Received: 10 May 2023 | Revised: 14 November 2023 | Accepted: 23 December 2023

DOI: 10.1111/vsu.14070

CLINICAL RESEARCH

WILEY

# Fluoroscopically-assisted closed reduction and percutaneous fixation of sacroiliac luxations in cats using 2.4 mm headless cannulated compression screws: Description, evaluation and clinical outcome

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**Abstract**

**Objective:** To describe fluoroscopically-assisted closed reduction and percutaneous fixation of sacroiliac-luxation (SIL) in cats and report radiographic results and long-term functional outcomes.

**Study design:** Retrospective clinical study.

**Animals:** Eleven cats.

**Methods:** Percutaneous fixation of 17 SILs in 11 cats was performed with 2.4 mm headless cannulated compression screws under fluoroscopic guidance. Luxation-reduction, screw placement and purchase within the sacral body, pelvic canal diameter ratio (PCDR) and hemipelvic canal width ratio (HCWR) were assessed on pre- and postoperative radiographs. Radiographic follow-up was performed to assess the same parameters when available. Long-term clinical outcome was evaluated with an owner questionnaire. Wilcoxon paired-test was performed for comparison.

**Results:** Mean age and bodyweight of the cats were $3.3 \pm 2.6$ years and $4.0 \pm 0.82$ kg, respectively. Nine cats presented with concurrent pelvic injuries. Median luxation-reduction was 94.1% (IQR = 13.9) and median screw-purchase within the sacral body was 73.3% (IQR = 17.0) immediately postoperatively. One screw exited the sacral body caudally. Upon 7-week radiographic follow-up, luxation-reduction (88.3%, IQR = 20.1) and screw-purchase (70.7%, IQR = 12.8) had decreased compared to immediately postoperatively ($p = .008$ and $p = .013$ respectively). Screw migration was not observed. PCDR and HCWR measured on postoperative radiographs indicated successful restoration of the pelvic canal width. Owners reported an excellent long-term functional outcome (mean postoperative time: $19 \pm 5$ months).

**Conclusion:** Fluoroscopically-assisted closed reduction and fixation of feline SIL using 2.4 mm headless cannulated compression screws allowed good reduction and optimal screw purchase within the sacral body. An excellent functional outcome was reported.

**Clinical significance:** Minimally invasive reduction and fixation with headless compression screws should be considered in cats with SIL.

## 1 | INTRODUCTION

Sacroiliac luxation (SIL) can affect cats of any breed, age and sex and commonly occurs secondary to trauma. In cats, 32% of fractures involve the pelvis, and 59% to 93% of pelvic bone injuries are SIL. Bilateral SIL is observed in 27% to 46% of the cases.[1,2] Due to the rigid box-like structure of the pelvis, one-sided sacroiliac fractures are always accompanied by pelvic symphysis separation and/or pubis and ischium fractures.[3] Surgery is recommended if cats are not ambulatory, display acute pain, neurological deficits, severe sacroiliac displacement or severe narrowing of the pelvic canal and if concurrent fractures of the weight-bearing axis exist.[1]

Various stabilization techniques have been described, using transarticular lag screw fixation, pins, a combination of both and tension band.[4–7] Open reduction with a dorsolateral approach to place a sacroiliac lag screw remains a popular surgical technique even though it is an invasive method and correct screw placement is hazardous. Indeed, the area available for correct screw placement is on average less than 0.5 $cm^2$ in cats, which is about 25% of the articular sacral wing surface.[8] Therefore, screw placement is reported to be correct in 33% to 87.5% of cases depending on the technique used.[9,10]

Accurate anatomical landmarks and the definition of safe corridors are necessary to achieve optimal reduction, correct screw placement, and to avoid screw exit.[8,11–14] Indeed, a dorsal exit in the vertebral canal could damage the cauda equina and a ventral exit could injure median sacral vessels and the lumbosacral plexus.[11,14] Screw exiting cranially could damage lumbosacral intervertebral disk or intervertebral foramen and first sacral nerves,[8,12] while a caudal exit may injure sacral nerves as well.[10,12]

To reduce these risks and to obtain easier and more accurate screw placement, fluoroscopically-assisted minimally invasive stabilization of SIL has been previously described in dogs and cats.[15–17] Such a minimally invasive approach has been shown to preserve surrounding soft tissues, limit pain and risks of postoperative infections and support faster functional recovery of the ipsilateral limb. Moreover, minimally invasive reduction and stabilization ensures accurate screw placement and purchase within the sacral body, thereby reducing the incidence of implant loosening and achieving accurate and long-term reduction.[15,17–19]

Fluoroscopically-assisted fixation with a cannulated screw in lag fashion has been described and evaluated in dogs,[15,18] but studies in cats alone remain rare. One study described fluoroscopically assisted fixation of a 2.4 mm cannulated screw ex vivo in cats,[16] and showed that this technique was feasible in cats. More recently, a clinical study described a minimally invasive surgical procedure for 23 SILs in cats using noncannulated lag screws, without long-term follow-up.[19] Thus, to the authors' knowledge, fluoroscopically-assisted sacroiliac reduction and fixation using a 2.4 mm headless cannulated compression screw has not previously been clinically evaluated in cats.

The first objective of our study was to describe fluoroscopically-assisted closed reduction and percutaneous fixation of SIL in cats using a 2.4 mm headless cannulated compression screw in clinical settings. The second objective was to assess immediate postoperative radiographic results. The third objective was to assess long-term functional outcomes. We hypothesized that this surgical method would be effective to obtain accurate reduction and screw purchase within the sacral body. We also hypothesized that this technique would provide a good long-term functional outcome in cats.

## 2 | MATERIALS AND METHODS

Clinical records and radiographs of all cats presented to a single veterinary surgical clinic, from October 2019 to October 2021, for surgical repair of SIL, were retrospectively reviewed. Inclusion criteria were cats with SIL repaired by fluoroscopically-assisted closed reduction and percutaneous fixation using a 2.4 mm headless cannulated compression screw with detailed clinical records, preoperative and immediate postoperative orthogonal radiographs, and at least long-term clinical outcome records. Cats with unilateral or bilateral SILs treated with an open surgical approach or with other techniques or implants were excluded. The signalment, presence of unilateral or bilateral SIL, time from onset of SIL to its surgical management and details of implants used were recorded. Peri- and postoperative major and minor complications related to SIL reduction and stabilization were also reviewed. Perioperative complications were those occurring during surgery and prior to recovery from anesthesia. Postoperative complications were those occurring after discharge from the hospital.[20] Any complication requiring a revision surgery was defined as a major complication. All other complications were defined as minor. Minor perioperative complications included unplanned conversion to open reduction and stabilization of the SIL and technical difficulties related to the instruments. Minor postoperative complications included superficial infections, postoperative pain requiring a change in the anticipated postoperative analgesia protocol, and temporary neurological deficit (including urination and defecation difficulties).

## 2.1 | Pre- and perioperative care

All procedures were performed under general anesthesia. Premedication was performed with medetomidine (10 μg/kg IV) or diazepam (0.5 mg/kg IV), combined with morphine (0.2 mg/kg IV). Induction was performed using propofol alone (2 mg/kg IV), or propofol and ketamine (2 mg/kg IV). An endotracheal tube was placed, and volatile anesthesia was maintained with isoflurane in dioxygen. Intraoperative pain management was provided by continuous rate infusion of ketamine 0.5 mg/kg/h and morphine 0.2 mg/kg/h. Each patient received surgical antibiotic prophylaxis with an injection of ampicillin and sulbactam (10 mg/kg IV) at the time of induction.

Postoperative pain was managed with morphine and buprenorphine, the dosage of which varied according to the intensity of pain experienced by the patient. Each animal also received a nonsteroidal anti-inflammatory drug meloxicam (0.3 mg/kg subcutaneously) immediately after surgery.

## 2.2 | Surgical technique

The animal was placed in lateral recumbency with the side of the SIL uppermost. Correct positioning of the cat was ensured by fluoroscopic guidance to verify superimposition of the transverse processes of the last lumbar vertebrae. If necessary, the position was maintained by a support cushion. For each fluoroscopic inspection (GE OEC compact 7700, Boston, Massachusetts), a foot switch that triggered the emission of ionizing radiation was used when the staff was outside the operating room, and thus outside the radiation exposure zone.[21] When a patient had bilateral SIL, each step was performed as previously described for each side.

All surgeries were performed by two experienced surgeons. After aseptic preparation of the surgical site, SIL was first reduced percutaneously using pointed reduction forceps applied both on the ischial tuberosity and the greater trochanter. Traction on the reduced hemipelvis was maintained until the sacroiliac joint was reduced. A first partially threaded positive profile Kirshner-wire (Synthes, West Chester, Massachusetts) was inserted percutaneously through the iliac wing and the body of the seventh lumbar vertebra using a power drill (De Soutter, Aston Clinton, UK) to temporarily stabilize the reduced SIL. Correct lateral recumbency was assessed by verifying superimposition of the iliac wings and transverse processes of the last lumbar vertebrae. Correct reduction of the SIL was evaluated by lateral and ventrodorsal fluoroscopy. A fluoroscopically-assisted small stab incision was made using a no. 11 scalpel blade at the geometric center of the sacroiliac joint. This corresponded to the intersection between the medial craniocaudal axis of the iliac wing and the medial dorsoventral axis of the ventro-cranial iliac spine.[8] A second 1.0 mm partially threaded Kirschner-wire (guide wire) was placed through the incision into the iliac wing using a power drill. The insertion of the Kirschner guide wire on the lateral surface of the ilium was located, in the craniocaudal direction, at a distance of 70% of the sacral tuber length from the cranial dorsal iliac spine. In the dorsoventral direction, it was located slightly ventral to the center of the iliac wing height measured from the sacral tuberosity.[8] Perpendicular direction of the Kirschner guide wire was fluoroscopically evaluated by superimposition of the proximal and distal ends of the Kirschner-wire into the iliac wing. Correct lateral recumbency was also verified at the same time (Figure 1). If necessary, pin placement was adjusted and reassessed using fluoroscopy. When the Kirschner guide wire was correctly positioned, it was inserted into the sacrum. Lateral and dorsoventral fluoroscopic controls were then performed to verify the Kirschner guide wire was correctly located in the described implantation corridors.[11–14] A 2.0 mm cannulated drill bit (VOI-Movora, Zurich, Switzerland) was placed over the Kirschner guide wire to perform drilling. Correct positioning of the drill bit was fluoroscopically verified, and the drill bit was removed making sure to leave the Kirschner guide wire in place. A 2.4 mm headless partially threaded and self-tapping cannulated compression screw, (VOI-Movora), was placed over the Kirschner guide wire using a cannulated shaft T8 screwdriver (VOI-Movora) fixed to a regular quick coupling handle. The correct screw length was evaluated from preoperative radiographs. Screw positioning was verified with fluoroscopy in both lateral and ventrodorsal plans. Then, the Kirschner guide wire and the temporary stabilization pin were removed. A single-stitch skin suture with an absorbable monofilament was finally performed as wound closure.

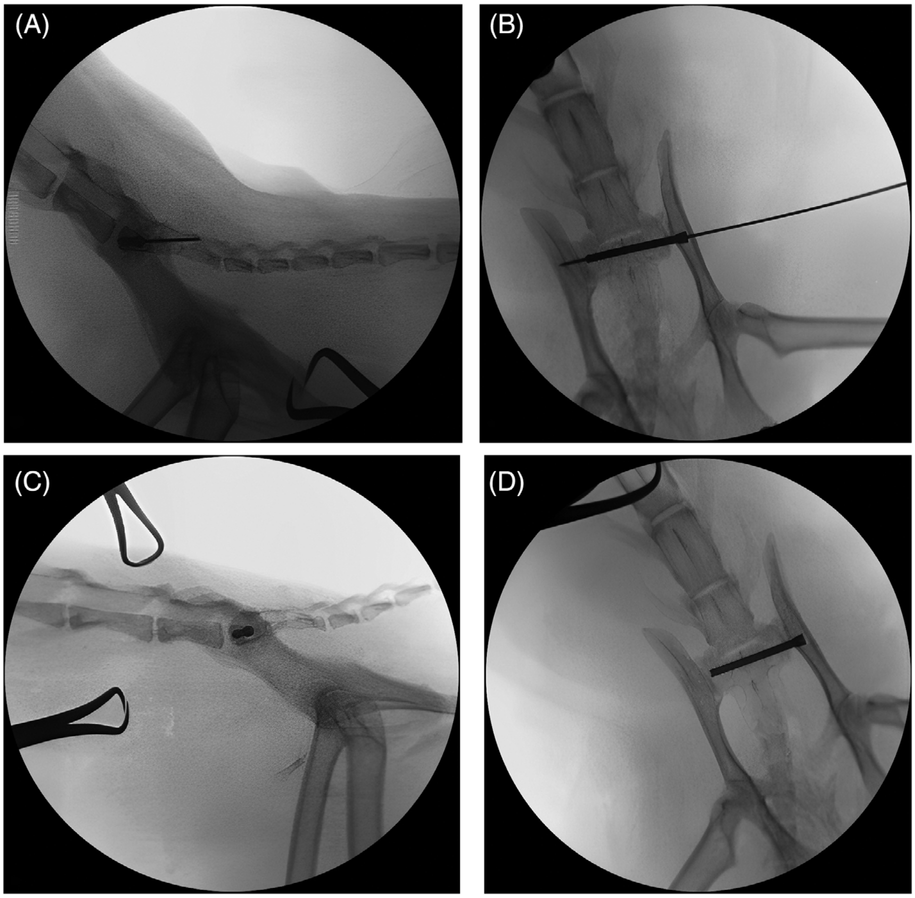


**FIGURE 1** Intraoperative fluoroscopic images to verify the screw positioning, using a fluoroscopic C-arm. Cannulated screw placed over the guide wire through the sacral body on lateral (A) and ventrodorsal (B) views, and cannulated screw through the sacral body once the guide wire is removed on lateral (C) and ventrodorsal (D) views.

### 2.3 | Radiographic evaluation

Lateral and ventrodorsal radiographs were performed preoperatively, immediately postoperatively, and at the first recheck several weeks after surgery. Initial sacroiliac joint displacement, sacroiliac joint reduction, screw purchase within the sacral body, pelvic canal diameter ratio (PCDR) and hemipelvic canal width ratio (HCWR) were assessed at each time point as previously described (Figure 2).[9,10,15,18,22] On immediate postoperative radiographs, the screw exits and their locations, on the cranial, caudal, ventral or dorsal face of the first sacral body, were recorded, according to previously established limits.[8] Optimal reduction was considered when it was >90%.[9] Optimal screw purchase within the sacral body was considered when it was >60%.[10] A PCDR $\geq$1.1 indicated the proper restoration of pelvic canal width and a HCWR value of one indicated a symmetrical pelvic canal.[18,22] The same radiographic measurements were repeated on animals presented at the clinic for a short-term postoperative follow-up. All radiographic measurements were performed by the same investigator.

### 2.4 | Follow-up

Complications were recorded by a veterinarian during postoperative clinical and radiographic examinations. The orthopedic examination parameters were also recorded. Long-term follow-up was carried out from 12 months after surgery during a phone call with the owners, using the questionnaire of the feline musculoskeletal pain index (FMPI).[23] This questionnaire was developed to assess chronic pain in cats related to joint degeneration, with questions pertaining to running, jumping, playing and interacting with congeners and owners. The 17 questions were each scored from zero to four corresponding respectively to total inability to perform the activity and completely normal behavior. The FMPI was then calculated according to the formula already described.[23] It ranged from zero to one, with a FMPI value of one meaning excellent clinical outcome. During the phone call interview, the owners were also asked about the administration of painkillers to ensure a representative evaluation of the functional outcome. The owners were asked about any urination or defecation difficulties. Finally, the owners were asked to rate

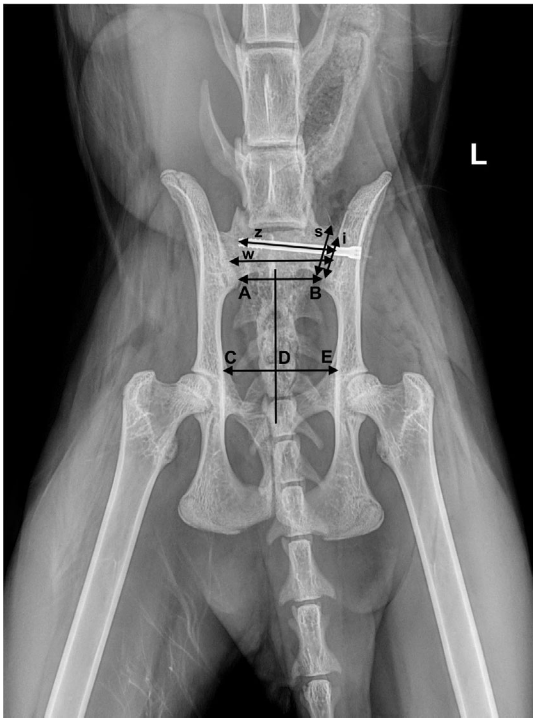


**FIGURE 2** Immediate ventrodorsal radiograph of a feline pelvis and sacrum explaining radiographic measurements. Line i represents the cranial to caudal length of the iliac surface overlapping the sacral articular surface, and line s represents the articular surface of the sacrum. Reduction was measured as line i/ line s x100. Line w represents the sacral body width, and line z represents the screw purchase within the first sacral body, with screw depth to sacral body width ratio equal to line z/line w. AB represents the width of the pelvic canal at the sacrum and CE represents the pelvic canal width at the cranial aspect of the acetabulum, with pelvic canal diameter ratio measured as CE/AB. A midline is drawn from the sacral spine to the pubic symphysis, with D the intersection point with CE. Hemipelvic canal width ratio was measured as DE/CD with DE always on the affected side.

their own appreciation on the functional outcome following surgery, on a zero-to-ten scale corresponding to a bad outcome and a full functional recovery respectively.

## 2.5 | Statistical analysis

Descriptive statistics were used for each pre- and postoperative radiographic measurement. In bilateral SIL repairs, each screw inserted was considered as a single case. A Wilcoxon paired-test was used to compare sacroiliac joint reduction, screw purchase within the sacral body, pelvic canal diameter ratio, hemipelvic canal width ratio for preoperative, immediate postoperative and short-term follow-up values using commercially available software (R). A value of $p < .05$ was considered significant. A Fisher's exact test was used to test the influence of unilateral or bilateral SIL and the existence of concomitant fractures on reduction and screw purchase. A value of $p < .05$ was considered statistically significant. Finally, a Pearson correlation test was performed to correlate patient weight, initial sacroiliac displacement, time from onset to surgery, and immediate postoperative implant purchase.

# 3 | RESULTS

A total of 11 cats were included, representing a total of 17 surgical procedures. Ten cats were conserved for long-term evaluation as one animal was lost during long-term follow-up. A supplementary short-term follow-up was obtained for eight cats. A fluoroscopically-assisted minimally invasive surgical technique was used to reduce and stabilize the SIL with a 2.4 mm headless cannulated compression screw in all cases. Five cats were females, three of which were spayed, and six were neutered males. Nine cats were European cats, one was a Siamese crossbreed cat, and one was a British Shorthair cat. The mean ($\pm$ standard deviation) age was $3.3 \pm 2.6$ years (0.75–9.5 years). The mean ($\pm$ standard deviation) weight was $4.0 \pm 0.82$ kg (2.8–5.48 kg). SIL was bilateral in six cats and unilateral in five cats, four left-sided and one right-sided. SILs were caused by traffic accidents in seven cats. One fell from a wall, and for three cases the cause was undetermined. The mean ($\pm$ standard deviation) from the onset of SIL to surgery was $3.1 \pm 2.3$ days (1–7 days). Five cats were nonambulatory on admission. Six cats were ambulatory with significant lameness, and among them, a comprehensive orthopedic examination was missing for three cats. Severe acute pain was present in all cats. Nine cats had concurrent pelvic fractures. Two cats had pelvic fractures associated with other musculoskeletal injuries, one with left talocalcaneal subluxation associated with pelvic fractures, the other with comminuted fractures of the right metatarsals II and III.

## 3.1 | Preoperative measurements

The craniocaudal displacement of the ilium relative to the sacrum was >50% for 10 SILs, with a median of 54.0% (IQR = 33.8, range [27.5%–100%]). For seven SILs, the craniocaudal displacement was <50%, and the values measured were 45.7%, 42.5%, 33.7%, 33.6%, 30.9%, 28.6% and 27.5%, respectively. The median PCDR was 1.11

(IQR = 0.21, range [0.81–1.46]). The median HCWR was 1.03 (IQR = 0.50, range [0.38–2.44]).

## 3.2 | Immediate postoperative measurements

The length of the screws used varied from 18 to 32 mm. The median sacroiliac reduction was 94.1% (IQR = 13.9, range [73.6%–100%]). Eleven reductions were ≥ 90%. On immediate postoperative radiographs, the iliac articular surface length in contact with the sacrum was higher compared to preoperative measurements ($p$-value = $7.63 \times 10^{-6}$). No correlation could be established between patient weight, time from onset to surgery, initial displacement, presence of concomitant fractures and percentage reduction. Finally, neither unilateral nor bilateral luxation had any demonstrable influence on the sacroiliac reduction.

The median screw purchase within the sacral body was 73.3% (IQR = 17.0, range [50.8%–93.2%]) with 14 screw purchases ≥ 60% (Figure 3). Two screw purchases were close to 60% (57.4% and 58.0%) and one reached only 50.8%. In one case, the screw exited caudally from the sacral body (Figure 4). No other screw exited either cranially, dorsally or ventrally from the sacral body. No correlation was found between the initial sacroiliac displacement and the screw purchase within the sacral body. Finally, neither the lateral or bilateral nature of the SIL nor the presence of concomitant fractures had any influence on screw purchase. The median PCDR was 1.16 (IQR = 0.17, range [0.92–1.66]). The median HCWR was 0.99 (IQR = 0.26, range [0.68–1.4]). Preoperative and immediate postoperative PCDR and HCWR were not different. Finally, personal dosimeters, worn by all the people present in the operating room during the surgical procedure, were sent for analysis, but values were not reported on patient records.

## 3.3 | Short-term follow-up

The short-term clinical and radiographic follow-up was available for eight cats, representing 12 SILs, as the other three cats had their short-term visit at the referring vet. It was performed on average 7 ± 2 weeks (5–10 weeks) after surgery, without general anesthesia. All cats with available clinical follow-up were ambulatory, and five of them had an unremarkable orthopedic examination. Two cats had a modified gait and another one presented with lameness of the contralateral limb affected by the SIL, associated with pain on manipulation. An aseptic

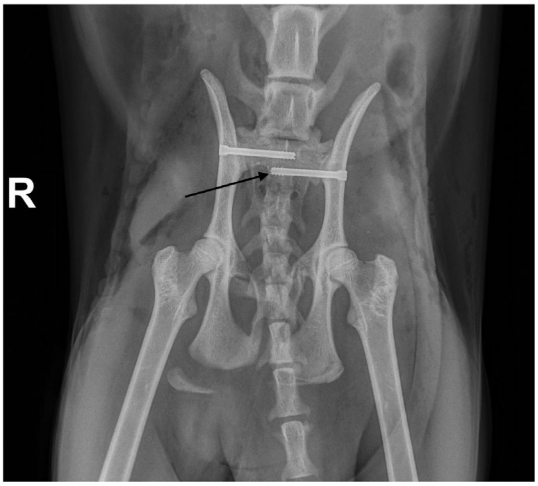


FIGURE 4 Immediate postoperative ventrodorsal radiograph after reduction and fixation of a bilateral sacroiliac luxation, revealing the left screw exiting the sacral body caudally (black arrow).

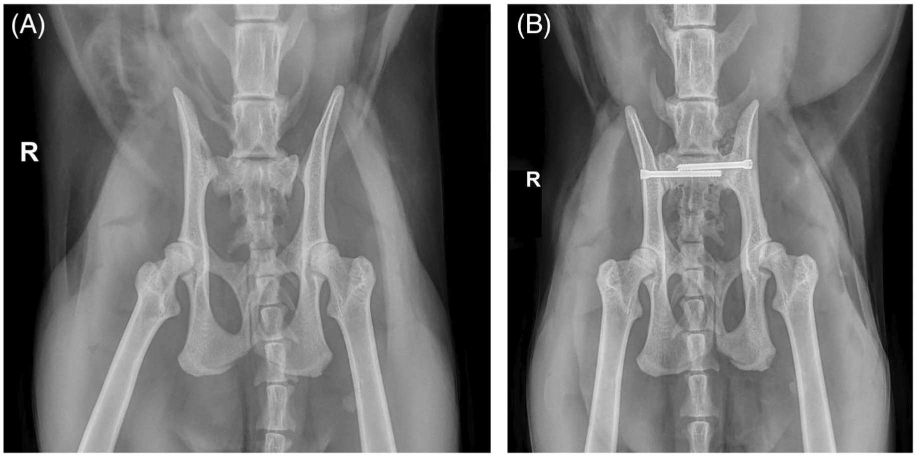


FIGURE 3 (A) Preoperative and (B) immediate postoperative ventrodorsal radiographs of the pelvis of a cat presenting bilateral sacroiliac luxation reduced and stabilized with two 2.4 mm headless cannulated screws, inserted in lag fashion under fluoroscopic guidance, resulting in an accurate placement of the screws through the body of the first sacral vertebra.

necrosis of the femoral head, unrelated to the SIL surgical procedure, was radiographically diagnosed and treated surgically. Thus, no major or minor complications were reported at the short-term follow-up. The median sacroiliac reduction was 88.3% (IQR = 20.1, range [68.8%–100%]) and six reductions were still ≥90% while six were not. Among the suboptimal reductions, three were already suboptimal in the immediate postoperative evaluation (immediate postoperative vs. short-term follow-up: 87.0% vs. 85.7%, 83.1% vs. 68.9% and 76.6% vs. 68.8%, respectively), while the other three were optimal (immediate postoperative vs. short-term follow-up: 96.3% vs. 71.2%, 94.9% vs. 77.1% and 91.2% vs. 81.0%, respectively). The immediate postoperative and short-term follow-up reductions were different ($p$-value = .008). The median screw purchase within the sacral body was 70.7% (IQR = 12.8, range [47.7%–86.0%]) and it was ≥60% for 10 SILs. One screw had already been qualified as suboptimal immediately after surgery (47.7% vs. 50.8% immediately postoperative) whereas the other one had an optimal purchase in the sacral body at the immediate postoperative radiographic assessment (55.2% vs. 63.2% immediately postoperative). The screw purchase within the sacral body was different between immediate postoperative and short-term follow-up evaluations ($p$-value = .013), with no incidence of screw loosening reported. The median PCDR was 1.15 (IQR = 0.27, range [0.90–1.34]). The median HCWR was 1.00 (IQR = 0.36, range [0.80–1.26]). There was no difference between immediate postoperative and short-term follow-up measurements for either the PCDR or the HCWR.

### 3.4 | Long-term follow-up

The long-term follow-up was carried out at least 12 months after surgery (mean time (± standard deviation) of 19 ± 5 months [13–29 months]) during a phone call interview with the owners using the FMPI questionnaire.[23] One cat could not be followed up due to the inability to contact the owners. Among the 10 cats that were included for long-term follow-up, all but one had a FMPI value ≥0.98. This cat with a much lower index value than the others (0.8 vs. 0.98, respectively) had the contralateral pelvic limb amputated before the occurrence of the SIL, causing a weight shift onto the only remaining pelvic limb affected by a SIL. No cats were under analgesic treatment at the time of the interview. In addition, urination and defecation were normal in all cats. No long-term complications directly related to the surgery were reported. Furthermore, owner satisfaction regarding functional recovery was excellent, with all cats scoring 10/10.

## 4 | DISCUSSION

This study describes and evaluates a fluoroscopically-assisted minimally invasive surgical technique using a 2.4 mm headless cannulated compression screw for the treatment of feline SIL in clinical settings. The technique allowed satisfactory SIL reduction, optimal screw purchase within the sacral body and excellent long-term functional outcomes. Therefore, our hypotheses were both accepted.

An optimal screw purchase within the sacral body is required to reduce the risk of screw loosening,[9,10] and to prevent iatrogenic damage to the structures close to the sacroiliac joint.[11] Compared to open surgeries, fluoroscopy leads to more accurate screw placement due to better control of lateral recumbency and better visualization of the insertion point and the orientation of the temporary fixation pin.[17,19,20] Accuracy is crucial in case of bilateral SILs as the first screw placed should not interfere with the contralateral screw placement. In this study, one screw exited the sacral body caudally in a case of bilateral SIL. An ex vivo study and an in vivo study in cats reported respectively 1/12 and 3/23 implanted screws exiting from the sacral body despite the use of fluoroscopy.[16,19] The screw exit observed in our study may be explained by the small space available in the sacral body to obtain an optimal placement of the two screws in case of bilateral SIL. Moreover, achieving correct placement of the guide wire may be difficult to obtain and may require several attempts in most cases. To overcome these difficulties, a novel sacroiliac luxation instrument system (SILIS) has been developed to maintain the reduction throughout the procedure, providing accurate screw placement while reducing exposure to ionizing radiation.[24] However, we did not use SILIS in this study. The screw exit may also be explained by the ongoing learning curve of the surgical technique using fluoroscopy. This underscores the importance of ensuring correct lateral recumbency throughout the entire surgical procedure to achieve optimal placement of the guide wire.[19]

A screw purchase within the sacral body >60% is recommended to decrease the risk of screw loosening.[10] In our study, the median immediate postoperative screw purchase within the sacral body was 73.3% (IQR = 17.0, range [50.8%–93.2%]), which is comparable to previous studies.[15–18,20] One screw purchase was only 50.8% as it conflicted slightly with a previously placed contralateral screw. At the short-term follow-up, the median screw purchase within the sacral body was 70.7% (IQR = 12.8, range [47.7%–86.0%]) and it was different from that measured immediately postoperatively ($p$-value = .013), but still higher than the recommended 60%. However, at the short-term follow-up, radiographs were performed without general anesthesia, resulting in suboptimal positioning, potentially impacting measurements in certain cases and possibly accounting for the results obtained. As previously described, even for screws with suboptimal purchase, no screw loosening was reported at the short-term follow-up.[18] The reduced surgical exposure and associated decrease in iatrogenic tissue damage when using closed techniques may explain that observation, even though this hypothesis needs further investigation.[10,15]

The implant used in our study was a 2.4 mm headless cannulated partially threaded compression screw. Cannulated screws allow accurate screw placement and optimal screw purchase within the sacral body, thanks to the guidance provided by a temporary pin. Cannulated cortical screws showed higher fatigue resistance compared to noncannulated screws, with fatigue being mainly dependent on the screw body diameter.[25] Moreover, it was reported that 2.4 mm diameter cannulated cortical screws had better pull-out strength than noncannulated screws in a synthetic bone model, supporting their clinical use in dogs and cats.[16,18,20,26] The use of headless compression screw in veterinary medicine is rarely reported. One cadaveric study reported no difference concerning anatomical reduction and yield loads between 3.0 mm headless compression screw constructs and 3.5 mm cortical lag screw fixation in the canine humeral condylar fracture model, supporting the efficacy of headless compression screws placed in lag fashion.[27] Partially threaded screws allow the articular surfaces of the sacrum and ilium to be compressed to each other, increasing the stability of the fixation.[16] According to the AO recommendations, the screw diameter should be around 40% of the cortical bone diameter. Considering a mean dorsoventral width at the narrowest point of the cat's sacrum of 5.9 mm, a 2.4 mm diameter screw appears appropriate (40/100 x 5.9 = 2.36 mm), explaining its previous successful use in cats.[16] In our study no screw loosening was reported, which supports the efficacity of 2.4 mm headless cannulated partially threaded compression screws for SIL fixation in cats.

Sacroiliac craniocaudal reduction is considered optimal when it is >90%.[9] The median immediate postoperative reduction in our study was 94.1% (IQR = 13.9, range [73.6%–100%]), meaning the described surgical technique is effective. Of the suboptimal reductions, one was 87.0% and was considered as near optimal, two were close to 84% (84.1%, and 83.9%, respectively), and one was 83.1%. Two others were lower (76.6% and 73.6%), and both were bilateral SILs associated with significant pubic and iliac fractures. Comparable results were previously reported in dogs and cats.[15,16,18,20] One study reported higher reduction in cats, but the luxation was artificially induced in ex vivo conditions which did not consider clinical contexts.[16] In the present study, the mean time from surgery to the short-term follow-up was 7 weeks, similar to other studies.[10,15,18] The median sacroiliac reduction at the short-term follow-up decreased from 94.1% to 88.3% (IQR = 20.1, range [68.8%–100%]), as similarly reported in dogs using fluoroscopy.[15] However, there was no screw loosening in our study during the entire follow-up period in any of the cases, as previously described.[18] This was consistent with the fact that a suboptimal reduction may not contribute to screw loosening.[10] This difference between the immediate postoperative and the short-term follow-up reduction may be related to differences in the positioning for radiographs, performed without general anesthesia at the short-term follow-up, or due to too early or strenuous return to activity.[15] As healing occurs during the first month postoperatively,[18] it is essential that the patient is kept strictly at rest during this period.

PCDR should be ≥ 1.1, indicating the proper restoration of pelvic canal width following surgery.[22] In this study, the median immediate postoperative PCDR was not significantly different from the preoperative one, which may be explained by a preoperative displacement <50% for seven SILs without consecutive pelvic canal stenosis. These cases were treated surgically because of severe acute pain, concomitant fractures or nonambulatory condition. In our study, the pelvic diameter was maintained until the sacroiliac joint healed, and PCDR values ranged from 0.90 to 1.34, which corresponds to post-healing PCDR values with no clinical signs of pelvic canal stenosis.[18,22] An HCWR value of 1, associated with PCDR, indicates a symmetrical pelvic canal and an accurate reduction.[18] The median immediate postoperative HCWR was 0.99 (IQR = 0.26, range [0.68–1.4]), and 1.00 (IQR = 0.36, range [0.80–1.26]) at the short-term follow-up, as previously reported.[15,18,20] Thus, the surgical technique used in this study achieved and secured the pelvic canal width and symmetry over time.[16,18]

Clinical examination at short-term follow-up was unremarkable except for three cats, which confirms a rapid functional recovery in most cases as previously reported.[18] At long-term evaluation, all but one cat had a FMPI value ≥ 0.98, meaning that functional recovery was excellent. For the cat that obtained a lower value of 0.8, the owners mainly reported difficulties in jumping up. However, this cat had had the contralateral pelvic limb amputated before the occurrence of the SIL, causing a weight shift onto the only remaining pelvic limb affected by a SIL.

The use of fluoroscopy requires expensive equipment, maintenance, and compliance with radiation protection protocols.[18] The duration of radiation emitted during each procedure was not recorded, but the operating room staff was outside of the operating room when radiation was emitted, reducing the exposure to direct and scattered ionizing radiation. Moreover, a cadaveric study in dogs reported that ionizing radiation absorbed by surgeons is minimal during percutaneous fluoroscopically guided lag screw fixation of SIL.[28] In this study, the only detectable exposure was located on the wrist of the dominant arm of the assistant, who maintained the reduction until the insertion of the K-wire. Clinical settings may complicate reduction and fixation, which could then increase the ionizing radiation exposure of the assistant. In our study, the staff was outside the operating room. Therefore, we can assume that the ionizing radiation absorbed by our team was less than previously reported.[28]

Our study had some limitations. Its retrospective nature may have impacted data collection and radiographic standardization leading to variations in radiographic technique between and within patients. Some follow-up radiographs were not available, and they were not taken at the same time point for each case. Moreover, the limited number of cases may be associated with significant variability between cases. This study did not compare cannulated screws with other types of implants or techniques. Despite concurrent pelvic injuries at presentation, owner assessments reported excellent long-term functional outcomes for nine out of the 10 cats included. Long-term orthopedic examination and radiographs would have objectively completed owner evaluations. A prospective randomized study would be necessary to address several of these limitations and record additional data, such as the duration of this minimally invasive surgical procedure compared to a conventional open approach and fixation. Computed tomography imaging would provide a better evaluation of both screw placement and quality of the SIL reduction.[17]

In this retrospective study, fluoroscopically assisted reduction and stabilization of feline SIL using a 2.4 mm headless cannulated compression screw ensured good reduction and optimal screw purchase within the sacral body in clinical settings. Excellent long-term functional outcomes were reported in all animals.

## AUTHOR CONTRIBUTIONS

Jourdain M, DVM: Secondary surgeon, data collection, data analysis, initial draft and manuscript review and editing. Fernandes D, DVM: Primary surgeon, study design. Védrine B, DVM, DESV: Primary surgeon, study design. Gauthier O, DVM: Study design, data analysis, scientific input and manuscript review and editing. All authors provided a critical review of the manuscript and approved the final version. All authors are aware of their respective contributions and have confidence in the integrity of all contributions.

## CONFLICT OF INTEREST STATEMENT

The authors report no financial or other conflicts of interest related to this article.

## ETHICS STATEMENT

The feasability of our technique has been previously studied. Particularly, it was assessed in a cadaveric study (Fisher et al 2012). Every owner accepted the technique to be realized on their cat.

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## REFERENCES

1. Bird FG, de Vicente F. Conservative management of sacroiliac luxation fracture in cats: medium- to long-term functional outcome. *J Feline Med Surg*. 2020;22(6):575-581.
2. Meeson RL, Geddes AT. Management and long-term outcome of pelvic fractures: a retrospective study of 43 cats. *J Feline Med Surg*. 2017;19(1):36-41.
3. Fossum TW, Cho J, Dewey CW, et al. Part three: Othopedics. *Small Animal Surgery*. 5th ed. Elsevier; 2019:1092-1095.
4. Yap FW, Dunn AL, Farrell M, Calvo I. Trans-iliac pin/-bolt/screw internal fixation for sacroiliac luxation or separation in cats: six cases. *J Feline Med Surg*. 2014;16(4):354-362.
5. Raffan PJ, Joly CL, Timm PG, Miles JE. A tension band technique for stabilisation of sacroiliac separations in cats. *J Small Anim Pract*. 2002;43(6):255-260.
6. Pratesi A, Grierson J, Moores A. Single Transsacral screw and nut stabilization of bilateral sacroiliac luxation in 20 cats. *Vet Comp Orthop Traumatol*. 2018;31(1):44-52.
7. Parslow A, Simpson DJ. Bilateral sacroiliac luxation fixation using a single transiliosacral pin: surgical technique and clinical outcomes in eight cats. *J Small Anim Pract*. 2017;58(6): 330-336.
8. Burger M, Forterre F, Brunnberg L. Surgical anatomy of the feline sacroiliac joint for lag screw fixation of sacroiliac fracture-luxation. *Vet Comp Orthop Traumatol*. 2004;17(3): 146-151.
9. DeCamp C, Braden TD. Sacroiliac fracture-separation in the dog: a study of 92 cases. *Vet Surg*. 1985;14:127-130.
10. Shales C, Moores A, Kulendra E, White C, Toscano M, Langley-Hobbs S. Stabilization of sacroiliac luxation in 40 cats using screws inserted in lag fashion: feline sacroiliac luxation. *Vet Surg*. 2010;39(6):696-700.
11. Shales CJ, White L, Langley-Hobbs SJ. Sacroiliac luxation in the cat: defining a safe corridor in the dorsoventral plane for screw insertion in lag fashion. *Vet Surg*. 2009;38(3):343-348.
12. Bowlt KL, Shales CJ. Canine sacroiliac luxation: anatomic study of the craniocaudal articular surface angulation of the sacrum to define a safe corridor in the dorsal plane for placement of screws used for fixation in lag fashion: sacral craniocaudal articular surface angulation for screw fixation. *Vet Surg*. 2011;40(1):22-26.
13. Philp H, Durand A, De Vicente F. Use of computed tomography to define a sacral safe corridor for placement of 2.7 mm

cortical screws in feline sacroiliac luxation. *J Feline Med Surg*. 2018;20(6):487-493.
14. Shales CJ, Langley-Hobbs SJ. Canine sacroiliac luxation: anatomic study of dorsoventral articular surface angulation and safe corridor for placement of screws used for lag fixation. *Vet Surg*. 2005;34(4):324-331.
15. Tonks CA, Tomlinson JL, Cook JL. Evaluation of closed reduction and screw fixation in lag fashion of sacroiliac fracture-Luxations. *Vet Surg*. 2008;37(7):603-607.
16. Fischer A, Binder E, Reif U, Biel M, Bokemeyer J, Kramer M. Closed reduction and percutaneous fixation of sacroiliac luxations in cats using 2.4 mm cannulated screws–a cadaveric study. *Vet Comp Orthop Traumatol*. 2012;25(1):22-27.
17. Déjardin L, Marturello D, Guiot L, Guillou R, DeCamp C. Comparison of open reduction versus minimally invasive surgical approaches on screw position in canine sacroiliac lag-screw fixation. *Vet Comp Orthop Traumatol*. 2016;29(4):290-297.
18. Tomlinson JL, Cook JL, Payne JT, Anderson CC, Johnson JC. Closed reduction and lag screw fixation of sacroiliac Luxations and fractures. *Vet Surg*. 1999;28(3):188-193.
19. Silveira F, Quinn R, Adrian A, Owen M, Bush M. Evaluation of the use of intra-operative radiology for open placement of lag screws for the stabilization of sacroiliac luxation in cats. *Vet Comp Orthop Traumatol*. 2017;30(1):69-74.
20. Rollins A, Balfour R, Szabo D, Chesvick CM. Evaluation of fluoroscopic-guided closed reduction versus open reduction of sacroiliac fracture-Luxations stabilized with a lag screw. *Vet Comp Orthop Traumatol*. 2019;32(6):467-474.
21. Radecki JJ, Aubert B, Cordier G, Fracas P. Implementation of the classification rules of working areas. *Radioprotection*. 2007;42(4):463-476.
22. Averill S, Schaeffer D. Risk factors associated with development of pelvic canal stenosis secondary to sacroiliac separation: 84 cases (1985-1995). *J Am Vet Med Assoc*. 1997;211:75-78.
23. Benito J, DePuy V, Hardie E, et al. Reliability and discriminatory testing of a client-based metrology instrument, feline musculoskeletal pain index (FMPI) for the evaluation of degenerative joint disease-associated pain in cats. *Vet J*. 2013;196(3):368-373.
24. Déjardin LM, Fauron AH, Guiot LP, Guillou RP. Minimally invasive lag screw fixation of sacroiliac luxation/fracture using a dedicated novel instrument system: apparatus and technique description. *Vet Surg*. 2018;47(1):93-103.
25. Merk BR, Stern SH, Cordes S, Lautenschlager EP. A fatigue life analysis of small fragment screws. *J Orthop Trauma*. 2001;15(7):494-499.
26. Kissel CG, Friedersdorf SC, Foltz DS, Snoeyink T. Comparison of pullout strength of small-diameter cannulated and solid-core screws. *J Foot Ankle Surg*. 2003;42(6):334-338.
27. Gonsalves M, Jankovits D, Huber M, Strom A, Garcia T, Stover S. Biomechanical comparison of 3.0. Mm headless compression screw and 3.5 mm cortical bone screw in a canine humeral condylar fracture model. *Vet Comp Orthop Traumatol*. 2016;29(5):353-360.
28. Naiman JH, Zellner EM, Petrovsky BL, et al. Radiation exposure associated with percutaneous fluoroscopically guided lag screw fixation for sacroiliac luxation in dogs. *Vet Surg*. 2021;50(5):1065-1075.

**How to cite this article:** Jourdain M, Fernandes D, Védrine B, Gauthier O. Fluoroscopically-assisted closed reduction and percutaneous fixation of sacroiliac luxations in cats using 2.4 mm headless cannulated compression screws: Description, evaluation and clinical outcome. *Veterinary Surgery*. 2024;53(4):603-612. doi:10.1111/vsu.14070