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ORIGINAL RESEARCH

Anaesthesiology registrars' knowledge of anatomy and assessment of two integrated anatomy teaching modalities: a comparative interventional study at a South African university

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Background: Knowledge of applied anatomy is essential for safe clinical practice in anaesthesiology. Despite the diverse use of applied anatomy and the negative consequences associated with inadequate knowledge, no formal postgraduate training course in applied anatomy exists for anaesthesiologists at any university in South Africa. To our knowledge, no prior study has been undertaken to assess knowledge or evaluate teaching modalities for applied anatomy among anaesthesiology registrars in African countries. This study aimed to assess applied anatomy knowledge and compare the effectiveness of two teaching modalities in anaesthesiology registrars at a central South African university.

Methods: A comparative interventional study was conducted. Data were collected using a questionnaire consisting of anatomy questions. Two randomised registrar groups wrote a pre-test and received different training modes: group A through a theoretical lecture and group B through an interactive anatomy museum cadaver and live model ultrasound demonstration. Their knowledge was re-evaluated immediately thereafter and one month after the training.

Results: There were 14 registrars who graduated from undergraduate medical school between 2010 and 2017 and participated in the study, divided into seven participants per group. The pre-test results indicated that the registrars' knowledge was below average (median score 44.6%, range 23.4–66.7%). No statistical difference was found between the two teaching modalities used in the study. Furthermore, no specific teaching modality was preferred, but simulation and lectures were more popular.

Conclusion: Most registrars' knowledge was inadequate for safe clinical practice. Intervention is required to keep anaesthesiology practitioners' knowledge at an acceptable level for patients' safety. Of the two teaching modalities, neither appeared superior. We highly recommend introducing a formal, structured postgraduate anatomy teaching programme encompassing diverse instructional strategies.

Keywords: applied anatomy, anatomy knowledge, health professions education, specialist training, training techniques

Introduction

Applied anatomy forms an integral part of anaesthesiologists' daily clinical practice. Limited anatomy knowledge is associated with various adverse events encountered by medical doctors, including morbidity and litigation due to damage to underlying structures.[1] Several studies have ascertained that limited knowledge among doctors and limited anatomy teaching compromise patient safety.[1-3]

Despite these associations, many new registrars are not adequately prepared in anatomy when starting their specialisation.[4,5] While some countries, such as Brazil, incorporate anatomy as part of their postgraduate anaesthesiology training programme, no literature was found on teaching applied anatomy to anaesthesiology registrars in African countries.[6] No formal scheduled postgraduate applied anatomy programme for anaesthesiologists is offered at the South African university where the study was conducted or at any other South African university.

Teaching postgraduate anatomy at this university in South Africa mainly involves informal discussions between the anaesthesiology registrars and consultants during clinical work and, less frequently, during departmental academic discussions of relevant cases. Senior registrars are taken to the anatomy museum for applied instructions on scheduled occasions. This differs from the university's undergraduate anatomy training, which involves a combination of mainly formal anatomy lectures, anatomical dissection of cadavers, tutorials, anatomy museum visits, and emergency case simulations for demonstrating anatomy to students. Despite this unstructured teaching, registrars are expected to be competent in anatomy on completion of their training. This has been described as having the relevant anatomy knowledge and being able to apply it in a clinical context.[7]

Several studies assessed anatomy knowledge in non-anaesthesiology doctors.[8-10] However, to our knowledge, no study has been conducted to assess such knowledge in anaesthesiology registrars at South African universities. Recent studies assessing knowledge in South African anaesthesiology registrars have concentrated on other aspects, such as the law, point-of-care viscoelastic testing, and neuromuscular monitoring.[11-13] In a recent study, obstetrics and gynaecology

registrars felt their applied anatomy knowledge was inadequate when they started their postgraduate training programme.[10] Conversely, a study among junior doctors comprising interns, medical officers, and registrars demonstrated that the doctors' knowledge was adequate for safe clinical practice. In this study, seniority and clinical experience had a positive association with being more knowledgeable.[8] Other doctors have also felt they had adequate anatomy knowledge for clinical practice.[14]

There has been extensive debate regarding effective methods of teaching anatomy. Globally, teaching in undergraduate programmes has revolved around the dissection of cadavers and lectures. Medical students indicated that they preferred dissection or exposure to cadavers for teaching anatomy.[15,16] In Saudi Arabia, efforts to teach clinical anatomy in an integrated way at one university included establishing an Anatomy Resource Centre that hosts, among others, an Anatomage, a clinical simulation centre, an ultrasound room, dissection, and various specimen rooms.[17]

Anaesthesiology registrars and consultants value anatomy teaching, although registrars mostly prefer integrated, learning-centred teaching.[6,18] A study in India described anaesthesiology registrars' satisfaction with vertical integration of anatomy in their postgraduate teaching programme.[19] Of the participating residents, 97.2% expressed overall satisfaction with the course, 94.5% indicated that the classes would be helpful in clinical practice, and 83.3% felt that the course covered mostly all the topics required for anaesthesiology practice.[19] The teaching modes preferred by South African registrars are unknown. This study aimed to establish the level of knowledge and the effective and preferred teaching modalities by anaesthesiology registrars and assess whether certain variables were associated with the level of knowledge.

Methods

Design

A comparative, interventional study was conducted using questionnaires, two teaching modalities, and pre- and post-tests.

Study population

The study population comprised postgraduate students registered as registrars in the Department of Anaesthesiology at the School of Clinical Medicine at a university in South Africa. The inclusion and exclusion criteria below were applied.

Inclusion criteria:

- Anaesthesiology registrars who were present on the days of data collection.
- Anaesthesiology registrars who gave consent to participate in the study.

Exclusion criteria:

- Anaesthesiology registrars who were not present on the day of data collection due to leave or clinical responsibilities such as working in emergency theatres, being on call that day, or the day before data collection.
- Anaesthesiology registrars who did not consent to participate in the study.

Ethical considerations

Approval to conduct the study was obtained in writing from the Health Sciences Research Ethics Committee (HSREC) of the University of the Free State (ethics approval number UFS-HSD2022/1875/2504). Approval was also obtained from the Department of Anaesthesiology, the Department of Basic Medical Sciences, and the university gatekeeper. Permission was obtained from Springer Nature and Wolters Kluwer to use copyrighted images in the learning content and tests. An information leaflet with the study information was given to participants. Voluntary completion of the questionnaire and the pre- and post-tests implied informed consent.

Measurements

Data were collected during academic time allocated by the department. The principal investigator designed a questionnaire that participants completed anonymously. It included information on participants' demographic characteristics, including age, gender, year of study, mode of anatomy teaching received in the undergraduate programme, previous anatomy exposure, and preferred mode of receiving anatomy teaching (Appendix 1).

Knowledge was assessed using a variety of applied anatomy questions. Only anatomy relevant to anaesthesiology practice was included in the questions. The principal investigator developed the questions and learning content according to Bloom's taxonomy[20] and in consultation with different stakeholders. These include a specialist anaesthesiologist and senior lecturer, a professor in health, and a lecturer and head of the anatomy division in the Department of Basic Medical Sciences.

For the pre-test, a total of 50 marks could be obtained. The first section consisted of 20 multiple choice questions (MCQ), the second consisted of two diagrams to annotate for 10 marks each, and the third section consisted of two short answer questions for five marks each. Each correct answer was scored one mark, and each incorrect answer was scored zero. No negative marking was applied. The total number of correct answers was summated for each participant and converted to a percentage. Knowledge was then graded according to the percentage scored as below average (< 50%), average (50–74%), and above average (≥ 75%).

The participants were randomly divided into two equal groups, A and B. Both groups wrote a similar pre-test. The post-test was different from the pre-test but the same for the two groups as a measure to reduce bias resulting from being assessed with the same set of questions immediately after being taught. Group A completed the pre-test and immediately received a formal lecture on anatomy before writing the post-test directly thereafter. Following the pre-test, group B received a

demonstrative lecture in the anatomy museum using cadaver specimens and ultrasound on a live model, then wrote the post-test directly after the session. The post-test results were used to compare the two teaching modalities and assess their efficacy in teaching applied anatomy.

One month later, both groups wrote another post-test to assess information retention. This test was the same for the two groups and similar to the pre-test. The two groups' performance was compared. For ethical considerations, group A received demonstrative training in the museum, and group B received a formal lecture to ensure exposure to both training modalities after the completion of data collection.

Pilot study

A pilot study involved five medical officers (not registered for postgraduate studies) in the Department of Anaesthesiology. Their data were not included in the final analysis as they were not part of the study population described. The pilot study aimed to identify potential deficiencies in the questionnaire and tests, and to make corrections before the main study. It also determined the time required to complete the questionnaire and tests and identify any mistakes or ambiguities in the documents. After the pilot study, one short-answer question was restructured, and the diagram questions were relabelled to the required total marks.

Methodological and measurement errors

Not all registrars could participate in the study, as some were on leave, off duty after working the night shift or covering emergency clinical duties. Questions might have been unclear to some participants, serving as a source of error. However, during data collection, the principal investigator and supervisor were present to clarify any unclear questions or other uncertainties.

Analysis

The data were analysed by the Department of Biostatistics at the university using the SAS program, version 9.4 (SAS Institute Inc., Cary, NC, USA). Anatomy knowledge was determined for each participant. One MCQ was excluded from test 2 due to all options being correct. The scores were categorised as below average (< 50%), average (50–74%), and above average (≥ 75%). Comparisons were made on anatomy knowledge between the two groups for each of the three tests. Numerical variables were summarised by medians, minimum and maximum. Categorical variables were summarised by frequencies and percentages. Differences between groups for categorical variables were evaluated using appropriate statistical tests (chi-square or Fisher's exact test) for unpaired data. Differences between groups for numerical variables were evaluated using the Wilcoxon two-sample test for unpaired data.

Results

In total, 14 of 24 registrars in the Department of Anaesthesiology participated in the study, representing a response rate of 58.3%. The participants' demographic, education, and clinical experience data are presented in Table I. Of the 14 participants, most were in the 30–34-years age group (n = 12, 85.7%) and were represented equally in both groups. Two participants were absent during the final part of data collection (test 3, written one month after the intervention), resulting in a total of 12 participants.

Regarding the sex distribution of the total group, most were male (n = 10, 71.4%), with a male-to-female ratio of 2.5:1. Group B comprised only male participants after randomisation. Participants had a median of 27 months (interquartile range [IQR] 18–36) experience in anaesthesiology before joining the registrar programme, and most (n = 10, 71.4%) had 6–10 years in practice since graduation from medical school. Two participants (28.6%) from each group had attended a prior applied anatomy course. Most participants were exposed to various teaching modalities as part of their undergraduate anatomy training.

Table I: Participants' demographic characteristics, experience, and education (n = 14)

Variable	*n* (%)
Sex	
Male	10 (71.4)
Female	4 (28.6)
Age (years)	
25–29	1 (7.1)
30–34	12 (85.7)
35–39	1 (7.1)
Years in practice	
6–10	10 (71.4)
> 10	4 (28.6)
Undergraduate anatomy teaching	
Dissection	13 (92.9)
Museum	12 (85.7)
Lectures	13 (92.9)
Tutorials	9 (64.3)
	Median (IQR)
Months in registrar programme	19.5 (15–21)
Months of experience in anaesthesiology before joining registrar programme	27 (18–36)

IQR – interquartile range

As shown in Table II, more than half of the participants scored below average in the pre-test (test 1) and immediate post-test (test 2). In both tests, the median scores were below 50%. Test 1's scores improved in the one-month post-test (test 3) by 22.9% and 8.3% for groups A and B, respectively. None scored above average in tests 1 and 2 in both groups, and only one participant in group A scored above average (79.2%) in test 3. Figure 1 illustrates the comparison of the two groups' performance throughout the tests in median percentage. No statistically significant difference occurred between the performance of the two groups on all three tests.

As part of the questionnaire, participants were asked to rate their anatomy knowledge. Their responses were compared with the actual scores obtained for the pre-test. Most participants rated

Table II: Comparison of the two groups' anatomy knowledge results for tests 1, 2, and 3

Group and test	Median score (%)	Below average	Average	Above average
		(< 50%) *n* (%)	(50–74%) *n* (%)	(≥ 75%) *n* (%)
Group A				
Test 1† (*n* = 7)	44.2	4 (57.1)	3 (42.9)	0 (0)
Test 2‡ (*n* = 7)	45.5	4 (57.1)	3 (42.9)	0 (0)
Test 3§ (*n* = 6)	67.1	1 (16.1)	4 (66.7)	1 (16.7)
Group B				
Test 1† (*n* = 7)	45.0	5 (71.4)	2 (28.6)	0 (0)
Test 2‡ (*n* = 7)	40.4	6 (85.7)	1 (14.3)	0 (0)
Test 3§ (*n* = 6)	53.3	3 (50.0)	3 (50.0)	0 (0)

Group A intervention – theoretical lecture, group B intervention – demonstrative lecture in the anatomy museum using a cadaver specimen and ultrasound on a live model
† pre-test
‡ post-test immediately after the intervention
§ post-test one month after the intervention

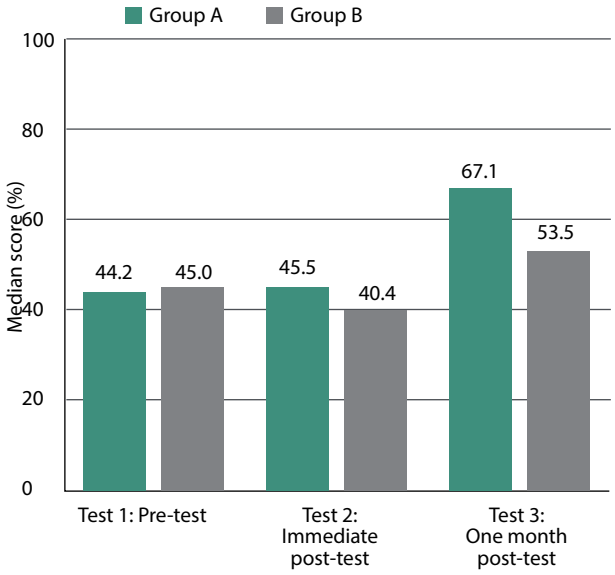

Figure 1: Comparison of test results in percentage (median) between groups A and B
Group A intervention – theoretical lecture, group B intervention – demonstrative lecture in the anatomy museum using a cadaver specimen and ultrasound on a live model

their anatomy knowledge as average, with a minority (14.3%) rating their perceived applied anatomy knowledge below average. However, 64.3% scored below average on the pre-test. The comparison between the perceived and actual anatomy knowledge is shown in Table III. One participant did not rate their anatomy knowledge; this participant scored below average on the pre-test.

Table III: Participants' perceived anatomy knowledge versus actual anatomy knowledge

Category	Perceived anatomy knowledge	Actual anatomy knowledge*
	n (%)	*n* (%)
Below average (< 50%)	2 (14.3)	9 (64.3)
Average (50–74%)	11 (78.6)	5 (35.7)
Above average (≥ 75%)	0 (0.0)	0 (0.0)
No response/rating	1 (7.1)	–

* Findings based on test 1 (pre-test) results.

When participants were asked to rate different teaching modalities as their preferred method of being taught anatomy during postgraduate studies, their responses were the simulation laboratory (*n* = 5, 35.7%), formal lectures (*n* = 4, 28.6%), tutorials (*n* = 3, 21.4%), and anatomy museum (*n* = 1, 7.1%). Two participants (14.3%) mentioned ultrasound as one of their preferred teaching methods, although it was the least preferred mode rated by most.

We compared performance according to anatomical regions and/or systems in the pre-test. Participants performed better in head and neck anatomy (median score 80.0%), followed by abdomen/pelvis/lower limb (median score 42.9%), central nervous system (median score 42.5%), cardiovascular system (median score 41.7%), and the respiratory system (median score 33.3%).

Discussion

Our participants' low levels of anatomy knowledge were in keeping with other studies involving doctors and registrars.[9,10,21] Throughout the study, there was no statistically significant difference in performance between the two groups, implying that neither of the teaching modalities was superior. The participants had been in the programme for at least 14 months and completed various rotations in the department. This pre-existing anatomy knowledge served as a confounding factor when assessing teaching modalities. Similar results were obtained in the pre-test for both groups (median 44.2% and 45.0%). Contrary to expectation, performance did not improve in the post-test taken immediately after the intervention (test 2). However, these results should be interpreted with caution as this test was different from the first one, so one cannot draw a reasonable conclusion regarding teaching modes and test 2 results.

In the test assessing information retention at one-month post-training (test 3, similar to the pre-test), participants' performance

improved compared with the pre-test. While there was no statistically significant difference between the two groups' performance in test 3, there was a 14% difference in the results (53.0% vs. 67.1%). Previous studies compared anatomy knowledge retention in undergraduate students at six months and postgraduate students at 18 months, finding no clinically significant improvement.[22,23] Prior studies failed to assess anatomy retention at one month.

The study participants were all junior registrars with similar years in practice since graduation. However, they had diverse anaesthesiology exposure before joining the registrar programme, which was equally represented between the two groups. Participants seemed to have had similar exposure to undergraduate teaching modes, mainly lectures, dissection, and museum cadaver specimens. Surprisingly, one participant did not indicate lectures as part of their undergraduate teaching. The association between anatomy knowledge and a participant's sex could not be assessed due to the asymmetrical distribution in the groups after randomisation, with all group B participants being male. However, one study found no association between sex and anatomy knowledge.[24]

Because of the small sample size, we could not establish a relationship between the level of anatomy knowledge and year of study, previous experience in anaesthesiology, or years of general clinical experience. An association between seniority and being more knowledgeable in anatomy has been reported by a single study, which was attributed to clinical experience and intense academic training.[8]

Of the 11 participants who perceived their anatomy knowledge as average, six (54.5%) obtained below-average scores in the pre-test. This was concerning because students who perceive themselves as having adequate knowledge are less likely to engage in activities that enhance their knowledge and are more likely to cause harm without realising it, referred to as the Dunning–Kruger effect.[25] Only two participants rated their anatomy knowledge below average and scored below average in the pre-test.

In our study, participants preferred various teaching modalities, with the simulation laboratory being the most popular and ultrasound the least. It has been reported in the literature that using simulation and dissection laboratories in addition to lectures yields favourable results in applied anatomy courses preparing doctors for different specialities.[26] Although surprisingly not popular in our study, ultrasound plays an invaluable role in an anaesthesiologist's clinical practice. Most of the anaesthesiologist's applied anatomy in clinical practice involves sonography and identifying sonoanatomy to perform procedures such as regional anaesthesia, vascular access, and cardiac assessment. While few studies investigated the role of simulation and ultrasound as teaching modalities in anaesthesiology registrars, they seem to elicit positive results in both registrars and undergraduate students.[27,28] Kathrada et al.[29] encouraged the incorporation of ultrasound in the training curriculum of anaesthesiologists in South Africa.

Radiology and prosection benefit students and anatomists, although not to the same extent as dissection.[16] On the contrary, undergraduate students in India rated a three-dimensional (3D) anatomy atlas as their preferred mode of teaching, followed by plastic models and, lastly, human cadavers. They also believed that imaging modalities, such as ultrasound, aided their understanding of the subject.[30] Our participants' choice of simulation as a preferred teaching mode could be attributed to the clinical nature of the applied anatomy employed in daily practice, as opposed to undergraduate medical students and anatomists who mostly learn gross anatomy and prefer dissection.

The findings of superior head and neck anatomy performance in the pre-test compared with other regions and/or systems could be attributed to anaesthesiology registrars being exposed to more general anaesthesia than regional anaesthesia during their daily clinical work. For general anaesthesia, registrars are more likely to revise head and neck anatomy as they secure the airway, obtain central venous access, or perform blocks involving the head and neck. The worst performance on the respiratory system could be because, by 19.5 months in the programme, most registrars have not rotated through the cardiothoracic block and hence would not easily answer most of the cardiorespiratory questions equally.

Regarding information retention, one study portrayed dissection and cadavers as effective means of teaching anatomy.[14] Limited research has been conducted concerning when and for how long anaesthesiology registrars should receive teaching in anatomy. In Waterston et al.'s[3] study, clinicians in all disciplines, anaesthesiologists included, believed that anatomy teaching should be continuous throughout medical school. Moreover, it has been proven that clinical integration, continuous education programmes, and problem-based education improve anatomy knowledge. Other doctors indicated that although their anatomy knowledge was adequate, they valued continuing anatomy education through refresher courses.[14]

These findings imply the need for a well-structured postgraduate training curriculum to address the lack of anatomy knowledge among anaesthesiology registrars. This curriculum would have to allow continuous education throughout the training period and include various teaching modalities identified by stakeholders at South African universities, emphasising methods to recurrently evaluate knowledge retention.

Study limitations

At the time of preparing the research protocol, there were 32 registrars at the Department of Anaesthesiology. However, at the time of data collection, some registrars had qualified and did not meet the inclusion criteria as registered registrars in the department. Only 24 registrars fulfilled the inclusion criteria, resulting in a small sample size. Consequently, a reliable conclusion could not be drawn between the level of anatomy knowledge and some variables of the study, and the findings are not generalisable.

Only junior registrars, defined as registrars in the first two years of their four-year training, were available on the day of data collection. It would have been meaningful to have data on the difference between results obtained by junior and senior registrars to give an overview of anatomy knowledge across the entire trainee group.

Despite obtaining expert input while formulating the assessment questions, our study ignored the fact that these were not standardised questions and, hence, could be ambiguous or misinterpreted by participants, leading to errors in the results.

Conclusion

A lack of adequate applied anatomy knowledge was evident among anaesthesiology registrars. We recommend a formal, structured programme aligned with the new Colleges of Medicine South Africa (CMSA) Part I Curriculum for anaesthesiology registrars.[31] We also encourage an integrated approach to teaching applied anatomy to anaesthesiology registrars. Although the sample size was a limitation, this study is a foundation for further studies of larger samples to validate our findings.

Conflict of interest

The authors declare no conflict of interest.

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Ethical approval

The authors declare that this submission follows the Responsible Research Publication Position Statements principles developed at the 2nd World Conference on Research Integrity in Singapore, 2010. Approval to conduct the study was obtained from the Health Sciences Research Ethics Committee (HSREC) of the University of the Free State (ethical clearance number UFS-HSD2022/1875/2504).

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