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Neuroanatomy Teaching in Australian and New Zealand Medical Schools

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TITLE: Neuroanatomy Teaching in Australian and New Zealand Medical Schools

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INTRODUCTION

Studies conducted in the early-to-mid 2000s brought attention to reduced anatomy knowledge of medical graduates in the context of integrated, problem-based curricular changes; particularly in central and peripheral nervous system anatomy.¹⁻³ Practically, lower levels of neuroanatomy knowledge are associated with poor confidence of junior doctors in managing neurological conditions^{4,5} and unsafe medical practice.¹

In efforts to improve knowledge acquisition and long-term knowledge retention, research has been conducted into developing innovative (largely digital) teaching strategies and techniques.^{6,7} Multimedia resources and 3-Dimensional (3D) digital representations of neuroanatomy are becoming commonplace.⁷ Virtual (VR) and augmented (AR) reality are amongst newer technologies now available for teaching.^{8,9} Anatomage Tables[®] (Anatomage, San Francisco) are virtual dissection, 3D anatomy visualization systems that have been introduced into medical schools.¹⁰ Sectra Tables[®] (Mentone Educational Center, Australia) are based on a similar design, with ergonomic touch screen displays allowing access to a specialist educational portal. No national curriculum for use of these tools exists, despite there being a core neuroanatomy curriculum published by Moxham et al. (2015).

Neuroanatomy teaching of medical students must be optimised in the context of integrated curricular changes and reduced time dedicated to teaching anatomy. The challenge in learning neuroanatomy goes beyond neuroanatomical knowledge acquisition; a major effect being the negative influence on the choice of neurosurgery or neurology as a career path in medicine.^{11,12} Because instruction of this important basic science is left up to the discretion of individual institutions, it is currently unknown how this is being done. The rationale for this study is to characterize neuroanatomy instruction to provide the basis for more informed discussion and future research into improving educational systems surrounding neuroanatomy. If researchers are aware of

the constraints within which neuroanatomy educators are working, developing technologies can be tailored to the needs of the end-user. Further, other educational institutions may be able to learn from the experiences of Australian and New Zealand medical schools. Internationalization of medical education through collaboration has been identified as an important part of medical education.¹³ To do so, this study aimed to describe the content, instruction and assessment of neuroanatomy in Australia and New Zealand medical schools.

MATERIALS AND METHODS

This descriptive, mixed methods study was approved by the Human Research Ethics Committee of The University of Western Australia (RA/4/20/5250) and endorsed by the Royal Australasian College of Surgeons. An electronically mailed survey containing 22 questions about course structure, neuroanatomy teaching, assessment and course development was sent to a key academic from the 22 Australian and two New Zealand medical schools (Supplementary Material Appendix A). The survey consisted of a combination of questions requiring binary (yes/no) responses (n=7), single-selection multiple choice (n=3), multiple-selection multiple choice (n=6), short-text responses (n=3), open-ended responses (n=2) and a response on a ten-point Likert scale (n=1). Respondents were asked to provide information regarding the 2019 academic year.

The SPICES model summarizes the six educational strategies relevant to the curriculum in a medical school. Each issue can be represented as a spectrum or continuum: student-centred/teacher-centred, problem-based/information-gathering, integrated/discipline-based, community-based/hospital-based, elective/uniform and systematic/apprenticeship-based.¹⁴ To better characterise whether neuroanatomy teaching in medical schools is related to the educational strategy employed by the institution, participants were asked to characterize where their university sits for each issue by using a sliding 1-10 scale.

Analysis

Survey data was collected using Qualtrics (Provo, Utah, USA). Frequency statistical analysis was required for binary, single- and multiple-selection and short-text responses and was conducted in Microsoft Excel (Version 16.39, 2020). No means testing between universities was necessary. An inductive approach to thematic analysis based on the phases described by Braun and Clarke (2013) was undertaken in this study to explore the open-ended survey responses' emerging themes.¹⁵ Quantitative data was reviewed by all authors. Patterns of responses were observed and recurring comments became 'codes'. Themes were produced after codes were diagrammed to visualise various relationships. These themes were then triangulated between authors and finalised by consensus

RESULTS

QUANTITATIVE FINDINGS

We received a total of 22/24 (91.7%) responses from medical schools across Australia (n=20) and New Zealand (n=2) shown in Table 1. There were 21 medical schools that submitted a single response, while one medical school, requiring information from two colleagues, submitted two surveys with responses compiled by the first author.

Course Structure

Ten universities (45.4%) had post-graduate (PG) medical schools. Six universities (27.3%) had undergraduate courses (UG) and six universities (27.3%) had combined UG and PG courses. Eleven universities (50%) had four-year courses, five universities had five-year courses (22.7%), and five universities had six-year courses (22.7%), shown in Table 2. One university with combined PG and UG entry had both a four- and five-year course respectively. This university was classified as a four-year course in this study based on the greater proportion of students enrolled. Eleven universities

had problem-based courses (54.5%), seven courses had integrated curricula (31.8%), three universities had systems-based courses (13.6%). Mean values $\pm$ SD for the SPICES model continuums are illustrated in Figure 1, which provide a cross-sectional snapshot of educational strategies employed by Australian and New Zealand medical schools. Analysis using the SPICES model reflects that half of the Australian medical schools are using student-centred learning, integrated and core or standard approaches to including neuroanatomy in the curriculum. Less than half are applying problem-based approaches, and most are teaching neuroanatomy in a hospital-based environment.

Teaching Methods

Cadaveric anatomy laboratories and lectures were utilised by 100% of respondent universities. Neuroanatomy-specific cadaveric labs were offered to first- and/or second-year medical students in 86% of universities, and in third-year or later in 32%. Plastic anatomical model or plastinate laboratories ('dry labs') were offered to first- and/or second-years in 55% of universities, and third-year or more in 27%. Lectures were offered to first- and/or second-years in 82% of universities, and third-year or later in 45%. The types of resources used in these labs and how frequently are indicated in Table 3. Sixteen universities (73%) responded saying they used technology to enhance laboratories including use of virtual and augmented reality (25%), Sectra Table[®] (13%), Anatomage Table[®] (8%), 3D prints and tablet software applications such as Visible Body[®] (4%). Specific applications were not specified by other respondents. Frequency of use of particular tools is summarized in Table 4.

Dissection was offered in 14 respondent universities (64%); as an elective course (n=6), prescribed course (n=6) or not specified (n=2). Courses varied in how this was delivered as either teacher-directed dissection (n=4), text-directed (n=5) or not specified (n=5). Specific dissection topics of four courses were peripheral nervous system dissection (n=1), animal dissection in comparative

neuroanatomy (n=1), lateral to medial dissections of brainstem (n=1) and cranial nerves dissection (n=1).

Twelve universities (55%) indicated that they adapted the teaching methodology to suit neuroanatomical content. Incorporating clinical images (n=4), emphasising 3D relationships (n=3), drawing (n=2), adapting combinations of wet and dry labs (n=1), emphasising theoretical models (n=1), interactive displays (n=1) and e-cases (n=1) were methods of adaption specified by respondent academics.

Neuroanatomy teaching time

The mean time dedicated to teaching neuroanatomy was 46.0h (± 38.1). Most (n=19) medical schools scaffold the teaching of their neuroanatomy over the duration of the course by teaching neuroanatomy in more than one year. Nineteen universities taught neuroanatomy in first year, seventeen in second year, eight in third year, three in fourth year and three in fifth year. The time ($\pm$ SD) dedicated to neuroanatomy teaching by course length is illustrated in Table 2. Six-year courses had the highest number of teaching hours dedicated to neuroanatomy (89.4h) followed by four-year courses (33.3h) and five-year courses (30h). Twenty medical schools taught less than 65 hours of neuroanatomy, and two universities taught 145 hours or more. Universities utilising a systems-based approach had the highest number of hours dedicated to teaching neuroanatomy at 63h on average (± 71), followed by problems-based courses ($36\text{h} \pm 13$) and integrated curricular ($29\text{h} \pm 7$).

In terms of the time of different teaching methods, cadaveric labs were on average 117 minutes, dry labs 107 minutes and lectures 72 minutes. The number of hours involved in cadaveric dissection was not specified.

Curriculum

Seven universities indicated they were using a set curriculum to guide neuroanatomical content delivered to their medical students, three of which were university-specific and four did not specify which curriculum had been set. Twenty universities (91%) indicated neuroanatomy teaching had changed significantly in the last five years, with content refined/condensed (n=6), greater use of imaging (n=5), more practical assessment (n=2), online content (n=2) and reduced time available (n=2) examples identified by academics. Seventeen universities (77%) indicated they evaluated their teaching, mostly through student evaluation surveys and evaluation of assessment results.

Seventeen universities (77%) integrated neuroanatomy teaching with other subjects, predominantly within clinical skills teaching sessions (n=9) and case-based learning curriculums (n=5). Others (n=2) indicated they transition from foundations of embryology, gross anatomy and histology for junior years to application in clinical scenarios, testing and imaging for more senior medical students.

Assessment

Twenty-one universities (95%) used some form of summative assessment to assess levels of neuroanatomy knowledge. Formative assessment of neuroanatomy was utilised by 19 universities (86%). Types of assessment include multiple choice questions (91%), short answer questions (64%), practical SAQ (55%), extended-matching questions (41%), practical MCQ (41%) and practical oral (18%).

QUALITATIVE FINDINGS

A thematic analysis of the open-ended responses from the respondents concerning overall students' engagement revealed three central themes: motivation for learning, anxiety about neuroanatomy and applied techniques for improved engagement. These themes and relevant codes are illustrated in Figure 2 and summarised with textual citations from survey responses in Table 5.

Motivation for Learning

There was a range of responses identifying the perceived level of motivation for learning neuroanatomy and the relative impact on engagement, as well as specific internal or external factors motivating learning. Assessment was a key motivating factor identified by respondents, others identified that student motivation was influenced by the student-teacher interactions and clinical focus of the course. Career aspirations of students in areas such as neurology or neurosurgery were also seen as motivating factors.

Anxiety about neuroanatomy

Anxiety about neuroanatomy was a key factor related to engagement of students identified by academics, citing subject difficulty as a major precipitating factor. Other factors that have contributed according to academics has been reduced teaching time, and increased volume of content required to teach. These experiences amongst educators have been a motivating factor to try alternative strategies to reduce anxiety and increase engagement.

Driving for improved engagement

Academics discussed techniques used to increase engagement either directly, or by increasing motivation or reducing anxiety. Scaffolding learning by introducing the content in the first year; then revisiting material and expecting students to apply knowledge into clinical examples in subsequent years was identified as a method to reduce anxiety. Respondents wrote about enhancing the clinical relevance to improve engagement. Using interactive teaching techniques such as online quizzes/continuous assessment so that students could monitor their own progress was identified as a strategy to improve engagement with the content. However, not all respondent academics agreed that technology definitively increased engagement. The quality of the demonstrators' or teachers' teaching was also identified as a key area for improving engagement and reducing anxiety.

DISCUSSION

This is the first review of neuroanatomy education in Australian and New Zealand Medical Schools. An overall impression of these results is the demonstration of heterogeneity between medical schools in the content, delivery, assessment and development of neuroanatomy teaching, with variable uptake of evidence-based methods. It is reflective of the current climate in which teaching of basic sciences, without an established curriculum guiding content or delivery, is left to the discretion of the academic. Since the 1990s, the curricular paradigm in the basic sciences teaching for medical students has undergone significant change. The shift towards integrated, interdisciplinary curricula is evident in the results of this study and is reflected in the variable methodology employed by academics to teach neuroanatomy.

Neuroanatomy teaching hours for medical students are highly variable between institutions, ranging from 12h to 160h. The mean time dedicated to neuroanatomy teaching in Australia and New Zealand is 42.5% less than that of US institutions' mean time of 80h.^{16,17} A high degree of variability was reported by McBride and Drake in this population also, as institutions reported a range of 4h to 200h. Based on the significant variability in these hours, there may be insufficient quantity of neuroanatomy education in some institutions. However, the authors recognize the difficulty in quantifying an ideal amount of neuroanatomy teaching for a medical degree. The analysis of hours by SPICES model responses also confirms the historical trend of decreasing hours in the context of integrated, problem-based curricular changes. That is, universities that utilise a predominantly problem-based model had the least neuroanatomy-specific teaching compared to systems-based approaches.

Learning strategies based on superficial learning are likely to increase neurophobia and reduce student performance in neuroanatomy.⁹ There are educational and assessment methods that

promote superficial learning and rote learning such as use of MCQs and didactic lectures present in every respondent university medical school, sometimes exclusively. This is an understandable finding, as universities must balance cost, time limitations, curriculum pressures, staffing and other factors while also trying to optimize teaching strategies.¹⁰ However, it is also sub-optimal; as universities should be encouraging deep learning approaches that enhance interest in the subject area.¹⁸

This is not to say didactic methodologies cannot be used at all. Generations of successful health care professionals learned their anatomy by these techniques. However, as techniques in health care have advanced, so too must educational methodologies. The difficulty with a didactic model is as follows. First, the reduced number of lecture slots in medical schools dedicated to anatomy is insufficient to transfer important anatomical principles and concepts necessary for students to gain a full appreciation of form and function. As a result, students may “learn” anatomy by rote-learning rather than with a sound under-pinning of principles to understand anatomy.² Second, there is minimal time for students to handle anatomical specimens. In student-led environments, the experience they do get is often on the content they know best and are happiest with, encouraged to migrate there by the didactic, tutorial-based practicums.¹⁹ Finally, there is a low degree of flexibility in these approaches to tailor the learning experience towards students’ individual needs.

There is a growing number of randomized trials comparing pedagogical tools used in neuroanatomy teaching, although most papers on the topic lack sufficient sample size and quality of design to make concrete recommendations.^{7,9} Further, research is often scaled to a single-institution with an independent-curriculum. It often lacks the applicability necessary for educators to have complete faith that results would be reproducible in their cohorts.⁹

This is reflected in the heterogenous uptake of these new technologies amongst medical schools. Even for those papers that show a significant difference between teaching methods, the link to

current practise has not been made. For example, Allen et al. (2016) demonstrated students who accessed 3D online resources based on data from the Visible Human Project scored significantly higher than students using 2D resources.^{20,21} However, only 28% of universities had incorporated 3D software in most or every session while 2D images were used in over 59%. There are methods such as mobile augmented reality²² and use of clay-modelling²³ known to reduce cognitive load and increase performance that are only used rarely (14%) or not at all (50%). This paper does not aim to provide an exhaustive list of differences between evidence-based methods and current practise, or act as a guideline for use of certain methodologies. However, it does illustrate that either there is a paucity of quality research into neuroanatomy pedagogy, and/or that there is a problem in its translation into practise.

In terms of curriculum, most medical schools scaffolded the teaching of neuroanatomy over the duration of the course by teaching neuroanatomy in more than one year, termed 'vertical integration'. This is a valuable methodology, as it allows students to not only demonstrate they can recall information, but also apply it in a clinical setting. By reaching higher levels of Bloom's Taxonomy - a theoretical model frequently used to structure curriculum learning objectives - greater learning may be effected.²⁴ However, few universities employed an established curriculum to their neuroanatomy teaching, and of these, most utilised university-specific guides. The lack of a standardized, evidence-based curriculum increases the workload for teaching academics in deciding what content to cover and inhibits strategy- and resource-sharing between institutions.

A Delphi study of neurologists, neurosurgeons and academics would be useful to standardize neuroanatomy learning objectives medical students and junior doctors should know. This would be beneficial in two areas: First, while it may not guarantee learning outcomes are met, the pressure may be taken off academics to decide what to teach, and rather on to how to teach it. Second, further research will be conducted on similar populations. Research based on populations of

students learning from national curriculum, endorsed by governing bodies such as RACS or the AMC, may facilitate the translation of research into practise and allow for standardized assessment of graduate levels of knowledge of neuroanatomy.

The qualitative themes emerging from the surveyed academics text responses are useful in framing the current focus of neuroanatomy educators. First, the motivation of students learning neuroanatomy are important considerations for teachers. Conscious efforts have been made to link clinical relevance to the content and adapt teaching methodologies to suit intrinsic and extrinsic motivators. Educators are also cognisant of the anxiety of their students, reducing the taught curriculum to the essential knowledge, scaffolding learning and introducing new technologies to mitigate neurophobia. Further research may attempt to elucidate the link between motivation and anxiety on learning neuroanatomy.

The findings of this study support those reported elsewhere, agreeing that despite the flaws of traditional approaches, limitations on curricular time, trained anatomy faculty, resources for gross anatomy courses in integrated curricular as well as historical trends of teaching mean academics still predominantly rely on didactic methodologies. At this time, there is not enough quality evidence to support the use of modern, self-directed alternatives such as mobile technology, mixed reality, artificial intelligence or virtual assistants for academics to take the brave leap away from traditional teaching approaches. This move may be favoured if research illustrates the deficit in neuroanatomy knowledge continues and pressures of integrated curriculum and limited time endure.

Limitations of the study

This study did not explore the relative effectiveness of teaching methodologies employed by universities' medical schools. Further, whether this heterogeneity produces tangible differences in

the level of graduate knowledge remains unknown. Future studies may compare graduates' neuroanatomical knowledge between institutions to determine whether any difference exists.

CONCLUSION

Content, delivery, assessment and development of neuroanatomical knowledge between medical schools in Australia and New Zealand is highly variable, particularly with regards to uptake of newer technologies. A problem remains in the transfer of evidence-based strategies from research to educational practice. As medical schools continue to adjust to problem-based, integrated curriculums with fewer hours dedicated to neuroanatomy teaching – this research translation will become increasingly important. A national curriculum for content and delivery would encourage strategy- and resource-sharing between universities, enabling research to be based on similar populations and facilitating uptake of significant advancements. The authors of this paper recommend a Delphi study of neurologists, neurosurgeons and academics be conducted in order to establish a national curriculum for this important basic science.

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FIGURE LEGENDS

Figure 1. Diagrammatic representation of SPICES Model Continuum scores illustrated as mean $\pm$ SD. Participants were asked to characterize their university according to the SPICES model on a ten-point Likert scale item.

Figure 2. Thematic map of qualitative themes extracted from open-ended responses. Academics were asked to comment on facilitators, challenges and opportunities in student engagement (in blue, large font) in neuroanatomy education. The diagram should be read from the bottom to the top. Yellow boxes (medium font) were the key themes relating to how educators sought increased engagement of their students. 'Techniques' used by educators are able to do so by increasing or decreasing motivation/anxiety of students respectively (blue lines). Green boxes (small font) are 'codes', recurring comments made by the respondents that relate to each of the three themes. Each have a connection to a relevant theme denoted by the black lines.

Table 1. Respondent Universities

Country	University
Australia	Australia National University Deakin University Flinders University Griffith University James Cook University Macquarie University Melbourne University Monash University The University of Newcastle Undisclosed University of Adelaide University of New England University of New South Wales University of Notre Dame Sydney University of Queensland University of Sydney University of Tasmania University of Western Australia University of Wollongong
New Zealand	University of Otago Auckland University

Table 2. Average number of neuroanatomy specific teaching hours by course length ($\pm$ SD) (*min-max*)

Course Length	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
4-Year Course (n=12)	11.3 $\pm$ 10.1 (1-40)	24.9 $\pm$ 17.5 (2-50)	12.5 $\pm$ 13.4 (3-120)	1.5 $\pm$ 0 (1.5-1.5)	NA	NA
5-year Course (n=5)	3.8 $\pm$ 2.2 (1-6)	22.0 $\pm$ 2.7 (20-25)	17 $\pm$ 17 (5-29)	0	5 $\pm$ 10 (5-5)	NA
6-year Course (n=5)	19.8 $\pm$ 9.2 (12-30)	33.8 $\pm$ 25.8 (10-70)	43.3 $\pm$ 51.9 (10-120)	20 $\pm$ 14.1 (10-30)	10 $\pm$ 0 (10-10)	0
All Courses (n=22)	11.5 $\pm$ 10.0 (1-40)	26.44 $\pm$ 17.77 (2-70)	29.0 $\pm$ 38.2 (3-120)	13.8 $\pm$ 14.6 (1.5-30)	8.3 $\pm$ 2.9 (5-10)	0

Table 3. Types of resources available in neuroanatomy laboratories from most used to least used.

Resource type	Every	Most	Some	Rarely	Never
Prosections	45% (10)	32% (7)	23% (5)	0% (0)	0% (0)
Radiologic images	23% (5)	36% (8)	36% (8)	5% (1)	0% (0)
Models	59% (13)	18% (4)	18% (4)	0% (0)	5% (1)
Computer models	23% (5)	27% (6)	32% (7)	9% (2)	9% (2)
Plastinated specimens	23% (5)	14% (3)	18% (4)	5% (1)	41% (9)
Dissection	0% (0)	14% (3)	18% (4)	27% (7)	41% (8)

Table 4. Types of technologies utilised by neuroanatomy teachers from most used to least used.

Resource type	Every	Most	Some	Rarely	Never
3D Software	14% (3)	14% (3)	18% (4)	14% (3)	41% (9)
eBook	9% (2)	18% (4)	27% (6)	0% (0)	45% (10)
Tablets	9% (2)	23% (5)	5% (1)	14% (3)	50% (11)
Virtual Reality	0% (0)	0% (0)	23% (5)	14% (3)	64% (14)
Virtual Dissection	9% (2)	9% (2)	5% (1)	5% (1)	73% (16)
HoloLens	0% (0)	0% (0)	9% (2)	5% (1)	86% (19)
Haptic	0% (0)	0% (0)	5% (1)	9% (2)	86% (19)

Table 5. Thematic analysis of qualitative survey responses.

Theme	Code	Citations
Motivation for learning	Assessment	<i>"Main motivation as always is passing the exam..." University 4</i>
		<i>"Their motivation varies but assessment is a (too) larger driver." University 7</i>
	Staff-student interactions	<i>"Student engagement and student motivation is high overall. Highly skilled and enthusiastic staff, high levels of staff-student interactions, pre-lab preparation materials make labs high value and high yield." University 5</i>
	Clinical relevance	<i>"... students are very well engaged and extremely interested about the neuroanatomy program. The strong clinical focus of the program is the main driving force." University 13</i>
		<i>"Student's strategies, their learning and their engagement is dependent on the assumed clinical relevance of the material. Delivering the material with an emphasis on the clinical links is a good motivator." University 16</i>
Anxiety	Difficulty	<i>"Students find neuroanatomy extremely overwhelming... The way we have attempted to reduce student anxiety is to teach neuroanatomy for 4 weeks..." University 6</i>
	Motivator for improving teaching	<i>"Most students are intimidated by neuroanatomy. We worked hard to make it easier to comprehend and digest, then provide clear pathways to applying it in a context suitable for a junior, general clinician, not a specialist." University 17</i>
Driving for improved engagement	Scaffolding learning	<i>"... we are building content in a spiral, with basic concepts presented in first year being expanded upon and enriched in future years of the program." University 15</i>
	Clinical relevance	<i>"Delivering the material with an emphasis on the clinical links is a good motivator." University 16</i>
		<i>"We have tried to make our teaching more clinically relevant, provide hands-on dissection experience, use e-cases to assist their learning...." University 2</i>
	Technology	<i>The use of technology has not necessarily increased engagement, some students are still more comfortable with 'traditional' teaching approaches" University 1</i>
		<i>"I'd say two of the major challenges are the consistency of teaching delivery and resource access when students reach clinical years (and so this content is delivered by different facilitators and in different locations across the cohort). Not sure what we can do to improve this - although an incorporation of teaching technologies has helped to minimise some of this." University 12</i>
	Demonstrator experience	<i>"...high-quality demonstrators with clinical experience adding to subjectively interesting and relevant material, challenging but not overwhelming amount of content each week (hopefully)..." University 18</i>

Abbreviations:

PG:

post-graduate;

UG:

under-graduate

Journal Pre-proof

Journal Pre-proof

Declarations of interest: none