Perceptions of Selected Undergraduate Medical Students in the Philippines on the Effectiveness of the Combined Use of Plastinated and Formalin-preserved Brains in Neuroanatomy Education: A Cross-sectional Study

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ABSTRACT

Background and Objective. Neuroanatomy is both terrifying to learn and problematic to teach, and the different methods of neuroanatomical education have their own strengths and weaknesses. In this cross-sectional study, we evaluated the perception of undergraduate medical students towards the combined use of plastinated and formalin-preserved brain specimen in their neuroanatomy course.

Methods. A bridging program was designed for students whose medical education was interrupted by the COVID-19 pandemic in order to reinforce the knowledge and understanding of anatomy that they acquired in a virtual environment. A total of 175 first year medical students participated in this learning activity, which included seven stations in neuroanatomy spread across two hours, and covered the anatomy of the circle of Willis, brainstem, cranial nerves, spinal cord, internal cerebrum, and external cerebrum. To evaluate short-term learning, the students were asked to take a quiz containing 10 multiple-choice questions before and after the learning activity. In addition, the students also answered a survey containing 11 Likert-type questions asking about their perception of the learningactivity.

Results. Following the learning activity, mean test scores increased from 4.73 (SD 1.74) to 5.32 (SD 1.52; mean difference 0.59, p = 0.008). Majority of the students (mean 81%, range 43-93%) had a neutral or positive perception of plastinated brain specimen, and on factor analysis, plastinated brain specimen were found to be both practical and useful for learning neuroanatomy. However, the participants perceived plastinated brain specimen alone to be insufficient for learning neuroanatomy, and a multimodal approach to learning neuroanatomy is ideal.

Conclusion. Plastinated brain specimens were found to be an effective complement to formalin-preserved brain, and these should be used by medical schools when designing neuroanatomy learning activities for their students.

Keywords: neuroanatomy, plastination, cadaver dissection, brain models

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INTRODUCTION

The study of neuroanatomy can be traced back to 1600 BC, where the Edwin Smith Papyrus gives the first description of the brain, meninges, and vertebrae.[1] However, the first public human dissection for medical education was not done until the third century BC, when it was pioneered by Herophilus (for whom the confluence of sinuses is named) and his disciple Erasistrasus.[2] Preserved cadaver dissection remains the "gold standard" for teaching neuroanatomy to this day,[3-5] but several new methods for teaching neuroanatomy have been developed, including plastination, 3D computer models, 3D-printed physical models, augmented reality models, and virtual reality models.[6-12]

The different methods of neuroanatomical education have distinct advantages and disadvantages. Augmented and virtual reality models have been shown to be more engaging for medical students and equally effective for knowledge retention,[11,12] but they require proprietary software or expensive equipment that would make the cost of providing them simultaneously to multiple medical students prohibitive. Cadaveric specimen have the advantage of providing tactile feedback and showing anatomic variability and sometimes brain pathology, but at the expense of an offensive odor, paucity, and being limited to use in the dissection laboratory.[13] In plastination, water and lipids are removed and replaced with silicone and polyester resins to create dry, durable, odorless specimens.[14] Silicone-plastinated whole brains can be used to teach the anatomy of the brain surface, while stained, polyester-plastinated brain sections have excellent color differentiation between gray and white matter and can be used to highlight sectional anatomy, and can be compared with computerized tomography (CT) and magnetic resonance imaging (MRI) images for integrated teaching.[7] Finally, physical 3D models are available as commercial models or can be 3D-printed from CT or MRI images, and are also effective in teaching neuroanatomy.[15,16]

In low- and middle-income countries such as the Philippines, almost all medical schools still use traditional methods of teaching neuroanatomy such as cadaver dissection or prosection and 2D atlases. The Department of Anatomy of the University of the Philippines College of Medicine has recently acquired plastinated brain specimens (PBS) as part of its Learning Enhancement in Anatomy Program (LEAP). This program was designed as a bridging program for students whose medical education was interrupted by the COVID-19 pandemic in order to reinforce the knowledge and understanding of anatomy that they acquired in a virtual environment. We sought to determine the usefulness of PBS on the neuroanatomic learning and attitudes of Filipino medical students. This will allow us to create courses that are approachable, engaging, effective, and memorable so that students retain neuroanatomic knowledge in their careers and are not dissuaded from pursuing neurologic specialties.

OBJECTIVES

General Objective

To determine the effectiveness of combining PBS and FPB in teaching neuroanatomy

Specific Objectives

1. To determine the neuroanatomic knowledge of medical students before and after an instructional module combining PBS and FPB
2. To determine the attitudes and perceptions of medical students towards learning neuroanatomy before and after using plastinated brain specimens, cadaver dissection, and commercially available brain models

METHODS

This is a descriptive cross-sectional study that was conducted at the University of the Philippines College of Medicine (UPCM) in Manila, Philippines during the academic year 2021-2022, as part of the Department of Anatomy's Learning Enhancement in Anatomy Program (LEAP). The LEAP was a curriculum designed to reinforce the knowledge and understanding of gross and correlative anatomy and histology of first year medical students, and included courses on the following: integration and control systems (including neuroanatomy), musculoskeletal anatomy, head and neck anatomy, thorax anatomy, histology, gastrointestinal anatomy, and ontogeny and parturition. Only first-year medical students were included. Medical students who were repeating their anatomy course were excluded. Written consent was obtained from the participants, and demographic data including age, sex, pre-medical course, and perceptions regarding the LEAP neuroanatomy learning activity were collected.

The PBS were acquired from Hong Kong Blue Bay Company (Hong Kong, China). Photographs of the PBS used in this study are shown in Figure 1. Meanwhile, the FPB were whole and cut brain specimen that had been prosected by the instructors beforehand. Prior to this learning activity, the students had completed organ system module for neuroanatomy with summative assessment at the end of the module via written multiple choice examination as part of their medical curriculum. All students took a 10-item move-type pre-test to measure their baseline neuroanatomy knowledge, which included multiple choice questions where students were asked to identify pinned structures on the brain specimen, and were also asked follow-up questions on the highlighted structures. The topics covered include the anatomy of the circle of Willis, brainstem, cranial nerves, spinal cord, internal cerebrum, and external cerebrum. This was followed by an instructional course during which the students were divided into groups of 6-8 students each and rotated through six different stations, spending 40 minutes at each station. Each station had a short clinical vignette, one FPB

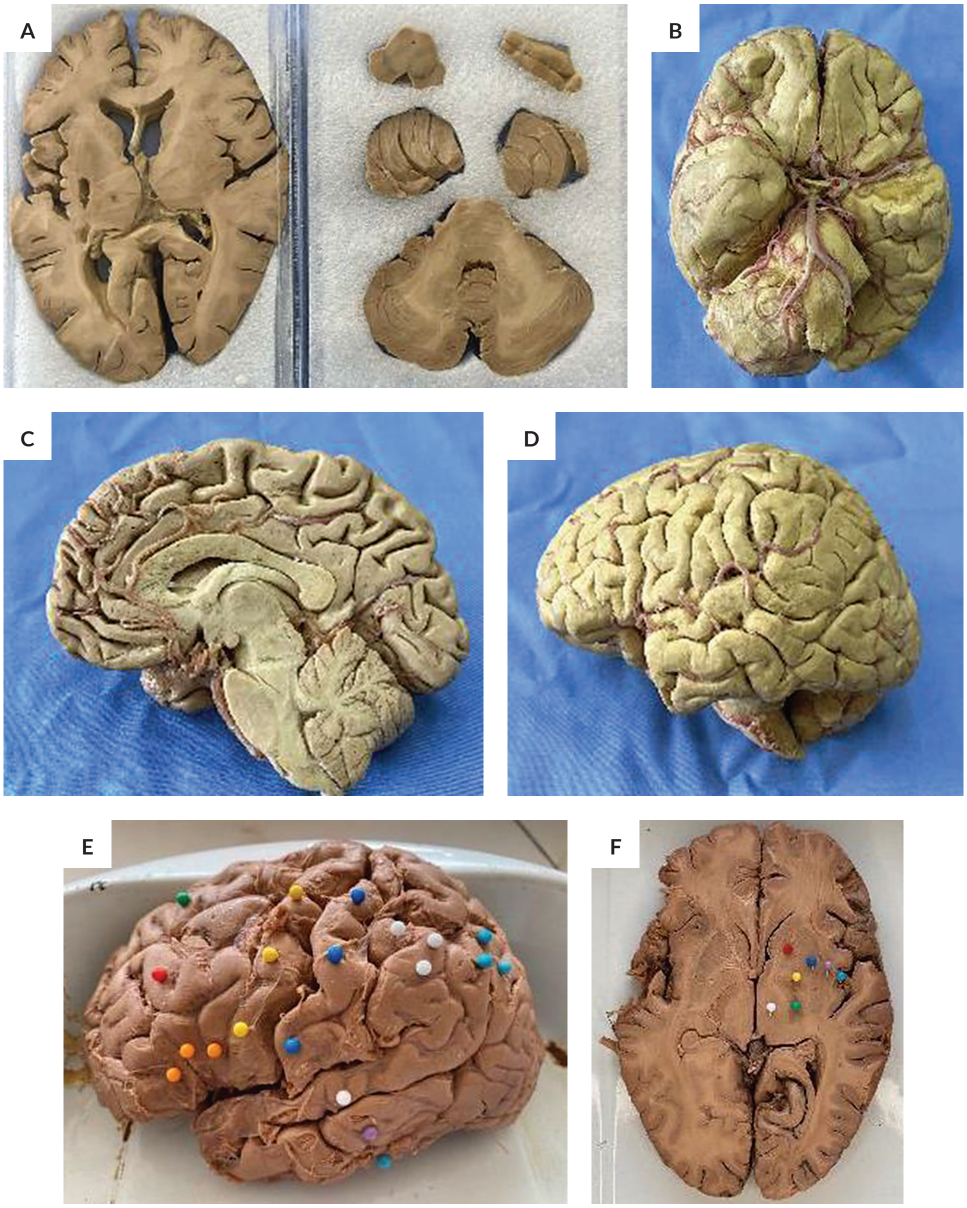

Figure 1. Representative photographs of the plastinated brain specimen used in teaching neuroanatomy. **(A)** cross-sectional specimen at the level of the third ventricle and the fourth ventricle; **(B)** inferior brain surface; **(C)** lateral brain surface; **(D)** medial brain surface; **(E–F)** lateral brain surface and cross-sectional specimen at the level of the third ventricle with colored pins to highlight important structures.

and one PBS, both with labels for the relevant neuroanatomy, and a text description of the highlighted structures. Each station also had guide questions to encourage the students to actively identify important structures and understand their relationship with each other. Instructors were also moving between stations to assist the participants and answer any questions. Afterwards, the students took a separate 10-item move-type post-test to measure the effectiveness of the teaching method. They also filled out an 11-item Likert-type questionnaire that was developed by the authors to provide information on their perception regarding PBS as an anatomic learning resource. In this original questionnaire, students were asked to evaluate statements regarding PBS on a 5-point scale from strongly disagree to strongly agree. Pre- and post-test scores were compared using a two-tailed t-test. Bartlett's test of sphericity was used to determine whether any meaningful factorization can be obtained from the students' answers to the questionnaire on their perceptions of the activity, and, if present, factor analysis was used to determine the dimensions that dictated the students' appreciation (or lack thereof) of the PBS based on the commonalities of their responses. Selection, non-response, and volunteer bias were minimized by including all the eligible participants instead of just a sample. Anonymity of responses was used to minimize ascertainment bias. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cross-sectional studies was used in making this report.

Ethical Considerations

This study was approved by the University of the Philippines Manila Research Ethics Board.

RESULTS

A total of 175 medical students were eligible to participate in the study; all 175 were able to take the pre-test, but five students developed respiratory symptoms and only 170 were able to take the post-test. The students had a mean age of 23 (range: 19 to 33), and 50%, 49.3% and 0.7% were male, female, and non-binary, respectively. The most common pre-medical courses were BS Biology and the Integrated Liberal Arts - Medicine (INTARMED), followed by BS Public Health and BS Psychology.

Pre-test and Post-test Quiz Scores

There was a significantly higher mean post-test score (5.32, SD 1.74) compared to mean pre-test score (4.73, SD 1.52) (total items = 10), with a mean difference of 0.59 (p=0.008).

Perceptions on Neuroanatomy Learning Activity

Majority of the students (mean 81%, range 43-93%) had a neutral or positive perception of plastinated brain specimen, with the highest proportion of students agreeing with the statements that plastinated brain specimen is helpful for learning neuroanatomy (93%) and is useful in the differentiation of structures (92%). Conversely, only 43% of the students agreed with the statement that PBS alone are sufficient to learn neuroanatomy even without FPB (Figure 2).

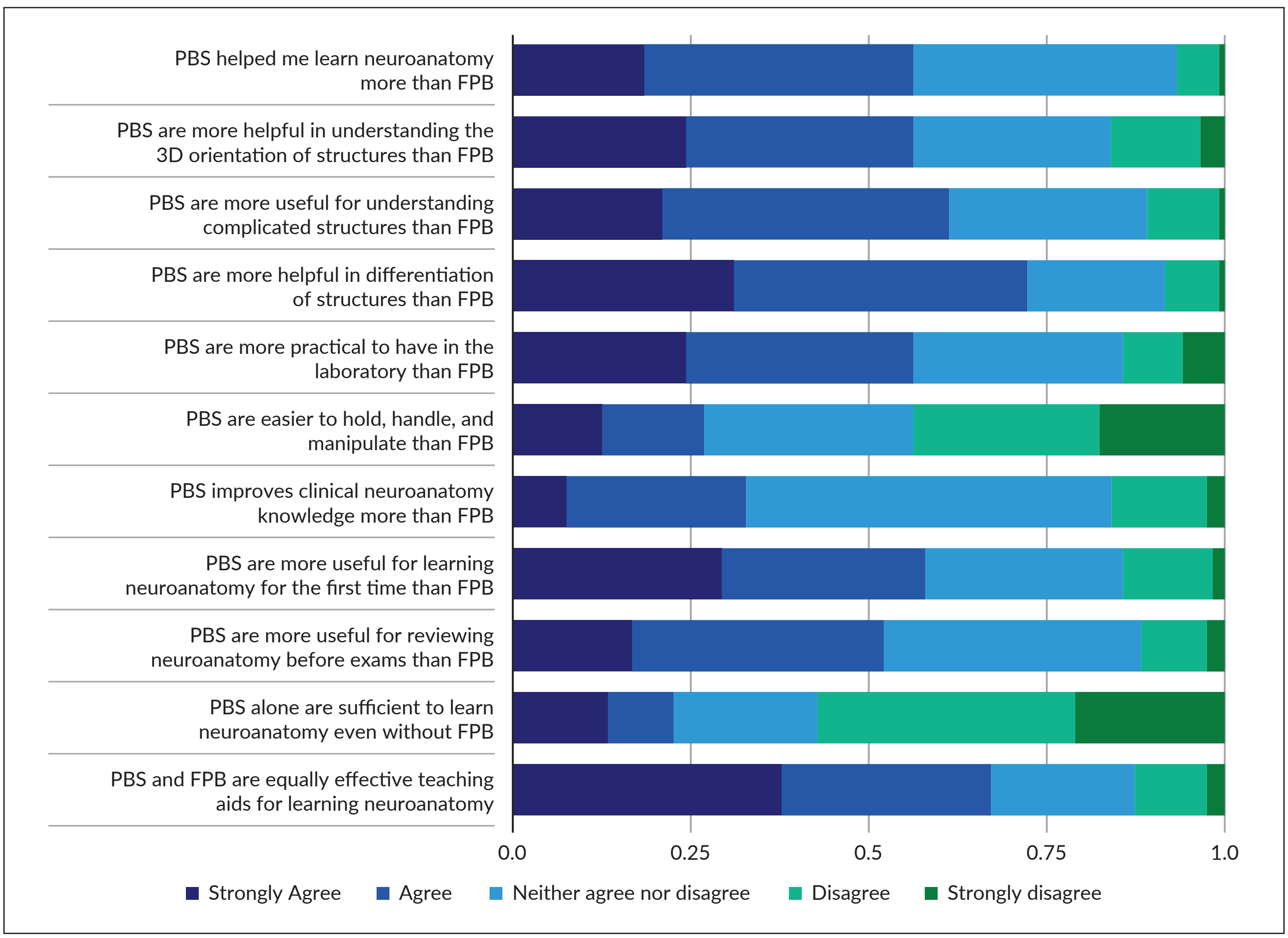

Figure 2. Likert questionnaire used and relative proportions of the responses (n=119).

PBS – plastinated brain specimen; FPB – formalin-preserved brain

Table 1. Factor Loadings of Individual Items to Two Constructed Factors (Factor 1 and Factor 2) Using a Varimax Rotation

	Factor 1: Practicality	Factor 2: Learning benefit
The use of plastinated specimen helped me learn neuroanatomy more than formalin-preserved brains	0.54	0.47
The use of plastinated specimen is more helpful in understanding the 3D orientation of structures than formalin-preserved brains	0.36	0.44
Plastinated specimens are more useful for understanding complicated structures than formalin-preserved brains	0.27	0.77
Plastinated specimens are more helpful in differentiation of structures than formalin-preserved brains	0.21	0.69
Plastinated specimens are more practical to have in the laboratory than formalin-preserved brains	0.66	0.20
Plastinated specimens are easier to hold, handle, and manipulate than formalin-preserved brains	0.43	0.24
Plastinated specimens improve clinical neuroanatomy knowledge more than formalin-preserved brains	0.53	0.47
Plastinated specimens are more useful for learning neuroanatomy for the first time than formalin-preserved brains	0.20	0.51
Plastinated specimens are more useful for reviewing neuroanatomy before exams than formalin-preserved brains	0.58	0.25
Plastinated specimens alone are sufficient to learn neuroanatomy even without formalin-preserved brains	0.71	0.20
Plastinated specimens and formalin-preserved brains are equally effective teaching aids for learning neuroanatomy	0.37	0.18

Factor Analysis of Perceptions Questionnaire

Factor analysis was used to determine if there were any over-arching themes that emerged from the questionnaire. In order to proceed with the factor analysis, the overall Measure of Sampling Adequacy was measured and found to be 0.85, indicating adequate sampling for factor analysis,[17,18] and Bartlett's test for Sphericity yielded a Chi-square test statistic of 434.98 ($p < 0.001$), indicating correlation (the further the value is from zero, the higher the correlation).

Two themes emerged following factor analysis, which we named after the idea behind the statement: practicality and learning benefit (Table 1). The students found that PBS were more practical to have and easy to use than formalin-preserved brain samples, and by themselves were enough for learning neuroanatomy. The students also found that PBS allowed them to learn neuroanatomy more efficiently, and in ways that conventional formalin-preserved brain samples could not. In particular, students felt that PBS were more advantageous than FPB in understanding complicated structures, or for differentiating between structures in the brain.

DISCUSSION

In this paper, we described the attitude and perception of undergraduate medical students at the UP College of Medicine towards the combined use of plastinated and formalin-preserved brain specimens in their neuroanatomy course. Neuroanatomy has the reputation of being an intimidating and discouraging topic to learn, and a difficult and unenviable subject to teach. The integration of clinical neurology to basic neuroanatomy has lessened the incidence of neurophobia, which is defined as a fear of the neural sciences and clinical neurology that is due to the students' inability to apply their knowledge of basic sciences to clinical situations.[19] However, much debate still exists as to how neuroanatomy should be taught, and how teaching methods should change to best meet the needs of the modern medical student. Most curricula will have a mixture of hands-on dissection, problem-based learning, and computer-assisted learning.[20] Of the three, hands-on dissection demands the most time, labor, and materials.

The current study showed that using PBS together with FPB led to a statistically significant increase of 12% in participants' post-test scores compared to baseline. The study also found that first year medical students perceived PBS to be non-inferior to FPB, and found PBS to be practical as well as helpful for understanding and differentiating complicated neuroanatomy. This is similar to the findings of other studies about the use of plastinated specimen in anatomy education in general.[21-25] However, the participants also felt that PBS alone were inadequate for learning neuroanatomy, which was consistent with other studies where plastinated specimen in general were found to be rigid, inauthentic, unable to familiarize students with the reality of death, and insufficient for the practice of manual dexterity among students with surgical career intentions.[22] Similar to previous studies, our results also support the conclusion that students prefer a combination of both teaching methods.[25] Indeed, a multimodal approach to teaching anatomy would be most effective and engaging for the learners; such approaches may include lectures, atlases, dissection/prosection, 3D printing, augmented or virtual reality, plastination, social media, videos, and online resources.[26,27] Unfortunately, medical schools in low- and middle-income countries may find the price excessive. Acquiring, preparing, and storing fresh cadaveric heads and brains can cost up to 100,000 PhP (1800 USD) whereas plastinated brain specimen can cost up to 400,000 PhP (7200 USD) each. However, the higher initial cost of

PBS can be offset by its durability, allowing it to be used over multiple semesters, and lower storage and maintenance costs.

PBS are not only useful for the learners, but for the instructors as well. The authors appreciated how PBS allowed for teaching of neuroanatomy with the structures in situ, as opposed to their usual distorted appearance in FPB. For instance, PBS showed the dura in their anatomic position apposed to the skull, instead of freely floating in the space between the brain and the bone. The authors also observed that students were more engaged and asked more questions during the activity.

The limitations of this study include the lack of a control group, the absence of randomization, and the cross-sectional assessment of neuroanatomic knowledge and perceptions among medical students. Future studies can compare different combinations of teaching methods and include long-term follow-up of the participants to determine the durability of information gained. Further studies can also include more topics in neuroanatomy including the anatomy of the thalamus and cerebellum. Another outcome that can be measured is the effect of the manner of neuroanatomy education on the proportion of medical students eventually going into a neurological specialty. The results of this study can be generalized to other low- and middle-income countries where expensive adjuncts to neuroanatomy education such as virtual and augmented reality are unavailable.

CONCLUSION

Medical students found the use of plastinated brain specimen to be an effective complement to formalin-preserved brains in the teaching of neuroanatomy; in particular, they were found to help in the mastery of complex structures while remaining practical to use. Medical schools should consider integrating the use of plastinated brain specimens to their neuroanatomy learning activities.

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Statement of Authorship

All authors certified fulfillment of ICMJE authorship criteria.

Author Disclosure

All authors declared no conflicts of interest.

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