SURGICAL FIXATION OF GERIATRIC SACRAL U-TYPE INSUFFICIENCY FRACTURES: A RETROSPECTIVE ANALYSIS

BENJAMIN R. PULLEY, MD[1] • STEVEN J. COTMAN, MD[2] • T. TY FOWLER, MD[2,3]

[1]Orthopaedic Associates of Zanesville, Zanesville, OH, USA • [2]Mount Carmel Health System, Columbus, OH, USA • [3]Orthopedic ONE, Columbus, OH, USA

DISCLOSURES

The US Food & Drug Administration (FDA) has approved use of all orthopaedic implants described. The authors did not receive financial support for this study and have no relevant financial disclosures.

OBJECTIVES

To define the incidence of the sacral U-type insufficiency fracture and describe management of a consecutive series of patients with this injury.

DESIGN

Retrospective analysis.

SETTING

Single level II trauma center.

PATIENTS/PARTICIPANTS

Sixteen adult patients with sacral U-type insufficiency fractures treated over a 36-month period.

INTERVENTION

Patients were indicated for percutaneous screw fixation of the posterior pelvis if they had posterior pelvic pain that prohibited mobilization.

MAIN OUTCOME MEASUREMENTS

Visual analog scale (VAS) for pain, distance ambulated on postoperative day (POD) 1, and change in sacral kyphosis.

RESULTS

The sacral U-type insufficiency fracture incidence was 16.7% (19/114); average patient age was 75 years-old. Delayed surgery was performed after primary nonoperative treatment had failed in 62.5% (10/16) at an average 83 days post-injury. Acute surgery was performed in 37.5% (6/16) at an average 5 days post-injury. Distance ambulated on POD 1 was 114.4 feet (95% CI [50.6, 178.2]) and 88.7 feet (95% CI [2.8, 174.6]) in the delayed and acute surgery groups, respectively, p=0.18. Change in VAS for pain was -3.2 (95% CI [-5.0, -1.4]) and -3.7 (95% CI [-7.0, -0.4]) in the delayed and acute surgery groups, respectively, p=0.15. Change in sacral kyphosis from presentation to surgery was 12.3 degrees (95% CI [6.7, 17.9]) and 0.3 degrees (95% CI [-0.2, 0.9]) in the delayed and acute surgery groups, respectively, p<0.01. Minimum follow-up was 12 months.

CONCLUSIONS

Treatment of sacral U-type insufficiency fractures by percutaneous screw fixation permits early mobilization, provides rapid pain relief, and prevents progressive deformity.

LEVEL OF EVIDENCE

Therapeutic level III.

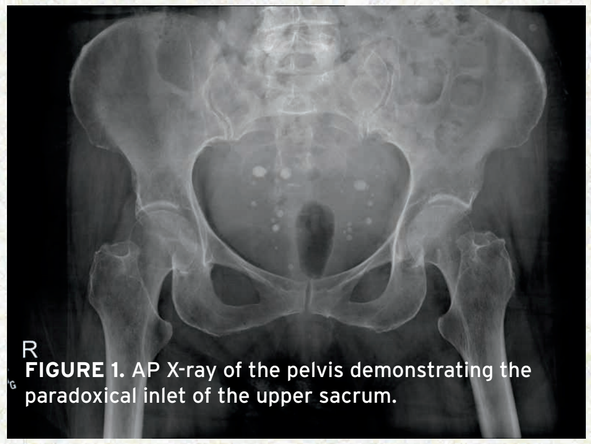

FIGURE 1. AP X-ray of the pelvis demonstrating the paradoxical inlet of the upper sacrum.

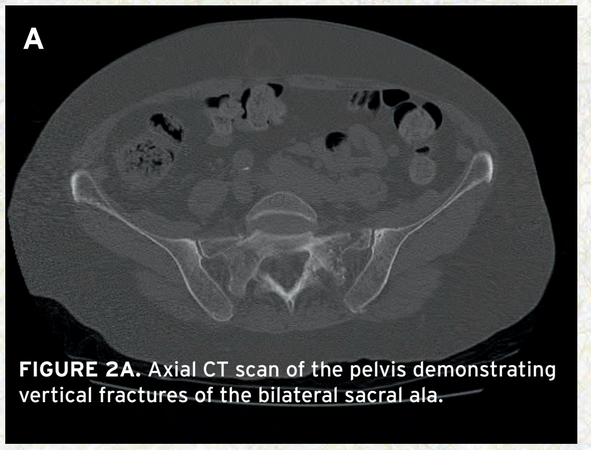

FIGURE 2A. Axial CT scan of the pelvis demonstrating vertical fractures of the bilateral sacral ala.

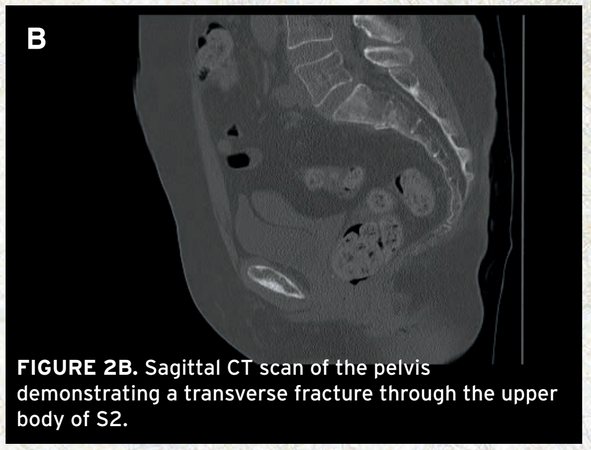

FIGURE 2B. Sagittal CT scan of the pelvis demonstrating a transverse fracture through the upper body of S2.

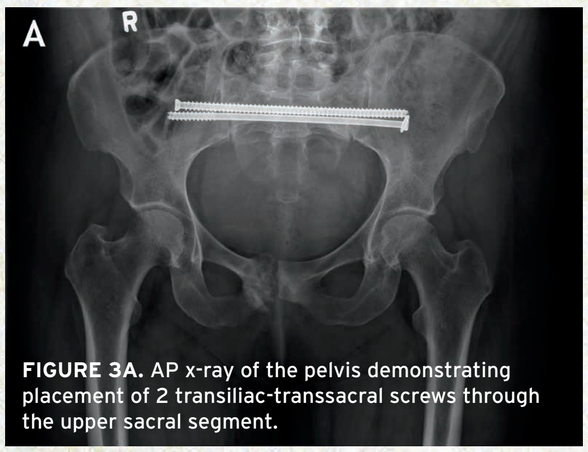

FIGURE 3A. AP x-ray of the pelvis demonstrating placement of 2 transiliac-transsacral screws through the upper sacral segment.

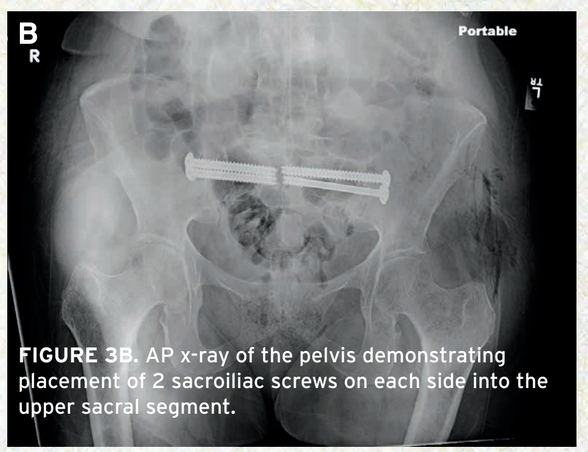

FIGURE 3B. AP x-ray of the pelvis demonstrating placement of 2 sacroiliac screws on each side into the upper sacral segment.

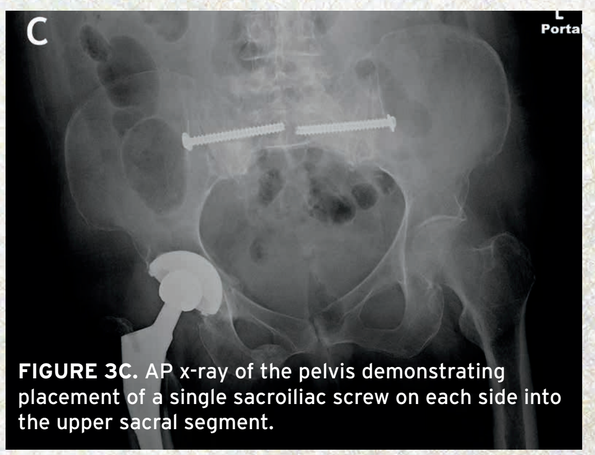

FIGURE 3C. AP x-ray of the pelvis demonstrating placement of a single sacroiliac screw on each side into the upper sacral segment.

Examples of screw fixation constructs used to control rotation of the upper sacral segment in the setting of a sacral U-type insufficiency fracture.

Pelvic Ring Insufficiency Fracture Descriptive Characteristics (n=114)		
Descriptive Characteristics	**Number**	**%**
No anterior ring fracture + unilateral sacral ala fracture incomplete	2	1.8
No anterior ring fracture + unilateral sacral ala fracture complete	1	0.9
No anterior ring fracture + bilateral sacral ala fracture incomplete	1	0.9
No anterior ring fracture + bilateral sacral ala fractures complete + transverse sacral body fracture	10	8.8
Unilateral anterior ring fracture + no posterior ring fracture	50	43.9
Unilateral anterior ring fracture + unilateral sacral ala fracture incomplete	28	24.6
Unilateral anterior ring fracture + unilateral sacral ala fracture complete	2	1.8
Unilateral anterior ring fracture + unilateral crescent fracture of the ilium	4	3.5
Unilateral anterior ring fracture + bilateral sacral ala fractures complete + transverse sacral body fracture	8	7
Bilateral anterior ring fracture + no posterior ring fracture	2	1.8
Bilateral anterior ring fracture + unilateral sacral ala fracture incomplete	4	3.5
Bilateral anterior ring fracture + unilateral sacral ala fracture complete	1	0.9
Bilateral anterior ring fracture + bilateral sacral ala fractures complete + transverse sacral body fracture	1	0.9
Any pattern including a sacral U-type fracture	19	16.7

TABLE 1. Descriptive characteristics of the pelvic ring insufficiency fractures identified by the retrospective analysis.

Demographic Data			
Patient	**Timing of Surgical Intervention**	**Days Between Injury and Surgery**	**Age**
1	Delayed	148	76
2	Delayed	59	52
3	Delayed	15	83
4	Delayed	241	86
5	Delayed	25	85
6	Delayed	24	87
7	Delayed	210	87
8	Delayed	17	70
9	Delayed	75	69
10	Delayed	14	86
11	Acute	2	57
12	Acute	2	73
13	Acute	4	85
14	Acute	9	72
15	Acute	12	56
16	Acute	2	83
	Mean Delayed Group	83	78
	Mean Acute Group	5	71
			p=0.14

TABLE 2. Patient demographic data, including: timing of surgical intervention (delayed versus acute group), days between injury and surgery, and patient age.

Outcome Data			
Patient	**Timing of Surgical Intervention**	**Distance Ambulated Postoperative Day 1 (ft)**	**△ VAS Pain Preoperative to Postoperative**
1	Delayed	100	-5.8
2	Delayed	150	-3.2
3	Delayed	300	-5.6
4	Delayed	160	-4
5	Delayed	175	-5.4
6	Delayed	5	-3.2
7	Delayed	30	3
8	Delayed	30	-3
9	Delayed	175	-3.2
10	Delayed	160	-1.4
11	Acute	15	-4.8
12	Acute	2	-8.8
13	Acute	150	-2.6
14	Acute	150	-1.8
15	Acute	*N/A	-2.8
16	Acute	#N/A	-6.8
	Mean Delayed Group	114.4 (95% CI[50.6, 178.2])	-3.2 (95% CI[-5.0, -1.4])
	Mean Acute Group	88.7 (95% CI[2.8, 174.6])	-3.7(95% CI[-7.0, -0.4])
		p=0.18	p=0.15

*Patient had a recent history of ischemic stroke with hemiparesis and had not yet recovered ambulatory status

#Patient had acute respiratory failure and required intubation in the intensive care unit (ICU) postoperatively

TABLE 3. Patient outcome data, including: feet ambulated at the first physical therapy session on postoperative day (POD) 1 and change in visual analog score (VAS) for pain from preoperative to postoperative.

Radiographic Data				
Patient	**Timing of Surgical Intervention**	**Level of Transverse Sacral Body Fracture**	**Sacral Kyphosis Angle Presentation**	**△ Sacral Kyphosis Angle Presentation to Surgery**
1	Delayed	S2	25	10
2	Delayed	S2	9	8
3	Delayed	S3	16	25
4	Delayed	S2	30	9
5	Delayed	S2	22	9
6	Delayed	S3	16	25
7	Delayed	S2	8	17
8	Delayed	S3	30	6
9	Delayed	S3	32	13
10	Delayed	S2	10	1
11	Acute	S2	8	1
12	Acute	S2	6	0
13	Acute	S2	9	0
14	Acute	S3	20	1
15	Acute	S2	8	0
16	Acute	S2	40	0
		Mean Delayed Group	18.0 (95% CI [11.4, 24.6])	12.3 (95% CI [6.7, 17.9])
		Mean Acute Group	15.2 (95% CI [1.4, 29.0])	0.3 (95% CI [-0.2, 0.9])
			p=0.24	p<0.01

TABLE 4. Patient radiographic data, including: level of the transverse sacral body fracture, sacral kyphosis angle (at presentation and intraoperatively), and change in sacral kyphosis from the time of patient presentation to the time of surgery.

Surgical Fixation of Geriatric Sacral U-Type Insufficiency Fractures: A Retrospective Analysis

Benjamin R. Pulley, MD, Steven B. Cotman, MD,† and T. Ty Fowler, MD†‡*

Objectives: To define the incidence of sacral U-type insufficiency fracture and describe management of a consecutive series of patients with this injury.

Design: Retrospective analysis.

Setting: Single Level II trauma center.

Patients/Participants: Sixteen adult patients with sacral U-type insufficiency fractures treated over a 36-month period.

Intervention: Patients were indicated for percutaneous screw fixation of the posterior pelvis if they had posterior pelvic pain that prohibited mobilization.

Main Outcome Measurements: Visual analog scale for pain, distance ambulated on postoperative day 1, and change in sacral kyphosis.

Results: The sacral U-type insufficiency fracture incidence was 16.7% (19/114); average patient age was 75 years. Delayed surgery was performed after primary nonoperative treatment had failed in 62.5% (10/16) at an average 83 days postinjury. Acute surgery was performed in 37.5% (6/16) at an average 5 days postinjury. Distance ambulated on postoperative day 1 was 114.4 feet [95% confidence interval (CI) (50.6, 178.2)] and 88.7 feet [95% CI (2.8, 174.6)] in the delayed and acute surgery groups, respectively, $P = 0.18$. Change in visual analog scale for pain was −3.2 [95% CI (−5.0, −1.4)] and −3.7 [95% CI (−7.0, −0.4)] in the delayed and acute surgery groups, respectively, $P = 0.15$. Change in sacral kyphosis from presentation to surgery was 12.3 degrees [95% CI (6.7, 17.9)] and 0.3 degrees [95% CI (−0.2, 0.9)] in the delayed and acute surgery groups, respectively, $P < 0.01$. Minimum follow-up was 12 months.

Conclusions: Treatment of sacral U-type insufficiency fractures by percutaneous screw fixation permits early mobilization, provides rapid pain relief, and prevents progressive deformity.

Accepted for publication July 13, 2018.
From the *Orthopaedic Trauma Service, Department of Orthopaedic Surgery, Stanford University Medical Center, Palo Alto, CA; †Department of Orthopaedic Surgery, Mount Carmel Health System, Columbus, OH; and ‡Orthopedic ONE, Columbus, OH.
The authors report no conflict of interest.
Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.jorthotrauma.com).
Reprints: T. Ty Fowler, MD, Mount Carmel West Hospital Medical Education, 793 W State St, Columbus, OH 43222 (e-mail: benjaminrpulley@gmail.com).

DOI: 10.1097/BOT.0000000000001308

Key Words: sacral U-type fracture, sacral fracture, sacral insufficiency fracture, insufficiency fracture, geriatric fracture, geriatric trauma, percutaneous pelvic fixation

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

(*J Orthop Trauma* 2018;32:617–622)

INTRODUCTION

Fractures of the sacrum are common in situations of both high- and low-energy trauma.[1,2] Since originally defined by Roy Camille in 1985,[3] U-type fractures of the sacrum—a unique fracture configuration consisting of bilateral vertical fractures of the sacral ala and a transverse fracture of the sacral body—have become increasingly recognized as a highly unstable fracture pattern that typically results from high-energy axial loading[4] and confers spinopelvic dissociation.[5] In the setting of high-energy trauma, nonoperative treatment of U-type sacral fractures has been reported to yield poor outcomes,[4] and surgical fixation is generally accepted as a preferred treatment measure. Established techniques include transiliac rod or plate fixation,[6–8] transsacral plate fixation,[9] triangular osteosynthesis,[10] iliosacral screw fixation,[8,11–14] and transiliac-transsacral screw fixation.[5,15] It is unknown whether these surgical treatment options are translatable to the sacral U-type insufficiency fracture.

There have been recent reports that help identify which sacral fractures associated with lateral compression pelvic ring injuries are more prone to future displacement[16] and studies that have advanced the understanding of the treatment of low-energy sacral fractures in elderly patients,[17] but the sacral U-type insufficiency fracture, in particular, has not been well defined or specifically addressed in a consecutive series of patients in the contemporary orthopaedic trauma literature.

The goal of this study, therefore, was to extend the definition of the sacral U-type fracture to include a subset of adult patients with low-energy mechanisms of injury in whom this injury manifests as an insufficiency fracture. We seek to establish an incidence and describe the management of a consecutive series of patients with this injury, as well as report their clinical outcomes.

PATIENTS AND METHODS

Patients

Adult patients with low-energy pelvic ring fractures treated at our Level II trauma center during a 36-month period (August 2013 through August 2016) were identified retrospectively using International Classification of Disease codes.

Patients were excluded if they were younger than 50 years or they had a reported mechanism of injury that was higher in energy than a ground-level fall. Radiographs were reviewed independently by the lead author to classify fracture patterns based on descriptive characteristics and to identify which fracture patterns included a U-type fracture of the sacrum (Table 1). In total, 114 adult patients with low-energy pelvic ring fractures were treated at our hospital during this time period, and 16.7% of them (19/114) were identified as having sacral U-type fractures. One of the 19 patients presented with a sacral U-type fracture nonunion that had been incompletely surgically stabilized at an outside facility 6 months before presentation; this patient was excluded from further analysis.

Radiographic Workup

Radiographic workup was standardized. X-rays of the pelvis were obtained to look for a pelvic ring fracture and to evaluate for the presence of the paradoxical inlet of the upper sacrum on the anteroposterior view of the pelvis[5] (see **Figure, Supplemental Digital Content 1**, http://links.lww.com/JOT/A479). When x-ray identified a pelvic ring fracture, computed tomography (CT) of the pelvis was obtained and evaluated for the presence of vertical fractures of the bilateral sacral ala on axial imaging and a transverse fracture of the sacral body on sagittal imaging (see **Figure, Supplemental Digital Content 2**, http://links.lww.com/JOT/A480). In select situations, when we were suspicious of a U-type fracture of the sacrum but CT was inconclusive, magnetic resonance imaging was used to confirm fracture continuity along the U-shaped fracture lines (see **Figure, Supplemental Digital Content 3**, http://links.lww.com/JOT/A481).

In all cases where we identified a sacral U-type fracture, we recorded the level of the transverse sacral body fracture based on the sagittal CT of the pelvis. In addition, we used the lateral x-ray view of the sacrum to measure the sacral kyphosis angle at the time of initial presentation and intraoperatively. We recorded the change in sacral kyphosis angle between these time points. The change in sacral kyphosis angle as reported represents the sacral kyphosis angle at the time of surgery minus the sacral kyphosis angle at the time of presentation, such that a positive value signifies an increase in sacral kyphosis angle.

Nonoperative Treatment Followed by Delayed Surgical Treatment

Sacral U-type fractures were initially treated nonoperatively in 63.1% of patients (12/19). These patients had presented to the emergency department with mild pain and minimal radiographic deformity and were able to mobilize acutely. They were instituted into our nonoperative fragility fracture treatment protocol, which included analgesics, limited weight-bearing, and physical therapy. In addition, all of these patients were evaluated for osteomalacia by 25-hydroxy vitamin D level measurement and instituted calcium plus vitamin D replacement when indicated. All of these patients were evaluated for osteoporosis by bone densitometry scanning and initiated bisphosphonate therapy when indicated. In select cases, patients were referred for consultation with an endocrinologist to evaluate for candidacy to initiate alternative pharmacological osteoporosis treatment (denosumab or teriparatide). Nonoperative treatment ultimately failed in all of these patients (2 of 12 patients were lost to follow-up during the nonoperative treatment window and were excluded from further analysis). This group of patients experienced progressive kyphosis of the upper sacral segment and worsening posterior pelvic pain that prohibited mobilization by the time the plan was made to abort nonoperative management and proceed with surgical intervention. We consider these 10 patients the "delayed surgery" group.

Acute Surgical Treatment

In 31.6% of the patients (6/19) with sacral U-type fractures, posterior pelvic pain at initial emergency department presentation was severe enough to prevent acute mobilization and warrant inpatient hospitalization. Ultimately, all 6 of these patients were treated with acute surgical intervention during the hospitalization. We consider these 6 patients the "acute surgery" group.

TABLE 1. Descriptive Characteristics of the Pelvic Ring Insufficiency Fractures Identified by the Retrospective Analysis

Pelvic Ring Insufficiency Fracture Descriptive Characteristics (n = 114)		
Descriptive Characteristics	**Number**	**%**
No anterior ring fracture + unilateral sacral ala fracture incomplete	2	1.8
No anterior ring fracture + unilateral sacral ala fracture complete	1	0.9
No anterior ring fracture + bilateral sacral ala fracture incomplete	1	0.9
No anterior ring fracture + bilateral sacral ala fractures complete + transverse sacral body fracture	10	8.8
Unilateral anterior ring fracture + no posterior ring fracture	50	43.9
Unilateral anterior ring fracture + unilateral sacral ala fracture incomplete	28	24.6
Unilateral anterior ring fracture + unilateral sacral ala fracture complete	2	1.8
Unilateral anterior ring fracture + unilateral crescent fracture of the ilium	4	3.5
Unilateral anterior ring fracture + bilateral sacral ala fractures complete + transverse sacral body fracture	8	7
Bilateral anterior ring fracture + no posterior ring fracture	2	1.8
Bilateral anterior ring fracture + unilateral sacral ala fracture incomplete	4	3.5
Bilateral anterior ring fracture + unilateral sacral ala fracture complete	1	0.9
Bilateral anterior ring fracture + bilateral sacral ala fractures complete + transverse sacral body fracture	1	0.9
Any pattern including a sacral U-type fracture	19	16.7

Surgical Technique

In the 16 patients with sacral U-type insufficiency fractures that were treated surgically, the CT of the pelvis was used to preoperatively plan the safe zone for screw insertion. The patient was positioned supine on a radiolucent operating table with 1–2 folded blankets placed beneath the sacrum to elevate the pelvis from the table and produce a slight lumbar lordosis. No further sacral reduction maneuvers were performed. Fracture stabilization was accomplished using fluoroscopically guided 7.0-millimeter (mm) cannulated screws (Zimmer Biomet, Warsaw, IN) inserted percutaneously to stabilize the upper sacral segment (ie, the portion of the sacrum proximal to the transverse sacral body fracture). Orthogonal inlet and outlet, as well as lateral fluoroscopic, views were obtained intraoperatively and correlated with the preoperative CT to ensure safe screw insertion[16,18] (see **Figure, Supplemental Digital Content 4**, http://links.lww.com/JOT/A482). Screws were positioned with the intention of providing rotational control of the upper sacral segment. Given the poor bone quality in this elderly patient population, the goal construct in each case was placement of 2 transiliac-transsacral screws through the upper sacral segment, but in the setting of pelvic dysmorphism, we placed 1 or 2 iliosacral screws bilaterally into the upper sacral segment (Fig. 1). We believe that a single in-line point of fixation through the upper sacral segment—as such is the case for a single transiliac-transsacral screw—may be insufficient to control rotation and prevent progressive kyphosis of the upper sacral segment in this fracture pattern. Patients were allowed to weight-bearing as tolerated after surgery without a thoracolumbarsacral orthosis.

Pain Scores

The visual analog scale (VAS) for pain is routinely used at our trauma center as part of the hourly perioperative rounding by the nursing staff. The values recorded represent an average of the 5 scores collected immediately before the patient left the floor for surgery (preoperative VAS pain) and an average of the 5 scores collected immediately after the patient returned to the floor after surgery (postoperative VAS pain). The change in VAS pain as reported represents the preoperative VAS pain minus the postoperative VAS pain, such that a negative value signifies a decrease in pain and a positive value signifies an increase in pain.

Statistical Analysis

Statistical calculations were performed in Microsoft Excel (Microsoft Corporation, Redmond, WA). Mean values are reported with a 95% confidence interval (CI) and a 1-tailed, two-sample unequal variance *t* test was used for comparison of mean values, when applicable. Alpha was set at 0.05.

RESULTS

The average patient age of the entire cohort of 114 patients with low-energy pelvic ring fractures was 78 years. The incidence of sacral U-type insufficiency fractures in this series was 16.7% (19/114). Of the 16 patients in the sacral U-type fracture cohort, the average age was 75 years (range 52–87 years); there were 17 women and 2 men. The average age in the delayed and acute surgery groups was 78 and 71 years, respectively, $P = 0.14$. None of the patients with sacral U-type fractures presented with neurological symptoms, but all ultimately had severe posterior pelvic pain that prohibited mobilization when the decision was made to proceed with surgical intervention. Surgical intervention was performed in a delayed fashion after failure of nonoperative treatment in 62.5% of patients (10/16) at an average of 83 days postinjury (range 14–241 days), whereas acute surgical fixation was performed in 37.5% of patients (6/69) at an average of 5 days postinjury (range 2–12 days) (Table 2). A total of 3 of the 19 patients were excluded from the analysis; 2 were lost to follow-up during the nonoperative treatment window and 1 presented with a sacral U-type fracture nonunion after being incompletely surgically stabilized at an outside facility.

In 81.3% (13/16), 2 transiliac-transsacral screws were placed through the upper sacral segment. Twelve of 13 patients had 2 screws placed through S1, and 1 of 13 patients had 1 screw placed through S1 and a second screw placed through S2. In 18.8% (3/16), pelvic dysmorphism prevented safe passage of 2 transiliac-transsacral screws through the

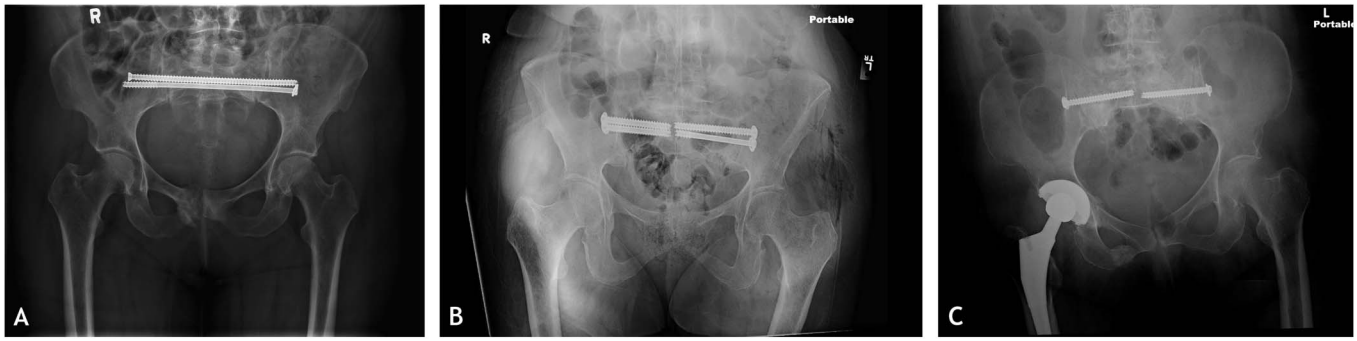

FIGURE 1. Examples of screw fixation constructs used to control rotation of the upper sacral segment in the setting of a sacral U-type insufficiency fracture. A, Anteroposterior (AP) x-ray of the pelvis demonstrating placement of 2 transiliac-transsacral screws through the upper sacral segment. B, AP x-ray of the pelvis demonstrating placement of 2 sacroiliac screws on each side into the upper sacral segment. C, AP x-ray of the pelvis demonstrating placement of a single sacroiliac screw on each side into the upper sacral segment.

TABLE 2. Patient Demographic Data, Including Timing of Surgical Intervention (Delayed Versus Acute Group), Days Between Injury and Surgery, and Patient Age

Demographic Data			
Patient	Timing of Surgical Intervention	Days Between Injury and Surgery	Age
1	Delayed	148	76
2	Delayed	59	52
3	Delayed	15	83
4	Delayed	241	86
5	Delayed	25	85
6	Delayed	24	87
7	Delayed	210	87
8	Delayed	17	70
9	Delayed	75	69
10	Delayed	14	86
11	Acute	2	57
12	Acute	2	73
13	Acute	4	85
14	Acute	9	72
15	Acute	12	56
16	Acute	2	83
Mean Delayed Group		83	78
Mean Acute Group		5	71
			$P = 0.14$

TABLE 3. Patient Outcome Data, Including Feet Ambulated at the First Physical Therapy Session on Postoperative Day (POD) 1 and Change in Visual Analog Score (VAS) for Pain From Preoperative to Postoperative

Outcome Data			
Patient	Timing of Surgical Intervention	Distance Ambulated on Postoperative Day 1 (ft)	△ VAS Pain Preoperative to Postoperative
1	Delayed	100	−5.8
2	Delayed	150	−3.2
3	Delayed	300	−5.6
4	Delayed	160	−4
5	Delayed	175	−5.4
6	Delayed	5	−3.2
7	Delayed	30	3
8	Delayed	30	−3
9	Delayed	175	−3.2
10	Delayed	160	−1.4
11	Acute	15	−4.8
12	Acute	2	−8.8
13	Acute	150	−2.6
14	Acute	150	−1.8
15	Acute	*N/A	−2.8
16	Acute	†N/A	−6.8
Mean Delayed Group		114.4 [95% CI (50.6–178.2)]	−3.2 [95% CI (−5.0 to −1.4)]
Mean Acute Group		88.7 [95% CI (2.8–174.6)]	−3.7 [95% CI (−7.0 to −0.4)]
		$P = 0.18$	$P = 0.15$

*Patient had a recent history of ischemic stroke with hemiparesis and had not yet recovered ambulatory status.

†Patient had acute respiratory failure and required intubation in the intensive care unit (ICU) postoperatively.

upper sacral segment, and alternative fixation constructs were used. Alternative fixation constructs included the following: 1 of 3 patients had 2 sacroiliac screws placed bilaterally into S1; 1 of 3 patients had 1 sacroiliac screw placed bilaterally into S1 and then 1 transiliac-transsacral screw through S2; and in the final 1 of 3 patients, 1 sacroiliac screw was placed bilaterally into S1.

All but 2 of the patients treated surgically were ambulatory on the morning of postoperative day (POD) 1; the average distance ambulated at the first postoperative physical therapy session was 114.4 feet [95% CI (50.6, 178.2)] in the delayed surgery group (range 5–300 feet) and 88.7 feet [95% CI (2.8, 174.6)] in the acute surgery group (range 2–150 feet), $P = 0.18$. One of the patients who did not ambulate on the morning of POD 1 had a preoperative history of a recent ischemic stroke with hemiparesis and had not yet recovered a baseline ambulatory status. The other patient who did not ambulate had acute respiratory failure that required intubation in the intensive care unit postoperatively. The average change in VAS for pain in the delayed surgery group was −3.2 [95% CI (−5.0, −1.4)] and in the acute surgery group was −3.7 [95% CI (-7.0, −0.4)], $P = 0.15$ (Table 3). None of the patients had iatrogenic neurologic sequelae postoperatively.

The level of the transverse sacral body fracture was at S2 in 73.7% of patients (14/19) and at S3 in 26.3% of patients (5/19). In the delayed surgery group, the average sacral kyphosis angle at presentation was 18.0 degrees [95% CI (11.4, 24.6)], and in the acute surgery group, the average sacral kyphosis angle at presentation was 15.2 degrees [95% CI (1.4, 29.0)], $P = 0.24$. The average change in sacral kyphosis from presentation to surgery in the delayed and acute surgery groups was 12.3 degrees (95% CI [6.7, 17.9]) and 0.3 degrees (95% CI [-0.2, 0.9]), respectively, $P < 0.01$ (Table 4). All patients were followed in the outpatient office for a minimum of 12 months postoperatively (range 12–37 months; mean 13 months); none had worsening of their clinical status and none required further surgical intervention to treat their pelvic injuries.

DISCUSSION

The sacral U-type fracture is a rare injury that has been described in the setting of high-energy trauma and spinal axial loading.[3–5,10,19,20] The incidence of this particular injury seems to be quite low in the adult trauma patient—reported 2.9% of pelvic ring fractures[5] and 0.1% of all trauma admissions.[4] Therefore, there is a limited understanding of its natural history. Diagnosis of this unique fracture pattern can be challenging because of the difficulty with imaging the upper sacrum on plain x-ray. The paradoxical inlet of the upper sacrum[5] may be present on the anteroposterior view of the pelvis, but pelvic CT scanning is critical to evaluate for the presence of vertical fractures of the bilateral sacral ala and a transverse fracture of the sacral body.[3]

TABLE 4. Patient Radiographic Data, Including Level of the Transverse Sacral Body Fracture, Sacral Kyphosis Angle (at Presentation and Intraoperatively), and Change in Sacral Kyphosis From the Time of Patient Presentation to the Time to Surgery

Radiographic Data					
Patient	Timing of Surgical Intervention	Level of Transverse Sacral Body Fracture	Sacral Kyphosis Angle Presentation	Sacral Kyphosis Angle Intraoperative	△ Sacral Kyphosis Angle Presentation to Surgery
1	Delayed	S2	25	35	10
2	Delayed	S2	9	17	8
3	Delayed	S3	16	41	25
4	Delayed	S2	30	39	9
5	Delayed	S2	22	31	9
6	Delayed	S3	16	41	25
7	Delayed	S2	8	25	17
8	Delayed	S3	30	36	6
9	Delayed	S3	32	45	13
10	Delayed	S2	10	11	1
11	Acute	S2	8	9	1
12	Acute	S2	6	6	0
13	Acute	S2	9	9	0
14	Acute	S3	20	21	1
15	Acute	S2	8	8	0
16	Acute	S2	40	40	0
Mean Delayed Group			18.0 [95% CI (11.4, 24.6)]	25.9 [95% CI (17.9, 33.9)]	12.3 [95% CI (6.7, 17.9)]
Mean Acute Group			15.2 [95% CI (1.4, 29.0)]	15.5 [95% CI (1.7, 29.3)]	0.3 [95% CI (−0.2, 0.9)]
			$P = 0.24$	$P = 0.01$	$P < 0.01$
SD acute			9.247221805	11.15994823	7.874713399
SD delayed			13.15167923	13.12630946	0.516397779
95% CI acute			6.615063979	7.983346035	5.633230612
95% CI delayed			13.80184091	13.77521697	0.541926234

The need for operative stabilization in all patients with these fractures is unclear; however, surgical fixation is generally accepted as a reliable means of restoring spinopelvic stability to permit early mobilization of the trauma patient. Open techniques for surgical fixation of this injury have been described, including transiliac rod or plate fixation,[6–8] transsacral plate fixation,[9] and triangular osteosynthesis,[10] but they are associated with longer operative times, increased blood loss, and the need for prolonged prone patient positioning.[5] Techniques for percutaneous sacral fixation with transiliac-transsacral screws[5,15] and iliosacral screws[8,11–14] are well-established means of avoiding the drawbacks of open techniques and have been used in the setting of the sacral U-type fracture with minimal complications.[5,8]

Insufficiency fractures of the sacrum have been described since the 1980s.[21] Many of these fractures are successfully treated nonoperatively; however, there are certain situations where these injuries can be a significant cause of morbidity in the frail elderly patients who sustain them.[22] Treatment options in the patients who fail conservative management remain poorly defined. Small series have reported promising results with sacroplasty,[23–25] transsacral bar fixation,[26,27] iliosacral screw fixation,[28] and transiliac-transsacral screw fixation,[17] but deciding on which treatment strategy to use in which patient and which fracture pattern remains ill-defined.

We report a consecutive series of 16 patients with sacral U-type insufficiency fractures that were treated surgically. In our level II trauma center, this series of patients represented 16.7% of all low-energy pelvic ring fractures sustained in elderly patients over a 36-month period, which is higher than the reported incidence of sacral U-type fractures in high-energy trauma patients.[4,5] Starr et al recently reported on a series of 11 elderly patients with sacral insufficiency fractures identified over 5 years at a level I trauma center, but only one of them was reported to be a U-type fracture pattern.[17] Ten patients in our series failed protocol-driven nonoperative fragility fracture care by an average of 83 days postinjury. Because of continued debilitating pain and nonunion, these patients were ultimately treated in a delayed surgical fashion with percutaneous transiliac-transsacral or bilateral iliosacral screws. They had rapid pain relief and return of ambulatory capacity. In addition, we treated 6 patients with acute percutaneous transiliac-transsacral or bilateral iliosacral screw fixation after their initial emergency department presentation resulted in an inpatient hospitalization, and they failed to mobilize because of severe posterior pelvic pain. They were able to ambulate with good pain control by the morning of POD 1.

We believe that this fracture pattern in this patient population requires special attention to effectively provide rotational control of the upper sacral segment and prevent progressive kyphosis. It is our belief that a single in-line point of fixation in the upper sacral segment (ie, a single transiliac-transsacral screw) for a sacral U-type insufficiency fracture does not provide adequate stability to permit fracture healing and prevent progressive kyphosis. Although a single transiliac-transsacral screw can help prevent anterior translation of the upper sacral segment, we believe that the sacral

U-type insufficiency fracture is prone to rotational deformity, and progressive kyphosis may continue to occur as the upper sacral segment rotates about the axis of fixation. Although compressing across fracture lines with a single lag screw can help achieve rotational stability in some situations, it is important to recognize that a single transiliac-transsacral screw cannot achieve compression in a sacral U-type fracture pattern because of the presence of the sacroiliac joints. Therefore, we believe that rotational control of the fracture must be achieved through 2 fixation points. These points of fixation can be achieved by using 2 transiliac-transsacral screws proximal to the transverse component of the U-type fracture, or—in the presence of a dysmorphic sacrum—bilateral iliosacral screws, which inherently are placed off axis to each other and provide the rotational stability needed.

Our study has significant limitations given its small sample size, but these 16 patients represent the largest series of consecutive patients with sacral U-type insufficiency fractures in the literature. We acknowledge that this retrospective series is heterogeneous in several regards, including the timing of surgical fixation, differences in surgical fixation constructs, and availability of certain aspects of the patient data (ie, bone densiometry scanning result, standardized postoperative x-rays, and postoperative CT pelvis to prove fracture union). However, given the increasing attention being directed toward fragility fracture care as a global public health initiative, we believe that it is important to raise awareness of this unique injury that has not been well defined in the setting of low-energy geriatric trauma.

Our outcome data have the typical limitations of a retrospective analysis. In addition, we do not have a group of nonoperatively treated patients to serve for comparison; however, 10 of our patients treated surgically had failed a rather lengthy window of nonoperative treatment (nearly 3 months average) that was driven by modern fragility fracture protocols before undergoing surgical fixation. This group of 10 delayed surgery patients experienced progressive sacral kyphosis during the period of nonoperative treatment, and this deformity was avoided in the group of 6 patients whom we treated with acute surgery. Further study of this topic would benefit from a prospective comparison of nonoperative and operative treatment groups, as well as standardized measurement of outcome scores.

CONCLUSION

The sacral U-type fracture has not been previously described as an insufficiency fracture. This injury is difficult to recognize on plain x-rays and may be missed initially, making workup with advanced imaging paramount. There is a paucity of data to determine the natural history of this unique fracture pattern, but our experience leads us to believe that the sacral U-type insufficiency fracture in a geriatric population may represent a similar level of inherent spinopelvic instability as the high-energy sacral U-type fracture. Fracture stabilization with more than 1 percutaneous transiliac-transsacral or bilateral iliosacral screws to control rotation of the upper sacral segment permits early mobilization, provides rapid pain relief, prevents progressive deformity, and may increase union rates in this frail patient population.

REFERENCES

1. Dennis F, Davis S, Comfort T. Sacral fractures: an important problem. Retrospective analysis of 236 cases. *Clin Orthop Relat Res.* 1988;227:67–81.
2. Vaccaro AR, Kim DH, Brodke DS, et al. Diagnosis and management of sacral spine fractures. *Instr Course Lect.* 2004;53:375–385.
3. Roy Camille R, Saillant G, Gagna G, et al. Transverse fracture of the upper sacrum. Suicidal jumper's fracture. *Spine.* 1985;10:838–845.
4. Gribnau AJG, Van Hensbroek PB, Haverlag R, et al. U-shaped sacral fractures: surgical treatment and quality of life. *Injury.* 2009;40:1040–1048.
5. Nork SE, Jones CB, Harding S, et al. Percutaneous stabilization of U-shaped sacral fractures using iliosacral screws: technique and early results. *J Orthop Trauma.* 2001;15:238–246.
6. Ebraheim NA, Coombs R, Hoeflinger MJ, et al. Anatomical and radiological considerations in compressive bar technique for posterior pelvic disruptions. *J Orthop Trauma.* 1991:5:434–438.
7. Stocks GW, Gabel GT, Noble PC, et al. Anterior and posterior internal fixation of vertical shear fractures of the pelvis. *J Orthop Res.* 1991;9: 237–245.
8. Ward EF, Tomasin J, Vander Griend RA. Open reduction and internal fixation of vertical shear pelvic fractures. *J Trauma.* 1987;27:291–295.
9. Letournel E. Surgical fixation of displaced pelvic fractures and dislocations of the symphysis pubis (excluding acetabular fractures). *Rev Chir Orthop Reparatrice Appar Mot.* 1981;67:771–782.
10. Schildhauer TA, Josten C, Muhr G. Triangular osteosynthesis of vertically unstable sacrum fractures: a new concept allowing early weightbearing. *J Orthop Trauma.* 1998;12:307–314.
11. Matta JM, Tornetta P, III. Internal fixation of unstable pelvic ring injuries. *Clin Orthop Relat Res.* 1996:129–140.
12. Routt ML, Jr, Nork SE, Mills WJ. Percutaneous fixation of pelvic ring disruptions. *Clin Orthop Relat Res.* 2000:15–29.
13. Routt ML, Jr, Simonian PT. Closed reduction and percutaneous skeletal fixation of sacral fractures. *Clin Orthop Relat Res.* 1996;329:121–128.
14. Routt ML, Jr, Simonian PT, Swiontkowski MF. Stabilization of pelvic ring disruptions. *Orthop Clin N Am.* 1997;28:369–388.
15. Gardner MJ, Routt ML. Transiliac-transsacral screws for posterior pelvic stabilization. *J Orthop Trauma.* 2011;25:378–384.
16. Bruce B, Reilly M, Sims S. Predicting future displacement of nonoperatively managed lateral compression sacral fractures: can it be done?. *J Orthop Trauma.* 2011;25:523–528.
17. Sanders D, Fox J, Starr A, et al. Transsacral-transiliac screw stabilization: effective for recalcitrant pain due to sacral insufficiency fracture. *J Orthop Trauma.* 2016;30:469–473.
18. Routt ML, Jr, Simonian PT, Agnew SG, et al. Radiographic recognition of the sacral alar slope for optimal placement of iliosacral screws: a cadaveric and clinical study. *J Orthop Trauma.* 1996;10:171–177.
19. Bellabarba C, Schildhauer TA, Vaccaro AR, et al. Complications associated with surgical stabilization of high-grade sacral fracture dislocations with spino-pelvic instability. *Spine.* 2006;31:S80–S88.
20. Hunt N, Jennings A, Smith M. Current management of U-shaped sacral fractures or spino-pelvic dissociation. *Injury.* 2002;33:123–126.
21. Lourie H. Spontaneous osteoporotic fracture of the sacrum an unrecognized syndrome of the elderly. *J Am Med Assoc.* 1982;248:715–717.
22. Tsiridis E, Upadhyay N, Giannoudis PV. Sacral insufficiency fractures: current concepts of management. *Osteoporos Int.* 2006;17:1716–1725.
23. Bayley E, Srinivas S, Boszczyk BM. Clinical outcomes of sacroplasty in sacral insufficiency fractures: a review of the literature. *Eur Spine J.* 2009;18:1266–1271.
24. Butler CL, Given CA, II, Michael SJ, et al. Percutaneous sacroplasty for the treatment of sacral insufficiency fractures. *Am J Roentgenol.* 2005; 184:1956–1959.
25. Garant M. Sacroplasty: a new treatment for sacral insufficiency fracture. *J Vasc Interv Radiol.* 2002;13:1265–1267.
26. Mehling I, Hessmann MH, Rommens PM. Stabilization of fatigue fractures of the dorsal pelvis with a trans-sacral bar. Operative technique and outcome. *Injury.* 2011;43:446–451.
27. Vanderschot P, Kuppers M, Sermon A, et al. Trans-iliac-sacral-iliac bar procedure to treat insufficiency fractures of the sacrum. *Indian J Orthop.* 2009;43:245–252.
28. Tsiridis E, Upadhyay N, Gamie Z, et al. Percutaneous screw fixation for sacral insufficiency fractures: a review of three cases. *J Bone Joint Sur Br.* 2007;89:1650–1653.