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THE IMPORTANCE OF VENTRICULAR MEASUREMENTS IN ESTABLISHING THE DIAGNOSIS OF HYDROCEPHALUS IN DOGS

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Abstract

Hydrocephalus is a multifactorial disorder that was properly diagnosed in dogs until the availability of advanced imaging techniques in veterinary practice. The study was conducted on a sample of 15 dogs, aged between 3 months and 12 years, both females and males, of different breeds. To perform the measurements, two ratios were calculated: V/C (width of ventricles/width of cerebral parenchyma), Vh/Ch (height of ventricles/height of cerebral parenchyma) and corpus callosum angle. The average ratio between V/C was 0.68 (values being between 0.52-0.83), the average ratio between Vh/Ch was 0.60 or 60% (values being between 0.88-0.26), and the average of the corpus callosum angle was 69.4° (values being between 56° and 88°). This article evaluates different ventricular measurements based on MRI techniques for establishing hydrocephalus in dogs.

Key words: *dog, hydrocephalus, MRI, ventricular measurements.*

INTRODUCTION

Hydrocephalus represents the distension of the ventricular system due to excessive accumulation of cerebrospinal fluid (CSF), due to an unbalanced situation between production and absorption or an obstructive problem in the flow of CSF into the ventricular system (Estey, 2016).

It is considered to be the most common malformation found in dogs. Thus, changes in ventricular dimensions and associated clinical signs in canine species have been described and documented for over 100 years in pathological studies (Schmidt et al., 2019).

However, before the advent of diagnostic imaging techniques, it was very rarely diagnosed in canine species (Przyborowska et al., 2013).

The purpose of the paper is to approach the diagnosis of hydrocephalus through MRI as completely as possible, to describe the resulting images from an imaging point of view, to apply the technique of making relevant measurements (this method being very rarely practiced in veterinary medicine), to demonstrate whether there is a breed predisposition and whether there is any form of hydrocephalus that is much more frequently encountered than another.

MATERIALS AND METHODS

The study was conducted on a sample of 15 dogs, aged between 3 months and 12 years, both females and males. The breeds that were included are: Pug, Pomeranian, Chihuahua, Yorkshire Terrier, English Bulldog, French Bulldog, Pekingese, Bichon Frise, Miniature Pinscher and mixed breed.

Before anaesthesia, all patients were clinically examined to assess their general health.

General anaesthesia was performed to prevent movement throughout the scan, as any movement can compromise image quality. Premedication was performed depending on the ASA status and their pathologies. Induction was performed with Propofol 3-5 mg/kg, intravenously. Patients were intubated and anaesthesia was maintained with 1.5% Isoflurane and 100% Oxygen; the oxygen flow was set at (500 ml + 10 ml/kg)/min. Spontaneous or intermittent positive airway pressure (IPPV) ventilation was maintained using a volume-cycled ventilator, delivering 12-15 breaths/min to achieve an end-tidal CO_2 of 35-45 mm/Hg. An ocular lubricant was applied to all patients to protect the cornea during the MRI examination (Pavel et al., 2024a).

Patients were perfused with Ringer's solution at a rate of 5-10 ml/kg/h throughout the scan to maintain hydration. All patients had a silicone hot water bottle placed under their abdomen, with their entire body also covered by a polyester cloth blanket to help maintain their temperature within normal values (Pavel et al., 2024b).
Patients during MRI examination were closely monitored (heart rate, respiratory rate, oxygen saturation, blood pressure), which was vital to ensure the safety and stability of anaesthesia, as all of them received during the scan a contrast media agent represented by gadolinium (Tudor et al., 2018).
The MRI protocol consisted of transverse, sagittal, and dorsal planes, using T1, T2, and FLAIR to completely visualize the brain structures (Săvescu et al., 2019).
T2 sequence was performed with a TR: 3000 ms, TE: 108 ms, section thickness: 2.5 mm; the FLAIR sequence used TR: 7000 ms, TE: 114 ms, sequence thickness: 3 mm, and T1 used TR: 500 ms, TE: 15 ms, section thickness: 2.5 mm.
The images obtained were exported in DICOM format and processed using the Syngo MR Workplace software. The selection of cerebral areas of interest was selected to identify the cerebral ventricles and other structures relevant to the study.
For the imaging diagnosis of hydrocephalus, a morphometric analysis was performed to evaluate the exact dimensions and shape of the cerebral ventricles and inter-thalamic adhesion.
Protocol sequences highlighted the cerebrospinal fluid in the ventricular system and adjacent structures. The linear measurements performed with the software were:
• maximum width in mm of the frontal horns of the lateral ventricles in the transverse plane;
• maximum width in mm of the cerebral parenchyma in the same image;
• height of the lateral ventricles in the transverse plane (the average of the height between the two ventricles was taken);
• height of the cerebral parenchyma in the same image.
After the measurements were taken, two ratios were calculated: V/C (width of the ventricles/width of the cerebral parenchyma) and Vh/Ch (height of the ventricles/height of the cerebral parenchyma).
Another relevant measurement for diagnosing hydrocephalus is the value of the corpus callosum angle. This is calculated using software on the T2 sequence, in the transverse plane and is formed between the corpus callosum (which is located between the cerebral hemispheres) and the internal edges of the lateral ventricles.

RESULTS AND DISCUSSIONS

The results from the measurements and calculations for the cases are found below in Table 1.

Table 1. Results obtained from measurements and calculations

No.	Ventricle width (mm)	Brain parenchym width (mm)	V/C	*Corpus callosum* angle (mm)	Ventricle height (mm)	Brain parenchyma height (mm)	Vh/Ch
1	20.43	27.71	0,73	64°	31,72	39.25	0,80
2	26,88	33,65	0,79	58°	32.12	38.52	0,83
3	34.79	48,32	0,71	66°	21,04	27,24	0,77
4	17,90	38,31	0,46	88°	7,97	30,16	0,26
5	23,5	42,3	0,55	79°	29,16	56,98	0,51
6	46,5	58,1	0,83	53°	33	37,2	0,88
7	33,1	47,2	0,70	72°	17,34	31,2	0,55
8	16,9	32	0,52	86°	13,6	37,13	0,36
9	28,6	43,1	0,66	75°	15,1	35,2	0,42
10	31,6	44	0,71	67°	19,4	28,9	0,67
11	40,1	52	0,77	62°	20,3	28,5	0,71
12	22,8	35,6	0,64	78°	12,6	32,45	0,38
13	34,3	42,5	0,80	56°	20,3	28,3	0,71
14	21,6	32,7	0,66	75°	14,53	38,2	0,38
15	44,6	57,2	0,77	62°	22	25,4	0,86

Following the measurements performed for the 15 patients, it was found that on average, the ventricles/brain ratio (V/C) = 0.68 (values between 0.52 and 0.83), this ratio orients the diagnosis of hydrocephalus (Figure 1).

According to Evans (1942), the reference values for this ratio are:

- 0.20-0.25 - normal;
- 0.25-0.30 - beginning of ventriculomegaly;
- over 0.30 - ventriculomegaly.

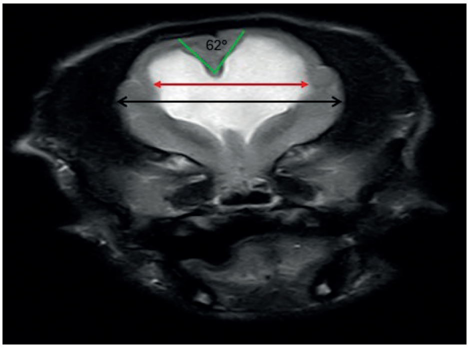

Figure 1. Example of how measurements are performed, T2-weighted transverse image: corpus callosum angle (green lines), width of lateral ventricles (red line), maximum width of cerebral parenchyma (black line). The same idea was used for the ventricle and brain height

The measurements performed revealed an average of corpus callosum angle: 69.4° (values between 56° and 88°). The reference value for the corpus callosum angle is 100-120 and values that are below 90 degrees indicate ventriculomegaly and, respectively, hydrocephalus.

Also, following the measurements, the average ratio between ventricular height/cerebral height (Vh/Ch) was reached = 0.60 or 60% (values obtained between 0.88 and 0.26). The reference values for this ratio, according to Przyborowska (2013) and Woo (2010) are:

- 0-14% - normal;
- 15-25% - moderate ventriculomegaly;
- Over 25% - ventriculomegaly.

In this study regarding the 15 cases of hydrocephalus, most cases were congenital, with a percentage of 79.9% found in brachycephalic and toy breeds and 20.1% of acquired type. Of these, 60% belonged to a brachycephalic breed and 33.3% to a toy breed. These percentages are comparable to the specialty literature that points to similar conclusions. Selby et al. (1979) following a study conducted on a sample of 564 dogs, described the fact that congenital hydrocephalus is most frequently diagnosed in brachycephalic and tiny breeds, such as English Bulldog, Bichon, Pug, Pekingese, and Yorkshire Terrier. One of the reasons for the association of these breeds with ventriculomegaly and hydrocephalus is the shape of the skull (Schmidt et al., 2019).

For the imaging diagnosis of this pathology, a series of measurements were made at the level of the ventricles and the cerebral parenchyma. The first calculation performed is a ratio between the height of the ventricles and the height of the cerebral parenchyma. In a study conducted by Woo et al. (2010) on a sample of 10 healthy Yorkshire Terrier dogs and 10 dogs with hydrocephalus of the same breed, it was concluded that for healthy canine patients, this ratio is below 25%, and for those with hydrocephalus it is well over 20%. Comparing these results with those obtained in my work, namely, the average ratio is 60%, the patients included in the study were correctly diagnosed with hydrocephalus.

Another calculation performed is the ratio between the maximum width of the lateral ventricles and the maximum width of the cerebral parenchyma. This ratio is called the Evans Index in the specialized literature in human medicine. The Evans index is determined by the maximum diameter of the frontal horns of the lateral ventricles divided by the internal diameter of the skull in the same plane. A value greater than 0.3 for the Evans index is the only essential morphological criterion of internal hydrocephalus (Ishii et al., 2008). In contrast, in veterinary medicine, Laubner et al. (2015) performed this measurement in a similar study and resulted in an index of 0.73 (values between 0.58 and 0.92), comparable to the results obtained in our work, which is: the average index of 0.68 (values between 0.52 and 0.83).

Also, the values of the callosal angle are described in human medicine as follows: a normal value is typically between 100 and 120°, in patients with hydrocephalus, that value is lower, generally between 50° and 80° (Gaillard et al., 2015). The value of the callosal angle that resulted from the measurements is 69.4° (values between 56° and 88°). The result obtained is not comparable to studies carried out in veterinary medicine. As far as is known, the callosal angle has not been measured before in canine patients. No significant differences were observed between the callosal angles of dogs with

ventriculomegaly and those with hydrocephalus (Laubner et al., 2015).
Other measurements that could be made by magnetic resonance for future research are: ventricular area and cerebral parenchymal area. Esteve-Rastch et al. (2001) wrote that using these measurements, they tried in a study to differentiate patients with clinical neurological manifestations from those without any symptoms.
Another quantitative measurement is the ventricular volume. This may be useful in the future for studying changes in ventricular volume associated with age, degenerative disease, and ventricular obstruction. When the normal value of the percentage of intracranial volume occupied by the ventricle for different breeds is determined, it is hoped that the diagnosis of hydrocephalus will be made more based on quantitative measurements (Vite et al., 1997).
To continue this study, in addition to the sequences already used (T1, T2, and FLAIR), certain special sequences for this type of pathology can be used. This category includes the DWI (diffusion-weighted imaging) and DTI (diffusion tensor imaging) sequences, which detect changes in the diffusion of water in the brain tissue, useful in detecting cerebral compression and highlighting structural alterations (Yuan et al., 2012). No studies have been carried out in this regard in veterinary medicine at the moment.
Also, to have a much more relevant study on this topic, it would be recommended to carry out a study sample made up of dogs that are of the same breed, as Vullo et al. (1997) did on 17 Beagle dogs from the same kennel. This type of study is more suitable to reduce the variability resulting from: brain anatomical differences, genetic predispositions, physical and biological characteristics specific to each breed, and environmental factors.

CONCLUSIONS

Following this study, it was concluded that MRI is one of the most current and reliable methods for diagnosing hydrocephalus in dogs, especially because it is a pathology that is difficult to diagnose strictly clinically. This is due to the accuracy and attention to detail that can lead not only to an actual diagnosis, but also to finding out the aetiology and mechanism of the pathology.
Finally, it was demonstrated that to have a much clearer and more accurate perspective on the degree of brain damage and, respectively, on the progression of the disease, the use of cerebral calculation and measurement methods is necessary.

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