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1 Multi-Centre Study of Long-Term Outcomes Following Traumatic Elbow Luxation in 37 Dogs

2

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5

6

7 Introduction

8 Canine traumatic elbow luxation is an uncommon injury owing to the inherent stability of the joint
9 construct. Stability provided by strong peri-articular muscular and ligamentous structures, as well as
10 the anconeal process engaging with the olecranon fossa results in peri-articular fracture being a
11 more common clinical occurrence ([Campbell 1969](#), [Pass and Ferguson 1971](#)). Luxations are usually
12 associated with high energy trauma such as road traffic incidents, falls, fights and limb entrapments
13 ([Campbell 1971](#), [Billings and others 1992](#), [O'Brien and others 1992](#), [Schaeffer and others 1999](#),
14 [Mitchell 2011](#)). Elbow luxation has been hypothesised to occur as a result of direct force acting on
15 the joint, or the indirect application of rotational forces transferred to the elbow via bridging
16 ligaments and regional musculature ([O'Brien and others 1992](#), [Schaeffer and others 1999](#), [Farrell and
17 others 2007](#)).

18 Excessive medial and lateral translation, abduction and adduction of the antebrachium are
19 prevented by the collateral ligaments. In dogs, more than 90% of reported elbow luxations are in a
20 lateral direction ([Campbell 1969](#)). This propensity is attributed to the larger humeral epicondyle and
21 its distally sloping articular surface providing more extensive encapsulation of the radial head and
22 providing greater protection against medial translation and subsequent luxation ([Billings and others
23 1992](#), [O'Brien and others 1992](#)). The importance of damage to the collateral ligaments during
24 luxation is contentious, with ligament injury reported in 18-50% of patients (Griffon 2010). Historical
25 cadaveric examination of the canine elbow demonstrated luxation with visually intact collateral
26 ligaments ([Campbell 1969](#)), however, in a more recent bio-mechanical evaluation, luxation was not
27 possible unless at least the lateral collateral ligament was transected. Transection of both medial
28 and lateral collateral ligaments was required for luxation in the feline elbow ([Farrell and others
29 2007](#)).

30 Closed reduction is reported to provide a successful outcome in the majority of canine elbow
31 luxation cases and is the recommended initial approach to treatment ([Campbell 1971](#), [Pass and
32 Ferguson 1971](#), [O'Brien and others 1992](#)). If closed reduction is not possible, open reduction with
33 surgical stabilisation is required. Numerous stabilisation methods following open reduction of elbow

34 luxations are described and include collateral ligament repair ([Campbell 1969](#)), reattachment of
35 ligamentous avulsions, collateral ligament replacement with synthetic suture or orthopaedic wire
36 ([Schaeffer and others 1999](#), [McCartney and others 2010](#)), transarticular external skeletal fixation
37 (TESF)(Griffon 2010) and transcondylar bone tunnels with biaxial suture repair ([Farrell and others](#)
38 [2007](#)). The 'Campbell's Test' remains the 'Gold Standard' non-invasive assessment of collateral
39 ligament integrity. Campbell (1969) described that in the normal dog, with the elbow and carpus
40 both flexed to 90°, the maximum range of antebrachial rotation was 40-50° for pronation and 60-70°
41 for supination. Compromise of the lateral collateral ligament resulted in a maximum supination of
42 120-140° and medial collateral injury permitted pronation of 90-100°. Following closed reduction
43 assessment of antebrachial rotation has been reported as essential for evaluation of residual
44 instability, with persistent instability being associated with disappointing functional outcome
45 ([Schaeffer and others 1999](#)). Subsequent recommendations for patients demonstrating residual
46 instability after closed reduction include surgical stabilisation as this may result in a more favourable
47 outcome when compared with closed reduction alone ([Schaeffer and others 1999](#), [McCartney and](#)
48 [others 2010](#)).

49 To date, all large studies of canine traumatic elbow luxation have included predominantly cases
50 managed by closed reduction with relatively few patients treated surgically. The purpose of this
51 study was to review a large series of dogs with traumatic elbow luxation treated surgically or by
52 closed reduction, and report the outcomes and complications encountered, plus long term follow-up
53 using the previously validated Canine Brief Pain Inventory (CBPI) ([Brown and others 2008](#)).

54

55 **MATERIALS AND METHODS**

56

57 *Data Collection*

58 This study was approved by the Royal Veterinary College Ethics and Welfare Committee (URN 2015
59 1367). Case records for all dogs presenting with traumatic elbow luxation to the Queen Mother
60 Hospital for Animals at the Royal Veterinary College, the Small Animal Hospital at the University of
61 Glasgow, the Small Animal Specialist Hospital in Sydney, the Veterinary Specialist Centre Sydney and
62 Anderson Moores Veterinary Specialists between 2006 and 2013 were reviewed. Data recorded
63 included patient signalment, luxation aetiology and direction, time to attempted reduction (within
64 24 hours, between 24-48 hours or greater than 48 hours), method of reduction ('closed' vs. 'open'),
65 surgical procedures performed, concurrent injuries, post-reduction care including method of
66 external coaptation and complications encountered. Dogs managed with closed reduction alone

67 were assigned to 'Group 1' and dogs managed with open reduction and/or surgical stabilisation
68 were assigned to 'Group 2'. Complications were divided into 'minor' or 'major'; complications
69 necessitating additional surgery or resulting in significant lameness or morbidity were described as
70 major. Cases with both minor and major complications were categorised as having major
71 complications.

72 Questionnaire follow-up was attempted for all dogs with owners contacted by telephone or e-mail
73 and asked to complete the Canine Brief Pain Inventory. Owners were presented with 11 questions;
74 four questions in which they were required to grade the severity of their dog's pain over the
75 previous seven days, six questions to evaluate function over the previous seven days and one final
76 question requesting a single global assessment of their dog's quality of life. Questions 1-10 were all
77 graded on a discrete 0-10 numerical scale, with 0 representing no pain or interference and 10
78 denoting extreme pain or complete interference. Owners were asked to describe the quality of life
79 of their dog as either 'poor', 'fair', 'good', 'very good' or 'excellent'. For each patient, the numerical
80 scores for the pain severity and functional outcome were averaged to give a mean pain and mean
81 function score for each dog.

82

83 *Statistical Analysis*

84 Statistical analysis was performed using a dedicated statistical software programme (SPSS 22.0, IBM).
85 Descriptive statistics were reported for all data. The influence of reported data on complications and
86 outcome was analysed using Chi-Squared test with a value of $P \leq 0.05$ considered statistically
87 significant.

88

89

90 **RESULTS**

91

92 Thirty-seven dogs were identified as having sustained a traumatic elbow luxation within the study
93 period. Twenty-two dogs were female (7 entire, 15 neutered) and 15 were male (5 entire, 10
94 neutered). Median age was 48 months (range 8-156 months) with a mean weight of 21.35kg
95 (± 10.42 kg). Breeds included Cross Breed (n=11), Cocker Spaniel (n=3), Labrador Retriever (n=3),
96 Rottweiler (n=3), Staffordshire Bull Terrier (n=3), Springer Spaniel (n=2) and one each of Australian
97 Cattle Dog, Boxer, German Shorthaired Pointer, Greyhound, Whippet, Griffon, Jack Russell Terrier,
98 Lhasa Apso, Lurcher, Papillion, Pug and Shih Tzu.

99 The most common cause of luxation was road traffic accident (n=22), followed by collisions, either
100 into a human or another dog (n=3), dog attack (n=3), limb entrapment (n=3), falls (n=2), and a kick
101 by a horse (n=1). Three causal incidents were not witnessed. Thirty-four of the 37 luxations were in a
102 lateral direction, for the remaining 3 cases the direction of luxation was not recorded in the clinical
103 records. Reduction was performed within 24 hours (n=24; 13 Group 1, 11 Group 2), between 24-48
104 hours (n=8; 5 Group 1, 3 Group 2) and greater than 48 hours (n=4; all Group 2). Time to reduction
105 was not recorded in one dog and was excluded from analysis involving time to reduction. Closed
106 reduction was not attempted in two cases due to concurrent anconeal process fracture. Of the
107 cases treated at, or greater than, 48 hours post injury, 1 was treated 4 days post-trauma and two
108 cases were treated one month after the initial luxation; these patients were referred due to
109 persistent, repeat luxation.

110 Of the 37 cases included, 17 elbows were treated by closed reduction alone (Group 1) and 20 elbows
111 required surgical intervention (Group 2). One patient had closed reduction with transarticular
112 external skeletal fixator (ESF) placement due to residual instability and was included in the Group 2.
113 Of the cases in Group 2, three had initially been treated with closed reduction but reluxated
114 following recovery from anaesthesia prompting surgical stabilisation. Indications for surgical
115 management were the inability to perform closed reduction or the presence of persistent
116 instability/reluxation following closed reduction. No case had open reduction without concurrent
117 stabilisation. Surgical stabilisation was grouped into 2 main categories; circumferential suture
118 prosthesis passed through transcondylar bone tunnels (n=11) and screw/anchor placement with
119 prosthetic ligament/orthopaedic wire placement (n=4). Combination treatments included
120 screw/anchor placement with prosthetic ligament plus circumferential suture (n=1), screw/anchor
121 placement with prosthetic ligament plus transarticular pin (n=1), screw/anchor placement with
122 prosthetic ligament plus TESF (n=1), open reduction plus transarticular TESF (n=1) and closed
123 reduction plus transarticular TESF (n=1).

124 Post-reduction external coaptation or fixation was employed in 30 cases; Spica splint (n= 20),
125 support bandages including Modified Robert Jones and limb casts (n=7) and transarticular external
126 skeletal fixation (n=3) (**Table 1**).

127 In total, 7 of the 37 dogs (19%) encountered major post-operative complications; reluxation (n= 6)
128 and infection requiring implant removal (n=1). Five reluxations occurred following closed reduction;
129 one was successfully managed with repeat closed reduction, three were surgically stabilised
130 (recorded in Group 2) and one dog was euthanised due to deterioration of concurrent injuries. One
131 reluxation occurred following surgical stabilisation (lateral screw and prosthetic ligament placement)

132 and was re-operated for placement of medial prosthetic ligament and relaxation did not occur. One
133 dog in Group 1 operated following failed closed reduction suffered major soft tissue complication as
134 a result of external coaptation and was euthanased.

135 Five (13.5%) minor complications were encountered; superficial splint/bandage abrasions (n= 3)
136 successfully managed conservatively and superficial surgical site infections (n=2) all of which
137 resolved with appropriate antibiotic medication.

138 Gender, age, weight, breed (pedigree vs. cross breed), morphology (chondrodystrophic vs. non-
139 chondrodystrophic) and time to reduction were not significantly associated with management
140 (Group 1 vs. Group 2) or the incidence of post-reduction complications (Table 2).

141 There was no significant difference between the Group 1 and Group 2 with respect to the incidence
142 of complications (P=1.000) or the occurrence of 'major' and minor complications (P=0.242). When
143 analysed independently, relaxation was not significantly different between Groups 1 and 2 (p=0.660)
144 nor was the incidence of relaxation associated with the presence or absence of external coaptation
145 (p=1.000) or the type of coaptation applied (p=0.691).

146 Orthopaedic injuries to additional limbs were observed in 9 cases and included unilateral
147 coxofemoral luxation (n=2), bilateral coxofemoral luxation (n=2), coxofemoral luxation plus tibial
148 fracture, tibial fracture plus bilateral sacroiliac luxation and unilateral tarsal instability, contralateral
149 humeral fracture, right femoral capital physeal fracture and soft tissue laceration with patella
150 ligament desmitis. Concurrent orthopaedic injury to another limb was significantly associated with
151 the incidence of elbow relaxation (p= 0.02).

152

153 Twenty-one owners were contactable and agreed to complete the CPBI questionnaire (Table 3).
154 Thirteen dogs were graded as having 'excellent' quality of life by their owners; nine from Group 2
155 (median pain score of 0 [range 0-2.5] and median functional score of 0 [range 0-3.33]) and four from
156 Group 1 (median pain score of 0 [range 0-0] and median functional of score 0 [range 0-1]). Six
157 patients were reported as having 'very good' function; two from Group 2 (median pain score of 1.63
158 [range 1.5-1.75] and median functional score 1.17 [range 1.17-1.17]) and four from Group 1 (median
159 pain score of 0.25 [range 1-1.25] and median functional of score 0.25 [range 0.17-5]). One patient in
160 Group 2 was reported as having good comfort and function (mean pain score of 3.75 and mean
161 functional score of 3.83) and one dog in Group 1 as having fair (mean pain of score 0 and mean
162 functional score of 4.67).

163

164

165 **Discussion**

166 A total of 37 canine patients with traumatic elbow luxations were treated over a seven year period
167 between five veterinary referral institutes confirming that this is a relatively uncommon injury.
168 Seventeen dogs were treated by closed reduction alone and twenty required surgical
169 reduction/stabilisation. Our treatment groups (closed reduction vs. open reduction/stabilisation)
170 were comparable with regards to patient numbers and patient signalment data and were
171 representative of the patient cohorts previously reported ([O'Brien and others 1992](#), [Schaeffer and
172 others 1999](#)).

173 We report a considerably larger number of elbow luxations treated surgically compared with
174 previous studies ([O'Brien and others 1992](#), [Schaeffer and others 1999](#)). Explanation regarding this
175 increase is likely multifactorial and potentially reflects shifts in treatment recommendations plus an
176 increased surgical focus following the recent description of a novel technique ([Farrell and others
177 2009](#)). Residual instability following closed reduction of traumatic elbow luxations has been
178 demonstrated to have a negative impact on the final outcome, with 'excellent' and 'good' follow-up
179 results only reported when the elbow was stable immediately after reduction ([Schaeffer and others
180 1999](#)). It is conceivable that this finding could lead to the adoption of more aggressive management
181 of patients in which minor instability was identified following closed reduction. The majority of
182 surgical stabilisations employed in the present study fell into two main categories; prosthetic
183 ligament placement with screw or suture anchors and circumferential suture prosthesis passed
184 through transcondylar bone tunnels. The identification of lateral collateral ligament damage in all
185 traumatic elbow luxations by McCartney (2010), plus the description of a new stabilisation technique
186 by Farrell (2009) may have increased the focus on surgical stabilisation resulting in a higher number
187 of surgically stabilised elbows. No significant difference in the relaxation rate or overall complication
188 rate was identified between the Groups suggesting either method to provide adequate post-
189 operative stability. A final explanation for the large number of surgically treated patients could be
190 associated with the study of a referral population of dogs. It is quite possible that the patients
191 referred reflect a sub-population of dogs in which closed reduction was more difficult or failed more
192 frequently in primary care practice and hence referral treatment was sought. The referral of cases
193 from primary care practices to the referral centres may also have resulted in an increased time to
194 attempted reduction.

195 The most common complication following reduction of elbow luxation is relaxation (Griffon 2010).
196 We identified no significant difference between Group 1 and Group 2 regarding the incidence of

197 relaxation. Farrell et al (2007) showed that elbow luxation was only possible in the ex-vivo canine
198 elbow following transection of at least the lateral collateral ligament, suggesting that in all luxations
199 collateral ligament damage is likely; a finding echoed by a small study of surgically stabilised elbows
200 in which all lateral collateral ligaments were found to be damaged at surgery ([McCartney and others](#)
201 [2010](#)). This is in contrast to early cadaveric evaluation of elbow luxation by Campbell (1969) who
202 demonstrated visually intact collateral ligaments in a dog with radiographic evidence of luxation.
203 One potential explanation for this could relate to the severity of collateral ligament damage
204 sustained during luxation, with severe injuries resulting in marked instability and potential for
205 relaxation where-as milder injuries retain sufficient constraint to maintain stability post-reduction.
206 Unfortunately, it was not possible to ascertain the extent of the ligamentous injuries sustained in all
207 operated patients from the clinical records and further discussion of this would be speculative.

208 External coaptation to allow fibrosis and healing of intrinsic support structures has been advocated
209 for adjunctive support following closed reduction and following open reduction and repair of
210 collateral ligaments (Griffon 2010). External coaptation focuses upon maintaining the limb in
211 extension with engagement of the anconeal process within the olecranon fossa, preventing lateral
212 translation and relaxation. Post-reduction coaptation was employed in 30 of the 37 cases reviewed,
213 with Spica splint and bandages/casts being most frequently applied. No significant difference was
214 observed in the occurrence of relaxation with respect to the presence or absence of external
215 coaptation or between the types of coaptation used. This finding should be interpreted cautiously as
216 we report relatively low numbers for each external coaptation variant, with variable lengths of
217 application preventing detailed comparison in this study. The theoretical benefits of external
218 coaptation must be weighed against the potential risk of complications, as compromise of the
219 adjacent soft tissue is not uncommon ([Meeson and others 2011](#)); as observed with 1 major soft
220 tissue injury and 3 cases of minor complication owing to external coaptation application. In one
221 review of human elbow luxations, prolonged immobilisation after luxation was strongly associated
222 with an unsatisfactory result with a significant increase in flexor contracture and more severe
223 symptoms of pain ([Josefsson and others 1987](#)). Although, there are significant differences with
224 regards to limb function in humans compared with canines, the deleterious effects of prolonged
225 joint immobilisation on the health of articular cartilage are well documented ([Bruce and others](#)
226 [2002](#)) and must be considered when the decisions for, and the duration of, external coaptation or
227 transarticular external skeletal fixation are made.

228 , the majority of elbow luxations in this study were sustained during motor vehicle incidents. This
229 type of trauma is likely to be of high energy and additional co-morbidity is not uncommon ([O'Brien](#)

230 [and others 1992](#), [Schaeffer and others 1999](#)). The incidence of elbow relaxation was significantly
231 increased in patients that had suffered concurrent orthopaedic injury; this phenomenon may be the
232 result of forced earlier limb usage placing increased stress upon the recently reduced elbow.
233 Recommendations regarding the most appropriate management of cases with concurrent,
234 additional limb, orthopaedic injuries are likely to include more robust fixation/coaptation although
235 strong evidence for a protective effect of either strategy is currently lacking.

236

237 A previous retrospective study reported that the best outcome following acute traumatic elbow
238 luxation was achieved by closed reduction under general anaesthesia without damaging the
239 cartilage or ligaments ([Schaeffer and others 1999](#)), with Campbell (1971) stating that when open
240 reduction was necessary a more definite lameness or stiffness would be expected post reduction. In
241 the present study, follow-up evaluation by owner completion of the CBPI was attempted for all
242 cases. The CBPI has previously been validated and used for evaluation of response to treatment
243 following a defined intervention ([Brown and others 2008](#)) and in the assessment of the severity and
244 impact of chronic pain in dogs with bone cancer ([Brown and others 2009](#)). The CBPI consists of two
245 dimensions; pain severity and pain interference, describing how that pain interferes with the dog's
246 daily activity ([CBPI user guide, www.CanineBPI.com](#)). In the present study, owners reported 'very
247 good' to 'excellent' quality of life in 11/12 (92%) cases treated surgically and 8/9 (89%) cases treated
248 by closed reduction. This suggests that owner perception of the outcome is comparable for either
249 surgical or non-surgical treatment. A combination of the CPBI with an objective measurement of
250 limb function such as gait analysis and clinical examination would provide more comprehensive
251 evaluation of long term function post reduction however is beyond the scope of the present study.

252 In conclusion, we report the treatment and outcome of a large population of traumatic elbow
253 luxations in dogs, with the greatest number of dogs treated surgically to date. In agreement with
254 previous studies, our results do not demonstrate a significant difference in the incidence of
255 complication, or the level of function to be expected, following either closed reduction or surgical
256 stabilisation. Additionally our study provides the first evidence that concurrent orthopaedic injury to
257 additional limbs is a significant risk factor for relaxation following reduction of traumatic canine
258 elbow luxation.

259

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 302

303 **Table 1:** The application of external coaptation in relation to closed reduction vs. surgically treated
 304 elbow luxations (TESF = transarticular external skeletal fixator)

	No Coaptation	External Coaptation		
		Spica	Cast/bandage	TESF
Group 1	3	10	4	1
Group 2	4	10	3	2

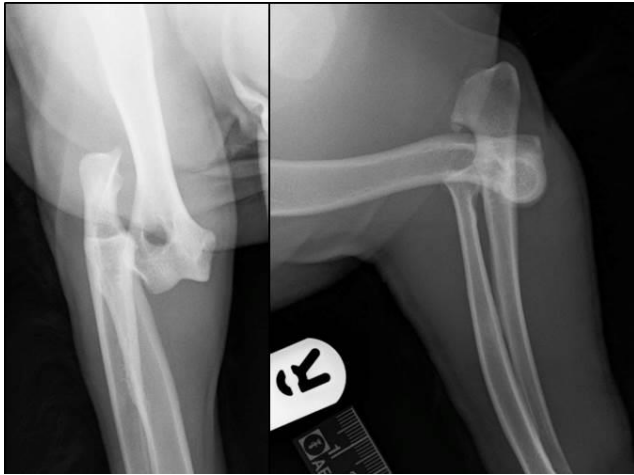
306 **Table 2:** The effect of variable on the incidence of closed reduction vs. open reduction/surgical
 307 stabilisation and the incidence of associated complications ('minor' and 'major' combined) $P \leq 0.05$
 308 considered statistically significant.

	Group 1 vs. Group 2	Incidence of complications
Gender	p= 0.325	p= 1.000
Age	p= 0.879	p= 0.807
Weight	p= 0.511	p= 0.948
Breed (pedigree vs. cross breed)	p= 0.151	p= 1.000
Morphology (chondrodystrophic vs. non-chondrodystrophic)	p= 0.693	p= 0.389
Time to reduction	p= 0.097	p= 0.325

309
 310 **Table 3:** Results of the Canine Brief Pain Inventory. Questions 1-4 evaluate the severity of pain over
 311 the previous 7 days. Questions 5-10 evaluate function over the previous 7 days. Question 11
 312 requests a single global assessment of the dog's quality of life

Case Number	Group	Q1	Q2	Q3	Q4	Mean Pain	Q5	Q6	Q7	Q8	Q9	Q10	Mean Function	Q11
7	1	0	0	0	0	0	0	0	0	0	0	0	0	Excellent
8	1	2	1	1	1	1.25	2	0	1	0	0	0	0.5	Very Good
12	1	0	0	0	0	0	1	0	0	0	0	0	0.17	Excellent
14	1	0	0	0	0	0	0	0	1	0	0	0	0.17	Very Good
15	1	2	0	0	0	0.5	0	0	2	0	0	0	0.33	Very Good
23	1	0	0	0	0	0	5	5	5	3	5	5	4.67	Fair
24	1	0	0	0	0	0	3	0	0	0	3	0	1	Excellent
26	1	0	0	0	0	0	0	0	0	0	0	2	0.33	Very Good
27	1	0	0	0	0	0	0	0	0	0	0	0	0	Excellent
3	2	6	1	2	1	2.5	2	1	2	4	7	4	3.33	Excellent
4	2	2	1	2	1	1.5	2	0	1	1	1	2	1.17	Very Good
10	2	2	0	0	0	0.5	0	0	0	0	0	0	0	Excellent
11	2	3	1	2	1	1.75	1	1	2	1	1	1	1.17	Very Good
13	2	0	0	0	0	0	0	0	1	1	0	1	0.5	Excellent
17	2	0	0	0	0	0	0	0	0	0	0	0	0	Excellent
20	2	0	0	0	0	0	0	0	1	0	1	0	0.33	Excellent
21	2	0	0	0	0	0	0	0	0	0	0	0	0	Excellent
22	2	0	0	0	0	0	0	0	0	0	0	0	0	Excellent
30	2	1	1	1	0	0.75	2	0	0	1	1	3	1.17	Excellent
31	2	6	2	4	3	3.75	4	5	3	4	3	4	3.83	Good
34	2	0	0	0	0	0	0	0	0	0	0	0	0	Excellent

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Figure 1: Craniocaudal (left) and mediolateral (right) radiographs demonstrating lateral elbow luxation in Patient 14.



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Figure 2: Craniocaudal (left) and mediolateral (right) of Patient 11. Radiographs demonstrate post-operative reduction and implant positioning following circumferential suture prosthesis passed through transcondylar bone tunnels and secured with metal crimps (Farrell and others 2007).