Intr oduction
Enbloc tumor resection of the sacrum can leave the posterior pelvis devoid of structural support and soft tissue coverage, putting patients at risk of postoperative complications and sacral herniation [1]. Compared to total sacrectomies, partial sacrectomy defects can often be managed without instrumentation to reconstruct the structural support of the spino-pelvic junction [2]. However, lack of skeletal support and often large soft tissue defects lead to challenges in decision-making for posterior pelvic reconstruction (PPR) [3]. A variety of tissue flaps have been previously described including gluteal muscle flaps, rectus abdominis myocutaneous flaps, paraspinous flaps and omental flaps [4]. Other support includes the use of synthetic materials and acellular dermal matrices [5,6]. The objective of this systematic review was to examine the current literature on PPR of partial sacrectomy defects involving soft tissue reconstruction.

Case Presentation
A retrospective review of the chart was initiated. A 75-year-old male presented with a one-year history of lower back pain. Computed tomography imaging demonstrated an 8 x 12 x 7cm destructive lesion in his upper sacrum later confirmed by biopsy to be a classic-type chordoma.
The procedure began with the reconstructive team raising an inferiorly-based vertical rectus abdominis myocutaneous (VRAM) flap and the general surgery team accessing and releasing the anterior portion of the tumor (Figure 2). In the second stage of the procedure, the spinal surgery team resected the remaining tumor requiring sacrifice of superior and inferior gluteal artery perforators (SGAP and IGAP) obviating gluteal-based flaps as a potential reconstruction (Figure 3). The resultant defect measured 20 x 20cm. To isolate the small bowel from herniating posteriorly, a 16 x 20cm acellular dermal matrix (ADM) was secured to remaining bone and gluteus muscle residuum, leaving a superior opening for the pedicled VRAM flap (Figure 4). The VRAM flap was de-epithelized and positioned over the ADM thus obliterating dead space (Figure 5). Primary closure was achievable. The patient was reassessed at 13 months post-operation and had no evidence of sacral herniation. The patient passed away 15 months post-operation.

Methods

Search strategy and Selection criteria

A systematic review identified relevant studies published through Medline Ovid from 1970 until July 2015. Search terms focused on (1) Reconstruction (2) Primary sacral tumors (Appendix). All study types were included in the initial search, including abstracts and pending publications available. Non-electronic versions were requested. Inclusion criteria required the publications to be pertaining to reconstruction of partial sacral defects from a primary sacral lesion. Articles were excluded if they had no reconstructive data or were not clinical cases. Two authors (J.S. and R.H.) independently reviewed the articles. Disagreements on consensus of inclusion or exclusion were arbitrated by a third author (M.B.).

Data extraction and Outcomes

Title, author, journal, publication year and study type were recorded. Data collection included the following when available: (1) Patient demographics (2) Sacral resection (3) Reconstruction of defect (4) Tumor pathology (5) Patient outcome – complications and follow-up.

Results

Study selection

Using the previously described search method, 1371 articles were identified. After articles were screened by title and abstract using our
A review of the literature on soft tissue reconstruction of the posterior pelvic defects is limited. A variety of reconstructions for sacral defects. A total of 59 patients met our inclusion criteria (Table 1). Eight articles reported on patients undergoing partial and total sacrectomies for primary neoplasms. Five of these, include reconstructive data for secondary neoplasms of the sacrum. Papers recording total sacrectomy and partial sacrectomies patients and/or secondary pathology of the sacrum in total numbers (specific data for partial sacrectomy patients could not be extracted) were excluded from the demographic calculations (denoted with *. The remaining 15 articles accounted for 28 male and 28 female who underwent soft tissue reconstruction for partial sacrectomies (3 not recorded). Patient age ranged from 23 – 71 years-old. The most common pathology was chordoma (n=49, 83%). Other pathology included giant cell tumor, myxopapillary ependymoma, and chondrosarcoma. The most common pathology reported in all articles was chordoma (18 of 23 articles) (Table 1). Follow-up time ranged from 6 - 96 months.

Soft tissue reconstruction

Soft tissue reconstruction was commonly utilized in partial sacrectomies. Eighteen articles used soft tissue flaps. Gluteal-based and vertical rectus flaps were most common (11 articles & 7 articles, respectively). Other closures included omental, paraspinous, gluteal thigh and free latissimus flaps. Five articles highlighted use of synthetic materials including Dacryl© mesh, Polypropylene, and an unknown mesh brand for structural support, with it being used in two patients for repair of late sacral herniation at 4 and 72 months (Atkin, Junge). Another late sacral herniation was treated with acellular dermal matrix one-year post resection (Brizidene). Acellular dermal matrices combined with gluteal-based reconstruction were used in 29 cases. Complications included infection, deep vein thrombosis, flap necrosis, wound dehiscence, seroma, and rectal perforation secondary to mesh. Complications are listed in Table 1 and include undifferentiated complications of total and partial sacrectomies as well as secondary malignancy reconstruction that could not be delineated for some articles.

Discussion

Compared to total sacrectomies, partial sacrectomy defects can often be managed without instrumentation to reconstruct the structural support of the spinopelvic junction, provided the sacrococcygeal (SI) joint is spared. However, lack of skeletal support and often large soft tissue defects lead to challenges in decision-making for posterior pelvic reconstruction. Without adequate reconstruction following partial sacrectomy, post-operative complications including infection, herniation, and fistula formation may ensue [7]. Resection volume has previously been determined to be a factor in choice of flap reconstruction [4]. Other factors that may determine flap reconstruction include previous radiation to the site or sacrifice of the gluteal vessels secondary to resection. Prior laparotomy or previous ostomy site once precluded the vertical rectus flap as an option, but this is no longer supported [8,9].

The most common flap reconstructions following partial sacrectomies were gluteal-based flaps. Reconstruction included unilateral or bilateral and sliding/advancement and turn-over methods. Advantages of this flap include adequate bulk, robust blood supply, and proximity to the defect [9,10]. Additionally, it allows for a posterior-only approach [11]. Disadvantages include possible disruption of gluteal perforators during tumor resection and risk of gluteal weakness affecting gait [7,9]. Vertical rectus flow-through flaps offer the advantage of having a robust blood supply as well as providing sufficient soft tissue bulk and long pedicle length [12]. Donor site complications including abdominal herniation and weakness should be factored into decision-making.

Marichevi et al. [13] present evidence that acellular dermal matrix (ADM) reconstruction decreased the number of intra-abdominal complications when compared to a control group. The use of ADM restores the continuity of the posterior abdominal wall as well as provides an additional barrier between intraperitoneal space and instrumentation if present. Addition of flap reconstruction helps to obliterate the dead space and minimizes seroma and infection. Sciubba et al. [3] present a decrease trend in surgical site infection with presence of soft-tissue flap reconstruction, further supporting other’s recommendations of utilizing flaps for sacrectomy defects. There are few published studies presenting partial sacrectomy reconstruction and their possible complications. The current published level of evidence available to guide the reconstructive surgeon in tackling partial sacrectomy defects is limited. A summary of options are presented in this manuscript.

Conclusion

A review of the literature on soft tissue reconstruction of the posterior pelvis following partial sacrectomy reveals that VRAM and gluteal perforator flaps are appropriate choices for obliterating dead space and closure of skin deficiencies, and ADM provides structural support and fewer intraabdominal complications.
Table 1: Summarized articles highlighting soft tissue reconstruction for partial sacrectomy defects.

<table>
<thead>
<tr>
<th>Article</th>
<th>Year of publication</th>
<th>Number of patients</th>
<th>Age</th>
<th>Sex</th>
<th>Flap</th>
<th>Other support</th>
<th>Complications</th>
<th>Pathology</th>
<th>Follow-up (months) – range or average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gillis [14]</td>
<td>2014</td>
<td>1</td>
<td>30</td>
<td>M (1)</td>
<td>Latissimus dorsi flap</td>
<td>-</td>
<td>Hardware removed</td>
<td>Chondrosarcoma (1)</td>
<td>96</td>
</tr>
<tr>
<td>Maricevich [13] &amp; 2014 Partial: 38 Total: 16</td>
<td>54a</td>
<td>ND M (36) F (18)</td>
<td>Gluteal advancement (14), vertical rectus abdominis myocutaneous (23), combined (1)</td>
<td>ADM (12)</td>
<td>ND – Early death due to bleeding and coagulopathy (2), parasacral hemia (1), pelvic abscess (9), pelvic hematoma (1), bowel obstruction (1), bowel perforation/fistula (2), CSF leak (2) donor site complications (10), flap complications (21)</td>
<td>ND – Chordoma (23), rectal cancer (18), sarcoma (9), MPNST (1), ependymoma (2), recurrent endometrial cancer (1)</td>
<td>27a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clarke [11] &amp; 2012</td>
<td>34</td>
<td>51a</td>
<td>ND M (18) F (18)</td>
<td>Vertical rectus abdominis myocutaneous (8)</td>
<td>-</td>
<td>ND – Wound complication (9) DVT (2), hyponatremia (1), ileus (1) tumor recurrence/ metastasis (6)</td>
<td>ND – Chordoma (30), osteoblastoma (2) sarcoma (1), hemangioma (1), MPNST (1), epidermoid (1), osteosarcoma (1)</td>
<td>47a</td>
<td></td>
</tr>
<tr>
<td>Dasenbrock [18]</td>
<td>2011</td>
<td>29</td>
<td>50a</td>
<td>Bilateral glutaeus maximus myocutaneous advancement (29)</td>
<td>ADM</td>
<td>Infection (5), reoperation (4) parasacral hemia and local tumor recurrence (1)</td>
<td>Chordoma (26), sarcoma (1), MPNST (1) osteoblastoma (1)</td>
<td>46a</td>
<td></td>
</tr>
<tr>
<td>Varga [26]</td>
<td>2010</td>
<td>1</td>
<td>57</td>
<td>M (1)</td>
<td>-</td>
<td>Dacron® mesh</td>
<td>-</td>
<td>Chordoma (1)</td>
<td>60</td>
</tr>
<tr>
<td>Abhinav [1]</td>
<td>2009</td>
<td>2</td>
<td>63, 61</td>
<td>M (1) F (1)</td>
<td>Bilateral glutaeus maximus transposition flap (1)</td>
<td>-</td>
<td>Permacol™</td>
<td>-</td>
<td>Chordoma (2)</td>
</tr>
<tr>
<td>Korn [6]</td>
<td>2009</td>
<td>1</td>
<td>63</td>
<td>M (1)</td>
<td>Bilateral glutaeus maximus transposition flap (1)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Chordoma (1)</td>
</tr>
<tr>
<td>Ramamurthy [23]</td>
<td>2009</td>
<td>6</td>
<td>23</td>
<td>M (2) F (4)</td>
<td>Omental transposition(1)</td>
<td>-</td>
<td>Wound dehiscence (1), tumor recurrence (3)</td>
<td>GCT (3) myxopapillary ependymoma (1), chondroblastoma (1), PNET (1)</td>
<td>ND – 24</td>
</tr>
<tr>
<td>Sahakirungruang [10]</td>
<td>2009</td>
<td>5</td>
<td>58a</td>
<td>M (5)</td>
<td>Bilateral glutaeus maximus (5)</td>
<td>-</td>
<td>DVT (2), seroma (1)</td>
<td>Chordoma (5)</td>
<td>38a</td>
</tr>
<tr>
<td>Schwab [24] &amp; 2009</td>
<td>42</td>
<td>NR</td>
<td>M (30), F (12)</td>
<td>Rectus abdominis myocutaneous flap (10)</td>
<td>-</td>
<td>ND – 19 wound complications requiring debridement (10), persistent drainage needing reoperation (1), pulmonary embolism (2), enterocutaneous fistula (1) bowel perforation (1), 2 deaths within 6 weeks post-op, perirectal abscess (1), septicemia (1), recurrence (17)</td>
<td>Chordoma (42)</td>
<td>46a</td>
<td></td>
</tr>
</tbody>
</table>
### Appendix

Search terms applied to Medline Ovid database.

**General scheme**

```
["tumor terminology" AND "sacral area terminology"]
OR ("sacral resection terminology") AND ["reconstruction terminology"]
```

**Search terms**

Appendix

Search terms applied to Medline Ovid database.

**General scheme**

```
["tumor terminology" AND "sacral area terminology"]
OR ("sacral resection terminology") AND ["reconstruction terminology"]
```

<table>
<thead>
<tr>
<th>Name</th>
<th>Year</th>
<th>Case</th>
<th>Gender</th>
<th>Tumor Type</th>
<th>Tissue Type</th>
<th>Flap Type</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheong [12]</td>
<td>2008</td>
<td>1</td>
<td>F</td>
<td>GCT</td>
<td>ADM</td>
<td>Vertical rectus abdominis myocutaneous (1)</td>
<td>Delayed reconstruction due to hemodynamic instability</td>
</tr>
<tr>
<td>Brizendine [17]</td>
<td>2006</td>
<td>1</td>
<td>F</td>
<td>Chordoma</td>
<td>ADM</td>
<td>Vertical rectus abdominis myocutaneous (1)</td>
<td>Developed sacral hernia 12 months after resection, no secondary complications</td>
</tr>
<tr>
<td>Giatt [8]*&amp;</td>
<td>2006</td>
<td>12</td>
<td>M (8)</td>
<td>Chordoma</td>
<td>ND Minor flap necrosis (3)</td>
<td>Vertical rectus abdominis myocutaneous (11)</td>
<td>Chordoma (9), osteogenic sarcoma (1), MFH (1), rectal ca (1)</td>
</tr>
<tr>
<td>Koh [21]</td>
<td>2004</td>
<td>4</td>
<td>F</td>
<td>Chordoma</td>
<td>Vertical rectus abdominis myocutaneous (1)</td>
<td>-</td>
<td>Developed sacral hernia 12 months after resection, no secondary complications</td>
</tr>
<tr>
<td>Atkin [5]</td>
<td>2003</td>
<td>1</td>
<td>M</td>
<td>Chordoma</td>
<td>Polypropylene mesh to repair hernia 2 yrs after initial sacrectomy</td>
<td>Bilateral lumbar fascial flap interposed between the rectum and instrumentation</td>
<td>Chordoma (1)</td>
</tr>
<tr>
<td>Junge [20]</td>
<td>2003</td>
<td>1</td>
<td>F</td>
<td>Chordoma</td>
<td>Knitted polypropylene mesh (Atrium®) to repair defec</td>
<td>Bilateral lumbar fascial flap interposed between the rectum and instrumentation</td>
<td>Chordoma (1)</td>
</tr>
<tr>
<td>Althausen [16]</td>
<td>2002</td>
<td>1</td>
<td>F</td>
<td>Chordoma</td>
<td>Polypropylene mesh to repair hernia 2 yrs after initial sacrectomy</td>
<td>Bilateral lumbar fascial flap interposed between the rectum and instrumentation</td>
<td>Chordoma (1)</td>
</tr>
<tr>
<td>Di Benedetto [19]</td>
<td>2002</td>
<td>3</td>
<td>ND</td>
<td>Chordoma</td>
<td>Spindle-cell rhabdomyosarcoma (1)</td>
<td>-</td>
<td>Chordoma (3)</td>
</tr>
<tr>
<td>Furukawa [7]</td>
<td>2000</td>
<td>2</td>
<td>M (1)</td>
<td>Chordoma</td>
<td>Gluteus maximus adipomuscular turnover flap (1)</td>
<td>-</td>
<td>Chordoma (2)</td>
</tr>
</tbody>
</table>

* – Data for total and partial sacrectomies not differentiated by patient
n – Data for flap reconstruction not differentiated by patient
& – Includes data for secondary neoplasms of sacrum
a – Average of all patients reported in article
ND – Not differentiated, results listed may include total sacrectomy patients
ADM – Acellular dermal matrix
MM – Multiple myeloma
GCT – Giant cell tumor
MPNST – Malignant peripheral nerve sheath tumor
DVT – Deep vein thrombosis
Ca – Carcinoma
MFH – Malignant fibrous histiocytoma
PNET – Primitive neuroectodermal tumor

**Tumor terminology**

“primary tumor” OR “neoplasm” OR “bone neoplasms” OR “chondrosarcoma” OR “chondrosarcoma” OR “giant cell tumor” OR “lymphoma” OR “multiple myeloma” OR “myeloma” OR “plasmacytoma” OR “Ewing sarcoma” OR “chordoma” OR “osteosarcoma” OR “osteogenic sarcoma” OR “spinal neoplasms” OR “bone cysts” OR “aneurysmal bone cysts”.

**Sacral area terminology**

“sacrum” OR “sacral” OR “Sacrum” OR “lumbosacral”
References


