Falling in the Netherlands: prevention, care, and follow-up of fall-related injury
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Chapter 2

U-Shaped Sacral Fractures; surgical treatment and quality of life


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Abstract

Background
U-shaped sacral fractures are rare and highly unstable pelvic ring fractures. They are not recognized in the standard classification systems of these fractures. The fracture pattern is associated with significant neurological injury and can lead to progressive deformity and chronic pain if not diagnosed and treated properly. In recent years a variety of surgical strategies have shown to facilitate early mobilization and reduce early mortality as compared to non-operative strategies. Poor evidence, however, has hampered the development of a standard treatment algorithm. As for the long-term morbidity, the influence of the operative treatment may be difficult to assess due to associated injury. However, evidence exists that there is a significant effect on the long-term morbidity.

Objective
This study aimed to assess the injury characteristics, choice of treatment and quality of life of U-shaped sacral fractures.

Methods
Eight polytraumatized patients with U-shaped sacral fractures were identified over a 6-year period and evaluated retrospectively. They were analyzed for fracture classification, associated injury, and injury severity. Clinical and radiological results were evaluated. Neurological outcome was retrospectively classified by Gibbons’ criteria. Long-term quality of life outcome was evaluated using the EuroQoL-6D questionnaire.

Results
The study population consists of five women and three men; with a median age was 29 years. All patients sustained severe associated injury. The Injury Severity Score ranged from 17 to 45 (median 23). The median time between trauma and definitive internal fixation was 4 days (range, 2 – 22 days). Definitive fixation included either percutaneous iliosacral screws (n=2), transsacral plate osteosynthesis (n=1) or triangular osteosynthesis with (n=4) or without transsacral plating (n=1). Early postoperative mobilization and early partial weight-bearing were encouraged when possible. Follow-up ranged from 5 to 65 months (median, 36 months). Pain, mood disorders and mobility problems mainly influenced patients’ present general health status.
**Conclusion**

U-shaped sacral fractures present a rare and heterogeneous injury. Operative treatment depended mainly on fracture type, associated spinal fractures, and the surgeon’s preference. Long-term quality of life is dominated by pain, mood disorders and moderate mobility problems.
Introduction

U-shaped sacral fractures are rare and by definition consist of bilateral longitudinal fractures in combination with a transverse fracture component within the sacral bone resulting in spino-pelvic dissociation.\(^3,10,11,28,41\) In a metabolically healthy individual, this structural disruption of the posterior pelvic ring requires high-energy injury mechanisms with severe spinal axial loading.\(^2,28,33,40\) Commonly these high-energy injury mechanisms are the result of falls (including suicidal leaps) from height, crushing injuries or motor vehicle accidents.\(^2,3,10,21,38\) Severe associated injury is virtually always present. The spino-pelvic dissociation frequently causes neurological deficits ranging from incomplete monoradiculopathies to a complete cauda equina syndrome.\(^3,5-8,15,21,27,29,31,34,37,43\) Furthermore, U-shaped sacral fractures may lead to progressive deformity and chronic pain, more so if not diagnosed and treated properly.\(^3,5-8,15,27,29,31,34,37,41,43\)

An essential indication for the diagnosis is given by a paradoxical inlet view of the upper sacrum on the standard anterior-posterior (AP-) pelvic radiograph. In addition, radiographic indicators such as a fractured L5 transverse process and a ‘stepladder sign’ indicative of anterior sacral foraminal disruption, have been identified.\(^21,30,40\) Delayed or missed diagnosis can be further prevented by a high index of suspicion based on the mechanism of injury and early radiographic imaging using sagitally reconstructed computed tomography (CAT) images.\(^21,30\)

Sacral fractures have been classified by Denis et al. into three types, depending on the sacral zone involved (Figure 1).\(^3\)

**Figure 1.** Denis classification of sacral fractures.
Fractures of this type have been subclassified by Roy-Camille et al. and modified further by Strange-Vognsen and Lebech (Figure 2).\textsuperscript{28,37} Figure 3 shows the fracture pattern in U-shaped sacral fractures.

**Figure 2.** Roy-Camille classification of zone-III-sacral fractures, as modified by Strange-Vognsen et al.

**Figure 3.** Impact force and fracture pattern in U-shaped sacral fractures.

Traditionally, conservative treatment has been first choice, also because operative treatment offered only limited capability for fracture reduction and effective stabilization.\textsuperscript{2,22} However, recent studies have demonstrated that surgical stabilization of pelvic ring injuries facilitates early mobilization, reduces
early mortality, and improves long term outcome in the polytraumatized patient compared to non-operative treatment.\textsuperscript{2,4,17,19,21,26,31,35,39,40,42} 
Due to the low incidence and heterogeneous nature of the U-shaped sacral fractures, the vast majority of individual surgeons have limited experience in treating these fractures.\textsuperscript{40} Few evidence based insights can be gathered from the current literature in this field since studies have been largely retrospective in nature and involve heterogeneous or small cohorts.\textsuperscript{1,6,8,10,15,22,29,43,44} Therefore, no general treatment paradigm for U-shaped sacral fractures has been formulated.\textsuperscript{2} 
Early realignment and fixation is thought to provide the best possible environment for safe, early mobilization of the polytraumatized patient.\textsuperscript{11,31} However, potential benefits of early surgery need to be weighed against increased risks of hemodynamic instability, severe blood loss, neurological damage and wound infection. Established techniques include iliosacral screw fixation\textsuperscript{19,26,42}, transiliac rod fixation or plating \textsuperscript{4,35,42}, local (transsacral) plate osteosynthesis\textsuperscript{17} or a combination of triangular osteosynthesis using a vertical lumbopelvic fixation and a transverse fixation of the sacrum.\textsuperscript{31} Biomechanical analysis has confirmed that triangular segmental lumbopelvic instrumentation is among the most stable methods of fixation.\textsuperscript{31,44} However, percutaneous iliosacral screw fixation is suitable in non-comminuted minimally displaced Denis Zone III fractures, Roy-Camille subtypes 1 - 3.\textsuperscript{2,21,25,27} All these operative techniques allow immediate mobilization in bed; weight-bearing, however, is commonly delayed due to the associated injury to the lower extremities.\textsuperscript{10} Complications related to lumbopelvic fixation may include superficial and deep (wound) infections, seroma formation, and problems with hardware prominence.\textsuperscript{2} In the majority of patients the severity of the injury does not allow for accurate preoperative neurological examination. Therefore, deterioration of nerve deficits or nerve injuries related to internal fixation of sacral fractures may be difficult to detect.\textsuperscript{39} Additionally, the neurological aspects and follow-up are rather scarcely commented upon in the medical records and literature. The influence of the operative treatment on the long-term morbidity following unstable sacral fractures is often difficult to assess due to the associated injury. However, there is evidence that there is still a significant effect on morbidity at one year after injury.\textsuperscript{39}
Objective

This study intended to assess the injury characteristics, choice of treatment and quality of life of U-shaped sacral fractures. In doing so we hoped to gain further insight into effects of operative treatment on the long-term morbidity in patients with U-shaped sacral fractures.

Materials and methods

Consecutive patients were selected from our institutional trauma database between 2001 and 2007. All patients who presented with a high-grade U-shaped sacral fracture (Denis zone III) were included in the study. The medical records of the included patients were reviewed retrospectively. The fractures were subclassified according to Roy-Camille and Strange-Vognsen and Lebech.

The following injury data were collected: demographics, trauma mechanism, additional injuries, and Injury Severity Score (ISS). Clinical neurological examination by a neurologist was performed if patients’ condition allowed. Preoperative imaging consisted of pelvic anterior-posterior radiographs and early CT scans. In our institution a Siemens Somatom Sensation 4-slice CT scan was used to precisely define the fracture pattern.

Neurological impairment was graded according to the classification of Gibbons et al. (Table 1). Postoperative data included the clinical and radiological assessment. Radiographic assessment of alignment, hardware position and decompression was done using standard radiography of the pelvis as well as CT scans. Additionally, multidisciplinary follow-up examination was performed by traumatologists, orthopedic surgeons and rehabilitation teams.

Table 1. The Gibbons classification of cauda equina impairment.

<table>
<thead>
<tr>
<th>Type</th>
<th>Neurological deficit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>Paresthesias only</td>
</tr>
<tr>
<td>3</td>
<td>Lower extremity motor deficit</td>
</tr>
<tr>
<td>4</td>
<td>Bowel/bladder dysfunction</td>
</tr>
</tbody>
</table>
Operative technique

All patients had initial assessment and resuscitation according to the Advanced Trauma Life Support® standards. They were kept on strict spine precautions until stabilization was performed. When sacral injury was suspected as part of complex pelvic ring dissociation, initial care focused on temporary pelvic ring reduction and stabilization. This was achieved primarily by pelvic sheet wrapping or application of a Pelvic Binder®. When indicated, the fracture was temporarily fixated with an anterior external fixator.25,31 Perisacral arterial bleeding sources, when suspected on CT scan were controlled by endovascular embolization. Initial surgical procedures if indicated, consisted of damage control procedures only.2,31

All patients received comprehensive posterior realignment with reduction and internal fixation, since an anterior external fixator alone cannot adequately stabilize the posterior pelvic ring.34 The method of fixation was individualized and consisted of either open posterior transsacral plate fixation, percutaneous sacroiliac screw fixation or open triangular lumbar sacral fixation. This was combined with transsacral plating if deemed necessary to create sufficient stability of the construct.39 In the triangular lumbar sacral fixation, the lumbar spine and central upper sacral segment were secured to the iliac bone by bilateral lumbar sacral pedicle and iliac screws interconnected with precontoured “S” shaped rods.2,31,32 Open reduction of the sacrum was achieved through direct or indirect manipulation. Indirect manipulation was done by placing terminally threaded Schanz screws into the cephalad aspects of each iliac wing and using them as joy sticks to manipulate the fracture elements.2 A sacral laminectomy was performed if an occlusion of the central canal was observed on the CT scan.39

Intra-operative radiological examination was performed using a C-arm.2 Inlet and outlet views were obtained to confirm the containment of screws within the ilium in the absence of medial and lateral penetration. Lateral and iliac oblique views confirm appropriate screw length. Fracture reduction was verified with C-arm imaging intra-operatively.2

All patients received 24 hour intra-operative antibiotic prophylaxis and low-molecular heparine as thromboprophylaxis during the complete period of immobilization.

Because of the relative rarity and heterogeneity of the injury as well as the commonly associated severe injuries, the authors’ hospital does not use a standard treatment protocol for U-shaped sacral fractures. Therefore, the postoperative mobilization regime was tailored individually.2,14,31,39 Early mobilization was encouraged, however, early weight-bearing was generally not possible because of associated injury to the lower extremities.2,14,31,39
Quality of life
The quality of life was measured with the EQ-6D questionnaire.\textsuperscript{16,36} To this questionnaire, a question was added regarding the patient’s general health status before and after treatment, and a Visual Analogue Scale (EQ-VAS) indicating the patients present health status (0 (worst) – 100 (best)). The EQ-6D is similar to the well validated EQ-5D with the addition of a cognitive dimension, assessing memory, concentration, coherence and IQ, to better describe the health status of neuropsychiatric patients.\textsuperscript{9,12,13,18} The EQ-6D was sent to all patients at the same time. This meant that the time interval between the fall and receiving the questionnaire ranged between 5 and 65 months (median, 36 months).

Results
Eight consecutive patients with Denis III fractures were identified. Table 2 lists the Roy-Camille and Strange-Vognsen fracture classifications. There were five female and three male patients. At the time of injury the median age was 29 years (range, 19-55 years). All patients suffered high-energy trauma. Mechanism of injury included suicidal leaps (n=7) and accidental falls from heights (n=1). The fall height ranged from 10 to 20m. Two of the patients were referred from regional hospitals because of either a progressive subdural hematoma or persistent hemodynamic instability. The median Injury Severity Score was 23 (range, 17-45).

Associated injury
All patients showed severe associated injuries. The most severe and most prevalent injuries are described per body region below. Three patients sustained fractures to the skull and one patient sustained a subdural hematoma. Facial fractures were present in five patients. Thoracic injuries consisted of multiple rib fractures (n=4), pneumothorax (n=1), hemopneumothorax (n=1), sternal fracture (n=1), and lung contusion (n=1). Four patients presented with a retroperitoneal hematoma and three of them required angiography and endovascular embolization. One patient showed a liver laceration. All fractures to the spinal column are listed in Table 2. Three patients showed fractures of upper extremities. These fractures included three humeral fractures, three elbow fractures (ulna), and three radial fractures. Five patients presented with calcaneal fractures of which four were bilateral. Six patients suffered fractures of the body of the pubic bone of which four on the left side and two bilaterally. Three patients suffered fractures of the acetabulum.
Neurological injury

In all patients the severity of their condition precluded early adequate evaluation of the neurological injuries. However, during secondary survey, standard digital rectal examination revealed loss of anal sphincter tone in

<table>
<thead>
<tr>
<th>Patient</th>
<th>RC class</th>
<th>Transverse fracture</th>
<th>Day exfix</th>
<th>Day intfix</th>
<th>Operative Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>S1-S2 S3-S5</td>
<td>0</td>
<td>22</td>
<td>Posterior lumbopelvic screw and rod fixation L4-os ilium AND posterior transsacral plate fixation</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>S1-S2 S4-S5</td>
<td>1</td>
<td>6</td>
<td>Posterior lumbopelvic screw and rod fixation L4-os ilium AND posterior transsacral plate fixation</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>S1-S2</td>
<td>1</td>
<td>3</td>
<td>Three iliosacral screws AND one K-wire</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>S2-S3</td>
<td>-</td>
<td>4</td>
<td>Two iliosacral screws</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>S1</td>
<td>-</td>
<td>12</td>
<td>Anterior laminectomy and spondylodesis L5-S1 AND posterior lumbopelvic rod fixation L3-os ilium AND posterior transsacral plate fixation</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>S1-S2</td>
<td>1</td>
<td>3</td>
<td>Posterior lumbopelvic screw and rod fixation L3-os ilium AND posterior transsacral plate fixation</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>S1-S2 S4-S5</td>
<td>-</td>
<td>4</td>
<td>Posterior lumbopelvic screw and rod fixation L1-os ilium</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>S2-S3</td>
<td>0</td>
<td>2</td>
<td>Posterior transsacral plate fixation</td>
</tr>
</tbody>
</table>

Table legend: RC class: Roy-Camille and Strange-Vognsen and Lebech classification:
Day ext fix/Day int fix: placement external/internal fixator in days after trauma.
one patient. In the course of the hospital stay all patients were completely evaluated neurologically. Neurological injuries of varying severity were diagnosed in all patients (Table 3). Four patients showed impaired bowel or

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**Table 2b.** Overview of fracture classification, operative treatment and associated spinal fractures.

<table>
<thead>
<tr>
<th>Reason delay</th>
<th>Associated spinal fractures</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laparotomy; internal plate fixation acetabulum; internal plate fixation radius</td>
<td>Transverse process fracture L5</td>
<td>-</td>
</tr>
<tr>
<td>External fixation bilateral distal femoral fractures; coiling bilateral epigastric arteries</td>
<td>Vertebral body fracture L1 with dissection AND Transverse process fracture L4 and L5</td>
<td>-</td>
</tr>
<tr>
<td>Unavailable</td>
<td>Stable vertebral body fracture L1 with fragment in spinal canal</td>
<td>Brace</td>
</tr>
<tr>
<td>Transfer from another hospital; hemodynamic instability; coiling hypogastric artery</td>
<td>Vertebral body L2 fracture with fragment in spinal canal AND spinous process fracture C7</td>
<td>Brace</td>
</tr>
<tr>
<td>Transfer from another hospital; hemodynamic instability, exonerate subdural hematoma, internal plate fixation radius and olecranon</td>
<td>Spondyloysis L5-S1, complete listhesis</td>
<td>See 'Operative Treatment'</td>
</tr>
<tr>
<td>Hemodynamic instability</td>
<td>Vertebral body fracture L1</td>
<td>Posterior screw and rod fixation L1-L3</td>
</tr>
<tr>
<td>External fixation femur</td>
<td>Vertebral body fracture L2</td>
<td>See 'Operative Treatment'</td>
</tr>
<tr>
<td>Internal fixation humerus</td>
<td>Transverse process fracture L5</td>
<td>-</td>
</tr>
</tbody>
</table>

**Table legend:** RC class: Roy-Camille and Strange-Vognsen and Lebech classification:
Day ext fix/Day int fix: placement external/internal fixator in days after trauma.
bladder function. Three patients developed severe sensory impairments due to a complete cauda equina syndrome and one patient developed sensory impairments due to a partial cauda equina syndrome.

Table 3. Follow-up data on neurological status, hardware removal, and quality of life.

<table>
<thead>
<tr>
<th>Patient</th>
<th>ISS</th>
<th>Gibbons Before operation</th>
<th>Gibbons Short-term</th>
<th>Gibbons Long-term</th>
<th>Follow-up (months)</th>
<th>Hardware removal</th>
<th>Comparison</th>
<th>EQ-VAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17</td>
<td>unavailable</td>
<td>3</td>
<td>2</td>
<td>70</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>24</td>
<td>unavailable</td>
<td>4</td>
<td>4</td>
<td>62</td>
<td>N</td>
<td>Equal</td>
<td>70</td>
</tr>
<tr>
<td>3</td>
<td>22</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>24</td>
<td>N</td>
<td>Improved</td>
<td>80</td>
</tr>
<tr>
<td>4</td>
<td>34</td>
<td>unavailable</td>
<td>4</td>
<td>4</td>
<td>20</td>
<td>N</td>
<td>Declined</td>
<td>70</td>
</tr>
<tr>
<td>5</td>
<td>29</td>
<td>unavailable</td>
<td>3</td>
<td>2</td>
<td>26</td>
<td>Y</td>
<td>Declined</td>
<td>50</td>
</tr>
<tr>
<td>6</td>
<td>45</td>
<td>unavailable</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>22</td>
<td>unavailable</td>
<td>4</td>
<td>3</td>
<td>12</td>
<td>N</td>
<td>Equal</td>
<td>70</td>
</tr>
<tr>
<td>8</td>
<td>22</td>
<td>unavailable</td>
<td>3</td>
<td>2</td>
<td>14</td>
<td>N</td>
<td>Declined</td>
<td>70</td>
</tr>
</tbody>
</table>

Table legend: ISS: Injury Severity Score; Comparison: current health status compared to before the injury; EQ-VAS: The quality of life according to the visual analogue scale of the EuroQol-6D.

Operative technique
An anterior external fixator was used for temporary fixation of the pelvic ring in five patients. Definitive internal fixation was undertaken between 2 and 22 days after the injury (median, 4 days). The operative technique and type of internal fixation depended on the stability of the fracture (including comminution), displacement of the fracture elements, and the surgeon’s preference. In two patients (patients 3 and 4) the relative stability of the sacral fracture and minor comminution allowed for fixation with percutaneously iliosacral screw fixation (Figure 4). Local (transsacratal) plate fixation using a 12-hole Locking Compression Plate (LCP) was performed in one patient (patient 8) with minor displacement (Figure 5).
Four patients were treated with triangular lumbosacral fixation with transsacral plating (Figure 6). These patients either suffered a multi-level sacral fracture (patients 1 and 2), a traumatic spondylolysis L5-S1 (patient 5), or an unstable sacral fracture (patient 6). In one patient (patient 7) because of an associated L2 fracture it was decided to extend the triangular lumbosacral fixation to L1 (Figure 7). The triangular fixation offered a stable construct and additional transsacral plating was deemed unnecessary.
Figure 4. Iliosacral screw fixation of the sacral fracture.

Figure legend: the arrows indicate the fracture lines.
Figure 5. Transsacral plate fixation of the sacral fracture.

Figure legend: the arrows indicate the fracture lines.
Figure 6. Triangular osteosynthesis with transsacral plate fixation of the sacral fracture.

Figure legend: the arrows indicate the fracture lines.
Figure 7. Triangular osteosynthesis of the sacral fracture.

Figure legend: the arrows indicate the fracture lines.
Postoperative course
Following definitive internal fixation, patients started early mobilization in bed and chair. Early postoperative mobilization with partial weight bearing was encouraged when the associated injury allowed it. However, full weight-bearing was delayed until 6 to 12 weeks after surgery, depending on type of fracture and associated injuries.

Fracture consolidation
Clinical and radiological assessment (anterior-posterior, lateral, inlet, and outlet radiographs of the pelvis) during the follow-up period revealed no cases with secondary loss of reduction.

Complications
Three patients showed wound healing problems. These problems resolved after surgical wash out and wound debridement and additional IV antibiotics. After this re-intervention, uneventful healing was observed in all three patients.
In three patients the hardware was removed after fracture healing had occurred. The reason for hardware removal was pain from posterior prominence of the hardware. One patient reported persistent local pain after hardware removal.
No iliac screw loosening was recorded. At the latest follow-up, no patients showed hardware failure.

Quality of life
Six of eight patients responded to the questionnaire. The remaining two patients were not available for evaluation. One of them (patient number 6) had died because of a subsequent suicide attempt six months after the U-shaped sacral fracture. Table 4 lists the results of the EQ-6D.

Table 4. Long-term quality of life and functional outcome assessed with EQ-6D questionnaires.

<table>
<thead>
<tr>
<th></th>
<th>Mobility</th>
<th>Self-care</th>
<th>Usual activities</th>
<th>Pain/disorder</th>
<th>Anxiety/depression</th>
<th>Cognition</th>
</tr>
</thead>
<tbody>
<tr>
<td>No problems/ none</td>
<td>(n) 8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Some problems/ moderate</td>
<td>(n) 5</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Severe problems/ severe</td>
<td>(n) 0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Missing</td>
<td>(n) 2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Table legend: Long term quality of life and functional outcome measured assessed with EQ-6D questionnaires (no. of patients)
All patients reported mobility problems; however, no patients were confined to bed. All patients were able to care for themselves and undertake some daily activities. Two patients reported severe pain or discomfort and half of the patients reported moderate anxiety or depression. None of the patients reported problems with cognition. Despite the severity of injury, two patients reported that their general health status had not changed compared to the time before the injury. One patient even reported better general health status than before the injury. According to this patient this was due to recovering from a pre-injury psychosis (Table 3). The median EQ-VAS score was 70 (range, 50 - 80; Table 3).

Discussion

U-shaped sacral fractures are rare injuries, even in polytraumatized patients. However, because of the distinct approach and definitive treatment, it is important that these injuries are well recognized. In our level I Trauma Center, with over 1000 trauma admissions yearly (ISS>15 = 175-200) we treated eight patients with U-shaped sacral fractures in eight years. The median age (33 years) in these patients was similar to other recent studies.\textsuperscript{2,3,10,21,31,38}  As expected, the patients all sustained high-energy trauma mechanisms that caused the specific sacral fracture. Current literature reveals that trauma mechanisms in U-shaped sacral fractures include falls, motor-vehicle accidents and crush accidents.\textsuperscript{10,21,31} In this series, however, all the patients made a fall from a great height and seven out of eight attempted to perform suicide. Furthermore, five patients sustained calcaneal fractures, of which four were bilateral. This is suggestive for the fact that all patients landed feet first, which probably is a factor in the typical aspect of the sacral fracture where the spine sort of dislocates through the pelvic ring. Furthermore it can be hypothesized that feet first landing has contributed to the survival of these patients, despite falling from extreme heights. This trauma mechanism is in line with early reports in literature.\textsuperscript{28} Despite landing on their feet, half of the patients sustained multiple rib fractures. Furthermore, seven patients sustained fractures to the humerus, ulna, or radius. These fractures probably resulted from secondary impact. The ISS is reported infrequently in literature. The ISS in this series seems to be somewhat higher than in another report.\textsuperscript{21} U-shaped sacral fractures have been classified and subclassified, however, Denis Zone III fractures remain widely heterogeneous.\textsuperscript{30,39} In our patient group we made similar observations as shown in Figures 4 and 5.
In this series, definitive fracture stabilization was performed after a median of 4 days. This period reflects the time required to optimize the patient’s physiologic status and initial treatment of multisystem injuries. Because of the relative infrequency, the variability and severity of associated injury, little evidence is available to formulate an accepted treatment paradigm. In recent years, internal fixation has shown marked benefits over non-operative treatment. For this reason all patients received operative treatment for their sacral fractures. Four different operative techniques were used, depending on the several factors. The amount of stability and comminution of the fracture, as well as the associated spinal fractures, were important factors that largely dictated the choice of operative technique.

As expected, early postoperative mobilization was frequently delayed by associated injury. A simple and frequent reason was the presence of calcaneal fractures in all patients, all but one bilateral. In our hospital patients with a calcaneal fracture are kept on a non-weight bearing regime for 8 to 12 weeks postoperatively.

The number of patients with short-term neurological deficits is in line with other series in literature. In this series, no neurophysiologic tests were used to objectively document the level of the motor nerve injury or differentiate between complete or partial nerve injuries in this study. Digital rectal examination as part of the secondary survey was used to diagnose anal sphincter function loss. However, no anal sphincter electromyography was used to confirm the diagnosis. The long-term neurological deficits reported in this series are in accordance with previous literature.

With six of eight patients who answered and returned the questionnaire, the response rate was acceptable. However, the fact that most of the patients leaped in order to attempt suicide, forces us to put the results of the questionnaire into perspective. One example is the patient who reported a better present general health status than before the fall, despite the severity of his injury. The reason for this improvement was his recovery from a psychosis. Furthermore, in this study the present mental status of the patients at the time of answering the questionnaire was not assessed. This means that the presence of another depressive disorder or psychosis can not be ruled out. Another fact is that the contribution of the pelvic trauma to the final outcome may be difficult to interpret because of the extent and severity of the associated injury. Severe associated injury, on the other hand, will always be present in these patients. It should therefore probably be considered common for patients after U-shaped sacrum fractures. Despite
these possible flaws in the quality of life measurement, the results of the questionnaire do tell us something about the long-term outcome after U-shaped sacral fractures. Important is that mobility problems are integrally present. Furthermore, pain and mood disorders seem to present the major long-term problem. Despite the pain, mood disorders, and decreased mobility, self-care and usual activities do not seem to be affected in a major way. Furthermore, reported pain, mood, and mobility problems seem to contrast with the reported present general health status on the EQ-VAS. With almost 70% this seems generally high. The EQ-6D index value of the patients was not taken into account in this study. Because of the small sample size and the high prevalence of psychiatric disorders in the cohort, the authors did not consider this index value relevant.

Aggressive and optimal care positively influences long term outcome. Despite the high percentage of self-inflicted injury and the severity of the initial trauma this is important and rewarding for both patient and treating physicians.

Limitations
This study suffers from all limitations of a retrospective study. Furthermore, it evaluates the treatment of an uncommon and still heterogeneous injury. It consists of a small sample size of only eight patients, does not present a control group, and mainly relies on comparisons with a limited number of previously published series.

Conclusion
In this study we found that U-shaped sacral fractures present a rare and still heterogeneous injury in the polytraumatized patient group. The type of operative treatment depended mainly on the nature of the fracture, associated spinal fractures, and the surgeon’s preference. Quality of life in this largely psychiatric patient group is dominated by pain, mood disorders and moderate mobility problems. Despite this, all patients were capable to care for themselves after rehabilitation and undertake the usual daily activities. The high incidence of long-term pain and mood disorders in our study group indicates that analgesic and thorough psychiatric counseling are of utmost importance.
References


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