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Technical Report

Outrigger rod technique for supplemental support of posterior spinal arthrodesis

Mark A. Palumbo, MD[a], Kalpit N. Shah, MD[a], Craig P. Eberson, MD[a], Robert A. Hart, MD[b], Alan H. Daniels, MD[a,*]

[a]*Department of Orthopedic Surgery, Alpert Medical School of Brown University, 2 Dudley St, Providence, RI 02905, USA*
[b]*593 Eddy St, Providence, RI 02903, USA*

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Abstract

BACKGROUND CONTEXT: Instrumentation failure is a recognized complication after complex spinal reconstruction and deformity correction. Rod fracture (RF) is the most frequent mode of hardware failure in long-segment spinal fusion surgery. This complication can negatively impact the clinical outcome by producing spinal pain, functional compromise, instability, and loss of deformity correction.

PURPOSE: To describe the outrigger rod surgical technique.

STUDY DESIGN: Review of literature, case review, and surgical technique description.

PATIENT SAMPLE: Two clinical cases are presented.

OUTCOME MEASURES: Rod fracture.

METHODS: Outrigger rod placement in posterior spinal arthrodesis is performed by supplementing primary spinal rods with outrigger rods attached with cranial and caudal side-by-side connectors providing a more robust construct.

RESULTS: This technique may be beneficial for preventing RF in patients undergoing surgery for three-column osteotomy for sagittal imbalance; pseudarthrosis surgery with previous hardware failure; transforaminal lumbar interbody cage placement at multiple levels in realignment procedures, long-segment spinal arthrodesis with impaired host fusion potential; long-segment instrumented fusions that span the cervicothoracic, thoracolumbar, or lumbosacral junction; and across spinal segments at high risk for RF (eg, after extensive resection of vertebral elements in the management of metastatic malignancy).

CONCLUSIONS: The risk of rod failure is substantial in the setting of long-segment spinal arthrodesis and corrective osteotomy. Efforts to increase the mechanical strength of posterior constructs may reduce the occurrence of this complication. The outrigger rod technique increases spinal construct stiffness and may improve the longevity of the construct. This technique should reduce the rate of device failure during maturation of posterior fusion mass and limit the need for supplemental anterior column support.

Keywords: Rod fracture (RF); Instrumentation failure; Spinal deformity; Long-segment fusion; Ourigger rod; Revision surgery

FDA device/drug status: Approved (Pedicle Screws).

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* Corresponding author. Department of Orthopedic Surgery, Alpert Medical School of Brown University, 2 Dudley St, Providence, RI 02905, USA. Tel.: 401-457-2101; fax: 401-457-2141.

E-mail address: alandanielsmd@gmail.com (A.H. Daniels)

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Introduction

Advances in spinal instrumentation have allowed spine surgeons to successfully address spinal pathology and deformities of increasing complexity [1–6]. However, there are high complication rates associated with major spinal reconstruction, including neurologic injury, infection, pseudarthrosis, junctional kyphosis, and instrumentation failure [1,7–14]. Fixation device failure is an important and a potentially preventable complication given that the mode of failure is typically fatigue over time as opposed to a single overloading event [15].

Rod fracture (RF) is the most common mode of device failure after complex spinal reconstruction (Fig. 1). Longitudinal rods must maintain structural integrity as the biologic fusion process progresses to a solid osseous union. Fracture of a rod typically occurs as a result of delayed union or pseudarthrosis subsequent to long-segment spinal arthrodesis and/or three-column osteotomy. Although a much less common scenario, device fatigue failure may occur in the setting of a solid fusion mass.

A prospective study by Smith et al. [16] examining 287 spinal deformity patients revealed an RF rate of 9% for adult deformity patients and 22% for patients after pedicle subtraction osteotomy (PSO) at minimum 1-year follow-up. Factors significantly associated with RF in this study were advanced age, elevated body mass index, more severe sagittal imbalance, performance of a spinal osteotomy, and large surgical correction of sagittal parameters. Theoretically, the failure rates documented by Smith et al. [16] would be expected to rise with a long-term follow-up.

Rod contour is another variable that can increase the risk of device failure. Biomechanical studies have demonstrated that rod contouring at an osteotomy site may produce metal fatigue, thereby increasing the potential for device failure [17,18]. Factors such as advanced age, smoking, poor nutrition, prior radiation, nonsteroidal antiinflammatory drugs, and disease-modifying antirheumatic drugs can also increase the risk of instrumentation failure by delaying or inhibiting arthrodesis [16,19].

Rod fracture can negatively impact clinical outcome by producing spinal pain, loss of deformity correction, and functional compromise [20–22]. This hardware complication often leads to revision spinal surgery with a negative impact on the patient and health care system alike. Focus on preventing rod fatigue failure has the potential to improve patient outcomes [23].

We describe an outrigger rod technique that enhances construct strength and stability. The outrigger rod construct is most useful when spinal implants are exposed to large magnitude biomechanical forces and/or the potential for delayed union/pseudarthrosis is elevated [16]. We have successfully used the technique in the setting of three-column osteotomy for sagittal imbalance; pseudarthrosis surgery with previous hardware failure; transforaminal lumbar interbody cage placement at multiple levels in realignment procedures; long-segment spinal arthrodesis with impaired

Fig. 1. Bilateral rod fracture at the thoracolumbar junction 7 years subsequent to the instrumented spinal arthrodesis procedure. (Left) anteroposterior and (Right) lateral radiographs.

host fusion potential; long-segment instrumented fusions that span the cervicothoracic, thoracolumbar, or lumbosacral junction; and across spinal segments at high risk of hardware failure (eg, after extensive resection of vertebral elements in the management of metastatic malignancy).

Surgical technique

Preoperative planning should take into consideration the outrigger rod construct. Specifically, the spinal implant system must include a full complement of side-to-side rod connectors (Fig. 2). Selection of the material and diameter of the rods is at the discretion of the surgeon. Stiffer rods (eg, 6.0 CoCr) may not be required because of the support provided by the supplemental rods.

Segmental fixation is established using polyaxial screws at all necessary levels. The two primary rods are cut to appropriate length and then carefully contoured to avoid stress-risers associated with sharp angular bends [18]. The rods are placed within the screw heads, and preliminary set-screw tightening is performed. Deformity correction maneuvers are executed using the two primary rods. Decortication and bone grafting are best performed before outrigger rod placement.

It is optimal to position a contoured outrigger rod alongside each primary rod. The supplemental rod can be positioned either medial or lateral to the primary rod depending on the desired area of bone graft placement and the anatomic characteristics of the spinal column. On each side of midline, the cranial and caudal ends of the outrigger rod should be connected to the primary rod using side-to-side connectors. Additional connectors can be added at intermediate points depending on the rod length. The outrigger rod does not need to be the same length as the primary rod but should span those vertebral segments that present the greatest risk of nonunion and RF (eg, an established nonunion site, the level of a three-column osteotomy, at the thoracolumbar/lumbosacral junction, and at transforaminal interbody fusion/facetectomy sites).

Fig. 2. Side-to-side, end-to-end, and crosslink rod connectors.

Occasionally, prior surgery or severe deformity makes seating the primary rod into the tulip heads of all ipsilateral screws difficult. In these cases, selected screws can be skipped by the primary rod and captured with the outrigger rod. Careful placement of standard iliac and sacral pedicle screw fixation will allow enough distance to place a side-to-side connector between one rod seated in the iliac screw and the other ipsilateral rod seated in the sacral screw head. Use of an S2-iliac screw can simplify the construct by allowing the primary rod to seat into both the S1 and S2 fixation sites.

One or two crosslinks are used to connect the two outrigger rods across the midline. Sections of the two primary rods that extend beyond the outrigger rods should also be crosslinked. All screws and connectors are final tightened. Full-length anteroposterior and lateral scoliosis radiographs are obtained during surgery to verify acceptable global spinal alignment and implant position.

It is not always feasible or necessary to create a four-rod construct. The pathoanatomy of the spinal column will sometimes allow for placement of only one outrigger rod. In this situation, the single supplemental rod can be connected in parallel to one primary rod using side-to-side connectors and then crosslinked to the contralateral primary rod (Fig. 3). Alternatively, the single supplemental rod can be connected at its caudal end to one primary rod and at its cranial end to the opposite side primary rod.

Case 1

A 75-year-old woman with positive sagittal balance after multiple prior spinal procedures and fracture at L4 level

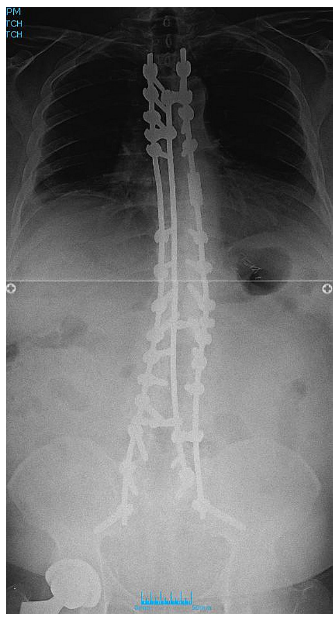

Fig. 3. Anteroposterior radiograph highlighting outrigger tri-rod construct in an adult spinal deformity patient after revision surgery for pseudarthrosis.

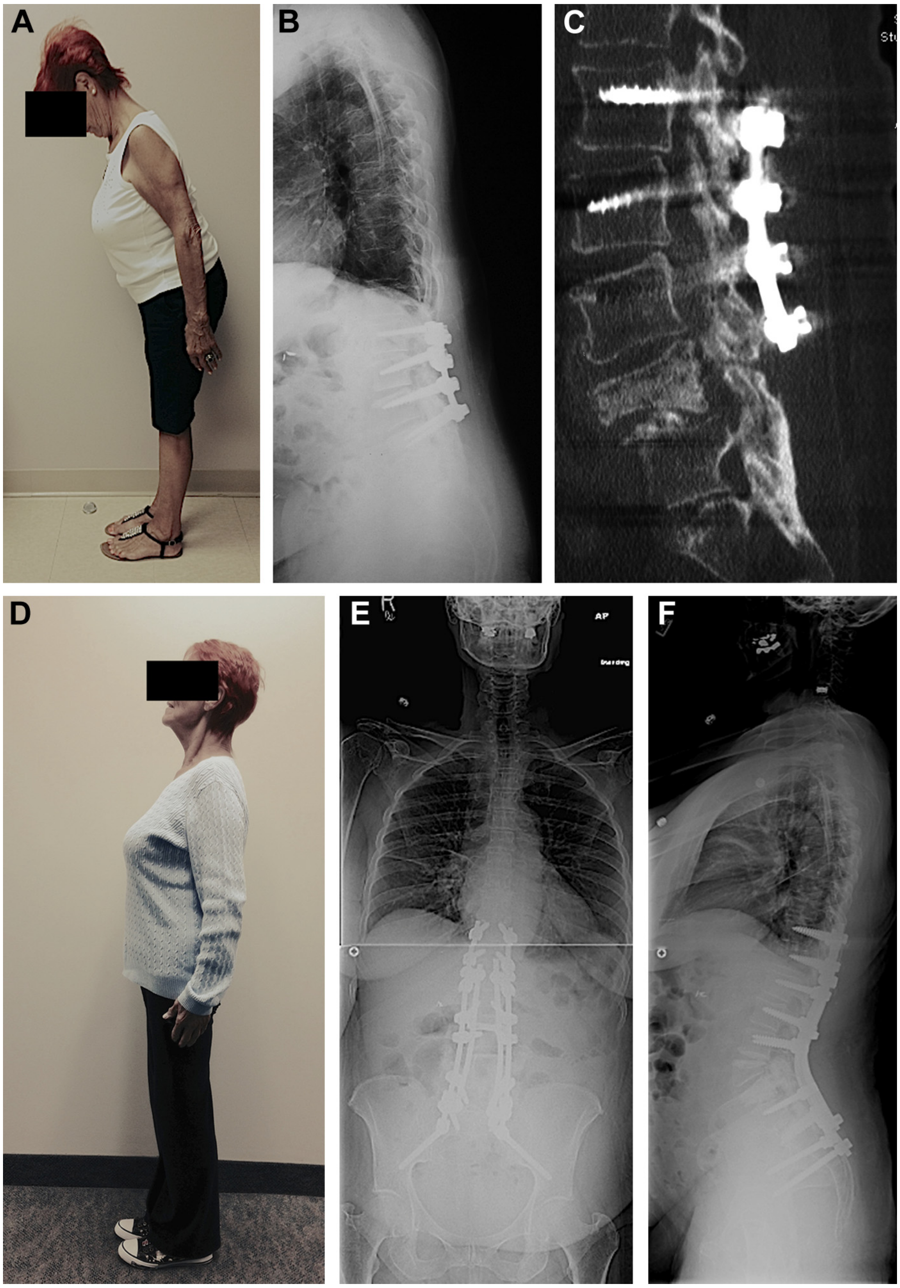

Fig. 4. Pedicle subtraction osteotomy and outrigger rod technique performed to correct global sagittal deformity because of L4 fracture through a previous posterolateral fusion mass. (A) Preoperative clinical photograph, (B) lateral radiograph, and (C) computed tomography scan; (D) postoperative clinical photograph and (E) anteroposterior and (F) lateral radiographs.

through a posterolateral fusion mass. T10–ilium posterior spine fusion with L3 PSO was performed. Outrigger rods were placed from T11–S1 to reinforce the instrumentation at the osteotomy site and across the thoracolumbar and lumbosacral junctional areas (Fig. 4).

Case 2

A 65-year-old woman with neglected adolescent idiopathic scoliosis. Compromised bone healing was predicted based on tobacco use and suboptimal nutrition. T3–ilium posterior arthrodesis was performed. A four-rod construct from T6–L5 was used due to the risk of delayed arthrodesis/pseudarthrosis (Fig. 5).

Discussion

The longitudinal rods of a spinal fixation construct must maintain structural integrity during and after the biologic process of spinal arthrodesis maturation. Fracture of a rod most typically occurs after long-segment spinal fusion

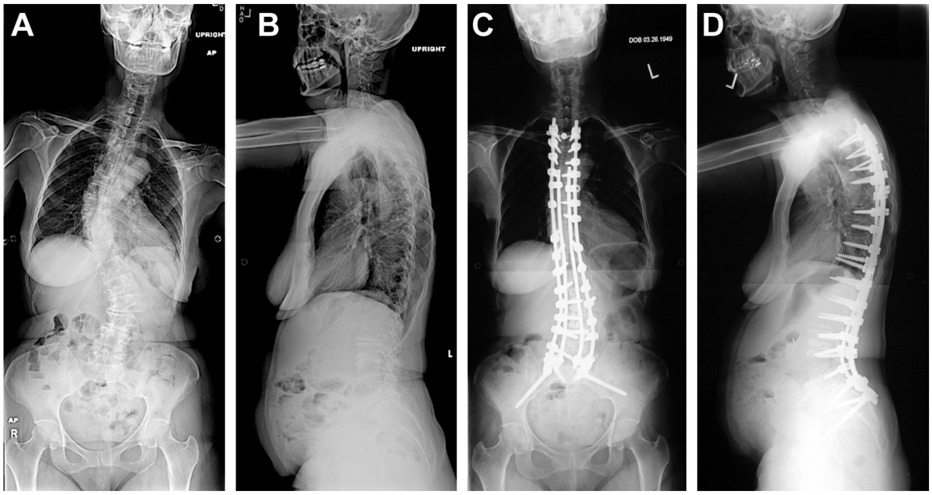

Fig. 5. Outrigger quad-rod reconstruction for neglected adolescent idiopathic scoliosis with poor osseous healing potential; (A) preoperative anteroposterior (AP) and (B) lateral scoliosis radiographs; postoperative (C) AP and (D) lateral scoliosis radiographs.

and/or when the fixation construct spans a three-column osteotomy site. In a multi-institutional series of 442 patients who underwent long fusions (>5 levels), Smith et al. [20] identified 30 patients (6.8%) who experienced a symptomatic rod failure with a higher rate in those undergoing PSO (70 patients; 15.8%). A follow-up investigation by the same group revealed an overall RF rate of 9% in adult spinal deformity patients with a 22% rate of RF in patients undergoing PSO with at least 1-year follow-up [16]. Rod failure rates are likely to be higher with longer term follow-up [24].

It is logical to assume that delayed osseous union or pseudarthrosis are major predisposing factors to RF. The outrigger rod construct represents an operative strategy to prolong the fatigue life of the instrumentation and reduce the potential for early RF. Theoretically, a longer lasting construct may decrease the rate of pseudarthrosis by allowing more time for maturation of the fusion.

Although less common, RF may occur in the setting of a continuous though not absolutely rigid fusion mass. Presumably, continued transfer of small forces to the instrumentation over time results in fatigue failure. The use of outrigger rods provides a stronger, more durable instrumentation construct that should reduce the likelihood of RF in this scenario.

Another factor that can increase the risk of device failure relates to the rod contouring process. Recent biomechanical reports indicate that rods contoured with a device such as a French bender, and those with extreme angular bends (eg, at a PSO site), display a significantly lower fatigue life [17,18]. In the case of a corrective osteotomy, the outrigger rod technique allows the placement of supplemental rods with less acute bends than the primary rods.

Alternative instrumentation methods can serve the same purpose as the described outrigger rod technique. In a retrospective review of 132 patients from a single institution, Hyun et al. [25] examined the efficacy of a variety of multiple-rod constructs for preventing RF in three-column spinal osteotomy patients. The use of multiple-rod constructs was found to significantly decrease rod breakage and revision surgery for pseudarthrosis at three-column osteotomy sites. Of the 66 patients with multiple-rod constructs, none had symptomatic implant failure at an average follow-up of 7 years. This study is an important proof of concept for the use of the outrigger rod technique. However, further study is necessary to examine its utility in clinical scenarios beyond spinal osteotomy.

Shen et al. [26] reported the use of a four-rod construct for lumbopelvic reconstruction using altered pedicle screw trajectories with the two ipsilateral rods each set into alternating screw heads [23,26]. This strategy necessitates the strategic placement of each pedicle screw to allow for alternating rod attachment. This technical requirement may be difficult to execute depending on the specific spinal pathoanatomy. Our technique allows for optimal screw orientation and the ability to connect two longitudinal rods to the same column of pedicle screws. With the use of side-connectors, the ipsilateral rods function as a single load bearing unit.

There are limitations associated with the outrigger rod technique described in this report. The first issue relates to implant bulk and its impact on the osseous healing process. Preparation of the fusion bed and bone grafting play a critical role in the arthrodesis process, especially in the setting of a multilevel reconstruction [27]. With increased space occupation by the instrumentation, proportionally less space is available for placement of graft material. It is also conceivable that stress shielding from the rigid instrumentation may negatively affect the quality of the fusion mass. The financial cost of additional implants is another concern that may be justified by a reduced potential for RF and a lower rate of revision surgery.

Lastly, it is critical to recognize that the outrigger rod technique is just one component of the overall strategy to enhance osseous healing and reduce the potential for hardware failure. The surgeon must consider and incorporate all available means to enhance osseous healing and reduce hardware failure. During the pre- and postoperative period, nutritional status and bone health should be optimized, tobacco use curtailed, and the use of antiinflammatory medications (steroidal and nonsteroidal) and disease-modifying antirheumatic drugs minimized. In terms of adjunctive surgical tactics, the entire fusion bed must be meticulously prepared before screw insertion. This necessitates resection of all soft tissue from the posterior spinal elements along with the removal of the facet joint cartilage at each level. Decortication and placement of graft material should be performed before seating of the outrigger rods. Achieving optimal spinal alignment and careful rod contouring by an experienced deformity surgeon are other relevant technical considerations. Lastly, the most appropriate combination of graft materials (autograft+/−allograft+/−bone morphogenic protein) must be selected to match the clinical situation.

Conclusion

The outrigger rod technique provides a sturdier construct compared with standard dual rod spinal fixation. The addition of supplemental rods theoretically reduces the risk of rod failure before (and after) maturation of the spinal fusion mass. This construct is most useful when the spinal implants are exposed to large magnitude biomechanical forces or the potential for delayed union/pseudarthrosis is elevated. Although this instrumentation method is in use and supported by preliminary evidence, additional clinical and biomechanical studies are necessary to establish efficacy of the technique.

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