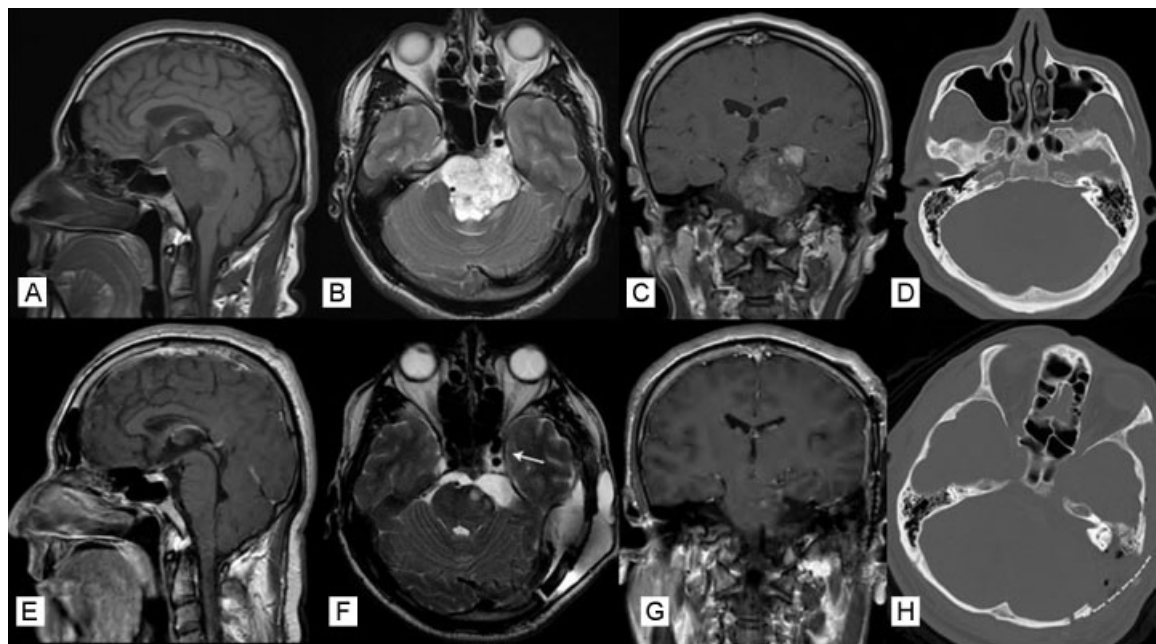
	Nonsurviving (n = 4)	Surviving (n = 28)	p value
Maximal diameter, cm	4.8 ± 0.8	3.2 ± 1.2	0.039
Age, y	39.8 ± 0.9 cm	39.5 ± 19.6	0.980
Sex	1 male/3 females	16 males/10 females	0.170
Enhancement	4 yes/0 no	21 yes/7 no	0.467
Pathology	4 chordoma/0 EP	26 chordoma/2 EP	0.358
Bony stalk	0 yes/5 no	3 yes/24 no	0.492
Ki-67, %	6.83 ± 1.21	1.03 ± 1.84	< 0.001

Abbreviation: EP, echordosis physaliphora.

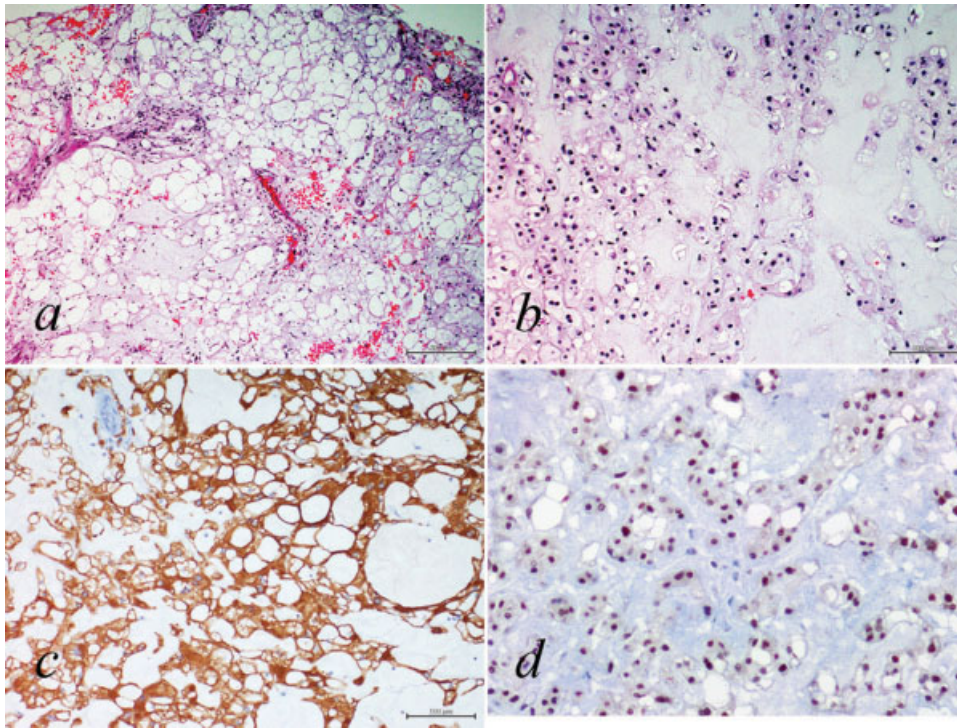
synchondrosis.<sup>10</sup> One year later, Müller correctly proposed a notochordal origin,<sup>11</sup> and in 1894, Ribbert and Steiger coined the term *echordosis* to reflect a presumed notochordal origin of these lesions.<sup>12</sup> EP is considered to be an ectopic notochordal remnant lacking internal proliferative potential.<sup>4</sup> Whether EP is the precursor of skull base chordoma remains controversial.<sup>13–15</sup> Furthermore, debate persists regarding whether large symptomatic EP is truly distinct from intradural chordoma, or whether they are terms describing the same pathologic entity.<sup>2,3,7</sup>

Wolfe and Scheithauer et al<sup>6</sup> proposed the term *intradural chordoma* should be for all lesions, including EP, whereas Rodríguez et al<sup>7</sup> argued that all instances of symptomatic, intradural, extrasosseous physaliphora cell growth should be classified as giant or symptomatic EP so long as the existence of an intradural chordoma is not definitely proved. Histologically, EP and intradural chor-

doma display many similarities including the presence of typical “vacuolated cells” and positive staining for Brachyury and Galectin-3. Pragmatically speaking, in many cases the pathologic diagnosis is influenced and supported by the clinical picture and radiologic findings. Specific histologic differences have been proposed including a smaller cell number and absence of extracellular mucous-like matrix or necrotic cells in EP.<sup>13–15</sup> Wang et al<sup>16</sup> described the volume of EPs to be characteristically less than intradural chordomas, with the largest reported diameter < 2 cm; however, there are literature instances of so-called EP with diameters of 4 cm,<sup>17</sup> 3 cm,<sup>7</sup> and 3 cm.<sup>18</sup> Other distinguishing features proposed include the presence of clinical symptoms including those related to brainstem compression and/or cranial nerves palsies in true chordomas, a low Ki-67 index in EP,<sup>19</sup> as well as contrast enhancement in true chordomas versus lack of



**Fig. 2** Preoperative (A) sagittal T1, (B) axial T2, and (C) coronal T1 magnetic resonance imaging (MRI) with gadolinium demonstrating a large left petroclival intradural chordoma. (D) Preoperative computed tomography (CT) did not demonstrate any bony involvement. (E–G) Postoperative MRI showing near-complete resection with a likely small residual in the left cavernous sinus (F, arrow). (H) Postoperative CT showing skeletonization of semicircular canals. Preoperative CT did not disclose any bony involvement.



**Fig. 3** Hematoxylin and eosin stained sections showing a tumoral proliferation composed of cells with (A) vacuolated cytoplasm and (B) areas resembling cartilage. (C) Cytokeratin immunohistochemistry was strongly positive. (D) There was nuclear positivity for brachyury. Final pathology was consistent with chordoma.

enhancement in EP.<sup>20</sup> The presence of a bony stalk was reported in several cases; however, we did not find it to be a distinguishing feature of EP versus chordoma, nor did it appear to affect prognosis.

Based on prior case reports and small series, intradural chordomas have generally been considered to have a more favorable prognosis and a different biologic behavior relative to typical cranial base chordomas.<sup>8</sup> The data from our systematic review suggest that both 5-year RFS and OS appear to be comparable with typical chordomas, particularly following a complete surgical resection. In a recent meta-analysis of cranial base chordomas,<sup>21</sup> 5-year RFS was 87% in patients with complete resection compared with 50% in patients with incomplete resection, and 5-year OS was 95% with complete resection versus 71% without. This is similar to our study, in which 5-year RFS for patients undergoing complete resection was  $83\% \pm 15$ , compared with  $64\% \pm 15\%$  for those with subtotal resection, and in which 5-year OS was  $92\% \pm 8\%$  with complete resection, compared with  $63\% \pm 18\%$  with incomplete resection ( $p < 0.001$ ). Thus although a gross total resection may be more feasible for true intradural chordomas, their biologic behavior may nevertheless be similar to classic skull base chordomas and is reflected by similar survival of both subtypes after complete and incomplete resections.

The cellular and molecular mechanisms by which chordomas effectuate bony invasion and overall aggressiveness remain poorly understood, and in light of the relative rarity of intradural chordomas and EP, differentiating features are as yet lacking. Proteases may be implicated in bony

destruction in chordomas. Matrix metalloproteinases<sup>22</sup> and cathepsin K<sup>22,23</sup> have been investigated as potential mediators; their increased expression appear related to worse prognosis. Adhesion proteins may also mediate tumor invasiveness in chordomas. Upregulation of N-cadherin and downregulation of E-cadherin may be correlated with worse clinical behavior of some chordomas.<sup>24</sup> Upregulation of specific proto-oncogenes have also been evaluated, including c-MET and hepatocyte growth factor expression.<sup>25</sup> Fascin overexpression was also correlated with increased chordoma invasiveness and dural penetration, implicating increased cell motility as a potential mechanism.<sup>26</sup> Increased telomerase activity also appears to correlate with chordoma recurrence and possible aggressiveness.<sup>27</sup> The cellular proliferative potential, as measured by the Ki-67 staining index, has been reported to distinguish EP from chordoma.<sup>14,15</sup> Reported cases of EP typically have a Ki-67 index  $< 1\%$ , whereas in chordoma it is  $> 2\%$ . Accordingly, all the cases included in our systematic review demonstrated a Ki-67 index  $< 2\%$  in EP.

Our study is subject to several important limitations. All included studies are of a retrospective nature composed primarily of case reports and a few small case series, and they subject our meta-analysis to potential publication bias. Heterogeneity in the compiled cohort was observed due to local differences in the use of adjuvant radiation therapy, and often unclear justification for the pathologic distinction between EP and true chordoma. The histologic distinguishing features between chordoma and EP are unclear; there is heterogeneity in the pathologic distinction of intradural

cases included in our literature synthesis. Finally, the overall small population limits statistical power.

## Conclusion

Intradural cranial base chordomas are extremely rare. There is lack of uniform agreement regarding the distinguishing features of chordoma and ecchordosis physaliphora, particularly for large symptomatic tumors. Based on our meta-analysis, the clinical behavior of intradural chordomas may be closer to typical cranial base chordomas than was previously recognized. This finding may influence clinical management, particularly the use of adjuvant radiation therapy as in our case illustration.

### Disclosure

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

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**Appendix A** Summary of included articles

Study	Country of origin	Tumor location	Age, y/Sex	Extent of resection	Adjuvant therapy	Pathology
Mathews and Wilson <sup>13</sup>	USA	Intrasellar	41/male	Complete	NA	Chordoma
Stam and Kamphorst <sup>28</sup>	The Netherlands	Prepontine	75/female	NA	NA	EP
Mapstone et al <sup>14</sup>	USA	Prepontine	26/male	Subtotal	None	Chordoma
Vaquero et al <sup>29</sup>	USA	Suprasellar	39/male	Complete	None	Chordoma
Yuhni et al <sup>2</sup>	N/A	Prepontine	28/male	NA	NA	Chordoma
Wolfe and Scheithauer <sup>6</sup>	USA	Intrasellar	44/male	Procedure terminated	None	Chordoma
	USA	Suprasellar	70/female	Complete	None	EP
Katayama et al <sup>30</sup>	Japan	Foramen magnum	30/female	Complete	None	Chordoma
Warnick et al <sup>1</sup>	USA	Tentorium cerebelli	58/male	Subtotal	None	Chordoma
Hardie <sup>31</sup>	N/A	Prepontine	28/female	NA	NA	Chordoma
Commins et al <sup>32</sup>	USA	Hypothalamus	51/female	Complete	None	Chordoma
Tashiro <sup>33</sup>	Japan	Prepontine	56/female	NA	None	Chordoma
Wanibuchi et al <sup>34</sup>	N/A	Suprasellar	54/male	Complete	None	Chordoma
Akimoto et al <sup>35</sup>	USA	Prepontine	51/female	Complete	None	EP
Nishigaya et al <sup>36</sup>	Japan	Prepontine	56/male	Subtotal	None	Chordoma
Toda et al <sup>37</sup>	Japan	Prepontine	56/female	Complete	None	EP
Korinth et al <sup>38</sup>	Germany	Basal cisterns	48/female	Subtotal	SRS to residual	Chordoma
Rodríguez et al <sup>7</sup>	Venezuela	Prepontine	54/female	Complete	NA	EP and chordoma
Danilewicz et al <sup>39</sup>	N/A	Prepontine	19/female	Complete	None	Chordoma
Cha et al <sup>40</sup>	USA	Prepontine	49/male	Complete	None	EP
Steenberghs et al <sup>41</sup>	Belgium	Prepontine	NA	NA	NA	Chordoma
Dow et al <sup>42</sup>	United Kingdom	Cerebellar	9/female	Complete	None	Chordoma
Masui et al <sup>4</sup>	Japan	Prepontine	63/male	Complete	None	Chordoma
Takeyama et al <sup>17</sup>	Japan	Prepontine	12/male	Subtotal	None	EP
Uda et al <sup>3</sup>	Japan	Prepontine	35/female	Subtotal	SRS to residual at recurrence	Chordoma
Ling et al <sup>18</sup>	Australia	Prepontine	45/male	Complete	None	EP
Roberti et al <sup>43</sup>	USA	Prepontine	NA	Complete	None	Chordoma
	USA	Sellar	NA	Complete	None	Chordoma
	USA	Prepontine	58/male	Complete	None	Chordoma

Appendix A (Continued)

Study	Country of origin	Tumor location	Age, y/Sex	Extent of resection	Adjuvant therapy	Pathology
Chang et al <sup>44</sup>	USA	Prepontine	9/male	Complete	None	Chordoma
Alkan et al <sup>45</sup>	Turkey	Prepontine	22/male	Subtotal	None	EP
Choo et al <sup>46</sup>	Korea	Prepontine	43/female	Subtotal	SRS to residual	Chordoma
Ciarpaglini et al <sup>47</sup>	Italy	Prepontine	60/male	Subtotal	None	Chordoma
Bergmann et al <sup>15</sup>	Germany	Prepontine	76/male	Subtotal	None	Chordoma
Bhat et al <sup>48</sup>	India	Prepontine	30/male	Complete	None	Chordoma
Ito et al <sup>49</sup>	Japan	Prepontine	59/female	Subtotal	LINAC fXRT	Chordoma
	Japan	Prepontine	75/female	Complete	Gamma knife SRS for recurrences only	Chordoma
Jiagang et al <sup>50</sup>	China	Suprasellar	51/male	Complete	None	Chordoma
Figueiredo et al <sup>51</sup>	Brazil	Pineal and intra-abdominal (history of VP shunt placement)	18/male	Biopsy	None	Chordoma; prior surgery for presumed germinoma 7 y prior (histologic diagnosis revised)
Anderson et al <sup>52</sup>	USA	Disseminated	13/female	Subtotal	fXRT	Chordoma
Kim et al <sup>53</sup>	Republic of Korea	Sellar-suprasellar	55/female	Complete	N/A	Chordoma
Wang et al <sup>16</sup>	China	Prepontine	22/male	Complete	None	Chordoma
	China	Prepontine	45/male	Subtotal	None	Chordoma
	China	Prepontine	28/male	Complete	None	Chordoma
	China	Prepontine	40/female	Subtotal	fXRT	Chordoma
	China	Prepontine	41/female	Subtotal	fXRT	Chordoma
	China	Prepontine	39/male	Subtotal	None	Chordoma
Current case	Canada	Petroclival	51/male	Near-complete	IMRT	Chordoma

Abbreviations: EP, ependymoma; fXRT, fractionated radiotherapy; IMRT, intensity-modulated radiation therapy; NA, not available; SRS, stereotactic radiosurgery.