Results of oral prednisolone administration or ventriculoperitoneal shunt placement in dogs with congenital hydrocephalus: 40 cases (2005–2016)

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OBJECTIVE
To evaluate signalment, clinical findings, and outcomes of dogs with congenital hydrocephalus treated medically with orally administered prednisolone or surgically by ventriculoperitoneal shunt placement.

DESIGN
Retrospective case series.

ANIMALS
40 client-owned dogs.

PROCEDURES
Medical records from 2005 to 2016 were searched to identify dogs with congenital hydrocephalus confirmed by MRI examination. Patients were categorized by treatment (medical vs surgical). Signalment, clinical signs, neurologic examination findings, results of diagnostic tests, duration of hospitalization, complications potentially related to treatment, and follow-up information were recorded. Outcome was categorized on the basis of clinical (neurologic) signs as improved, stabilized, or deteriorated. Variables of interest were compared between groups by Fisher exact or Mann-Whitney *U* tests.

RESULTS
28 and 12 dogs had surgical and medical treatment, respectively; 3 medically treated dogs subsequently underwent ventriculoperitoneal shunt placement. No significant differences were noted in clinical or imaging findings between surgically and medically treated dogs. Median follow-up time was 9 months and 15.5 months for medically and surgically treated dogs, respectively. Of 12 medically treated dogs, 6 improved and 6 deteriorated. Of 26 surgically treated dogs with data available, 14 (54%) improved, 1 (4%) stabilized, and 11 (42%) deteriorated; 4 (15%) had known postoperative complications.

CONCLUSIONS AND CLINICAL RELEVANCE
Approximately half of the dogs treated with prednisolone in this population had neurologic improvement at last follow-up; results of surgical treatment were comparable to those in previous studies. Further research is needed to assess factors associated with acceptable outcomes for dogs with congenital hydrocephalus. (*J Am Vet Med Assoc* 2019;254:835–842)

Multiple medical and surgical options have been described for the treatment of congenital hydrocephalus in dogs. Surgical treatment typically consists of VPS placement. However, this procedure can be associated with complications and implant failure.[1–8] A recent study[2] reported clinical improvement in 26 of 36 (72%) surgically treated animals (dogs and cats). However, 8 (22%) animals developed postoperative complications and 13 (36%) died or were euthanized as a result of hydrocephalus.[2] Similar complication rates have been reported in smaller studies[1,3] following VPS placement for treatment of hydrocephalus in dogs.

ABBREVIATIONS

VBHR Ventricle-to-brain height ratio
VPS Ventriculoperitoneal shunt

The goal of medical management for this condition is to decrease CSF production or increase CSF absorption. A variety of medications, including glucocorticoids,[5] have been suggested for decreasing CSF production. Although the exact mechanism of action of glucocorticoids in terms of their effects on CSF are not completely understood, results of experimental studies in rabbits[7] as well as dogs[8] have revealed decreases in CSF production following administration of these drugs. However, to the best of the authors' knowledge, no previous veterinary studies have evaluated the clinical variables and outcomes of dogs treated with corticosteroids for congenital hydrocephalus, and this type of treatment is generally considered to achieve only temporary alleviation of clinical signs. Other drugs that have been investigated as a means to decrease CSF production include furosemide (a loop

diuretic), acetazolamide (a carbon anhydrase inhibitor), and omeprazole (a proton pump inhibitor).[9–12]

The aim of the study reported here was to identify the clinical findings and outcomes of dogs with congenital hydrocephalus treated medically with oral prednisolone administration or surgically with VPS placement. We hypothesized that no differences would exist in clinical findings between dogs treated medically and surgically, and that surgical management would result in better response to treatment and outcome than medical management.

Materials and Methods

The retrospective study was approved by the Royal Veterinary College Ethics and Welfare Committee (protocol number URN 2015 1425). The survey used to obtain follow-up information was created by the authors (SD and ZG) and was reviewed and approved by the same committee.

Case selection criteria

Hard-copy and electronic medical records of the University of London Royal Veterinary College Small Animal Referral Hospital from January 1, 2005, through October 1, 2016, were reviewed to identify dogs that had a diagnosis of congenital hydrocephalus made on the basis of findings consistent with the diagnosis on MRI evaluation,[13] full neurologic examination by a board-certified veterinary neurologist, and clinical signs compatible with the disease. Keywords for electronic records searches included "hydrocephalus," "congenital hydrocephalus," and "ventriculoperitoneal shunt." Dogs were included in the study if the complete medical record and diagnostic images were available for review. For study purposes, records were considered complete if the following information was available: signalment (including body weight at the time of evaluation), history, signs for which the patient was initially examined, duration of signs prior to evaluation, age at onset of clinical signs, treatment prior to evaluation at the study hospital and response to prior treatment (if applicable), physical and neurologic examination findings on initial evaluation, results of diagnostic imaging, treatment received, and duration of stay at the study hospital.

All diagnostic images and medical record files were reviewed by a board-certified veterinary neurologist (SD) to evaluate diagnostic information and study eligibility. Dogs were excluded if the medical files or imaging records were not available or if other abnormalities were detected that could have caused or contributed to the dog's clinical signs.

Medical records review

Data collected for each dog included signalment, duration and type of clinical signs, and neurologic examination findings. Diagnostic tests performed and their results, treatments received (medical or surgical and any postoperative medications), reported complications, and duration of hospitalization were also recorded. Dogs were categorized for study purposes as being treated medically or surgically.

Procedures

Imaging—Diagnostic MRI was performed prior to referral or at the time of admission with dogs under general anesthesia. When MRI was performed at the study hospital, a 1.5T unit[a] was used. Dogs were placed in dorsal recumbency for scanning; protocols included a minimum of T2-weighted and T1-weighted sagittal and transverse images, fluid-attenuated inversion recovery, and T1-weighted transverse images after administration of gadolinium-based contrast medium[b] (0.5 mL/kg [0.23 mL/lb], IV). Owners were informed of treatment options by a veterinary neurology specialist or specialist in training. The treatment undertaken was determined on the basis of owner preference.

The MRI images were retrospectively examined by 1 investigator (SG), and the cerebral VBHR ([cerebral ventricle height/brain height] × 100) was calculated as previously described.[14] The T1-weighted images were assessed at the level of the interthalamic adhesion. A mean VBHR was calculated for each dog from values calculated for the left and right ventricles. These values were used in intergroup comparisons.

Surgical treatment—Dogs were premedicated with methadone (0.2 mg/kg [0.09 mg/lb], IV), and anesthesia was induced with propofol (4 mg/kg [1.8 mg/lb], IV). Following endotracheal intubation, general anesthesia was maintained with isoflurane in oxygen. Placement of a unilateral VPS was performed as previously described.[1] Dogs were positioned in partial sternal recumbency (head and shoulders) and partial right lateral recumbency (pelvis). The shunt was placed into the ventricle of the brain that was considered to be most dilated on examination of the diagnostic images. A commercial shunt system[c] with an ultra-small, low-low or medium pressure valve (opening pressures of 1 and 8.5 cm H_2O, respectively) was used in all dogs. A rostrotentorial craniotomy approach was used with a burr hole created in the parietal bone over the selected region by means of a pneumatic drill.[d] An incision was made into the dura mater, and the ventricular catheter was introduced through the cerebral cortex via a stylet. An anchor was fitted into the burr hole and sutured to the periosteum or temporalis muscle fascia. Following incision and dissection of the flank region skin, muscle layers, and peritoneum, the distal catheter was inserted into the abdominal cavity and secured in place with polypropylene suture in a finger-trap suture pattern. The free end of the distal catheter was passed through a subcutaneous tunnel to the cervical region, where it was attached to the one-way valve. All incisions were routinely closed in 3 layers over the shunt. Postoperative analgesic treatment was provided with methadone (0.1 to 0.2 mg/kg [0.05 to 0.09 mg/lb], IV, q 4 h) and paracetamol (10 mg/kg [4.5 mg/lb], PO, q 12 h). After surgery, all dogs received a tapering dose of

prednisolone (beginning with 0.2 to 0.5 mg/kg, PO, q 12 to 24 h). An antiepileptic medication (phenobarbitone, 2 to 3 mg/kg [0.9 to 1.4 mg/lb], PO, q 12 h) was also administered if the patient had a history of seizures. Prednisolone treatment was typically discontinued for surgical patients 9 to 14 days after surgery.

Medical treatment—Patients that were treated by medical management alone received prednisolone at an initial dose of 0.5 to 1 mg/kg (0.23 to 0.45 mg/lb, PO, q 12 to 24 h), tapering down to a minimally effective dose or discontinued if possible. Antiepileptic medication (phenobarbitone, 2 to 3 mg/kg, PO, q 12 h) was added if the patient had a history of seizures.

Follow-up—Short-term follow-up information was obtained from the medical records of reexamination at the Royal Veterinary College Small Animal Referral Hospital 2 to 6 weeks after VPS placement (surgical treatment group) or after starting oral prednisolone treatment (medical treatment group). Recent history and neurologic signs were recorded and compared with the data obtained on initial examination.

Complete follow-up (including long-term follow-up, if applicable) and outcome information was obtained from a combination of telephone interviews with referring veterinarians and owners. Referring veterinarians were first contacted and asked a series of questions regarding the patient's clinical status, current medications, neurologic deficits present, and progression after commencement of treatment. If the dog had died, the date, cause of death (if known), and last recorded neurologic status were recorded. Conforming to local ethics and welfare guidelines, the owners of dogs known to have died were not contacted further. Owners of dogs last known to be alive were mailed a letter that included the study details and a standardized questionnaire developed by the authors (**Supplementary Appendix S1**, available at avmajournals.avma.org/doi/suppl/10.2460/javma.254.7.835). At this stage, owners were given the opportunity to opt out of being contacted further. Questionnaires were subsequently completed by owners who elected to participate via telephone interview with 1 investigator (ZG). Treatment outcome was determined from the data acquired from both referring veterinarians and owners; dogs were categorized as improved, stabilized, or deteriorated on the basis of change in the original clinical (neurologic) signs. Dogs that initially showed signs of improvement or stabilization but subsequently had clinical deterioration were categorized as deteriorated at long-term follow-up.

Statistical analysis

Statistical analysis was performed with a commercial software package.[e] Data were assessed for normality with the Shapiro-Wilk test. Fisher exact tests were used to investigate differences in sex, presence of various neurologic signs, short-term outcome, and long-term outcome between groups. Mann-Whitney *U* tests were used to investigate intergroup differences in age at diagnosis, VBHR, body weight, and duration of clinical signs at diagnosis. For all comparisons, values of $P < 0.05$ were considered significant.

Results

The records search identified 52 dogs with congenital hydrocephalus. Of these, 5 were excluded owing to incomplete medical records or imaging files; another 7 were excluded because they were euthanized without treatment owing to financial concerns and uncertainty about long-term outcome and quality of life. Forty dogs with congenital hydrocephalus were enrolled in the study; 28 and 12 underwent surgical and medical management, respectively. One dog treated medically received prednisolone PO for 4 days prior to referral; the treatment start date for this patient was recorded from the day on which steroids were first administered. No other patients received medical treatment for the condition prior to referral. Three medically treated dogs subsequently underwent VPS placement because they had an unsatisfactory response to medical management; these 3 dogs were not included in the surgical group for description and statistical analysis. Five dogs underwent MRI prior to the referral examination, and 35 had the procedure performed on admission to the study hospital.

The most commonly represented breeds were English Bulldog (n = 5), Chihuahua (4), and Pug (3). Other breeds included Maltese, Border Collie, Dachshund, and Lhasa Apso (2 of each), as well as French Bulldog, Cavalier King Charles Spaniel, English Cocker Spaniel, Shetland Sheepdog, Papillion, Akita, Great Pyrenees, Golden Retriever, Labrador Retriever, Samoyed, Gordon Setter, Boxer, Yorkshire Terrier, and Jack Russell Terrier (1 of each). There were 6 mixed-breed dogs. Of the 40 dogs, 19 were females (8 spayed and 11 sexually intact) and 21 were males (7 neutered and 14 sexually intact). The median age of all dogs was 12 months (range, 2 to 123 months) and median weight was 6.5 kg (14.3 lb; range, 1.1 to 34 kg [2.4 to 75.0 lb]).

The median duration of clinical signs before diagnosis was 1.6 months (range, 1 day to 57 months). Thirty-seven of 40 (93%) dogs had neurologic abnormalities on initial examination. The remaining 3 dogs had a history of seizures without abnormalities detected during neurologic examination. Observed neurologic abnormalities included proprioceptive deficits (n = 27); inappropriate mentation (22); absent menace response unilaterally (4) or bilaterally (21); vestibular (9), proprioceptive (7) or cerebellar (2) ataxia; and circling (8). Bilateral ventrolateral strabismus was observed in 5 dogs, and 7 dogs had a head tilt. A dome-shaped head was noted for 8 dogs. Generalized tonic-clonic seizures were reported for 14 dogs, and focal seizures were reported for 1 dog. On MRI, the median cerebral VBHR was 43.22% (range, 20.93% to 92.96%).

Twenty-two dogs had CSF analysis performed (16 and 6 in the surgical and medical treatment groups, respectively). For surgically treated dogs, the median total nucleated cell count was 2.5 cells/µL (range, 0 to 152 cells/µL; reference range, < 5 cells/µL), and the median CSF protein concentration was 16.5 mg/dL (range, 5 to 3,000 mg/dL; reference range, < 25 mg/dL). For medically treated dogs, the median total nucleated cell count was 2.5 cells/µL (range, 0 to 8 cells/µL) and median CSF protein concentration was 13.5 mg/dL (range, 11 to 23 mg/dL). Six dogs in the surgical treatment group and 1 in the medical treatment group had total nucleated cell counts or CSF protein concentrations greater than the upper limit of the respective reference range. Three dogs (all treated surgically) had both of these findings.

No significant differences were observed between medically and surgically treated dogs for age, body weight, sex, duration and type of clinical signs, presence and type of neurologic deficits, seizure history, or VBHR measured on MRI **(Table 1)**. Owner questionnaires were completed by 12 individuals (5 and 7 owners of dogs that had medical and surgical treatment, respectively).

Short-term follow-up

Medically treated dogs—Ten of the 12 medically treated dogs had short-term follow-up visits recorded. Six of the 10 dogs were classified as neurologically improved, 1 was classified as deteriorated, and 3 were classified as stabilized at the time of the last short-term follow up visit. The 3 dogs that initially had medical treatment and subsequently underwent VPS placement had the surgery performed 3.5 weeks, 2.5 months, and 3.8 months after medical treatment was initiated. The procedure was successfully completed in all 3 dogs, and the dogs continued to improve neurologically after hospital discharge.

Surgically treated dogs—Surgical placement of a VPS was uneventful in all 28 dogs, and the median duration of hospitalization was 3 days (range, 1 to 13 days) after surgery. Two dogs had seroma formation over the calvarial surgical site in the immediate postoperative period. Twenty-five of the 28 dogs had short-term follow-up visits. At the time of the last short-term follow-up visit, 20 of 25 (80%) dogs had improved, 3 (12%) had deteriorated, and 2 (8%) had stabilized. All 3 dogs that had deteriorated despite surgery were euthanized between 2 and 3 weeks after surgery without further diagnostic investigations.

Intergroup comparisons—The described proportions of dogs in the medical and surgical treatment groups that were categorized as improved, stabilized, or deteriorated at the last short-term follow-up visit were compared. These proportions did not differ significantly between groups ($P = 0.393$, $P = 0.128$, and $P = 1.0$, respectively).

Outcomes

Medically treated dogs—None of the 12 medically treated dogs were lost to follow-up. The median follow-up time was 9 months (range, 3.5 weeks to 71.7 months) after the start of medical treatment. Six dogs in the medical treatment group were categorized as improved, compared with their pretreatment neurologic condition, and 3 of the 6 were reported to be neurologically normal at the time of last follow-up. Five of these 6 dogs were still alive at last follow-up (median follow-up time, 67.4 months; range, 56 to 71.7 months). One dog died 10 months after starting treatment for reasons unrelated to hydrocephalus or its medical management. Four of the 6 dogs that were

Table 1—Signalment, clinical data, and diagnostic imaging findings of interest at the time of initial examination for 40 dogs in a retrospective study to evaluate clinical findings and outcomes of dogs with congenital hydrocephalus treated medically with orally administered prednisolone or surgically by VPS placement.

Variable	Surgically treated dogs (n = 28)	Medically treated dogs (n = 12)	*P* value
Age (mo)	9.5 (2–123)	17 (4–88)	0.247
Body weight (kg)	6 (1.1–34)	10 (2.7–33)	0.066
Sex			0.494
Male	16 (57)	5 (42)	
Female	12 (43)	7 (58)	
Duration of clinical signs (mo)	1 (0.03–57)	3.6 (0.2–19.7)	0.900
Seizure history	10 (36)	5 (42)	0.736
Neurologic abnormalities on examination	27 (96)	10 (83)	0.209
Inappropriate mentation	16 (57)	6 (50)	1.0
Ventrolateral strabismus	3 (11)	2 (17)	0.672
Absent menace response	19 (68)	6 (50)	0.311
Proprioceptive deficits	21 (75)	6 (50)	0.154
Ataxia	13 (46)	5 (42)	1.0
Cervical hyperesthesia	8 (29)	3 (25)	1.0
Circling behavior	6 (21)	2 (17)	1.0
Head tilt	4 (14)	3 (25)	0.410
Dome-shaped head	5 (18)	3 (25)	0.677
VBHR (%)	48.57 (20.93–92.96)	38.29 (25.40–88.36)	0.114

Values are number (%) or median (range). Values of $P < 0.05$ were considered significant.

reported to be neurologically normal at the time of last follow-up had been weaned off of prednisolone completely; the median duration of treatment for these dogs was 12 months (range, 9 to 15 months). The remaining 6 dogs had deteriorated despite medical treatment. Three of these dogs were euthanized 1.7 months, 2.9 months, and 8 months after treatment was initiated. The other 3 were the dogs that subsequently underwent VPS placement because of deterioration with medical management. One of these dogs experienced shunt migration and occlusion 8.9 months after surgery and was subsequently euthanized; the other 2 died 1 year and 2.5 years after surgery for reasons unrelated to hydrocephalus or VPS placement.

All of the 5 medically treated dogs that had a history of seizures at the start of treatment were still receiving antiepileptic medication (phenobarbitone, 2 to 3 mg/kg [0.91 to 1.36 mg/lb], PO, q 12 h) at the time of last follow-up. Two dogs had continued to have seizures at rates similar to those reported prior to treatment; these were the dogs that were euthanized 1.7 months and 8 months after treatment started. The cause for euthanasia of 1 dog was aggression and incontinence, and that for the other dog was the lack of improvement in seizure frequency. One other dog had an increase in seizure frequency and was euthanized because of status epilepticus 2.9 months after treatment started. The remaining 2 of 5 dogs had reduced seizure frequency, and both were alive at last follow-up (56 and 67.4 months after treatment was initiated).

Surgically treated dogs—Two of the 28 surgically treated dogs were lost to long-term follow-up. The median duration of complete follow-up for the remaining 26 dogs was 15.5 months (range, 2 weeks to 70.8 months) after surgery.

Fourteen of 26 (54%) dogs with follow-up available had improved, compared with their pretreatment neurologic condition, and 9 of these 14 were reported to be neurologically normal at last follow-up. All 14 dogs were still alive at last follow-up (median follow-up time, 33.3 months; range, 1.9 to 70.8 months). Eleven of 26 (42%) dogs had deteriorated despite surgical intervention, and 1 (4%) had stabilized. Of the 11 dogs classified as deteriorated, 5 were perceived to have initial improvement or stabilization of neurologic signs prior to a sudden deterioration that was observed a median of 27.3 months (range, 5 to 46.7 months) after surgery. Ten of these 11 dogs were euthanized at a median of 4.9 months (range, 2 weeks to 50 months) after surgery. The dog that was classified as stabilized was alive at last follow-up (52 months) and continued to experience cluster seizures at a frequency similar to that reported prior to surgery.

All 10 nonsurviving dogs were euthanized as a presumed direct consequence of the condition or complications related to treatment. Three of these were the dogs euthanized in the short-term follow-up period because of neurologic deterioration. Six other dogs were euthanized because of neurologic deterioration (n = 3), increase in seizure frequency (1), occurrence of status epilepticus (1), or cluster seizures (1) between 2.5 and 50 months after surgery; no further diagnostic tests were performed to determine the cause of deterioration. One dog was euthanized because of a complication after VPS placement; overshunting led to collapse of a lateral ventricle and subdural hemorrhage 5 months after surgery.

Another 3 dogs in this group were known to have complications directly related to VPS placement. These included catheter migration and blockage (1.6 months after surgery), shunt exteriorization (8 months after surgery), and kinking of the catheter in the peritoneum (5.3 months after surgery). All of these dogs underwent successful revision surgery and were alive at last follow-up.

Of 10 surgically treated dogs that had a history of seizures, 1 was lost to long-term follow-up. Two of the remaining dogs were reported to have reduced seizure frequency at last follow-up, compared with that prior to VPS placement, and 4 continued to have seizures at rates similar to those before surgery. The other 3 dogs had been euthanized because of seizure activity as previously described.

Intergroup comparisons—The reported proportions of dogs in the medical and surgical treatment groups that were categorized as improved, stabilized, or deteriorated at the time of last follow-up (or the time the treatment approach was changed [for the 3 medically treated dogs that later had surgery]) were analyzed. These values did not differ significantly (P = 1.0, P = 1.0, and P = 0.734, respectively) between groups.

Discussion

Although VPS placement is considered the treatment of choice for dogs with congenital hydrocephalus, it is associated with well-known complications and potential failure. To the authors' knowledge, no previous veterinary studies have evaluated the outcome of dogs treated with corticosteroids for congenital hydrocephalus. Overall, we did not detect any significant differences in selected signalment variables, duration of clinical signs, presence and type of neurologic deficits, seizure history or cerebral VBHR on diagnostic MRI images between surgically and medically treated dogs with congenital hydrocephalus. It remains unclear which clinical characteristics currently influence owners and clinicians to prefer or recommend one treatment option over the other. Given the small numbers of patients included in the study, these findings should be interpreted with caution. However, approximately half of the dogs in both groups had good long-term outcomes; 6 of 12 medically treated dogs were considered neurologically improved and 5 were still alive at last follow-up, whereas 14 of 26 surgically treated dogs were described as neurologically improved and 15 (includ-

ing 1 considered neurologically stabilized) were still alive at last follow-up. Although this study failed to provide evidence of superiority for surgical or medical management, our results suggested that medical management can be associated with a positive outcome in selected cases.

In an effort to select as homogenous a patient population as possible, only dogs with a confirmed diagnosis of congenital hydrocephalus following MRI and examination by a board-certified veterinary neurologist were included in the study. The breeds, ages, and clinical signs of affected dogs in this study were similar to those reported previously.[1,3,15,16]

Seven dogs with congenital hydrocephalus were euthanized after a diagnosis was reached without treatment attempted. Financial concerns and uncertainty about long-term outcome were the factors leading to this decision in each case. It could not be excluded that the owners of these dogs would have considered another decision if they would have been aware of the potential response to glucocorticoid administration. This confirmed the need for further studies evaluating the outcome of nonsurgical treatment for dogs with congenital hydrocephalus. Although the findings of this small study may not be completely representative of the larger population of dogs with this condition, it is hoped that the results can provide practitioners with additional information to help advise dog owners more completely about available treatment options and outcomes for dogs with congenital hydrocephalus.

The finding that 6 of 12 medically treated dogs had neurologic improvement on long-term follow-up, with 5 dogs still alive at this time (all ≥ 4.5 years after treatment started) and 4 dogs having been tapered off of prednisolone completely, suggested that neurologic status of some dogs with congenital hydrocephalus can improve or stabilize for a substantial period of time with corticosteroid treatment. The effects of glucocorticoids on CSF production and absorption remain incompletely understood. Their use is generally recommended to stabilize clinical signs until VPS placement is performed or as alternative treatment when surgery is not feasible.[5,17] The goal of medical treatment is to decrease CSF production, lower CSF volume, and reduce tissue destruction.[18] Results of experimental studies[7,8] in rabbits and dogs have shown reduced CSF production following short-term and prolonged administration of glucocorticoids. Five days of treatment with betamethasone reduced CSF production by 43% in healthy rabbits, and a rapid decrease in CSF production was found in healthy dogs ≤ 1 hour after IV dexamethasone administration.[7,8] It has been proposed that glucocorticoids exert this effect through reduction of choroid plexus transport capacity and of sodium-potassium ATPase activity.[7] In addition, these drugs may reduce periventricular edema if it is present.[13]

In human patients, chronic hydrocephalus can sometimes develop beginning in infancy but arrest without evidence of neurologic deterioration. This condition has been described as arrested hydrocephalus, previously untreated congenital hydrocephalus, compensated hydrocephalus, long-standing overt ventriculomegaly of adults, or a syndrome of hydrocephalus in young and middle-aged adults.[19,20] Consensus on the treatment of that condition is lacking, and some clinicians advocate a conservative approach with serial reassessment.[21,22] However, more recent evidence has suggested that the condition leads to a slow and continuous neurologic decline in most patients, and this has resulted in recommendations for prompt surgical intervention at the time of diagnosis.[20,23–25] It is unknown whether a similar condition exists in dogs; however, a slow neurologic decline might be more difficult to observe in such patients.

In laboratory settings, omeprazole significantly reduced CSF production (by 26% to 50%) following ventriculocisternal or IV administration in studies of healthy dogs and rabbits.[9,10] However, a recent pilot study[26] of 15 healthy Beagles found that a 2-week course of oral omeprazole treatment had no significant effect on CSF production. Similarly, oral administration of acetazolamide for 3 weeks (1 dog) or 6 weeks (6 dogs) did not improve clinical signs or reduce ventricular volume in clinical patients with congenital hydrocephalus.[27,28]

In the present study, 20 of 25 (80%) dogs that underwent VPS placement (excluding dogs that had surgery after failure of medical management) and were seen for follow-up visits had neurologic improvement between 2 and 6 weeks after surgery. These results were comparable to previous veterinary studies[1,3] in which neurologic improvement was detected in 13 of 14 dogs and 8 of 12 dogs at recheck visits between 2 and 4 weeks after surgery. Similarly, in a recent study comprising 36 cases of congenital hydrocephalus in dogs and cats, 26 (72%) animals had improvement in clinical signs at a median follow-up time of 6 months after surgery.[2] In the present study, 14 of 26 (54%) dogs with long-term follow-up information available had neurologic improvement at the time of final data capture (median, 15.5 months after surgery) and 11 (42%) had deterioration, including 5 that were reported to be doing well prior to a sudden decline. Unfortunately, many of these dogs did not undergo further diagnostic investigations, and the exact cause of neurologic deterioration was unknown.

The complication rate after hospital discharge for dogs that underwent VPS treatment and had the information available (4/26 [15%]) in the present study was comparable to rates of 8 of 36 (22%) and 4 of 14 found in other retrospective veterinary case series that included dogs with hydrocephalus[2,3]; it should be noted that 1 of another 3 dogs in our study that underwent VPS placement after clinical deterioration during medical management also had shunt-related complications. In agreement with a previous study,[2] complications most commonly developed in the early postoperative period, and all occurred < 9 months after surgery in the present study. Complications following VPS placement can include infection, signs of

pain, and overshunting leading to ventricular collapse and subdural hematoma formation. Undershunting can occur with catheter occlusion, kinking, disconnection, or shunt migration.[1–3,5,6] The complication rate in the present study was possibly underestimated, given that multiple dogs were euthanized following neurologic deterioration without further diagnostic testing. Overall, 10 of 26 (38%) surgically treated dogs with known outcomes were euthanized because of unresolved clinical signs or complications associated with VPS placement. Similar results have been reported[1,2] previously, with euthanasia of 3 of 12 dogs and 13 of 36 (36%) dogs and cats with congenital hydrocephalus. In a multicenter study[29] of 344 hydrocephalic children that had 1 of 3 VPS valve types placed, shunt failure rates requiring additional surgery were approximately 40% at 1 year after implantation, regardless of shunt design. It is important that owners are aware of the prevalence of shunt-related complications and the potential for a lack of improvement after shunt placement, which might necessitate additional diagnostic investigations and revision surgery in the future.

Of 9 surgically treated dogs that had a history of seizures and had outcome data available, only 2 had reduced seizure frequency after surgery in the present study. Three of the remaining 7 were euthanized because of increased seizure frequency or occurrence of status epilepticus. The number of such dogs in our study was too small for conclusions to be drawn; however, this finding was in agreement with observations in another small study.[3] Further research is needed to determine whether VPS placement is truly ineffective for reducing seizure frequency in dogs with congenital hydrocephalus.

The present study was limited by the small number of dogs and by its retrospective nature, which necessitated reliance on medical records accuracy, and did not allow for standardized treatment or follow-up assessment for all dogs. Although no significant differences were detected between the medically and surgically treated groups in terms of the investigated signalment (age, weight, and sex), clinical (duration of clinical signs, presence of neurologic abnormalities, and seizure history) and imaging (VBHR) variables, comparisons between the 2 groups were likely influenced by the lack of random treatment assignment as well as the small numbers of dogs available for inclusion and high degree of interindividual variability for most measures. Although follow-up data were collected from a combination of referring veterinarian interviews and owner questionnaires, it was possible that owner recall bias influenced the outcome results in some cases. Furthermore, not all medically treated dogs had CSF analysis performed owing to concerns of high intracranial pressure suggested by MRI findings, and it could not be completely excluded that some of the medically treated dogs had inflammatory CNS disease (eg, meningoencephalitis of unknown etiopathogenesis). It is unknown whether neurologic signs would have stabilized in some patients regardless of treatment, and further studies are warranted to evaluate the natural progression of congenital hydrocephalus and investigate potential prognostic factors for successful medical and surgical treatment.

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Footnotes

a. Intera 1.5T, Philips Medical Systems, Eindhoven, Netherlands.
b. Gadiovist 1.0 mmol/mL solution for injection, Bayer, Berlin, Germany.
c. PS Medical CSF-Flow Control, Medtronic, Minneapolis, Minn.
d. Hall Surgairtome II, Hall, Largo, Fla.
e. IBM SPSS Statistics for Windows, version 23.0, IBM Corp, Armonk, NY.

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From this month's *AJVR*

Development and assessment of a novel precordial lead system for accurate detection of right atrial and ventricular depolarization in dogs with various thoracic conformations

Roberto A. Santilli et al

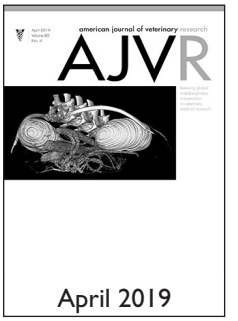
OBJECTIVE
To assess recording accuracy of right atrial and ventricular depolarization during 12-lead ECG when precordial lead V_1 was positioned at each of 5 locations on the thorax of dogs with various thoracic conformations.

ANIMALS
60 healthy client-owned dogs.

PROCEDURES
20 dogs were allocated to each of 3 groups (brachymorphic, mesomorphic, or dolichomorphic) on the basis of thoracic conformation. Each dog remained unsedated and was positioned in right lateral recumbency for a series of five 12-lead surface ECGs, with V_1 located adjacent to the sternum in the fifth intercostal space (ICS; control), at the costochondral junction (CCJ) of the right first ICS (1st-R), at the CCJ of the right third ICS, at the right third ICS where the thorax was the widest, and at the CCJ of the left first ICS. Electrocardiographic variables were compared among the 5 ECG tracings.

RESULTS
When V_1 was at the control location, the P wave was positive for all dogs; however, consistent recording of right atrial and ventricular depolarization (ie, R wave-to-S wave ratio [R/S] < 1) occurred more frequently for brachymorphic dogs (16/20) than for dolichomorphic (7/20) and mesomorphic (6/20) dogs. When V_1 was at the 1st-R location, the P wave was negative for most dogs, and R/S was < 1 for the majority of dogs in the brachymorphic (19/20), mesomorphic (17/20), and dolichomorphic (16/20) groups. The median R/S for V_1 at the 1st-R location was significantly lower than that for the other 4 V_1 locations.

CONCLUSIONS AND CLINICAL RELEVANCE
Results indicated that placement of V_1 at the 1st-R location provided correct evaluation of right atrial and ventricular depolarization in most dogs regardless of thoracic conformation. (*Am J Vet Res* 2019;80:358–368)



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