

Materials and Methods

Anesthesia and Magnetic Resonance Imaging

All dogs had a CBC and serum biochemistry analysis performed before anesthesia for imaging using a 3.0T MRI unit with an 8-channel phased array extremity coil. Dogs received butorphanol (0.2mg/kg IV) and diazepam (0.2mg/kg IV) as premedication; anticholinergic drugs (atropine or glycopyrrolate) were administered based on heart rate and blood pressure. Anesthesia was induced with propofol (4mg/kg IV or to effect) and was maintained with sevoflurane.

Dogs were positioned in sternal recumbency with the head flexed using the same positioning pad to mimic head position in standing dogs. Magnetic resonance images of brain and cervical spinal cord from C1 through C7 were obtained in the sagittal and transverse planes using the following pulse sequences:

T1-weighted fluid-attenuated inversion recovery (T1W FLAIR), T2-weighted (T2W), and T2W FLAIR.

The following MRI parameters were used: field of view of 721 x 530, slice thickness of 2 mm on sagittal images, slice thickness of 3 mm on transverse images with an interslice gap of 0 mm, and matrix size of 512 x 512. T2W images: time to repeat (TR) of 4,000 milliseconds, time to echo (TE) of 87–117.6 milliseconds. For T1W FLAIR images: TR of 2,596 milliseconds, TE of 10 milliseconds. For T2W FLAIR images: TR of 9,502 milliseconds, TE of 127 milliseconds.

Preliminary Data

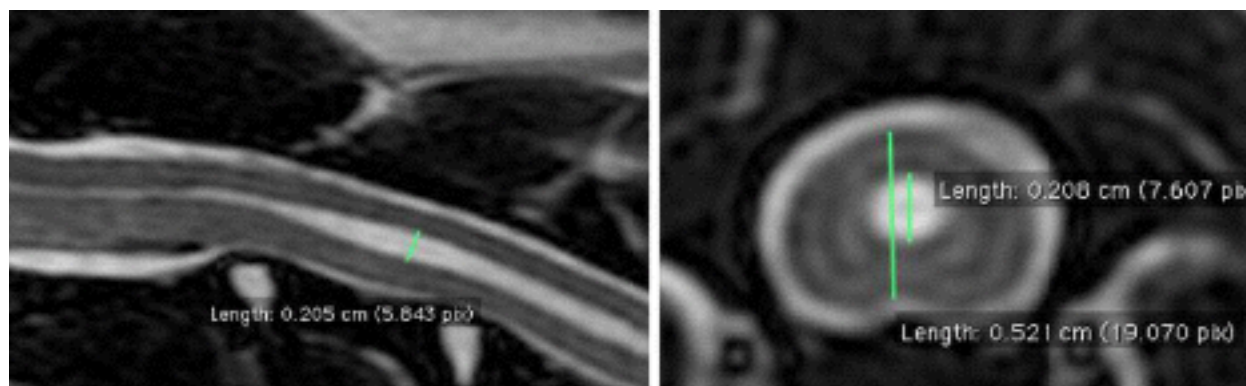
Morphologic examination for CM

1. The presence of CM was subjectively assessed by recording the presence of cerebellar deviation and cerebellar herniation.
2. CM was also graded by an amended version of the British Veterinary Association (BVA)/Kennel Club (KC) CMSM Scheme (Freeman et al, JVIM 2014).

BVA grade	Cerebellar changes	Crainoplasty	Autograft	% of study population
Grade 0	No CM	N/A	N/A	
Grade 1	Cerebellum indented (not rounded). Indentation by supra occipital bone but signal consistent with CSF between caudal cerebellar vermis and FM	9	12	46%
Grade 2	Cerebellum impacted or herniated through FM	5	20	54%

Morphologic examination for SM pre and postoperatively

1. Central canal or syrinx dorsoventral heights (mm) in the sagittal and transverse planes were measured using transverse and sagittal T2 weighted images as demonstrated below.



2. SM was graded using a version of the current BVA grading scheme (see below)
3. Syrinx length was measured in units of cervical vertebral body length with the third cervical vertebra used as reference (Adopted from Freeman et al., JVIM 2014).

***SM Preoperative**

BVA Grade	CC/syrinx characteristics	Age	Cranioplasty	Autograft	% of study population
Grade 0	Normal (no CC dilation, presyrinx or syrx)	Any age	N/A	N/A	N/A
Grade 1	CC dilation <2mm	any age*	7	4	24%
Grade 2	CC dilation >2mm	<6 years	1	4	76%
Grade 3	Syrinx/presyrinx/ CC dilation >2mm	any age	6	24	76%

- 4. All included dogs were a grade 1 or 2 in terms of their CM and a grade 1 or above for SM. Dogs with no CM and no SM were excluded, even if surgery was performed**

***SM Postoperative**

BVA Grade	CC/syrinx characteristics	Age	Cranioplasty	Autograft
Grade 0	Normal (no CC dilation, presyrinx/ syrx)	Any Age	N/A	N/A
Grade 1	CC dilation <2mm	Any Age	11	23
Grade 2	CC dilation >2mm	<6 years	0	1
Grade 3	Syrinx/presyrinx/CC dilation >2mm	any age	3	8

- 5. Specific MRI measurements (on Excel spreadsheet)**
1. diameter on axial images
 2. diameter on sagittal images
 3. length on sagittal images

Morphologic examination for clinical signs (pain scores) pre *and* postoperatively

Pain Score-Preoperative

1. Dogs were given a subjective pain score (0-4) as outlined in the grant

***SM Grade 1 Dogs**

Pain Score	Cranioplasty	Autograft
0	0	0
1	1	0
2	2	1
3	3	3
4	1	0

***SM Grade 2 & 3 Dogs**

Pain Score	Cranioplasty	Autograft
0	0	0
1	0	1
2	3	6
3	3	13
4	1	8

***Preoperative pain scores for all dogs**

Pain Score	Cranioplasty	Autograft
0	0	0
1	1	1
2	5	7
3	6	16
4	2	8

Pain Score-Postoperative

1. Dog were given a pain score (0-4) as outlined in the grant
2. Pre and postoperative pain scores were compared

***Postoperative pain scores for all dogs**

Pain Score	Cranioplasty	Autograft
0	0	0
1	5	6
2	2	13
3	5	11
4	2	2

***Overall surgical outcome based on neurologic examinations**

Outcome	Cranioplasty	Autograft
Improved	2 (14%)	26 (82%)
Worse	3 (21%)-required plate removal	0
Stable/Unchanged (persistent pain and/or phantom scratching)	9 (64%) -compared to 75% that were painful/scratching preoperatively	6 (18%) -compared to 86% that were painful/scratching preoperatively

***Overall surgical outcome based on owner perception**

Outcome	Cranioplasty	Autograft
Improved	5 (36%)	26 (82%)
Worse	3 (21%)	0 (0%)
Stable/Unchanged (persistent pain and/or phantom scratching)	6 (43%)	6 (18%)

Results

To date, 46 dogs from diverse geographic regions in the United States participated in the study, including 32 females and 14 males. Breeds represented included 42 CKCS, 3 Yorkshire terriers and one Chihuahua. The mean age was 50 months (range 8-135; median 42.5). Although over half the dogs so far (56% 26/46) were > 3 years of age, 5 dogs (10%) were <2 years and 1 dog was < 1 year (8months).

Thirty three dogs (72%) had pain, neurologic deficits, or both detected on their preoperative neurologic exam. Fourteen dogs underwent the cranioplasty procedure and 32 dogs had the autograft surgical procedure.

Chiari-like malformation

CM was present in all dogs included in this study. Twenty-one dogs (46%) had cerebellar deviation (Grade 1), 25 dogs (54%) had both cerebellar herniation and cerebellar deviation (Grade 2).

Syringomyelia-Preoperative

Thirty-five dogs (76%) had a CC/syrinx height of >2mm (Grade 2 & 3) and 11 dogs (24%) had CC/syrinx height <2mm (Grade 1). The mean maximum dorsoventral CC height was 2.34mm (median 1.86mm; range 0-7.23mm) in the sagittal plane and 2.5m (range, 0-7.6mm, median 2.05mm) in the transverse plane. The mean SM length was 3.6 cervical vertebrae (range 1-7, median 3).

Syringomyelia-Postoperative

None of the dogs improved to a SM grade 0 postoperatively, however the majority of dogs undergoing surgery showed objective and subjective improvement in clinical signs.

- Cranioplasty: One dog improved from a SM grade 2 to SM grade 1 by 10 months postoperatively. This dog remained mildly symptomatic, however he did improve one pain score level. All 7 dogs that were SM grade 1 preoperatively remained unchanged; 4 of these dogs showed improvement in clinical signs and 3 remained symptomatically unchanged. Three dogs that

were SM grade 3 remained unchanged after 12 months. One of these dogs showed an improvement in neurologic signs.

- Autograft: Four of the SM grade 1 dogs remained SM grade 1 postoperatively, however all became asymptomatic within 12 months. Three of the SM grade 2 dogs improved to SM grade 1; two of these dogs had an improved pain score and one became asymptomatic. Sixteen of the SM grade 3 dogs improved to SM grade 1 and the majority (14) of these dogs showed improvement in their pain scores and clinical signs. Two dogs remained clinically unchanged.

Neurologic deficits

The presence of preoperative neurologic deficits other than pain and phantom scratching appear to be associated with increased syrinx size (sagittal and transverse heights and length), as neurologic deficits were present in 39% of dogs with a preoperative syrinx >2mm and only 18% of dogs with syrinx <2mm. Examples of such neurologic deficits include scoliosis, titubation, tremors, absent menace response, paresis, ataxia, proprioceptive deficits, cerebellar/vestibular signs, seizures and facial nerve paresis/paralysis.

Clinical Signs and Morphologic Abnormalities

Phantom scratching at the neck and shoulders (which may represented paresthesia or allodynia) was the most common clinical finding in our patients thus far. This may be a result of our study population because many dogs presented for persistent neurologic signs postoperatively. Persistent postoperative cervical pain was identified in 18% of dogs receiving the autograft procedure (compared to 86% preoperatively) and 64% of dogs that had the cranioplasty (compared to 75% preoperatively). Other neurologic signs such as paresis, scoliosis and ataxia were less common in this study population.

In addition, 37% of the cranioplasty dogs were thought to be clinically normal postoperatively by their owners versus 82% for dogs receiving the autograft procedure.

Three dogs with persistent postoperative cervical pain had their cranioplasty plates removed. All three dogs showed progressive improvement and eventual resolution of their cervical pain and partial improvement in their phantom scratching within 7 months. (**I am hoping to rescan these dogs within a 12 month time frame to evaluate the syrinx again**)