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Direct anterior decompression of L4 and L5 nerve root in sacral fractures using the pararectus approach: a technical note

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Abstract

Purpose To describe a new surgical technique for neurolysis and decompression of L4 and L5 nerve root entrapment after vertical sacral fractures via the pararectus approach for acetabular fractures, and to present four case examples.

Patients and methods We retrospectively evaluated four patients suffering radiculopathy from entrapment of the L4 or L5 nerve root in vertical sacral fractures between January and December 2016. The mean follow-up period after surgery was 18 (range 7–27) months. All patients underwent direct decompression and neurolysis of the L4 and L5 nerve roots via the single-incision, intrapelvic, extraperitoneal pararectus approach.

Results In all patients, the L4 and L5 nerve root was successfully visualized and decompressed, proving feasibility of the pararectus approach for this indication. No patient presented with a neural tear. Complete neurologic recovery was present in one patient at last follow-up; two patients had incomplete recovery of their radiculopathy; and one patient had no improvement after nerve root decompression.

Conclusions The pararectus approach allows for sufficient visualisation and direct decompression and neurolysis of the L4 and L5 nerve root entrapped in vertical sacral fractures. Although neurologic recovery was not achieved in all patients in this small case series, the approach may be a suitable alternative to posterior approaches and other anterior approaches such as the lateral window of the ilioinguinal approach.

Keywords Vertical sacral fractures · Nerve root entrapment · Radiculopathy · Neurolysis · Pararectus approach · L4-nerve root injury · L5 nerve root injury · Anterior approach lumbar plexus

Introduction

Sacral fractures resulting from high-energy trauma are frequently associated with concomitant injury of the lumbar plexus, and range from incomplete radiculopathies to a complete cauda equine syndrome depending on the fracture pattern and dislocation [1]. As far back as 1987, Denis and colleagues [2] proposed the until today widely implemented classification system of vertical sacral fractures based on the location of the fracture (lateral to, through or medial to neural foramina; Zones I–III) and their association with neurologic injury. The prevalence of concomitant neurologic injury increases with medialization of the fracture line and presence of additional transverse sacral fractures [3]. Due to their close anatomic relationship, the L4 and L5 nerve root is commonly affected by any fracture extending into the antero-superior aspect of the sacral ala (zone I and II, spinopelvic dissociation injuries extending in sacral ala) [2, 4, 5]. The reported prevalence of neurologic injury in zone I fractures ranges from

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1.9% [6] to 5.9% [2], and from 5.8% [6] to 28.4% [2] in zone II, respectively. The mechanism of neural injury depends on the fracture pattern and dislocation. In vertical shear injuries, the nerve roots may suffer traction damage or complete tears [7]. Nerve root entrapment in the fracture itself or between the cranially dislocated sacral ala and the transverse process of L5 has been reported as an alternative cause of L5 radiculopathy [2]. Furthermore, anteriorly dislocated fracture fragments, typically seen in comminuted lateral compression type fractures, may cause compression of the L4 and L5 nerve roots in their extraforaminal course over the antero-superior aspect of the sacral ala prior to entering the true pelvis [8]. Iatrogenic L4 and L5 radiculopathy following surgical intervention may occur due to implant malpositioning or intraoperative nerve root entrapment from fracture reduction [9, 10].

As a neurologic deficit reportedly improves in up to 80% independently of treatment [11], indication and timing of surgical decompression remain a matter of debate. In case of decision for surgical intervention, neurologic structures can be released indirectly through fracture reduction or directly by decompression and neurolysis [12]. The latter is traditionally performed by means of laminectomy, foraminotomy and extraforaminal neurolysis through a classical posterior approach. However, in the context of extraforaminal L4 and L5 nerve root lesions related to fractures of the sacral ala, posterior approaches are limited by insufficient exposure of the nerve roots in their extraforaminal course over the sacral ala into the true pelvis.

We have recently extended the indication of the pararectus approach to achieve anterior exposure and neurolysis of lumbosacral plexus, particularly the L4 and L5 nerve roots in their extraforaminal course over the antero-superior aspect of the sacral ala (Fig. 1). The pararectus approach was initially described by Keel and colleagues for fixation of acetabular fractures [13]. The approach has also been described for harvesting vascularized iliac crest grafts [14].

This technical note aims at presenting the pararectus approach for visualization, exploration, decompression, and neurolysis of the lumbar plexus. Furthermore, we present four case examples with L4 and/or L5 radiculopathy from nerve root entrapment related to sacral fractures affecting zone I and zone II according to Denis et al. treated via this approach.

Patients and methods

Between January and December 2016, we treated four patients who presented with unilateral L4/L5 radiculopathy related to vertical sacral fractures sustained from high-energy trauma. For diagnostic workup, we used clinical examination and imaging studies (CT, X-ray, as well as MRI in one patient case). All patients underwent staged antero-lateral neurolysis and direct decompression of the nerve roots using the pararectus approach. The minimum follow-up was 7 (range 7–27) months. At each follow-up visit (6 weeks, 12 weeks, 6 months, 1 year, and 2 years), patients were examined clinically including the assessment of peripheral neurologic status (motor and sensory function of the affected nerve roots) [15]. We assessed fracture

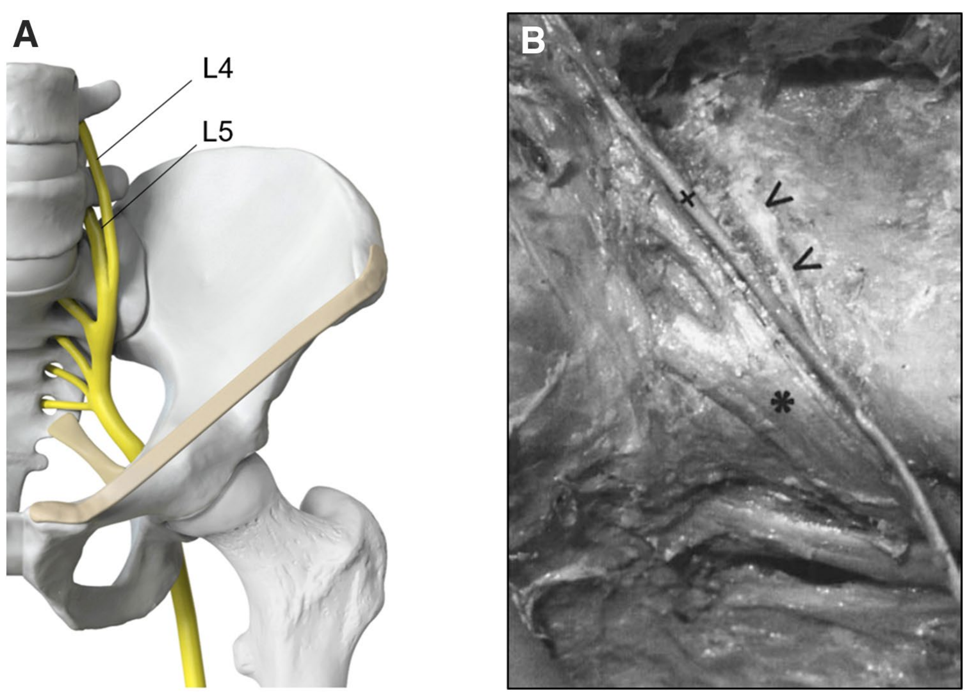

Fig. 1 **a** Anterior view of the left pelvic ring showing the course of the L4 and L5 nerve root above the shoulder of the sacrum. Image provided by Synbone. **b** Anterior view of the sacroiliac joint (<) showing the lumbosacral trunk (*) with the L4 and L5 nerves running near the joint. The obturator nerve (+) that was dissected free of its surrounding tissue lies over the sacroiliac joint [23]

healing and secondary loss of position radiographically (AP pelvis view, inlet and outlet projection, and a lateral view of the sacrum). Patient demographics are depicted in Table 1.

Surgical technique

The patient is positioned supine with appropriate padding of all contact points. The legs and thorax are draped leaving the groins caudally, the umbilicus cranially, and the anterior superior iliac spine (ASIS) laterally free for surgery. Landmarks for the skin incision include the umbilicus, ASIS, and the symphysis. A line is drawn on a point between the lateral and middle third of a line connecting the umbilicus and ASIS to a point between the medial and middle third of a line connecting the ASIS and the symphysis. In contrast to the original report by Keel et al. describing the pararectus approach for fixation of acetabular fractures [13], the incision for neurolysis of the lumbosacral plexus shifted 4–5 cm cranially (Fig. 2a). After subcutaneous dissection through the scarpa fascia, the anterior abdominal wall is exposed. The lateral border of the rectus abdominis muscle can be palpated, prior to incision of its sheath medially to its lateral border. After opening of the rectus abdominis sheath, the muscle is mobilized and retracted medially exposing the underlying transverse fascia. Depending on the individual anatomy, the cranial part of the incision can be above the arcuate line requiring incision of the deep layer of the rectus sheath prior to exposure of the transverse fascia. The transverse fascia is thereafter incised. In some cases, the inferior epigastric vessels may become visible at the caudal end of the incision. Care must be taken not to injure the epigastric vessels and the peritoneum that is located directly underneath the transverse fascia. The peritoneal sac is mobilized and gently retracted medially, thereby developing the retroperitoneal space. Continued blunt dissection in the retroperitoneal plane will expose the iliopsoas muscle laterally and the external iliac vessels medially. The external iliac vessels are followed cranially to the common iliac vessels until the arterial and venous bifurcation is visualized (Fig. 2b). Thereafter, the iliolumbar vessels are identified and ligated or clipped prior to mobilizing and retracting the common

Table 1 Patient demographics

Patient	Age (years)	Sex	Side	Mechanism of Injury	ISS (points)	Follow-up (months)
1	18	M	Left	Fall 4 m (Ski)	nd	27
2	29	F	Right	Fall 9 m (suicidal)	34	18
3	45	M	Left	Fall 30 m (crevasse)	57	18
4	49	M	Left	Traffic accident (rollover by car)	50	7 (lost to follow-up)

ISS injury severity score [28]

nd not described

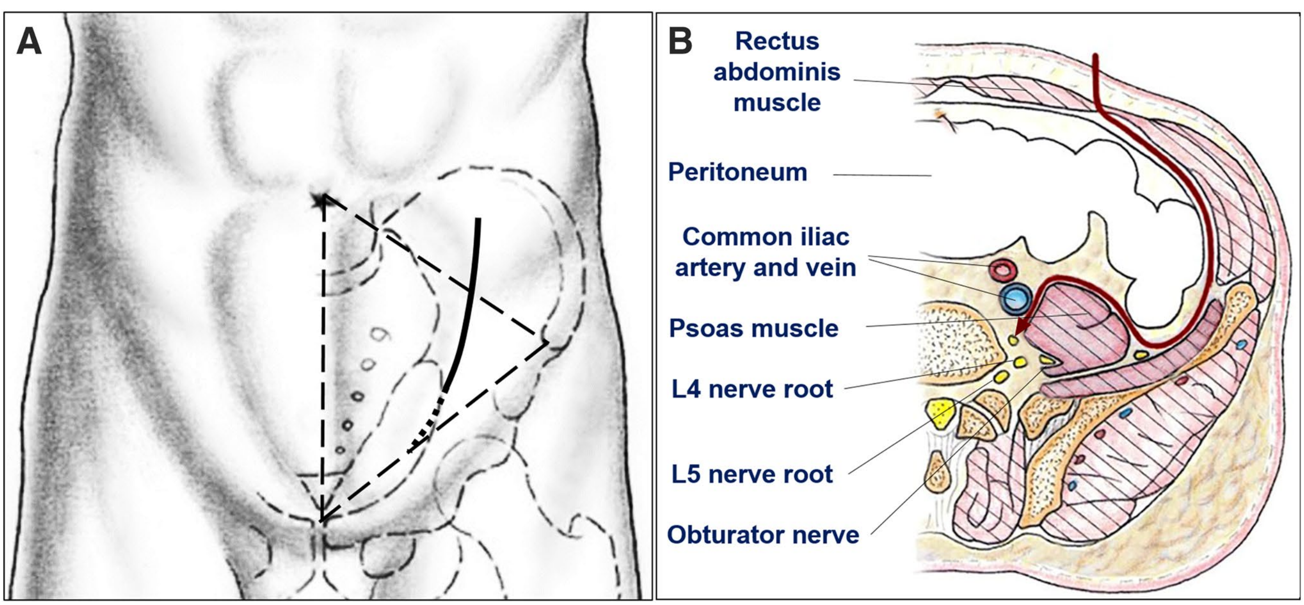

Fig. 2 **a** Landmarks and skin incision of the pararectus approach: Triangle "umbilicus—anterior superior iliac spine (ASIS)—pubic symphysis" with the 'pararectus' skin incision. **b** Scheme showing the cross-sectional anatomy at the level of the sacroiliac joint, with red arrow indicating the dissection plane within the false pelvis [13]

iliac vessels medially, thereby exposing the plane between the iliopsoas muscle and the common iliac vessels. Damage to the iliolumbar vein prior to ligation can cause severe bleeding. Note that anatomical variations of this vessel have been described previously [16]. The ureter crossing the common iliac vessels in a cranio-lateral to caudal-medial direction is also visualized and carefully retracted medially together with the iliac vessels. At this point, the fractured sacral ala is visualized alongside its overlying neural structures. These include from medially to laterally the L4 and L5 nerve root, as well as the obturator nerve. The femoral nerve runs more laterally in a plane between the psoas and iliacus muscle, and is not be visualized at this point. A ring retractor is recommended for stable exposure and comprehensive overview of the operating field. Neurolysis can be performed by liberating the nerve roots from their surrounding soft tissue, removing prominent fracture fragments compressing the nerve roots or applying traction. If the nerve roots are entrapped in the fracture, liberation can be achieved by stepwise removal of surrounding bone structures using a Kerrison punch. The L4 and L5 nerve roots can be liberated cranially towards their origin, the intervertebral foramen, and distally in their course entering the false pelvis to their junction with the S1–S3 nerve roots forming the sciatic nerve.

Case examples and results

Case 1

This 18-year-old male patient suffered a high-velocity skiing accident. He was primarily assessed in a peripheral hospital. The fracture was missed on the initial AP pelvic X-ray (Fig. 3a) and the patient was discharged without further imaging. Six weeks following the accident, the patient presented to our outpatient clinic with ongoing pain and reduced muscle strength [15] of greater toe extension (M2/5), a reduced Achilles tendon reflex, and dysesthesia of the left foot. Subsequent CT scan 6 weeks after the accident revealed a left lateral compression type I injury of the pelvis with left transforaminal sacral fracture (Denis Zone II) extending cranially into the sacral ala and a displaced free fragment at the anterior sacral cortex (Fig. 3b).

The indication for surgery was made after MRI confirmation of the entrapped L5 nerve root (Fig. 3c) via pararectus approach for inspection and neurolysis of the lumbar plexus, The L5 nerve root was compressed by a bony fracture fragment (Fig. 3e). Following neurolysis (Fig. 3f), the left sacral fracture was fixed with a percutaneous transiliac S1-screw (Fig. 3d). The patient is asymptomatic since the second postoperative day (great toe extension M5/5) (Table 2).

Case 2

This 29-year-old female patient attempted suicide jumping from 9 m height. Primary assessment was performed in a peripheral hospital. A lateral compression injury type II with lumbopelvic dissociation and a right sacral fracture (Denis Zone II), fracture of the left superior and inferior pubic ramus, and a fracture of the right acetabulum were diagnosed (Fig. 4a, d). The patient was referred to our institution for operative treatment of the pelvic fracture 3 weeks after injury; this delay was due to a traumatic pancreatitis that had to be treated first. We performed a spinopelvic fixation L4 to iliac bone, a S1 screw on the right side as well as an open reduction and internal fixation of the anterior ring and acetabulum via the Stoppa approach (Fig. 4g). On the first postoperative day, the patient developed a new dysesthesia of the L5/S1 nerve roots and an incomplete paresis of the right lower limb (Table 2). A radiograph and CT scan (Fig. 4j) showed a displacement of the anterior bone fragment as compared to the preoperative CT scan likely because of the transiliac S1 screw insertion (partial thread) and compression of the fracture. This fragment was in direct contact with the right L4 and L5 nerve roots. The revision surgery using the pararectus approach was performed 2 days after the initial procedure. Intraoperatively, a haematoma and a bony fragment were found to be compressing the L4 and L5 nerve roots. A 3 × 2-cm bone fragment, in direct contact with the nerve roots, was removed (Fig. 4m). At follow-up 18 months after surgery, the neurologic deficits improved slightly (Table 2).

Case 3

This 45 year old man fell from an approximate height of 30 m into a crevasse. After on-field intubation, he was transferred directly to our emergency unit. The patient was critically injured and presented with hypothermia (27 °C) and metabolic acidosis. He had severe abdominal injuries combined with a pelvic fracture (APC III), with a lateral fracture of the left sacrum (Denis Zone 1) and symphysis rupture (ISS 57). The pelvic ring was initially stabilized with a pelvic C-Clamp. Sedation was stopped 8 h after admission allowing for peripheral neurologic examination. Spinopelvic fixation was performed the following day (Fig. 4h). Postoperatively, the patient had a neurologic deficit of the left lower limb with L5-paraesthesia, and motor weakness of the left foot and greater toe extension (Table 2). A CT scan showed multiple bony fragments (Fig. 4k). Due to worsening of neurologic symptoms, the decision was taken to perform a nerve root decompression via the pararectus approach 8 days after initial surgery. During surgery, three bone fragments compressing the L4 and L5 nerve roots were removed. A CT scan showed the successfully removal of the bony fragment

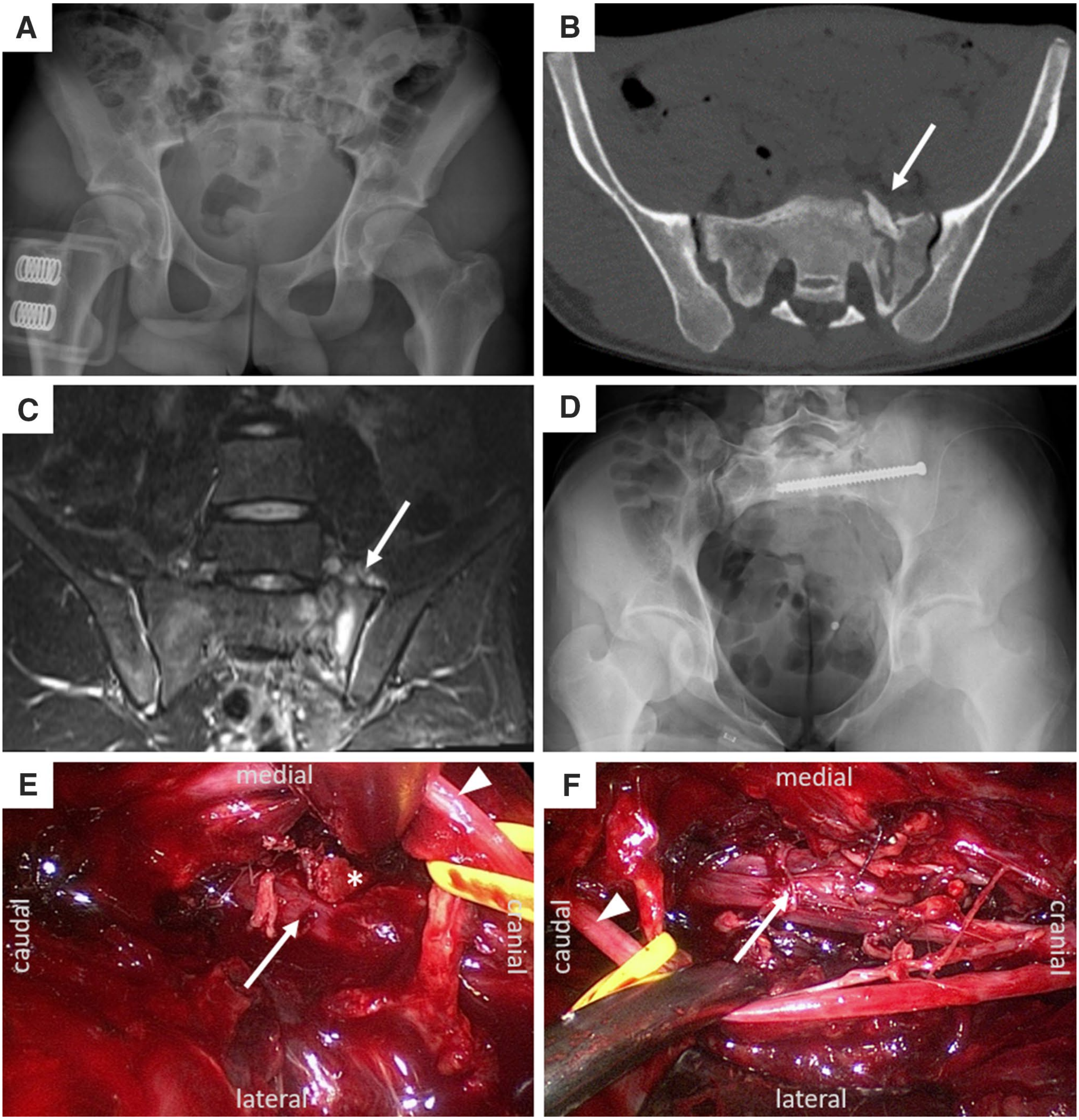

Fig. 3 Initial anteroposterior radiograph of the pelvis of an 18-year-old man after fall from height whilst skiing (patient 1). The vertical shear fracture left was not initially diagnosed. **a** Anteroposterior radiograph of the pelvis immediately after trauma revealed no major displacement of the pelvic ring. **b** CT scan was performed 6 weeks after the trauma, and revealed the left vertical shear injury with a transforaminal sacral fracture. The arrow shows the displaced bone fragment that could affected the lumbar Plexus (L5 nerve root). **c** Additional MRI scan of the pelvic was performed. The coronal view shows the vertical sacral fracture (T2 TIRM). **d** Postoperative inlet view of the pelvis showing the transiliac screw fixation. **e** Intraoperative view of the compressed left L5 nerve root by the bony fracture fragment. (Filled triangle) obturator nerve (secured by a vessel loop); (star) bony fragment; (arrow) L5 nerve root. **f** Decompressed nerve after removal of the fragment. (Filled triangle) obturator nerve (secured by a vessel loop); (star) bone fragment; (arrow) L5 nerve root

(Fig. 4n). At 28-month follow-up, these neurologic deficits showed a partial improvement (Table 2).

Case 4

This 49-year-old male patient suffered a road-traffic accident. His past medical history included intravenous

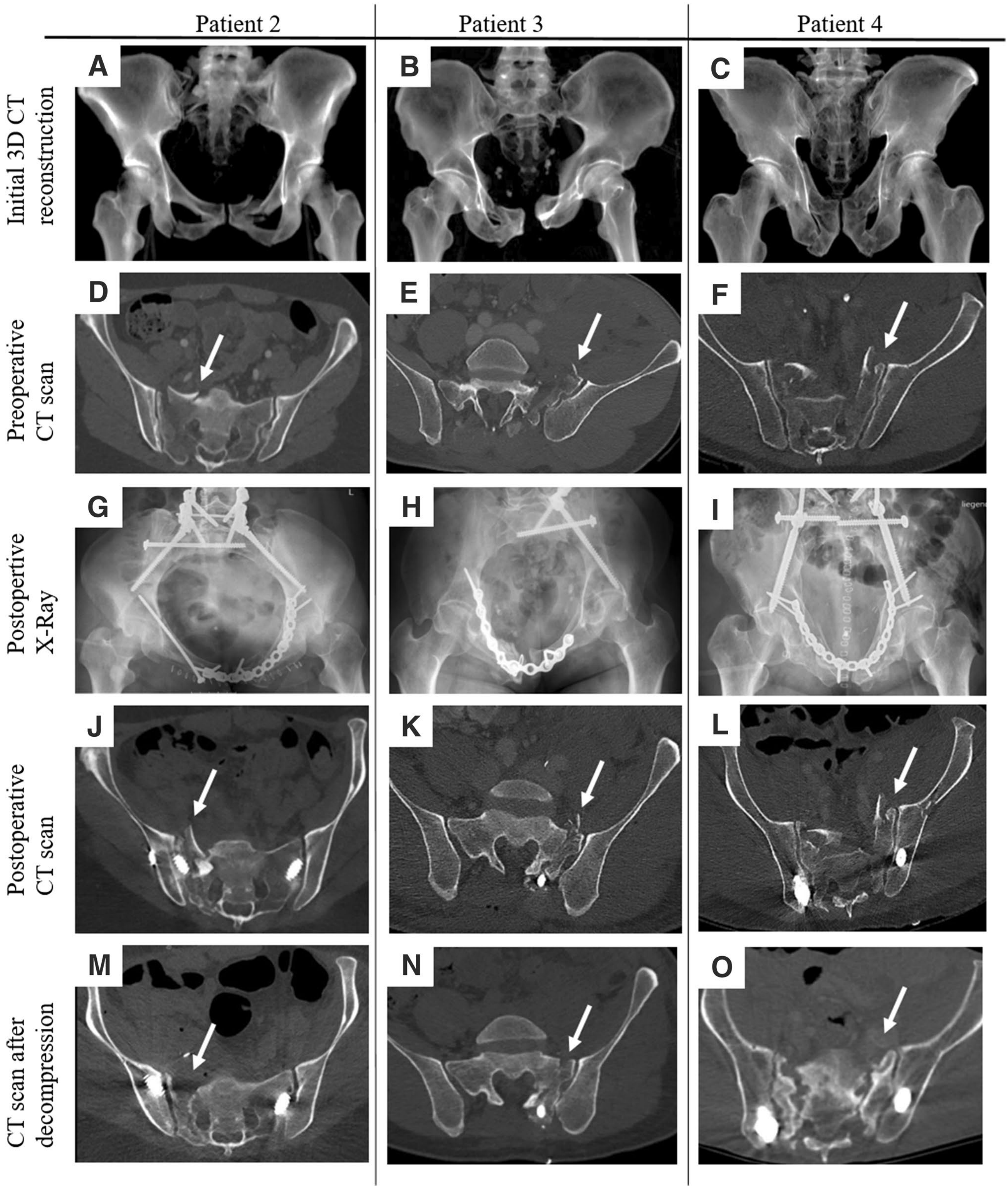

Fig. 4 Images of three similar clinical courses (patients 2–4). 3D reconstruction of the pelvis from CT scan at admission (**a**–**c**). Arrows indicating the bony fracture fragment on initial CT scan (**d**–**e**). After spinopelvic stabilization and osteosynthesis of the anterior pelvic ring (**g**–**i**), the subsequent CT scan showed a dislocation of the fracture fragment (arrow, **j**–**l**). CT scan after decompression showed the complete removal of the bony fracture fragment (**m**–**o**)

drug abuse, chronic hepatitis B, COPD, and paranoid schizophrenia. An unstable pelvic ring injury (APC III) with a sacral fracture left (Denis Zone II) was diagnosed on admission (Fig. 4c, f). Due to haemodynamic instability caused by internal haemorrhage, a C-Clamp was applied, and an explorative laparotomy (with pelvic packing due to a bleeding in this region) was undertaken. A definitive osteosynthesis of the anterior pelvic ring and the lumbopelvic stabilization was carried out 3 days after admission (Fig. 4i). Postoperatively, the patient developed sensory deficit of the left lower limb, and a motor weakness (Table 2). A CT scan showed a bony fragment, near to the left L5 nerve root (Fig. 4l). Because of the persistent neurologic deficit, a second look was carried out using the pararectus approach. Intraoperatively, a 3 × 2 × 5-mm bone fragment, which was in contact with the L5 nerve root, was removed (Fig. 4o). The nerve was exposed and showed a contusion but was intact. Several days later, a retroperitoneal hematoma developed which was surgically evacuated. The patient was discharged to a rehabilitation clinic with mobilisation by wheelchair. At follow-up 7 months postoperatively, the paresis persisted. The patient died to an unrelated cause (lost to follow-up).

Discussion

Neurologic symptoms following lateral or transforaminal fractures of the sacrum most frequently occur as a direct result of the trauma [2, 5, 12, 17–22]. Because the L4 and L5 roots are firmly attached to the sacral ala by fibrous connective tissue [23], traction injury [7] or complete tears are the most common reasons for L4 and L5 nerve root damage [24]. Nerve root entrapment in the fracture [2] or compression from bone fragments in comminuted fractures is an alternative cause of L4 and L5 radiculopathy [8]. Iatrogenic neurologic deficits following surgical procedures, on the other hand, are rarely described in the literature [9, 10, 25], and commonly refer to malpositioning of sacro-iliac screws affecting the lumbosacral trunk or the S1 spinal nerve [24]. In this context, we observed postoperative L4 and L5 radiculopathy related to sacral fractures extending in the sacral ala after fracture reduction and compression despite correct implant positioning. The role of surgical treatment of traumatic lumbosacral plexus injury is controversial with reported spontaneous recovery in up to 70–80% [7, 19]. In cases where the injury is likely caused by persisting compression in the spinal canal or the sacral foramen, an early posterior surgical decompression might be beneficial [19]. Thus, strict indication and rigorous patient selection are prerequisites for successful outcome.

There is only one case report in the literature describing surgical extraforaminal decompression and neurolysis in the context of a sacral fracture fragment abutting the L5 nerve root [8]. The decompression in this case was done by a sub-iliac approach [8]. The indication for the pararectus approach, which we routinely perform for fixation of acetabular fractures, has previously been extended for visualization, exploration, decompression, and neurolysis of the lumbosacral plexus, particularly the L4 and L5 nerve roots in their extraforaminal course over the sacral ala as they enter the true pelvis. In 2016, we treated four patients suffering L4 or L5 radiculopathy which we

Table 2 Summary of results

Patient number	Diagnosis	Main neurologic deficits	operative procedure via pararectus	Intraoperative findings	Recovery and outcome
1	Stable pelvic ring fracture left (Denis Zone II/LC I)	Left: EHL M2/5	Neurolysis of L4 and L5-nerve roots	Severe swelling of the L5 nerve root (calibre approximately 8 mm), massive cicatrisation	Left: EHL M5/5
2	Unstable pelvic ring fracture right (Denis Zone II/LC II)	Right: TA M0/5 EHL M0/5	Neurolysis L4-, L5- and obturator nerve, resection of callus and bone fragments	Severe irritation of the L4- and L5-root with partial ossifications, anterior fragment (3 × 2 cm)	Right: TA M1/5 EHL M1/5
3	Unstable pelvic ring fracture left (Denis Zone I/APC III)	Left: TA M1/5 EHL M2/5	Hematoma evacuation, neurolysis L4 and L5 nerve roots, resection of a bone fragments	Three fragments with direct contact to the L4 and L5 nerve roots	Left: TA M3/5 EHL M3/5
4	Unstable pelvic ring fracture left (Denis Zone II/APC II)	Left: TA M0/5 EHL M0/5	Neurolysis of L5 nerve root, resection of a bone fragment	Compression of the L5 nerve root by a bone fragment (3 × 2 × 5 mm)	Left: TA M0/5 EHL M0/5

Diagnosis: Young and Burgess classification of pelvic ring injuries [29], and Denis classification of sacral fractures [2]

Grade of muscle strength according to the MRC (Medical Research Council) scale [15]

LC lateral compression, *APC* anterior–posterior compression, *TA* tibialis anterior muscle, *EHL* extensor hallucis longus muscle believed to be directly related to nerve root entrapment and compression from osseous fracture comminution in sacral fractures extending into the sacral ala using the pararectus approach.

The pararectus approach has several advantages for this indication. In contrast to the first window of the ilioinguinal approach, where the visualisation of the anterior sacrum is limited due to the overlying iliopsoas muscle, the pararectus offers a direct visualisation of the L4 and L5 (and potentially S1) nerve root anterior to the sacrum. To date, only surgery for L4/L5 nerve root decompression has been performed using the pararectus approach. Extensions for decompression/exploration of the S1 nerve root or the entire lumbar and sacral plexus are possible, but are rarely needed for this indication. The pararectus approach allows safe inspection and evaluation of the integrity of the nerve root as well as removal of compressing fracture fragments. Although the approach is technically demanding, the direct visualisation of the nerve roots is a major advantage.

The technique has some risks: the chance of opening the peritoneum, as well as minor vascular damage is approximately 4% [26]. To minimize the risk of injury to the iliac vessels or thromboembolism, a ring retractor, used for a stable surgical field, should be used as shortly as possible. In addition, the pararectus approach may be unsuitable in obese patients, patient with scaring form previous abdominal surgery, abdominal distension, ileus, or bowel obstruction [26].

This study has limitations. In general, the design of this technical note with only four case examples does not allow to draw conclusions related to the indication for conservative or surgical treatment in patients suffering neurologic injury from sacral fractures. We observed full neurologic recovery in only one, partial in two and no neurologic recovery in one of the four cases at latest follow-up. In the latter case, the follow-up period was only 7 months, because the patient died unrelated to the fracture and surgical treatment. The period for neurologic revovery both with conservative or surgical treatment is reported to occur within six months [27]. Therefore, the presented follow-up period appears to be sufficient to report about this specific outcome.

Conclusions

The pararectus approach allows for excellent visualisation and direct decompression and neurolysis of the L4 and L5 nerve roots in their extraforaminal course over the antero-superior aspect of the sacral ala prior to entering the true pelvis. Although neurologic recovery was not achieved in all patients, the approach may be a suitable alternative to conservative treatment or other surgical approaches particularly in patients suffering neurologic deficit from direct compression of the lumbar plexus by nerve root entrapment resutling from vertical sacaral fractures.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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