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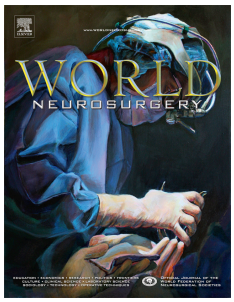

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Pelvic reconstruction surgery using a dual-rod technique with diverse U-shaped rods after posterior en bloc partial sacrectomy for a sacral tumor: Two case reports and a literature review

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Key words: Pelvic reconstruction; U-shaped rod; Sacrectomy; En bloc resection

Abbreviation list

CT: computed tomography

MRI: magnetic resonance imaging

USR: U-shaped rod

Abstract

Background

Spinopelvic reconstruction after sacrectomy for a sacro-pelvic tumor can result in various complications and requires a highly complicated surgical technique. We report two cases of pelvic reconstruction surgery using diverse U-shaped rods (USRs) after partial sacrectomy.

Case Description

A partial sacrectomy was performed for two different cases: one case was a metastatic sacral tumor and the other was a chordoma. In the first case, reconstruction was completed with an inner straight rod and an outer USR. The other patient underwent reconstruction using an inner USR and an outer straight rod. In both cases, there was no instrument failure, and the lumbosacral junction was reconstructed in balance. One of the patients died of metastatic lung cancer, and the other patient is alive and has experienced no other complications.

Conclusions

A pelvic reconstruction technique using diverse USRs showed good spinopelvic stability without complications. This technique may be a surgical option for reconstructive surgery after partial sacrectomy.

Running title: Pelvic reconstruction using a U-shaped rod

Introduction

Total or partial sacrectomy is performed for management of sacral or pelvic tumors, including chordoma, multiple myeloma, and metastatic tumor. En bloc resection with reconstruction for tumor management requires a difficult surgical technique and involves high risk of complications. Due to the anatomical and biomechanical characteristics of the surgical site, it is important not only to perform a functionally adequate surgery, but also to prevent postoperative complications.[1,2] For sacral reconstruction, numerous surgical techniques have been reported that aim to obtain stable spinopelvic reconstruction and help early ambulation and return to normal activities.[3-7] However, standard protocols for reconstruction after total or partial sacrectomy have not been determined. Among the many methods of sacral reconstruction, from a biomechanical and structural point of view, U-shaped rods (USRs) might be effective.[6,7] Varga et al. reported on a closed-loop technique with a single USR; this technique harmonically distributes biomechanical stress across spinopelvic structures.[7] Herein, we report two cases of sacral tumors that were managed with en bloc sacral resection and pelvic reconstruction using diverse USR instrumentation at our spine center and discuss the characteristics of our surgical technique compared with others for spinopelvic reconstructions.

Surgical Technique

Surgery was performed in a single stage using a posterior-only approach. The skin incision stretched from the lower back to the coccyx in order to obtain wide exposure of the posterior sacrum, and the caudal end of the incision was directed slightly to the right or left. The dorsolumbar fascia was cut, and the gluteal fascia and muscle were separated bilaterally from the midline of the sacrum. Laterally, the fibers of the gluteal muscles were dissected along with the perisacral ligaments. The piriformis muscle was detached medially from the sacral lateral margin. If the coccyx was free from the tumor margin, the coccyx and the attached ligamentous complex were preserved. After dissecting the tumor margins, lateral

iliac or sacral osteotomy was performed. Sacral nerve roots that were encased by the tumor were ligated and divided. Once the tumor and encased nerve roots were exposed and the mass lesion was sufficiently elevated, the caudal part was bluntly dissected and separated from the coccyx and the ventral margin of the tumor. After resecting the tumor, tumor-margin osteotomy was performed to decrease the possibility of local recurrence.

Reconstruction of the Sacrum

The pelvic ring was reconstructed by creating a spino-iliac connection. Either one or two iliac screws were placed on each pelvic side, and combined rods were positioned at the head of the lumbar pedicle and the iliac screws, and fastened with lateral connectors. Rod size and type were determined based on tumor size and extent of sacrectomy, and proper selection is important to prevent herniation of internal organs into the defect site. U-shaped and straight rods were slightly bent to match the natural lumbosacral curvature in the sagittal plane. Finally, posterolateral fusion using auto/allografts was performed through the L5, pelvic rim, and the iliac crests. Remaining muscle and fascia were meticulously sutured; no flaps were used.

Case Description

Case 1

A 67-year-old male patient with severe back pain, sciatica, and voiding difficulty was referred to our spine center. The patient had been suffering from intractable back and leg pain for six months, which had become particularly aggravated three months prior to presentation. He had been diagnosed with colon cancer five years previous, at which time he underwent complete surgical removal at our hospital. No metastatic lesions were observed at that time. Plain radiography and computed tomography (CT) showed an osteolytic lesion from the lower S1 body to the upper S4 body (Fig. 1). Magnetic resonance imaging (MRI) revealed a large enhancing mass with an irregular margin (Fig. 2). En bloc resection with partial sacrectomy was performed using a posterior-only approach. The S2 – 5 nerve roots were ligated and cut, and reconstruction was achieved with an inner straight rod and an outer USR (Fig. 3). The total bleeding volume was 3400 mL in a seven-hour operation. Histopathologic examination indicated the patient had a metastatic adenocarcinoma originating from the sigmoid colon. Several days after surgery, the patient's intractable pain had decreased, although his voiding difficulty was unchanged. No other complications were observed during his hospital stay. Ten months after his operation, the patient died from metastatic lung cancer. Prior to the patient's death, we successfully performed a spinopelvic fusion with no observable hardware failure. Until his death, he was able to walk without aid and live comfortably with his family.

Case 2

A 50-year-old woman with coccygodynia and voiding difficulty presented to our outpatient clinic and was subsequently admitted. Her medical history included only a diagnosis of thrombocytopenia three years prior. On examination, she did not exhibit motor weakness in her legs. Lumbo-sacral X-ray and CT revealed bony destruction and a soft tissue mass at the S2-5 levels (Fig. 4). MRI showed a lobulated mass

104 at the sacrum that was 7.6 x 7.8 x 4.2 cm in size and heterogeneous enhancement (Fig. 5). The S3 – 5
105 nerve roots were cut, and the tumor was removed by en bloc resection. The coccyx was preserved, and
106 instrumental reconstruction was performed using an inner USR and an outer straight rod (Fig. 6). The
107 total bleeding volume was 2400 mL in a five-hour operation. The patient was diagnosed with chordoma
108 by a pathologist; thus, adjuvant radiotherapy was planned. No wound problems developed, and the
109 stitches were removed 12 days after surgery. The patient underwent radiation therapy and was discharged.
110 At her follow-up visit, the coccygodynia and back pain were improved, but she still could not urinate
111 satisfactorily. In the latest follow-up (14 months after operation) images, it was difficult to accurately
112 determine whether fusion was obtained (Fig. 7).

Discussion

En bloc resection is an appropriate surgical technique for managing a sacral tumor with sufficient margins.[3,8,9] Surgical resection of sacral tumors is difficult because of the tumor location and size and because of the complex pelvic anatomy.[3,10] After resection, the continuity between the lumbar spine and pelvis is lost, and spinopelvic instability can occur. Additionally, a large empty space results from surgery and is vulnerable to infection, bowel herniation, and continuation of neurologic deficits.[1,2,11,12] Although spinopelvic reconstruction in cases involving total or partial sacrectomy is mandatory, an optimal reconstruction surgery has not yet been determined.

In this study, the focal point of our reconstruction technique was the use of a dual-rod system including diverse USRs. The use of this technique maintained structural stability and allowed reconstruction of a defective sacrum. First, considering biomechanical stability, various studies have reported that multiple-rod systems provide robust stability and reduce instrumentation failure and non-union rates compared with single-rod systems.[6,13,14] In spinopelvic reconstruction, Mindea et al. have investigated four models using various rods and iliac screws in vitro, recommending double-rod and iliac-screw techniques for strong fixation.[15] Varga et al. have recommended a closed-loop technique with a single USR in order to achieve instrument stabilization for spinopelvic fixation.[7] Recently, Lim et al. have suggested that a dual-USR technique is useful for improving spinopelvic stability after partial sacrectomy.[6] We determined that the dual-rod technique with USRs was an effective method for enhancing biomechanical stability and decreasing instrumentation failure. Second, although many surgical techniques using various rods and screws have been shown to enhance stability and evenly distribute mechanical stress, they are limited in their ability to reconstruct defects after wide resection of the sacrum.[6] After prominent reporting of cases of sacral herniation after sacrectomy,[1,16] soft tissue reconstruction techniques were introduced.[17-19] Our technique using diverse USRs occupied the large empty space resulted from sacrectomy, acting as mechanical barriers against herniation of abdominal structures. Regarding the three-dimensional structure

of the sacrum, the rod curved slightly in the sagittal plane and bent into a U-shape in the coronal plane. This allowed the maintenance of the spinopelvic sagittal curvature and the sacral margin. Thus, sacral herniation was prevented without plastic reconstructive surgery or use of flaps or mesh.

Other important features of our surgical technique include a modified linear skin incision and preservation of the coccyx to allow the muscular and ligamentous complex to remain attached to the coccyx when possible. Because the soft tissues of the sacrococcygeal area are very thin, we performed a slightly curved skin incision so as not to apply direct compressive force to the surgical wound. This technique was sufficient to support a wide surgical field without wound dehiscence or pressure necrosis and did not require a skin flap. Furthermore, we determined that preservation of the coccyx and aspects of the coccygeal complex, such as the coccygeus and rectococcygeus, was important for soft tissue reconstruction. Because the coccyx and paracoccygeal structures are parts of the pelvic floor,[20] they are critical for maintaining stability of the lower pelvic cavity. However, if these structures are invaded by a tumor, preservation of the coccyx is not applicable.

We obtain three postoperative plain radiographs after pelvic reconstruction surgery in our spine center (Fig. 8). They show that diverse USRs can be used effectively in pelvic reconstruction (Figure 8a is an image of a case not described in the present study). We think that there is no great difference in the three types of USR technique from the point of view of instrumental stability. There is no difference in terms of using the dual-rods, only a difference in the locations of the rods. The locations of USRs and straight rods were determined by the size of preoperative sacrum, pelvic cavity, and postoperative defected sacrum. For example, if the patient has a narrow pelvic cavity and the extent of sacral resection is relatively small, we choose an inner USR technique, as shown in Figure 8c. Otherwise, an outer USR or a dual-USR technique is selected in consideration of lateral sacral margin and defect size. These criteria are not absolute, and there will be some differences according to the surgeon’s decision and skill.

Because our sample size of sacral reconstruction is very small and follow-up durations are not long, we do not yet know the main limitations of our technique. Nevertheless, this surgical technique might be helpful for reconstructive instrumentation in cases where surgeons know the exact indications and can accurately apply them to the surgical field.

Conclusions

Diverse USRs provide rigid fixation, stability, and a mechanical barrier in the pelvic cavity for patients undergoing partial sacrectomy. We propose that this method might be an appropriate choice for pelvic reconstruction surgery after partial sacrectomy in patients with a sacral tumor. However, the operator must have thorough knowledge of the pelvic anatomy and a solid conceptualization of the geometrical configuration of each individual patient.

Acknowledgements: none

Conflicts of interest: none

References

1. Abhinav K, Shaaban M, Raymond T, Oke T, Gullan R, Montgomery AC. Primary reconstruction of pelvic floor defects following sacrectomy using Permacol graft. Eur J Surg Oncol. 2009;35(4):439-443.
2. Maricevich M, Maricevich R, Chim H, Moran SL, Rose PS, Mardini S. Reconstruction following partial and total sacrectomy defects: an analysis of outcomes and complications. J Plast Reconstr Aesthet Surg. 2014;67(9):1257-1266.
3. Doita M, Harada T, Iguchi T, Sumi M, Sha H, Yoshiya S, Kurosaka M. Total sacrectomy and reconstruction for sacral tumors. Spine (Phila Pa 1976). 2003;28(15):E296-301.
4. Gallia GL, Haque R, Garonzik I, Witham TF, Khavkin YA, Wolinsky JP, Suk I, Gokaslan ZL. Spinal pelvic reconstruction after total sacrectomy for en bloc resection of a giant sacral chordoma. Technical note. J Neurosurg Spine. 2005;3(6):501-506.
5. Wuisman P, Lieshout O, van Dijk M, van Diest P. Reconstruction after total en bloc sacrectomy for osteosarcoma using a custom-made prosthesis: a technical note. Spine (Phila Pa 1976). 2001;26(4):431-439.
6. Lim SH, Jo DJ, Kim SM, Lim YJ. Reconstructive surgery using dual U-shaped rod instrumentation after posterior en bloc sacral hemiresection for metastatic tumor: case report. J Neurosurg Spine. 2015:1-5.
7. Varga PP, Bors I, Lazary A. Sacral tumors and management. Orthop Clin North Am. 2009;40(1):105-123, vii.
8. Fourney DR, Rhines LD, Hentschel SJ, Skibber JM, Wolinsky JP, Weber KL, Suki D, Gallia GL, Garonzik I, Gokaslan ZL. En bloc resection of primary sacral tumors: classification of surgical approaches and outcome. J Neurosurg Spine. 2005;3(2):111-122.
9. Newman CB, Keshavarzi S, Aryan HE. En bloc sacrectomy and reconstruction: technique modification for pelvic fixation. Surg Neurol. 2009;72(6):752-756; discussion 756.
10. Cheng JS, Song JK. Anatomy of the sacrum. Neurosurg Focus. 2003;15(2):E3.
11. Cheng EY, Ozerdemoglu RA, Transfeldt EE, Thompson RC, Jr. Lumbosacral chordoma. Prognostic factors and treatment. Spine (Phila Pa 1976). 1999;24(16):1639-1645.

12. Fujimura Y, Maruiwa H, Takahata T, Toyama Y. Neurological evaluation after radical resection of sacral neoplasms. Paraplegia. 1994;32(6):396-406.

13. Hyun SJ, Lenke LG, Kim YC, Koester LA, Blanke KM. Comparison of standard 2-rod constructs to multiple-rod constructs for fixation across 3-column spinal osteotomies. Spine (Phila Pa 1976). 2014;39(22):1899-1904.

14. Sudo H, Ito M, Kaneda K, Shono Y, Abumi K. Long-term outcomes of anterior dual-rod instrumentation for thoracolumbar and lumbar curves in adolescent idiopathic scoliosis: a twelve to twenty-three-year follow-up study. J Bone Joint Surg Am. 2013;95(8):e49.

15. Mindea SA, Chinthakunta S, Moldavsky M, Gudipally M, Khalil S. Biomechanical comparison of spinopelvic reconstruction techniques in the setting of total sacrectomy. Spine (Phila Pa 1976). 2012;37(26):E1622-1627.

16. Breault SR, Heye T, Bashir MR, Dale BM, Merkle EM, Reiner CS, Faridi KF, Gupta RT. Quantitative dynamic contrast-enhanced MRI of pelvic and lumbar bone marrow: effect of age and marrow fat content on pharmacokinetic parameter values. AJR Am J Roentgenol. 2013;200(3):W297-303.

17. Glatt BS, Disa JJ, Mehrara BJ, Pusic AL, Boland P, Cordeiro PG. Reconstruction of extensive partial or total sacrectomy defects with a transabdominal vertical rectus abdominis myocutaneous flap. Ann Plast Surg. 2006;56(5):526-530; discussion 530-521.

18. Ruggieri P, Angelini A, Pala E, Mercuri M. Infections in surgery of primary tumors of the sacrum. Spine (Phila Pa 1976). 2012;37(5):420-428.

19. Dasenbrock HH, Clarke MJ, Bydon A, Witham TF, Sciubba DM, Simmons OP, Gokaslan ZL, Wolinsky JP. Reconstruction of extensive defects from posterior en bloc resection of sacral tumors with human acellular dermal matrix and gluteus maximus myocutaneous flaps. Neurosurgery. 2011;69(6):1240-1247.

20. Li R, Song Y, Ma M. Relationship between levator ani and bony pelvis morphology and clinical grade of prolapse in women. Clin Anat. 2015;28(6):813-819.

Figure captions

Figure 1. Anteroposterior plain radiograph (A) and sagittal CT image (B) showing an osteolytic lesion of the tumor at the sacrum.

Figure 2. Sagittal T1-weighted (A) and axial T1-weighted (B) MR images obtained after enhancement, revealing a heterogeneous enhancing lesion at the sacrum.

Figure 3. Postoperative surgical field photo (A) and lateral plain radiograph (B) showing successful reconstruction with a screw and dual-rod system. The remaining coccyx is observable along the black *dotted* line. Partial sacrectomy was achieved (C).

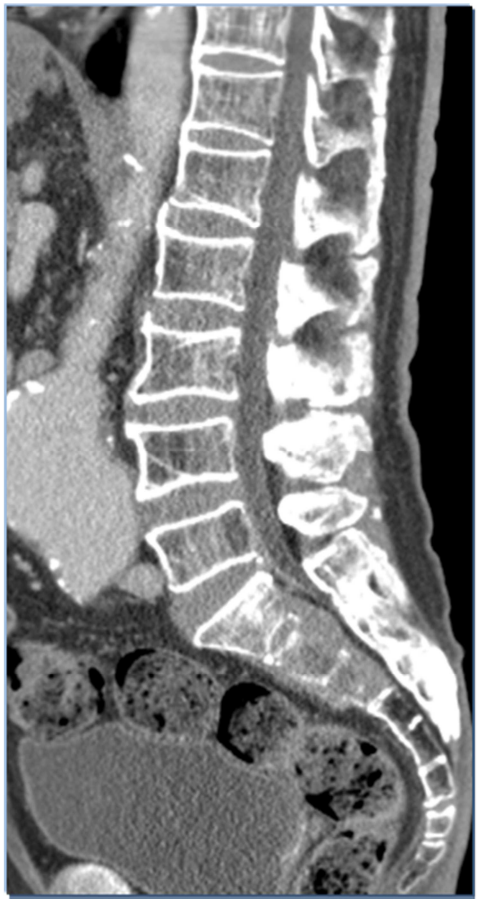
Figure 4. Anteroposterior plain radiograph (A) and sagittal CT image (B) showing an osteolytic lesion of the tumor at the sacrum.

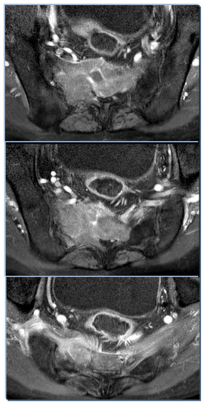
Figure 5. Sagittal T1-weighted (A) and axial T1-weighted (B) MR images obtained after enhancement, revealing a heterogeneous enhancing lesion at the sacrum.

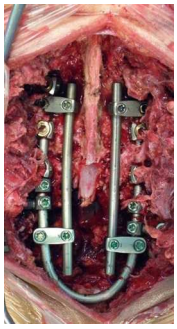
Figure 6. Postoperative surgical field photo (A) and lateral plain radiograph (B) showing successful reconstruction with a screw and dual-rod system. The remaining coccyx is observable along the black *dotted* line.

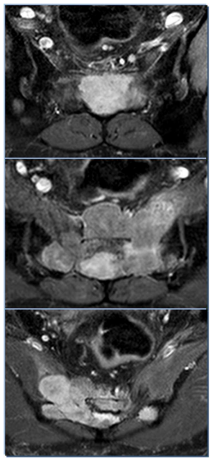
Figure 7. Flexion and extension images (A, B) revealing no motion of fused vertebrae. Bony bridging is observable along the black *dotted* line at axial CT images (C).

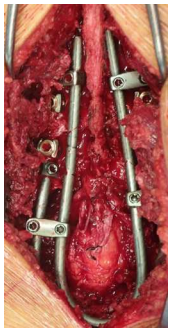
Figure 8. Pelvic reconstruction technique with diverse U-shaped rods: dual U-shaped (A), outer U-shaped (B), and inner U-shaped (C).

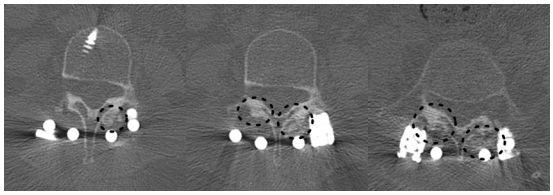


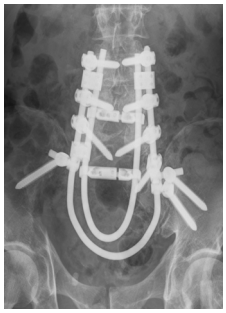


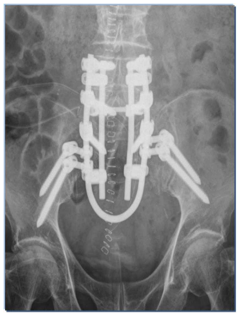












Highlights

1. Partial sacrectomy was performed in two cases and pelvic reconstruction was achieved with U-shaped rod.
2. The spinopelvic reconstruction was successfully performed and resulted in a good outcome.
3. The literature regarding this technique was reviewed.

1 Abbreviation list

2 CT: computed tomography

3 MRI: magnetic resonance imaging

4 USR: U-shaped rod