A paradigm shift for sternal reconstruction using a novel titanium rib bridge system following oncological resections†

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Abstract

OBJECTIVES: The postoperative course following sternectomy for cancer carries significant morbidity due to paradoxical breathing, pulmonary infections and infectious complications. The purpose of this report is to evaluate the outcomes in patients undergoing sternal reconstruction using an innovative titanium rib bridge system (STRATOS).

METHODS: From 2008 to 2011, 24 patients underwent sternectomy with a titanium rib bridge system reconstruction. Soft coverage tissue was performed concurrently using a prosthetic mesh and pedicled or free flaps. Postoperative data were collected prospectively.

RESULTS: The median age was 56 (31–85 years). The indications for sternal resection were primary sarcoma (n = 4), metastasis (n = 15) and radiation-induced sarcoma (n = 5). Twenty-one subtotal and three total sternectomies were performed. Resection margins included the anterior rib (n = 13, mean: 2/patient), clavicles (n = 9), breast (n = 4), superior vena cava (n = 1), pericardium (n = 5), phrenic nerve (n = 4), lung (n = 6) and diaphragm (n = 1). The stability of the chest wall typically required an average of two titanium bars and rib clips per patient. There was no perioperative mortality. Twenty-three patients were extubated within the first 24 h. The mean intensive care unit and hospital stay was 3.5 and 14 days, respectively. Wound infection did occur in one patient but did not require the removal of the titanium rib system. The postoperative forced expiratory volume in 1 s did not differ significantly from the preoperative status (P = 0.07).

CONCLUSIONS: After sternectomy for cancer, reconstruction with a titanium rib bridge system has low morbidity and permits a rapid return to baseline pulmonary mechanics.

Keywords: Sternectomy • STRATOS • Chest wall reconstruction • Morbidity

INTRODUCTION

Multiple techniques have been used to correct chest wall defects following subtotal or total sternectomy. Indeed, the impact of a sternectomy on chest wall function is major, including paradoxical respiration, prolonged intensive care unit (ICU) stay, prosthetic material infections and reoperation [1–3]. The evolution of the material used for sternal reconstructions has changed several times over the last several decades with the goal of reducing morbidity and improving the postoperative course.

The primary goals for sternal reconstruction are to obtain chest wall rigidity and to preserve the respiratory mechanics. In addition, the ideal reconstruction would eliminate paradoxical chest wall respiration (resulting in respiratory failure and a prolonged hospital stay), protect the mediastinal organs and avoid prosthetic material infections. Several years ago, we reported our series of sternal reconstructions using synthetic materials [such as a Marlex or Vicryl mesh or a polytetrafluoroethylene (PTFE) patch with methylmethacrylate reinforcement]. These were associated with soft tissue coverage offering a non-negligible level of morbidity and mortality [4]. We have developed a novel approach over the last decade that maintains sound oncological principles while having superior reconstructive outcomes.

We retrospectively reviewed our experience after sternectomy using the STRATOS (Strasbourg Thoracic Osteosyntheses System; MedXpert GmbH, Heitersheim, Germany) titanium rib bridge system for chest wall reconstruction. This report describes our experience with this novel approach.

MATERIALS AND METHODS

From 2008 to 2011, 24 patients [four (16%) males and 20 (84%) females, ranging from 31 to 85 years, mean age 56 years] underwent sternectomy for malignant tumours with a titanium rib bridge system reconstruction with associated soft tissue coverage at the Marie Lannelongue Hospital. The diagnostic work-up included a standard chest X-ray and a thoracic...
computed tomography (CT) scan and magnetic resonance imaging (MRI) in all cases to delineate the extent of the bone, soft tissue, and pleural and mediastinal involvement. If the pathological diagnosis was unavailable at the time of our office visit, a CT or surgical biopsy was performed. In all cases, a positron emission tomography/CT scan confirmed a localized disease to the sternum with no distant metastases. The pre- and postoperative forced expiratory volume in 1 s (FEV1) were, respectively, recorded 2 days before and 3 months after surgery.

Patient characteristics data are summarized in Table 1. The surgical and pathological reports of all sternal lesions were carefully reviewed and classified into three broad categories: a primary tumour of the sternum (chondrosarcoma and Ewing’s sarcoma), a radiation-induced sarcoma and metastatic (secondary) tumours to the sternum. Each tumour was evaluated for size, histological type, grade and location. Prior treatments were also recorded. Histology and previous treatments are summarized in Table 2.

### Extent of sternectomy

We categorized our sternal resections into three categories based on the extent of the operation: total sternectomy (including the manubrium, sternal body and xiphoid process), subtotal sternectomy (defined as resection ≥90% of the longitudinal diameter of the sternum) and partial sternectomies (defined as resection <90% of the longitudinal diameter of the sternum). All surgical resections begin with an excision of the mass, the overlying skin and a 3 cm margin. Mobilization is typically started from one side of the sternum, exposing each anterior rib segment and resection of the costal cartilage. All resections include the affected portion of the sternum and 3 cm of costochondral cartilages. We do not manipulate any point of tumour attachment to the mediastinum and the lung. Occasionally, for a subtotal sternectomy, a saw is used to transect the sternum at its upper or lower free margin. Bilateral internal thoracic vessels are clipped at the same level. Finally, we turn our attention to the contralateral side and repeat the resection of the sternum with a clear 3 cm margin around the tumour and excise the costal cartilages. The resection is then completed by removing any tissues involved behind the sternum that has mediastinal involvement (Table 3).

### Sternal reconstruction

All patients required chest wall reconstruction due to defects >10 cm. The stability of the chest wall was obtained by a prosthetic material sutured to the edges of the sternal defect with non-absorbable sutures. We utilized a PTFE patch (W.L. Gore & Assoc, Flagstaff, AZ, USA) in five patients and a Vicryl® mesh (Ethicon, Summerville, NJ, USA) in 19 patients. The stability of the chest wall was reinforced with the STRATOS (MedXpert GmbH) titanium rib bridge system for chest wall reconstruction (Fig. 1). The technique has been previously described by Gonfotti et al. [5]. The rib clips are fixed bilaterally and angled with special surgical pliers. The clips are placed perpendicular to the position of the bar that is located between the two clips. In our experience, most patients required (on average) two bars (Table 4).

All resections and reconstructions were covered with muscle. The soft tissue coverage of the sternal defect was

### Table 1: Patient characteristics data

<table>
<thead>
<tr>
<th>Age</th>
<th>Median (years)</th>
<th>Range (years)</th>
<th>Follow-up</th>
<th>Mean (months)</th>
<th>Range (months)</th>
<th>Gender [n (%)]</th>
<th>Co-morbidity</th>
<th>BMI (mean)</th>
<th>Diabetes [n (%)]</th>
<th>Smoking history [n (%)]</th>
<th>%</th>
<th>Preoperative FEV1</th>
<th>%</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Male</td>
<td>Female</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>31–85</td>
<td></td>
<td>13.5</td>
<td>32–4</td>
<td></td>
<td></td>
<td>4 (16.7)</td>
<td>20 (83.3)</td>
<td>24.5</td>
<td>3 (13)</td>
<td>10</td>
<td></td>
<td>89</td>
<td>50–123%</td>
</tr>
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</table>

### Table 2: Histological type of sternal tumours

<table>
<thead>
<tr>
<th>n</th>
<th>Histology</th>
<th>Previous treatment</th>
<th>Surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Chemotherapy Radiation therapy</td>
<td></td>
</tr>
<tr>
<td>Primary tumours</td>
<td>1</td>
<td>Sarcoma</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Chondrosarcoma</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Ewing’s sarcoma</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Metastatic tumours</td>
<td>8</td>
<td>Breast</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Ovary</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Thyroid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Kidney</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Liposarcoma</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Thymic carcinoma</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Lung</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Radiation-induced sarcoma</td>
<td>5</td>
<td>Sarcoma</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
performed using the pectoralis major muscle with skin advancement in 12 patients, a musculocutaneous pedicled flap (latissimus dorsi) in nine patients who required large chest wall resections, and a deep internal epigastric perforating (DIEP) free flap in one patient. An omentoplasty was performed in one patient with a DIEP flap that had been previously used for breast reconstruction due to recurrent breast cancer surgery in the past.

Statistics

Pre- and postoperative FEV1 were compared with a paired t-test. The data analysis was performed using StatView (SAS Institute Inc., Cary, NC, USA). The significance was defined as $P \leq 0.05$.

RESULTS

Histology

Soft tissue and bone resection margins were tumour-free in all patients. Among sarcomas, the histological grade was high in two patients, intermediate in six patients and low in one patient. The results are shown in Table 2.

Intraoperative findings

Ten patients required a wide skin excision due to skin invasion or ulceration by the tumour or inflammatory process. All patients underwent a radical en bloc resection of the tumour and involved structures. Three total sternectomies, 17 subtotal sternectomies and four partial sternectomies were performed. The resection were extended to the anterior chest wall (beyond the costal cartilages) in three patients, lung in six patients (one right upper lobectomy and five wedge resections), brachiocephalic vein in three patients, superior vena cava with PTFE revascularization in one patient, pericardium in five patients, diaphragm in

<table>
<thead>
<tr>
<th>Surgical resection</th>
<th>n</th>
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<tr>
<td>Sternectomy</td>
<td>24</td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
</tr>
<tr>
<td>Subtotal</td>
<td>21</td>
</tr>
<tr>
<td>Ribs (mean)</td>
<td>2</td>
</tr>
<tr>
<td>Clavicles</td>
<td>9</td>
</tr>
<tr>
<td>Lung</td>
<td></td>
</tr>
<tr>
<td>Wedge</td>
<td>5</td>
</tr>
<tr>
<td>Lobectomy</td>
<td>1</td>
</tr>
<tr>
<td>Phrenic nerve</td>
<td>4</td>
</tr>
<tr>
<td>Pericardium</td>
<td>5</td>
</tr>
<tr>
<td>Diaphragm</td>
<td>1</td>
</tr>
<tr>
<td>Breast</td>
<td>4</td>
</tr>
<tr>
<td>SVC</td>
<td>1</td>
</tr>
<tr>
<td>TVI</td>
<td>3</td>
</tr>
<tr>
<td>Axillary nodes</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 3: Extent of chest wall resection

Figure 1: The STRATOS system used for sternal reconstruction after a total sternectomy Ewing’s sarcoma. Preoperative CT scan (A and B) with invasion of the sternum. An operative view of the en bloc resection enlarged to the biopsy scar and lung (C). An operative view before reconstruction (D) and after reconstruction with the STRATOS system (D).
one patient and the phrenic nerve in four patients. A mastectomy was performed concurrently in four cases. All margins were macroscopically tumour-free in all patients.

### Postoperative course

Twenty-three patients (96%) were extubated during the first postoperative day (Table 5); one patient (one subtotal sternectomy) was extubated in the ICU on postoperative day 2. There were no perioperative mortalities. No major septic complications nor flap-related complications occurred. One patient required reintubation secondary to a pulmonary infection and required prolonged mechanical ventilation and ultimately tracheotomy. On the whole, postoperative ICU stays averaged 3.5 days (range: 0–29 days). The mean hospital stay was 14 days.

Two patients developed a seroma (after subtotal sternectomy) and were treated conservatively without consequences. We did not experience any paradoxical chest wall movement with this rigid reconstruction (Table 5).

### Outcomes

We had one local recurrence in two patients (8%) at 13 and 26 months after surgery. This occurred after two subtotal sternectomies for a high-grade sarcoma and for a thymic carcinoma. They were treated by completion sternectomy and postoperative radiotherapy. Following these procedures, the patient presented 26 months later with a pulmonary metastasis that was managed by wedge resection. One delayed infection occurred 12 months after surgery and was managed by removing the PTFE mesh while preserving the myocutaneous flap.

### Pulmonary function tests

Follow-up respiratory capacity and postoperative lung function were measured in all patients.

Postoperative FEV1 did not differ significantly from the preoperative status ($P = 0.07$; Fig. 2).

### DISCUSSION

The primary aim of sternal resection for cancer is to achieve a complete (R0) resection. The potential benefit of such a complex procedure is balanced with the postoperative morbidity of an extended resection. Respiratory mechanics for successful pulmonary ventilation require a rigid chest to counteract the intrathoracic volume changes that occur during diaphragmatic contraction and inspiration. If the rigidity of the chest wall cavity is not re-established after sternectomy, this can lead to paradoxical respiration with acute ventilatory insufficiency, difficulty in weaning from the ventilator and a high risk of reintubation and pneumonia. To prevent local and general complications, the goal of chest wall reconstruction after resection is to restore the rigid chest cavity [6–8].

In 1878, Holden [9] was the first to describe a partial sternectomy for a primary sarcoma without any reconstruction. Now, for large anterior chest wall defects (>10 cm) after sternectomy, reconstruction is typically recommended to ensure a low level of complication [6, 10, 11]. In our prior experience, local septic complications occurred in 10% of the patients (4/38 patients) at the Marie Lannelongue Hospital from 1986 to 2002 [4].

Prior reports for reconstructing the anterior chest wall have been previously described. Lequaglie et al. reported that 11% (10/88) of the patients with sternectomy who underwent reconstruction using prolene, dacron or PTFE developed local infections [11]. Martini et al. reported a 7% (4/54) infection rate [8], and Incarbone et al. noted an 11% (6/52) infection rate [12]. These institutions used Marlex and PTFE mesh. For smaller resections and repairs, we still recommend this approach.

Following the use of a PTFE patch, a polypropylene or a methylmethacrylate mesh anchored to the inner edges of the defect, surgeons try to perform a rigid reconstruction. Different prostheses such as a ceramic prosthesis [13], Ley prosthesis (titanium) [14] and cryopreserved iliac bone homograft [15] have been...
recently reported for sternal reconstruction. However, the use of these inert synthetic materials to reconstruct the sternum is still subject to an infection to a variable degree (33% for Ley prosthesis) [16].

Recently reported, the use of the STRATOS system for chest wall and sternectomy reconstruction seems to offer superior postoperative results: no local infection for 41 patients (nine sternectomies) for Gonfiotti et al. [5] and 10% (2/17 patients including seven sternectomies) for Berthet et al. [17]. In our series, only one wound infection occurred (4%) at 4 months, but did not require prosthesis removal and was treated by reoperation. Delayed rupture of the STRATOS material has been recently reported; however, we did not observe this in the 3-year follow-up in our series [16]. The postoperative mortality rates after sternectomy have been reported as between 0 and 9.5% in a literature overview of sternal resections [18]. In this series, there was no perioperative mortality. We postulate that this is due to the low level of pulmonary infection.

The advantages of the titanium material are that it can be quickly and precisely adapted to the shape of the thoracic wall, rarely degrades and has no corrosion, is biocompatible and is chemically inert. The titanium system can be used for Ewing’s sarcomas in young patients because it does not limit the chest wall development as methylmethacrylate does. In addition, during the oncological follow-up with both CT and MRI, no radiological artefacts or scattering were observed when reconstructions were performed using the titanium bars. Frequent imaging is not uncommon to monitor for recurrences.

At the beginning of our experience with this material, the reconstruction was performed using a PTFE mesh to prevent lung injury [19]. But PTFE did lead to seromas (n = 2 patients); thus, we transitioned our practice to an absorbable Vicryl mesh (Ethicon), which had no complications. Ninety-one per cent (22/24) of the patients required a free or pedicled flap. Especially for a radiation-induced sarcoma and recurrent breast cancer, the need for well-vascularized tissues is essential for patients who will undergo long treatment courses with a high likelihood of postoperative wound complications.

One of the primary concerns following chest wall reconstruction is alteration of the respiratory function following surgery. Lung function tests are particularly important in patients with cardiopulmonary diseases, chronic obstructive pulmonary disease, prior radiotherapy and all subjects requiring pulmonary resections. We adopted standard preoperative evaluation criteria, and we considered a resection possible if the predictive lobe FEV1 was more than 50% of the predicted FEV1. After statistical analysis, the postoperative FEV1 did not differ significantly from the preoperative values (P = 0.07) in our series. Paradoxical chest wall motion was never observed. The benefits to pulmonary function may be related to the low level of pulmonary infections and lack of an acute respiratory distress syndrome, which is known to progress to poor outcomes [2, 18, 20, 21]. From Fig. 2, it is seen that FEV1 was reduced in 22 out of 24 patients. Thus, the non-significance of the paired t-test is due to the increase of ~40% of FEV1 in one patient. Indeed, for most patients, we usually observed a small decrease in the FEV1. But for a very large tumour (a huge Ewing’s sarcoma in this case), tumour resection could offer a real benefit in terms of ventilation. On the other hand, phrenic nerve resection usually leads to a significant decrease in the pulmonary function (three cases, 12.5%).

Often, doing a partial resection to preserve the upper portion of the sternum or minimize upper extremity impairment has a high risk of local recurrence and significant likelihood of positive margins after surgery [16]. As a consequence, we firmly support a complete sternectomy for oncological benefits. Our novel system and superior outcomes suggest that this approach can encourage full sternectomies.

Finally, postoperative pain was not particularly increased after this operation and the cosmetic result of the reconstruction was acceptable.

CONCLUSION

After a sternectomy for cancer, reconstruction with a titanium rib bridge system is safe can be performed with minimal morbidity and prevents paradoxical breathing. The use of the STRATOS system offers the best outcomes available and is superior to materials that have been utilized in the past. This also increases the possibilities for more extended resections and may develop new surgical indications. Long-term results are needed to recommend the use of the STRATOS system for extended sternal reconstruction.

Conflict of interest: none declared.

REFERENCES

APPENDIX. CONFERENCE DISCUSSION

Dr K. Athanassiadi (Athens, Greece): Out of 24 patients, only three had total sternectomies, if I'm correct.

Dr Fabre: Yes.

Dr Athanassiadi: In cases of total sternectomy, there is no doubt that one has to reconstruct the thoracic skeleton in order to prevent, as you said, the paradoxical movement and to extubate the patient very quickly. When there is a subtotal sternectomy, I cannot think that by placing bars you eliminate paradoxical movement and to extubate the patient very quickly. When there is a subtotal sternectomy, I cannot think that by placing bars you eliminate infection, as you said in your introduction, and why you cannot do, for instance, omental transposition plus myocutaneous flaps when you have subtotal sternectomy. I would like to hear your views on this. You had practically disease-free resection margins every time. You come from an experienced group. You probably have a certain policy, because when you do a frozen section, your frozen section is limited to the adjacent tissues. What was your policy?

My third question relates to the titanium. Titanium is a very good metal, and with the pliability you can easily adapt to the ribs, it can be imaged really safely by CT and MRI, but in cases where you wouldn't have R0 resection, you would have sent these patients for radiotherapy. Unfortunately, there are not too many things in the literature concerning irradiation and titanium, and the only literature I could find was in dental implants where there are some problems concerning the strength of irradiated titanium implants.

Dr Fabre: I will start with your third question. We do not have any infection with titanium because there is no microbial adherence on this material. We use Vicryl mesh between the lung and the titanium bar, there is also adherence on the tissue and on the Vicryl mesh, and there is no zone of seroma. So we have no infection.

In your second question, you were speaking about the margins. We have the pathological results only five days after the surgery, and so the patients won't leave the hospital without the results of the pathological examination. So we don't begin the radiotherapy before having histological margins. After the resection margin results, we extend the resection if needed, and we can place some larger bars if necessary.

The question about subtotal sternectomy, we define subtotal sternectomy resection as leaving only 10% of the sternum, and with only 10% even of the manubrium, you have an important paradoxical respiration. We need to have a margin of more than 3 cm, and this margin is very important in radio-induced sarcomas. I think for those indications, you need to have larger free margins.

Dr Athanassiadi: I have a comment on what you said because there are young residents in here. You cannot have a 100% free margin histology within five days from a bone. It's actually impossible.

Dr Fabre: No. We have good pathologists.

Dr J.R. De Campos (Sao Paulo, Brazil): I have two questions for you. We also started this procedure in Brazil. We have fewer cases than you; we have 14. Your advice could be helpful for me with the next ones. I'm talking about chest wall instability. You used PTFE in the beginning and then you changed to Vicryl. Can you explain why? Was it maybe because of seroma?

Dr Fabre: Yes. In two cases we had seroma with PTFE, and after removing the PTFE, we haven't had any seroma or infection. We changed progressively.

Dr De Campos: But for me, our interpretation, for chest wall stability you need to have your PTFE or Vicryl mesh very tight, and maybe we also tighten the mesh with the titanium bars. Do you think this is important or not?

Dr Fabre: Yes, we put some Vicryl mesh to have more adherence between the lung and the titanium bars and to have no movement. Also the surgical procedure is well defined: you put your chest drain first, then you put your Vicryl mesh, then you put your titanium bar, and after, you cover with your flap, and there is no complication with that sequence.

Dr C. Deschamps (Rochester, Minnesota, USA): First, I would like to commend you for your innovative use of those stabilizing bars. I think Dr Darteville's team has always liked those big surgeries, and I think that even if it's a little bit overkill, there will be an indication for some of those patients.

My comment is about the price, the cost of that. You know, we have been blamed in Rochester for using Gore-Tex forever, and I think for only those 24 cases, you have beat us for 20 years of using Gore-Tex. This is very expensive material, and I would like you or Philippe to comment about the price of that material, because we can’t afford to use this on every cancer patient we operate, even if we would like to. Please comment on this.

Dr Fabre: The price is 3,000 EUR for each bar. We usually use two bars.

But, the ICU stay is shorter for all patients. You have fewer complications. I think the total cost for each patient is lower than in the last series we published.

Dr J.M. Wihlm (Strasbourg, France): I have watched this important series since the beginning, from Strasbourg.

I have just a first comment to Claude Deschamps. The price of this material will obviously go down with more frequent use. I am really surprised that the U.S. cannot afford good titanium material anymore, especially in Rochester.

But for your team I have a comment about not using Gore-Tex and PTFE as a first layer anymore. I think the concept of every chest wall reconstruction is in fact like a sandwich with at least three layers, including a soft mesh, the titanium bars, and a good muscle layer on top for the blood supply. So you are not using a first soft layer, expecting only the natural fibrosis, or a little bit induced by Vicryl mesh, if I understand? It might be a reason for the breakages you mentioned in two cases. If you use a true first layer in 2 mm PTFE, and you may fold it in two, having 4 mm for the same price, you will have a kind of banjo skin effect, which distributes the tension all around, and also the tension from one side to the opposite side in cases of total sternectomy. I think this is an important part of the sandwich technique. A second tip to avoid breakages is to never overlap the angled part of the rib clips. You must allow a sort of natural anatomical movement, thus bending the bar slightly in anterior convexity, and never overuse the flat-nose pliers and destroy the structure of the titanium.

Dr E. Rendina (Rome, Italy): I have a very simple and quick question. Why do you place either the Vicryl mesh or Gore-Tex under the titanium bars? Wouldn’t it be more logical to place the titanium bars first and then the soft material over the titanium bars?

Dr Fabre: We don’t want to injure the lung under the titanium bar, so we put Vicryl under the bar to avoid injury to the lung.

Dr Athanassiadi: I insist on my last question, and I would ask the audience, what about irradiation, is there any study? I couldn’t find any. I think that’s the point when we do oncological surgery.

Dr E. Fadel (Le Plessis-Robinson, France): We have a large experience with titanium used for spinal resection. Most of those patients were irradiated and we didn’t have any complications from radiation-induced lesions with the titanium. I don’t know where you found your data on titanium. We published our results last month with titanium used for spinal resection. We only found complications related to irradiated bone. The screw moved in the spine and instability developed in two patients.