Ventriculomegaly in the Canine Patient

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Introduction

Ventriculomegaly is the result of the increased accumulation of cerebrospinal fluid (CSF) within the ventricular system.[7] This accumulation of fluid has been described as a normal finding in brachycephalic breeds, Beagles, German Shepherds, and Yorkshire terrier dogs.[11;14] Ventriculomegaly is differentiated from hydrocephalus by the absence of neurologic clinical signs. Hydrocephalus is classified based on the location of the fluid accumulation, etiology, morphology, and pressure within the ventricular system.[7] Internal hydrocephalus is defined as an accumulation of CSF within the ventricular system, while external hydrocephalus is the accumulation of CSF in the subarachnoid space.[5] The presence of communication of the ventricular system with the subarachnoid space is termed communicating hydrocephalus and this is usually due to an obstruction after the fourth ventricle.[18] Compensatory hydrocephalus occurs when loss of brain parenchyma due to infection, trauma, or necrosis causes CSF to occupy the space previously occupied by the brain.[5] Breed predisposition for hydrocephalus include the Maltese, Yorkshire terrier, English bulldog, Chihuahua, Lhasa Apso, Pomeranian, Toy Poodle, Cairn terrier, Boston terrier, pugs, and Pekingese.[15]

Clinically, hydrocephalus can be classified as congenital or acquired. The precise etiology of congenital hydrocephalus, which is often accompanied by an early onset of clinical signs as well as stunted growth, is not well understood but genetics, developmental abnormalities, prenatal infections, and brain hemorrhage may play a role on its development.[7] The most common cause of congenital hydrocephalus is stenosis of the mesencephalic aqueduct associated with fusion of the rostral colliculi.[18] Acquired hydrocephalus is rare and is usually secondary to tumors or intracranial inflammation causing CSF outflow blockade.[18] Edema resulting from acute

inflammatory processes is often seen as periventricular hyperintensities in the white matter on magnetic resonance imaging (MRI).[5]

History and Presentation

Physical exam findings in congenital hydrocephalic patients include a large, dome-shaped head, open cranial sutures, skull defects, and bilateral ventral or ventrolateral strabismus.[5] Neurologic exam findings include abnormal mentation ranging from depression to hyperexcitability, behavioral changes reflecting a forebrain disorder, compulsive behaviors, inability to train, ataxia, seizures, circling, pacing, vestibular dysfunction, auditory impairment, and blindness.[5; 18] Clinical signs may be absent, progress over time, improve after some time, or remain static.[1; 14; 18]

Pathophysiology

In dogs, CSF is produced at a rate of 0.03-0.5 ml/min by the choroid plexuses in the lateral, third, and fourth ventricles by an energy-dependent process that is dependent on carbonic anhydrase.[3] Cerebrospinal fluid flows from the lateral ventricles through the interventricular foramen and into the third ventricle through the mesencephalic aqueduct to the fourth ventricle and then flows into the subarachnoid space of the brain and spinal cord after leaving through the lateral apertures.[18] The arachnoid villi, which are projections of the subarachnoid space into the lumen of the dorsal sagittal sinus, is responsible for the majority of CSF absorption.[5] A lesser degree of absorption is done by the venous and lymphatic drainage around the spinal and cranial nerves. The movement of CSF into the venous sinuses is a result of osmotic pressure and occurs

when CSF pressure is higher than venous pressure.[18] When venous pressure is higher than CSF pressure, the villi collapse hence preventing the flow of blood into the subarachnoid space.[3]

Hydrocephalus most commonly develops as the result of an obstruction rather than an increase in CSF production.[18] The resulting resistance of CSF flow can be compensated by increased absorption by the periventricular capillaries and the nasal lymphatics.[18] The presence and severity of neurologic deficits is correlated to increased intracranial pressure (ICP) and loss of brain parenchyma rather than the degree of ventriculomegaly secondary to hydrocephalus.[11;18] As ventriculomegaly secondary to hydrocephalus progresses, damage to the periventricular white matter, periventricular axons, corpus collosum, corticospinal tract, and fimbria/fornix projections from the hippocampus occur.[18] In rats and humans, damage to the cerebral cortex is minimal until later in the disease process when white matter becomes eroded.[4] The pathophysiology of clinical signs in dogs has not been well studied but in human and rat models motor skill deficits have been correlated to stretching and damage to primary motor cortex axons, while damage to the corpus collosum, fimbria, and fornix has been associated with gait, cognition, and memory dysfunction.[4]

Differential Diagnosis

The main challenge for the diagnosis of clinically relevant hydrocephalus is differentiating it from ventriculomegaly. Ventriculomegaly is a normal finding in up to 47% of dogs regardless of age.[10;13] Furthermore, mild ventriculomegaly and ventricular asymmetry can be correlated with breed, sex, and body weight and it is expected for the ventricles to progressively distend as age increases.[1;19]

Diagnostic Approach/Considerations

The diagnosis of clinically relevant hydrocephalus must be done by confirming ventriculomegaly in conjunction with clinical signs. Advanced imaging modalities have a higher sensitivity when compared to conventional radiology. Ventricular ultrasonography can be attempted in patients with persistent fontanelles.[18] In normal dogs, the lateral ventricles are visualized as paired slit-like anechoic structures on either side of midline separated by the septum pellucidum.[18] With hydrocephaly, ventricular enlargement appears as two large or a single, large anechoic structure in severe cases where the septum pellucidum is compressed.[5] Computed tomography (CT) and MRI offer higher tissue contrast compared to ultrasound and in some cases, it is also capable of identifying causes of obstruction and quantitate the degree of ventriculomegaly.[18] Quantification of the degree of ventriculomegaly can be achieved by several methods. The ventricle/hemisphere ratio measures the height of the lateral ventricle and compares it to the width of the cerebral hemisphere. Hydrocephalus is considered if the ventricle/hemisphere ratio is greater than 0.19.[8] A ventricle/brain-index, which is the distance between the ventricles divided by the maximum width of the brain parenchyma, over 0.6 has been found to be significantly increased in dogs with clinically relevant hydrocephalus.[11] Findings on MRI associated with clinically relevant hydrocephalus include dilation of the ventricular system, elevation of the corpus collosum, dorsoventral flattening of the interthalamic adhesion, thinning of the cortical sulci, narrowing of the subarachnoid space, and disruption of the internal capsule adjacent to the caudate nucleus.[1;18]

Treatment and Management Options

The goal of medical management is to decrease CSF production and provide temporary relief of clinical signs and is indicated in patients that are not candidates for immediate surgery.[18]

Decreased CSF production can be achieved by using carbonic anhydrase inhibitors, loop diuretics, and/or corticosteroids. Acetazolamide, a carbonic anhydrase inhibitor, at 10 mg/kg orally (PO) every 8 hours, is often the drug of choice.[5] Similarly, loop diuretics such as furosemide at 1 mg/kg PO every 24 hours, partially inhibit carbonic anhydrase.[18] Historically, omeprazole at 1 mg/kg PO every 24 hours has been recommended for the long-term management of hydrocephalic patients but this is controversial.[18] The mechanism by which omeprazole decreases CSF production is not well understood but it is thought that it acts as a specific hydrogen-potassium pump inhibitor in the choroid plexus.[12] While it has been shown that intravenous or intraventricular administration of omeprazole can decrease CSF production by 26 to 50% in dogs and rabbits, a more recent study demonstrated that chronic oral omeprazole administration may not have an effect in reducing CSF production.[6;12] Anti-inflammatory doses of glucocorticoids have been anecdotally used in hydrocephalic patients. Prednisone at 0.25 – 0.5 mg/kg twice daily is started until improvement of clinical signs is achieved and then, it is tapered at weekly intervals until 0.1 mg/kg every other day or the minimum effective dose.[5] In cases with evidence of increased intracranial pressure, mannitol is an alternative. Mannitol acts by creating a hyperosmotic gradient in the intravascular space which pulls fluid from the brain parenchyma and promotes reflex vasoconstriction which results in decreasing intracranial pressure.[5] The use of mannitol should be short-term since potential side effects of its administration include hypovolemia, electrolyte imbalances, and acute renal failure.[5]

Placement of a ventriculoperitoneal shunt (VPS) is the current treatment of choice. A ventriculoperitoneal shunt has 4 main components: the ventricular catheter, a reservoir from which CSF can be collected, a one-way valve, and the peritoneal draining tube.[16] Prior to surgery, brain imaging is crucial for planning the surgical placement of the ventricular catheter. The patient is clipped and prepped from the head to the side of the abdomen where the peritoneal tube will be

placed.[18] An incision is made 2 to 3 cm lateral to the nuchal crest and a hole that is slightly larger than the shunt diameter is drilled into the skull. Smaller holes are made in the skull adjacent to the site of the shunt placement to allow anchorage of the shunt to the bone with non-absorbable sutures. The dura is then incised and the location of shunt placement through the cerebrum is marked using a 22-gauge needle. The ventricular catheter is then inserted through the cerebral parenchyma into the ventricle and then is anchored to the bone using non-absorbable sutures through the anchoring holes once CSF is visualized flowing through the catheter. A second incision is then made 2 to 3 cm caudal to the last rib. A subcutaneous tunnel is then created by inserting a shunt passer to connect the cranial incision with the abdominal incision. One third to one half of the shunt length is then inserted into the peritoneal cavity. The shunt is then secured using non-absorbable suture and the tubbing and abdominal muscles are opposed using absorbable sutures. The subcutaneous and skin incisions are closed routinely. Postoperative radiographs or CT imaging are used to assess proper shunt placement.[5] A variation of this surgery is for the shunt to drain into right atrium of the heart or jugular vein but this practice is not attempted in veterinary patients due to the small size of the jugular in patients.[18] Up to 29% of dogs treated with VPS placement experience complications postoperatively, usually within the first 2 months after surgery.[2] Shunt-associated infections are the most common reported complication with *Staphylococcus* spp. being the most common bacteria isolated.[18] Other less common complications include occlusion of the catheter, misplacement, migration, and/or disconnection of the VPS, and overdrainage of CSF.[2;5]

Another surgical alternative for the treatment of hydrocephalus in humans is the third ventricle or arachnoid cyst marsupialization. Arachnoid cyst marsupialization is achieved using a midline sub-occipital craniectomy.[20] The cyst is then evacuated and the cyst wall is marsupialized.

In a retrospective study following 4 human patients which underwent cyst marsupialization after VPS failure, all patients were asymptomatic 14 years after surgery.[20]

Expected Outcome and Prognosis

The success rate of dogs treated with VPS ranges between 72% to 100%.[2;16] Studies about the length of clinical sign remission in veterinary patients are not available, but in humans, 50% of patients that have a VPS will experience failure of the shunt after 2 years of placement.[9] The median survival time in one study was 320 days.[17] Patient outcome is improved with early treatment such as to decrease damage to the brain parenchyma.[4]

Conclusion

Ventriculomegaly, which can be a normal finding in many dog breeds, can be differentiated from hydrocephalus by the absence of clinical signs. In patients with hydrocephalus, clinical signs can range from motor and cognition deficits, compulsive behaviors, and gait abnormalities. Although medical management for hydrocephalus is feasible, it is only meant to be a short-term solution. Placement of a VPS is the most successful treatment modality. Although post-operative complications can be as high as 25%, placement of the VPS can greatly improve the quality of life of dogs with clinically relevant hydrocephalus.

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