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# Partial Vertebrectomies without Instrumented Stabilization During En Bloc Resection of Primary Bronchogenic Carcinomas Invading the Spine: Feasibility Study and Results on Spine Balance

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1 **Partial vertebrectomies without instrumented stabilization during en bloc**  
2 **resection of primary bronchogenic carcinomas invading the spine:**  
3 **feasibility study and results on spine balance**  
4

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15

16 **Key words**

17 Primary bronchogenic carcinomas, Non-small-cell lung cancers, Lung  
18 cancers, Pancoast tumors, Vertebrectomies, Vertebral resection, Spine  
19 deformity  
20

21 **Abbreviations and Acronyms**

22 CCA: Coronal Cobb angle

23 CT: Computed tomography

24 NSCLC: Non-small-cell lung cancers

25 PBCIS: Primary bronchogenic carcinomas invading the spine

26 PET: Positron emission tomography

27 SCA<sub>EOR</sub>: Sagittal Cobb angle at the edge of the resection

28 SCA<sub>T1-T12</sub>: T1-T12 sagittal Cobb angle

29 VB: Vertebral body

30

### 31 **Abstract**

#### 32 Objective:

33 It is unknown if spinal instrumentation is required to prevent deformity  
34 after partial vertebrectomy in the treatment of primary bronchogenic  
35 carcinomas invading the spine (PBCIS). In this study, we focus on the  
36 postoperative spine deformity in patients operated for partial  
37 vertebrectomies without instrumentation during en bloc PBCIS  
38 resection. Our objective was to determine if deformity depends on the  
39 type of vertebral resection and if any vertebral resection threshold  
40 can be observed to justify additional spinal instrumentation.

#### 41 Methods:

42 This is a retrospective study, including all patients with PBCIS operated  
43 without spinal instrumentation from 2009 to 2018. Partial  
44 vertebrectomies were classified into categories A, B and C depending on  
45 vertebral resection. Patients had a long-term radiological follow-up  
46 assessing the spine deformity evolution.

#### 47 Results:

48 Eighteen patients were included. The median follow-up was 27 months.  
49 Four patients underwent a secondary posterior instrumentation  
50 surgical procedure due to progressive spinal deformity. A low-risk

51 group of deformation was characterized as type A resection and type B  
52 resection on less than three vertebrae.

### 53 Conclusion:

54 There are no validated criteria to justify a systematic spinal  
55 instrumentation when performing a partial vertebrectomy during en  
56 bloc resection of PBCIS. Performed alone without spine instrumentation,  
57 both type A and type B resections on less than three resected vertebrae  
58 were not subject to sagittal and coronal deformity even after a long  
59 follow-up, emphasizing that a systematic stabilization is not needed in  
60 this low-risk group. These results could help to reduce the  
61 perioperative morbidity of these procedures that are usually long and  
62 complex.

63

### 64 **Text**

65

### 66 Introduction:

67 Primary bronchogenic carcinomas invading the spine (PBCIS) are mainly  
68 represented by non-small-cell lung cancers (NSCLC)<sup>1,2</sup> located along  
69 the costovertebral gutter. When invading the superior pulmonary  
70 sulcus tumors (Pancoast tumors), characteristic symptoms are complete  
71 or partial Pancoast-Tobias syndrome. Invasion of the ribs, the vertebrae  
72 and the subclavian vessels causes pain in the shoulder area; invasion of  
73 the lower part of the brachial plexus and invasion of the nerve roots  
74 causes radicular pain or muscle weakness; and invasion of the stellate  
75 ganglion and sympathetic chain is revealed by Horner syndrome<sup>3,4</sup>.

76 Spinal invasion is commonly considered to be a negative prognostic  
77 factor in primary bronchogenic carcinomas, making them historically  
78 considered as incurable<sup>5</sup>. With the advances in the delivery of  
79 chemotherapy, radiation and surgical management, carefully selected  
80 patients with spine-invading NSCLC can be eligible to complete surgical  
81 resection, allowing a major increase of survival<sup>6-8</sup>. Neoadjuvant  
82 treatment with chemotherapy induction and concurrent radiation  
83 followed by complete en bloc resection is now a standard treatment  
84 option with demonstrated oncological results<sup>9,10</sup>. This procedure  
85 usually requires thoracic and spine surgery teams and the  
86 perioperative mortality rate remains high and varies from 9% to 58%<sup>10-</sup>  
87 <sup>12</sup>. A spinal instrumented stabilization is always performed when a  
88 complete vertebrectomy is required, increasing the mean operative time,  
89 the blood losses and the postoperative morbidities. However, the  
90 usefulness of a spinal instrumentation to prevent spine deformity has  
91 not yet been assessed, especially concerning partial vertebrectomies. In  
92 this study, we focused on the postoperative spine deformity in patients  
93 operated with en bloc resection of PBCIS without instrumented  
94 stabilization. The objective was to determine if a secondary spine  
95 deformity depends on which type of vertebral resection was performed  
96 and if any vertebral resection threshold can be observed to justify  
97 additional spinal instrumentation.

98

99 Patients and Methods:

100 This is a retrospective single-center study, including all patients with  
101 PBCIS operated from 2009 to 2018. Data were retrieved from the  
102 electronic medical records. All patients underwent preoperative  
103 neoadjuvant chemotherapy and radiation. Immediate preoperative spine  
104 invasion was assessed with Weinstein, Boriani and Biagini<sup>13</sup> (WBB)  
105 staging (**Figure 1**) and the Spine Instability Neoplastic Score<sup>14</sup> (SINS) (**Table**  
106 **1**). Both lung, chest wall resection and partial vertebrectomy were  
107 performed during a single-stage procedure. Surgical approaches  
108 included anterior cervico-thoracotomy (n=1) and posterolateral  
109 thoracotomy with extended incision to expose the spine (n=17). No patient  
110 underwent spinal instrumentation during procedure.

#### 111 *Surgical technique*

112 The patient is positioned in lateral position to expose the side invaded by  
113 the tumor upwards (Shaw-Paulson approach). A posterolateral incision  
114 passing below the tip of the scapula is performed. The scapula is then  
115 mobilized laterally and superiorly after a careful dissection of the  
116 trapezius and rhomboid muscles. The penetration into the chest cavity is  
117 performed laterally to identify the tumor without violating its  
118 margins. Intrathoracic procedure including lung, bronchus and  
119 vascular dissection is performed by the thoracic surgeon. The incision is  
120 then extended posteriorly to expose the affected vertebrae. Partial  
121 vertebrectomies using osteotomes are then performed in the affected  
122 levels. If the posterior vertebral elements are invaded, the tumor is  
123 isolated from the unaffected vertebra by performing a unilateral  
124 laminectomy. The dura and nerve roots are then gradually exposed.

125 Invaded nerve roots are clipped to prevent cerebrospinal fluid leakage  
126 and cut. The osteotomy is extended to the vertebral body (VB). It is  
127 performed medially to the ipsilateral pedicle, allowing a facet and  
128 pedicle removal en bloc with the tumor. The invaded VB osteotomy is  
129 performed through osteotomy and followed by the section of the  
130 anterior longitudinal ligament. A safety margin is respected to avoid  
131 any violation of the tumor. After removing the tumor en bloc (**Figure 2**),  
132 mediastinal lymphadenectomy is performed.

### 133 *Spine balance analysis*

134 Immediate postoperative computed tomography (CT) scan were analysed  
135 and compared to preoperative CT scan. We used the classification  
136 described by Jain<sup>15</sup> (**Figure 3** and **Figure 4**) and created three groups  
137 depending on the quantity of resected bone measured on the CT scan:  
138 type A were partial vertebrectomies including costotransversectomy  
139 and/or less than 25% VB resection, type B were partial vertebrectomies  
140 including pedicle resection and/or facetectomy and/or less than 50% VB  
141 resection, and type C were partial vertebrectomies including more than  
142 50% VB resection. The amount of resected VB was measured on a single  
143 axial section of the immediate postoperative CT scan. We chose  
144 systematically the single axial section showing the most extensive  
145 resection of the VB. The vertebra with the most important resection was  
146 chosen in case of multiple vertebral resection. Two composite groups  
147 were also created: a low-risk group of deformity, including group A and  
148 group  $B_{n<3}$ , and a high-risk group including group  $B_{n\geq 3}$  and group C.  
149 Operative time length, blood loss volume and hospital length of stay

150 were recorded. Each patient had a long-term clinical and radiological  
151 follow up with spine CT scans and spine X-rays. The end-point of the  
152 follow-up was at the time of the last X-ray retrieved from medical  
153 records, or at the time of the second surgery for spine stabilization if  
154 needed. The need for a second surgery was decided by the spine surgeon  
155 and after a multidisciplinary consultation. Reoperation for  
156 stabilization was decided according to importance of the progressive  
157 spine deformity, back pain, performance status, operability and patient  
158 demand. Coronal Cobb angle (CCA), sagittal Cobb angle at the edge of  
159 the resection ( $SCA_{EOR}$ ), T1-T12 sagittal Cobb angle ( $SCA_{T1-T12}$ ) were  
160 reported immediately after surgery and at the end of the follow-up  
161 (**Figure 5**). The difference between immediate post operative angles and the  
162 late postoperative angles was then reported and compared between  
163 each vertebral resection group and according to the number of  
164 resected vertebrae. We also provide a qualitative analysis concerning  
165 the risk factors of a sagittal deformity over  $5^\circ$  and  $10^\circ$ .

166

#### 167 Statistical analysis:

168 We used Student's *t*-tests for spine angles analyses. The distribution of categorical variables  
169 was compared with Fisher's exact test. All tests were two-sided and a p-value of  $\leq 0.05$  was  
170 considered to be statistically significant. Statistical analyses were performed using Statview  
171 version 5.0 software (SAS Institute, Cary, NC, USA).

172

#### 173 Results:

174 Eighteen patients were included. The median age was 60 years-old (range  
175 46-81 years-old). Demographic and intraoperative data are summarized in



176 **Table 2.** WBB staging and SINS are reported in **Table 3.** The tumor histology  
177 was adenocarcinoma in 11 patients, squamous cell carcinoma in 5  
178 patients, and undetermined or other NSCLC in 2 patients. The average  
179 blood loss was 1614 ml (200-4500 ml) and average operative length was  
180 390 minutes (range 140-650 min). The average hospital length of stay was  
181 13 days (range 5-37 days). No patient suffered from a serious  
182 complication within the 30 days following the surgery. A cerebrospinal  
183 fluid leak due to a dural tear occurred in one patient. Three patients  
184 underwent type A vertebral resection (Group A), fourteen patients  
185 underwent type B vertebral resection (Group B) and one patient  
186 underwent type C vertebral resection (Group C). Among group B, five  
187 patients had less than 3 resected vertebrae (Group  $B_{n<3}$ ) and nine  
188 patients had 3 or more resected vertebrae (Group  $B_{n\geq 3}$ ). The overall  
189 average number of resected vertebrae was 2,8 (range, 1-5) from level T1  
190 to T9. The median overall follow-up was 27 months (range 2-109). A  
191 second surgical procedure for posterior spinal stabilization was needed  
192 for 4 patients (median delay was 8,5 months, range 2-18 months). Among  
193 these 4 patients, 3 were re-operated because of back pain and progressive  
194 deformity (angles for these patients were reported from preoperative X-  
195 rays, and reported in the **Table 4**). All of them had good performance  
196 status without progression of their disease. The fourth reoperated  
197 patient received emergency surgery for decompression and stabilization  
198 5 months after en bloc resection because of local tumor recurrence  
199 revealed by a spinal cord compression. Among the fourteen other  
200 patients, three patients died respectively 5 months, 6 months and 34

201 months after surgery because of the progression of their cancer. Among  
202 the remaining patients (n=11), the median follow-up was 36 months (range  
203 10-109). The variation of angles between immediate and late  
204 postoperative assessment by specimen and for each groups are reported  
205 in **Table 4** and **Table 5**. Since only one patient was in the group C, we did not  
206 perform statistical analysis with this subgroup alone. There was no  
207 statistical difference on the sagittal or coronal balance between  
208 group A and group B (**Table 6**). Within the group B, resection of three  
209 vertebrae or more trended to be associated with a higher risk of  
210 sagittal deformity, even if the statistical significance was not reached  
211 with  $p=0,061$  ( $SCA_{EOR}$ ) and  $p=0,066$  ( $SCA_{T1-T12}$ ). Among the composite groups,  
212 the high-risk group showed significantly more sagittal deformity at the  
213 end of the follow-up ( $p=0,01$ ) (**Table 6**). We then made a categorical  
214 analysis of which patients had a progression of the sagittal kyphosis of  
215 more than  $5^\circ$  and more than  $10^\circ$ . We confirmed that the high-risk group  
216 was significantly associated with a worsening of the local and  
217 regional kyphosis ( $p=0.01$  and  $p=0.004$ , respectively) whereas the low-risk  
218 group was not (**Table 7**). This trend showing a threshold in term of  
219 sagittal balance when more than 3 vertebrae were resected was  
220 supported by our clinical experience: within the four patients who  
221 needed additional spinal stabilization, three patients were from group  
222  $B_{n \geq 3}$  and one of them was from group C, all of them belonging to the  
223 high-risk group.

224

225 Discussion:

226

227 *Preoperative status, assessment and staging of the disease*

228 The management of BPCIS has evolved through the last decade. Tumors  
229 with an invasion of the spine have long been considered as inoperable  
230 and fatal<sup>5</sup>. An appropriate staging with a careful assessment of the  
231 oncologic status prior to the surgery is essential to choose between  
232 therapeutic options. Actually, an incomplete tumoral resection is  
233 associated with a poorer oncologic outcome<sup>6,16</sup>. The Tumor, Node and  
234 Metastasis classification makes chest wall involvement at least grade  
235 T3 and VB involvement grade T4<sup>17</sup>. Preoperative evaluation of the  
236 mediastinum with CT, MRI, positron emission tomography (PET) and/or  
237 mediastinoscopy are required to determine lymph nodes invasion and  
238 metastatic status before any curative surgery attempt. The role of  
239 preoperative radiotherapy and chemotherapy is widely supported in the  
240 literature<sup>5,6,10,18-20</sup>. Potential benefits are the decrease in the size of  
241 the tumor, the improved resectability and a lower dissemination rate of  
242 the tumor during surgery<sup>10</sup>. Various classifications about primary and  
243 secondary bone tumors are provided in the literature. The aim of these  
244 classifications is to help the surgeon in planning the most appropriate  
245 tumoral resection in spinal tumors. The WBB staging<sup>13</sup> were reported to  
246 describe with more accuracy the characteristics of our cohort, even if  
247 the relevance of this classification is not evaluated for BPCIS. In our  
248 study, the local extension often came from the junction between the rib  
249 and the VB by contiguity invasion, explaining why the WBB sector was

250 usually scored between 3-4 and 9-10 and always started at layer A. The  
251 SINS was developed by Fisher et al<sup>14</sup> to define neoplastic-induced  
252 instability of the spine. The SINS was also quite homogenous due to  
253 contiguity invasion of the VB: involvement of spinal posterior elements  
254 was always unilateral (score = 1), without VB collapse (score 0 or 1),  
255 and without spinal alignment abnormalities or deformity (score = 0).

256

### 257 *Surgical techniques*

258 Different surgical techniques have been described for lung cancers  
259 invading the spine. Intralesional resection was studied by several  
260 authors like Bolton et al<sup>21</sup> who reviewed two case-series of 17 patients  
261 and 39 patients with NSCLC invading the spine, or Bilsky et al<sup>22</sup> who also  
262 reported 42 intralesional approach with a combined two-staged  
263 procedure (posterolateral approach and midline posterior approach).  
264 Grunenwald et al<sup>6</sup> reported a 19-patients study of superior and non-  
265 superior sulcus tumors invading the spine treated with en bloc surgical  
266 technique. Fadel et al<sup>20</sup> and Collaud et al<sup>16</sup> also performed en bloc  
267 resection technique in a 54-patients study (although 17 patients were  
268 concerned with hemivertebrectomies) and in a 48-patients study  
269 respectively, both with excellent overall survival rates. Rates of  
270 local and distant recurrence seem similar between these different  
271 methods, whether the en bloc resection or the intralesional technique  
272 was performed. However, more recent reports favour en bloc resection  
273 through less invasive procedures: Stoker et al<sup>23</sup> reported a case-series

274 of 8 en bloc resection with a sequential video-assisted thoracoscopic  
275 surgery combined with posterior spinal resection, showing a lower  
276 estimated blood loss quantity and lower length of the hospital stay.  
277 Tomita et al<sup>24</sup> and Jain et al<sup>15</sup> described a single-stage posterior midline  
278 approach for en bloc resection with circumferential spinal  
279 stabilization. This approach offers a one-stage definitive resection and  
280 stabilization. Overall comparison of previously cited studies tends to  
281 show a better rate of complete resection with en bloc resection  
282 techniques<sup>6,10,16,25</sup>. In our study, all patients underwent a single-stage  
283 procedure through a posterolateral thoracotomy with an extended  
284 incision over the posterior midline to expose the spine. When an anterior  
285 cervico-thoracotomy was required due to anatomical consideration, no  
286 second-stage was necessary because posterior spinal instrumentation  
287 was not performed. All resections were performed with en bloc  
288 technique without violating the edge of the tumors.

289

#### 290 *Survival status and perioperative morbidity and mortality*

291 In most studies involving surgical treatment with vertebral resection,  
292 the 5-year survival rate ranges between 10 and 61%<sup>6,15,21,22</sup>. High rates of  
293 postoperative morbidity or mortality<sup>6,10,16,18,20,25</sup> makes surgical  
294 management challenging for multidisciplinary teams. Trying to reduce  
295 operative time length and blood loss is a key point to improve  
296 postoperative course. Various postoperative complications are reported  
297 in the literature: bronchopleural fistula, meningitis, atelectasis, acute  
298 respiratory distress syndrome, hypovolemia, deep infection, compression

299 fracture at the distal end of instrumentation, spinal device dislocation  
300 or wound dehiscence<sup>23</sup>. Few reports take into consideration operative  
301 blood loss and mean operative time. Stoker et al<sup>23</sup> reported a mean  
302 estimated blood loss of 813 mL for video-assisted thoracoscopic  
303 thoracotomy combined to posterior spinal approach, and an estimated  
304 blood loss of 1250 mL concerning opened thoracotomies. In our study,  
305 the mean operative time reported was 367 minutes (thoracoscopic  
306 thoracotomy) and 518 minutes (opened thoracotomy). Anraku et al<sup>10</sup>  
307 reported an analysis over 23 consecutive patients with systematic spinal  
308 instrumentation. Nine patients underwent a one-stage operation and 14  
309 underwent a two-stage operation. The average number of vertebrae  
310 resected were 3,5 (staged surgery) and 2,5 (1-stage surgery), which seems  
311 to be comparable to the average number of vertebrae resected in our  
312 study (n=2,8). Mean operative time was 12,3 hours and 19,3 hours  
313 respectively with mean blood loss during surgery of 2700 mL and 4000mL  
314 respectively. Median duration of hospitalization was 23 days and 2  
315 patients (8,7%) died during immediate postoperative course because of  
316 pneumonia and bronchopleural fistula. In our study, we report lower  
317 operative blood loss (mean bleeding was 1614 mL), lower operative time  
318 (mean operative time was 390 minutes), lower duration of hospitalization  
319 (median was 13 days) and no postoperative death.

320

### 321 *Spinal instrumentation and spine deformity*

322 There is no consensus about spinal instrumentation after partial  
323 vertebrectomy for PBCIS. Bolton et al<sup>21</sup> performed instrumentation

324 only in case of total vertebrectomy (n=15) excepted for the case of one  
325 patient who underwent resection of all posterior elements over two  
326 adjacent levels. However, most authors perform at least anterior or  
327 posterior instrumentation, or even both anterior and posterior  
328 instrumentation in case of pre-existent spinal deformity or multilevel  
329 vertebral involvement<sup>26</sup>. From our experience, the outcomes in terms of  
330 spinal deformity depend on the type of the vertebral resection and on  
331 the number of adjacent resections. It is commonly admitted that type A  
332 resections do not require complementary spinal instrumentation  
333 whereas type B resections require posterior instrumentation and type C  
334 resections require both anterior and posterior instrumentation<sup>15,27</sup>.  
335 While we found this postulate acceptable for type A and type C  
336 resection, we made the hypothesis that type B resection group does not  
337 require complementary spinal instrumentation in any cases. To our  
338 knowledge, no vertebral resection threshold was previously reported  
339 in the literature to justify spinal instrumentation. There is also a  
340 paucity of the literature concerning deformity issues and outcome  
341 concerning this population. Our results suggest that type A and type B  
342 with less than 3 resected vertebrae (low-risk group) are not subject to  
343 important sagittal and coronal deformity even after a late follow-up  
344 while type B on more than three vertebrae and type C resection are  
345 more likely to present a sagittal deformity. Statistical difference  
346 between low risk and high risk groups was only reached in term of  
347 sagittal deformity. This suggesting that a systematic stabilization  
348 might be avoided in the low-risk group, thus limiting the surgical

349 morbidity associated with these procedures. However, our study  
350 clearly suffers from a lack of statistical power. Further investigations  
351 with larger controlled case-series are needed to confirm these results.

352

### 353 Conclusion:

354 Selected patients with PBCIS are eligible to curative surgical attempt  
355 with en bloc resection including complete or partial vertebral  
356 resection. There are no validated criteria to justify a systematic spinal  
357 instrumentation in these procedures. Our results suggest that selected  
358 patients with partial vertebrectomies do not need additional spine  
359 stabilization. A low-risk profile remains to be defined with a higher  
360 level of evidence but our results suggest that this profile depends on  
361 the type of vertebral resection combined with the number of resected  
362 vertebrae. These results could help to reduce the perioperative  
363 morbidity of these procedures that are usually long and complex.  
364 Further prospective studies are needed to validate these preliminary  
365 results.

366

### 367 Figures

368

#### *Figure 1 (COLOR)*

369 Modified Weinstein, Boriani and Biagini (WBB) surgical staging system by  
370 consensus of the Spine Oncology Study Group. 12 radiating zones are  
371 numbered from 1 to 12 in a clockwise order. Six concentric layers are  
372 described: A (extraosseous soft tissues), B (intraosseous superficial), C  
373 (intraosseous deep), D (extraosseous extradural), E (extraosseous  
374 intradural) and F (Vertebral artery involvement).



375

376

Figure 2 (COLOR)

377 Specimen of an en bloc resected tumor involving lung, chest wall and  
378 three vertebrae.

379

380

Figure 3 (COLOR)

381 Different types of partial vertebrectomies: type A partial  
382 vertebrectomy includes costotransversectomy and/or less than 25%  
383 vertebral body resection, type B partial vertebrectomy includes  
384 pedicle resection and/or facetectomy and/or less than 50% vertebral  
385 body resection, and type C partial vertebrectomy includes more than  
386 50% vertebral body resection.

387

388

Figure 4

389 CT scan axial section reconstructions showing Type A (A), Type B (B) and  
390 Type C (C) partial vertebrectomies.

391

392

Figure 5 (COLOR)

393 Thoracic spine represented on sagittal plane (left) and on coronal  
394 plane (right). Yellow marks illustrate T1-T12 sagittal Cobb angle  
395 ( $SCA_{T1-T12}$ ), red marks illustrate sagittal Cobb angle at the edge of the  
396 resection ( $SCA_{EOR}$ ) and blue marks illustrate coronal Cobb angle (CCA).

397

398 **Tables**

399 **Table 1: The Spine Instability Neoplastic Score (SINS)**

400

401 **Table 2: Preoperative spinal invasion assessment: Weinstein, Boriani, Biagini (WBB)**  
 402 **classification and Spine Instability Neoplastic Score (SINS).**

403  
 404 **Table 3: Characteristics of the surgical cohort**

405  
 406 **Table 4: Difference between immediate and late CCA, SCA<sub>EOR</sub>, SCA<sub>T1-T12</sub> by specimen.**

407  
 408 **Table 5: Difference between immediate and late CCA, SCA<sub>EOR</sub>, SCA<sub>T1-T12</sub> by subgroups.**

409  
 410 **Table 6: Comparison of spine deformity depending on type of vertebral resection**

411  
 412  
 413 **Table 7: Comparison of effectives with variation of the sagittal kyphosis over 5° and**  
 414 **over 10°**

415  
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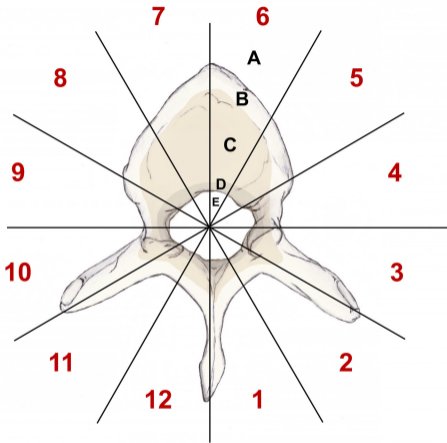
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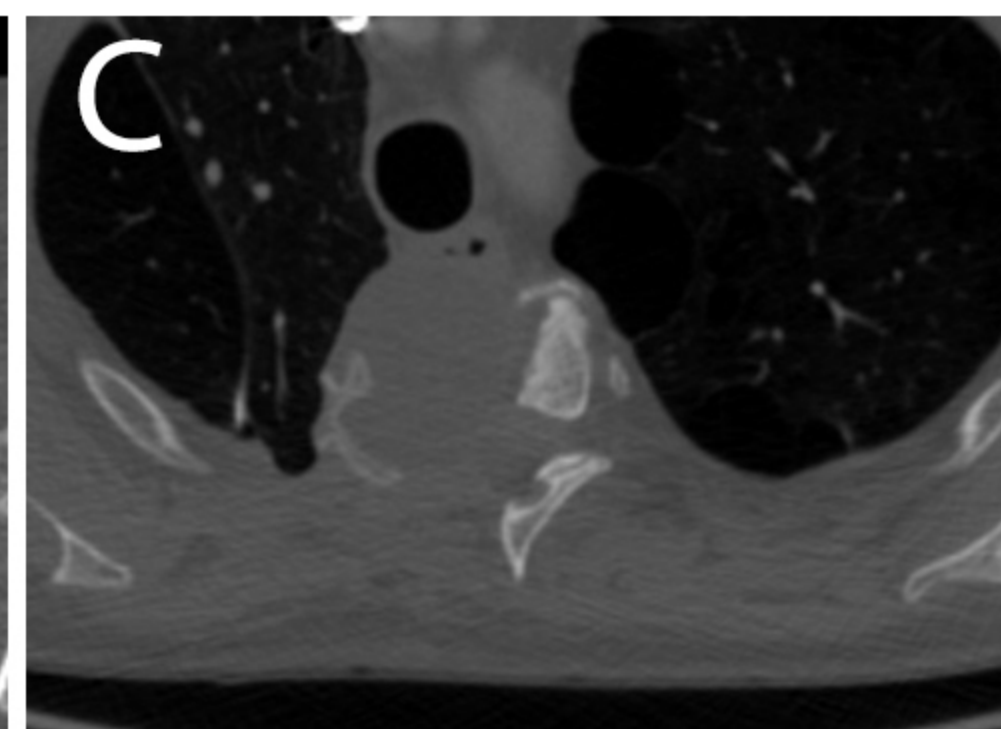
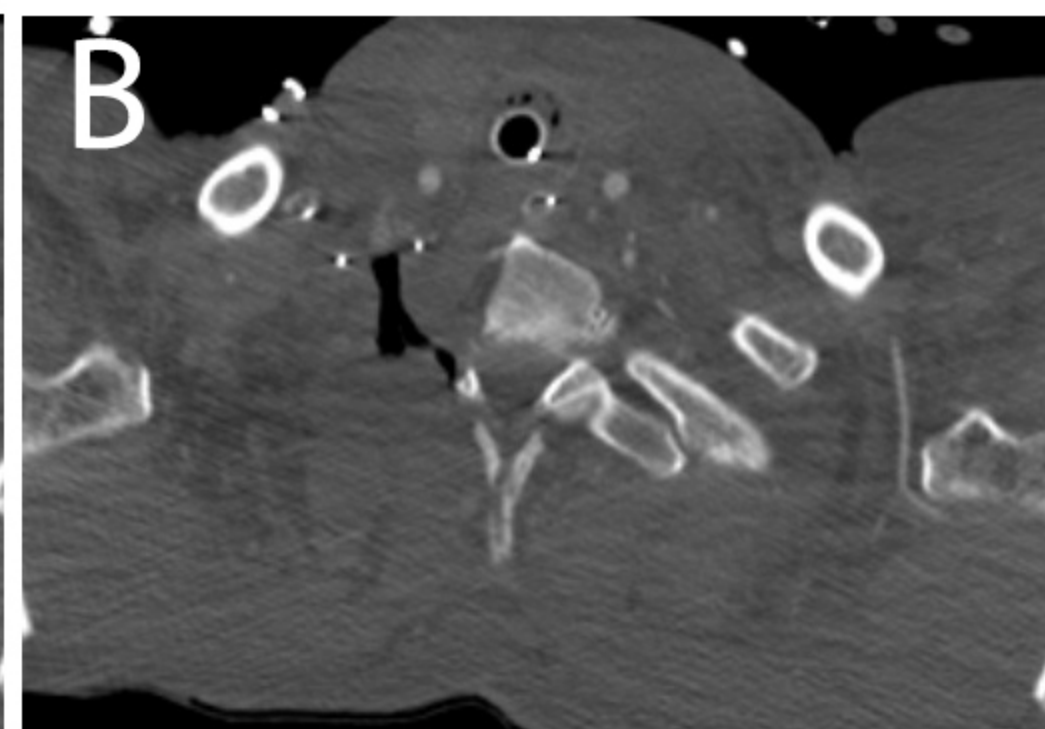
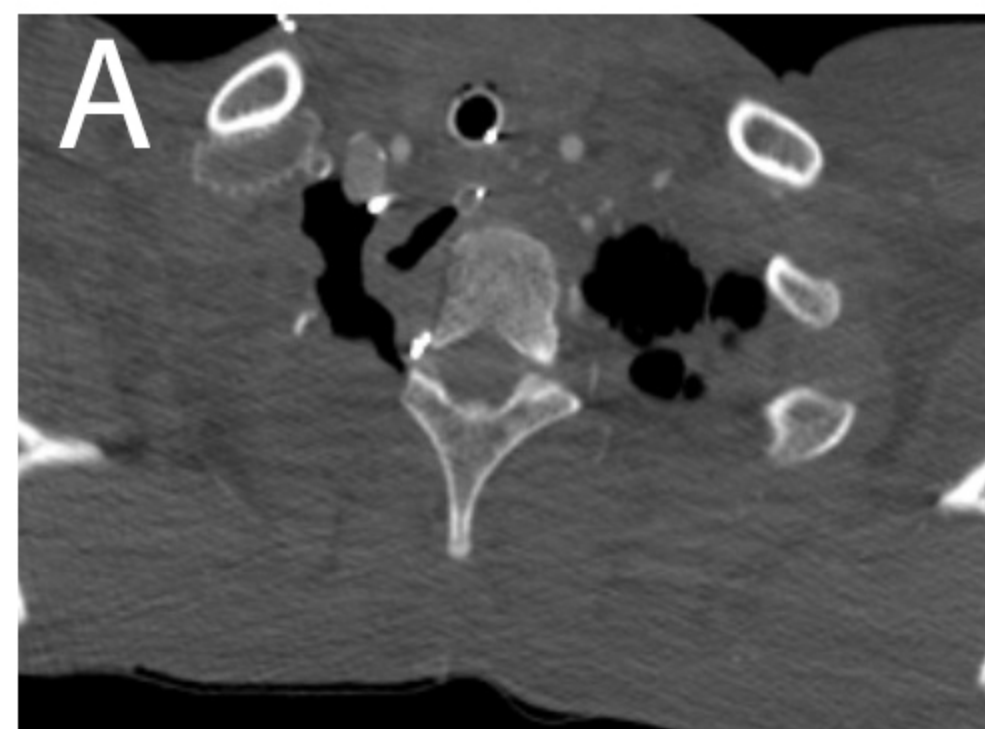
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<b>Element of SINS</b>	<b>Score</b>
<b>Location</b>	
Junctional (occiput -C2, C7-T2, T11-L1, L5-S1)	3
Mobile spine (C3-C6, L2-L4)	2
Semi-rigid (T3-T10)	1
Rigid (S2-S5)	0
<b>Pain relief with recumbency and/or pain with movement</b>	
Yes	3
No (occasional pain but not mechanical)	1
Pain free lesion	0
<b>Bone lesion</b>	
Lytic	2
Mixed (lytic/blastoid)	1
Blastic	0
<b>Radiographic spinal alignment</b>	
Subluxation/translation present	4
De novo deformity (kyphosis/scoliosis)	2
Normal alignment	0
<b>Vertebral body collapse</b>	
>50% collapse	3
<50% collapse	2
No collapse with >50% body involved	1
None of above	0
<b>Posterolateral involvement of the spinal elements</b>	
Bilateral	3
Unilateral	1
None of the above	0

**Table 1: The Spine Instability Neoplastic Score (SINS).**

Variables		n (%)
Gender	Female	4 (22)
	Male	14 (78)
Histology	Adenocarcinoma	11 (61)
	Squamous cell carcinoma	5 (28)
	other	2 (11)
Type of vertebral resection	Type A	3 (17)
	Type B	14 (78)
	Type C	1 (5)
Number of vertebral resection	One	0
	Two	9
	Three	6
	Four	2
	Five	1
Level of vertebral resection	T1	4
	T2	9
	T3	11
	T4	9
	T5	5
	T6	4
	T7	2
	T8	3
	T9	2
Residual margin	R0	16 (89)
	R1	2 (11)
Blood loss	Median (ml)	1400
	Standard deviation (ml)	1157
	>1000ml	5
	1000-2000ml	7
	>2000ml	6
Hospital length of stay	Median (days)	11
	Standard deviation (days)	7,7
	<10 days	7 (39)
	10-20 days	9 (50)
	>20 days	2 (11)
Survival	Survival	15 (83)
	Death	3 (17)
	12-months survival rate (%)	86
Second surgery for spinal instrumentation	Second surgery	4 (22)
	No second surgery	14 (78)

**Table 2: Characteristics of the surgical cohort**

Case	Weinstein, Boriani, Biagnini (WBB) classification		Spine Instability Neoplastic Score (SINS)
	WBB Sector	WBB Level	
1	7-8	A-B	7
2	5-6	A-C	4
3	5-7	A-B	7
4	7-10	A-C	11
5	4-6	A-B	7
6	8-10	A-C	8
7	8-11	A-B	9
8	8-10	A-D	9
9	8-10	A-C	9
10	7-9	A-C	7
11	4-7	A-C	9
12	8-10	A-C	7
13	3-7	A-C	9
14	7-10	A-D	9
15	3-5	A-C	9
16	3-4	A-C	7
17	6-9	A-B	7
18	6-11	A-D	10

**Table 3: Preoperative spinal invasion assessment: Weinstein, Boriani, Biagnini (WBB) classification and Spine Instability Neoplastic Score (SINS).**

Case	Vertebral Resection Type	Difference between immediate and late CCA (°)	Difference between immediate and late SCA <sub>EOR</sub> (°)	Difference between immediate and late SCA <sub>T1-T12</sub> (°)	Later instrumented stabilization
1	A	0	0	2	no
2	A	0	0	3	no
3	A	3	1	2	no
4	B	8	21	23	yes
5	B	2	1	2	no
6	B	0	6	10	no
7	B	16	23	26	yes
8	B	4	16	16	no
9	B	3	3	6	no
10	B	1	0	2	no
11	B	7	3	4	no
12	B	3	0	3	no
13	B	0	26	30	no
14	B	15	52	58	yes
15	B	6	3	4	no
16	B	3	1	2	no
17	B	0	0	0	no
18	C	16	17	25	yes

**Table 4: Difference between immediate and late CCA, SCA<sub>EOR</sub>, SCA<sub>T1-T12</sub> by specimen.**

<b>Vertebral resection subgroups</b>	<b>Difference between immediate and late CCA (°)</b>	<b>Difference between immediate and late SCA<sub>EOR</sub> (°)</b>	<b>Difference between immediate and late SCA<sub>T1-T12</sub> (°)</b>
Group A <i>mean</i> <i>median</i>	1 0	0 0	2 2
Group B <i>mean</i> <i>median</i>	5 3	11 4	13 5
Group B <sub>n&lt;3</sub> <i>mean</i> <i>median</i>	3 3	1 0	2 3
Group B <sub>n&gt;=3</sub> <i>mean</i> <i>median</i>	6 4	16 16	19 16

**Table 5: Difference between immediate and late CCA, SCA<sub>EOR</sub>, SCA<sub>T1-T12</sub> by subgroups.**



<b>Variables</b>	<b>n</b>	<b>p-value</b>	<b>95% Confidence interval</b>
<u>Group A vs Group B</u> Coronal deformity: CCA Sagittal deformity: SCA <sub>EOR</sub> Sagittal deformity: SCA <sub>T1-T12</sub>	3 vs 14	0.225 0.235 0.286	-10.300 ; 2.629 -29.857 ; 7.953 -31.439 ; 9.962
<u>Group B<sub>n&lt;3</sub> vs Group B<sub>n≥3</sub></u> Coronal deformity: CCA Sagittal deformity: SCA <sub>EOR</sub> Sagittal deformity: SCA <sub>T1-T12</sub>	5 vs 9	0.628 0.061 0.066	-7.557 ; 4.749 -32.192 ; 0.903 -34.520 ; 1.320
<u>Low-risk group vs High-risk group</u> Coronal deformity: CCA Sagittal deformity: SCA <sub>EOR</sub> Sagittal deformity: SCA <sub>T1-T12</sub>	8 vs 10	0.092 <b>0.010</b> <b>0.007</b>	-9.566 ; 0.816 -28.726 ; -4.523 -31.982 ; -5.934

**Table 6: Comparison of spine deformity depending on type of vertebral resection**

<b>Variables</b>	<b>n</b>	<b>SCA<sub>EOR</sub> (p-values)*</b>	<b>SCA<sub>T1-T12</sub>(p-values)*</b>
<u>Kyphosis progression over 5° in sagittal plane</u>			
Group Bn<3 versus Group Bn>=3	5 vs 9	<b>0.031</b>	<b>0.031</b>
Low-risk group vs High-risk group	8 vs 10	<b>0.025</b>	<b>0.004</b>
<u>Kyphosis progression over 10° in sagittal plane</u>			
Group Bn<3 versus Group Bn>=3	5 vs 9	0.086	<b>0.031</b>
Low-risk group vs High-risk group	8 vs 10	<b>0.013</b>	<b>0.004</b>

*\*Fisher exact test*

**Table 7: Comparison of effectives with variation of the sagittal kyphosis over 5° and over 10°.**