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**Artefact induced by a transponder during in-vivo magnetic resonance imaging
on horse brain.**

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Short title: Artefact induced by a transponder in MRI

Keywords: horse; brain; magnetic resonance imaging; susceptibility artefact

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22 **Summary**

23 Magnetic Resonance Imaging (MRI) is now widely used in equine veterinary practice.
24 However, the mandatory European legislation regarding horse identification imposes the
25 implantation of a transponder within the fatty tissue of the neck cervical ligament. While
26 performing brain MRI for scientific purposes in ponies, we faced artifacts produced by such
27 transponder and reported here this problem. Indeed, pony mares were anesthetized for 2 hours
28 and placed, bedded on their back, in a 3 Tesla MRI scanner. A 4-element flexible antenna
29 positioned around the head was used. Three MRI sequences were performed on each animal:
30 3D T1, 3D T2 and 2D T1. The anesthesia allowed the acquisition of MRI for 2 hours. The
31 images for the 3 MRI sequences for each pony exhibited great quality on all of the anterior
32 parts of the brain but began to become distorted posteriorly to the pineal pituitary axis and
33 completely disappeared at the level of the cerebellum. **To find the origin of the artifact, the**
34 **transponder used for the identification of the animal was inserted in an inert gel and imaged in**
35 **the same conditions as the ponies.** The images obtained looked similar to the observed
36 artifact. **Our study thus advocates for the further exploration of such kind of artifact when**
37 **using 3T MRI in brain imaging in horses.**

38

39 Introduction

40 Magnetic Resonance Imaging (MRI) allows the visualization of soft tissues with an
41 accuracy that is dependent upon the strength of the magnetic field applied. At the brain level,
42 MRI approaches are not only of interest for clinical diagnostics but also for fundamental
43 research. In equine medicine, the use of MRI is strongly developed for the diagnosis of
44 lameness using low field MRI. By contrast, the use of MRI for other organs such as the brain
45 has been quite poorly described. A few publications have described the standard
46 neuroanatomical organization of the horse brain following MRI imaging [1, 2, 3, 4, 5, 6]. For
47 clinical purposes, MRI studies have been used only in few, serious pathological cases,
48 resulting in the publication of clinical case descriptions (for example [7, 8, 9]). Manso-Diaz et
49 al. [10] described 65 horses with neurological disorders and 14 with sinonasal disorders. To
50 date, no study has been performed to explore fundamental regulations of brain physiology
51 using MRI. However, MRI would make it possible to explore and better understand several
52 fundamental biological characteristics of horses, for example, those related to season
53 (reproduction, etc. [11]), to cognitive function [12], or to behavior, especially in relation to
54 stress and welfare [13].

55 While performing brain anatomical MRI acquisition on anaesthetized horses, we faced
56 the problem of an artifact on MRI images, probably due to the presence of the magnetic
57 transponder used for the identification of animals. Indeed, in Europe, the identification of
58 animals, especially horses, has become widely recognized as important in relation to animal
59 welfare or sanitary issues. In some European countries, the identification of horses is now
60 performed through the mandatory insertion of a magnetic transponder within the fatty tissue
61 of the cervical ligament in the middle of the neck in the area of the nuchal ligament (UE
62 2015/262). A transponder is an implantable electronic device, working as a passive
63 identification method that contains metallic components. Performing magnetic resonance
64 imaging (MRI) in the presence of such metallic device raises concerns due to local signal
65 increase, signal void or distortion (susceptibility artifact) on MR images. Knowing that such
66 distortion can profoundly affect the quality of MRI images, we document here this problem in
67 horses, as previously reported in other species such as dogs for example [14].

68

69 **Materials and methods**

70 **Animals**

71 This experiment was performed in accordance with the National Animal Ethics
72 Requirements (French Ministry of Agriculture). Our experimental MRI platform and horse
73 stable received a veterinary agreement under reference E37-175-2, and our protocol received
74 the authorization of the regional committee for ethics on animal experimentation under the
75 reference 2016100713288243 (Comité d’Ethique en Expérimentation Animale Centre Val-de-
76 Loire). Animals were subjected to a clinical examination before the start of the protocol.

77 For this study, two Welsh pony mares were used (A: 198 kg, 2 years old and B:
78 198 kg, 4 years old). These mares are identified in our experimental herd with both an earring,
79 which is classically used for bovines, and with a transponder. The earring is commercialized
80 by AllFlex Europe SA (Vitré, France). The use of a transponder is a legal obligation in the
81 European Community (Europe 2015). It was intramuscularly injected in the upper part of the
82 horse necks approximately 10 to 15 cm behind the head. This injection was performed by a
83 veterinarian before the end of the birth year of the foal. In our experimental ponies, the
84 transponder is a Backhome® Biotec Slim Transponder, which can be read at 25 cm and which
85 is only 2 mm in diameter and 10 mm in length.

86

87 **Anesthesia**

88 One hour before the induction of anesthesia, the horse was **sedated** in order to limit
89 stress before and during the sleeping phase. **Sedation** was induced with an intramuscular
90 injection of acepromazine 0.1 mg/kg (Calmivet® CEVA Santé Animale, Libourne, France).
91 An intravenous catheter was then placed in the jugular vein. After that, 0.05 mg/kg (1 mL) of
92 romifidine hydrochloride (Sédivet® Boehringer-Ingelheim Vetmedica Inc.) was injected iv as

93 a **premedication**. Five minutes afterward, 2.5 mg/kg (5 mL) ketamine hydrochloride
94 (Imalgène® Boehringer-Ingelheim Vetmedica Inc.) and 0.08 mg/kg (1 mL) diazepam
95 (Valium® ROCHE, Boulogne-Billancourt, France) were injected via the catheter **to induce**
96 **anaesthesia**. The animal was bedded in dorsal recumbency, and endotracheal intubation was
97 performed. The anesthesia was maintained with a mixed gas of 2% isoflurane, 49% oxygen
98 and 49% air. Just before the imaging session, a new injection of 5 mL of Imalgène® and
99 2 mL of Valium® were performed. During the imaging session, the mare was perfused with
100 5 L of Ringer's solution with 50 mL of heptaminol acefylline added (Vétécardiol®.
101 Boehringer-Ingelheim, Vetmedica Inc. MSD, Beaucouze, France). A urinary Foley probe was
102 inserted in the bladder to evacuate the urine into a receptacle. **The anesthesia was monitored**
103 **for 3 hours, this duration also including the time for the animal positioning**. After the
104 anesthesia, during the reawakening, 5 L of Ringer's solution was perfused; for additional care,
105 a packet of Twydil-Protect-Plus® was administered *per os* (combination of antioxidant
106 vitamins and specific antioxidants, PavescoAG, Basel, Switzerland).

107 After endotracheal intubation, the pony mare was manually lifted and bedded on an
108 MRI table that was covered with a medical mattress specially made to avoid compression
109 (SARL Kohlas, Venissieux, France). The pony mare was bedded on her back for the purposes
110 of animal comfort and to facilitate the introduction of the head into the bore magnet of the
111 MRI. The mare was wedged by cushions and strapped in this position. The head was covered
112 by a radio frequency (RF) coil. In this position, the head was placed close to the center of the
113 bore magnet.

114

115

116 **MRI**

117 We used a 3T Magnetom Verio® MRI scanner (Siemens, Erlangen, Germany). This
118 device, with a strong magnetic field, ensures high image quality of the brain. The size of the
119 bore magnet is sufficient to insert the horse's head. In addition, the table is also strong enough
120 to accept small ponies of up to 200 kg.

121 A 4-element flexible coil positioned around the head was used. Three MRI sequences
122 were performed on each animal and were set as follows:

- 123 ● a 3D T1 sequence of “magnetization prepared rapid acquisition gradient echo”
124 (MPRAGE); with the following parameters: repetition time (TR) = 2500 ms, echo time
125 (TE) = 2.93 ms, inversion time (TI) = 900 ms, flip angle = 12 degrees, field-of-view
126 (FOV): 260 mm², and matrix: 384²; bandwidth: 150 Hz/Px, slice thickness: 0.7 mm, and
127 integrated parallel acquisition technique (iPAT) of 2; number of excitations (NEX): 3,
128 acquisition time: 33 min 24 sec, and voxel size: 0.7 x 0.7 x 0.7 mm³.
- 129 ● a 3D T2 sequence of sampling perfection with application-optimized contrasts (SPACE);
130 with the following parameters: TR = 4000 ms, TE = 415 ms, TI = 380 ms, FOV: 180
131 mm², and matrix: 256²; bandwidth: 349 Hz/Px, turbo factor: 309, slice thickness: 0.7 mm,
132 and iPAT of 2; NEX: 2.5, acquisition time: 34 min 42 sec, and voxel size: 0.7 x 0.7 x 0.7
133 mm³.
- 134 ● a 2D T1 Spin Echo (SE); with the following parameters: TR = 500 ms, TE = 8.4 ms,
135 FOV: 220 mm², and matrix: 256²; bandwidth: 201 Hz/Px, slice thickness: 4 mm, and
136 NEX: 1; concatenations: 2, acquisition time: 3 min 45 sec, and voxel size: 0.9 x 0.9 x 4
137 mm³.

138 These sequences were chosen to have a high spatial resolution for scientific purposes and
139 were not designed for clinical examination.

140 Results

141 The anesthesia did not induce any problems during the 2h of MRI examination. After

142 these 2 hours, the horses were transported to their stall and awakened safely. One hour later,
143 they were free in a paddock.

144 On the MR images, sufficient contrast was obtained between gray matter, white matter
145 and cerebrospinal fluid (figure 1). This makes the visualization of the main cerebral structures
146 such as the hippocampus, the corpus callosum, the caudate-putamen nucleus and the
147 hypothalamus straightforward, as previously reported [5]. These images are of sufficiently
148 high quality to also allow image processing, such as, for example, 3D reconstruction of the
149 brain.

150 However, when acquiring the images, we noticed the presence of an important artifact
151 on the MRI images. A clear **black/white ring can be seen on the limit of the signal loss,**
152 **suggesting the presence of a metal artifact. In this experiment, we attempted two different**
153 **echo sequences (gradient echo and spin echo), and they both produced artifacts. Even with the**
154 **use of the SE sequence which is much less sensitive to susceptibility-induced artifacts,**
155 **important artifacts were observed on the MRI images (see figure 2).** The images were not
156 usable from the hypothalamus and toward the rear, which corresponds to 1/3 of the entire
157 brain (figure 2). The 3D reconstruction of the brain was possible, but the reconstruction was
158 distorted (figure 3).

159 Two objects can create this artifact: the earring bearing the number of the pony or the
160 transponder bearing its official identification number. **To find the origin of the artifact, the**
161 **earring was inserted in an inert gel and placed in the MRI scanner.** The same sequences as the
162 ones used with the ponies were employed. The metal part of this earring is composed of brass,
163 and no artifact was seen. On the other hand, the transponder inserted in the gel created an
164 important artifact comparable to that observed in vivo in the image, even with the less
165 sensitive SE sequence. These transponders consist of a ferrite core surrounded by a solenoid,
166 which makes them incompatible with MRI. It was determined that the transponders of the two

167 pony mares used were still legible after MRI and were therefore not destroyed.

168

169

170 **Discussion**

171 We showed here that the transponder used for the mandatory identification of horses
172 within the European Union creates a significant artifact on MRI images, thus preventing the
173 correct visualization of the brain behind the pineal-hypothalamic axis. **One solution to avoid**
174 **this problem is to use alternative imaging strategies, including the use of advanced imaging**
175 **techniques such as VAT (view angle tilting)-SEMAC (slice encoding metal artefact) and**
176 **MAVRIC (multiacquisition variable-resonance image combination) [15,16]. Such approaches**
177 **are certainly very effective in the reduction of metal artifacts, but they do not suppress them**
178 **completely.**

179 Another solution could be to retrieve the chip. However, there is the need of a precise
180 localization of the chip in order to extract it surgically. Here, we used a chip reader that allows
181 an approximate location of the chip within a rectangular area of approximately 20 cm by
182 10 cm. We were able to physically locate the chip just 15 cm below the ear of the horse,
183 which corresponds to the placement of the transponder by a veterinarian. However, this
184 localization was insufficiently precise to extract it through surgery. In this area, we also tried
185 to locate the cyst induced by the chip with ultrasound. For that purpose, we employed an
186 ultrasound scanner (EXAPad from ECAP®) with a 5 Hz linear probe. The transponder was
187 apparently too small or could not be detected by ultrasound. **However, the use of an X-ray**
188 **scanner or fluoroscopy would indicate the location of the transponder, and it could be possible**
189 **to surgically extract the chip in an only slightly injurious manner.**

190 **Following the recommendations for the transponder implantation reported in the UE**

191 2015//262, the transponder has to be inserted in the middle of the neck. Further studies should
192 be made to investigate a correctly placed transponder and the susceptibility-induced artifact
193 with 3T magnets in ponies. In conclusion, caution should be taken to be sure of the
194 implantation location of the transponder; this location should be far enough from the brain
195 (therefore strictly following the EU recommendation) to avoid problems when performing
196 brain MRI under clinical examination or for scientific purposes.

197

198 **List of abbreviations:**

199 MRI: Magnetic resonance imaging

200

201 **Conflict of interests:**

202 The authors declare that they have no competing interests.

203

204 **Authors contributions:**

205 AE and HA drove the MRI and corrected the final manuscript. GG drove the gas anesthesia
206 and the cardiac monitoring. IL and CD are equine specialized veterinarian and followed the
207 horse from the beginning of anesthesia to waking up. HA is responsible of the MRI. FR took
208 care of the ponies and prepared them for the anesthesia. MK supervised the work, worked on
209 animal experimentation and prepared the manuscript. DG supervised the work, worked on
210 animal experimentation, and prepared the manuscript.

211

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216

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219

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Figure captions:

Figure 1: On the left, the image of a para-sagittal section of the mare brain showing the impact of the transponder, destroying the images of the cerebellum and the spinal cord and affecting the gray levels of hypothalamus. On the right, images of frontal cuts at the indicated levels from 1 to 4.

Figure 2: Horizontal 2D T1 SE image of horse head. The effect of the transponder can be observed even with a poorly inducing artefact sequence.

Figure 3: Individual 3D reconstruction of the equine brain. We can notice the deformation induced by the transponder at the back of the brain (white arrows) which prevents analysis on the posterior regions (trunk, cerebellum, occipital lobe).

Figure 1: Equine Brain Magnetic Resonance Imaging with T1W MPRAGE sequence

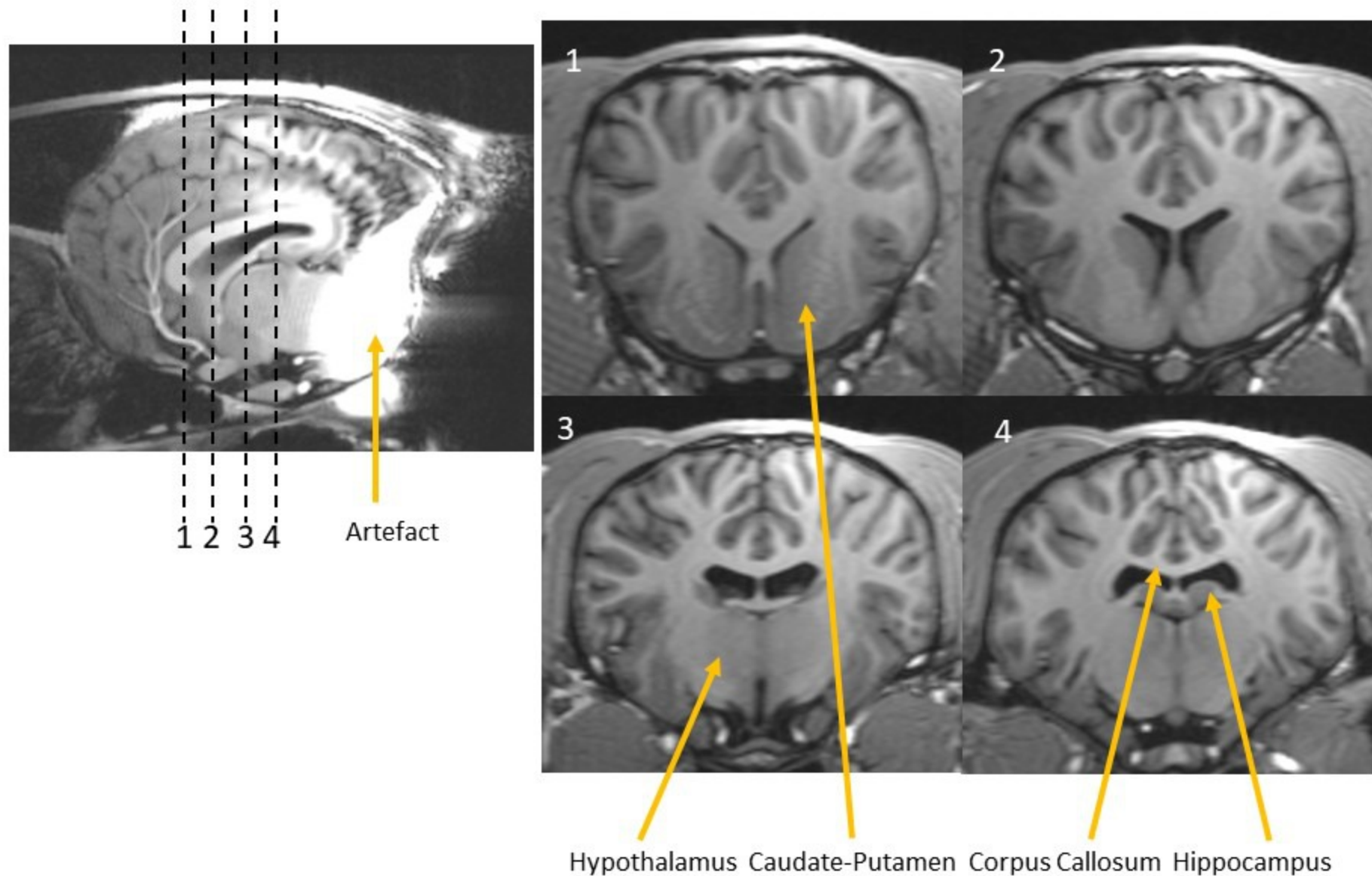


Figure 2 In vivo artefact induced by the transponder

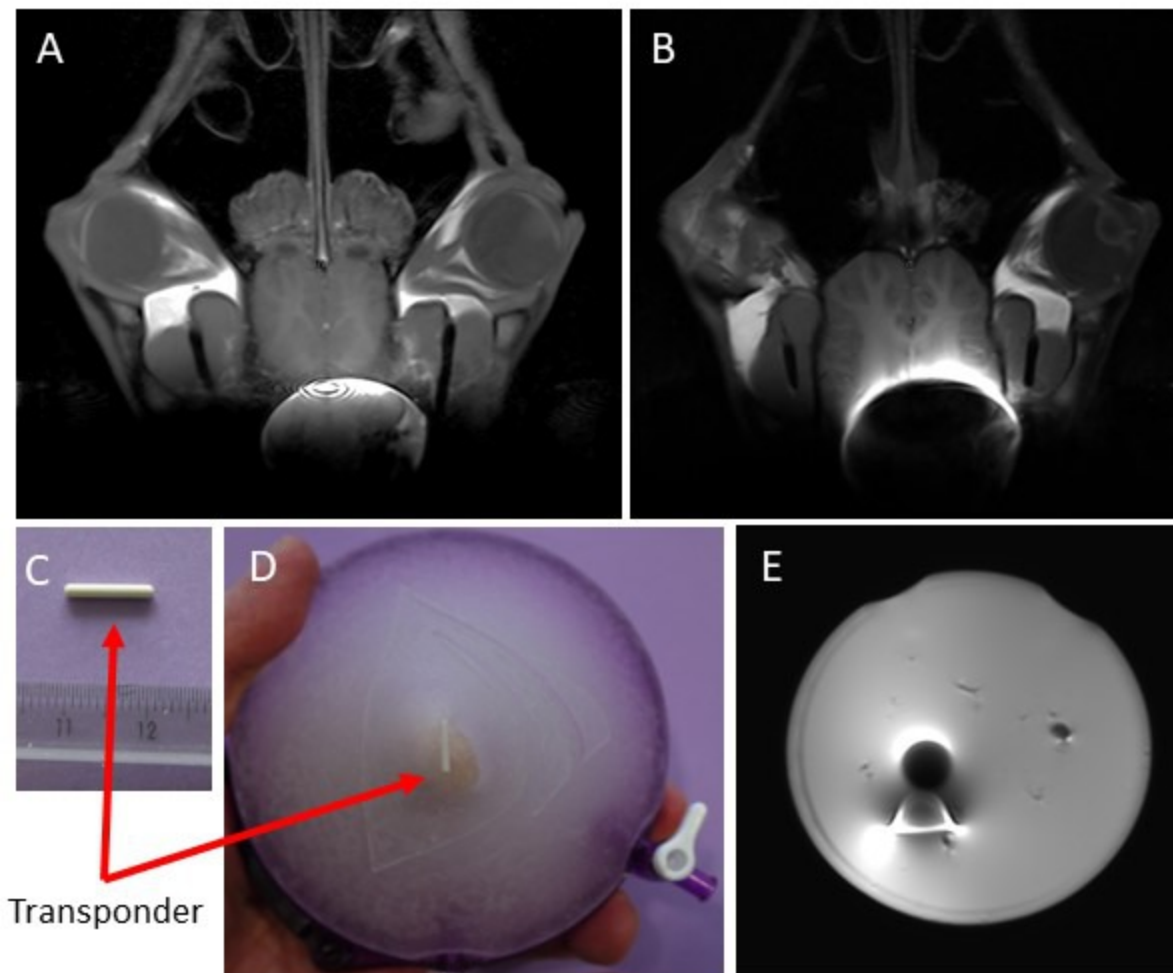


Figure 3: 3-dimensional reconstruction of the brain of one mare

