Closed reduction and percutaneous fixation of sacroiliac luxations in cats using 2.4 mm cannulated screws – a cadaveric study

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Sacroiliac luxation, cannulated screw, cat

Summary

Objectives: To describe fluoroscopically assisted percutaneous placement of 2.4 mm cannulated screws for fixation of artificially induced sacroiliac luxations in cats, and to evaluate the success of this technique in restoration of normal pelvic anatomy.
Methods: Fluoroscopically assisted closed reduction and percutaneous fixation of sacroiliac luxations using 2.4 mm cannulated screws was performed in cadavers of 12 cats. Pre- and postoperative radiographs and postoperative computed tomographic scans were used to evaluate screw placement, screw purchase within the sacral body, reduction of the sacroiliac joint, pelvic canal diameter ratio, and hemipelvic canal width ratio.
Results: Mean total surgical time was 6 minutes and 10 seconds ± 53 seconds and mean total time of fluoroscopic screening for each procedure was 44 seconds ± 6 seconds. Mean percent of reduction was 98.33% and mean screw purchase within the sacral body was 73%. Eleven out of 12 screws were placed in a satisfactory location in the sacral body. Pelvic canal diameter ratio and hemipelvic canal width ratio indicated successful restoration of the pelvic anatomy.
Clinical significance: Our results confirm that fluoroscopically assisted percutaneous placement of 2.4 mm cannulated screws is a feasible technique for fixation of sacroiliac luxations in cats. Mechanical properties of this fixation technique need to be evaluated before the use in clinical patients.

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Introduction

Sacroiliac fracture-luxation is a common injury in cats, accounting for 19% to 27% of pelvic bone injuries (1). Due to the rigid box-like structure of the pelvic canal, ilial displacement is always accompanied by fractures of the pubis and ischium or by separation along the pelvic symphysis (2). Surgical or conservative treatment options are available. Minor luxations with minimal instability, minimal pain, and absence of neurologic deficits or narrowing of the pelvic canal may be considered for conservative treatment (2, 3). Surgery is indicated if the cat is showing signs of pain, is non-ambulatory, displays severe neurologic deficits or severe narrowing of the pelvic canal, and if concurrent orthopaedic injuries exist (4, 5). Various surgical techniques have been described using trans-articular screws and pins alone or in combination (4, 6–9). When additional stability is required, the technique can be supplemented with a transilial implant (2, 10, 11). Fixation of bilateral sacroiliac luxations with a single trans-sacral screw or rod and nuts has been recommended (12–14). Although a ventral approach has been described, open reduction and transarticular lag screw placement by a dorsal approach remains a popular stabilization method (5, 8, 15). Open reduction techniques are invasive and correct screw placement can be challenging. Reported success rates for satisfactory screw placement using closed techniques range from 33% to 87.5% (9, 16). Accurate placement of the screw and adequate screw purchase within the sacral body with at least 60% penetration of the sacral body is important to prevent screw loosening (9, 17, 18). Anatomic landmarks and safe corridors for accurate screw placement have been described for dogs and cats (18–23).

In human medicine, minimally invasive closed reduction and percutaneous lag screw fixation of the sacroiliac joint using intraoperative fluoroscopy has increasingly gained importance in recent years and has successfully been performed in dogs as well (6, 7, 14, 24). The purpose of this study was to describe a closed reduction and percutaneous lag screw fixation technique for sacroiliac luxations in cats using 2.4 mm cannulated screws. We hypothesized that with this technique, appropriate screw placement and restoration of the pelvic canal can be achieved. First experience and results of this technique in 12 feline cadavers are reported.

Fig. 1 Ventrodorsal radiograph of a feline pelvis and sacrum. The left hemipelvis is luxated after cutting the pubic pecten and the ischiatic arch.

Fig. 2 Instrumentation set for Ø 2.4 mm cannulated screws: handle with quick coupling, 1.7 mm/0.8 mm double drill guide, cannulated screwdriver shaft Stardrive® T8, guide wire Ø 0.8 mm /length 100 mm, stainless steel washer and 26 mm long cannulated screw Ø 2.4 mm. Magnification: cannulated Stardrive® T8 head, cannulated self-drilling and self-tapping tip.

Materials and methods

Cadavers of 12 cats, euthanatized for reasons unrelated to this study, were used. The cadavers were frozen at 18°C and thawed at room temperature 48 hours before the surgical procedure. To induce the artificial sacroiliac luxation a ventral approach to a randomly selected hemipelvis was performed. The pubis and ischium was transacted cranial and caudal to the obturator foramen using bone cutting forceps. The sacroiliac joint was approached through a ventral abdominal incision, the joint capsule was incised and the isolated hemipelvis luxated manually. Ventrodorsal hip extended radiographs were used to determine preoperative grade of sacroiliac luxation (▶Fig. 1).

Surgical technique

After clipping of the surgical site the cadavers were placed in dorsal recumbency on a radiolucent operating table. The sacroiliac luxation was reduced manually using digital pressure or pointed reduction forceps[a] percutaneously applied to the ilial wing. Correct reduction of the sacroiliac joint and alignment of the slope of the hemipelvis was assessed by laterolateral and ventrodorsal fluoroscopy[b]. Once the sacroiliac joint was reduced the cats were placed in lateral recumbency with the affected side uppermost while manually maintaining the traction on the reduced hemipelvis. A fluoroscopically guided small stab incision was made with a no. 11 scalpel blade at the level of the sacral body. A 1.25 mm partially threaded Kirschner-wire[c] was placed through the ilium into the sacral body for temporary fixation of the sacroiliac joint. A 1.7 mm/0.8 mm double drill guide[d] was inserted through the stab incision and centred over the body of the first sacral vertebra. Exact lateral positioning of the cadaver was verified by superimposition of both hemipelves. Perpendicular direction of the drill sleeve was verified fluoroscopically by superimposition of the proximal and distal opening of the drill sleeve. The drill sleeve was handled using a 280 mm Kocher-Ochsner artery forceps[e] to increase the distance between the surgeon's hand and the radiographic beam. A 0.8 mm guide wire[f] was driven through the ilial wing into the sacral body in an oscillating mode. The drill sleeve was removed and the C-arm was used again to verify correct placement of the guide wire within the sacral body. If necessary, pin placement was adjusted and rechecked using fluoroscopy. A 2.4 mm partially threaded cannulated self-drilling and self-tapping cortical screw (thread Ø 2.4 mm, core Ø 1.7 mm, head Ø 3.5 mm, cannulation Ø 0.9 mm) was armed with a stainless steel washer and placed over the guide wire and inserted using a cannulated shaft T8 screwdriver[g] attached to a regular quick coupling handle (▶Fig. 2). For the study, 22 mm screws with a 10 mm thread and 26 mm screws with a 12 mm thread were available. The appropriate screw length was measured from preoperative radiographs. In the first five cats, standard 7.2 mm/ 3.2 mm steel washers from a hardware store were used as there were not any washers for 2.4 mm screws available. For the last seven cats, 4.5 mm/ 2.0 mm stainless steel washers[h] for 2 mm screws were used. Screw placement was verified fluoroscopically in

[a] Pointed reduction forceps: Synthes GmbH, Umkirch, Germany
[b] C-arm, Philips BV 25 gold: Philips GmbH, Hamburg, Germany
[c] Kirschner-wire: Synthes GmbH, Umkirch, Germany
[d] 1.7 mm/0.8 mm double drill guide: Synthes GmbH, Umkirch, Germany
[e] 280 mm Kocher-Ochsner artery forceps: Aesculap AG, Tuttlingen, Germany
[f] 0.8 mm guide wire: Synthes GmbH, Umkirch, Germany
[g] Cannulated shaft Stardrive® T8 screwdriver with coupling handle: Synthes GmbH, Umkirch, Germany
[h] 4.5 mm/2.0 mm stainless steel washers: Synthes GmbH, Umkirch, Germany

Fig. 3 **A)** Laterolateral and **B)** ventrodorsal radiographs after closed reduction and fixation of a left sided sacroiliac luxation with a 26 mm screw.

both the laterolateral and ventrodorsal plane, and the guide wire as well as the temporary fixation pin were removed. All surgical procedures were performed by one surgeon (AF). Total time needed for reduction and fixation, total time of fluoroscopic screening, and technical difficulties were noted for each cat.

After the fixation, laterolateral and ventrodorsal radiographs (▶Fig. 3 A & B) were taken and computed tomographic scans (▶Fig. 4 A-C) were performed (25). The amount of screw length within the sacral body was expressed as a percentage of the sacral width (screw length in the sacral body/sacral width x 100%) (16). Craniocaudal reduction of the sacroiliac joint was defined on ventrodorsal radiographic views as a percentage of the cranial to caudal length of the ilial joint surface in contact with the sacral articular surface (11, 16). Dorsoventral reduction was measured from postoperative computed tomographic scans at the level of the screw. Pelvic canal diameter was measured from pre- and postoperative radiographs, and hemipelvic canal width was measured from postoperative radiographs as described earlier (7) (▶Fig. 5). Results were expressed as pelvic canal diameter ratio (pelvic canal width at the cranial aspect of the acetabulum divided by the width of the sacrum) and hemipelvic canal width ratio (hemipelvic canal width of the side with the sacroiliac luxation divided by the opposite side hemipelvic width) (3). All radiographic measurements were obtained by a single investigator (AF). Wilcoxon signed-rank test was used to analyze comparison of mean pelvic canal diameter ratio for preoperative to postoperative values using commercially available software[i]. A value of $p \leq 0.05$ was considered significant.

Results

In nine cats, a 26 mm screw was used, and in three cats a 22 mm screw was used. Mean total time needed for reduction and fixation was 370 seconds ± 53 seconds and mean total time of fluoroscopic screening for each procedure was 44 seconds ± 6 seconds. Technical difficulties occurred in nine procedures. In seven cats, the position of the guide wire had to be corrected several times due to incorrect placement within the sacral body. In four cats the screws could only be partially inserted (approximately 75%) due to locking of the screw and the guide wire. After removal of the guide wire, screw insertion could be completed in all cases. Preoperative craniocaudal degree of luxation ranged from 22% to 45%, with a mean of 32.9%. The percent of craniocaudal reduction of the sacroiliac

[i] SPSS 14.0: SPSS Inc., Chicago, Illinois, USA

Fig. 4 **A)** Transverse, **B)** dorsal, and **C)** sagittal computed tomographic images after closed reduction and fixation of a right-sided sacroiliac luxation.

joint on the postoperative radiographs ranged from 90% to 100%, with a mean of 98.3%. One hundred percent of dorsoventral reduction was achieved in eight cats. In the other four cats, three had a mean of 13.6% of dorsal luxation present, and one had 15% ventral luxation of the hemipelvis. Screw length / sacral width ratio within the sacral body ranged from 51% to 100% (mean, 73.08% ± 12.18%). Eleven screws (92%) were placed in a satisfactory location within the sacral body as evaluated from the postoperative radiographs and computed tomographic scans. One screw was directed ventrally and exited the sacral body (▶Fig. 6). Mean pelvic canal diameter ratio measured from the preoperative radiographs ranged from 1.02–1.46 (mean, 1.27 ± 0.12). The same ratio measured on the postoperative radiographs ranged from 1.09–1.42 (mean, 1.25 ± 0.10). There was no significant difference in the pelvic canal diameter ratio between pre- and postoperative measurements ($p = 0.61$). The postoperative hemipelvic canal width ratio ranged from 0.92–1.04 (mean, 1.00 ± 0.04).

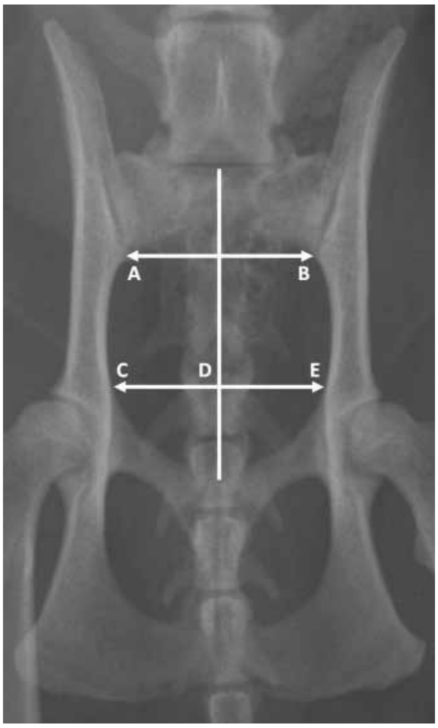

Fig. 5 Ventrodorsal radiograph of a feline pelvis and sacrum. Pelvic canal diameter ratio was measured as CE/AB. Hemipelvic canal width ratio was measured as CD/DE, whereas CD represents the luxated side.

Fig. 6 Transverse computed tomographic image after closed reduction and fixation of a left-sided sacroiliac luxation. Approximately half of the threaded part of the screw exits the sacral bone.

Discussion

We investigated a minimally invasive surgical approach for lag screw fixation of sacroiliac luxations in cats. We could demonstrate that fluoroscopically controlled percutaneous application of cannulated screws using a guide wire is a feasible technique for accurate screw placement. Eleven out of 12 screws were placed in a satisfactory location within the sacral body. Our results are comparable to the reported 87.5% accuracy achieved with open stabilization techniques (9). We classified the one screw exiting the sacral body on the ventral side as malpositioned. Stability may be significantly decreased as the threads of the screw are not fully engaged within the sacral body, however other authors considered ventral screw exit as being acceptable (9).

Accurate placement of the guide wire is the most challenging part using this technique. Several attempts were necessary in more than half of the cats to ensure correct pin placement within the centre of the sacral body. We speculate that the slope of the sacroiliac joint surfaces might redirect the small diameter pin when using too much pressure during pin insertion (23). Therefore cautious drill technique is necessary to prevent redirection of the pin.

Our results have demonstrated that acceptable dorsoventral and craniocaudal reduction can consistently be achieved with closed reduction technique (90% to 100%, with a mean of 98.33%) which is comparable to open reduction techniques. Correct reduction is best evaluated in a ventrodorsal radiographic projection, whereas correct placement of the temporary fixation pin is best achieved in a lateral projection. Therefore cats had to be rotated while maintaining the traction on the reduced hemipelvis. Our results have shown that at least in cadavers accurate reduction is achieved using this technique. In a clinical situation it might be more practical to rotate the C-arm instead of rotating the patient. Although optimal reduction of sacroiliac luxations seems not to be essential for a satisfactory clinical outcome, and does not influence incidence of screw loosening, correct anatomical reconstruction should always be aspired (9). The fact that the cadavers had simple unilateral sacroiliac luxations, no other pelvic injuries, a moderate degree of luxation, and no muscle contraction due to chronic luxation means there is a likelihood that both the reduction and the placement of the screw might be more challenging in clinical and severely traumatised patients. Therefore adequate case selection is necessary when applying this technique to clinically affected cats.

Meanwhile we would recommend using a non-threaded pin for temporary fixation as well to ensure that an oscillating drill mode can be used. Removal of the temporary fixation pin before definitive tightening of the lag screw will increase compression of the joint surfaces in cases where the pin is not completely parallel to the screw.

Previous studies have shown that accurate implant placement within the sacral body and screw purchase >60% are critical variables in preventing screw loosening in dogs and cats (6, 9, 12, 16). Two different screw lengths were used in this study and >60% screw purchase was achieved in all but one cat. In one cat, short screw selection was based on incorrect scaling of the digital radiographs and this mistake was not recognized during fluoroscopy. Based on the results of this study we recommend using screws >22 mm in length in adult cats to achieve sufficient screw purchase. No screw loosening occurred in 10 dogs with percutaneous sacroiliac lag screw fixation where the screw purchase in the sacral body was <60%. Therefore the authors assume that due to the minimal invasive approach, there is less interruption of the surrounding soft tissue structures, such that a 60% screw length/sacral width ratio may not be necessary to prevent screw loosening (7). In a clinical situation, the adequate screw length can be measured on preoperative ventrodorsal radiographs, or it can easily be determined by measuring the depth of the penetration of the guide wire using a second wire of the same length. The difference between the two wires equals the purchase of the guide wire within the sacral bone and therefore the appropriate screw length. Also, a commercially available cannulated screw measuring device[j] can be used. Compression of the sacroiliac joint increases friction between the joint surfaces, increasing stability of the fixation (12). The partially threaded shaft of the cannulated screw provides compression of the reduced sacroiliac joint. With this implant, overdrilling of the ilial wing to create a glide hole is not necessary, but decreased screw pullout properties could be due to the relative short threaded part when compared with a fully threaded screw inserted through an ilial glide hole. Several previous studies did not find any significant differences in mean pullout strength between solid and cannulated large diameter cortical screws (3.5 mm to 7.0 mm) in synthetic bone substitute and bovine and canine cortical and cancellous bone (26–30). However, strength has a linear correlation with thread length such that each additional thread inserted into the bone increased the pullout strength (30). Therefore we can assume that 12 mm threaded cannulated 2.4 mm screws of 26 mm length have greater pullout strength than 22 mm or 24 mm screws with a 10 mm thread. Interestingly a recent study revealed greater pullout strength for 2.4 mm cannulated cortical screws than their solid-core counterparts (31). The authors explained this result with drill-bit excursion and vibration which creates a pilot hole slightly larger than the actual core diameter of the screw especially in soft cancellous bone (32). In contrast, no drilling is required with the cannulated self drilling and self tapping screws, thereby maximizing the amount of thread to bone contact. According to fatigue properties cannulated cortical screws performed well relative to solid screws, thereby supporting their clinical use (33).

Diameter is reported to be the most important screw dimension for pullout strength such that pullout strength increases with increasing screw diameter (28). In cats, mean dorsoventral sacral dimension at its narrowest point is 5.9 mm (9, 23). According to the AO[k] recommendations of a 40% screw size relative to the bone diameter in cortical bone, the chosen 2.4 mm screw diameter represents an appropriate implant size for most feline sacral bones (40% of 5.9 mm = 2.36 mm) (34). Despite the cancellous composition of the sacral bone, fixation of sacroiliac luxations with cortical lag screws is a popular stabilization method (5). In a synthetic bone substitute model with properties between that of cortical and cancellous bone, 4.0 mm cancellous screws had significantly less pullout strength compared with 3.5 mm cortical screws (30).

In previous reports, 2.0 mm and 2.7 mm screws were successfully used for open reduction and stabilization of feline sacroiliac luxations (9, 17). Although we were not aware of any studies comparing the mechanical properties of 2.0 mm, 2.4 mm and 2.7 mm screws in cancellous bone, we assumed that the 2.4 mm partially threaded cannulated cortical screws inserted percutaneously can be a sufficient stabilization technique for sacroiliac luxations in cats. According to the pitch and the thread height, 2.4 mm cannulated screws are identical to solid screws of the same diameter and are in between 2.0 mm and 2.7 mm screws (pitch / thread height: 2.0 mm screw = 0.75 mm/0.6 mm; 2.4 mm screw = 1.0 mm/0.7 mm; 2.7 mm screw = 1.0 mm/0.8 mm). Additional studies would be necessary to validate a successful clinical application of 2.4 mm screws.

Pelvic canal diameter ratio was calculated to verify whether the width of the pelvic canal was re-established after surgery. Normal pelvic canal diameter ratio is ≥1.10 (3). In this study, mean pelvic canal diameter ratio measured on the postoperative radiographs ranged from 1.09 to 1.42 (mean, 1.25 ± 0.10) indicating that closed reduction and percutaneous lag screw fixation is effective in re-establishing normal pelvic canal width after artificially induced sacroiliac luxation.

Hemipelvic canal width ratio was calculated to detect lateralization or medialization of the luxated hemipelvis. Postoperative hemipelvic canal width ratio ranged from 0.92 to 1.04 (mean, 1.00 ± 0.04) indicating symmetry between the hemipelvis with the repaired sacroiliac luxation and the contralateral side (6).

The need for fluoroscopy is a potential disadvantage of closed reduction and percutaneous fixations techniques. However, with sufficient radiation protection practice, the radiation absorbed even by vascular surgeons with a high endovascular workload does not exceed the safety limits recommended by the International Commission on Radiation Protection (35). Therefore we conclude that the benefits of intraoperative fluoroscopy outweighs its potential risks.

Locking of the wire with the screw occurred in four cases and was assumed to happen due to minimal deflection and bending of the guide wire during insertion. This problem did not occur when the screw was inserted stepwise (half an anti-clockwise turn after approximately two clockwise turns). Therefore we speculate that bone debris, which are produced at the cutting flute of the screw tip, might have been trapped between the 0.8 mm guide wire and the 0.9 mm hollow core of the screw, when the screws were screwed in a continous clockwise direction. Stepwise insertion of the screws might promote clearing of bone debris from the cutting side.

Our results confirm that fluoroscopically assisted percutaneous placement of 2.4 mm cannulated screws for fixation of manually induced simple and unilateral sacroiliac luxations in cats is possible.

[j] Cannulated screw measuring device: Synthes GmbH, Umkirch, Germany

[k] AO/ASIF: AO Foundation / Association for the Study of Internal Fixation

Mechanical properties of this fixation technique and application in more complicated cases need to be evaluated before the use in clinical patients.

Conflict of interest

None declared

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