

## Macroscopic aspects of *Saimiri sciureus* dura mater<sup>1</sup>

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**ABSTRACT.**- Barcellos F.M., Branco E., Fioretto E.T., Imbeloni A.A., Muniz J.A.P.C. & Lima A.R. 2011. **Macroscopic aspects of *Saimiri sciureus* dura mater.** *Pesquisa Veterinária Brasileira* 31(Supl.1):7-10. Instituto de Saúde e Produção Animal, Universidade Federal Rural da Amazônia, Campus de Belém, PA 66077-530, Brazil. E-mail: [erika.branco@ufra.edu.br](mailto:erika.branco@ufra.edu.br)

*Saimiri sciureus* is a small New World primate (NHP) commonly called macaco-de-cheiro that inhabits the tropical forests of the Amazon basin. Anatomical features are not well studied in most primates, and the encephalic morphology and related structures are still quite unknown. Comparative anatomy of the meninges in South American primates is still scarce. Dura mater, arachnoid and pia mater are a group of stratified layers that surrounds and promotes protection to the *medulla spinalis*. This study aimed to shed light on the anatomy of dura mater in *Saimiri sciureus* in order to contribute to the neuroscience in primates. We investigated three young females and two males of *S. sciureus*. Specimens were fixed through perfusion with a 10% formaldehyde aqueous solution. In *S. sciureus* encephalus few gyrus and circunvolutions, and a very delicate system consisting of eight *sinus venosus* was found between the dura mater layers. Based on our findings, we can conclude that the *Saimiri sciureus* dura mater is quite similar to other mammals, however we detected a new *sinus venosus* formation at the level of parietal bone, named *sinus parietalis*, what appears to be its first description.

INDEX TERMS: *Saimiri sciureus*, brain, dura mater, *sinus venosus*, *sinus parietalis*.

**RESUMO.**- [Aspectos macroscópicos da dura mater de *Saimiri sciureus*.] *Saimiri sciureus*, com nome comum de macaco-de-cheiro, é um pequeno primata do Novo Mundo (PNM) que habita as florestas tropicais da Bacia Amazônica. Os detalhes anatômicos de primatas são pouco conhecidos e a anatomia comparada de animais selvagens da América do Sul é escassa, mais especificamente, sobre as meninges de PNM. Meninges pertencem a um sistema de

membrana responsável por envolver e proteger o Sistema Nervoso Central; consiste em três membranas: dura mater, aracnoide e pia mater. Este estudo objetivou a elucidação do comportamento anatômico da dura mater de *S. sciureus* com o intuito de contribuir para a área de neurociências em primatas. Foram investigados três fêmeas e dois machos jovens de *S. sciureus*. Os espécimes de meninges foram fixados por perfusão usando solução aquosa 10% de formaldeído. O encéfalo de *S. sciureus* demonstrou um número baixo de giros e circunvoluções, e um sistema delicado de oito seios venosos foi verificado entre as camadas da dura mater. Baseados em nossos achados podemos concluir que a dura mater de *S. sciureus* é similar aos de outros mamíferos, no entanto, apresenta a formação de um novo seio venoso em nível ao osso parietal, sendo denominado de seio parietal. Isto parece ser a primeira descrição deste seio.

TERMOS DE INDEXAÇÃO: *Saimiri sciureus*, encéfalo, dura mater, seio venoso, seio parietal.

### INTRODUCTION

*Saimiri sciureus* is a common small New World primate (NHP) that inhabits the tropical forests in Amazon basin.

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Its common name is Macaco-de-cheiro, the weight of which varies from 554g to 1150g for males and 651g to 1250g for females. *S. sciureus* is considered the smallest primate in the *Cebidae* family; usually males are a little larger than females, 318mm and 316mm respectively. Its fur is short, thick, soft, blitheness and colored. A light-warm colored hair is present around the eyes and in the ears (white tuft); head and neck are usually dark gray or dark-cool, while hands, feet, forearm are yellow-orange; shoulder demonstrates a thin grayish fur; tail is bicolored. Hands have nails instead of claws, and teeth are sexually dimorphic; males have large canine teeth (Hill 1957, 1958, Auricchio 1995, Castelo et al. 1997, Emmons & Feer 1997).

Meninges are a system of membranes which surrounds and protects the nervous system. It consists of three layers: Dura mater (pachymeninge), arachnoid membrane and pia mater, both known as leptomeninge (Pereira et al. 2010). In the skull, dura mater demonstrates two layers, endosteal and meningeal. Endosteal dura mater is the most external, thick layer, closest to the calvaria; additionally, it is tough and inflexible. Meningeal dura mater demonstrates two major folds and two minor folds. Major folds are the *tentorium cerebelli* (separates *cerebellum* and brainstem) and the *falx cerebri* (separates hemispheres). Minor folds are the *cerebellar flax* (partially separates the cerebellar hemispheres) and *sellar diaphragm* (roof over the hypophysial fossa) (Crippen 2009, Vinas & Pilitsis 2009). These structures limit oscillatory brain movements and have been

considered a major obstacle to remove the intact brain during necropsy of domestic animals (Dyce et al. 2004).

Anatomical features are usually little known about most primates; nonetheless, encephalic morphology and related structure are still not well known. Comparative anatomy involving South American wild animals, more specifically NHPs, regarding about meninges are very scarce. This study aims to shed light on the anatomical features of dura mater in *Saimiri sciureus* in order to contribute to the neuroscience in primates.

## MATERIALS AND METHODS

We investigated young *Saimiri sciureus*, three females and two males. Animals came to death by natural cause, and were obtained at Centro Nacional de Primatas (CENP) in Ananindeua, PA, Brazil. All procedures were in accordance to the Ethical Committee for Animal Research of Evandro Chagas Institute (CEPAN/IEC), Process nº 0007/2004.

Specimens were fixed by perfusion using a 10% formaldehyde aqueous solution. Perfusion was made through right common carotid artery. In order to optimize brain fixation, we injected the fixative solution in the brain cavity through a small aperture on the frontal bone. Specimens were kept immersed in fixative solution for seven days, after bone removal: frontal, parietal, occipital and part of the temporal, exposing the entire brain covered by three meninges, which were carefully removed sectioning the spinal cord. The first meninge to be accessed was the Dura mater, following a longitudinal fissure along the brain. When opened was possible to identify the arachnoid and pia mater. All meninges

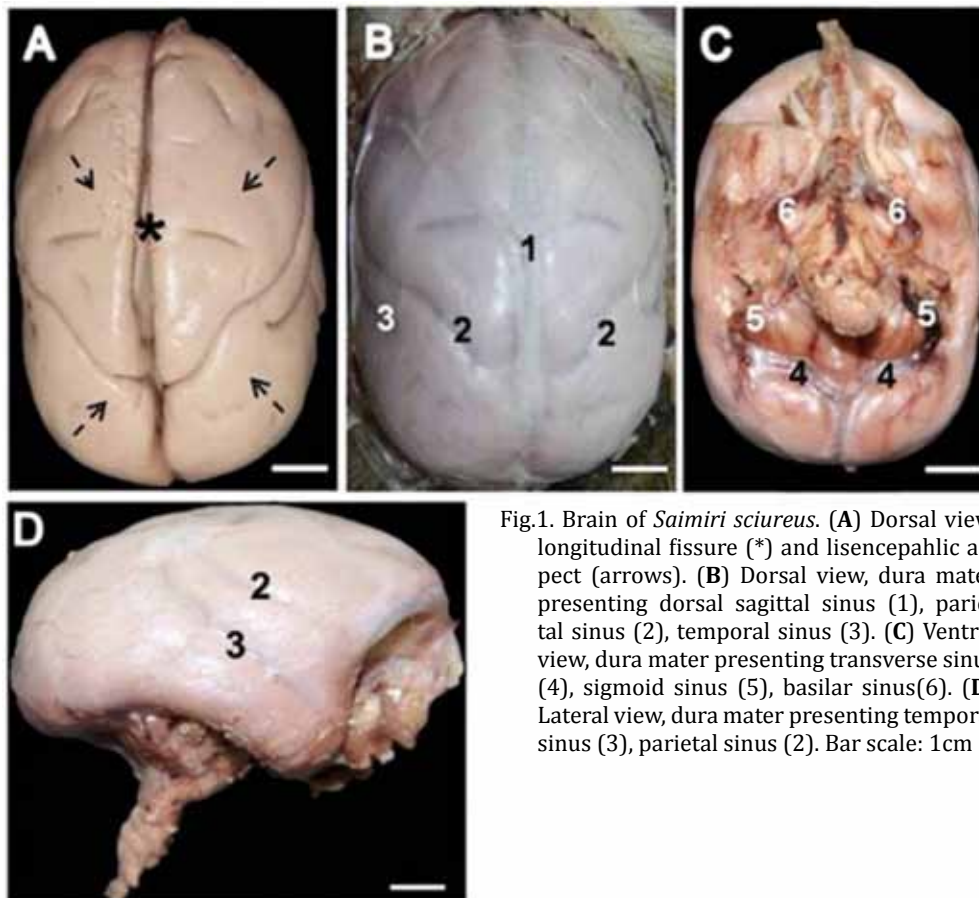


Fig.1. Brain of *Saimiri sciureus*. (A) Dorsal view, longitudinal fissure (\*) and lissencephalic aspect (arrows). (B) Dorsal view, dura mater presenting dorsal sagittal sinus (1), parietal sinus (2), temporal sinus (3). (C) Ventral view, dura mater presenting transverse sinus (4), sigmoid sinus (5), basilar sinus(6). (D) Lateral view, dura mater presenting temporal sinus (3), parietal sinus (2). Bar scale: 1cm

were gently removed with the aid of an anatomical clamp to expose the cerebral cortex and *cerebellum*.

Nomenclature followed the International Committee on Veterinary Gross Anatomical Nomenclature (2005) and Illustrated Nomina Anatomica (Schaller 1999).

## RESULTS

*Saimiri sciureus* encephalus showed a small number of gyrus and circunvolutions (Fig.1A). Dura mater was firmly attached to the bones, and projected two laminar folds at the level of internal parietal crest, the *falx cerebri* and the *tentorium cerebelli* (Fig.1D). Encephalus longitudinal fissure was deep (Fig.1A).

A very delicate system of venous sinus was observed between the dura mater layers. Eight venous sinus were identified: 1) transverse sinus - bilateral laying along the insertion of *tentorium cerebelli* (Fig.1C, 2A,B); 2) Dorsal sagittal sinus - single, median, laying along the insertion of *falx cerebri* (Fig.1B,D); 3) Ventral sagittal sinus - single, median, laying along the free border of *falx cerebri* (Fig.1D, 2A,B); 4) recto sinus - single, median, laying along the common border of *tentorium cerebelli* and *falx cerebri* (Fig.1D, 2A,B); 5) temporal sinus - bilateral, laying along the meningeal rostral border of temporal lobe and ventral to the parietal sinus (Fig.1B, 2C); 6) sigmoid sinus - bilateral, laying rostral-caudally along the meningeal basal layer (Fig.1C, 2A,B); 7) basilar sinus - bilateral, laying along the hypophysial region at the meningeal basal layer (Fig.1C, 2A); 8) parietal sinus - bilateral, laying dorsally to the temporal sinus, linking to the dorsal sagittal sinus (Fig.1B, 2C).

## DISCUSSION

Not differently to other animals (Hildebrand 2006), *Saimiri sciureus* presented covering membranes over brain, oblongata medulla, pons, cerebral peduncles and cerebellum, however, not clearly delimitation was observed between the membranes.

Besides, *S. sciureus* encephalon demonstrates few gyrus, circunvolutions, its general appearance is considered quite similar to most human primates (Van de Graaff 2003, Drake et al. 2005, Dangelo & Fattini 2007), nevertheless, *S. sciureus* should be classified as lissencephalic. It is worthwhile to appoint that lissencephaly in human is a rare brain disorder, the symptoms of which include psychomotor retardation, failure to thrive, seizures, muscle spasticity or hypotonia (Jones 2006); Despite demonstrating a lissencephalic brain morphology, *S. sciureus* develops normally.

*Falx cerebri* and *tentorium cerebelli* are proportionally well developed in *S. sciureus*, in agreement to human descriptions, however, *S. sciureus falx cerebri* differs from domestic mammals which demonstrate a narrow *Falx cerebri* and a shallow longitudinal fissure (Habel 1951, Schwarze & Schröder 1972, Getty 1975, Bruni & Zimmerl 1977, Evans & De Lahunta 1994). This feature was similar to *Bradypus torquatus* and *Bradypus variegatus* (Ferreira et al. 2005).

*S. sciureus sinus venosus* are connected to regional veins similarly to human (Machado 2004), meanwhile, due to the presence of transverse sinus, *S. sciureus* differs from *Nemestrina macaca* (Hill 1990); *S. sciureus sinus venosus*

have some similarity to *Bradypus torquatus* and *Bradypus variegatus* (Ferreira et al. 2005), which, additionally, have the orbicular-olfactory sinus, cerebellar parasagittal sinus and intertransverse sinus. It is worthy to detach that the parietal sinus is, by now, the first time described in literature.

Dorsal sagittal sinus in *S. sciureus* were slightly different from *B. torquatus* and *B. variegatus* (Ferreira et al. 2005) in

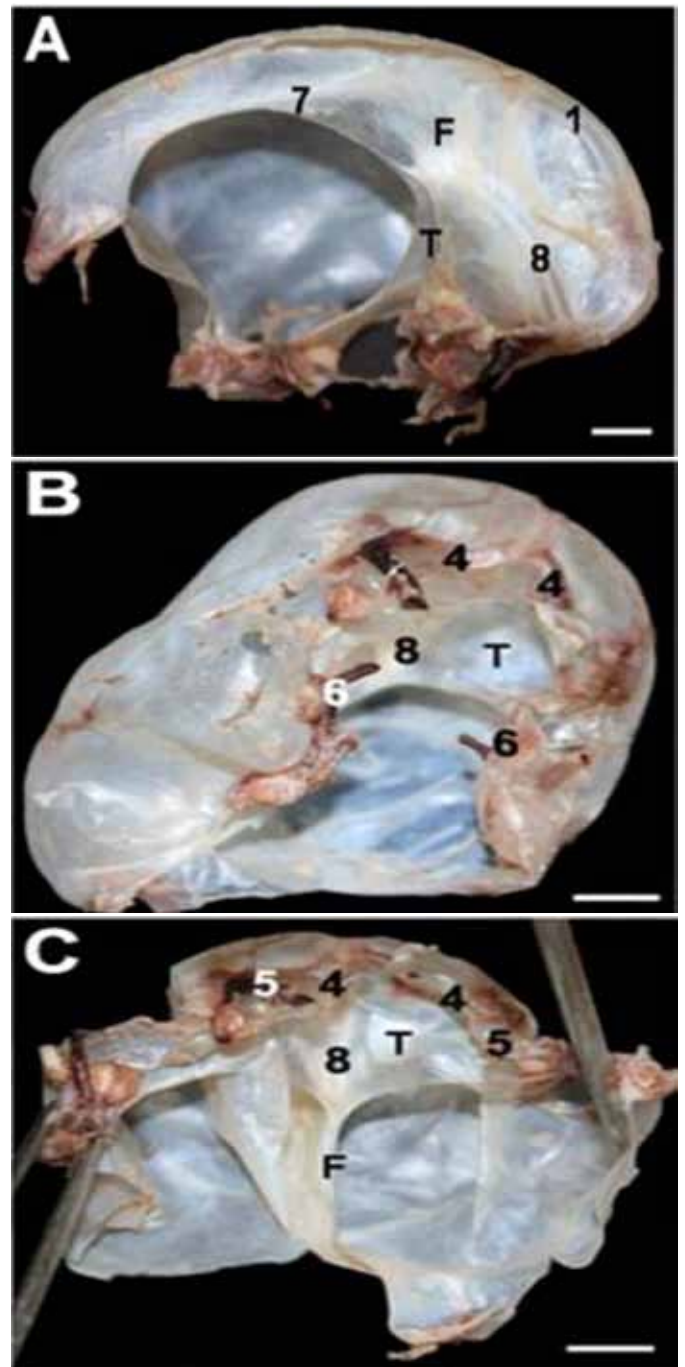


Fig.2. Dura mater of *Saimiri sciureus*. (A) Longitudinal view, dorsal sagittal sinus (1); ventral sagittal sinus (7); recto sinus (8), *falx cerebri* (F), *tentorium cerebelli* (T). (B,C) Ventral and internal views, demonstrating transverse sinus (1)(4), sigmoid sinus (2)(5), basilar sinus (3)(6), recto sinus (8), *tentorium cerebelli* (T), *falx cerebri* (F). Bar scale: 1cm

the angle of its relation to the transverse sinus. This particular arrangement is related to the position of the brain in relation to the cerebellum, which in primates are ventral to the brain, whereas it is caudal in quadrupeds (Hill 1960, Lockhart et al. 1983, Dangelo & Fattini 1988, Gosling et al. 1992, Machado 2004, Abrahams et al. 2005, Rohen et al. 2006).

### CONCLUSION

Based on our findings, we can conclude that the *Saimiri sciureus* dura mater has some similarity to the one of other mammals; however, we found a new venous sinus formation at the level of parietal bone, which was named *sinus parietalis*.

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### REFERENCES

- Abrahams P.H., Marks Jr S.C. & Hutchings R.T. 2005. Atlas Colorido de Anatomia Humana de MacMinn. 3<sup>rd</sup> ed. Manole, São Paulo. 384p.
- Auricchio P. 1995. Primatas do Brasil. Terra Brasilis, São Paulo. 165p.
- Bruni A.C. & Zimmerl U. 1977. Anatomia degli Animali Domestici. Vol.2. Casa Editrici Dottor Francesco Vallardi, Milano. 736p.
- Castello R.K., Dickinson C., Rosenberger A.L., Boinski S. & Szalay F.S. 1997. Squirrel monkeys (genus *Saimiri*) taxonomy: A multidisciplinary study of the biology of the species, p.177-210. In: Kimbel W.H. & Martin L.B. (Eds), Species, Species Concepts, and Primate Evolution. Plenum Press, New York.
- Crippen D.W. 2009. Head trauma. <<http://emedicine.medscape.com/article/433855-overview>> Accessed Febr. 4, 2010.
- Dangelo J.G. & Fattini C.A. 2007. Anatomia Humana Sistemática e Segmentar. 3<sup>a</sup> ed. Atheneu, São Paulo. 763p.
- Drake R.L., Vogl W. & Mitchell A.W.M. 2005. Gray's Anatomia para Estudantes. Elsevier, São Paulo. 848p.
- Dyce K.M., Sack W.O. & Wensing C.J.G. 2004. Tratado de Anatomia Veterinária. 3<sup>a</sup> ed. Guanabara Koogan, Rio de Janeiro. 813p.
- Emmons L.H. & Feer F. 1997. Neotropical Rainforest Mammals: A field guide. 2<sup>nd</sup> ed. University of Chicago, Chicago. 298p.
- Evans H.E. & De Lahunta A. 1994. Guia para a Dissecção do Cão. 3<sup>a</sup> ed. Guanabara Koogan, Rio de Janeiro. 206p.
- Ferreira J.R., Oliveira V.L., Oliveira K.M. & Oliveira M.A. 2005. Contribuição ao estudo anatômico da dura-máter de *Bradypus torquatus* (Linnaeus, 1758) e *Bradypus variegatus* (Schinz, 1825). Braz. J. Vet. Res. Anim. Sci. 42(5):381-387.
- Getty R. 1975. Sisson and Grossman's Anatomy of the Domestic Animals. 5<sup>th</sup> ed. W.B. Saunders Company, Philadelphia. 1211p.
- Gosling J.A., Harris P.F., Humpherson J.R., Whitmore I. & Willan P.L.T. 1992. Anatomia Humana: Atlas colorido e livro texto. 2<sup>a</sup> ed. Manole, São Paulo. 368p.
- Habel R.E. 1951. Guide to the Dissection of the Cow. Cornell Cooperative Society, New York. 375p.
- Hildebrand M. & Goslow G. 2006. Análise da Estrutura dos Vertebrados. 2<sup>a</sup> ed. Atheneu, São Paulo. 638p.
- Hill W.C.O. 1957. Primates Comparative Anatomy and Taxonomy. Edinburgh University, Edinburgh. 354p.
- Hill W.C.O. 1958. Primatology Handbook of Primatology. S. Karger, New York. 704p.
- Hill W.C.O. 1960. Primates Comparative Anatomy and Taxonomy. IX. Cebidae, Part A. University Press, Edinburgh, p.63-68.
- Jones K.L. 2006. Smith's Recognizable Patterns of Human Malformation, 6<sup>th</sup> ed. Elsevier Saunders, Philadelphia. 976p.
- Lockhart R.D., Hamilton G.F. & Fyfe F.W. 1983. Anatomia do Corpo Humano. 2<sup>a</sup> ed. Guanabara Koogan, Rio de Janeiro. 669p.
- Machado A. 2004. Neuroanatomia Funcional. Atheneu, Rio de Janeiro. 363p.
- Nomina Anatomica Veterinaria 2005. International Committee on Veterinary Gross Anatomical Nomenclature. 4<sup>th</sup> ed. ICVGAM, New York. 166p.
- Pereira K.F., Lima V.M., Conegero C.I. & Chopard R.P. 2010. Histomorfometria das meninges encefálicas de ratos Wistar em diferentes faixas etárias. Pesq. Vet. Bras. 30(11):996-1002.
- Rohen J.W., Yokochi C. & Lütjen-Drecoll E. 2006. Color Atlas of Anatomy: A photographic study of the human body. 6<sup>th</sup> ed. Medical Publishers, New York. 532p.
- Schaller O. 1999. Nomenclatura Anatômica Veterinária Ilustrada. Manole, São Paulo. 614p.
- Schwarze E. & Schröder L. 1972. Compendio de Anatomía Veterinária. Acribia, Zaragoza. 247p.
- Van de Graaff K.M. 2003. Anatomia Humana. Manole, São Paulo. 880p.
- Vinas C.F. & Pilitsis J.P. 2009. Penetrating head trauma. <<http://emedicine.medscape.com/article/247664-overview>> Accessed Febr. 4, 2010.