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Development of an Interactive Multidisciplinary Platform for the Bovine Neuroanatomy Study

Desarrollo de una Plataforma Interactiva Multidisciplinar para el Estudio de la Neuroanatomía Bovina

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SUMMARY: The anatomy study is part of the basic cycle of disciplines that composes Veterinary Medicine college curriculum, and its comprehension is essential for other courses subject understanding. However, the current student's profile, the reduced time frame of superior education programs, and the multidisciplinary approach nowadays have made anatomy teaching method outdated and ineffective. Addressing the problem we developed an interactive and multidisciplinary platform based on the blended learning methodology, which could serve as a valuable tool for bovine neuroanatomy comprehension. To produce a new study tool, photos from bovine specimens fixed in formaldehyde, platinated brain pieces sectioned in a metameric order, as well as histological slides of the bovine central nervous system were used. These materials were applied to photos and schemes production, that were correlated with image exams correlation, as well as written content and videotaped classes. The obtained content was compiled into a digital platform, that can serve as an effective additional method to bovine central nervous system study. Furthermore, our results serve as a guide for the development of other blended learning methodologies in veterinary medicine and anatomy teaching. The platform provides a great tool for those who wish to accomplish a better understanding of bovine neuroanatomy and its clinical, surgical and image diagnosis correlations.

KEY WORDS: College education; Study platform; Blended learning; Bovine neuroanatomy; Dissection.

INTRODUCTION

Established as the basis of the study on Veterinary Medicine, the anatomy discipline has been losing space on the college's curriculums with the springing of new lines of work in the medicine field. This is also related to the restricted number of corpses available for dissection, that need to be pre-dissected for practical classes (Leung *et al*., 2006). Additionally, considering that the new teaching methodologies incline to a multidisciplinary approach integrating anatomy with other morphology and physiology disciplines, reducing even more the time available for teaching anatomy, its comprehension has been even more compromised (Chang Chan *et al*., 2019).

The increasing market demand for skilled and competent professionals, that are always updating their skills, is also a new challenge for professors that teach disciplines from the basic education cycle, such as anatomy (Neto & Wagner, 2019). Considering that, the anatomy field still based on medieval and modern teaching methodologies, are conflict has arisen with the converging with the current student's profiles (Dilullo *et al*., 2011). Contemporary graduates are responsible for great content from streaming and social platforms, having easy and quick access to information. However, many study materials that are available online are not subject to review or quality verification that could ensure

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their veracity (Barry *et al*., 2016). In this way, students are only serving as processors and diffusers of information, not really absorbing the contents. The need for virtual content increased with the Covid-19 pandemic, showing the importance and lack of optimized virtual teaching methodologies (Vrakking, 2009; Neto & Wagner, 2019).

These problems could be solved by using the blended learning, or b-learning methodology, that is already used in 25 % of virtual disciplines, allowing greater interaction between students and teachers. The b-learning can be disseminated through virtual platforms that offer verified study content endorsed by highly qualified professors (Barry *et al*., 2016; Chytas, 2019). In the anatomy study, Jaffar (2012) and Green *et al*. (2018) reported that the application of b-learning technologies increased the understanding and recollection of the content lectured. However, while using this method, it's important to prioritize the subject matter and material quality instead of the attractiveness of the platform itself, since already existing social media sites are highly alluring, but are lacking in excellent study content (Chang Chan *et al*., 2019).

Moreover, bovine and other ruminants are few of the main models studied in Comparative Anatomy, from which the Neuroanatomy is considered one of the most difficult topics. Considering this scenario, we developed a virtual platform with a multidisciplinary approach, displaying anatomic pieces of the neurological system in different views and counting with an interactive method, that exposes video classes, PDF documents and audios explaining all the produced content.

MATERIAL AND METHOD

This platform was developed in a partnership between the authors and the Software producing company "Fábrica de Códigos" (www.fabricadecodigos.com.br), following the forthcoming standards:

- Programming language:
  PHP 7.2;
  HTML 5;
  Javascript
- Framework PHP
  Code-igniter
- Frameworks Javascript
  jQuery 2
  Bootstrap 3.6
- Data base:
  PostgreSQL 11

The anatomic pieces (n=100) and microscopic slides (n=400) were obtained from the collection of the Laboratory of the Farm and Wild Animal Anatomy Sector of the Surgery Department of School of Veterinary Medicine and Animal Sciences of the São Paulo University (USP), and Anatomy Laboratory of the School of Veterinary Medicine of the University of Marilia (UNIMAR). Different pieces were produced according to the following protocols:

Pal-Weigert Staining Technique:

The slide samples contained transverse sectioned brain and spinal cord were stained by modified Pal-Wiegert technique. The cuts were hydrated and immersed in a 4 % iron aluminum solution for 3 minutes. After solution excess removal, the slides were subsequently immersed in a solution containing lithium carbonate and Hematoxylin for 30 minutes. The samples were then washed, dehydrated, and diaphanized. After slides evaluation, the hundred best samples were selected and captured for uploading to the platform (Pic. 1). The staining promoted a bluish aspect to the myelin fibers, a grayish yellow aspect to the nerve cells and a black staining to the nucleus.

Plastination Technique:

Pieces from two bovine brains were sent to the University of Toledo in the state of Ohio in the United States of America (USA), where they were plastinated by him in a technique with sequential cuts in polyester P40 and Silicone S10.

For the P40 technique, a specimen pre fixated in formalin 10 % was added to a jelly cube to be easily cut through by a circular saw in 5 mm slices. The slices were then washed and placed between two steel mashes and protected by a filter paper, being added in a reservoir filled with acetone at 25 °C. The dehydration process was completed by three consecutive washings, and the slices were placed in a vacuum chamber to be catalyzed in an acrylic resin and P40 with E6, promoting the fixation of the resin and elimination of the acetone. After the fixation, the samples were placed and sealed between two glass slides to avoid damage. Then, the slides were submitted to a UV light in a proper chamber to stiff the polyester (Pic. 2).

Selection, preparation and dissection of the bovine anatomic pieces:

Macerated skulls samples were used to illustrate the bovine bones that compose the neurocranium. Three other samples were injected with latex (DULATEX, centrifuged twice and pre-vulcanized), followed by a fixation procedure

with formalin 10 % and placed in a medium with the same solution for conservation.

For dissection exemplification, another 100 Central Nervous System samples were selected. Samples were identified in the lateral, ventral and dorsal views, and cut in sagittal, transversal, and longitudinal directions. This procedure allowed some of the structures from the Peripheral Nervous System to be observed.

The selected samples were cleaned, dried, and captured in a PVC background with the following equipment:

- Camera: Nikon D810
- Lenses: Nikon 105mm 2.8VR e 50mm 1.4
- Flash: Elinchrom Dlite 400
- Modifier: Sofbox 80x120 and 2 hitters.

Capture data:

- Speed: 1/200
- ISO: 100
- Opening: f11- f28

Microscopic slides were captured with a digital USB camera (MEM1300 CE & RoHS, from Future Optics) using an image capturing Software from Future WinJoe1.6 (Future Optics). The design app Procreate® from Savage Interactive Pty Ltd was used to appoint the anatomical and histological structure in the produced content.

RESULTS

The platform was divided into topics that contain the identified images of the bovine neuroanatomy structures, including microscopic slides images (Fig. 1A) and procedures of plastination technique (Fig. 1B), for example. PDF documents with written theory explanations, and video classes from anatomists were also included. The platform has an initial page (Fig. 1C), and the division was made accordingly to the following sequence:

1. Development, division, and organization of the Bovine Nervous System
2. Neurocranium and cranial nerves
3. Spinal cord, spinal nerves, and meninges
4. Brain cavities and vascularization
5. Brain structures and division
6. Autonomic Nervous System
7. Nerve Pathways
8. Brain Sections Atlas
9. Anatomy-clinic correlations
10. Bovine Brain Plastination

As example, some included images show bovine fetus (Fig. 2A), Cranial nerves (Fig. 2B), such as the olfactory, optic, trochlear, trigeminal, abducent, facial, vestibulocochlear, glossopharyngeal, vagus, accessory, and

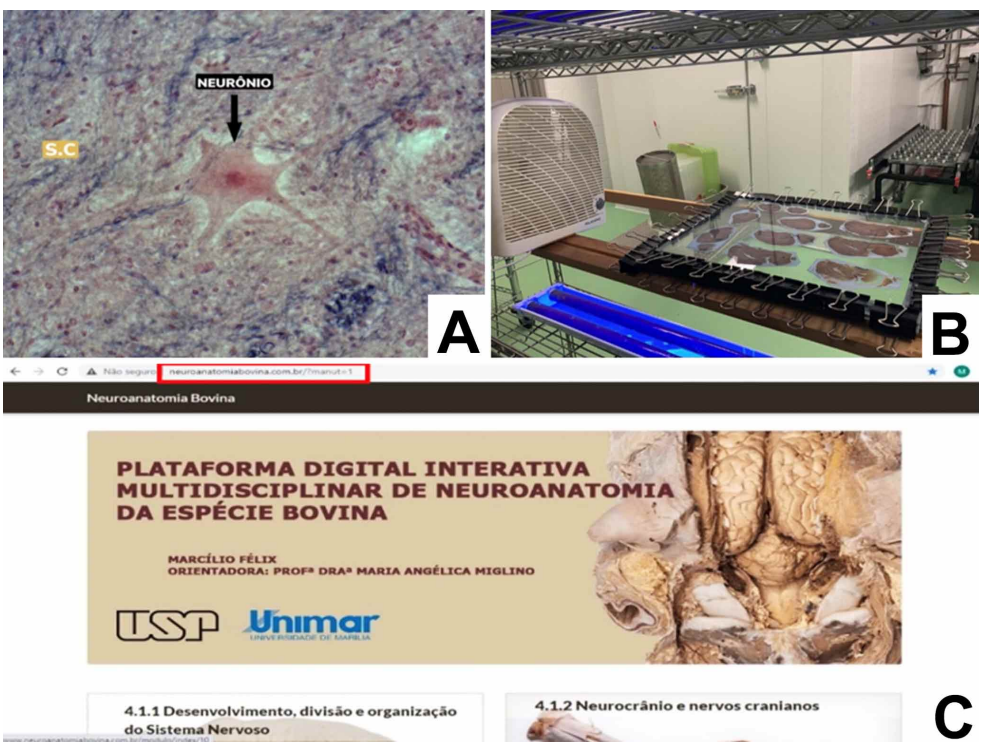

Fig. 1. A: Slide sample of Spinal Cord - Transversal cut of the gray substance, showing neuron (black arrow). 400X Increase. B: Plastination technique: Bovine brain slides under UV light for polyester stiffening. Source: Baptista, 2020. C: Print Screen of the front page of the website, in a partnership between the University of São Paulo and the University of Marília.

the hypoglossal Nerve. Segments of bovine spinal were also included (Fig. 2C).

Bovine brain samples with cavities (Figs. 3A and B), as well as the illustration of topography of the ascending somatic pathways (Fig. 3C), and topography of the thoracic and pelvic limbs innervation (Fig. 3D), were clearly represented by the platform content. Bovine brains slide (Fig. 4A), bovine diencephalon specimen picture (Fig. 4B), as well as bovine brain plastinated with polyester P40 (Fig. 4C). Additionally, the platform contains several other pictures illustrating and facilitating the bovine neuroanatomy understanding.

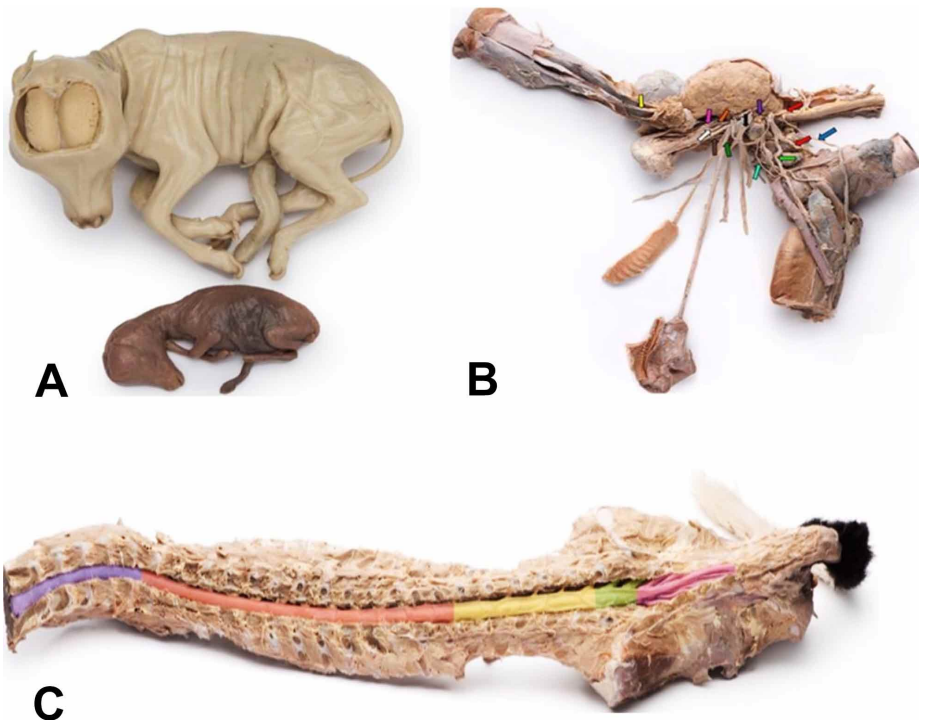

Fig. 2. A: bovine fetus with exposed smooth brain. A: Cranial Nerves Sample - Olfactory Nerve (yellow arrow); Optic Nerve (pink arrow); Oculomotor Nerve (white arrow); Trochlear Nerve (orange arrow); Trigeminal Nerve (black arrow); Abducent Nerve (brown arrow); Facial Nerve (dark green arrow); Vestibulocochlear Nerve (purple arrow); Glossopharyngeal Nerve (light blue arrow); Vagus Nerve (light green arrow); Accessory Nerve (red arrow); Hypoglossal Nerve (dark blue arrow). C: "In situ" bovine spinal cord. Dorsal view. Cervical Segment (purple); Thoracic Segment (red); Low Back Segment (yellow); Sacrum Segment (green) and Flow Segment with the Equine Tail (pink)

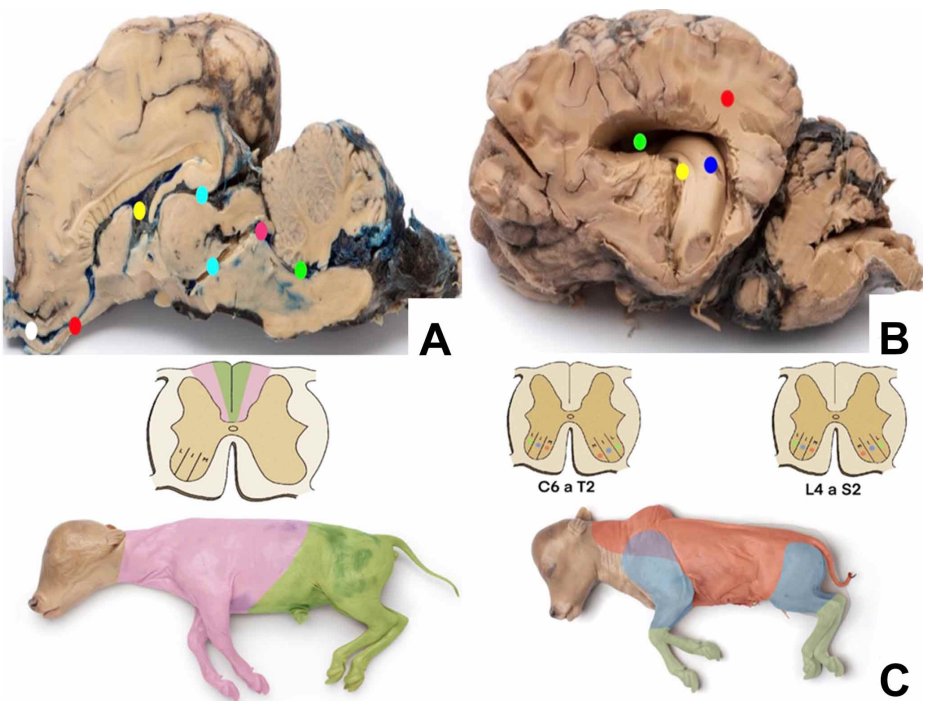

Fig. 3. A: Bovine Brain sample with cavities. Sagittal View. Left Ventricle (yellow); Communication site between the LV and Olfactory cavity (red); olfactory cavity (white); Third Ventricle (blue); Cerebral Aqueduct (pink) and Forth Ventricle (green). B: Bovine brain. Lateral view. Left Ventricle (green); Brain Cortex (red); Hippocampus (blue) and fimbria (yellow). C: Topography picture of the ascending somatic pathways; ascending somatic receptors of the cuneiform fascicle (pink) and ascending somatic receptors of the graceful fascicle (green). D: Topography picture of the thoracic and pelvic limbs innervation with the presence of the lower motor neurons of the ventral segment of the spinal cord; medium segment of the spine (red); intermediate portion of the spine and spinal cord (blue); lateral portion of the spine and spinal cord (green)

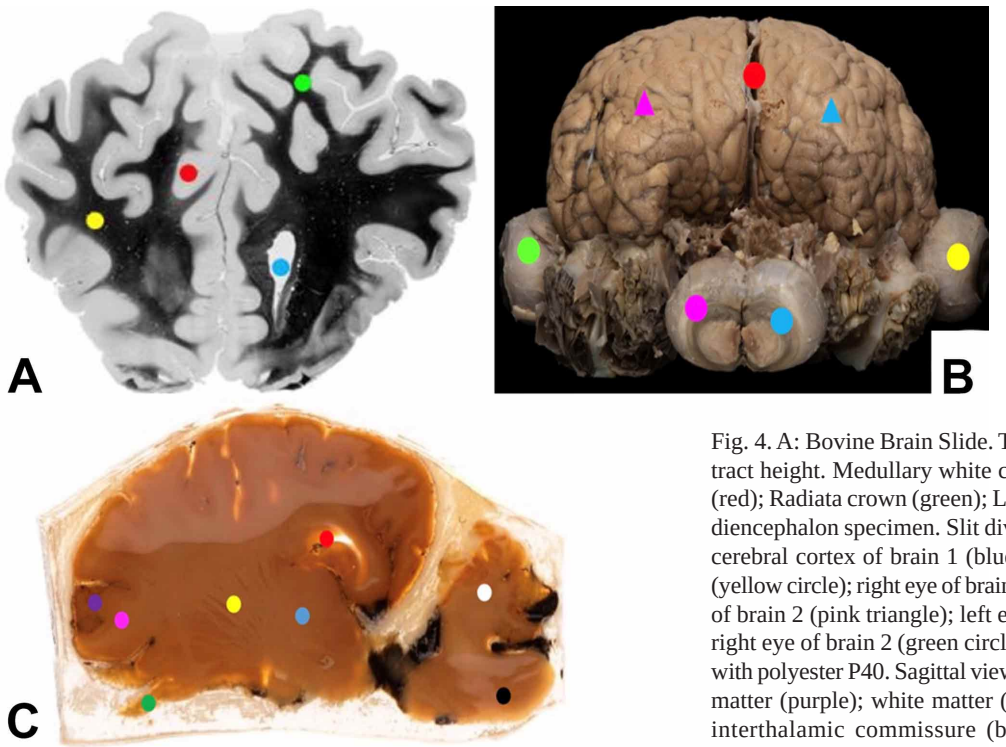

Fig. 4. A: Bovine Brain Slide. Transversal cut at the olfactory tract height. Medullary white centrum (yellow); brain cortex (red); Radiata crown (green); Left Ventricle (blue). B: Bovine diencephalon specimen. Slit dividing both brains (red circle); cerebral cortex of brain 1 (blue triangle); left eye of brain 1 (yellow circle); right eye of brain 1 (blue circle); cerebral cortex of brain 2 (pink triangle); left eye of brain 2 (pink circle) and right eye of brain 2 (green circle). C: Bovine Brain platinated with polyester P40. Sagittal view. Intern capsule (yellow); grey matter (purple); white matter (pink); olfactory bulb (green); interthalamic commissure (blue); lateral ventricle (red); cerebellum (white); bulb (black); forth ventricle (blue).

The full content is available at http://www.neuroanatomiabovina.com.br/login, being accessible after a subscription with the video classes available in the YouTube platform in the channel "Neuroanatomia Bovina"(https://www.youtube.com/channel/UCPNipRfQMAv1Dy1bYjcWEyg).

DISCUSSION

Digital platforms that use the blended learning methodology have been developed, for example the "Digital Atlas of the dog brain" (https://cfn.upenn.edu/aguirre/wiki/public:data_plosone_2012_datta); "Dog neuroanatomy courseware" (http://vanat.cvm.umn.edu/WebSitesNeuro.html); "Horse Limb Anatomy" (http://apps.cvm.iastate.edu/limbanatomy/horse.html); "Bovine Limb Anatomy" (http://apps.cvm.iastate.edu/limbanatomy/bovine.html), and others. B-learning is an important tool for students; however, it has not been largely applied in Veterinary Medicine (Jaffar, 2012; Barry *et al*., 2016; Green *et al*., 2018). Our platform could serve as a guide for those who wish to teach using the b-learning method, especially in the face pandemic scenario, such as the one produced by COVID-19.

The innovative potential of this product only increases when considering the reliable and multidisciplinary presented program. Its interactive character enables an autonomous study where the student takes an active role, different from what commonly happens in the superior education courses. Another highlight is the lack of a time limit like those imposed by the current curriculum, that reduces the workload of the anatomy discipline (Drake *et al*., 2009; Craig *et al*., 2010; Cho & Hwang, 2013; Topping, 2014; Halliday *et al*., 2015). Furthermore, the platform fits the current student's profile and enhances anatomy comprehension, having the potential for changing the current method of neuroanatomy teaching and study while adapting the discipline for the XXI century scenario.

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ETHICS APPROVAL. This study was approved by the Comissão de Ética no Uso de Animais da Faculdade de Medicina Veterinária e Zootecnia da Universidade de São Paulo (protocol number 9411060918).

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RESUMEN: El estudio de la anatomía forma parte del ciclo básico de disciplinas que componen el currículo de la facultad de Medicina Veterinaria, y su comprensión es fundamental para el entendimiento de las materias de otros cursos. Sin embargo, el perfil del estudiante actual, la reducción de los tiempos de los programas de educación superior y el enfoque multidisciplinario actual han hecho que el método de enseñanza de la anatomía sea obsoleto e ineficaz. Abordando el problema desarrollamos una plataforma interactiva y multidisciplinar basada en la metodología blended learning, que podría servir como una valiosa herramienta para la comprensión de la neuroanatomía bovina. Para producir una nueva herramienta de estudio, se utilizaron fotografías de especímenes bovinos fijados en formaldehído, piezas de cerebro plastinadas y seccionadas en un orden metamérico, así como láminas histológicas del sistema nervioso central bovino. Estos materiales se utilizaron en la producción de fotos y esquemas, que se correlacionaron con exámenes de imágenes, así como contenido escrito y clases grabadas en video. El contenido obtenido se compiló en una plataforma digital, que puede servir como un método adicional y eficaz para el estudio del sistema nervioso central bovino. Además, nuestros resultados sirven como guía para el desarrollo de otras metodologías de aprendizaje semipresencial en la enseñanza de la medicina veterinaria y la anatomía. La plataforma proporciona una gran herramienta para aquellos que deseen lograr una mejor comprensión de la neuroanatomía bovina y sus correlaciones clínicas, quirúrgicas y de diagnóstico por imágenes.

PALABRAS CLAVE: Educación universitaria; Plataforma de estudio; Aprendizaje combinado; Neuroanatomía bovina; Disección.

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