Quantitative analysis of the Kudu brain (*Tragelaphus strepsiceros*)

Lena Yu[1], Tate Vernon[1], Mark Haagensen[2], Paul R. Manger[3] & Muhammad A. Spocter[1,3]

[1]Department of Anatomy, Des Moines University, Des Moines, Iowa; [2]Department of Radiology, University of the Witwatersrand-Donald Gordon Medical Centre, Johannesburg, Republic of South Africa; [3]School of Anatomical Sciences, University of the Witwatersrand, Republic of South Africa.

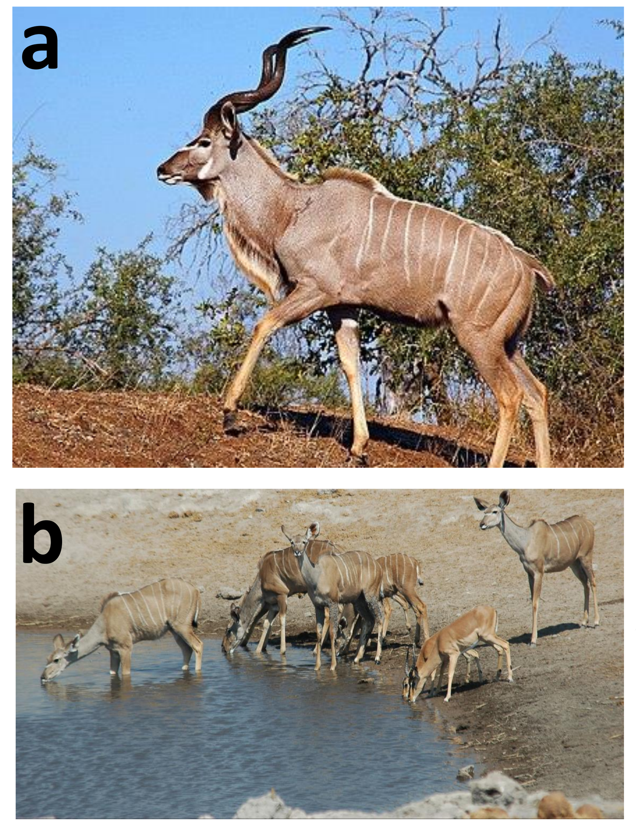
DES MOINES UNIVERSITY
MEDICINE & HEALTH SCIENCES

Abstract

The Kudu is a member of the antelope family and is relatively understudied from an anatomical perspective. To date, no published studies have detailed the underlying neuroanatomical structure of the Kudu brain or provided 3D segmentation or volumetric data on its subcortical anatomy. Using MRI scan data obtained from a postmortem scan of an adult specimen (male), we provide a preliminary MRI atlas and accompanying 3D reconstructions of the hippocampus and caudate nucleus. These volumetric data were compared with whole brain size using published data on other mammals. This project provides an anatomical baseline for comparisons between domestic and wild type artiodactyls and identifying the neuroanatomical substrate supporting complex behavior within this group.

Introduction

The greater kudu is an African antelope found in the woodland of southern Africa extending into east Africa. It is one of the largest species of antelope and weighs between 420-600 lbs (63 in tall at the shoulder). They have a life span of around 7 years in the wild but may live as long as 23 years in captivity. They are not territorial. Both females and males may live in small herds 6-10, although males are generally solitary and more widely dispersed (Furstenburg, 2009).



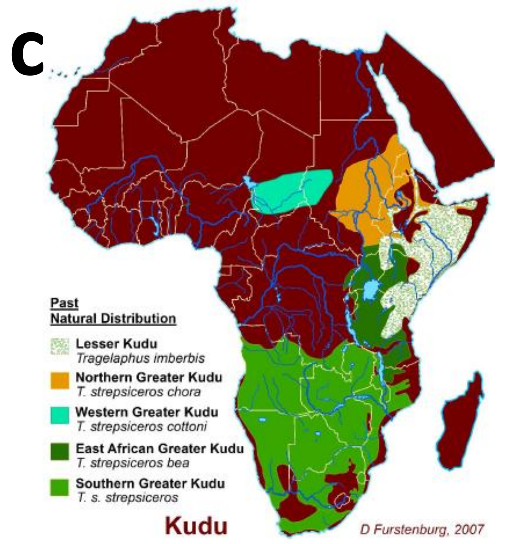


Figure 1: a- An adult male Kudu (Kruger Park, South Africa); b- Juvenile male and female Kudu around a watering hole; -c A map showing the distribution of wild Kudu. (nationalgeographic.com)

Methods

Magnetic resonance (MR) imaging was performed on the donated postmorten whole brain of an adult male Kudu (*Tragelpahos strepsiceros*) obtained with relevant permissions and consent through collaboration with the Blank Park Zoo. MR imaging was performed in the Department of Radiology, Icahn School of Medicine at Mount Sinai, New York. The brain was removed within 4 hours of death and fixed in 4% paraformaldehyde for 10 days followed by storage for three months prior to scanning. Before scanning the specimen was rinsed and placed in Fomblin solution and packed in gauze in a special container for MR image acquisition on 7 T Bruker Biospec MR System. A 3D FLASH sequence with the following parameters was used for scanning: TR=36ms, TE=23ms, Flip angle=15 degrees, FOV=8cm, matrix size 384*384*384, 20 averages. Resulting dicoms were converted to nifty format and loaded into ITKSNAP for post processing and image analysis. Using the Region of Interest (ROI's) and editing tools the image intensity was optimized for visualization and the scan data was inverted (T2 to T1 scan). Every 10th image slice was saved to the work station and placed within a Powerpoint file for identification and labelling. **Segmentation:** 3D surface files were created in ITKSNAP and the total brain volume data was computed. **Statistical Analysis**: We compared brain mass to body mass in a range of eutherian mammals using data collated from the literature (Minervini et al., 2016). The kudu brain volume was converted to brain mass (g) by conversion using the specific mass of brain tissue (Stephan & Bachaut, 1969). Brain mass was then compared for this large bodied artiodactyl with a general mammalian regression line computed in CurveExpert 1.6.

Methods

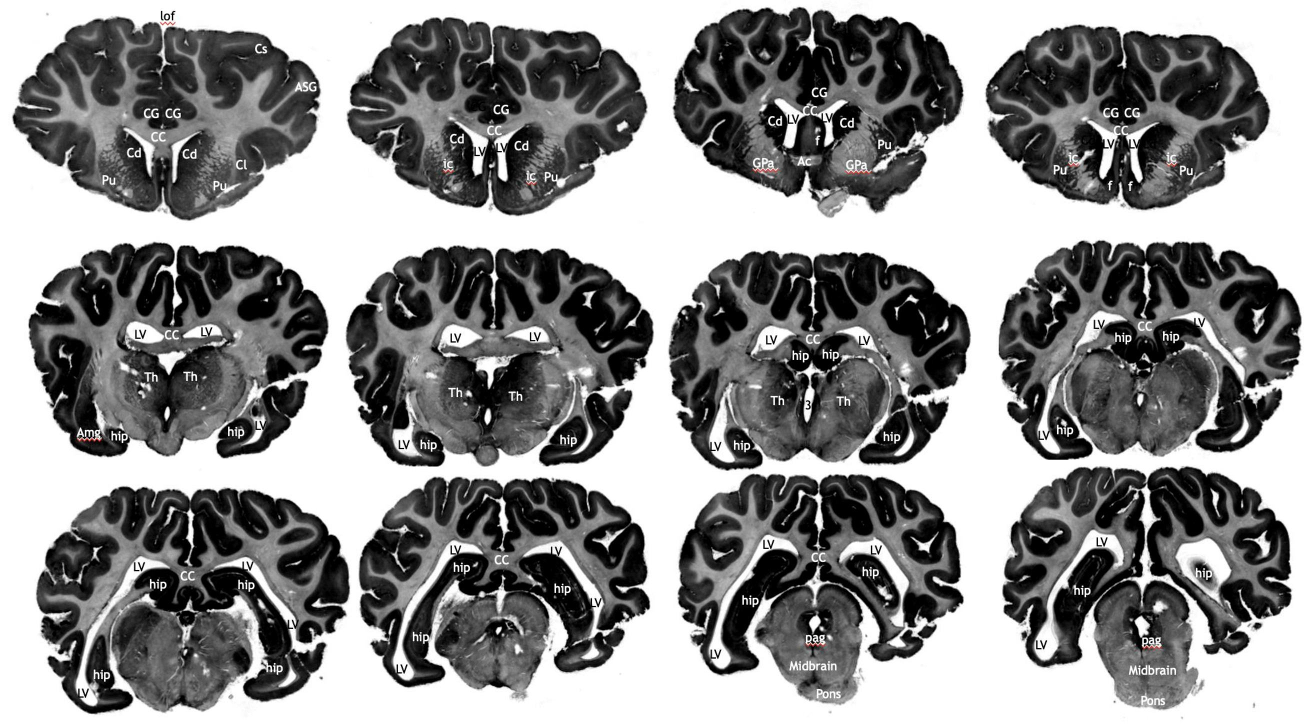


Figure 2: A rostro-caudal sequence of coronal images through the diencephalon and midbrain of the Kudu brain. Labelled components include the : hip = hippocampus; Amg = amygdala; CC = corpus callosum; LV = lateral ventricle; Th = thalamus; pag = periaqueductal grey; 3 = third ventricle

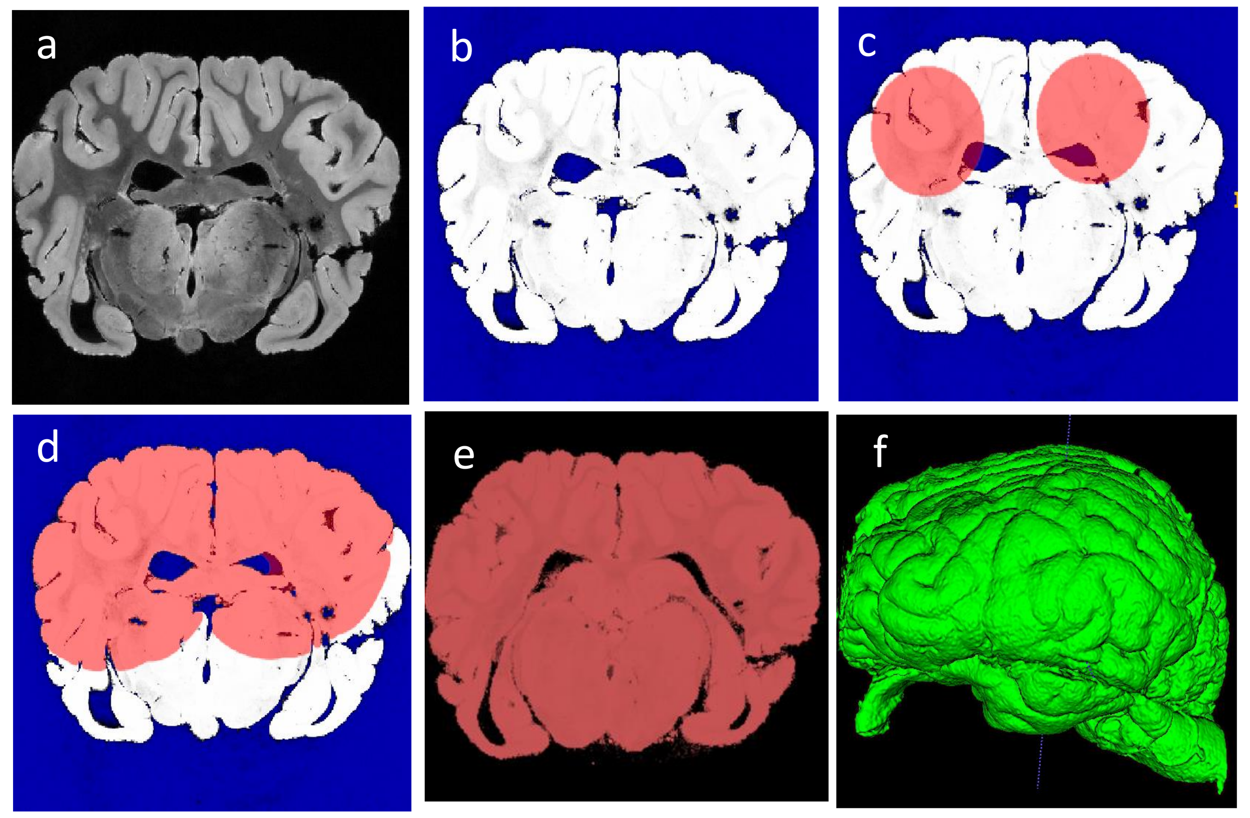


Figure 3: MRI segmentation process used for mesh extraction in the software package ITKSNAP. a-unprocessed scan; b-thresholding; c-initialization; d & e-contour evolution; f- generated 3d mesh.

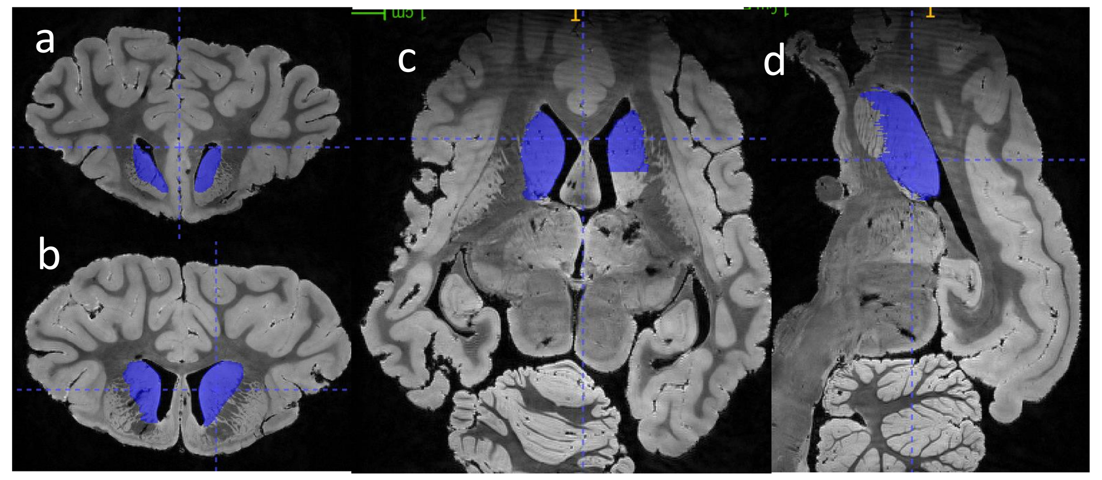


Figure 4: Screenshots showing manual segmentation of the caudate nucleus in ITKSNAP. A & b- coronal sections at level of the anterior horn of lateral ventricle of the Kudo brain; C- transverse section showing head and body of caudate nucleus; d – saggital section showing the medial surface of the caudate head and body

Results

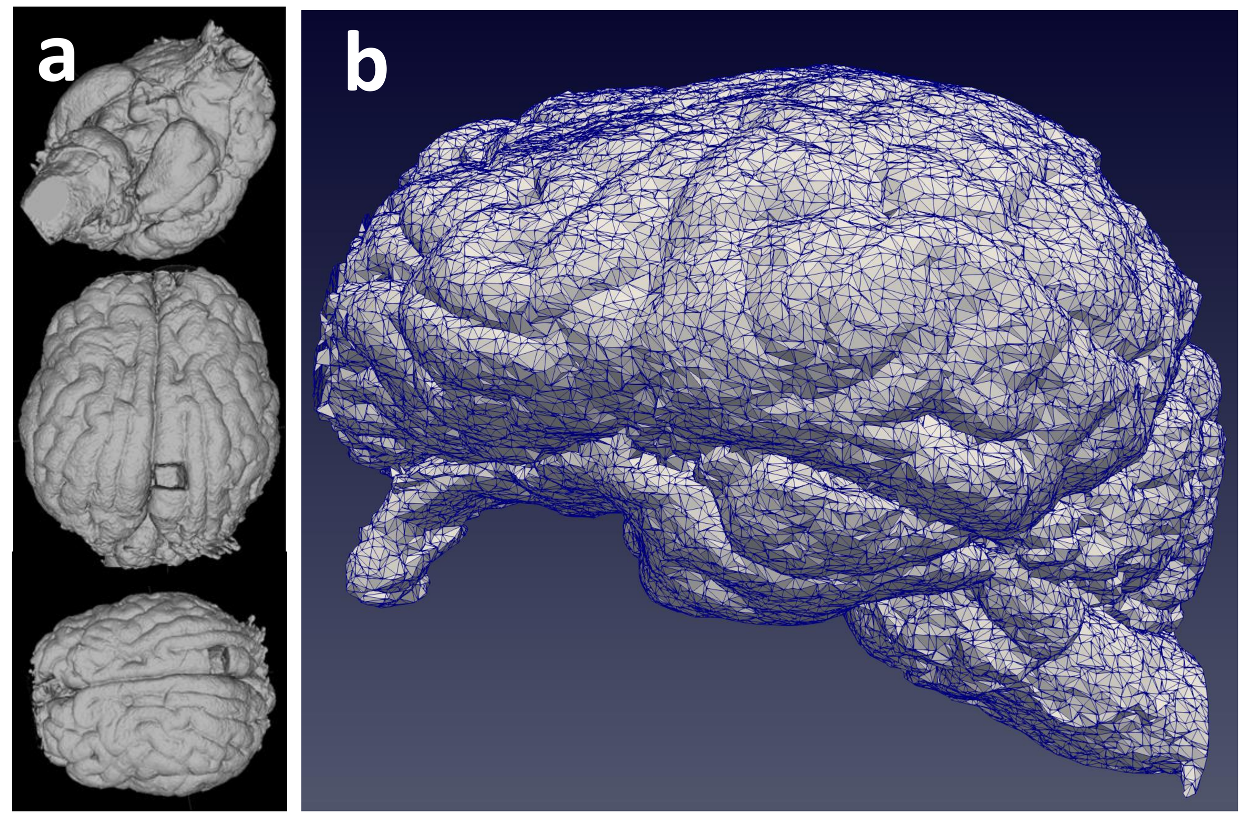


Figure 5: Preliminary 3 dimensional reconstructions of the inferior and superior cortical surface of the Kudu brain. Surface meshes were extracted using semi-automatic segmentation in ITKSNSAP. b- lateral view of the Kudo brain. The surface mesh was imported into Paraview for post processing. Note a 1X1cm cube of tissue was removed from the primary motor cortex.

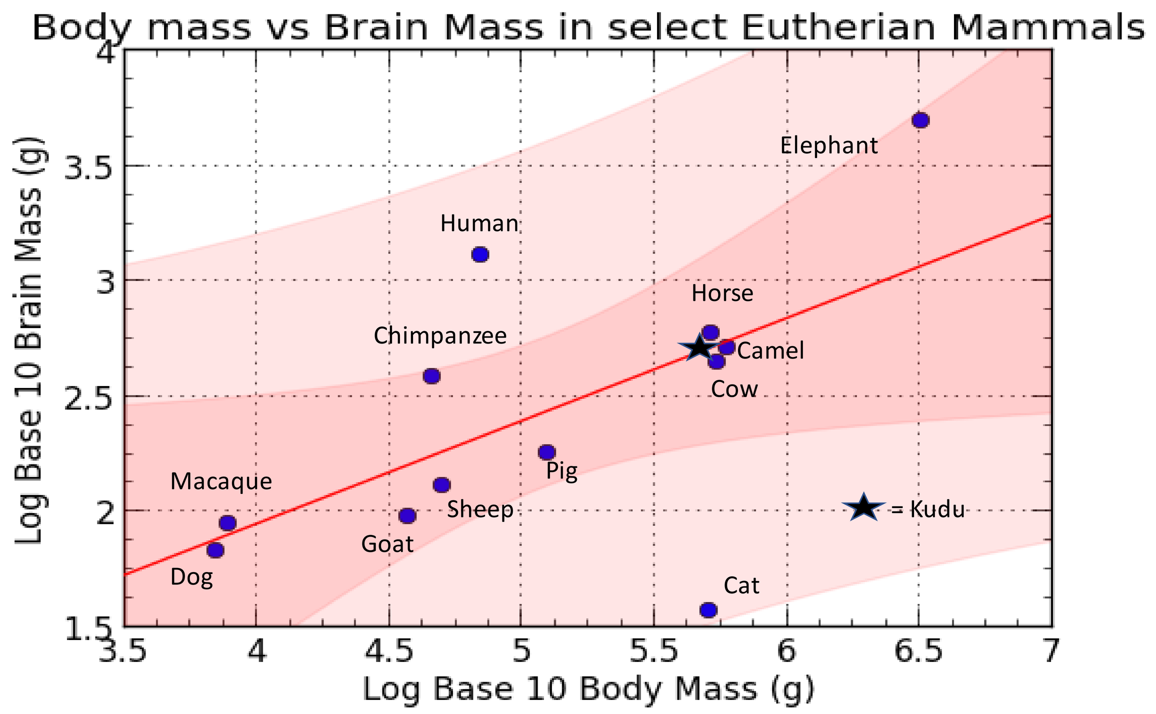


Figure 6: Linear regression (least squares) plot of body mass (g) vs brain mass (g). Note, that the brain mass of the Kudu is as one would predict for a mammal of its given body size.

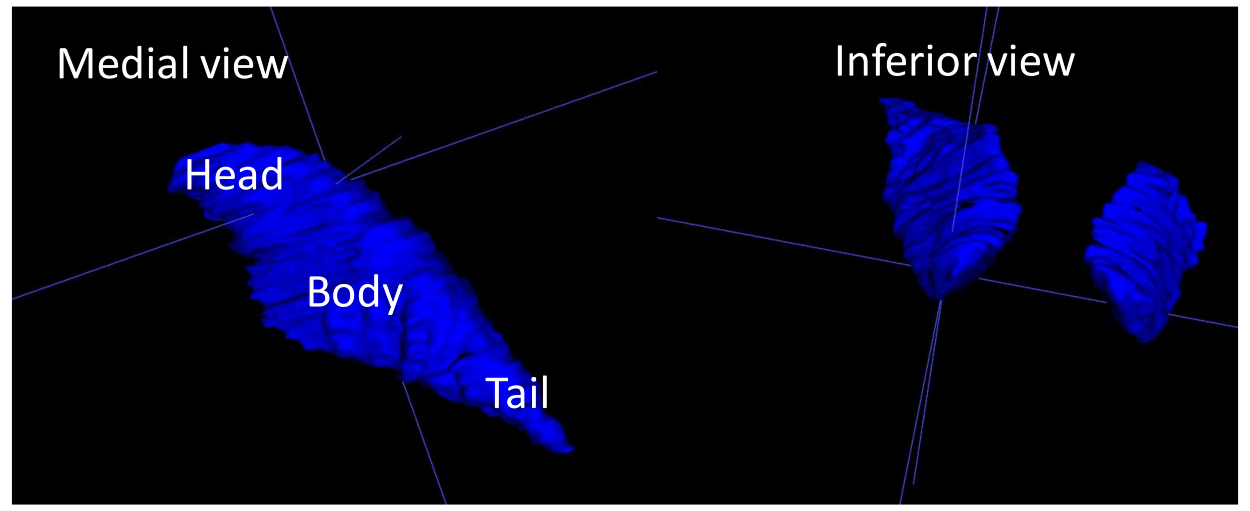


Figure 7: 3D reconstructions of the head, body and tail of the caudate nucleus in the Kudu. Segmentations and reconstructions were completed in ITKSNAP with no smoothing of the external surface

Conclusion

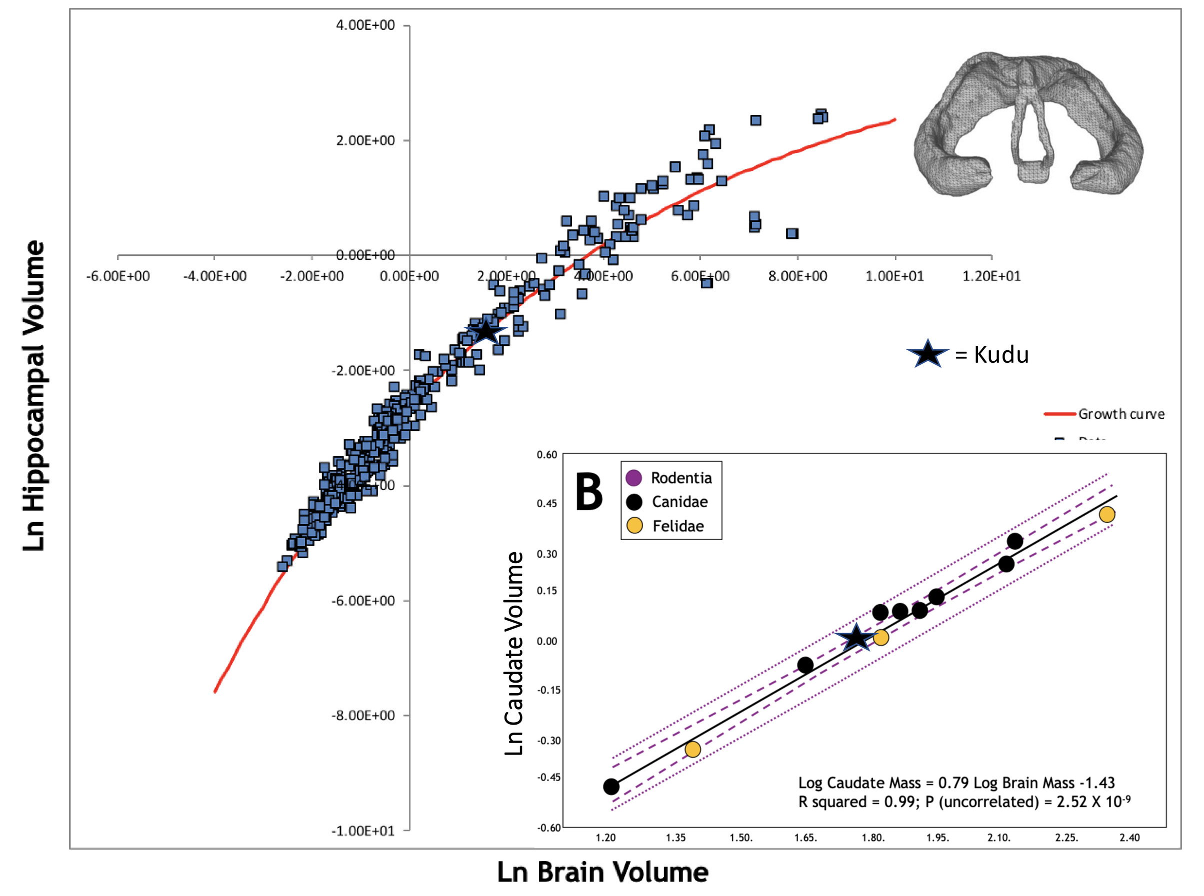


Figure 8: Regression analysis of hippocampal volume plotted against brain volume and brain volume plotted against caudate volume for all mammals. Superimposed on the regression lines is the data point for the kudu used in this study. The hippocampal and caudate volume for the kudu lie well within the prediction interval for the regression line.

MR imaging and segmentation provided good visualization of all major cortical and subcortical structures. No major qualitative anatomical differences were noted in structure and basic qualitative comparison of brain size to body size and hippocampal and caudate size to brain size revealed that the Kudu brain was as one would predict for a mammal of its given body size. These results are inline with that of a recent comparative study of brain size in the Artiodactyl brain (Spocter et al., 2018) as well as scaling relationships of hippocampal volume (Patzke et al., 2015) and basal nuclei scaling (Foster et al., In Press). In addition comparative analyses of the dendritic tree, derived from tissue used in the current study, indicate that the Kudu primary motor cortex has Betz cells and pyramidal neurons typical for an artiodactyl (Jacobs et al 2018).

Further analysis using comparative histological and histochemical procedures as well as a comparison of the neuropil space in various brain regions of the Kudu brain are planned for future studies.

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Acknowledgments

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