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Caudoventral hip luxation in 160 dogs (2003–2023): A multicenter retrospective case series

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Abstract

Objective: To describe patient characteristics, etiology, treatment outcomes and complications of caudoventral hip luxation (CvHL) in a large cohort of dogs and investigate factors associated with nonsurgical treatment outcomes.

Study design: Multicenter retrospective case series.

Animal population: A total of 160 client-owned dogs (170 limbs).

Methods: Medical records from 2003 to 2023 were reviewed for signalment, history, treatment outcomes and complications. Logistic regression was performed to investigate factors associated with nonsurgical treatment outcome.

Results: Low-trauma accidents accounted for 82.9% of cases. Over-represented breeds included poodles (38.1%) and poodle crosses (11.3%). On a per-treatment basis, success rates of closed reduction alone, closed reduction/Ehmer sling, closed reduction/hobbles were 9.1%, 15.2% and 48.8%, respectively. When accounting for repeated attempts using closed reduction alone, Ehmer sling, or hobbles, eventual success rate increased to 10.3%, 18.5% and 61.8%, respectively. Success rate for toggle rod stabilization was 88.2%. Complication rate of hobbles was 31.9% versus 60.6% for Ehmer slings. Use of hobbles (OR:7.62, $p = .001$, CI:2.23–26.05), treatment by specialist surgeons (OR:2.68, $p = .047$, CI: 1.01–7.08) and increasing age (OR:1.15, $p < .005$, CI: 1.08–1.23) were associated with successful nonsurgical treatments.

Conclusion: Low-trauma etiology, and poodles and their crosses were over-represented in cases of CvHL. Success rate of nonsurgical treatments was lower than previously reported. Hobbles were 7.6 times more likely to be successful when compared to dogs treated without hobbles and remains a viable noninvasive first-line treatment.

Clinical significance/impact: Hobbles are recommended as a low-morbidity first-line treatment for CvHL. An Ehmer sling is not recommended. Toggle rod stabilization is an effective surgical treatment for CvHL.

1 | INTRODUCTION

Hip luxation is common, accounting for up to 90% of all luxations.[1–16] Craniodorsal hip luxation (CdHL) is most common, accounting for 73%–90% of cases, with motor vehicular accidents accounting for 59%–83% of those cases.[1–3,5,7–11,13,15,16] Caudoventral hip luxation (CvHL) is rare and accounts for 1.5%–3.2% of cases.[1,2,5–13] It typically occurs when the pelvic limb abducts.[4,9,10,12,13] This levers the femoral head through or over the transverse acetabular ligament resulting in stretching/tearing of the ligament of the femoral head and joint capsule.[4,12] Some have speculated that coxofemoral abnormalities and deficient transverse acetabular ligament may contribute, but this is not well-defined, or confirmed with mechanical studies in the literature.[9,12] Hip dysplasia has not been directly linked to increased risk of CvHL.

There are nonsurgical and surgical treatments for CvHL. Nonsurgical options include closed reduction +/− application of hobbles.[4,10] Ehmer sling is not recommended because it causes hip abduction and internal rotation; the forces required for reluxation in cases of CvHL.[8] Surgical options for treatment of CvHL include primary capsulorrhaphy,[10,13] prosthetic capsulorrhaphy,[10,13] toggle rod stabilization,[10–13] suture repair of transverse acetabular ligament and augmentation of transverse acetabular ligament using extracapsular sling,[9,10,13] autogenous iliac shelf graft,[9,10,13] pectineus muscle transfer,[9,10,13] and bone plate augmentation of ventral acetabular rim.[9,10,13] Salvage procedures include femoral head and neck ostectomy and total hip arthroplasty.[4,5,13]

Current literature describing common patient characteristics, etiology, treatment outcomes and factors associated with successful nonsurgical treatment of CvHL is limited to small case series. Nonsurgical treatment of CvHL with or without hobbles was reported to have a success rate of ∼80%.[4] Sample size was small (only 9 cases with documented outcomes) and may not reflect the true success rate of nonsurgical treatment. Furthermore, to the authors' knowledge, there are no publications exploring if underlying pathologies, such as hip dysplasia or neurological disease contribute/predispose to CvHL. Based on clinical impression, we hypothesized that the success rate of nonsurgically treated CvHL is lower than previously reported. Therefore, we sought to retrospectively evaluate the patient characteristics, etiology, treatment outcomes and complications of CvHL in a large cohort of dogs and investigate the factors associated with nonsurgical treatment outcomes.

2 | MATERIALS AND METHODS

Five referral hospital groups across Australia (14 hospitals) contributed cases for this study. Keywords used in electronic medical record search included: "hobbles", "caudoventral", "ventrocaudal", "hip dislocation", "hip luxation", "coxofemoral dislocation" and "coxofemoral luxation." Medical records between 2003 and 2023 were reviewed individually and patients with documented radiographic diagnosis of CvHL were included in the study. Data extracted from medical records were organized into descriptive data and analytical data in Microsoft Excel (Microsoft, Redmond, Washington).

Descriptive data collected included age (at the time of injury), sex (male/female), neutered status (yes/no), breed, bodyweight (kg), side of luxation (left/right), initiating trauma (motor vehicular accidents [MVA], low-trauma accidents or unknown), presence/absence of hip osteoarthritis in affected or contralateral hip recorded on review of radiographs (where available) or in case-notes, and concurrent orthopedic injuries. As the study period spanned 20 years, radiographs were not available for direct review by the authors in every case. Descriptive data were used to describe the patient characteristics and etiology of CvHL.

Analytical data collected included type of treatment, training level of treating veterinarian (general practitioner, emergency veterinarian, surgery resident/registrar or specialist surgeon), number of previous treatment attempts, reluxation (yes/no), limb use (weight-bearing vs. nonweight-bearing), and complications (skin irritation, slippage, soiling, swelling, self-trauma). Treatment attempts were excluded if they involved euthanasia, pain relief only without reduction or lost to follow up. The latest medical records were requested from the patient's regular veterinarian via email. Medical records were used as the primary source of outcome data and follow-up owner phone call were used as secondary source of outcome data if clinical records were unavailable/insufficient. When considering phone call follow up, owners were first contacted via SMS text messaging to provide a brief overview of this study and obtain their consent to be contacted. Consenting owners were contacted via telephone call. Duration of follow up was defined as the date of last treatment to the date of last follow up for living patients or date of death for deceased patients. Successful outcome was defined as return of weight-bearing function and absence of palpable reluxation. Salvage procedures (total hip arthroplasty or femoral head ostectomy) were not counted as successful outcomes.

Being a multicenter retrospective study, treatment decisions were not standardized. Analysis of success rates was complicated by the fact that many cases were treated with different type of treatments, different number of attempts, and in different order. For this reason, treatment outcomes were reported in two methods: per-treatment and per-case. When analyzing per-treatment success rate, attempts of the same treatment type across all cases were grouped together and the success rates were tallied. When analyzing per-case success rates, any case that underwent a given treatment type was evaluated as a case, regardless of the number of attempts at that given treatment type. If the case underwent a different treatment type prior to eventual outcome, the case was evaluated for success within both treatment types. Per-case success rates were reported as: % successful (median number of treatments; range). Dogs that experienced bilateral, temporally separated CvHL were counted as two separate cases.

2.1 | Statistical analysis

Logistic regression analysis was used to describe effects of patient variables on success rate of nonsurgical treatment options on a per-treatment basis. For purposes of logistic regression analysis, breeds were categorized. Poodles, Border Collies and Cavalier King Charles Spaniels were independent categories. Schnoodles, cavoodles, spoodles, labradoodles were categorized as "Poodle X". Breeds under 10 kg were categorized as "small breeds." Breeds over 10 kg were categorized as "Others." Age, gender, neutered status, breed group, bodyweight (kg), side of luxation, number of previous treatment attempts, type of veterinarian and treatment type were included in the model to be investigated for positive association with successful nonsurgical treatment. Stata 17 software (StataCorp, College Station, Texas) was used for statistical analysis in this study. As the outcome variable is binary, univariate logistic regression was used to provide insights into the relationship between each variable and the outcome. Each treatment attempt was defined as an event. Dogs with multiple treatment attempts had each individual treatment outcome analyzed separately (232 nonsurgical treatment attempts in total). Logistic regression was selected due to its ability to adjust the standard error for potential clustering effect (i.e., standard error of 232 treatment attempts adjusted for 153 clusters in case number to obtain a robust standard error). Clustering is related to the same animal data used for separate treatment attempts. For categorical variables such as gender, neutered status, breed, side of luxation, number of previous treatment attempts, type of veterinarian and treatment type, the odds were interpreted in relation to the selected base.

Univariate logistic regression was used first to assess head-to-head relationship between the binary outcome variable and each predictor. Multivariate logistical regression analysis was performed on variables that had a p-value of .2 or less in the univariate logistical regression analysis. This elimination scheme was used because if a variable has a p-value greater than .2 in a univariate analysis, it is unlikely to contribute to a model which includes other variables. Age, gender, side of luxation, type of veterinarian and treatment type met the inclusion criteria to be included in the multivariate analysis. During model reduction, log likelihood ratio tests were used to remove nonsignificant predictors (one predictor at a time), and to compare models with and without different combinations of predictors. A parsimonious model, where all predictors contributed (at a statistically significant level) to the understanding of the adjusted relationship between the response and predictors was obtained. Statistical significance was set at $p < .05$. Odds ratios (OR) are reported as OR; p-value; 95% confidence interval (CI).

3 | RESULTS

CvHL was identified in 160 dogs between 2003 to 2023. A total of 10 had CvHL in the contralateral side on a separate occasion, resulting in 170 cases in the study period. Median age of presentation was 8.4 years (range: 0.5–19.7 years). There were 90 male (56.25%) and 70 female dogs (43.75%). A total of 142 dogs (88.75%) were neutered and 18 dogs (11.25%) were intact. There were 92 right-sided cases (54.1%) and 78 left-sided cases (45.9%). MVA accounted for 11 cases (6.5%), low-trauma accidents accounted for 141 cases (82.9%) and unknown causes accounted for 18 cases (10.6%) (Table 1). Breeds affected by CvHL are summarized in Table 2. Poodles and poodle X were overrepresented accounting for 49.4% of the cases.

Following review of radiographs (available in 108/170 cases), 106/108 cases did not show any evidence of radiographic osteoarthritis or hip dysplasia; however, many of the radiographs were taken in frog-leg ventrodorsal position, which does not evaluate hip laxity optimally. Due to the retrospective nature of the study, assessment of Ortolani sign was not possible. Concurrent orthopedic injuries were uncommon and found in only eight cases (4.7%), seven cases of which were caused by motor vehicular accidents and the remaining case was caused by dog attack. No neurological deficits were noted in the neurological examination of any of the patients.

There were 318 treatment attempts in total. Eleven treatment attempts were excluded due to euthanasia, seven treatment attempts were excluded due to unknown treatment outcome and one treatment attempt was excluded due to only pain relief provided without reduction. Therefore, 299 treatment attempts were included in

TABLE 1 Etiologies of CvHL and their proportions.

Etiology	Cases (%)	
Motor vehicular accidents	11 (6.5)	
Low trauma accidents		
Jumping off objects (furniture/stairs etc.)	30 (17.6)	141 (82.9)
Falling off objects (furniture/stairs etc.)	34 (20)	
Slipping	11 (6.5)	
Running	33 (19.4)	
Jumping	3 (1.8)	
Collision with an object/animal	7 (4.1)	
Dog attack	5 (2.9)	
Object/owner/animal landing/stepping on patient	9 (5.3)	
Leg getting caught (car seats, stairsteps, dog door)	3 (1.8)	
Others (walking, rolling, getting up)	5 (2.9)	
Seizure	1 (0.6)	
Unknown	18 (10.6)	

Abbreviation: CvHL, caudoventral hip luxation.

TABLE 2 Breed categories affected by CvHL and their proportions.

Breed categories	Number of dogs	Percentage (%)
Poodle	61	38.1
Poodle X	18	11.3
Border Collie	16	10
Cavalier King Charles Spaniel	12	7.5
Kelpie	10	6.3
Pomeranian	7	4.4
Papillion	5	3.1
Small breeds	20	12.5
Others	11	6.9
Total	160	100

Abbreviation: CvHL, caudoventral hip luxation.

the treatment data. Median time between the first luxation and initial treatment was 0.5 days (range: 0–18 days). On a per-treatment basis, the success rate of closed reduction alone was 9.1% (3/33), closed reduction and Ehmer sling was 15.2% (5/33), and closed reduction and hobbles was 48.8% (81/166) (Table 3). Overall success rate of nonsurgical treatment attempts on a per-treatment basis was 38.8% (90/232). When evaluating success rate of sequential attempts with hobbles, regardless of prior nonsurgical treatment type, success rate of closed reduction and hobbles on a per treatment basis, in dogs that had 0, 1, 2 and 3 previous luxations were 47.5%, 52.9%, 46.2% and 0%, respectively (Table 4).

When considering success rate of hobbles alone, a total of 131/170 cases with documented outcomes were treated with hobbles at some point in their management. If prior attempts using closed reduction +/− Ehmer slings were eliminated, when considering the number of treatment attempts using hobbles only, then success rates on a per-case basis for those that underwent their first, second and third attempt with hobbles were 49.6%, 46.7% and 66.7% respectively (Table 5). Summatively, a total of 81/131 (61.8%) cases had a successful outcome with the use of hobbles eventually, with a maximum of three attempts (Table 5). Not all cases underwent the same number of treatment attempts with hobbles before the clinician elected to perform surgical treatment. In comparison, success rate on a per-case basis for closed reduction alone was 10.3% (3/29, median = 1, range = 1–2) and success rate of Ehmer sling was 18.5% (5/27, median = 1, range = 1–3).

On a per-treatment basis, the success rate of toggle rod stabilization was 88.2% (30/34), transarticular pinning was 100% (2/2), and ventral capsulorrhaphy was 80% (4/5) (Table 3). Overall success rate of surgical management of CvHL on a per-treatment basis was 87.8%. Median number of failed nonsurgical treatment attempts prior to surgery was 1 (range: 0–4). On a per-case basis, the success rate of toggle rod stabilization was 90.9% (30/33, median = 1, range = 1–2).

Type of toggle-rod suture material did not appear to affect success rate as of the four cases of failure, two occurred with nylon leader line, and two occurred with braided ultrahigh molecular weight polyethylene suture (TightRope mini, Arthrex, Fort Myers, Florida). Due to low case numbers and complication rate, statistical analysis of surgical treatment outcomes was not evaluated for risk factors. One of four instances of toggle rod implant failure and reluxation had repeated toggle rod stabilization, which was successful.

When performing follow-up assessment, of 160 dogs in this study, 10 dogs were excluded from follow-up as they were euthanized prior to any documented outcome, 1 dog was excluded because only pain relief was administered and reduction was not performed. Therefore, 149 dogs were eligible for follow-up. Referring veterinarians' medical records were available in 70.5% of dogs (105/149). Participation rate for the long term follow-up phone call was 71.8% (107/149). A total of 32 of 44 dogs

TABLE 3 Success rate of different types of nonsurgical and surgical treatment for CvHL.

Treatment	Attempts	Successful outcome	Success rate (%)
Nonsurgical			
Closed reduction alone	33	3	9.1
Closed reduction and Ehmer sling	33	5	15.2
Closed reduction and hobbles	166	81	48.8
Surgical			
Toggle rod stabilization	34	30	88.2
Transarticular pinning	2	2	100
Ventral capsulorrhaphy	5	4	80
Total hip arthroplasty[a]	1	N/a	N/a
Femoral head and neck ostectomy[a]	25	N/a	N/a
Total	299	N/a	N/a

Abbreviation: CvHL, caudoventral hip luxation.
[a]Total hip arthroplasty and femoral head and neck ostectomy were not considered for treatment success calculations.

TABLE 4 Success rate of closed reduction and hobbles after different number of previous failed nonsurgical treatments.

Number of previous failed nonsurgical treatment[a]	Successful outcome with closed reduction and hobbles		Total
	Yes (%)	No (%)	
0	48 (47.5%)	53 (52.5%)	101
1	27 (52.9%)	24 (47.1%)	51
2	6 (46.2%)	7 (53.8%)	13
3	0 (0%)	1 (100%)	1

[a]Nonsurgical treatments include closed reduction +/− Ehmer slings/ hobbles.

TABLE 5 Success rate of closed reduction and hobbles for each attempt.

Attempt[a]	Successful outcome with closed reduction and hobbles		Total
	Yes (%)	No (%)	
1	65 (49.6%)	66 (50.4%)	131
2	14 (46.7%)	16 (53.3%)	30
3	2 (66.7%)	1 (33.3%)	3
Eventual outcome	81 (61.8%)	50 (38.2%)	131

[a]Cases that experienced reluxation after prior treatment with closed reduction +/− Ehmer slings then treated with hobbles were considered as treatment attempt #1 with hobbles for the purpose of this summary.

that had no follow-up information from the referring veterinarian's medical records had phone call follow-up information. Therefore, follow-up data were available in 91.9% of dogs (137/149). Median duration of follow up was 815 days (range: 32–3972 days).

Overall complication rates on a per-treatment basis for hobbles and Ehmer sling were 31.9% and 60.6%, respectively. Complications associated with hobbles and Ehmer sling are summarized (Table 6). Regardless of the type of treatment, all patients were weightbearing during follow-up where reluxation did not occur.

Univariate logistic regression showed that age, gender, side of luxation, type of veterinarian and treatment type were significant in their relationship with successful nonsurgical treatment (Table 7). These variables were all subsequently included in the final multivariate model. This subsequently identified three significant variables. For each year of age, likelihood of treatment success increased by 1.15 times (OR: 1.15, $p < .0005$, CI:1.08–1.23). Case managed by specialist surgeons are 2.68 times more likely to be successful than those managed by general practitioner (OR:2.68, $p = .047$, CI: 1.01–7.08).

TABLE 6 Complications associated with hobbles and Ehmer slings.

Complications	Hobbles[a]	Ehmer sling[a]
Overall complication rate	53/166 (31.9%)	20/33 (60.6%)
Skin irritation	21/166 (12.7%)	5/33 (15.2%)
Slippage	20/166 (12%)	13/33 (39.4%)
Soiling	15/166 (9%)	1/33 (3%)
Swelling	2/166 (1.2%)	2/33 (6.1%)
Self-trauma	14/166 (8.4%)	4/33 (12.1%)

[a]Complication rates are based on a per-treatment basis, as several dogs were treated with both Ehmer sling, followed by hobbles, making a per-case complication rate not possible to report.

Lastly, use of hobbles were 7.62 times more likely to be successful than cases managed with closed reduction alone (OR:7.62, $p = .001$, CI:2.23–26.05) (Table 8).

4 | DISCUSSION

This study has demonstrated that primary etiology of CvHL was predominantly caused by low-trauma etiologies, which is distinct from that of CdHL where motor vehicular accidents (MVA) predominate. MVA accounted for only 6.5% of the CvHL cases in this study as compared to 59%–83% of the CdHL cases reported in the literature.[1–3,5,7–10,13] Our study has also identified a breed predisposition for CvHL, with poodles and their crosses representing 49.4% of cases. Poodles also appeared overrepresented in an earlier study, making up 4/14 (28.5%) cases.[4] The low force necessary for luxation in majority of cases suggests that many cases experiencing CvHL may have conformational or functional differences in coxofemoral joint connective tissue and associated muscles compared to unaffected dogs. A specific breed predisposition also supports the assertion that inherited conformational or connective tissue abnormalities may be responsible for CvHL in many cases, although further investigation is required to determine this. We did not identify a significant incidence of hip osteoarthritis in the patient population, with only 2/108 dogs showing evidence of radiographically detectable osteoarthritis. As the majority of dogs with significant laxity develop osteoarthritis changes, this is suggestive, but not conclusive evidence, that dogs suffering CvH are not predisposed to hip dysplasia. This assertion is, however, limited by the fact that we are unable to evaluate hip laxity specifically due to the retrospective nature of the study making palpation for laxity impossible. Additionally, as many of the preoperative radiographs available included only frog-leg ventrodorsal projections of the pelvis, radiographic assessment of hip laxity was not possible. To the author's knowledge, there is no supporting literature to suggest that hip osteoarthritis or hip dysplasia are predisposing factors to CvHL. Also, our study did not identify an increased incidence of cases with these factors, with very low numbers demonstrated to have these pathologies. Future prospective studies examining hip laxity with Ortolani testing or PennHip distraction index scoring with sufficient case numbers would be needed to make these conclusions with greater confidence.

Closed reduction with hobbles was successful in 61.8% of cases. This is lower than the previously reported success rate of ∼80% in an earlier study with far lower case numbers, although due to methodology differences between studies, direct comparison is not possible.[4] However, considering the dogs in the present study underwent multiple attempts to achieve successful reduction, which ultimately increased the overall success rate, we can, despite differences in data reporting between studies, fairly confidently report that the success rate of conservative management in this study was lower than that reported in the earlier small-scale study.

In the present study, the success rate following treatment with hobbles was significantly higher than that reported following closed reduction alone. Multivariate logistic regression demonstrated that the chance of successful outcome with hobbles was 7.62 times greater than with closed reduction alone. Furthermore, the number of previous attempts at nonsurgical management does not affect the likelihood of success with treatment with hobbles. Prior attempts at reduction using closed reduction alone, Ehmer sling or hobbles did not result in a lower chance of success when ultimately using hobbles. Given outcome with hobbles was still similarly successful following repeated failure with other treatments as it was on initial usage, this suggests that ineffectual treatment modality was the primary cause of poor outcome rather than pre-existing pathology. Repeated attempts with hobbles alone demonstrated similar likelihood of treatment success up to three attempts (Table 5). It is important to note that the cases selected for repeated closed reduction and hobbles attempts were likely selected based on their perceived suitability for repeated attempts. This may naturally bias the population to those most likely to succeed with closed reduction alone in the eyes of treating clinician and may falsely elevate the reported success rates. Conversely, cases that were taken to surgery immediately, or after one or two failed attempts may have been successful with further attempts using hobbles. Due to the retrospective nature of the study, and nonstandardized treatment decision making by the clinicians inherent in a retrospective study, it is difficult to make too many inferences on the effect of clinician biases.

TABLE 7 Univariate logistic regression results.

Variable	Odds ratio	p-value	95% Confidence interval
Age	1.17	**<.0005**[a]	1.10–1.24
Gender (base = male)			
Female	2.04	**.009**[a]	1.19–3.49
Neuter status (base = desexed)			
Entire	1.83	.210	0.77–4.35
Breed (base = Border Collie)			
Cavalier King Charles Spaniel	0.76	.645	0.23–2.47
Poodles	1.14	.762	0.48–2.74
Others	1.02	.966	0.40–2.59
Bodyweight	1.01	.644	0.97–1.05
Side of luxation (base = right)			
Left	1.89	**.016**[a]	1.12–3.18
Number of previous treatment attempts (base = 0)			
1	1.31	.374	0.72–2.37
2	1.40	.525	0.50–3.91
Vet type (base = GP)			
Emergency	4.10	**<.0005**[a]	1.85–9.07
Surgery resident/registrar	3.01	**.094**[a]	0.83–10.94
Specialist surgeon	4.82	**<.0005**[a]	2.28–10.18
Treatment type (base = closed reduction alone)			
Closed reduction and Ehmer sling	1.79	**.446**[a]	0.40–7.92
Closed reduction and hobbles	9.76	**<.0005**[a]	2.81–33.87

[a]Variables with *p*-values in bold were retained for use in the multivariate logistic regression model.

TABLE 8 Multivariate logistic regression results.

Variable	Odds ratio	p-value	95% Confidence interval
Age	1.15	<.0005	1.08–1.23
Vet type (base = GP)			
Emergency	2.35	.090	0.88–6.33
Surgery resident/registrar	1.58	.592	0.30–8.40
Specialist surgeon	2.68	.047	1.01–7.08
Treatment type (base = closed reduction alone)			
Closed reduction and Ehmer sling	3.24	.137	0.69–15.28
Closed reduction and hobbles	7.62	.001	2.23–26.05

These points are important to consider when discussing with the client potential treatment options and relative success, as the degree of invasiveness of closed reduction and hobbles placement is far lower than treatment with surgical reduction and stabilization, and likely less costly. Conversely, multiple episodes of CvHL recurrence and the associated pain of repeated/recurrent luxation may distress some owners, so careful counseling on the relative benefits and risks of nonsurgical versus surgical option is important.

Success rate of closed reduction with Ehmer sling, per-case, was low (18.5%). When Ehmer sling is used in the management of CdHL, success rate is reported to be 56.5%.[17] This discrepancy is likely attributed to the fact that Ehmer slings cause abduction and internal rotation of the coxofemoral joint which are the forces required to cause reluxation in CvHL patients but prevent reluxation in CdHL patients.[8] The authors do not recommend use of Ehmer sling in the treatment of CvHL.

Total complication rate following placement of hobbles was lower (31.9%) than that reported following use of Ehmer sling (60.6%). It must be considered that the rates reported in this paper are reported on a per-treatment basis, and the complication rate is not directly comparable to previously reported literature, which reported complication rate of 50% with Ehmer sling, including severe soft tissue wounds in 37% of these dogs and one instance of limb amputation.[17] Reported skin irritations associated with hobbles in the present study were mostly minor in severity and self-resolving.

Older dogs were more likely to have a successful outcome following nonsurgical management. The authors theorize that dogs that luxate at a younger age may have more severe underlying conformational or functional hip abnormalities, such as deficient transverse acetabular ligament predisposing to CvHL, resulting in increased likelihood of CvHL in these dogs earlier in life. In comparison, older dogs with more mild abnormalities predisposing to CvHL may experience periarticular joint capsule fibrosis, some joint remodeling and potentially learn to alter gait and posture to stabilize the hips and reduce likelihood of luxation. Review of initial radiographs available in this case series did not identify an increase in degenerative joint disease and osseous remodeling; however, if remodeling comprises part of the reported improvement in success rate with age, then it is not severe enough to result in radiographically obvious remodeling.

Cases managed nonsurgically by specialist surgeons were 2.7 times more likely to be successful than those managed by general practitioners. As hobbles use was such a strong predictor of success, it appears likely to be a confounding variable to this finding as specialist surgeons almost invariably used hobbles while general practitioners and emergency veterinarians used a variety of nonsurgical treatments. As hobbles efficacy remains similar regardless of attempt number (Tables 4 and 5), and we have been unable to identify any pre-existing pathological risk factors in our study population, we feel it is likely that the general practitioners and emergency veterinarians' lower chance of success may be largely related to their more frequent choice of inappropriate nonsurgical treatment option (closed reduction alone and Ehmer sling, instead of hobbles). It may also be that specialist surgeons have greater experience in managing these cases, are better at evaluating hip pathology, making treatment decisions, placing hobbles with appropriate spacing and were more conscious of providing appropriate counsel to owners on the risks and appropriate aftercare following nonsurgical management than is provided in most general or emergency practices. Lastly, poorly placed hobbles/Ehmer sling may predispose to treatment failure or complications and general practitioners/junior emergency vets may have less experience in appropriate placement of these treatments.

Surgical management of CvHL was generally more successful than nonsurgical treatment. Case numbers treated by transarticular pinning and ventral capsulorrhaphy were very low, so comparison of clinical outcomes of different surgical treatments was challenging.

Toggle rod stabilization was used most frequently as a surgical treatment for CvHL, and success rate, per-treatment, was 88.2%. This is consistent with the previously reported success rate of about 85% in dogs and cats with CdHL; with good limb function and client satisfaction during long term follow-up.[14,15,18] Reluxation (11.8%) was the only surgical complication documented in this study. This is consistent with reluxation rates (5.8%–14.8%) and complication rates (11.8%–26%) reported in previous CdHL studies.[11,14-16] Overall, our findings support the assertion that toggle rod stabilization is an effective surgical treatment for CvHL. Craniolateral and ventral approaches to the hip joint have been described.[1,12] A ventral approach, recently reported by some of the authors, preserves the dorsal hip stabilizers while allowing assessment and primary repair/augmentation of the ventral joint capsule, ligament of the femoral head and transverse acetabular ligament.[12,13]

Interestingly, three of the four dogs that had a failed toggle rod stabilization reluxated their hip >6 months after the surgery. It is possible that the presence of underlying structural or functional hip abnormalities may have hindered adequate fibrosis of the joint, or additionally, left residual laxity in the secondary stabilizers, resulting in cyclic loading and failure of the toggle rod construct. This is probably due to a similar etiology of failure as suspected with the increased reported incidence treatment failure in low-trauma CdHL cases treated by toggle-rod stabilization.[15] Statistical analysis was not performed in the present study due to low case numbers of failed toggle rod stabilization. Larger studies of surgically treated cases could provide useful information on whether a particular surgical approach or type of suture material was superior in preventing reluxation.

There were several limitations in the present study. The most obvious was its retrospective nature. The lack of standardization of treatment decisions and complexity of the data resultant from patients having several treatments each also makes data analysis and interpretation more challenging. Additionally retrospective data relies heavily on the accuracy and comprehensiveness of the medical records. While most follow-up examinations were performed by veterinarians, some complications may not be documented in the medical records, and reasons for treatment decision making may not be clearly described. Furthermore, when relying on owner's follow-up, particularly when cases range over two decades, recall bias is possible because of the long duration of follow-up. In addition, any lameness reported may be attributed to osteoarthritis later in life and may not be truly reflect the limb function after treatment. Assessment of long-term limb function was based on referring veterinarian's assessment and occasionally owner follow up which can be limited and subjective. Lastly, the techniques for application of hobbles and Ehmer sling were not standardized. Therefore, poor placement may be a confounder to treatment failure.

Areas suggested for future investigation include more detailed investigation of "at-risk" breeds such as poodles and poodle-cross breeds, to evaluate conformational or functional abnormalities which may predispose to CvHL. CT imaging and kinematic or kinetic gait analysis, and comparison to a case-matched control cohort may help provide insights into the etiology of this condition. Situations such as abnormal limb abduction or internal rotation during gait, and abnormal ventral acetabular anatomy could increase likelihood of CvHL. Furthermore, CT evaluation and prospective evaluation of hip laxity in the contralateral hip of the affected population, including all breeds of dog may also help determine conformational and anatomical factors that may predispose to CvHL and could better explain etiology of low-trauma luxation. Additionally, a larger study exploring the success of surgical treatment outcomes for CvHL dogs to evaluate the effect of varied treatment approaches would help clarify the most appropriate techniques for surgical management of CvHL.

In conclusion, CvHL is a distinctive injury that is predominantly caused by low-trauma etiologies. Poodles and their crosses were overrepresented for this injury. Success rate of nonsurgical treatment was lower than previously reported, but repeated attempts with closed reduction and hobbles provided an overall success rate of 61.8%. Earlier failed attempts at treatment using closed reduction alone, Ehmer slings, or hobbles did not appear to affect the likelihood of success following treatment with hobbles. Increasing age, hobbles placement and treatment by specialist surgeons were statistically significant protective factors associated with successful nonsurgical treatment. Hobbles should be an integral part of nonsurgical treatment, and repeated attempts of closed reduction and hobbles placement are still met with reasonable success up to three attempts, provided appropriate owner counsel is provided. The Ehmer sling is not recommended, and toggle rod stabilization is an effective surgical treatment in cases where treatment with closed reduction and hobbles fails.

AUTHOR CONTRIBUTIONS

Loh JR, BVSc (Hons), MANZCVS (Small Animal Surgery): Primary author who performed case search in the database of all the participating hospitals, reviewed all the medical records, recruited cases that met the inclusion criteria, performed data collection including long term follow up data from the referring veterinarians' medical records, follow up phone call with the owners, drafted and revised the manuscript. Cleland N, BVSc (Merit), FANZCVS (Small Animal Surgery): Contributed to the design of the study, data collection and provided constructive reviews of the manuscript and contributed to its scientific content. Beierer L, BVSc (Hons), GradDipEd, MVetSurg, DACVS (Small Animal): Identified suitable medical records, provided constructive reviews of the manuscript and contributed to its scientific content. Drew J, BVSc (Hons), MANZCVS (Small Animal Surgery), MVetClinStud, MVetSurg, DECVS: Identified suitable medical records, provided constructive reviews of the manuscript and contributed to its scientific content. Wilson L, BVSc (Hons), FANZCVS (Small Animal Surgery): Identified suitable medical records, provided constructive reviews of the manuscript and contributed to its scientific content. Delisser P, BVSc (Hons), Cert-SAS, DECVS, FHEA, PhD: Contributed to the design of the study, identified suitable medical records, provided constructive reviews of the manuscript and contributed to its scientific content. All authors provided a critical review and endorse the final version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare that there is no financial support, financial or other conflict of interest of any author related to a company or product used in the report. The results of this study were presented in part at the Veterinary Specialist Services Conference, March 12, 2023, Hilton Brisbane, Australia. ANZCVS Science Week, July 29, 2023, Gold Coast Convention and Exhibition Center, Australia.

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