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Full limb amputation in chondrodysplastic dog breeds results in acceptable mobility and high owner satisfaction

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Objective
To evaluate functional outcome and owner satisfaction of chondrodysplastic dog breeds undergoing full limb amputation.

Methods
Medical records from 4 academic institutions were reviewed for chondrodysplastic dog breeds that underwent limb amputation from March 2015 to April 2024. Data collected included signalment, reason for amputation, day of return to ambulation with or without assistance, and comorbidities. Owner satisfaction was investigated via a nonvalidated questionnaire. Continuous data were analyzed for normal distribution and expressed as means if normally distributed and medians if nonnormally distributed. Categorial data were reported as frequencies, and comparisons between groups were performed with the Fisher exact test.

Results
At the time of discharge, 19 of 28 dogs (68%) were walking unassisted, 8 of 28 (29%) were walking with assistance, and 1 of 28 (4%) was unable to walk. Eighty-seven percent (13 of 15) of dogs that underwent a thoracic limb amputation were able to ambulate without assistance at the time of discharge, while only 46% (6 of 13) of dogs in the pelvic limb group were able to do so. Over the course of the postoperative period, 25 of 28 dogs (89%) were independently ambulatory. Overall, 18 of 28 owners (64%) completed the satisfaction questionnaire, and 13 of 18 (72%) were very satisfied with the outcome

Conclusions
The majority of chondrodysplastic dog breeds did well following amputation and achieved the ability to ambulate independently. Furthermore, dog owners reported high levels of satisfaction following this procedure.

Clinical Relevance
This information may help dog owners make informed decisions when considering a limb amputation for a chondrodysplastic dog.

Keywords: dog, amputation, ambulation, chondrodysplastic, owner satisfaction

Thoracic limb amputation (TLA) and pelvic limb amputation (PLA) are effective treatment options for a variety of disease processes including neoplasms, infections, and traumatic injuries in dogs.[1,2] Despite the hesitation of some dog owners to pursue such a radical procedure, the data available on owner satisfaction following canine limb amputation is markedly positive.[1–4] Additionally, various retrospective studies[1–4] spanning from the 1970s to 2010s have described a good postoperative mobility and quality of life in dogs after limb amputation.

Despite dogs reportedly adapting well to limb amputation, there are a variety of biomechanical changes that have been described following the amputation of a thoracic or pelvic limb and the resulting tripedal locomotion.[5–8] With tripedal locomotion, in the nonchondrodysplastic canine population, there is increased joint range of motion, redistribution of body weight among remaining limbs, and alterations in appendicular muscle recruitment.[5,7–10] Following TLA, increases in vertical, breaking, and propulsion forces as well as stance duration have been described.[8,10] No loss of balance was appreciated following TLA, despite measurable weight redistribution (14% increase of weight bearing on remaining

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thoracic limb, 17% increase to pelvic limbs).[8,10] The carpus, ipsilateral hip and stifle joints, and lumbosacral vertebral region all had significantly greater flexion at the trot, while the thoracolumbar vertebral region's range of motion increased in the sagittal and horizontal planes.[10] Following PLA, an increased tarsal range of motion and increased vertebral range of motion at T1 and T13 occur at a trot as well as increased lateral bending in the horizontal plane toward the remaining pelvic limb, resulting in a laterally deviated gait.[5] Additionally, asymmetric changes in the timing and level of activity of the muscle longissimus dorsi highlight asymmetric functional requirements of the trunk and pelvis, with the activity of the ipsilateral longissimus dorsi's muscle excitation almost doubling throughout the locomotor cycle.[7]

Based on anatomic differences and previously documented changes in biomechanics, limb amputations may affect chondrodysplastic dog breeds differently than nonchondrodysplastic breeds. Chondrodysplasia is a hereditary skeletal disorder affecting cartilage development resulting in disproportionate limb length development.[11–14] Chondrodystrophy is also a hereditary skeletal disorder affecting cartilage development and is associated with premature vertebral disk degeneration and increased susceptibility to disk herniation.[11,12] Dogs can be solely chondrodysplastic, solely chondrodystrophic, or both. For example, chondrodystrophy has been described in Nova Scotia Duck Tolling Retrievers, although they are not a chondrodysplastic breed.[12,15] In comparison, Dachshunds are a chondrodysplastic breed and individuals can be variably chondrodystrophic.[11–13] Chondrodysplastic breeds that have been found to frequently have chondrodystrophy include French Bulldogs, Dachshunds, Beagles, and Corgis.[14] Chondrodysplastic breeds are best known for their short limbs, or "disproportionate dwarfism" phenotype, seen in breeds such as Basset Hounds, French and English Bulldogs, Corgis, Scottish Terriers, Pekingese, and Dachshunds.[11–13] This unique pattern of skeletal maturation is attributed to 2 *FGF4* retrogene insertions on chromosomes 12 and 18 in the dog.[12,13] The insertion on chromosome 18 is linked to chondrodysplasia, resulting in a short-legged phenotype secondary to shortened long bone length due to early growth plate calcification.[12,13,16] The insertion on chromosome 12 is suspected to be responsible for chondrodystrophy, also variably causing a short-legged phenotype but, more notably, is linked to premature intervertebral disk degeneration.[12,14–16] This chromosomal insertion is considered autosomal dominant for intervertebral disk disease (IVDD) and semidominant for height. It is variably present in both chondrodysplastic and nonchondrodysplastic breeds.[11–13,15] Chondrodysplastic and some chondrodystrophic dogs have premature closure of appendicular growth plates, commonly resulting in inherited angular limb deformities.[13,17] These angular limb deformities can cause abnormal loading of the thoracic limb, resulting in osteoarthritis.[18] Additionally, these extreme conformational traits have been linked to abnormal function, specifically in carpal and elbow range of motion.[17,19] Lastly, there is evidence that chondrodysplastic breeds may bear more weight on their thoracic limbs (65% to 69% of body weight) compared to nonchondrodysplastic breeds (60% of body weight).[17,20,21] These differences in carpal and elbow function, in addition to disproportionate thoracic limb weight bearing, may introduce unique challenges to chondrodysplastic dogs undergoing limb amputation, particularly given the documented increase in carpal range of motion and increased vertical force production in the remaining limbs.[8,10]

Given chondrodysplastic breeds' extreme conformation and unique biomechanics, their postoperative recovery and ambulatory capabilities following limb amputation may differ from that of nonchondrodysplastic dogs, but clinical outcomes and owner satisfaction in chondrodysplastic breeds following limb amputation have not been evaluated. The primary objective of this study was to analyze a cohort of chondrodysplastic dogs undergoing limb amputation and report the percentage of dogs that returned to an acceptable level of mobility as described by their owners. The secondary objective was to evaluate differences in mobility throughout the postoperative period as well as owner satisfaction between dogs that underwent a TLA and those that underwent a PLA.

Methods

Case selection and data collection

This was a retrospective study including chondrodysplastic dogs that underwent a thoracic or pelvic full limb amputation for any reason from 4 academic institutions (Colorado State University Veterinary Teaching Hospital, University of Missouri Veterinary Teaching Hospital, University of Pennsylvania Veterinary Teaching Hospital, and The Ohio State University Veterinary Medical Center) from March 2015 to April 2024. Breeds evaluated in this study included those previously defined as *chondrodysplastic* based on phenotypic and genotypic evaluations.[12,14,16,19] The breeds eligible for inclusion were Basset Hounds, Beagles, Corgis, Dachshunds, English Bulldogs, French Bulldogs, Glen of Imaal Terriers, Pekingese, Pugs, Scottish Terriers, Skye Terriers, and West Highland White Terriers. Crossbred dogs were not included in this study due to the marked variation in morphology seen in chondrodysplastic breed mixes. No minimum follow-up was required for inclusion to this study. Cases were included if there were complete medical records for review (including a surgery report) and there was information relating to ambulation in the medical record at the time of hospital discharge.

Procedures

Medical records of chondrodysplastic dogs undergoing TLA or PLA were reviewed to obtain information on signalment; weight; indication for amputation; preexisting comorbidities; intraoperative, immediate postoperative, and postoperative complications (*intraoperative complications* defined as complications occurred in surgery, *immediate postoperative complications* defined as complications occurred between surgery and hospital discharge, and *postoperative complications* defined as complications occurred after hospital discharge); duration of hospitalization; and subjective evaluations of mobility throughout the postoperative period. Intraoperative complications were graded according to the Classification of Intraoperative Complications, ranging from grade 0 (no deviation from intraoperative course) to 4 (any deviation from intraoperative course resulting in death of the dog).[22] Postoperative complications were classified with the contracted Accordion severity grading system of surgical complications.[23] A nonvalidated owner questionnaire was created to assess the ability of dogs to ambulate on 3 limbs, changes in activity before and after amputation, interest in exercise, need for chronic medications to maintain activity, owner satisfaction, signs of postoperative pain, and whether or not they would make the decision to amputate again if in the same situation **(Supplementary Table S1)**. Questions were formulated to create nominal (ie, yes/no) and ordinal scale data (ie, ranging from poor to very good) with space for free text for additional information. Using Google forms, the survey was distributed to owners of these dogs via email and/or telephone interview at a minimum of 2-weeks postoperatively. Owners were emailed the survey, and a follow-up phone call was performed if a survey response was not received by email. If the owner responded by phone, one of the authors transcribed responses for them with the online survey.

Statistical analysis

All statistical analyses were done on proprietary software (Prism 10; GraphPad Software). Continuous data were analyzed for normal distribution with the Shapiro-Wilk test and expressed as mean ± SD if normally distributed and median (95% CI) if nonnormally distributed. Categorial data were reported as frequency (%), and comparisons between groups were performed with the Fisher exact test. *P* values of ≤ .05 were considered statistically significant.

Results

Population

Twenty-eight dogs met the inclusion criteria, consisting of 9 English Bulldogs (9 of 28 [32%]), 5 French Bulldogs (5 of 28 [18%]), 5 Dachshunds (5 of 28 [18%]), 3 Beagles (3 of 28 [11%]), 2 Pugs (2 of 28 [7%]), 2 Basset Hounds (2 of 28 [7%]), and 2 Scottish Terriers (2 of 28 [7%]). The population included 13 spayed females (46%) and 15 neutered males (54%). The mean age and body weight were 8.7 ± 3.4 years and 16.8 ± 9.7 kg, respectively. Body condition scores, reported as a numerical value on a 1-to-9 scale, were available for 20 of 28 dogs. The median body condition score was 6/9 (range, 1 to 8).[24] Fifteen dogs (54%) had a TLA, while 13 dogs (46%) had a PLA. Comorbidities were documented in 18 of 28 dogs (64%) and consisted of a concurrent orthopedic condition in 9 of 28 (32%), neoplasia present elsewhere in the body in 3 of 28 (11%), and cardiac disease in 3 of 28 (11%; **Supplementary Table S2**). Orthopedic comorbidities included a suspected cranial cruciate ligament rupture in 1 of 28 dogs (3%; PLA), radiographic evidence of coxofemoral osteoarthritis or pain on range of motion in 5 of 28 dogs (18%; 3 PLA, 2 TLA), medial patellar luxation in 2 of 28 dogs (7%; 2 PLA), and the following comorbidities in 1 of 28 dog (3%) each: right carpal hyperextension (TLA), scapulohumeral osteoarthritis (TLA), elbow osteoarthritis (PLA), and coxofemoral luxation (PLA). Primary neoplasia was the most common reason for amputation (22 of 28 [79%]), followed by fracture (5 of 28 [18%]) and infection/trauma (1 of 28 [4%]). All TLAs were performed as forequarter amputations, while one of the PLAs consisted of a complete hemipelvectomy and the others were coxofemoral disarticulations.

Histopathology was available for 22 dogs that underwent amputation (limb amputations for traumatic fractures did not have histopathology included). Osteosarcoma (9 of 22 [41%]) and soft tissue sarcoma (7 of 22 [32%]) were the most common histologic diagnoses. Other diagnosed neoplasms included mast cell tumors (3 of 22 [14%]), histiocytic sarcoma (2 of 22 [9%]), trichoblastoma (1 of 22 [5%]), squamous cell carcinoma (1 of 22 [5%]), carcinosarcoma (1 of 22 [5%]), hemangiosarcoma (1 of 22 [5%]), and cutaneous lymphoma (1 of 22 [5%]).

Complications

Intraoperative complications, immediate postoperative complications, and postoperative complications were recorded and are described in **Table 1**. One out of 28 dogs (4%) experienced grade 2 intraoperative complications (Classification of Intraoperative Complications), consisting of prolonged hypotension. Three out of 28 dogs (11%) experienced complications prior to hospital discharge. All complications prior to discharge were graded as mild and described as an increased respiratory rate and exacerbation of

Table 1—Type of complications encountered intraoperatively, in the immediate postoperative period, or after discharge in chondrodysplastic dogs undergoing full limb amputation.

Case No.	Time period	Complication	Complication grade
9	Following discharge	Hyporexia, panting	Accordion grade 1
10	Intraoperative	Prolonged hypotension	CLASSIC grade 2
11	Following discharge	Vocalization, restlessness	Accordion grade 1
15	Postoperative	Tachypnea, dyspnea, exacerbated heart murmur	Accordion grade 1
16	Following discharge	Restlessness, pain	Accordion grade 1
20	Postoperative	Urinary retention	Accordion grade 1
20	Following discharge	Surgical site infection	Accordion grade 2
26	Postoperative	Regurgitation	Accordion grade 1

CLASSIC = Classification of Intraoperative Complications.

a previous heart murmur in 2 dogs, urine retention in 1 dog that underwent a forequarter amputation, and regurgitation in 1 dog. Following discharge, 3 out of 28 dogs (11%) experienced postoperative complications, described as suspected postamputation pain in 2 dogs (restlessness and spontaneous crying, clinical signs consistent with pain following limb amputation), and a surgical site infection in 1 dog.[25] According to the expanded Accordion severity classification of postoperative complications, the postamputation pain was classified as grade 1, while the incision site infection was classified as grade 2.

Functional outcome

At the time of discharge (median, 1 day postoperatively; range, 1 to 4 days), 19 of 28 dogs (68%) were walking unassisted, 8 of 28 (29%) were walking with assistance, and 1 of 28 dog (4%; a Dachshund) was unable or unwilling to walk (this dog was then lost to follow-up). In the TLA group (15 of 28), 13 of 15 dogs (87%) were able to ambulate without assistance, while only 6 of 13 dogs (46%) in the PLA group were able to ambulate without assistance. The time to discharge varied, with the reason for continued hospitalization not specified in the medical record but likely based on clinician discretion. This difference was statistically significant (P = .04; OR, 7.6; 95% CI, 1.2 to 41.1). At the time of the first postoperative recheck, 22 of 28 dogs were available for follow-up. This recheck took place at a median of 14 days (range, 12 to 16 days), and 20 of 22 dogs (91%) were walking unassisted. One dog was walking with assistance (TLA; a Pug), and 1 dog was unable to walk with or without assistance (PLA; an English Bulldog). In addition to ambulation, other mobility issues were noted. One dog was unable to posture to urinate (the same English Bulldog not walking at the first recheck), 1 dog was able to ambulate but had general difficulty doing so (a Pug that underwent a TLA), and 1 dog had ataxia and was subsequently diagnosed with IVDD (a Basset Hound that underwent a TLA).

At the last time of follow-up (median, 160 days; range, 58 to 282 days), 22 of 28 dogs were able to be assessed (79%), with the remaining having been lost to follow-up. Some of the dogs able to be evaluated at this recheck had been evaluated elsewhere for their initial postoperative recheck. For 5 of 22 dogs (26%), their most recent evaluation was emergent and resulted in euthanasia; however, 4 of these 5 dogs (80%) had been independently ambulatory either prior to hospital discharge or at the time of their first recheck. For these 5 dogs, cause of euthanasia was hypovolemic shock in 1 dog, seizures in 1 dog, respiratory distress in 1 dog, disease progression causing bony lysis of the pelvis in 1 dog, and unknown in 1 dog. Seventeen out of 22 dogs (77%) were walking unassisted. Of these dogs, 10 of 17 (59%) were PLAs and 7 of 17 (41%) were TLAs. The dog that was not able to ambulate at the first recheck was walking without assistance 358 days postoperatively. Therefore, over the course of the entirety of the postoperative period, 25 of 28 dogs (89%) were independently ambulatory following amputation prior to either being lost to follow-up or euthanized.

Of the 28 dogs in the study, 9 of 28 (32%) had a known orthopedic comorbidity. These dogs still adapted to tripedal locomotion effectively, with 7 of these 9 dogs (78%) walking without assistance by the time of their last recheck.

Survey responses

Surveys were distributed to each dog owner, with 18 of 28 owners (64%) having responded to the survey. Interviews were performed at a minimum of 2 weeks postoperatively to a maximum of 9 years postoperatively. Of the 18 responses, 9 (50%) were from owners whose dogs had a TLA and 9 (50%) were from owners whose dogs had a PLA. Results of the survey are summarized in Supplementary Table S1. Overall, 15 of 18 owners (83%) felt their dogs had either good or very good mobility (*very good mobility* being no change in mobility from preoperatively, and *good mobility* being few changes to mobility compared to preoperatively). In this group of dogs, 8 of 15 (53%) were TLAs and 7 of 15 (47%) were PLAs. Half of owners (9 of 18 [50%]) reported their dog had no change in activity level following amputation, 6 of 18 (33%) reported a decrease in activity level, and 3 of 18 (17%) reported an increase in activity level. Perceived interest in activity was not affected in 12 of 18 dogs (67%), while the remaining 6 of 18 (33%) were reported to have a reduced interest in activity. Two out of 18 owners (11%) felt their dog required chronic medication or treatment to maintain their activity levels. Medications and treatments included gabapentin, carprofen, ketamine gel cubes, and acupuncture.[26] Overall, owner satisfaction was reported as “very satisfied” in 13 of 18 (72%), “somewhat satisfied” in 1 of 18 (6%), “neutral” in 3 of 18 (11%), “disappointed” in 0 of 18 (0%), and “very disappointed” in 1 of 18 cases (6%). In the context of TLA and PLA, 4 of 9 respondents (44%) with dogs that had a TLA were “very satisfied,” compared to 9 of 9 respondents (100%) with dogs that had a PLA. The remainder of the TLA group had respondents that answered they were “somewhat satisfied” (1 of 9 [11%]), “neutral” (2 of 9 [22%]), and “very disappointed” (1 of 9 [11%]). Owners were specifically asked to report any behavioral changes that would be consistent with postamputation pain,[25] based on what they observed of their dog at home. These were namely the following: increased anxiety, spontaneous vocalization, “restlessness at night,” or “excessive licking/biting at the amputation site.” Ten out of 18 owners (56%) did not report any signs that would be consistent with postamputation pain, while 8 of 18 did (44%). Half of these 8 owners (4 of 8) specified that these behaviors consistent with postamputation pain resolved within the first week following discharge. One owner specified that signs of postamputation pain resolved at approximately 4 months following discharge, while the other 3 owners did not specify duration of clinical signs. When asked whether they would make the same decision in terms of amputation for their dog again, 14 of 18 owners (78%) said they would and 4 of 18 (22%) said they would not. One of the respondents said they would not perform the procedure again due to the dog having early recurrence of their neoplastic disease postoperatively (metastatic high-grade mast cell neoplasia; this dog was euthanized 238 days postoperatively for hypovolemic shock). No other owners commented on why they would not have made the choice for amputation again.

Discussion

Chondrodysplastic dog breeds could have acceptable outcomes following limb amputation, with 89% of dogs being independently ambulatory postoperatively within a period of a few days to a few months. Our data suggested that chondrodysplastic dog breeds can appropriately compensate and regain mobility following limb amputation. Similarly to previous literature,[2,4] ambulatory capabilities at the time of discharge may not reflect long-term outcomes. In this group, 71% of dogs were walking unassisted at the time of discharge, increasing to 89% at their first recheck. This is similar to a previous retrospective study[4] of 64 dogs of various nonchondrodysplastic breeds undergoing amputation, with 73% of dogs walking unassisted at discharge, increasing to 90% at 1 week postoperatively. This gradual improvement in ambulatory status suggests mobility at discharge may improve over time.

Postoperative activity levels of chondrodysplastic dogs were largely improved or static, consistent with previous studies[2,3,9] demonstrating that most dogs return to similar activity levels as prior to amputation. Previous evaluation of dogs' activity levels following amputation documented that between 73% and 100% of dogs maintained their preoperative activity levels following limb amputation. This is slightly to moderately higher than the 67% of owners reporting no change or an increase in activity level for this group.[2,3,9] Additionally, most survey respondents also expressed satisfaction (14 of 18 [78%]) and willingness to make the decision to amputate their dog's limb again (14 of 18 [78%]), suggesting an acceptable postoperative outcome to most dog owners. Owner satisfaction was also found to be comparable to other studies[1–4,9] of nonchondrodysplastic breeds following amputation, with 4 retrospective studies showing between 86% and 100% of surveyed owners reporting that they would make the decision to amputate their dog's limb again if in the same situation. Given high rates of owner satisfaction for limb amputation in this study, amputation appears to be a reasonable surgical treatment option for chondrodysplastic dogs.

The presence of comorbidities, even those of orthopedic nature, did not seem to preclude chondrodysplastic dogs from a potentially good outcome from both a mobility and owner satisfaction standpoint. The majority (16 of 28 [57%]) of chondrodysplastic dogs in this study were reported to have at least 1 comorbidity, with 9 of 28 dogs (32%) having at least 1 orthopedic comorbidity. The most common orthopedic comorbidity was radiographic evidence of coxofemoral joint osteoarthritis or decreased hip range of motion. This may have contributed to the discrepancy in early outcomes between dogs undergoing PLA and TLA. Dogs in this study population had varying body condition scores, and dogs with higher body condition scores may struggle to adapt following amputation. Overweight and obese dogs were recorded as having a higher incidence of lameness, osteoarthritis, and cranial cruciate ligament disease, making it logical that dogs with higher body condition scores may be more likely to struggle to adapt to tripedal locomotion.[27,28] Despite this, the majority of dogs (with or without comorbidities) still had good outcomes when evaluating ambulatory capabilities and owner satisfaction. Of the 9 dogs with an orthopedic comorbidity, 7 (78%) were able to ambulate independently by the time of the last recheck. These findings suggested orthopedic disease may not prevent chondrodysplastic dogs from being candidates for amputation. This is further supported by a previous study[29] that documented minimal postural changes in amputee dogs that underwent a tibial plateau leveling osteotomy, suggesting that concurrent orthopedic conditions may not greatly impact amputee kinetics and kinematics. This supports the idea that orthopedic comorbidities in both chondrodysplastic and nonchondrodysplastic amputee dogs do not preclude them from independent ambulation.[29]

Previously reported[2,30] postoperative complication rates for limb amputation range from 11% to 13%. This incidence rate is lower than that of the cohort of this study, with 21% of dogs experiencing a postoperative complication following discharge. In the current study, only 4% of dogs (1 of 28) experienced a surgical site infection, which is lower than the reported surgical site infection rate of 13% for dogs undergoing amputation.[31] Similar to the reported literature demonstrating that dogs with amputation occurring secondary to or concurrently with infection or traumatic injury are more likely to result in surgical site infection, the dog in the current study had an amputation secondary to an infected trichoblastoma.

Within this cohort of chondrodysplastic dogs and within the existing veterinary literature[2,4] there are dogs that failed to adapt to tripedal locomotion in a timely manner postoperatively, with some never reaching an acceptable level of ambulation. The overall study population did have reported ongoing mobility issues in 3 of 28 dogs (11%), described in 1 dog as difficulty posturing to urinate, 1 dog that struggled to ambulate generally, and 1 dog noted to have postoperative ataxia. Additionally, 8 of 18 of owners (44%) that responded to the survey noted transient signs of postamputation pain in dogs, similar to 31% of owners in another study[2] appreciating signs of pain in their postamputee dogs at the time of discharge. Of note are 2 dogs that were noted to have cervical pain or were diagnosed with IVDD. Knowing that many breeds included in this study may also carry the retrogene insertion for chondrodystrophy, genome sequencing was not available to determine whether the dog that was diagnosed with IVDD was chondrodystrophic, as well as chondrodysplastic. Both of these dogs had a TLA performed, a notable correlation given the described increase in cervicothoracic region range of motion following TLA.[8,10]

Based on the potential for a predisposition to chondrodystrophy, it is possible that TLA and the resulting increase in cervicothoracic range of motion may lead to cervical pain and onset of IVDD in these dogs. However, it is possible that clinical signs of preexisting IVDD became more apparent postoperatively given the new challenge of adapting to tripedal locomotion. Research regarding kinetic and kinematic evaluation of chondrodysplastic dog breeds following limb amputation has not been published, and there is evidence that ambulatory biomechanics are variable among different dog breeds.[21,32] Therefore, it is possible that ambulatory biomechanics present in postamputation chondrodysplastic- (and particularly chondrodystrophic-) breed dogs could contribute to an increased likelihood in developing IVDD following a full limb amputation. Future research into this subject is imperative, especially with the recent increase in popularity of some chondrodysplastic (and variably chondrodystrophic) breeds such as the French Bulldog.[33]

When evaluating differences in outcomes between dogs undergoing TLA and PLA, the difference in ambulatory capabilities at the time of discharge following surgery was most notable. At the time of discharge, most dogs in the TLA group (13 of 15 [87%]) were able to ambulate without assistance, compared to only 7 of 13 dogs (54%) in the PLA group. Previous research[1,4,34] performed in nonchondrodysplastic dogs showed no difference in mobility between dogs having undergone TLA or PLA, even at the time of discharge. Additionally, with dogs carrying more weight on a single remaining thoracic limb than they would on a single remaining pelvic limb, logically it would be expected that thoracic limb amputees may struggle to adjust more than pelvic limb amputees.[5,8] There are multiple potential factors that may result in chondrodysplastic breed dogs having a slower adjustment to a PLA than a TLA in the immediate postoperative period. A potentially simple explanation is the recruitment of the pelvic limbs required for a sit-to-stand transition, potentially resulting in pelvic limb amputees not necessarily struggling to walk, but to transition to standing.[35] Detailed information regarding the ambulatory status was not available for all dogs. Dogs that struggled to transition to stand may have been considered dogs that were unable to independently ambulate, even if they would have been able to walk independently if helped into a standing position. Chondrodysplastic dog breeds tend to have a greater discrepancy between body length and height, which may contribute to greater difficulty adapting to a pelvic limb amputation in the immediate postoperative period. Following TLA, gait adaptations are largely described as increases in vertical, breaking, and propulsion forces.[8] Following PLA, an increased vertebral column range of motion in the sagittal plane has been noted, as amputees laterally bend in an effort to place the remaining pelvic limb closer to the ipsilateral thoracic limb, resulting in a laterally deviated gait.[5] With chondrodysplastic breed dogs having shorter limbs and longer bodies, it may inherently be more difficult to adjust to this lateral deviation in gait compared to a simpler adjustment following TLA. There is also reportedly a greater range of motion of thoracic vertebral bodies in dogs following PLA, and the reported frequency of vertebral body malformations in many chondrodysplastic-breed dogs (French Bulldog, English Bulldog, Pug, Boston Terrier) may play a role in difficulty adapting to ambulating in a way requiring greater vertebral range of motion.[36,37] Further kinetic and kinematic analysis of chondrodysplastic breeds both normally and following a limb amputation may provide greater insight into differences in biomechanics and compensatory mechanisms for the chondrodysplastic phenotype when compared to the nonchondrodysplastic canine population.

Limitations of this study included its retrospective nature, small sample size, lack of follow-up available for some dogs, lack of survey validation, lack of standardization of surgical and postoperative procedures, variable surfaces and environments across institutions for mobility evaluation, and subjectivity of the assessment of dogs' mobility. Objective measurements such as activity monitoring or force plate analysis were not included in this study; rather, subjective assessments from both clinicians and pet owners were retrospectively evaluated in conjunction with a nonvalidated owner survey. There was also the potential for different clinicians to be evaluating a dog throughout the postoperative period, resulting in discontinuity and interobserver variability. A component of case selection bias cannot be ruled out, as these were all dogs deemed appropriate candidates for limb amputation, and there may be a subset of chondrodysplastic individuals that would have worse outcomes following limb amputation. Additionally, there is the potential for owner bias in both choosing to respond to the survey as well as the responses provided. Therefore, although the majority of dogs in this study did acceptably well following limb amputation, careful consideration of an individual dog's condition and comorbidities should be taken into account prior to recommending limb amputation. Additionally, information on which dogs received regional analgesia (such as an epidural) was not available for all dogs, potentially confounding gait assessment at the time of discharge, specifically for dogs spending only 1 day in the hospital postoperatively.

Ultimately, these data suggested that chondrodystrophic dog breeds can adapt acceptably well following limb amputation, with most dogs able to ambulate independently and the majority of owners being satisfied with the surgical procedure. Chondrodysplastic dogs undergoing a PLA may struggle to adapt in the immediate postoperative period in comparison to dogs undergoing TLA. Chondrodysplastic dogs undergoing PLA may require additional time in hospital postoperatively or a higher level of owner support at home during their recovery period. Chondrodysplastic dog breeds should be considered for amputation when clinically warranted, and the information from this study could be shared with owners to help with informed decision-making.

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Supplementary Materials

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