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Hydrocephalus: where to start on MRI

Hussein, AK
Surgical and obstetrics department, Veterinary College, Baghdad University, Iraq

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Corresponding Author

Hussein, AK

Abstract

Different imaging techniques were used for identifying the hydrocephalus including the magnetic resonance imaging (MRI) technique; however, three dimensions were used. The aim of this study was to define the hydrocephalus using a single dimension, the midline sagittal plane of MRI.
32 dogs of different breeds were divided into two groups: Normal group (no abnormalities in their brains and the hydrocephalic group (clinically diagnosed with hydrocephalus). The shape of the ventricular system was defined in normal and abnormal groups. Then the areas of 1) the ventricular system (lateral, 3rd, 4th ventricles and mesencephalic aqueduct), 2) the interthalamic adhesion and 3) cerebellum were measured in the two groups using a single dimension, the midline sagittal plane of MRI technique. The correlation between the area of the ventricular system and both of the head conformation and the bodyweight were also determined.
The shape of the ventricular system was well defined in normal group and it was deviated in the hydrocephalic group. The corrected area of the ventricular system was significantly enlarged in hydrocephalic group. The corrected area of the interthalamic and cerebellum were significantly decreased in abnormal group in comparison to the normal group. The head conformation and the bodyweight had no significant correlation with the area of the ventricular system in both normal and abnormal groups.
It is conclude that both of the shape and area of the ventricular system can be considered for defining the hydrocephalus in dogs' brain using a single dimension, the midline sagittal plane of MRI.

Introduction:

Radiography, ultrasonography, CT and MRI can be used for evaluation of the normal and abnormal canine brains (Farrow, 2003). Plain radiography is not proper for imaging the brain unless lesions have a secondary impact on overlying bone such as has been recorded in severe hydrocephalus (Farrow, 2003; Kealy and McAllister, 2005). Open fontanelle is essential for identifying some brain abnormalities, such as hydrocephalus (Kealy and McAllister, 2005). In 1990s, Veterinary institutions started using the MRI technique for clinical use, particularly in the field of neurology (Patrick RG, 2011). The morphological and pathological features of the central nervous system can be gained using MRI technique in both man and animal (D-C Woo et al, 2010). Furthermore, MRI technique is considered to be valuable tool for investigating hydrocephalus (Przyborowska,P, et al, 2013).
The term hydrocephalus can be classified depending on location of accumulation of CSF into: internal, the ventricles are enlarged, or external, subarachnoid space is enlarged. (Thomas 1999, 2010; Hecht and Adams 2010). It can also be classified according to the etiology as congenital or acquired forms (Thomas 1999; Hecht and Adams 2010). The congenital hydrocephalus is highly occurred in toy breeds due to genetic factors that develop anomalies, bleeding in the brain and so on (Vullo et al. 1997; Esteve-Ratsch et al. 2001). The other type of hydrocephalus is secondary to decrease brain parenchyma which occurs after brain infarction, necrosis or atrophy (Hecht and Adams 2010). Obstructive hydrocephalus is alternative terms that may be used. When the obstruction occurs within the ventricular

system or through the lateral apertures, the term called non-communicating hydrocephalus. The communicating hydrocephalus is defined when a connection between the ventricular system and subarachnoid space still persists (Thomas 1999; Hecht and Adams 2010).

Obstructions may become apparently secondary to congenital stenosis of mesencephalic aqueducts or lateral apertures (Hecht and Adams 2010). In mature dogs, diseases like tumors and intracranial inflammations frequently cause acquired obstructive hydrocephalus (Thomas 1999, 2010).

Depending on the pressure, hydrocephalus can be associated with increasing pressure within intracranial space due to blockage of cerebrospinal fluid (CSF) outflow in the ventricles or in the subarachnoid space. Alternatively, the condition may result from an overproduction of CSF fluid, from a congenital malformation blocking normal drainage of the fluid, or from complications of head injuries or infections (Horbar et al., 1983; Gaston and Jones, 1989; Del Bigio, 1993; Emerson et al., 1994; Braun et al., 1997).

The aims of this research were to compare the shape of the ventricular system between normal and hydrocephalus group; identify the effect of the hydrocephalus on the area of ventricular system, the interthalamic adhesion and the area of the cerebellum. Finding out the effect of head conformation and bodyweight on the area of the ventricular system of normal group using a single plane of MRI technique, the midline sagittal.

Material and methods:

This research was performed in small animal hospital of Veterinary school in Glasgow University between June-September 2014. All the data were calibrated using ImageJ software. This study included 32 dogs of different breeds divided according to their brain status into normal and hydrocephalus group as following:

Normal group: 16 dogs which had normal brain on MRI and diagnosed with idiopathic epilepsy. This group included the following breeds: Boxer (n=7), Golden retriever (n=2), Shih tzu (n=2), and one of the following breeds: Bichon fries, German shepherd, Lhasa apso, Shetland sheepdog and Staffordshire bull terrier. The age ranged between 1.1-9.9 years (M±STDEV=4.6±2.7), while their bodyweight range was between 7-34kgs (M±STDEV=22.9±11.4).

Hydrocephalus group: The dogs of this group have been identified with hydrocephalus according to their final diagnosis. It included 16 dogs of the following breeds: Chihuahua (n=4), Caviler King Charles Spaniel (CKCS) (n=3), Lhasa apso (n=2), Maltese terrier (n=2) and one of the following breeds [American bulldog, Cross breed, Miniature poodle, Papillon and Yorkshire terrier]. The age ranged from 1.7-15 years (M±STDEV=5.2±3.5) while, the bodyweight was between 3-15kgs (M±STDEV=5.2±3.4)

The shape of the ventricular system on midline sagittal plane was determined. The area of the ventricular system was measured using imageJ software on midline sagittal plane of T2 MRI, the midline sagittal plane. This was including lateral ventricle, 3rdventricle, mesencephalic aqueduct and 4th ventricle. The interthalamic adhesion and the cerebellum were also examined for identifying the effect of hydrocephalus on these structures. The transverse plane of MRI was also examined for identification of the septum pellucidum existence. All the areas were corrected to the brain area to normalize all the data. Finally, the head conformation was determined using the technique of measuring the olfactory bulb angle (Hussein et al, 2012) to find out the effect of head conformation on deviation of the ventricular system.

The descriptive statistics (mean standard deviation and range). The normality test and the two tailed t-test were also examined when needed.

Results and Discussions:

The MRI features of the ventricular system:

The 3rd ventricle, the mesencephalic aqueduct and the 4th ventricle were normally seen in the normal dogs (Fig. 1-A). Anatomically on longitudinal midline plane of the brain, the 3rd ventricle, the mesencephalic aqueduct and the 4th ventricle are well recognized (Fitzgerald, 1961; Horodyska and Kreiner, 1962; Beitz and Fletcher, 1993) and by using CT scan and MRI technique (Assheuer and Sager, 1997). The lateral ventricle was seen however, in very small area on midline sagittal plane in some cases. While a one case showed apparently partial missing of the septum pellucidum (Fig.1-B). However, the shape of the ventral angulation of the corpus pellucidum was well identified in the entire normal group. Groups of researchers referred to presence of this angle in canine brain in all normal dogs except those have passive or active hydrocephalic features (Milhorat et al. 1970, Hussein, et al, 2012).

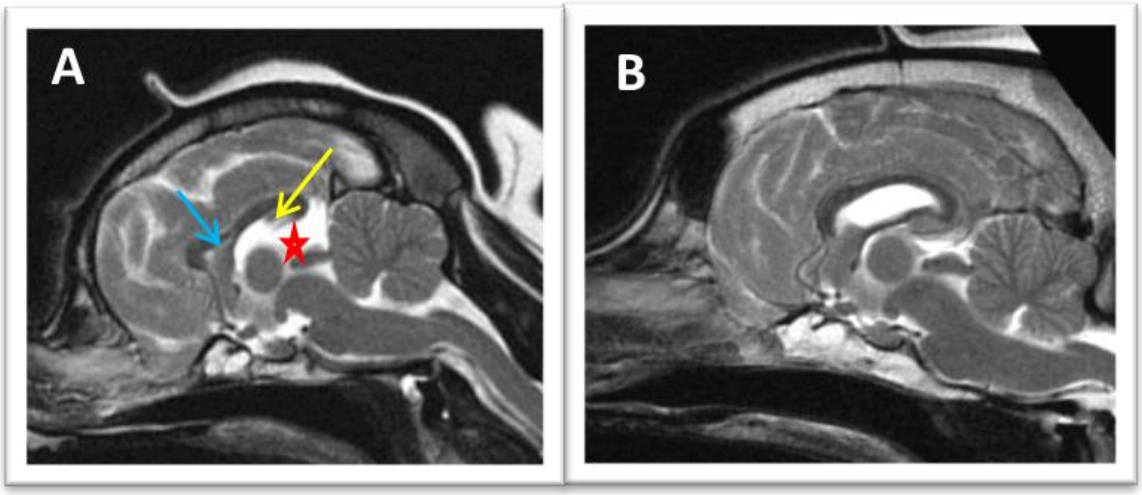

Figure 1: These images showed the (A): the ventricular system (red star) and the presence of the septum pellucidum (blue arrow) and presence of the ventral angulation of the corpus callosum (yellow arrow); (B) partial missing of the septum pellucidum.

In abnormal group, all the above structures were seen in all dogs however with deviated shape (Fig.2). The area of the lateral ventricle was enlarged in most cases associated with apparently missing the septum pellucidum in half of the group when it was examined on transverse plane. It is found that a ventriculomegaly may lead to lack of the septum pellucidum (Hussein, et al., 2012) and a brain malformation by others (AJ Barkovich and D Norman, 1989). Other researchers referred to the degree of absence of the septum pellucidum are highly correlated to the degree of the hydrocephalus (Barkovich, A. and Norman, D., 1989). Supporting this finding, a significant dilation of the lateral ventricle was seen in a group of Beagles within six hours of induced hydrocephalus but no other ventricles (Vullo et al. 1998).

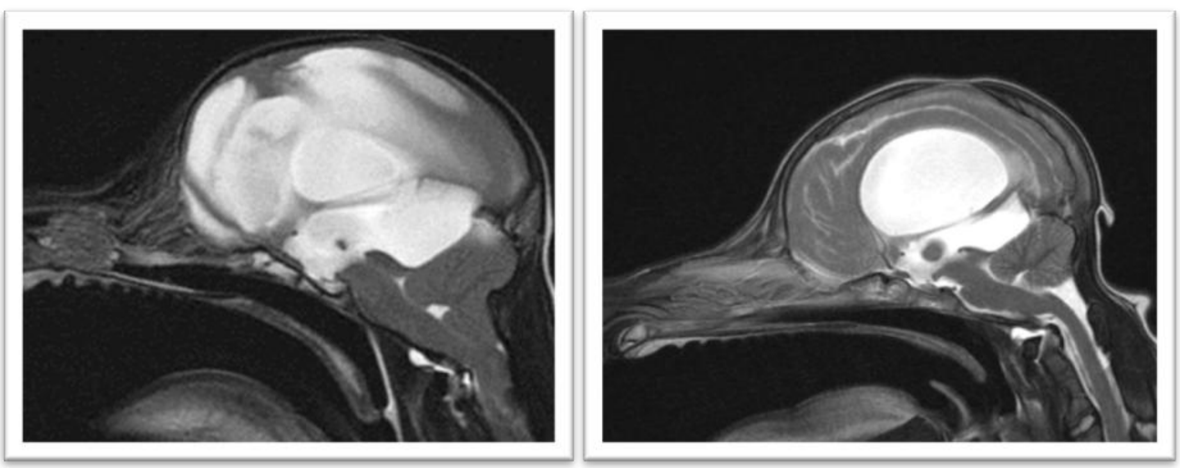

Figure 2: These images showed the deviated shape of the ventricular system, the interthalamic adhesion and the cerebellum of the brain when they examined using a midline sagittal plane of MRI

The corpus callosum shape had changed and their ventral angulations were mostly disappeared (Fig.3). The shape in some dogs' brain becomes cord like on the midline sagittal plane of MRI according to this study. In mongrel dogs, the normal ventral angulation of the corpus callosum was absent in association with increased size of the lateral and 3rd ventricles, leading to elevation of the roof of the 3rdventricle (Milhorat et al. 1970).

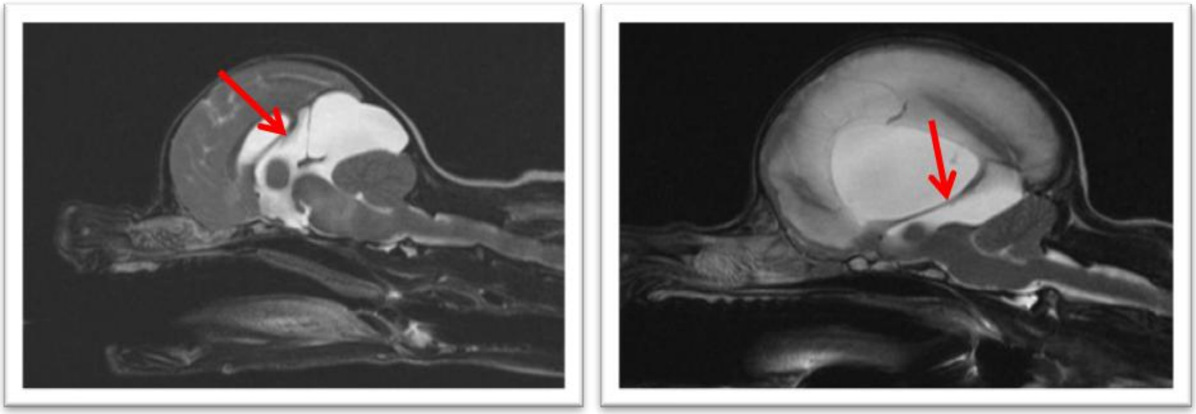

Figure 3: These images showed the absence of the ventral angulation of the corpus callosum (red arrow) which only seen when there are a significant changes in the brain structures

The 3rd ventricle, mesencephalic aqueduct and the 4th ventricles areas were enlarged in some of the hydrocephalic group however, in others a stenosis was apparently seen instead in these structures. The 3rd and the 4th ventricles were seen to have variable shape in term of hydrocephalus depending on the type of the hydrocephalus (Wisniewski et al, 1969, Milhorat et al, 1970; Vullo et al, 1998; Hellwig et al, 2005). It is appeared that the area of these structures are correlated to the site of obstruction (i.e. if the obstruction occur within the either of them so the affected site will represent small area instead)

Dimensions of the brain structures

The mean of the corrected area of the ventricular system in normal group was M±STDEV=12.56±2.28 while, the area increased up to M±STDEV=30.39±15.24 in hydrocephalic group. So a significant differences was seen between the two groups in term of the area of the ventricular system ($P<0.0001$) (Fig.4-A). The evaluation of ventricular system can be done using the MRI technique by measuring its height, area or the volume for identifying the hydrocephalus in dogs as others stated (Przyborowska,P. et al, 2013).The volume of the ventricular system significantly increased after inducing hydrocephalus in dogs as other stated (Vullo et al, 1998).

The corrected area showed not to be affected by either the bodyweight or the head conformation when they examined ($P=0.7661$, $P= 0.4701$ respectively). It has been suggested that brachycephalic breeds are at a higher risk of hydrocephalus than other breeds (Selby et al. 1979). However, in this study the degree of the brachycephalia did not show a significant correlation with the increase of the ventricular system in hydrocephalic group.

Not only the area of the ventricular system, the corrected area of the interthalamic adhesion altered too in abnormal group ($P<0.0001$). The mean of the corrected area of the interthalamic area in normal group was 1.94±0.2.2 while, it decreased to 1.14±0.5 in abnormal one (Fig.4-B). Hasegawa et al represented a significant difference between the depth of the interthalamic adhesion in normal dogs and those have dementia and also found that enlargement of the ventricular system may result in decreased interthalamic adhesion thickness, reflecting the intracranial pressure changes caused by obstructive hydrocephalus (Hasegawa et al, 2005).

The cerebellum was also deviated in abnormal group ($P=0.0071$) apparently due to increase in the size of the 4th ventricle, increase the size of the mesencephalic aqueduct, and/or pathological increase of the quadrigeminal cistern (Fig.4-C). The corrected area decreased significantly in hydrocephalus group (M±STDEV=13.36±1.71 and 10.59±2.73 for the normal and hydrocephalic groups respectively).

It is concluded that brain structures of the canine head may alter in hydrocephalic canine brains.an increase in the area of the ventricle system is suspected when there is hydrocephalus while, a significant decrease in the brain parenchymal structures is noticed. For the above, the single plane, the midline sagittal plane of MRI is good plane for predicting the hydrocephalus in dog’s brain and supporting the clinical examination for emphasizing the diagnosis.

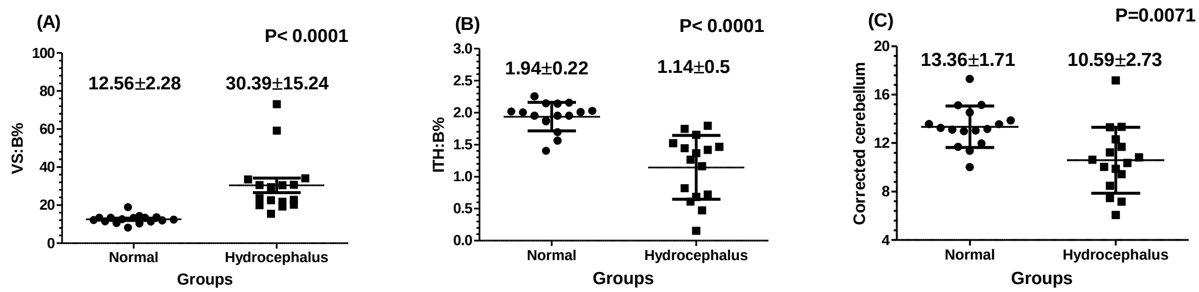

Figure 4: scattered plot (Vertical) graphs with mean and standard deviation representing the differences between the normal and hydrocephalic groups in term of A) the corrected area of the ventricular system(VS:B%); B) the corrected are of the interthalamic adhesion (ITH:B%); and C) the corrected area of the cerebellum when a single dimension, the midline siagttil plane of MRI was used.

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