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3D Printed Ferret Cradle with Anesthesia and Commercial Coil Integration for Brain MRI at 7T

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Synopsis

Keywords: Small Animals, Preclinical, 3D Printing, MR Compatible Cradle, Ferret

Motivation: Ferret brain imaging requires custom-built cradles to make acquisition feasible.

Goal(s): Improve current female setup to accommodate male ferret size and achieve similar field of view coverage and fit as our previous live imaging acquisitions.

Approach: We created 3D-printed anesthesia and cradle components in the female and male ferret. We used female and male skull phantoms to assess signal coverage and fit of our improved cradle design.

Results: Measurements of male and female ferrets drove dimensional requirements for our cradle design. Additionally, cradle was tested for fit with commercial surface coil. Cradle design had comparable coverage of both male and female skull phantoms.

Impact: Creating custom ferret cradle that integrates commercial-coils may benefit other researchers that are imaging animal models.

Introduction

Species-specific cradles are an essential tool for animal model imaging by reduction of motion artifacts through stabilization and maintenance of anesthesia and physiology by integrated pieces. For specialized applications, the design and open source distribution of 3D printed custom cradles has provided more standardized, and cost-effective solutions from rodents to marmosets[1,6,8] although there is not currently such a resource in the ferret. The ferret is the smallest gyrencephalic animal and has a larger white matter to grey matter ratio compared to its rodent counterpart[3,5]. The ferret's brain features make it an excellent candidate for MR imaging, however, there is no commercially available cradles that can accommodate the ferret, requiring special in-house designs to accommodate imaging. Ferret sex differences in body and brain size – males are ~1.5 times as large as females – present a challenge to studies that seek to include both sexes in their experimental design or that explicitly study sexual dimorphisms[2-4]. Because sex differences in the ferret create limitations to applying the same MR cradle solutions to both sexes for in-vivo imaging, design of sex-specific cradles is necessary. In this abstract, we highlight our current female ferret setup that incorporates a commercial rat cardiac coil adapted with custom made anesthesia device and adapt the basic design concepts to accommodate the male ferret. Using comparative analysis of male and female ferrets we demonstrate the dichotomy in size and brain volume; corroborating previous findings on sexual dimorphic differences in the ferret[2-4]. Our male ferret custom cradle with integrated anesthesia and commercially available surface coils will be made publicly available in the form of 3D printable files. The custom cradle can be adapted as a specific solution to reduce motion artifacts and minimize preparation time and consequently animal anesthesia time for both male and female ferrets for future imaging studies.

Methods

Fused Deposition Modelling printers were used for the cradle and anesthesia components using PLA filament. Acquisition setup for the female is shown in (fig. 1), where animal is in the supine position and fitted with a cone that connects to both oxygen and anesthesia delivery via tube connections. To test our setup for the custom cradle, we segmented previously collected male and female ferret T2 anatomical (the negative space where skull can be extracted) using ITKSNAP[7] and we filled with 1% agarose and imaged on the 7T Bruker to evaluate feasibility of the cradle (field of view and susceptibility artifacts from printing materials).

Results

Our female ferret setup has successfully been applied to 28 scan sessions in the female ferrets at our institution which is outlined in (fig. 3). Observations from physiological measurements of the ferrets, revealed that the female cohort are smaller than the males, most notably in weight (94% smaller; $p<0.05$), body diameter (41% smaller, $p<0.05$), head width (34% smaller, $p<0.05$), and body length (28% smaller) (see fig. 1). The measurement differences between the sexes motivated the dimension requirements of our cradle design, particularly the diameter (which is only 5.7 cm on our current female ferret cradle setup). We observed a 21% percent smaller brain volume in females compared to males ($p<0.005$), which prompted the need to evaluate our surface coil coverage for brain imaging. Our prototype was able to integrate with a rat head surface receiving coil (placed ventrally to allow for supine imaging) and fit in the center of our 86 mm transmitting coil (fig. 4 and 5). Our phantom testing showed a field of view of 40x26x14mm for both the female and male skull phantoms, which is comparable to the in-vivo female ferret coverage that we currently can achieve.

Discussion

We have worked closely with our Veterinary staff to improve our MR setup for ferret imaging, including feasibility for imaging male ferrets, improving integration of anesthesia placement, integration of a commercially available surface coil to fit closely to the head, and adjustable locations for placing physiological monitoring. The next phase of our cradle includes in-vivo imaging of the male ferret and comparing directly to the female ferret.

Conclusions

Conclusions We aim to apply the cradle to longitudinal imaging of the ferret and evaluate how well the custom cradle adapts to age-related changes in the ferret (e.g weight and body size fluctuations). We also are currently adapting our cradle to accommodate imaging the animal in a prone position as well. Although we have not yet tested this cradle on live imaging of male ferrets, our phantom testing shows promise that the imaging acquisition we have been able to carry out in females will be possible in the male ferret.

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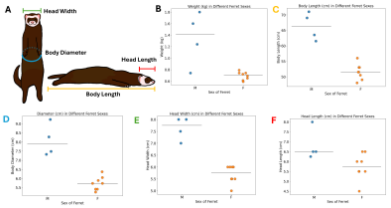
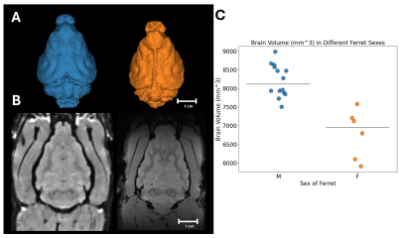
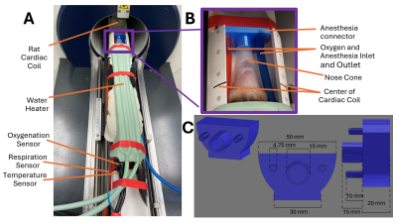
Figures



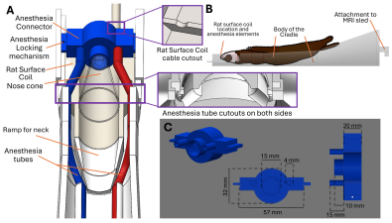
A) Sexual Dimorphic Differences Between Male and Female for B) Weight (kg) C) Body Length (cm) D) Diameter (cm) E) Head width (cm) F) Head Length (cm)



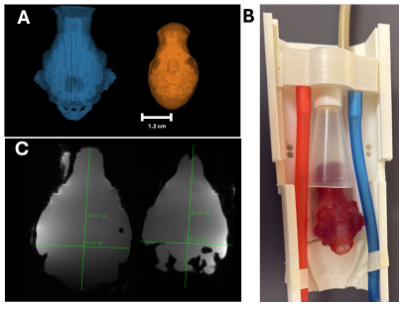
A) Brain Volume render of both male and female (right and left, respectively) B) Brain Volume Differences (from previously collected T2 weighted images on male ferret brains from another institute) compared to collected T2 weighted images of female ferret brains



A-C) Initial Cradle Design for Female Ferrets A: Direct heating element (circulating water system). B & C) Custom 3D-printed inhaled anesthetic delivery system.



A) Male ferret cradle design B) Sagittal view of whole cradle design and planned ferret placement C) Anesthesia connector design adapted to slide along cradle



A) Male and Female Approximate Skull Render (left and right respectively) B) Cradle

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setup with skull and brain phantom placement C) Axial view of T2 weighted images of male and female skull phantoms (left and right respectively) with field of view measurements in green