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Objective—To evaluate long-term neurologic outcome in dogs with atlantoaxial subluxation (AAS) that were treated nonsurgically with a cervical splint.

Design—Retrospective study.

Animals—19 dogs with AAS and managed with a cervical splint.

Procedure—Medical records from 2 university hospitals were reviewed. Information pertaining to trauma, duration of clinical signs prior to admission, results of laboratory testing, results of diagnostic imaging, neurologic status at the time of discharge, duration of time the cervical splint was used for treatment, and neurologic status at the time of splint removal and at a final reexamination was extracted from the medical records. Long-term outcome was defined as neurologic status greater than or equal to 1 year after splint removal. Factors associated with a good or poor long-term outcome were determined.

Results—A good final outcome was reported in 10 of 16 dogs. Median duration of clinical signs prior to referral was 29 days; dogs that were affected ≤ 30 days were significantly more likely to have a good long-term outcome, compared with dogs affected > 30 days. The neurologic grade at admission, radiographic appearance of the dens, age at onset of clinical signs, and history were not associated with outcome.

Conclusions and Clinical Relevance—Nonsurgical management of AAS by use of a cervical splint is a viable treatment modality for young dogs with a first episode of acute-onset clinical signs, regardless of the severity of neurologic deficits at admission. (J Am Vet Med Assoc 2005;227:257–262)
nonsurgical management of AAS in dogs, regardless of neurologic deficits that were recorded at the time of admission. The purpose of this study was to evaluate the short- and long-term neurologic outcome of dogs treated with a cervical splint for AAS. In particular, we wanted to determine whether neurologic status at the time of admission correlated with outcome in dogs treated with a cervical splint.

Criteria for Selection of Cases

The medical records of all dogs that were managed with a cervical splint for treatment of AAS at the University of Georgia Veterinary Teaching Hospital and Purdue University Veterinary Teaching Hospital between 1992 and 2001 were reviewed. Radiographic reports were reviewed to confirm the diagnosis of AAS prior to including a dog in the study. A minimum follow-up time of 12 months was necessary for inclusion of a dog in the evaluation of long-term follow-up.

Procedures

Information retrieved from records included signalment, type of onset (traumatic or unknown), duration of clinical signs prior to admission, medical treatment given prior to admission, results of neurologic and physical examinations at the time of admission, results of laboratory testing and diagnostic imaging, type of cervical splint (ie, dorsal splint, ventral splint, or soft padded bandage), duration of hospitalization, neurologic status at the time of discharge, duration of time the splint was used for treatment, neurologic status at recheck examinations, and complications associated with the splint.

Clinical evaluation and neurologic grade—The neurologic status of each dog was assigned on the basis of a described grading system.11 Grade 1 corresponded with tetraplegia, grade 2 corresponded with nonambulatory paresis, grade 3 corresponded with ambulatory paresis, grade 4 corresponded with ataxia or spasticity, and grade 5 was used to denote a normal gait. Nociception was present in the limbs of all dogs at the time of admission correlated with outcome in dogs treated with a cervical splint.

Outcome—Final outcome was scored on the basis of the neurologic grade of the dog when evaluated a minimum of 12 months after removal of the splint. A good outcome was defined as having a final neurologic grade of 4 or 5. A poor outcome was defined as having a final neurologic grade of < 4 or being euthanized or dying because of AAS. Dogs that were lost to follow-up or died from an unrelated cause were not included in evaluation of final outcome.

Statistical analyses—Dogs were grouped according to long-term outcome (good vs poor). Data regarding age and duration of clinical signs prior to admission were compared between groups by use of an unpaired Student t test. A Fisher exact test was used to compare the occurrence of radiographic abnormalities of the dens, history of trauma, and neurologic grade at admission (≤ grade 2 or ≥ grade 3) between groups. Values of P < 0.05 were considered significant.

Results

Signalment and history—Nineteen dogs met the criteria for inclusion in the study. Signalment of dogs, duration of clinical signs, and other data were analyzed. Mean and median age were 2.7 and 2 years, respectively. The duration of clinical signs before admission ranged from 1 day to 3 years (mean, 4.5 months; median, 1 month). A history of trauma was reported in 10 dogs; duration of clinical signs was considered acute in 8 and chronic in 2 of those dogs. Types of trauma recorded included falling down the stairs in 2 dogs; falling off of furniture in 3 dogs; dog-fight injuries in 2 dogs; and being dropped while held, running into the wall, and being grabbed by the neck in 1 dog each. There was no history of trauma in 9 dogs. Four of those 9 dogs were considered to have an acute onset and 5 were considered to have a chronic onset of clinical signs. Fifteen of the 19 dogs received medical treatment before admission to the referral hospital. Treatment with either injectable or oral corticosteroids was administered in 12 dogs before admission. Other treatments, including antimicrobial drugs, non-steroidal anti-inflammatory drugs, opiates, and muscle relaxants, were administered in 7 dogs. Two dogs were treated with antimicrobials only, and another was treated with an opiate drug only.

Neurologic evaluation—At the time of admission, 6 of 19 dogs were ambulatory; 3 dogs had a neurologic grade of 3, and 3 had a neurologic grade of 4. Thirteen of 19 dogs were nonambulatory; of those dogs, 11 had a neurologic grade of 2 and 2 had a neurologic grade of 1. Other findings noted in the medical records included multiple bite wounds, possible seizure, cyanosis and open-mouthed breathing, fontanelle, and medially luxated patellas.

Diagnostic imaging—Certain radiographic findings, including dorsal displacement of the body of the axis and increased space between the dorsal arch of the
atlas and the dorsal vertebral column of the axis, confirmed the diagnosis of AAS in all cases. Abnormalities of the dens were noted on ventrodorsal or lateral radiographic views in 10 dogs and included dens aplasia in 5 dogs, dens hypoplasia in 3 dogs, and a fragmented dens in 2 dogs. The dens appeared normal or no comment was made in 9 dogs. Radiographs obtained after application of the cervical splint revealed improved alignment in 5 of 10 dogs and equivocal alignment, compared with previous radiographs, in 5 dogs.

**Treatment**—A cervical bandage was used to stabilize the atlantoaxial joint by immobilizing the cervical vertebral column in an extended position in all dogs. A splint was manufactured out of fiberglass cast material and incorporated into the bandage in 18 of 19 dogs. The remaining dog was initially placed in a splint, but the splint was removed and a soft padded bandage applied after 5 days because of the dog’s unwillingness to move or eat in the splint. The splint was applied to the ventral aspect of the bandage, extending from the rostral extent of the mandible caudally to the xiphoid in 13 dogs. In 4 dogs, the splint was applied dorsally and extended from a point caudal to the bony orbit caudally to the last thoracic vertebra. Dorsal and ventral splints were incorporated into the bandage of 1 dog. In 1 of the dogs treated with a dorsal splint, the dorsal splint was replaced with a ventral splint after 2 weeks to permit topical treatment for bilateral fungal otitis externa. In 1 dog in which both dorsal and ventral splints were applied, the immobilization was destabilized by removal of the dorsal splint at 6 weeks. Treatment times for immobilization with the splint ranged from 4 to 15 weeks (mean, 8.5 weeks; median, 8.5 weeks). Medical treatment with cortico-steroids administered at the referral hospital was noted in the medical records of 8 dogs. Six of those dogs had received treatment with corticosteroids prior to admission at the referral hospital and 2 of the dogs had not. Injectable corticosteroids were administered at admission or prior to manipulation of the neck for radiography in all 8 dogs. Treatment was continued with orally administered corticosteroids in 3 dogs. Oral administration of corticosteroids was discontinued in 1 dog after 4 days because of melena and hematochezia. In the other 2 dogs, treatment was continued for 8 and 21 days. Other medical treatments initiated at the referral hospital included administration of mannitol, diazepam, methocarbamol, acepromazine, and cimetidine.

**Follow-up Neurologic Status**

**Status at discharge**—Dogs were hospitalized for a range of 2 to 11 days (mean, 4.6 days; median, 3.5 days). At the time of discharge from the hospital, 10 dogs were ambulatory and 7 dogs were nonambulatory; whereas at the time of admission, 6 dogs were ambulatory and 13 were nonambulatory. Information regarding the ability to ambulate at the time of discharge was not noted in the medical record in 2 dogs. Of the 10 dogs that were ambulatory at the time of discharge, 5 had a neurologic grade of 3 and 5 had a neurologic grade of 4. All 7 of the nonambulatory dogs had a neurologic grade of 2 at the time of discharge from the hospital.

**Status at time of splint removal**—At the time of splint removal, 16 of the 19 dogs were classified with a neurologic grade of 4 or 5. Those dogs were clinically affected for a mean of 38 days prior to treatment with a splint; mean duration of treatment with a splint was 8.6 weeks, and the mean neurologic grade at initial evaluation was 2.4. Three of 19 dogs were classified as neurologic grade 2 at the time of splint removal. One dog was euthanatized after treatment with a splint for 9 days because of deterioration in neurologic grade (grade 2). Prior to euthanasia, evidence of increased subluxation at the atlantoaxial joint was noted on survey lateral radiographs. That dog had been chronically affected and had progressive worsening of neurologic status for 2 years prior to referral. Another dog died 4 weeks after placement of the splint because of acute onset of dyspnea and respiratory distress of unknown cause. That dog was chronically affected for 105 days prior to treatment with a splint. The last of these dogs had been ataxic for 3 years prior to referral and was euthanatized because of a lack of improvement after 9 weeks of treatment with a splint.

**Status at long-term follow-up examination**—Information regarding neurologic status 12 months after removal of the cervical splint was available for 11 dogs. Six dogs had died or been euthanatized for lack of improvement or deterioration in neurologic status after removal of the splint. One dog was lost to follow-up after removal of the splint. One dog was euthanatized secondary to complications of hydrocephalus.

**Neurologic grade 1**—One dog with an initial neurologic grade of 1 had normal results of a neurologic examination at the time of splint removal but had a relapse of clinical signs to neurologic grade 3 one week after removal of the splint. That dog had a chronic duration of clinical signs (3 to 4 months) prior to receiving treatment. Surgical decompression and stabilization via a ventral approach and lag-screw technique was performed. The dog died within 24 hours of surgery because of respiratory compromise and arrest.

**Neurologic grade 2**—Three dogs that were assigned a neurologic grade of 2 at admission were classified as a neurologic grade of 5 at final outcome. Follow-up times for these dogs were 3 years, 3 years, and 1 year, respectively, after splint removal. All 3 dogs had a history of acute onset of neurologic signs, with a mean duration of clinical signs of 23 days prior to treatment. Three dogs were classified as a neurologic grade of 4 at final outcome. Final outcome was established for these dogs at 21 months, 12 months, and 60 months, respectively. All dogs had a history of acute onset of clinical signs, with a mean duration of clinical signs of 11.3 days prior to admission. One dog that originally had a neurologic grade of 2 progressed to a neurologic grade of 4 at the time of splint removal and had relapse of clinical signs 3 months after removal of the splint. At the time of relapse, the dog was classified as a neurologic grade of 2. That dog had a history of chronic neurologic deficits for 3.5 months prior to receiving treatment. The owners elected euthanasia because of the severity of neurologic deficits. Another dog had relapse...
of clinical signs from a neurologic grade of 5 at the time of splint removal to a neurologic grade of 2 one and a half years after removal of the splint. Atlantoaxial subluxation was detected on radiographs, and the dog was treated with a cervical splint. Initial improvement to a neurologic grade of 5 was noted on recheck examination 1 week later. The dog was then lost to follow-up. One dog had acute onset of status epilepticus and secondary cranial nerve deficits 3 months after splint removal. The owners elected euthanasia because of the severity of neurologic dysfunction. A necropsy examination and histologic evaluation of the brain and cervical spinal cord revealed no abnormalities within the cervical spinal cord, but severe hydrocephalus was diagnosed. One dog that was classified as a neurologic grade of 5 at the time of splint removal (8 weeks) was lost to follow-up.

Neurologic grade 3—Two of 3 dogs with a neurologic grade of 3 at admission were classified as a neurologic grade of 5 at final outcome. Follow-up times for these dogs were 18 and 24 months, respectively. These dogs had a history of acute onset of clinical signs for 1 and 2 days, respectively, prior to receiving treatment. One dog had a relapse of clinical signs from a neurologic grade of 4 to a grade of 3 three weeks after splint removal. The dog was again treated with a cervical splint but had minimal improvement in neurologic status. The owners elected euthanasia after an additional 6 weeks because of persisting severe neurologic deficits (neurologic grade 3) and complications associated with the splint (corneal ulcer). This dog had an acute exacerbation of neurologic deficits for 3.5 days prior to receiving treatment.

Neurologic grade 4—Both dogs that originally arrived at the referral hospital with a neurologic grade of 4 had a final neurologic grade of 5 at 48 and 14 months, respectively, after treatment. One dog had a history of chronic neurologic deficits for 8 weeks prior to referral. The other dog had an acute onset of clinical signs for 30 days prior to examination at the referral hospital.

Complications—Complications associated with the splint were noted in the records of 7 dogs. Two of the 7 dogs treated with a ventral splint developed corneal ulcers from bandage material contacting the cornea. Progressive decline in neurologic status was attributed to inadequate stabilization and further displacement of the atlantoaxial joint in 1 dog. Other complications included accumulation of food between the splint and mandible, moist dermatitis and ulceration of the skin, otitis externa, and decubital ulcers.

Final outcome—Information regarding the final neurologic outcome was available for 16 dogs. Dogs that were lost to follow-up or dogs that were euthanized for an unrelated condition were not included. Ten dogs were classified as having a final neurologic grade of either 4 or 5 at a minimum of 12 months after removal of the splint and were therefore designated as having a good final outcome. Seven of the 10 dogs were 2 years of age or younger, with mean and median ages of 2.84 and 2 years, respectively. The mean neurologic grade of the 10 dogs at the time of admission was 2.6.

Six of 16 dogs either died or were euthanatized because of clinical signs of AAS and were designated as having a poor final outcome. Four of the 6 dogs were older than 2 years, with mean and median ages of 3.4 and 3.5 years, respectively. The neurologic status of 2 dogs declined while the dogs were wearing the splint, after 9 days in 1 dog and after 4 weeks in the other. One dog did not improve while wearing the splint and was euthanatized after 9 weeks. Three of the 6 dogs had relapse of clinical signs after the splint was removed; mean time to relapse was 5.3 weeks. The mean neurologic grade at the time of admission was 2.2. Age and initial neurologic grade were not correlated with final outcome (P = 0.35 and P = 0.6, respectively).

Duration of clinical signs in 9 of the 10 dogs that had a good final outcome was classified as acute, and 7 of the 10 dogs had a history of trauma. The mean duration of clinical signs prior to receiving treatment in those dogs was 18.8 days. Five of the 6 dogs with a poor outcome had a chronic duration of clinical signs, and 1 had a history of trauma prior to receiving treatment. The mean and median duration of clinical signs in those 6 dogs was 12.4 and 3.5 months, respectively. Duration of clinical signs prior to admission was significantly (P = 0.02) different between the 2 groups, with an acute duration of clinical signs associated with a better neurologic outcome. There was no difference (P = 0.06) in outcome between groups on the basis of a history of trauma.

Radiographic abnormalities associated with the dens were diagnosed in 4 of the 10 dogs with a good final outcome and in 5 of the 6 dogs with a poor final outcome. Of the 4 dogs with a good final outcome, a fragmented dens was diagnosed in 2 dogs and hypoplasia of the dens was reported in 1 dog each. Aplasia of the dens was diagnosed in 4 dogs and hypoplasia of the dens was diagnosed in 1 dog of the 6 that had a poor final outcome. An abnormal radiographic appearance of the dens was not significantly different between groups (P = 0.13).

Discussion

Surgical stabilization is traditionally the preferred treatment for AAS. Nonsurgical treatment and dorsal surgical techniques are dependent on formation of fibrous tissue for a favorable outcome, whereas ventral surgical techniques rely on permanent fusion for long-term stabilization of the atlantoaxial joint. Although histologic evaluation of the periarticular tissues was not performed in any of the dogs in this report, stabilization was presumably achieved by the formation of fibrous tissue around the atlantoaxial joint in dogs that improved. In the present study, 10 of 16 dogs treated nonsurgically for AAS had a good final outcome. This figure compares favorably with the results reported in other studies6–11 in which 5 of 10 dogs treated with a cervical splint had a good outcome at varying follow-up times. The rate of successful outcome in the dogs of our study was similar to that reported in a previous review of dogs treated for AAS with surgery. In that report, a successful outcome, defined as improvement

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in clinical signs and no need for reoperation, was reported for 62% of dogs that underwent a ventral-approach surgical procedure and for 61% of dogs that underwent a dorsal-approach surgical procedure. In another report, use of a surgical ventral lag-screw technique for stabilization of the atlantoaxial joint resulted in a recovery rate of 91%, with no perioperative complications for a mean of 1 year after surgery. Comparisons of outcome among reports are difficult because of differences in the definition of successful versus unsuccessful outcomes.

Residual or continued neurologic deficits after surgical treatment have been reported. In 1 study, 25% of dogs had an ataxic gait, 10% of dogs had persistent signs of cervical pain after surgery, and 3 (30%) dogs had persistent ataxia or spasticity. Residual or continued neurologic deficits in dogs treated surgically or nonsurgically may result from progressive demyelination, axonal degeneration or malacia, continued atlantoaxial instability, or concomitant neurologic disease.

Permanent fusion of the atlantoaxial joint may be accomplished by use of ventral surgical techniques; this factor is cited as an important advantage over dorsal and nonsurgical techniques. In an experimental study of the use of transarticular Kirschner wires with an autogenous cancellous bone graft, joint fusion was verified via histopathologic examination in 6 of 12 dogs, whereas the joint in 2 of the 12 dogs was mobile or grossly unstable, with no fibrous reaction. Whether joint fusion is necessary in the treatment of AAS is not known.

In the present study, 6 of 16 dogs were classified as having a poor final outcome and were euthanized or died. Among 118 reported dogs that underwent surgical treatment for AAS, the perioperative mortality rate was 17.8%. In our study, 2 of 6 dogs had acute deterioration in neurologic status while wearing a splint. Although radiographs revealed increased subluxation of the atlantoaxial joint in only 1 dog, it is likely that inadequate stabilization with the cervical splint resulted in recurrence or progression of clinical signs. One of the 6 dogs did not improve while wearing a splint. That dog had a chronic history of clinical signs, increasing the likelihood of progressive demyelination, axonal degeneration, or malacia. Three of 6 dogs in our study had a relapse of clinical signs after the splint was removed. Cervical splints were reapplied in 2 dogs, but the dogs were eventually euthanized because of poor response to treatment. It is possible that clinical signs relapsed secondary to inadequate stabilization of the atlantoaxial joint. Surgical stabilization may have provided improved stability in those dogs and should be recommended in cases of relapse. Histopathologic evaluation of the periarticular tissues of the atlantoaxial joint was not performed in any of the dogs of our study; therefore, the degree of stability of the atlantoaxial joint was unknown. The time required for adequate stability of the joint to be attained with splinting is unknown, but factors such as anatomic abnormalities, rigidity of the splint, metabolic status of the dog, and medical treatment likely play an important role. Ventral surgical stabilization was performed in one of these dogs after relapse of clinical signs, and that dog died in the acute postoperative period.

The most important reported prognostic indicator in dogs with spinal cord injury is nociception; loss of response to noxious stimuli is correlated to severity of spinal cord injury and a grave prognosis. Because of the severity of compression required for loss of nociception in cervical spinal cord lesions, respiratory paralysis and death are likely sequelae. Therefore, intact nociception is of little prognostic value for dogs with AAS. A positive correlation has been reported between the initial and final neurologic grades in dogs treated surgically for AAS. Knipe et al reported that neurologic recovery was negatively affected by increasing severity of initial neurologic status in 17 dogs that underwent a modified ventral surgical technique. An association between initial neurologic grade and outcome was not detected in the present study. It is interesting to note that 6 of 9 dogs in this study that were admitted to the referral institution with a neurologic grade of 2 (nonambulatory tetraparetic) had a good long-term outcome. It is difficult to draw conclusions regarding an association between severity of initial neurologic status and outcome in nonsurgically managed dogs because only 1 of 10 dogs in previous reports was nonambulatory and tetraparetic at admission. Two of those dogs were ambulatory and tetraparetic, and the remaining 7 dogs had only mild neurologic deficits or intermittent signs of cervical pain. Results of the present study suggest that despite severe initial neurologic deficits, nonsurgical treatment is a viable treatment modality in selected cases of AAS. In dogs with an acute onset of clinical signs and no prior history of neurologic disease, in young dogs with immature bone in which surgical fixation may not provide adequate stability, and when there are financial constraints, nonsurgical management should be considered.

Dogs with clinical signs for longer than 30 days were significantly more likely to have a poor final outcome. Conversely, a good long-term outcome was observed for dogs that were admitted with clinical signs of recent onset. This finding is similar to that reported in a previous study that evaluated risk factors associated with surgical treatment of AAS in which the duration of clinical signs was found to significantly affect the final neurologic grade. In that report, dogs that were affected for 10 months or less had significantly better final neurologic grades. Knipe et al also reported a negative correlation between neurologic recovery and increasing duration of clinical signs prior to admission in dogs undergoing surgery for AAS.

The ages of dogs in this study were consistent with other reports. Beaver et al reported that age at onset of clinical signs was the best predictor of outcome in dogs with AAS that were surgically treated. In that report, dogs older than 2 years at admission had a significantly worse final neurologic grade. The authors posited that young dogs may have an increased capacity for neurologic recovery. No association between the age of dogs and final outcome was detected in our study, suggesting that, irrespective of the age of the dog, irreversible neurologic injury may not occur until substantial neurologic deficits are observed.

In the present study, 10 of 19 dogs had a diagnosis of AAS with a concomitant anatomic abnormality of
the median atlantoaxial joint, yet abnormalities of the dens were not associated with outcome. Likewise, radiographic appearance of the dens was not a factor associated with a successful outcome in 46 dogs with AAS that were treated surgically.4–8 Stability of the atlantoaxial joint with dens dysplasia is unknown and comparison of different types of anatomic abnormalities was not evaluated in the present study. Dogs with anatomic aberration of the dens were evaluated as a group in this study because subjective criteria used to radiographically evaluate the dens and differences in patient positioning for radiographs may have resulted in different interobserver diagnoses. Objective inclusion criteria for radiographic evaluation of the dens and associated structures would be necessary to establish guidelines for prognoses made on the basis of specific congenital defects.

The breeds of dog represented in this study were consistent with those reported in other studies. No differences in long-term outcome were noted between breeds or sex. There was no significant difference in long-term outcome between dogs with or without a history of trauma.

Fourteen of the 19 dogs in this study were treated with either orally or parenterally administered corticosteroids as part of a treatment regimen at the referral hospital or prior to admission. Oral administration of corticosteroids was continued in 2 of these dogs. Difference in long-term outcome between dogs that received corticosteroids and those that did not was not evaluated because drugs, dosages, and treatment regimens were not controlled and were highly variable. On the basis of information obtained from medical records, bolus administration of parenteral corticosteroids was given prior to radiographic manipulation and splint application in some instances. Because of variation in treatments, conclusions cannot be made regarding outcome and corticosteroid treatment.

A low rate of complications was detected in this study. Inadequate stabilization of the cervical vertebral column occurred in 1 dog in which increased displacement of the atlantoaxial joint was detected radiographically 9 days after placement of the splint. Two other dogs developed corneal ulcers from bandage material contacting the eye. Appropriate splinting technique, diligent monitoring and frequent evaluation of the bandage by veterinary staff, and thorough client education on bandage care are of paramount importance and may decrease the incidence of complications.

Nonsurgical management of dogs with AAS by use of a cervical splint or bandage was associated with a good long-term outcome in 10 of 16 dogs and should be considered a viable treatment modality. Dogs with an acute onset of clinical signs and that have no prior history of neurologic disease, young dogs with immature bone in which surgical fixation may not provide adequate stability, and dogs for which there are financial constraints should be considered for nonsurgical management. Ventral surgical stabilization techniques should be recommended in dogs with AAS for which there is a chronic history of clinical signs, when clinical signs have relapsed or nonsurgical treatment has failed, and with mature bone capable of supporting surgical implants. Improvement to a normal or near-normal neurologic status may be achieved in dogs with severe neurologic deficits. A good long-term outcome was associated with an acute duration of clinical signs. Dogs' neurologic grades at admission, radiographic appearance of the dens, age, or a history of trauma were not correlated with long-term outcome. Radiographs should be performed after application of a splint to evaluate alignment, and owners should be counseled on proper bandage management and nursing care, educated about common complications, and advised that surgical treatment may be necessary if there is worsening of neurologic status.

References