

Multi-Centre retrospective study of the long-term outcome following suspected traumatic elbow luxation in 32 cats

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OBJECTIVES: To describe reduction techniques and clinical outcome in a series of traumatic elbow luxations in cats.

MATERIALS AND METHODS: Retrospective review of unilateral elbow luxations treated at five specialist referral centres. Data included signalment, aetiology, concurrent injuries, luxation direction, time to reduction, primary reduction technique, surgical procedure and complications. Cases were excluded if reduction technique was unknown. Telephone owner questionnaire follow-up was completed using a Feline Musculoskeletal Pain Index.

RESULTS: Thirty-two cats were included. Lateral luxations were most common (n = 21). Time (hours) until attempted initial closed reduction was <24 (n = 12), 24–48 (n = 13), >48 (n = 3) or unrecorded (n = 4). Luxation was treated by closed reduction alone (n = 7) or by surgery (n = 25); 14 of 25 cases underwent primary surgical reduction and 11 of 25 were secondary procedures following failure of closed reduction. Transcondylar bone tunnels and circumferential suture (n = 19) was the most commonly used surgical technique. Catastrophic (n = 1), major (n = 11) and minor complications (n = 5) were recorded; relaxation occurred more frequently after closed reduction (n = 8) than after open reduction with fixation (n = 0). Feline Musculoskeletal Pain Index data were available for 12 cats; outcome was good-excellent in all 12, with a median function score of 64.5/68 (range: 55–68) and a median pain score of 0/15 (range: 0–5). Outcome was not associated with reduction technique.

CLINICAL SIGNIFICANCE: Elbow relaxation occurred in 61% of cats following primary closed reduction but did not occur in any open reduction cases. Relaxation rate increased with duration from injury. Most cats had good-excellent owner-assessed outcome, regardless of reduction technique.

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INTRODUCTION

Elbow luxation is an uncommon traumatic injury in cats, with indirect or direct force more commonly resulting in peri-articular

or articular fractures (Billings *et al.* 1992, Farrell *et al.* 2007, Mitchell 2011). The elbow is an intrinsically stable compound joint, with uniaxial hinge-like movement (Andersson 2004) and comprising of humeroulnar, humeroradial and proximal

radioulnar articulations (Mitchell 2011). Pronation and supination are primarily achieved through carpal motion although movement within the elbow may increase the possible range of pronation-supination (Andersson 2004). The canine elbow is optimised for parasagittal movement (Andersson 2004), with deep humeral and ulnar trochlear notches and a prominent anconeal process affording greater congruence than in the feline elbow. In dogs, engagement of the anconeal process with the olecranon fossa stabilises the elbow in extension (Bordelan *et al.* 2005, Mitchell 2011). The collateral ligaments (CLs), as primary stabilisers, limit medial and lateral elbow translation and pronation-supination (Bordelan *et al.* 2005, Mitchell 2011).

Compared with dogs, cats have increased thoracic limb dexterity, conferred by shallower trochlear furrows, larger and distally-projecting humeral trochleas and smaller anconeal processes (Andersson 2004). Additionally, feline oblique and olecranon ligaments are relatively large compared to those of dogs, and act as important secondary stabilisers (Bordelan *et al.* 2005). The feline olecranon ligament is twice the width and one-third the length of the canine olecranon ligament (Engelke *et al.* 2005). Combined, these features provide extra stability within the feline elbow against forces acting in a non-parasagittal plane. Elbow luxations thus occur secondary to high-energy indirect rotational forces. Elbow luxation can occur with an intact radioulnar joint, with radioulnar joint disruption and humeroulnar luxation, or as a Monteggia-like lesion (radial head luxation with concurrent ulna fracture) (Voss *et al.* 2009).

Elbows with an intact radioulnar joint most commonly luxate laterally, with the larger medial humeral trochlea and its more acute distal articular slope minimising medial movement (Billings *et al.* 1992, O'Brian *et al.* 1992, Guzel *et al.* 2006, Sajik *et al.* 2016). Medial (Billings *et al.* 1992) and caudal elbow luxations (Scott & McLaughlin, 2006) have also been reported in cats. In feline cadavers, injury to both the medial collateral ligament (MCL) and lateral collateral ligament (LCL) were required to enable lateral luxation of the feline elbow (Farrell *et al.* 2007). In contrast, collateral ligament rupture is identified surgically in only 18–50% of traumatic canine elbow luxations (Sajik *et al.* 2016, Krotscheck & Böttcher 2018). Mid-substance collateral ligament tears are most commonly reported (Farrell *et al.* 2007, 2009) and have been treated by primary repair with or without augmentation, using bone tunnels or screws and washers (Farrell *et al.* 2007, 2009). Campbell's test provides a non-invasive assessment of collateral ligament function by defining excessive ante-brachium rotation in collateral ligament-insufficient joints. With the elbow and carpus flexed to 90° (Campbell 1969), Farrell *et al.* (2007) demonstrated a mean pronation angle of approximately 50° and a mean supination angle of approximately 129° in feline cadaveric elbows with intact collateral ligaments. Significantly increased angles of supination and pronation have been demonstrated in cadaveric feline and canine elbows following LCL and MCL transection, respectively (Farrell *et al.* 2007).

Closed reduction is recommended for initial treatment in acute traumatic elbow luxations in cats and dogs without concurrent articular or peri-articular fractures. Excellent outcomes are reported for elbows that remain stable following closed reduction,

with no benefit of surgical stabilisation for such cases (Bordelan *et al.* 2005). The reported owner-perceived outcome for feline elbow luxation managed by closed reduction is excellent (Mitchell 2011). Chronic luxations, or those with significant concurrent intra- or peri-articular injuries are reported to have a poorer prognosis than luxations managed acutely (Bordelan *et al.* 2005).

Surgical stabilisation is undertaken in cases in which on-going instability renders closed reduction unsuccessful (as demonstrated by an abnormal Campbell's test or recurrence of the luxation). Cases in which concurrent elbow fractures preclude successful joint alignment and articulation with closed reduction must be managed as articular fractures and surgically stabilised (Piermattei & Flo 1997, Johnson & Hulse 2002, Dassler & Vasseur 2003). Previously reported techniques for surgical stabilisation of feline elbow luxations include locking sutures (Billings *et al.* 1992, Scott & McLaughlin 2006), ligament prosthesis using screws (Voss *et al.* 2009), open reduction with circumferential sutures using bone tunnels (Farrell *et al.* 2009) and transarticular pins (Scott & McLaughlin 2006). Collateral ligament stabilisation is reported to reduce the risk of reluxation, and reduce instability-associated osteoarthritis (Voss *et al.* 2009). Transarticular external skeletal fixators have also been reported to augment closed reduction in elbows with continued instability (Kalff *et al.* 2013). External coaptation is recommended following closed reduction (Johnson & Hulse 2002, Mitchell 2011) and primary collateral ligament repair (Farrell *et al.* 2009), using spica splints, support bandages or Robert Jones bandages (De Camp 2003, Mitchell 2011). Post-operative re-examination of cats that underwent open reduction demonstrated resolution of lameness and no pain response on elbow manipulation (Billings *et al.* 1992, Farrell *et al.* 2009).

While a recent multi-centre case series has outlined the long-term outcome for closed and open management of traumatic canine elbow luxations (Sajik *et al.* 2016), the corresponding literature in cats is limited to a closed reduction series (11 cats, Mitchell 2011) and case reports of open reduction (Billings *et al.* 1992, Scott & McLaughlin 2006, Farrell *et al.* 2007, 2009, Voss *et al.* 2009). Here we report the clinical findings and outcome of a multi-centre series of traumatic intact radioulnar joint feline elbow luxations managed by closed reduction or surgical stabilisation.

MATERIALS AND METHODS

The ethical and welfare committee (URN 2016 1566) granted study approval. Clinical records for cats with suspected traumatic elbow luxation at six referral institutions were reviewed (2005–2016). Elbow luxation was diagnosed as a palpable medial, lateral or caudal displacement of the radius from the humeral capitulum and ulna from the humeral trochlea and anconeal process, with associated lameness. Orthogonal radiographs were obtained to confirm disarticulation of the elbow with an intact radioulnar joint and absence of concurrent articular elbow fractures or Monteggia-like lesions. Post-procedure elbow reduction was confirmed radiographically. Data collected included signalment, aetiology, direction of luxation, time to reduction (<24 hours, 24–48 hours, >48 hours), reduction method (closed/surgical stabilisation), lig-

aments damaged, result of Campbell's testing (stable/unstable), surgical procedure, intra-/post-operative complications, concurrent injuries and use of coaptation. Where available, radiographs and radiographic reports were reviewed by the primary author. Closed reduction was defined as external manual manipulation to reduce the luxated elbow. Cats managed with closed reduction alone were defined as Group 1. Surgical stabilisation was defined as stabilisation of the luxated elbow using surgical implants, *via* open reduction or a transarticular external skeletal fixator; these cats were defined as Group 2. Surgical stabilisation was further categorised as a first-line treatment method (primary surgical stabilisation), or as a secondary procedure following failed closed reduction (secondary surgical stabilisation). Recurrence of luxation was defined as subsequent elbow luxation (as previously defined) following closed reduction. Complications were classified as catastrophic, major or minor according to definitions from Cook *et al.* (2010). Cats with more than one classification of complication were categorised into the more severe category.

Telephone questionnaire follow-up by a single investigator was attempted for all cases. The Feline Musculoskeletal Pain Index (North Carolina) (Benito *et al.* 2013) was used, with the addition of questions regarding on-going analgesic use, owner-observed lameness as a separate categorical pain score, and owner-assessed quality of life and limb function (Appendix 1).

All data were reported using descriptive statistics, with the mean values reported for normally distributed data and the median values reported for non-normally distributed data.

RESULTS

Thirty-two cats were included. Evaluation of cases was distributed between specialist referral institutions Queen Mother Hospital for Animals (Royal Veterinary College [RVC]) (n = 12), Fitzpatrick Referrals (n = 16), University of Glasgow Small Animal Hospital (n = 2) and 1 case each at Langford Veterinary Services Small Animal Hospital (University of Bristol) and Small Animal Specialist Hospital (Sydney). In three cases seen at the RVC, treatment was performed by a primary care practice (n = 2) or further referral service (n = 1) for financial reasons. Signalment data are shown in Table 1: most of the cases were male neutered domestic short hair cats (n = 23) and all elbow luxations were unilateral. Of the

13 cases with a witnessed traumatic luxation, falling from a height (n = 4) and road traffic accidents (n = 4) were the most common causes. The direction of luxation was recorded as lateral (n = 21), medial (n = 8), caudal (n = 2), or unrecorded (n = 1; craniocaudal radiographic view unavailable). Time to reduction and primary reduction method are recorded in Table 2.

Concurrent orthopaedic injuries were reported in four of 32 cases (Table 3) which affected the ipsilateral pelvic limb (Case 31) or multiple limbs (Cases 3, 10, 15). These cases underwent treatment by primary closed elbow reduction (n = 1) or secondary surgical stabilisation following failed closed reduction (n = 3). One cat without concurrent injuries (case 6) had radiographically visible pre-existing elbow osteoarthritis identified at the time of luxation diagnosis.

Management of elbow luxations is outlined in Fig. 1. Following opioid analgesia and general anaesthesia, manual closed reduction (method according to De Camp *et al.* 2016) was performed as the primary management method in 18 cases. Of these, seven were successfully managed by closed reduction alone (Group 1). Six cases managed by closed reduction alone had additional coaptation, including spica splint (n = 4), palmar splint (n = 1) and spica splint following by dressing (n = 1). Duration of coaptation was known for five cases with a median application duration of 3.5 weeks. Results of Campbell's testing of post-reduction stability are demonstrated in Fig. 2. In cats managed by primary closed reduction, Campbell's testing was accurate in predicting stability in 10 of 13 cats. When time to primary closed reduction post-injury was considered, 50% of elbows reduced in <24 hours had recurrent luxation, compared to 67% reduced within 24–48 hours and 100% reduced in >48 hours (Table 2). After reduction, cats were discharged with meloxicam analgesia. Activity was restricted to cage rest with incremental periods of supervised floor exercise over 5–8 weeks. After clinical and radiographic reassessment, activity was gradually further increased to normal levels. Passive range of motion exercises were performed from discharge in cats without coaptation or following coaptation removal in cases in which coaptation was used.

In total, 25 cases underwent surgical management of elbow luxation under opioid analgesia and general anaesthesia (Group 2). Surgical stabilisation was the primary management method in 14 cases and as secondary stabilisation in 11 cases in which primary closed reduction had failed (Fig. 1). Campbell's testing was performed in five of 14 cats that underwent primary surgical management, with all of the elbows assessed judged to be stable (Fig. 2). Campbell's testing was performed in 13 of 18 cats that underwent primary closed reduction (Fig. 2). Following primary closed reduction, five cats had elbows judged as unstable on Campbell's testing and underwent secondary surgical management (Fig. 2). Subsequent reluxation did not occur in any cases following primary or secondary surgical management. Table 4 details surgical techniques used and ligament injuries. Post-surgical coaptation (spica splint), of unknown duration, was used in two cases. After surgery, cats were discharged for home management under the same guidelines as the closed reduction cases.

Complications involving the affected limb were recorded in 17 of 32 cases (Table 5). Recurrent luxation (n = 8) was the

Table 1. Signalment data of 32 cats with suspected traumatic elbow luxation

		Total (n)
Sex	Male neutered	23
	Male entire	0
	Female neutered	9
Breed	Domestic short hair	21
	Domestic long hair, British short hair	Two of each (4)
	Domestic semi-long hair, Maine coon, ragdoll, Asian, Siberian, Bengal, Burmese	One of each (7)
		Range
Median age (months)	49	8–185
Median weight (kg)	4.49	2.9–7.70

Table 2. Time elapsed between initial injury and attempted reduction, management method and occurrence of recurrence of elbow luxation

Time to primary reduction (hours)	<24		24–48		>48		Not recorded	
Number of cats	12		13		3		4	
Primary reduction method (n)	Closed 8	Surgical 4 (1 TESF)	Closed 9	Surgical 4	Closed 1	Surgical 2	Closed 0	Surgical 4 (1 TESF)
Recurrence of elbow luxation (n)	4	0	6	0	1	0	0	4
Percentage cases with recurrence of elbow luxation (%)	50	0	67	0	100	0	–	0

Abbreviation: TESF Transarticular external fixator

Table 3. Injuries incurred by cats with traumatic elbow luxation and concurrent orthopaedic injuries

Case number	Traumatic elbow luxation	Concurrent injuries	Treatment
3	Left elbow luxation, lateral	Bilateral mandibular body fractures, split hard palate, pneumothorax, right carpal instability, left MC IV fracture, myiasis wound to tuber ischii.	Primary closed elbow reduction followed by secondary open reduction due to relaxation. Right carpal arthrodesis, BEARD, left MC IV dowel pinning.
10	Right lateral elbow luxation	Non-ambulatory tetraparetic, widening of T12-T13 intervertebral disc space, bilateral scapula body fractures. Pulmonary contusions, pleural effusion.	Primary closed elbow reduction followed by secondary open reduction due to relaxation. Conservative management of T3-L3 myelopathy and scapula fractures.
15	Caudal luxation of radius/ulna, unknown limb	Fracture of the caudal right glenoid with minimally displaced fragment, luxation, dorsal displacement and mid-diaphyseal fracture of right MC II-V. Left MC III-V diaphyseal fractures.	Primary closed elbow reduction. Right pancarpal arthrodesis. Left MC III-V dowel pinned.
31	Left lateral elbow luxation	Left hip luxation, pleural effusion.	Primary closed elbow reduction followed by secondary open reduction due to relaxation. Left hip luxation-FHNE.

Abbreviations: MC Metacarpal, BEARD Bignathic encircling and retaining device, T3-L3 3rd thoracic vertebrae to 3rd lumbar vertebral spinal segment, FHNE Femoral head and neck excision

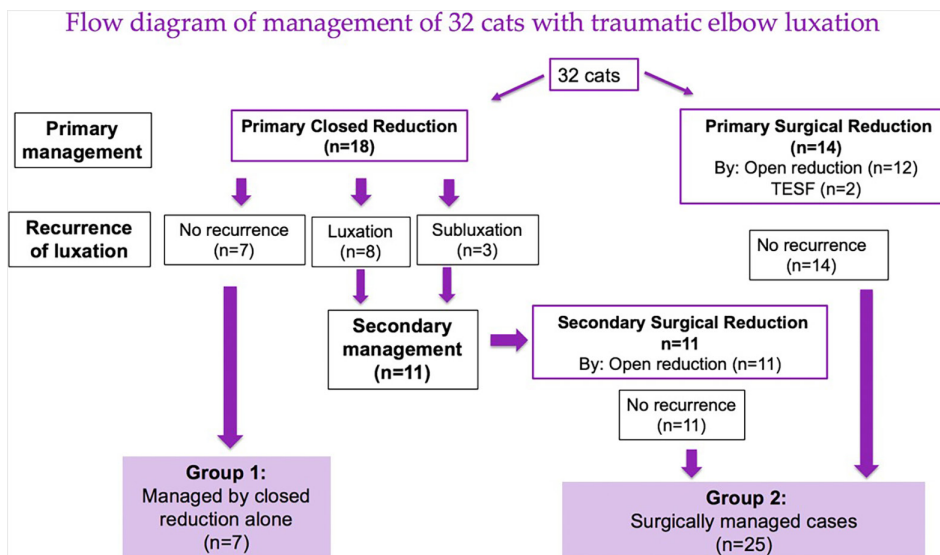


FIG 1. Flow diagram of management of 32 cats with traumatic elbow luxation

most common complication, but only occurred in cases that had undergone primary closed reduction. Closed reduction was deemed to have failed in a further three cases in which severe elbow instability persisted, requiring secondary surgical stabilisation. Overall, primary closed reduction failed in 11 of 18 cats. Of 18 cats that underwent primary closed reduction, four had concurrent injuries. Elbow relaxation occurred in three of the four cats with concurrent injuries, representing three of the 11 cats in

which primary reduction failed. Of the 14 cats that underwent primary closed reduction that did not have concurrent injuries, relaxation occurred in eight of 14 cases. By comparison, of seven cats in which primary reduction did not fail, only one had concurrent orthopaedic injuries.

Median body weight of cats in which primary closed reduction failed was greater (4.63 kg [range: 3.6–6.6 kg]) than that of cats in which primary closed reduction did not fail (4.0 kg

Flow diagram of post-reduction Campbell's test results in cats with traumatic elbow luxation

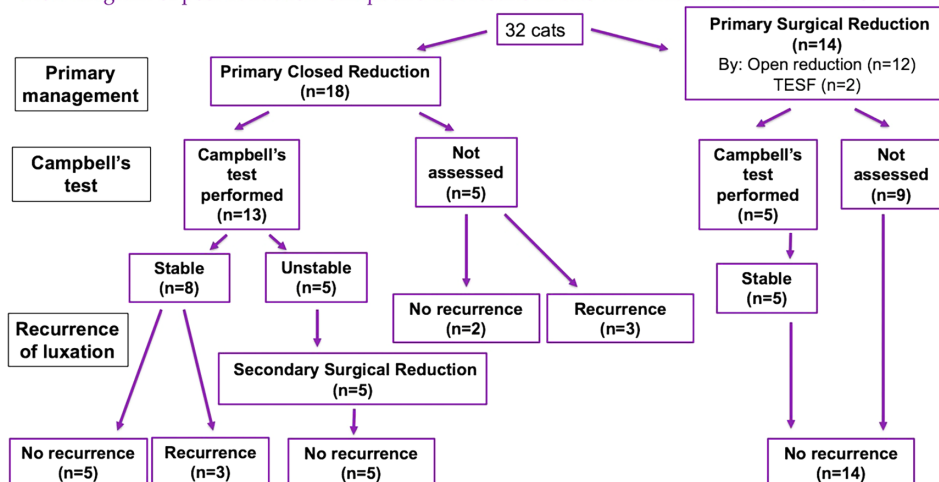


FIG 2. Flow diagram of post-reduction Campbell's test results in cats with traumatic elbow luxation

Table 4. Analysis of surgical techniques and ligament injuries in 32 cats with traumatic elbow luxation

Feature	Total number of cases	Categories					
Surgical techniques	25	Bone tunnels and biaxial collateral ligament suture prostheses ¹	TESF	Prosthetic ligament and suture	Screw and washer collateral ligament attachment		
n		19	2	2	2		
Ligament injuries	11	LCL only	MCL only	MCL & LCL	LCL & annular	LCL, MCP & annular	Unrecorded
n		5	0	4	1	1	14

Abbreviations: TESP Transarticular external skeletal fixator, LCL Lateral collateral ligament, MCL Medial collateral ligament
¹Farrell et al. 2007

Table 5. Complications occurring in 32 cats managed for traumatic elbow luxation

Total complications		Catastrophic	Major	Minor
Number of cases		1	11	5
Initial management method	Closed reduction	Severe ¹ on-going lameness without radiographic osteoarthritis or elbow instability (n = 1) [*]	Elbow luxation recurrence following initial closed reduction (n = 8) [†] Severe subluxation requiring surgery (n = 3)	Inter-digital pyoderma secondary to the spica splint and restriction in elbow range of motion (n = 1)
	Surgical reduction	0	0	Mild carpal hyperextension – no treatment required (n = 1) [^] Seroma (n = 1) Restriction in elbow range of motion following TESP (n = 1) Mild lameness at 10 weeks post-operatively (n = 1)

Abbreviation: TESP Transarticular external fixator
^{*}Cat had concurrent lateral collateral ligament injury, and had undergone open reduction with bone tunnels and biaxial collateral ligament prostheses (Farrell et al. 2007)
[†]Lameness severity according to scheme by Voss & Steffen 2009
[^]One cat had repeated elbow luxation following closed reduction, resulting in severe on-going lameness, and categorisation as a catastrophic complication

[range: 3.19–5.1 kg]). While lateral luxation was the most common direction in cats both groups, a greater proportion of cats in which closed reduction failed had medial luxation (n = 3/11) compared to those in which it did not (n = 1/7). A greater proportion of cats in which closed reduction was successful had reduction performed in less than 24 hours of injury (four of seven cats in <24 hours), compared to cats in which reluxation occurred following closed reduction (four of 11 cats in <24 hours). Coap-

tation-related soft tissue complications occurred in one of eight cases in which coaptation was used. Surgical stabilisation was required in two of eight primary closed reduction cases in which adjunctive coaptation had been used.

Follow-up was available by telephone interview only (n = 2), clinical records only (n = 14) and by both methods (n = 10) for 26 of 32 cats. Subjective follow-up through clinical records was available at a median follow up time of 1.5 months after

intervention (range: 5 days to 30 months). Cases with clinical record follow-up had undergone closed reduction ($n = 3$), primary surgical stabilisation ($n = 8$) and secondary surgical stabilisation ($n = 13$). Post-operative survival was documented in 31 of 32 cases. One polytrauma case (cat 31) was euthanised 5 days post-operatively having systemically deteriorated secondary to a hypercoagulopathy and suspected cerebral vascular accident. For 23 surviving cats with clinical record follow-up, 10 cats were reported to not be lame, with a normal range of elbow motion. Six cats were judged mildly lame (Grade 1, Voss & Steffen 2009), and a further five cats were reported to have mild restriction to elbow range of motion without lameness. Two of the cats with mildly restricted range of elbow motion were assessed immediately following transarticular external skeletal fixator removal. One cat assessed at 6 weeks following primary closed reduction was reported to be moderately lame (Grade 2, Voss & Steffen 2009), with mild discomfort on elbow manipulation and range of motion reduced by approximately 20° . One cat assessed 8 months following secondary surgical stabilisation had persistent severe lameness on the affected leg (Grade 3, Voss & Steffen 2009). Elbow flexion was 90° , with no radiographic abnormalities detected. A meloxicam trial was undertaken. Further follow-up was unavailable for these two cats. Questionnaire follow-up was not available for cats in which lameness was reported within clinical records.

Modified Feline Musculoskeletal Pain Index (FMPI) and pain score follow-up was completed by telephone for 12 cats, which were managed with primary closed reduction ($n = 3$), or bone tunnels and biaxial collateral ligament suture prostheses (Farrell *et al.* 2007) as primary surgical stabilisation ($n = 3$) and secondary surgical stabilisation ($n = 6$). Median time to questionnaire follow up was 48 months (range: 4–109 months). Median FMPI function score was 64.5/68 (range: 55–68). The function of the injured leg was described as excellent ($n = 4$), very good ($n = 3$), good ($n = 1$) or fair ($n = 1$) for surgical cases. The function of the injured leg was described as excellent ($n = 1$) or very good ($n = 2$) for cases managed by primary closed reduction. Median pain score was 0/15 (range: 0–5). Median FMPI and pain scores are shown in Table 6; scores did not differ by management technique. Quality of life was graded as excellent ($n = 10$) or good ($n = 2$).

Ten cases had both short-term follow-up available (within 3.5 months post-management) through clinical records and longer term follow-up through questionnaire data (median

48 months after intervention). Two cases had been managed by primary closed reduction and eight had been managed surgically. Eight of these cases were reported to have normal limb use at short-term follow-up, with long-term limb use reported to be excellent ($n = 5$), very good ($n = 2$) and fair ($n = 1$, case 23). One cat (case 34) with mild lameness at short-term follow-up 3 months following primary secondary stabilisation with bone tunnels was reported to have a very good long term limb function at 20 months post-operatively. One cat (case 26) with mildly restricted range of motion at transarticular external skeletal fixator removal 4 weeks post-operatively was reported to have very good limb use at 109 months post-operatively.

DISCUSSION

In this series, 32 cats with traumatic elbow luxations were treated at five specialist veterinary referral centres over an 11-year period, demonstrating that elbow luxation is a relatively rare injury. To our knowledge, this is the largest reported cohort of feline traumatic elbow luxations. The direction of luxation in this series was most commonly lateral (21 of 32 cats). While less frequently observed than lateral luxation, medial and caudal elbow luxations were also observed in this series, as previously reported in cats (Billings *et al.* 1992, Scott & McLaughlin 2006).

Recurrence of elbow luxation was the most frequent complication in this series, but only occurred following primary closed reduction. Additionally, luxation recurrence was associated with increased injury duration before initial closed reduction. Muscle contraction has been proposed to increase the difficulty in manual closed elbow reduction with injury chronicity (De Camp *et al.* 2016). Traction of contracted muscles on the reduced joint may result in a less stable joint after reduction and increase the risk of luxation recurrence. There was no recurrence in any cat that had undergone primary surgical reduction or secondary surgical reduction following failure of primary closed reduction. As none of the cats in this series were managed with repeated closed reduction following luxation recurrence, we cannot comment on the success of that alternative strategy.

Forced early loading of the affected limb because of concurrent orthopaedic injuries has been proposed to worsen outcome for patients with elbow luxation (Mitchell 2011, Sajik *et al.* 2016). Following initial primary closed reduction, reluxation occurred in three of four cats with concurrent injuries, compared with 11 of 14 cats without concurrent injuries. No cat with concurrent orthopaedic injuries was managed with initial surgical reduction, making comparison of this factor alone complicated. In Case 3, secondary surgical stabilisation of the luxated elbow was successful, but contralateral pancarpal arthrodesis infection and implant failure resulted in contralateral thoracic limb amputation. It would therefore seem appropriate that cats with elbow luxation and concurrent injuries are managed with primary surgical stabilisation rather than primary closed reduction to reduce the risk of complications affecting the luxated elbow or the concurrent injuries. Surgical management also appears favourable in cats without concurrent injuries when compared to a reluxation rate of more

Table 6. Outcome parameters by elbow luxation management technique

Outcome parameter	Elbow luxation management technique		
	Primary closed reduction	Primary surgical stabilisation	Secondary surgical stabilisation
Number of cats	3	3	6
Median FMPI function score	66	63	65.5
Median pain score	0	1	0

Abbreviation: FMPI Feline Musculoskeletal Pain Index (Benito *et al.* 2013)

than 50% following primary closed reduction. Owners should be counselled that primary surgical stabilisation of feline elbow luxation is associated with a lower relaxation rate (zero in this series) than primary closed reduction (>60% in this series). However, in the event that surgical stabilisation is not undertaken, this series demonstrates that many cats with traumatic elbow luxation can be successfully managed with primary closed reduction.

In canine traumatic elbow luxation cases managed by primary closed reduction, reoccurrence of luxation was reported in 29% of dogs (Sajik *et al.* 2016). It is considered likely that the increased frequency of relaxation following primary closed reduction in the feline elbow compared to canine elbow reflects the relatively increased severity of damage to the collateral ligaments in the cats (Farrell *et al.* 2007). Cadaveric studies have demonstrated that 83% of canine elbows luxate following transection of the lateral collateral ligament alone, whereas feline elbow luxation requires transection of both the medial and the lateral collateral ligaments (Farrell *et al.* 2007). Ligament damage was inconsistently recorded in these surgically-managed cases and cannot be confirmed in cases undergoing closed reduction alone, preventing analysis of the severity of ligament damage as a risk factor for relaxation.

Our data demonstrate increased frequency of recurrent luxation in feline elbows undergoing primary closed reduction (~60%) compared to those managed by primary (0%) or secondary surgical reduction (0%). This would support surgical stabilisation as the initial management method for traumatic feline elbow luxation. While external coaptation has been advocated to increase support following closed reduction, the efficacy of these methods to prevent elbow luxation recurrence in dogs has been questioned (Sajik *et al.* 2016). In this series, two of 12 cats in which luxation reoccurred had external coaptation applied. Coaptation-related soft tissue injuries, which can cause significant morbidity and increased treatment costs (Meeson *et al.* 2011), occurred in one of eight cats in this series. Although the use of appendicular coaptation and spica splints are reported, it is widely accepted that their maintenance can be challenging in cats. We would suggest that this data does not support the use of coaptation methods for management of elbow luxation and that any elbow that is not demonstrably stable following closed reduction should be considered a candidate for surgical stabilisation.

Campbell's test has been reported as a means of functionally assessing elbow stability after reduction (Farrell *et al.* 2007). Campbell's test was performed in 13 of 18 cases that underwent primary closed reduction (Fig. 2). Of these, five were unstable and therefore failed primary closed reduction. Campbell's test was not recorded in five primary closed reduction cases, with subsequent recurrence of luxation in three untested cases. Had elbow instability been demonstrated in these cases by an abnormal Campbell's test, surgical stabilisation may have been performed under the same general anaesthetic, potentially decreasing patient morbidity and cost associated with secondary surgical stabilisation as a subsequent procedure. In the three elbows initially judged as stable by Campbell's test that later luxated, luxation occurred within 72 hours of closed reduction in two cases, and at 6 weeks after closed reduction in one case. Recurrent luxation

may therefore have occurred following reduction in soft tissue swelling that had initially masked the severity of elbow instability. Increased patient activity with soft tissue swelling reduction may also contribute to increased instability with time after injury. In humans, simple elbow dislocations are assessed fluoroscopically in varus and valgus stress following closed reduction to quantitatively gauge severity of joint instability (Schnerzke *et al.* 2015). Severely unstable elbows that dislocate during testing undergo primary open stabilisation (Schnerzke *et al.* 2015). Human elbows with moderate reduction instability ($\geq 10^\circ$) after closed reduction have a significantly worse elbow extension range following non-surgical treatment and have significantly higher odds of complication and revision surgery rates, compared with people with $< 10^\circ$ of elbow instability (Schnerzke *et al.* 2015). Fluoroscopy may be a useful tool for assessing the stability of grossly stable feline and canine elbows following closed reduction, with secondary surgical management chosen if instability is diagnosed.

Outcome following traumatic elbow luxation was assessed by clinical record review, and using a modified previously reported owner-questionnaire to assess patient function, and owner-perceived pain. Although follow-up was available for 26 of 32 cats (81% of cohort) when all follow-up methods were combined, it was not completed for all cases, nor conducted at standardised time points. Post-operative survival was documented in 31 of 32 cases, with the death of one of six cats with concurrent injuries. Analysis for factors such as polytrauma influencing the survival of cats with traumatic elbow luxations would have been under-powered in this cohort. Clinical records follow-up demonstrated that ~90% of surviving cats had a positive outcome following elbow luxation management, with normal limb use ($n = 10/23$), mild lameness ($n = 6$) or mildly restricted range of motion without lameness ($n = 5$). Both cases managed with a transarticular external skeletal fixator had mildly restricted range of motion when the device was removed, and physical rehabilitation was advised. Prolonged joint immobilisation, as achieved with transarticular external skeletal fixation, has a negative effect on joint mobility due to altered intra-articular physiology (Jaeger *et al.* 2005). Long-term follow-up was available in one of these cases (case 26), with limb use reported to be very good, suggesting an improvement in joint mobility with unrestricted limb use.

Overall, eight of 31 surviving cats were reported to be lame on clinical follow-up. Questionnaire follow-up was available for one of eight lame cats (case 34). Mild lameness was reported at 3 months clinical follow-up following primary surgical stabilisation with bone tunnels, with very good limb use at 20 months post-operatively on questionnaire follow-up, suggesting improvement. Removal of nylon prosthetic ligaments was considered to address the lameness at 3 months; it is uncertain from records whether this was performed. Two cats (cases 4 and 21, 9% of cohort) were reported to have severe lameness at 8 and 1.5 months follow up respectively. Both cases were lateral elbow luxations without concurrent orthopaedic injuries, and were judged to be stable with Campbell's test following management. In Case 4, luxation reoccurred following closed management and the cat underwent secondary surgical stabilisation with bone tunnels. In Case 21,

closed reduction was performed within 48 hours after injury without recurrence of luxation. Additional follow-up not available for these cases, preventing evaluation of response to analgesia management or further treatment, or progression of lameness. Further work is required to assess risk factors for cases in which severe lameness persists.

Functional outcome was reported to be excellent or very good in 10 of 12 cases in which questionnaire follow-up was available, with no significant difference in modified FMPI scores between surgical and closed reduction management methods. Activities most frequently reported to be graded “moderately worse than normal” or worse were jumping to kitchen counter height (two of 12 cats unable to perform activity) and jumping down (three of 12 cats moderately worse). Jump height has previously been identified as a reduced functional activity in cats following pancarpal or partial carpal arthrodesis (Calvo *et al.* 2009) and femoral head and neck excision (Yap *et al.* 2015), and appears a sensitive performance parameter. The cat reported to have a “fair” outcome (case 23) at 81 months following primary surgical stabilisation (bone tunnels) had a modified FMPI score of 58/68 and a pain score of 2/15. Activities reported to be “moderately worse” were walking, running and tolerance of handling. The responses to questions regarding jumping ability being “moderately worse” and “normal” were conflicting. Quality of life was reported to be “good,” and analgesia was not being administered. Overall questionnaire reported quality of life was reported as excellent (n = 10) or good (n = 2). While secondary osteoarthritis would be expected to have a deleterious effect on mobility with time after injury, median follow-up time at questionnaire response was >3 years post-injury, suggesting that elbow osteoarthritis within this time period did not have a negative effect on owner-perceived quality of life. Completion of serial questionnaires over a longer follow-up period, repeated veterinary clinical assessment and objective measures such as kinetic or kinematic analysis would potentially increase the accuracy of follow up, and decrease possible caregiver bias.

Limitations of this study are inherent to its retrospective, multicentre design, with incomplete records and variability introduced by veterinary surgeons at multiple primary care and referral centres. A bias for surgical management may have originated within a referral population, especially within cats in which closed reduction before referral had not been achieved or had failed. The cohort size, while larger than those previously reported is still small, and so conclusions regarding comparative efficacy of therapies must be tentative.

In conclusion, this series demonstrates that primary closed reduction of feline elbow luxations is associated with more frequent relaxation than in cases managed surgically. Recurrence appeared to occur in a greater proportion of cases in which the elbow was luxated for longer before initial closed reduction. Our data show that the relaxation rate following closed elbow reduction in cats is higher than previously reported. We conclude that primary surgical reduction should be considered in those cases in which elbow instability is identified on Campbell’s test and there are concurrent orthopaedic injuries. Furthermore, if primary closed reduction is performed, it should be performed promptly, and cases monitored closely for signs of luxation recurrence.

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Conflict of interests

The authors have no conflicts of interests to declare.

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Supporting Information

The following supporting information is available for this article:

Appendix S1: Owner Questionnaire results for 12 cats following elbow luxation reduction, by method of reduction (Q1-17, modified FMPI (Benito 2013)).