SMALL ANIMALS

Risk factors affecting the outcome of surgery for atlantoaxial subluxation in dogs: 46 cases (1978–1998)

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Objective—To identify risk factors for successful surgical management of dogs with atlantoaxial subluxation (AAS).

Design—Retrospective study.

Animals—46 dogs managed surgically for AAS.

Procedure—Age at onset of clinical abnormalities, duration of clinical abnormalities prior to surgery, radiographic appearance of the dens, type (dorsal or ventral procedure) and number (1 or 2) of surgeries performed, grade of postoperative atlantoaxial joint reduction, and neurologic status prior to surgery (preoperative), when dogs were discharged from the hospital (postoperative), and during a follow-up evaluation (final) were obtained from the dogs' medical records. Risk factors for surgical success and degree of neurologic improvement were identified and analyzed for predictive potential.

Results—Age at onset of clinical abnormalities ≤ 24 months was significantly associated with greater odds of a successful first surgery and final outcome and a lower postoperative neurologic grade. Duration of clinical abnormalities ≤ 10 months was significantly associated with greater odds of a successful final outcome and a lower final neurologic grade. A preoperative neurologic grade of 1 or 2 was significantly associated with a lower final neurologic grade. Potential risk factors that did not affect odds of a successful outcome included type of surgery performed, grade of atlantoaxial joint reduction, radiographic appearance of the dens, or need for a second surgery.

Conclusions and Clinical Relevance—Age at onset of clinical abnormalities, duration of clinical abnormalities prior to surgery, and preoperative neurologic status are risk factors for success of surgical management of AAS in dogs. (*J Am Vet Med Assoc* 2000; 216:1104–1109)

Atlantoaxial subluxation (AAS) is typically a congenital or developmental disease affecting immature toy breed dogs.[1] In dogs with AAS, instability of the atlantoaxial joint results from a loss of intervertebral ligamentous support, often with concurrent aplasia, dysplasia, or degeneration of the dens.[2,3] Acute or chronic spinal cord compression can result in neurologic abnormalities that range from mild cervical hyperpathia and ataxia to quadriparalysis, respiratory compromise, and death.[1] Traumatic AAS may occur in any breed of dog and at any age.[2] Nonsurgical methods of management have been described for dogs with AAS and mild clinical abnormalities[4]; however, most surgeons advocate surgical stabilization for dogs with neurologic dysfunction.[5-17] Several methods of surgical stabilization have been described.[5] Dorsal procedures include the use of orthopedic wire, prosthetic suture, nuchal ligament, or a metal retractor to fix the dorsal spine of the atlas to the dorsal arch of the atlas.[5-13] A dorsal procedure that uses Kirschner wires and polymethylmethacrylate has also been described.[14] To our knowledge, studies evaluating long-term outcome in a large number of dogs with AAS that were treated with dorsal procedures have not been performed, but in a review article, a high rate of failure (39%) associated with this procedure was reported.[1] Ventral procedures have been described that use lag screws, plates, or Kirschner wires with or without polymethylmethacrylate reinforcement.[7,12,15-17] In 1 review article, ventral stabilization with Kirschner wires in 19 dogs resulted in only 9 successful outcomes.[1] A more recent study described a ventral procedure that used 5 or 6 Kirschner wires and polymethylmethacrylate; this procedure was successful in 8 of 9 dogs.[16]

Most studies of dogs with AAS have focused on the success of surgical management with respect to the surgical procedure used. We hypothesized that there are other risk factors that may also help predict success of surgery. The purpose of the study presented here was to identify risk factors for successful surgical management of dogs with AAS.

Criteria for Selection of Cases

Medical records for dogs with AAS admitted to the Veterinary Medical Teaching Hospitals at the University of Florida between 1978 and 1998 and Louisiana State University between 1988 and 1993 were reviewed. All dogs with complete medical records that underwent surgical stabilization of the atlantoaxial joint using a dorsal wire or suture procedure or ventral with Kirschner wire procedure with or without polymethylmethacrylate reinforcement were included in this study.

Procedures

Signalment, including body weight, breed, sex, age at onset of clinical abnormalities, age at time of surgery, history of trauma, primary complaint, cervical hyper-

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pathia, type and number of surgeries, and neurologic status were obtained from the medical records. Neurologic status prior to surgery (preoperative), when dogs were discharged from the hospital after the first or only surgery (postoperative), and during a follow-up evaluation (final) were graded according to the following scale: grade 1 = no neurologic impairment, grade 2 = ambulatory with ataxia or paresis, grade 3 = nonambulatory paresis, grade 4 = quadriplegia, grade 5 = dead. Lateral, lateromedial oblique, and ventrodorsal radiographic views of the vertebral column were obtained when possible, and mild ventroflexion was used to confirm the diagnosis when necessary. Radiographic appearance of the dens was recorded.

Type of surgery was classified as dorsal or ventral procedures. Dorsal procedures involved passing a loop of orthopedic wire or nonabsorbable suture under the dorsal arch of the atlas and securing the wire or suture through holes drilled in the spine of the axis.[2,6] Ventral procedures involved removing the articular cartilage from the atlantoaxial joint, placement of cancellous bone graft in most cases, and insertion of 2 or more Kirschner wires through the body of the axis and atlantoaxial joint and into the atlas.[15] In several ventral procedures, a small amount of polymethylmethacrylate was placed on the ends of the Kirschner wires that were left protruding from the axis.[10] Type, number, and size of surgical implants were recorded. Postoperative reduction of the atlantoaxial joint was graded as good, satisfactory, or poor on the basis of radiographic appearance. Each dog was assigned a preoperative and postoperative neurologic grade, and the dog's condition relative to its preoperative status (improved, the same, or worse) was recorded. Placement of a neck brace and duration that a neck brace was used were noted. Complications during the perioperative period were recorded.

Time from surgery until final follow-up evaluation was recorded. Data at final evaluation were obtained by physical examination of each dog. Condition, including neurologic status and cervical hyperpathia, was evaluated. Dogs were assigned a final neurologic grade. If a dog required 2 surgeries, the final neurologic grade was attributed to the second surgery. Radiographs of the cervical region of the vertebral column were obtained. Owner satisfaction was recorded. Additional follow-up data were obtained from referring veterinarians or owners.

Statistical Analyses

All statistical analyses were performed, using commercially available software.[a] Age at onset of clinical abnormalities, duration of clinical abnormalities prior to surgery, preoperative neurologic grade, radiographic appearance of the dens, type of procedure performed, grade of postoperative atlantoaxial joint reduction, and need for a second surgery were identified as potential predictors of treatment success. Three outcome variables were considered in the analysis. Because 6 dogs had 2 surgeries of different types, first-surgery outcome (outcome after the first or only surgery, success or failure; failure was defined as death or need for a second surgery) and final outcome (outcome after the only or second surgery, success or failure) were analyzed separately. Final neurologic grade was determined during final follow-up evaluation.

Receiver-operating characteristic (ROC) analysis[18] was used to find the cutpoints for the age at onset of clinical abnormalities, duration of clinical abnormalities prior to surgery, preoperative neurologic grade, and postoperative atlantoaxial joint reduction grade that resulted in the best diagnostic performance for predicting treatment success (ie, highest mean of sensitivity and specificity). **Odds ratios (OR)** for treatment success and corresponding exact 95% **confidence intervals (CI)** were then estimated. The Fisher exact test[19] was used to compare percentage of treatment successes between subgroups defined by each binary predictor. Univariate OR for age at onset of clinical abnormalities and duration of clinical abnormalities prior to surgery considered as continuous risk factors were estimated by use of logistic regression.[19] Nonlinearity in the logistic model was tested by use of cubic spline functions[20] of the continuous risk factors. The Wilcoxon rank-sum test[19] was used to compare final neurologic grade or change from preoperative neurologic grade between subgroups defined by each binary risk factor. The Wilcoxon signed rank test[19] was used to determine whether final neurologic grade changed significantly from preoperative grade across all dogs. Degree of linear association between the age at onset of clinical abnormalities, duration of clinical abnormalities prior to surgery, preoperative neurologic grade, or postoperative reduction grade and the final neurologic grade and change from preoperative grade were assessed by use of Spearman rank correlation.[19]

Results

Composition of study population—Forty-six dogs met the criteria for inclusion in this study. All were small- or toy-breed dogs. Yorkshire Terrier (n = 15; 32.6%) and Poodle (12; 26.1%) were the most common breeds represented. Other breeds included Pekingese (n = 4; 8.7%), Pomeranian (3; 6.5%), Shih Tzu (3; 6.5%), Dachshund (2; 4.3%), Chihuahua (2; 4.3%), Maltese (1; 2.2%), Bichon Frise (1; 2.2%), Pug (1; 2.2%), Shetland Sheepdog (1; 2.2%), and mixed-breed (1; 2.2%). Twenty-seven dogs (59%) were females, and 19 (41%) were males.

Preoperative clinical abnormalities—Age at onset of clinical abnormalities was < 12 months in 32 (70%) dogs, ≤ 24 months in 37 (80.4%) dogs, and > 24 months in 9 (19.6%) dogs . Median age at onset of clinical abnormalities for all dogs was 8 months (range, 1 to 120 months). Although 28 (61%) dogs had a history of trauma, trauma in all cases was minor. Eighteen (39%) dogs did not have a history of trauma. Duration of abnormal clinical signs prior to surgery was ≤ 1 week in 31 (67.4%) dogs, ≤ 10 weeks in 37 (80.4%) dogs, and > 10 weeks in 9 (19.6%) dogs. Median duration of clinical signs prior to surgery was 1 month (range, 0.25 to 71 months). Primary owner complaint was almost equally divided among paresis (n = 16; 34.8%), cervical hyperpathia (14; 30.4%), and ataxia (14; 30.4%); only 2 (4.3%) dogs were quadriplegic.

Table 1—Mean (± SD) neurologic grades for 46 dogs with atlantoaxial subluxation

TIme	All dogs (median)	Dogs that had dorsal procedure (median)	Dogs that had ventral procedure (median)
Prior to surgery*	2.17 ± 0.76 (2.00)	2.38 ± 0.52 (2.00)	2.11 ± 0.80 (2.00)
At discharge*	2.00 ± 1.03 (2.00)	1.88 ± 0.64 (2.00)	2.11 ± 1.20 (2.00)
At final evaluation†	1.79 ± 1.37 (1.00)	1.89 ± 1.27 (2.00)	1.76 ± 1.42 (1.00)

*Neurologic grade attributed to first or only surgery. †Neurologic grade attributed to second or only surgery.

Median preoperative neurologic grade for all dogs was 2 (range, 1 to 4; **Table 1**). Radiographic assessment of dens morphology revealed that 21 (46%) dogs lacked a dens, 14 (30%) dogs had a dens with abnormal conformation, and 11 (24%) had a normal dens.

Number and type of surgeries—Forty (87%) dogs had only 1 surgery, whereas 6 (13%) dogs required 2 surgeries. Ventral procedures were chosen for the initial surgery in 38 of 46 (82.6%) dogs and for the second surgery in 2 of 6 dogs. Dorsal procedures were chosen for the initial surgery in 8 of 46 (17.4%) dogs and for the second surgery in 4 of 6 dogs. For all dogs that required a second surgery, the alternate procedure was used during the second surgery. We did not detect a significant (*P* = 0.229) difference in rank sums of mean preoperative neurologic grade between dogs that had ventral procedures and those that had dorsal procedures.

Suture (nylon, polypropylene, polyester,[b] polytetraflouroethylene[c]) was used in 11 of 12 (91.7%) dorsal procedures; suture material ranged in size from 1 to 5. Orthopedic wire was used in 1 of 12 (8.3%) dorsal procedures. Diameter of Kirschner wire used in ventral procedures ranged from 1.2 to 1.6 mm. Two Kirschner wires were used in 34 of 40 (85%) ventral procedures; however, 3 or 4 Kirschner wires were used in 6 of 40 (15%) ventral procedures. Polymethylmethacrylate reinforcement was used in 13 of 40 (32.5%) ventral procedures. Bone grafts were used in all but 3 ventral procedures.

Neurologic status after surgery—Reduction of the atlantoaxial joint following the 40 ventral procedures was graded as good in 35 (87.5%) dogs, satisfactory in 3 (7.5%) dogs, and poor in 2 (5%) dogs. Reduction following the 12 dorsal procedures was graded as good in 5 (41.7%) dogs, satisfactory in 3 (25%) dogs, and poor in 2 (16.7%) dogs; reduction grade was not available for 2 (16.7%) dogs.

Preoperative neurologic grade was not significantly (*P* = 0.087) different from postoperative neurologic grade. We also did not detect a significant (*P* = 0.322) difference in postoperative neurologic grade between dogs that had a dorsal procedure and dogs that had a ventral procedure. Relative condition at discharge from hospital was improved in 29 (63%) dogs and unchanged in 12 (26.1%) dogs. Five (10.9%) dogs died while hospitalized, and 1 (2.2%) dog that was improved at discharge was euthanatized within 3 weeks of surgery.

Surgical success—Nine (22.5%) of the 40 ventral procedures were considered unsuccessful. Five dogs that had ventral procedures died, and 4 dogs required a second surgery. The second surgery in all cases was a dorsal procedure. Reasons for a second surgery after ventral procedures included Kirschner wire migration or breakage and loss of atlantoaxial joint reduction. Causes of death following ventral procedures were respiratory arrest in the immediate postoperative period, euthanasia 2 days after an episode of cardiac arrest during surgery, severe electrolyte abnormalities that developed 4 days after surgery, pulmonary edema that developed 3 days after surgery, and euthanasia following fracture of the axis that occurred 20 days after surgery.

Three of the 12 (25%) dorsal procedures were unsuccessful. One dog died, and 2 dogs required a second surgery. The second surgery in both cases was a ventral procedure. Reasons for a second surgery after a dorsal procedure included breakage of suture, fracture through holes drilled in the spine of the axis, and loss of atlantoaxial joint reduction. One dog that had a dorsal procedure died 10 days following surgery. Death was attributed to spinal cord impingement by the polytetraflouroethylene suture; however, a necropsy was not performed.

Six of 40 (15%) dogs that had ventral procedures developed complications in the postoperative period that did not require a second surgery. These complications included gagging or coughing (n = 2), right laryngeal paralysis (1), severe pneumonia (1), dyspnea (1), and torticollis (1). Kirschner wires migrated in 8 of 40 (20%) dogs that had ventral procedures; polymethylmethacrylate was not used in any of these dogs. Two of these 8 dogs required a second surgery because of loss of atlantoaxial joint reduction, and 1 dog required surgery to remove a Kirschner wire. A Kirschner wire broke in 1 dog that had a ventral procedure. Polymethylmethacrylate had been used in that dog, but surgical intervention was not required.

Final follow-up evaluation—Forty of the 46 (87%) dogs survived the immediate postoperative period. Nine of 10 (90%) dogs that had a dorsal procedure and 31 of 36 (86.1%) dogs that had a ventral procedure as the definitive surgery survived the immediate postoperative period. Median time until final evaluation for dogs that survived the immediate postoperative period after ventral procedures was 7 months (range, 1 to 50 months). Median time until final evaluation for dogs that survived the immediate postoperative period after dorsal procedures was 23 months (range, 1.5 to 108 months). A cervical brace was used after surgery in 36 of the 40 (90%) surviving dogs. Four of the 6 dogs that required a second surgery did not have a brace placed after the first surgery. Among the dogs that had ventral procedures, we did not detect a significant (*P* = 0.815) difference in final neurologic grade between dogs in which polymethylmethacrylate reinforcement was used and those in which it was not used.

At the time of final evaluation, ataxia was detected in 4 of 9 (44.4%) dogs and cervical hyperpathia in 1 of 9 (11.1%) dogs that had dorsal procedures. Ataxia was detected in 6 of 31 (19.4%) dogs and cervical hyperpathia in 3 of 31 (9.6%) dogs that had ventral procedures.

Owners of all dogs that survived surgery (n = 40)

Table 2—Summary of univariate predictors of treatment success for dogs with atlantoaxial subluxation

Predictor	Groups A	Groups B	Successful final outcomes* Group A	Successful final outcomes* Group B	P value†	OR (A/B)	Sensitivity (%)	Specificity (%)
Age at onset‡	≤ 24 mo	> 24 mo	94.3 (33/35)	50.0 (4/8)	0.007	16.4	89.2	66.7
Duration of signs§	≤ 10 mo	> 10 mo	91.9 (34/37)	50.0 (3/6)	0.027	11.4	91.9	50.0
Preoperative neurologic grade	1 or 2	3 or 4	93.3 (28/30)	69.2 (9/13)	0.058	6.2	75.7	66.7
Dens conformation	Normal	Abnormal	100.0 (11/11)	81.3 (26/32)	0.312	∞	29.7	100.0
Final procedureII	Dorsal	Ventral	88.9 (8/9)	85.5 (29/34)	1.000	1.4	21.6	83.3
Reduction grade¶	Good	Sat/poor	87.1 (27/31)	88.9 (8/9)	1.000	0.8	22.9	80.0
Need for second surgery	No	Yes	86.5 (32/37)	83.3 (5/6)	1.000	1.3	86.5	16.7

*Percentage (absolute numbers). †Percentage of successful outcomes compared between groups by use of Fisher exact test. ‡Age at onset of clinical abnormalities. §Duration of abnormal clinical signs prior to surgery. IIEither first and only surgery or second surgery. ¶Postoperative atlantoaxial joint reduction grade.
OR = Odds ratio. Sat = Satisfactory.

were satisfied with the surgical outcome, even when 2 surgeries were required. Owners whose dogs died following surgery (6) were not satisfied with the outcome of surgery.

Analysis of potential predictors—Sufficient data were available from 43 of 46 (93.5%) dogs to identify potential predictors of treatment success. Receiver-operating characteristic analysis indicated that the following cutpoints yielded the highest mean of sensitivity and specificity for a successful final outcome: age at onset of clinical abnormalities ≤ 24 months, duration of clinical abnormalities prior to surgery ≤ 10 months, preoperative neurologic grade of 1 or 2 (vs grade 3 or 4), and a postoperative atlantoaxial joint reduction grade of good (vs fair or poor; **Table 2**).

Only the age at onset of clinical abnormalities, considered as either a binary or continuous predictor, was significantly associated with the odds that the first-surgery outcome would be successful. Odds of success were 8.1 times greater (95% CI, 1.1 to 62.5) in dogs for which the age at onset of clinical abnormalities was ≤ 24 months, compared with older dogs (82.9 vs 37.5% success rates, respectively; $P = 0.017$). Success rate was slightly but not significantly ($P = 0.061$) greater in dogs with a preoperative neurologic grade of 1 or 2 (83.3%), compared with dogs with a grade of 3 or 4 (50%).

Age at onset of clinical abnormalities, considered as either a binary or continuous predictor, and duration of clinical abnormalities prior to surgery, considered as a binary predictor, were significantly associated with the odds of a successful final outcome (Table 2). The odds of success were 16.4 times greater (95% CI, 1.6 to 200.0) in dogs for which age at onset of clinical abnormalities was ≤ 24 months, compared with older dogs (success rates, 94.3 and 50.0%, respectively; $P = 0.007$). The odds of success were 11.4 times greater (95% CI, 0.96 to 125.0) in dogs for which duration of clinical abnormalities prior to surgery was ≤ 10 months, compared with dogs for which duration was > 10 months (success rates, 91.9 and 50.0%, respectively; $P = 0.027$). The difference in final success rates was slightly but not significantly ($P = 0.058$) greater for dogs with a preoperative neurologic grade of 1 or 2 (93.3%), compared with dogs with a grade of 3 or 4 (69.2%).

Final neurologic grade was significantly ($P = 0.004$) greater in dogs for which age at onset of clinical abnormalities was > 24 months (median grade, 3.5), compared with younger dogs (median grade, 1.0). In addition, final neurologic grade was greater in dogs for which duration of clinical abnormalities prior to surgery was > 10 months (median grade, 3.5) or preoperative neurological grade was 3 or 4 (median grade, 2.0), compared with dogs for which duration was ≤ 10 months (median grade, 1.0; $P = 0.006$) or preoperative score was 1 or 2 (median grade, 1.0; $P = 0.023$), respectively. The change in final neurologic grade from the preoperative grade differed significantly ($P = 0.005$) between dogs for which age at onset of clinical abnormalities was ≤ 24 months (median change, –1.0) and those for which age at onset was > 24 months (median change, +1.5). Change in neurologic grade also differed significantly ($P = 0.043$) between dogs for which duration of clinical abnormalities prior to surgery was ≤ 10 months (median change, –1.0) and those for which duration of clinical abnormalities prior to surgery was > 10 months (median change, +1.0). Preoperative neurologic grade was positively correlated ($r = 0.32$; $P = 0.039$) with final neurologic grade and negatively correlated ($r = –0.43$; $P = 0.004$) with change in grade. Duration of clinical abnormalities prior to surgery was positively correlated ($r = 0.32$; $P = 0.036$) with change in neurologic grade.

Discussion

Other studies that evaluated surgical management of AAS in dogs focused on success rates with respect to surgical procedure. After reviewing the records of 46 dogs that had surgery for AAS, we identified 6 additional potential risk factors for the surgical success. First-surgery outcome and final outcome were analyzed separately, because 6 dogs had 2 surgeries. Success for these 2 outcome variables was defined as surviving surgery and not requiring another surgery. We believed that this definition was suitable, because dogs that were quadriparetic or quadriplegic would not be represented at the time of final evaluation because they would have had another surgery, died during the perioperative period, or been euthanatized. The clinical condition of all dogs that survived the perioperative period was greatly improved at the time of final evaluation. Final neurologic grade was also used as an outcome variable.

Age at onset of clinical abnormalities provided the best diagnostic performance of the potential predictors analyzed. However, with a sensitivity of 89.2% and a specificity of 66.6%, age at onset of clinical abnormalities was only moderately predictive of a successful outcome. We cannot explain why dogs that were young (≤

24 months) at the onset of clinical abnormalities were more likely to have a successful surgical outcome than older dogs. Although we did not specifically evaluate age at time of surgery as a risk factor, most of the dogs had surgery soon after onset of clinical abnormalities (median time after onset, 1 month; range, 0.25 to 71 months). Perhaps surgery was more likely to be successful in young dogs. Young dogs that undergo atlantoaxial fusion could have more rapid and more complete bony fusion than older dogs; however, all surgical failures and deaths in the present study occurred within 20 days of surgery. It is possible that young dogs may have a greater ability to recover neurologic function than old dogs.

With a sensitivity of 91.9% and a specificity of 50.0%, duration of clinical abnormalities prior to surgery should be considered only moderately predictive of successful outcome. Dogs with chronic AAS may have more permanent structural damage to the spinal cord than dogs with a shorter duration of clinical abnormalities. Therefore, in dogs with chronic AAS, there may be an increased susceptibility to trauma induced by surgical manipulation, and the potential for long-term neurologic improvement may be limited.

We hypothesized that a poor neurologic status prior to surgery may be an important risk factor for surgical success. A preoperative neurologic grade of 1 or 2 was significantly associated with a low final neurologic grade but was not associated with first surgery or final success. Preoperative neurologic status was only marginally sensitive (75.7%) and specific (66.7%) in predicting a successful final outcome.

Whether a dorsal or ventral procedure was performed did not change the odds of a successful outcome. Final success rates for ventral procedures (85.3%) were comparable to success rates for dorsal procedures (88.9%). Residual neurologic effects were detected in a greater percentage of dogs that survived dorsal procedures (mild ataxia, 44.4% of dogs; cervical hyperpathia, 11.1%), compared with dogs that survived ventral procedures (mild ataxia, 19.4%; cervical hyperpathia, 9.7%). However, final neurologic grade did not differ between dogs that had ventral procedures and dogs that had dorsal procedures. Many (8/12) of the dorsal procedures were performed in the first 10 years of the study. However, a few (4/12) of the dorsal procedures were performed more recently. We did not assess surgical era as a risk factor to determine whether improvements in management, skills, and training affected surgical outcome.

The ventral procedure appeared to be the preferred procedure; it was used for the initial surgery in 38 of 46 (82.6%) dogs. A major advantage of the ventral procedure is that it allows for curettage of the articular surface of the atlantoaxial joint to promote a bony fusion. Cancellous bone graft was placed in all but 3 of these 38 dogs. Despite this, incomplete bony fusion of the atlantoaxial joint was detected at the final radiographic examination in many of these dogs. Complications developed following use of the ventral technique and included coughing, gagging, laryngeal paralysis, and dyspnea. These complications may have been related to the approach used or to the placement of Kirschner wires. The trachea and adjacent soft tissues may be traumatized during lateral retraction. Because all of these dogs were toy breeds and most of them were immature, the atlas and axis were small and the bone was soft. Therefore, margins of error for correct Kirschner wire placement were small, and wires may have inadvertently been placed within the spinal canal. Misplacement of a Kirschner wire was believed to have contributed to cause of death in 1 dog that died following a ventral procedure. Kirschner wires could also easily fracture out of the ventral surface of the atlas or axis, requiring placement of additional wires. Iatrogenic trauma to the cervical region of the spinal cord may occur either from manipulation during surgery or penetration of the spinal cord with a Kirschner wire.

Polymethylmethacrylate was used in 13 of 40 (32.5%) ventral procedures to add strength to the fixation and prevent Kirschner wire migration. Kirschner wire migration was documented in 8 dogs that had a ventral procedure; polymethylmethacrylate was not used in any of these dogs. Disadvantages of using polymethylmethacrylate include thermal damage, pressure necrosis of structures in the neck, and infection. However, these complications were not noted in the medical records of dogs included in the present study. Recently, a modification of the ventral procedure used in this study was described.[16] In addition to the 2 Kirschner wires placed across the atlantoaxial joint, 2 Kirschner wires are placed in the atlas, and 2 are placed in the axis. Polymethylmethacrylate is then molded around the exposed ends of the wires. This procedure was successful in 8 of 9 dogs and may represent an improvement over the ventral procedure used in the present study. However, because accurate Kirschner wire placement is technically demanding, morbidity may increase with the placement of additional wires.

Advantages of the dorsal procedure include ease of approach and good exposure of the dorsal aspects of the atlas and axis. A disadvantage is that there is no access to the articular surface of the atlantoaxial joint; thus, the atlas and axis cannot be permanently fused. The dorsal arch of the atlas and the spine of the axis are thin and soft in most dogs with AAS. Long-term stability after dorsal procedures presumably is attributable to fibrosis across the dorsal aspects of the atlas and axis. However, it is not known how much stability this fibrosis provides. In the 1 dog that died following a dorsal procedure, the suture may have impinged on the spinal cord. The spinal cord can be damaged when orthopedic wire or suture are passed under the dorsal arch of the atlas. Suture was used in all but 1 of the 10 dorsal procedures. There may be less chance of trauma to the spinal cord with passage of suture rather than orthopedic wire.

Cervical braces were placed on most dogs (36/40; 90%) following the definitive surgery. A cervical brace was not placed after the first surgery in 4 of 6 dogs that required a second surgery. Cervical braces that adequately immobilize the head may protect the surgical site during the early healing period.

Postoperative atlantoaxial joint reduction graded as good was not significantly associated with greater odds of successful outcome or a low neurologic grade.

Postoperative atlantoaxial joint reduction was not significantly different between dogs that had the ventral procedure and those that had the dorsal procedure. Reduction could be lost after the postoperative period in dogs for which surgical fixation was inadequate.

The variation in radiographic appearance of the dens among dogs with AAS was similar to that described by others.[1-17] Radiographic appearance of the dens was classified as normal or abnormal and was not predictive of surgical success or final neurologic grade.

The need for a second surgery was not predictive of surgical success or final neurologic grade. Regardless of whether the first surgery was a ventral or dorsal procedure, the opposite approach was used for the second surgery. Neurologic grade after the second surgery did not differ from grade after the first surgery. Long-term outcome was generally as good in dogs that had 2 surgeries, compared with dogs that had only 1 surgery.

Clinical condition had improved in all dogs at the final follow-up evaluation. Prognosis is good for dogs treated surgically for AAS, provided that the dog survives the perioperative period. Owner satisfaction directly correlated with the survival of their dog; all owners were satisfied with the outcome if their dog survived.

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[a]SAS version 6.12, SAS Institute Inc, Cary, NC.
[b]Mersilene suture, Ethicon Inc, Somerville, NJ.
[c]Gore-tex suture, WL Gore & Associates, Flagstaff, Ariz.

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