Curr Surg Rep (2022) 10:255–264
https://doi.org/10.1007/s40137-022-00331-y

Spine Reconstruction: From Basics to Cutting Edge

Ashleigh M. Francis[1] · Alexander F. Mericli[1]

Accepted: 14 October 2022 / Published online: 28 November 2022

Abstract

Purpose of Review Plastic surgery reconstruction involving the spinal region may be necessary to fill dead space, buttress a durotomy repair to help prevent or treat a cerebrospinal fluid (CSF) leak, resurface the skin, and/or transfer vascularized bone to augment stabilization after vertebrectomy or sacrectomy. Reconstruction can be employed in the prophylactic setting—in patients at high-risk for wound healing complications – or in the therapeutic setting, to treat wound healing complications after they have occurred. In general, the goals of soft tissue reconstruction include coverage of vitals structures and spinal hardware, obliteration of dead space, and a layered water-tight closure; goals of bony reconstruction include providing a stable vertebral construct by increasing the rapidity and durability of the osseous union.

Recent Findings Paraspinous muscle advancement flaps remain the workhorse for midline posterior trunks wounds. Multiple studies including a systematic review and meta-analysis have established that immediate spinal reconstruction decreases wound complications and increases hardware retention. This approach has been shown to be cost-effective and safe in those considered to be at high-risk for wound healing complications. Regarding osseous reconstruction, transferring vascularized bone is associated with a higher union rate and a shortened time to union in patients requiring vertebrectomy or sacrectomy for primary bony tumors.

Summary Plastic surgery reconstruction remains an important adjunctive maneuver to optimize healing in high-risk spinal surgery patients. A multidisciplinary approach between the spinal surgery team and plastic surgery team is key for surgical planning and patient optimization. It is important to consider the utility of prophylactic spinal reconstruction in patients who are deemed high-risk for wound healing complications (previous spine surgery, previous radiation, obese, diabetes, malnutrition) in order to prevent complications before they occur. Once a post-operative wound healing complication has occurred following spinal surgery, spinal reconstruction can also be pursued with the goal of protecting spinal hardware and preventing impending exposure.

Keywords Spine surgery · Posterior trunk reconstruction · Paraspinous muscles · Vascularized bone · Surgical flaps · Free flaps

Introduction

Plastic surgery reconstruction involving the spinal region may be necessary to fill dead space, reinforce a durotomy repair to help prevent or treat a cerebrospinal fluid (CSF) leak, resurface the skin, and/or transfer vascularized bone to augment stabilization after vertebrectomy or sacrectomy. The goals of a soft tissue spinal reconstruction are: coverage of vital structures and spinal hardware, obliteration of dead space, and a layered water-tight closure; in general, the goals of reconstruction with vascularized bone are an efficient and durable osseous union. Paraspinous

This article is part of the Topical Collection on *Plastic Surgery*.

✉ Alexander F. Mericli
AFMericli@mdanderson.org

Ashleigh M. Francis
afrancis@mdanderson.org

1 Department of Plastic Surgery, M.D. Anderson Cancer Center, The University of Texas, 1400 Pressler Street, Unit 1488, Houston, TX 77030, USA

muscle advancement flaps remain the workhorse for midline posterior trunk wounds, especially when reconstruction is employed in the prophylactic setting. The workhorse bone flap for augmenting the spinal construct is the free fibula flap; however, a number of pedicled options are available depending on the location of the defect, including vascularized rib, iliac crest, and outer-table calvarium. It is extremely important to consider prophylactic spinal reconstruction in high-risk cases, such as patients with a history of radiation, multiple previous spinal surgeries and oncologic cases involving large resections/instrumentations.

Anatomy and Physiology

Before proceeding with spinal reconstruction, it is essential to have a working knowledge of the cross-sectional musculoskeletal anatomy at the cervical, thoracic, and lumbosacral regions. The spinal cord travels through the vertebral foramen. The foramen can be divided into the anterior wall, which makes up the posterior aspect of the vertebral body; the posterior wall, which consists of the bilateral lamina and spinous process; and the side walls, which make up the bilateral pedicles. The cord ends at L1/L2 and the dural sac terminates at S3. The paired paraspinous muscles, sometimes referred to as the erector spinae, run alongside both sides of the spine. These muscles travel the entire length of the spine, from occiput to sacrum, and function to stabilize and extend the vertebrae. They are made up of three distinct muscle bellies—spinalis, longissimus, and iliocostalis. The trapezius muscle is the most superficial muscle in the midline posterior trunk; it spans from the occiput to the T12 spinous process and attaches to the bilateral scapular spines laterally. From T7 to T12, the trapezius overlaps with the latissimus dorsi muscle in the midline. The latissimus dorsi muscle transitions into the thoracolumbar fascia in the midline, which is most prominent in the lumbar region. In the region of the latissimus dorsi, the paraspinous muscles are immediately deep to the latissimus dorsi. However, in the T10-L1 location, the serratus posterior inferior muscle can be found between the paraspinous and latissimus dorsi muscles.

Etiology

Soft tissue reconstruction in the spinal region may be necessary in either the prophylactic (immediate) or therapeutic (delayed) settings. Until recently, plastic surgeons were not commonly consulted about spinal soft tissue reconstruction until after a wound healing complication had occurred. In recent years, several studies have been published by our group and others that clearly show clinical and economic advantages to prophylactic (immediate) spinal soft tissue reconstruction in patients deemed to be at high-risk for wound healing complications [1–7]. A systematic review and meta-analysis established a consensus that patients with the following history and comorbidities will likely benefit from an immediate soft tissue spinal reconstruction [5]:

- Obesity
- Prior Spine Surgery with Instrumentation
- Diabetes Mellitus
- Prior radiotherapy
- Concern for possible cerebrospinal fluid leak

Other features noted by some authors to benefit from immediate soft tissue spinal reconstruction included traumatic spinal injury, oncologic spinal surgery, malnutrition, chronic steroid use, tobacco use, and a lumbosacral location.

Large tumor resections may involve anterior and posterior spinal approaches. These complex oncologic surgeries are often associated with extensive instrumentation, which requires wide undermining and subperiosteal stripping; this creates significant dead space which can impede wound healing. With the changing and advancing field of oncologic spinal surgery, immediate spinal soft tissue and bony reconstruction has emerged as an important adjunctive tool to ensure the long-term success of these complex surgeries.

Reconstruction after spinal surgery can either involve soft tissue or bony reconstruction, with the former being much more common. This is largely because non-vascularized particulate bone grafting remains the mainstay of bony fusion in spine surgery along with rigid fixation. However, with segmental osseous defects of the spine that are larger than 4 cm, the rate of failed fusion can be as high as 50% [8]. In these long spanning defects of greater than 4 cm and in cases of anticipated radiation therapy, vascularized bone flaps should be considered as an adjunct to rigid fixation and particulate bone grafting [9–14]. Vascularized bone has also demonstrated success in spinal surgery patients that have failed to fuse after conventional particulate bone grafting [11].

In the therapeutic setting, soft tissue reconstruction of the posterior trunk is required after a wound healing complication (infection, hematoma, seroma, dehiscence or hardware exposure) has already occurred following spinal surgery, putting the spinal hardware and or vital neurologic structures at risk for exposure. Infections following spinal surgery are considered "early" when they occur less than 6 weeks from the index procedure. These are best treated with aggressive antibiotic therapy, surgical debridement and muscle flap reconstruction with a primary goal of maintaining the spinal instrumentation and avoiding exposure. Chronic hardware infections, which are always deep space infections, occur at least 6 months after hardware placement and can be difficult to eradicate completely. An MRI is often obtained to rule out vertebral osteomyelitis. While debridement and flap surgery remain the workhorse for treatment, it is important to keep in mind that ultimately the patient may require hardware removal and replacement for definitive treatment.

Reconstructive Algorithm

Midline Posterior Trunk Defects

A systematic approach is required when treating wound healing complications after spinal instrumentation. Moreover, these should be handled aggressively and with great care, because deep space infections, skin edge separations, seromas, and hematomas can easily lead to hardware exposure or loss—which can ultimately lead to far worse complications such as ascending meningitis, paralysis, or death. These cases require a multidisciplinary approach with close communication between the plastic surgeon and the spine surgeon. Important discussion points include: (1) Profile of the hardware, (2) Durotomy at the time of surgery suggesting possible CSF leak, (3) Anterior vs posterior vs combined approach, (4) Previous spinal surgeries, 5) Need for imaging to rule out undrained fluid collections. The patient's wound healing physiology should also be optimized by initiating a high protein diet and taking precautionary measures when available such as: 1) Vitamin A supplementation if the patient is receiving steroids, 2) Pressure offloading with a low-pressure mattress if the patient is immobile or paralyzed, and 3) Amelioration of involuntary muscle spasms and joint contractures in paralyzed patients, as these can cause excessive wound tension.

In the operating room, the first critical step for management of the postsurgical back wound is a thorough debridement. The incision should be reopened in its entirety and all spinal hardware exposed. It is important for the plastic surgeon to have details regarding the initial spinal surgery such as if a laminectomy or partial/total vertebrectomy has been performed; in these instances, the spinal cord and dura are exposed and vulnerable to injury during debridement. Any soft tissue deemed to have poor vascularity or be nonviable should be removed as well as unincorporated bone graft. Additionally, any purulent fluid or collections seen on imaging should be drained. Lastly, the wound should be copiously irrigated with saline solution containing antibiotic. As with any wound, it is important to determine if the wound can be adequately debrided with a single procedure or will require multiple debridements prior to definitive closure. In general, if the wound has frank purulence or has not yet demarcated, then a sequential debridement approach is strongly recommended. Multiple drains should be placed making sure to include the deep space, and the paraspinous muscles should be loosely approximated over the vertebra and hardware. However, if a dural repair has been performed or if a CSF leak is present, consultation with the spine surgeon is imperative before placing a drain in the epidural, submuscular space. In most cases, the skin should be left open, the adjacent muscles loosely approximated over the vertebra and hardware; if there is low risk for a CSF leak, then a negative pressure wound dressing can be used for temporary closure in between debridements. A negative pressure wound dressing should never be placed directly over the spinal cord or spinal nerve roots. Once the wound is ready for definitive closure, then it should be closed over multiple drains, with the addition of a well-vascularized muscle flap for dead space obliteration, protection of the cord and hardware.

In contradistinction from how most extremity wounds are treated with exposed or infected hardware, spinal hardware is not commonly removed during debridement [15]. Spinal instrumentation protects the spinal cord, maintains spinal stability, and helps to stabilize the wound. Indeed, stable hardware has been shown to promote healing by eliminating micromotion and shearing of the fragile, traumatized soft tissues [16]. A few caveats to this rule exist: if the hardware is loose, broken, or bathed in purulent fluid it should be removed and replaced with new hardware during the same surgical episode.

Paraspinous Muscle Flaps

The paraspinous muscle flap is the workhorse flap for reconstruction of midline posterior trunk defects. The paraspinous muscles, as their name suggests, are paired muscles that parallel the spine from the occiput and mastoid process down to the lumbosacral recess. Each side of paraspinous muscles consist of three separate muscles: spinalis, longissimus, and iliocostalis. It can be difficult to distinguish between the separate muscles, as the muscle bellies tend to be indistinct, interdigitating, and appear as a single muscle on either side of the spine. The paraspinous muscles are Mathes and Nahai type 4 flaps, perfused through a medial and lateral row of segmental perforating vessels from the lumbar, intercostal, or vertebral vessels, depending on the level. For paraspinous muscle advancement, dissection is performed in the plane just superficial to the paraspinous muscles until their lateral border is reached. The fascia overlying the muscles' lateral border is divided, allowing for medial advancement. The muscles are imbricated into the midline defect with a Lembert suture, which allows the medial third of the flap to be advanced and be secured into the dead space (Fig. 1). A summary of other common flaps for midline posterior trunk reconstruction can be found in Table 1.

Reconstructive Approach by Location

Cervical Region

The most common indications for cervical spine instrumentation include cervical spinal stenosis and degenerative disk disease. In these cases, an anterior approach is often employed, and these wounds rarely develop complications. The posterior approach to the cervical spine is more prone to wound healing complications or infection. Bilateral paraspinous muscle flaps remain the workhorse for posterior cervical wound reconstruction, despite their thinner caliber in the cervical region [17••]. Trapezius muscle flaps are another excellent option, although they are prone to seroma formation [18]. When there is a cutaneous defect, the trapezius muscle flap can be designed with a skin paddle. Lastly, fasciocutaneous perforator flaps are an alternative option for midline posterior cervical spine defects requiring cutaneous reconstruction [19].

Thoracic Region

Multiple reconstructive options exist for midline posterior thoracic wounds after spine surgery. Bilateral paraspinous muscle advancement flaps remain the first-line option. However, there are times when the paraspinous muscles may be unavailable or inadequate for the obliteration of dead space and hardware protection. These situations often arise when the paraspinous muscles are resected secondary to spinal malignancy and in patients who have had multiple previous surgeries or have undergone radiation therapy, which can lead to scarring and fibrotic, immobile musculature. In these instances, the latissimus dorsi muscle is a good alternative option and can be used an advancement flap. If the defect is more inferior or much larger, then a better option is a reverse latissimus dorsi flap, based on the thoracic and lumbar perforating vessels [20]. An omental flap is another good option for larger defects with significant dead space along the thoracic spine and can be tunneled through the retroperitoneum [21]. If a cutaneous defect exists, a skin paddle can be harvested with either of the latissimus dorsi flaps. Other options include skin grafting overtop of the pedicled muscle or omental flap. For superficial cutaneous flaps, keystone flaps can be a good option but are limited in terms of their mobility and generally require a large flap design to achieve appropriate degree of advancement.

Locally advanced lung cancers and some primary bone tumors of the thoracic vertebrae may necessitate a composite resection of the chest wall and thoracic spine. In instances where a partial or total vertebrectomy has been performed and the pleural space has been entered, then the spinal cord and chest cavity are now in continuity. The goal of reconstruction is to restore the natural anatomic separation of the chest cavity from the spinal cord and vertebral hardware; this is best achieved by the interposition of vascularized soft tissue such as a latissimus or trapezius muscle flap [22]. The other principles of chest wall and thoracic reconstruction still apply. Paraspinous muscle flaps are imbricated to protect the thoracic spinal cord and hardware. Skeletal chest wall reconstruction is performed in the standard fashion to restore chest wall contour and prevent paradoxical respiration.

Lumbar and Lumbosacral Region

In the lumbar region, the paraspinous muscles reach their peak size and mobility, again establishing them as the first-line for reconstruction. Another option in the lumbar region is the reverse latissimus dorsi muscle or myocutaneous flap. If additional dead space obliteration is required, a superior gluteal artery or lumbar artery perforator propeller flap can be de-epithelialized and dropped into the defect [23]. Given the more dependent location and lordotic spinal curvature, lumbar region reconstructions are associated with a higher rate of minor wound healing complications (seroma, skin edge separation, etc.) [16]. Closed suction drains should be placed liberally to mitigate seroma formation.

Reconstructions of the sacral and lumbosacral spine are oftentimes associated with a partial or total sacrectomy defect. The goal of reconstruction for these defects is to obliterate dead space to prevent seroma and abscess formation as well as perineal hernia [10]. There is some debate over whether to place a bridging bioprosthetic mesh in the sacral defect to minimize perineal bulge, as this practice has been associated with a higher complication rate [24]. Partial sacrectomies that are inferior to the sacroiliac joint (S3 level and below) can be performed from a prone approach. These defects are often reconstructed with either a V–Y or rotational fasciocutaneous advancement flap. In defects with a larger cutaneous requirement or less adjacent skin laxity, the superior gluteal artery or lumbar artery perforator flap are other reliable options and can be advanced or propellered up to 180 degrees to cover the defect (Figs. 2 and 3) [25–27]. Sacrectomies that includes the sacroiliac joint and/or the S1 or S2 level are much more complex as these resections require a dual

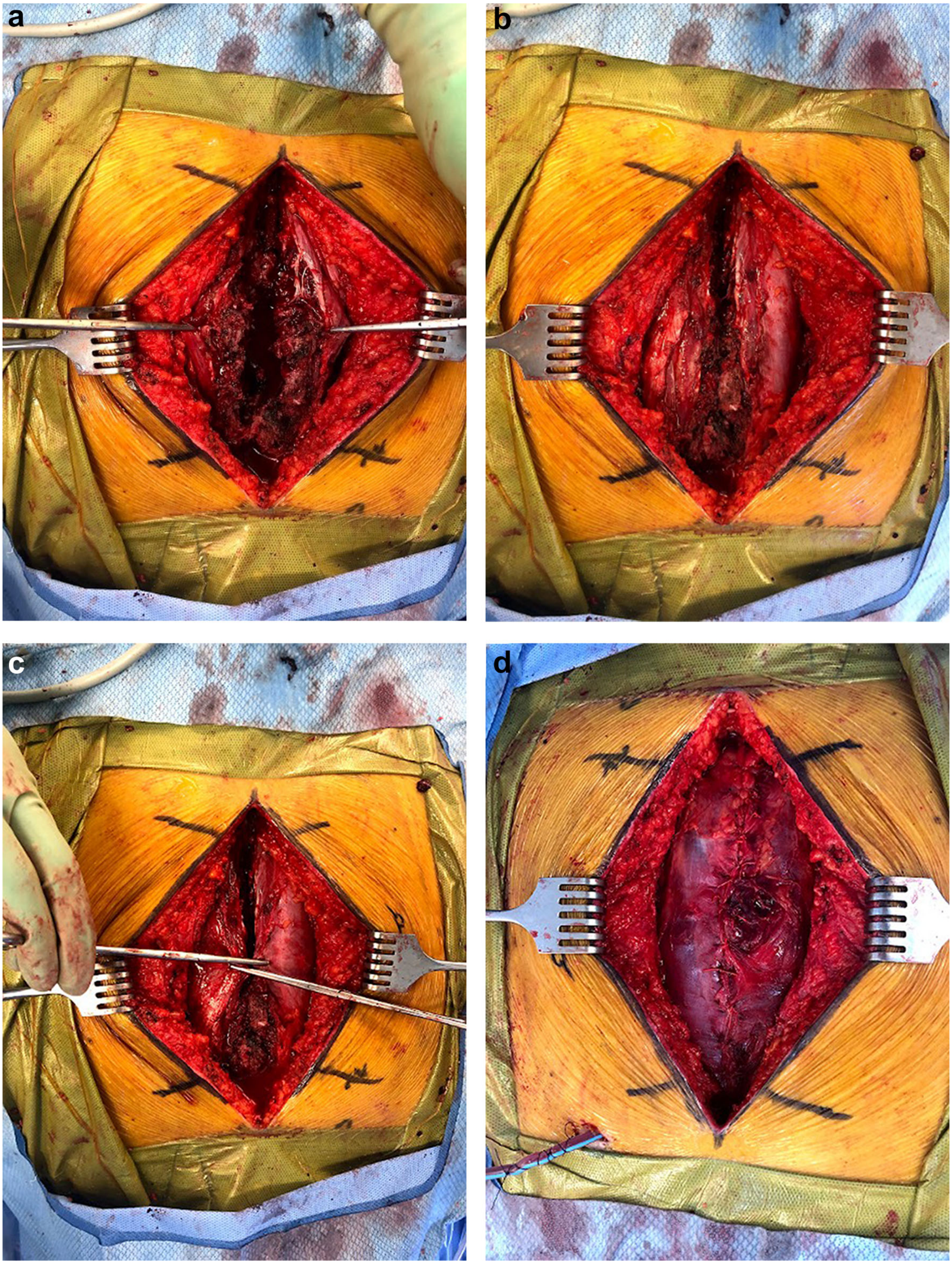

Fig. 1 Bilateral paraspinous muscle advancement flaps for prophylactic reconstruction of a lumbar spine wound. **A** Spinal defect after oncologic resection and posterior instrumentation. **B** Release of subcutaneous tissue superficial to the paraspinous muscle fascia. **C** Release of the paraspinous muscle fascia, permitting medial advancement. **D** closure and imbrication of the bilateral advancement flaps

Table 1 Common flaps for midline posterior trunk reconstruction

Flap	Type	Approximate size (cm)
Pectoralis major	Muscle or myocutaneous	15 × 23
Latissimus dorsi	Muscle or myocutaneous	25 × 35
Serratus anterior	Muscle	15 × 20
Omentum	Visceral adipose	Variable
Rectus abdominis	Muscle or myocutaneous	25 × 6
External oblique	Myocutaneous	15 × 30
Intercostal artery perforator flap	Fasciocutaneous	5 × 15
Thoracodorsal artery perforator flap	Fasciocutaneous	8 × 35

approach (supine and prone). Subtotal sacrectomies that maintain the pelvic ring may be reconstructed with iliolumbar spinal instrumentation but may not require vascularized bone. In general, a subtotal sacrectomy requires soft tissue reconstruction in order to optimize healing and prevent perineal hernia formation [28]. Abdominal flaps based on the deep inferior epigastric vessels, such as a vertical rectus abdominus musculocutaneous (VRAM) flap, are considered the primary option because: 1) a laparotomy is already being performed, 2) the flap is bulky and can obliterate dead space, and 3) has the ability to resurface the sacrum with a skin paddle. While rare, the lumbosacrum is the posterior trunk region most likely to require a free flap; these reconstructions are more likely to require vein

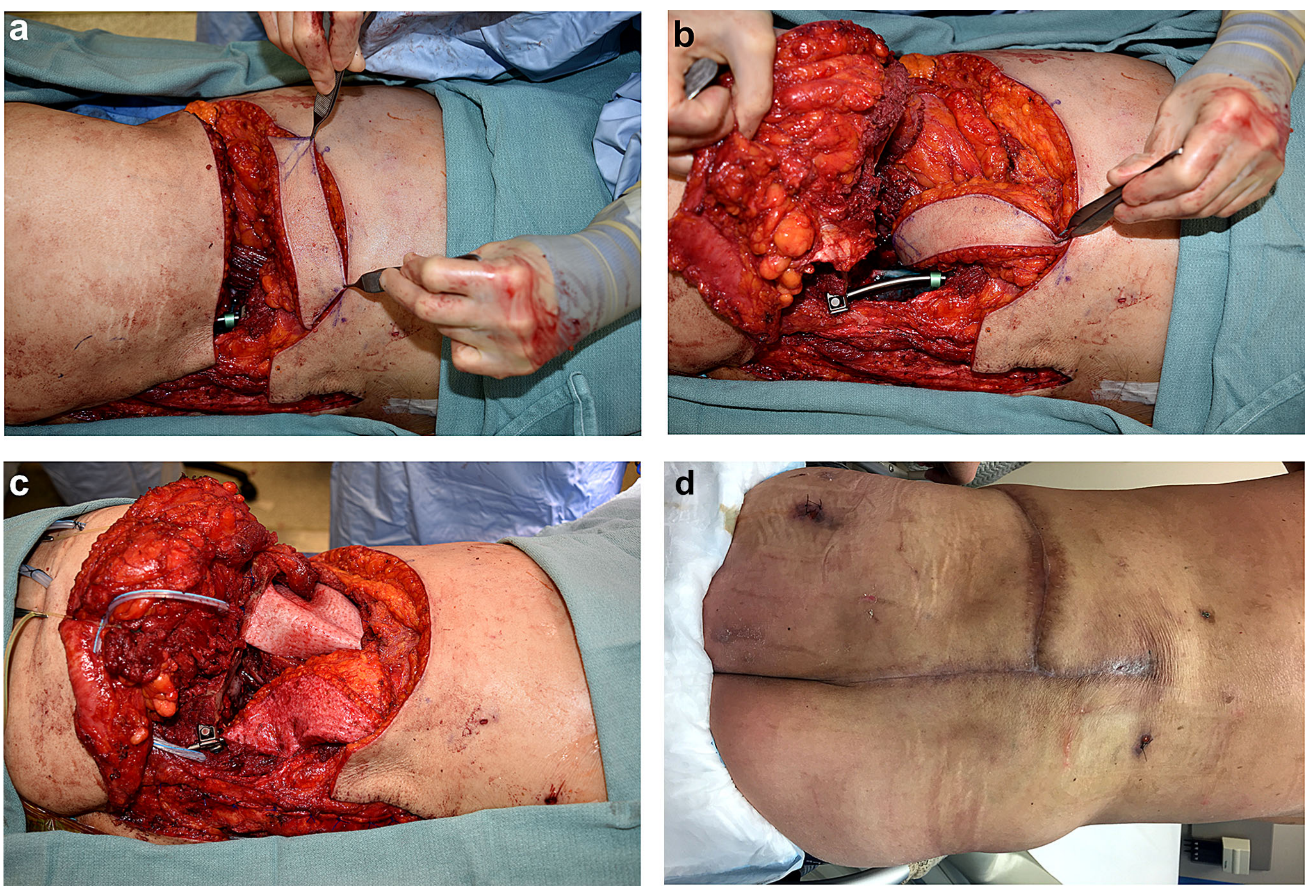

Fig. 2 Lumbar artery perforator flap for deadspace obliteration and hardware coverage. The paraspinous muscles were involved in the sarcoma and had to be resected and the defect was too inferior to be reconstructed with a reverse latissimus dorsi muscle flap yet too superior for an SGAP flap to reach. **a** Flap design with initial incisions made. **b** Flap rotated 90 degrees to fill deadspace and protect the hardware. **c** Flap inset after de-epithelialization. **d** Healed wound 2 months postop

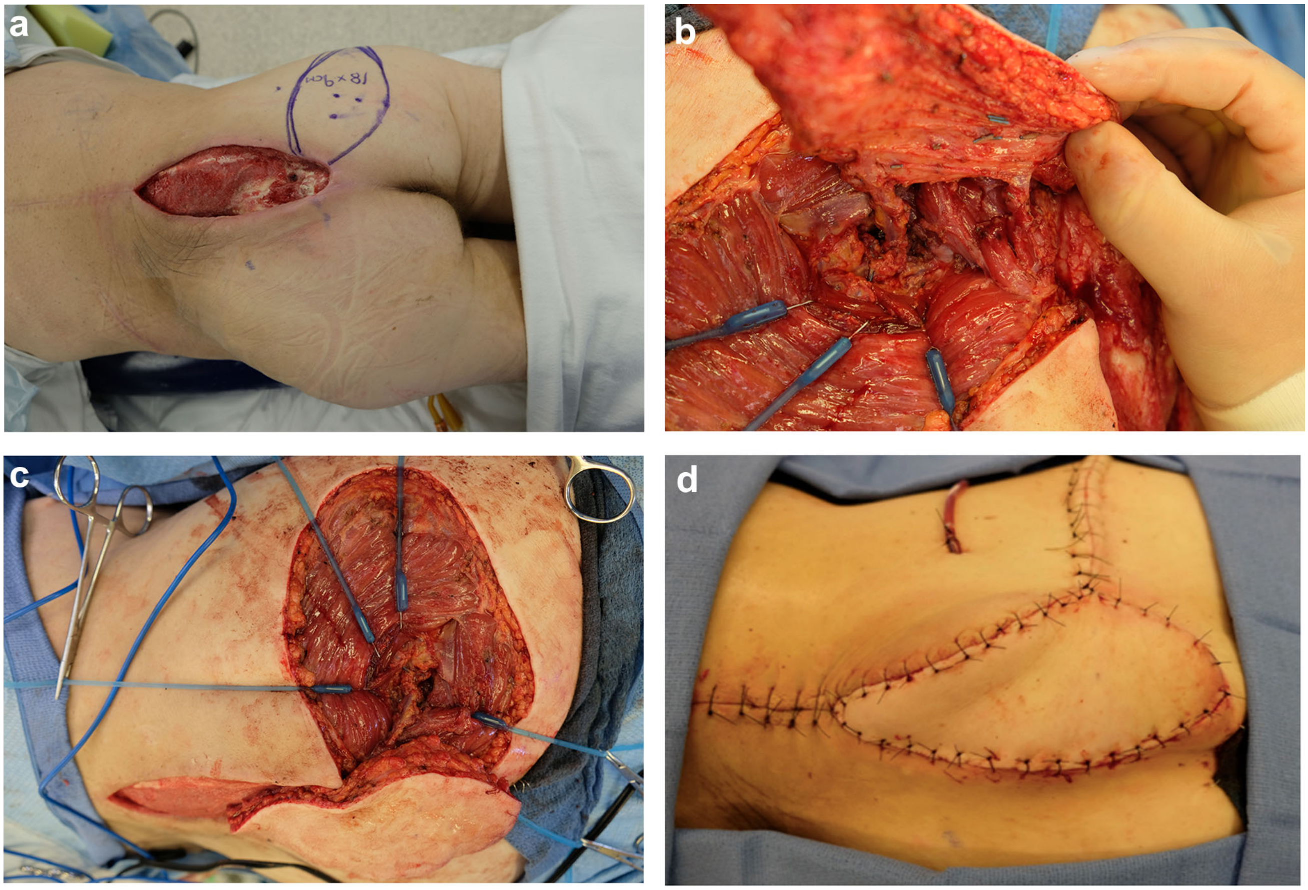

Fig. 3 Superior gluteal artery perforator flap for lumbar reconstruction. **a** Lumbar defect with perforator signals and flap design marked. **b** Perforator identification. **c** Deep pedicle dissection. **d** Final closure

grafting and thus are prone to higher complication rates [29].

A total sacrectomy is highly destabilizing as a result of the discontinuity created along of the pelvic ring and spinopelvic junction; this represents one of the most challenging spinal defects to reconstruct. These resections require reconstruction with vascularized bone and soft tissue in order to optimize the patient's short-term healing and long-term function. Sacrifice of the bilateral sacroiliac joints causes substantial biomechanical instability; an iliolumbar instrumentation-only reconstruction, without bone flaps or strut graft, is associated with hardware failure rates ranging from 25 to 70% [30–33]. In a recent study, compared to vascularized bone flap reconstruction, total sacrectomy with non-vascularized fibular allograft struts was associated with a nearly 8 × greater odds of nonunion as well as longer mean time to union (12 months vs. 8 months; $p = 0.001$) [34]. Considering these substantial challenges, most high-volume sacrectomy centers recommend using vascularized free fibular flaps as a means to supplement the anterior column component of the sacrectomy defect [10, 30, 31, 34]. This is usually combined with a pedicled VRAM flap or some other method of soft tissue reconstruction for filling the profound deadspace and mitigating perineal hernia risk. The free fibula flap is the flap of choice because of the length of bone provided (up to 26 cm), its ability to tolerate osteotomies, and the ability to orient it as double-barrel or A-frame strut to meet the biomechanical demands and the dimensions of the defect (Fig. 4). The external and internal iliac vessels provide a multitude of recipient vessel options for the flap; however, vein grafts are still commonly necessary to achieve adequate pedicle length and accessibility. Free fibula flaps will usually demonstrate radiographic signs of ossification at 3–8 months whereas fibula bone grafts may require 12 months or more for bony union.

Outcomes, Complications, and Management

Cerebrospinal Fluid Leak

One should consider the potential for a CSF leak after persistent serous drain output. Additionally, subjective

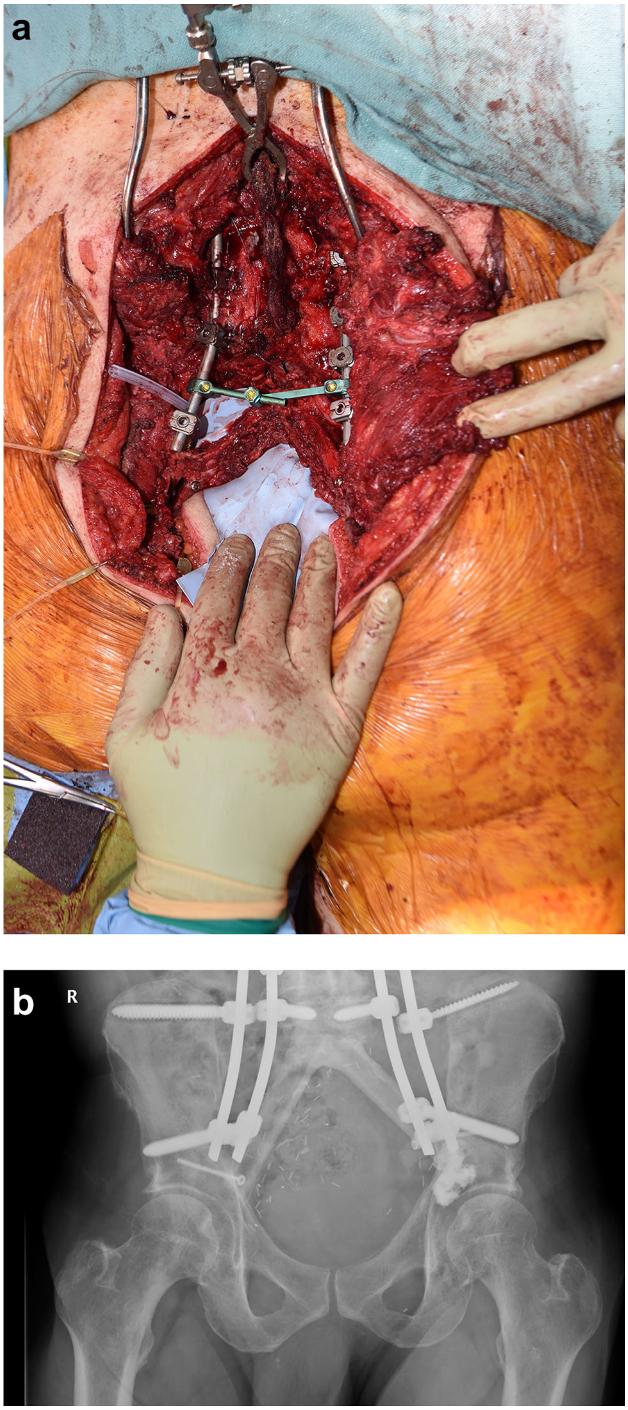

Fig. 4 Free fibula flap inset as a double-barrel A-frame strut to reconstruct the anterior column component of the total sacrectomy defect. **a** In-situ photograph. **b** Radiograph of the fused fibula 12 months after reconstruction

complaints from the patient regarding postural headache can also point to the diagnosis of a CSF leak. To confirm this clinical suspicion, the drain fluid is tested for beta-transferrin—its presence is pathognomonic for a CSF leak. Most CSF leaks are treated conservatively with positioning restrictions (supine or prone positioning) and the avoidance of straining. If the leak persists, a lumbar drain or external ventricular drain can be placed to offload pressure on the leak site to promote healing. Rarely, a chronic occult CSF leak can lead to a pseudomeningocele. This often requires operative repair in which the dura is either repaired primarily or with a patch; the repair site can be further buttressed with a muscle flap to help seal the leak.

Hematoma

Spinal surgeries tend to incur a large amount of blood loss, especially when bony work and instrumentation are required. In spinal reconstruction, drains are of upmost importance to evacuate blood and mitigate the effects of pressure accumulation against the spinal cord in the setting of hematoma formation. Drains should be placed deep to the muscle flaps in the epidural space as well as in the superficial space, between the skin and fascia. Epidural drains are of critical importance when laminectomies or vertebrectomies have been performed as they help to drain away the excess serosanguinous fluid and blood that can cause cord compression if allowed to accumulate. The clinician should be wary of a hematoma in the epidural space; these require emergent evacuation in the operating room to prevent injury to the spinal cord. Generally, superficial hematomas can be managed expectantly, except in cases of impending skin compromise which warrant drainage.

Hardware Exposure

Hardware exposure is classified into two categories: 1) Acute – occurring within 6 months of placement, and 2) Chronic – occurring more than 6 months after hardware placement. In general, an acute exposure is treated with aggressive debridement, irrigation, muscle flap closure, and culture-directed antibiotics. A chronic exposure can be more challenging to treat and oftentimes requires removal of hardware due to the presence of bacterial biofilm. In these cases, all loosened hardware bathed in purulent fluid should be removed and replaced, while hardware encased in bone can stay in place. A muscle flap should be performed to bring in vascularized soft tissue into the wound bed and promote healing; numerous drains should be left in place.

Conclusion

The majority of cases requiring spinal reconstruction are related to spinal surgery and involve soft tissue reconstruction rather than bony reconstruction. A multidisciplinary approach between the spinal surgery and plastic surgery teams is key for surgical planning and patient optimization. A thorough understanding of the cross-section musculoskeletal anatomy of the posterior trunk is important prior to undertaking spinal reconstruction. The paraspinous muscle advancement flap remains the workhorse for most posterior trunk reconstructions. It is important to consider the utility of prophylactic spinal reconstruction in patients who are deemed high-risk for wound healing complications (previous spine surgery, previous radiation, obesity, diabetes, malnutrition) in order to prevent complications before they occur. Once a postoperative wound healing complication has occurred following spinal surgery, spinal reconstruction can also be pursued with the goal of protecting spinal hardware and preventing impending exposure.

Declarations

Conflict of interest Neither Dr. Mericli nor Dr. Francis have any relevant conflicts of interest in regard to the content of this review article.

Human and animal rights informed consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:
- • Of importance
- •• Of major importance

1. Chang DW, Friel MT, Youssef AA. Reconstructive strategies in soft tissue reconstruction after resection of spinal neoplasms. Spine. 2007;32(10):1101–6.
2. Devulapalli C, et al. Soft-tissue reconstruction of large spinal defects: a 12-year institutional experience. Plast Reconstr Surg. 2017;140(4):806–14.
3. Dumanian GA, et al. Muscle flap salvage of spine wounds with soft tissue defects or infection. Spine. 2003;28(11):1203–11.
4. • Garvey PB, et al. Immediate soft-tissue reconstruction for complex defects of the spine following surgery for spinal neoplasms. Plast Reconstr Surg. 2010;125(5):1460–6. *This article was one of the first to demonstrate an advantage to prophylactic muscle flap reconstruction of complex spinal wounds.*
5. Mericli AF, et al. Immediate reconstruction of complex spinal wounds is associated with increased hardware retention and fewer wound-related complications: a systematic review and meta-analysis. Plastic and Reconstructive Surgery-Global Open. 2019. https://doi.org/10.1097/GOX.0000000000002076.
6. •• Mericli AF, et al. Immediate reconstruction of oncologic spinal wounds is cost-effective compared with conventional primary wound closure. Plast Reconstr Surg. 2019;144(5):1182–95. *This article was the first to identify a cost savings associated with reconstructing high risk spinal wounds. This article established that not only was a preventative approach clinical effective, but it was also cost effective from a third-party payor perspective.*
7. Sawh-Martinez R, et al. Immediate plastic surgery closure at index spinal surgery minimizes complications compared to delayed reconstruction: A retrospective cohort review. J Plast Reconstr Aesthet Surg. 2020;73(8):1499–505.
8. •• Saraph VJ, et al. Evaluation of spinal fusion using autologous anterior strut grafts and posterior instrumentation for thoracic/thoracolumbar kyphosis. Spine. 2005;30(14):1594–601. *This article identified that there is a significantly higher complication rate associated with nonvascularized bone grafts placed in the spine longer than 4 cm in length.*
9. Clemens MW, et al. Composite extremity and trunk reconstruction with vascularized fibula flap in postoncologic bone defects: a 10-year experience. Plast Reconstr Surg. 2012;129(1):170–8.
10. Houdek MT, et al. Outcomes and complications of reconstruction with use of free vascularized fibular graft for spinal and pelvic defects following resection of a malignant tumor. Journal of Bone and Joint Surgery-American. 2017. https://doi.org/10.2106/JBJS.16.01458.
11. Moran SL, et al. The use of vascularized fibular grafts for the reconstruction of spinal and sacral defects. Microsurgery. 2009;29(5):393–400.
12. Bradford DS, Daher YH. Vascularized Rib grafts for stabilization of kyphosis. Journal of Bone and Joint Surgery-British. 1986;68(3):357–61.
13. Bradford DS, et al. Anterior strut-grafting for the treatment of kyphosis - review of experience with 48 patients. Journal of Bone and Joint Surgery-American. 1982;64(5):680–90.
14. Lonstein JE, Winter RB. Long multiple struts for severe kyphosis. Clin Orthop Relat Res. 2002;394:130–8.
15. Mericli AF, et al. Paraspinous muscle flap reconstruction of complex midline back wounds risk factors and postreconstruction complications. Ann Plast Surg. 2010;65(2):219–24.
16. Mericli AF, et al. Technical changes in paraspinous muscle flap surgery have increased salvage rates of infected spinal wounds. Eplasty. 2008;8: e50.
17. •• Mericli AF, et al. Reconstruction of complex posterior cervical spine wounds using the paraspinous muscle flap. Plast Reconstr Surg. 2011;128(1):148–53. *This article established that paraspinous muscle flaps could be effectively utilized for posterior cervical spine wound reconstruction. Prior to this article, the trapezius flap was considered standard of care; the trapezius flap is notorious for a higher seroma rate.*
18. Disa JJ, Smith AW, Bilsky MH. Management of radiated reoperative wounds of the cervicothoracic spine: The role of the trapezius turnover flap. Ann Plast Surg. 2001;47(4):394–7.
19. Sadigh PL, et al. The trapezius perforator flap: an underused but versatile option in the reconstruction of local and distant soft-tissue defects. Plast Reconstr Surg. 2014;134(3):449e–56e.
20. Mcgeorge DD, Stilwell JH. The use of the reverse latissimus dorsi flap in the closure of lower spinal defects. Zeitschrift Fur Kinderchirurgie-Surgery in Infancy and Childhood. 1988;43:30–2.
21. O'Shaughnessy BA, et al. Pedicled omental flaps as an adjunct in the closure of complex spinal wounds. Spine. 2007;32(26):3074–80.
22. Coon D, et al. Use of biological tissue matrix in postneurosurgical posterior trunk reconstruction is associated with higher wound complication rates. Plast Reconstr Surg. 2016;138(1):104e–10e.
23. Moon SH, et al. Feasibility of a deepithelialized superior gluteal artery perforator propeller flap for various lumbosacral defects. Ann Plast Surg. 2015;74(5):589–93.
24. Atkin G, Mathur P, Harrison R. Mesh repair of sacral hernia following sacrectomy. J R Soc Med. 2003;96(1):28–30.

25. Hernekamp JF, et al. Perforator-based flaps for defect reconstruction of the posterior trunk. Ann Plast Surg. 2021;86(1):72–7.
26. Pietro, GDIS., et al., *Reconstruction of Spinal Soft Tissue Defects With Perforator Flaps From the Paraspinal Region.* In Vivo, 2019. **33**(3): p. 827–832.
27. Falinower, H., et al., *Use of the Propeller Lumbar Perforator Flap: A Series of 32 Cases.* Plastic and Reconstructive Surgery-Global Open, 2020. **8**(1).
28. Asaad M, et al. Flap reconstruction for sacrectomy defects: A systematic review and meta-analysis. J Plast Reconstr Aesthet Surg. 2020;73(2):255–68.
29. •• Akdeniz-Dogan Z, et al. Free flap reconstruction of posterior trunk soft-tissue defects: single-institution experience and systematic literature review. Plast Reconstr Surg. 2021;147(3):728–40. *This is the largest series to date detailing free flap reconstruction of large posterior trunk wounds. The article includes a systematic literature review and meta-analysis as well as a single institution experience. It offers technical suggestions for the use vein grafts and also provides important information for postoperative care.*
30. • Mericli AF, et al. Free fibula flap for restoration of spinal stability after oncologic vertebrectomy is predictive of bony union. Plast Reconstr Surg. 2020;145(1):219–29. *This article establishes that the free fibula flap is superior to bone allograft for vertebrectomy defect reconstruction.*
31. •• Mericli AF, et al. Restoration of spinopelvic continuity with the free fibula flap after limb-sparing oncologic resection is associated with a high union rate and superior functional outcomes. Plast Reconstr Surg. 2020;146(3):650–62. *This article establishes that the free fibula flap is safe and effective for function reconstruction of hemipelvectomy and sacrectomy wounds.*
32. Randall RL, et al. Sacral resection and reconstruction for tumors and tumor-like conditions. Orthopedics. 2005;28(3):307–13.
33. Tang XD, et al. Factors Associated With Spinopelvic Fixation Mechanical Failure After Total Sacrectomy. Spine. 2018;43(18):1268–74.
34. Wellings EP, et al. Comparison of free vascularized fibular flaps and allograft fibular strut grafts to supplement spinopelvic reconstruction for sacral malianancies. Bone & Joint Journal. 2021;103-B(8):1414–20.