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Frontloading gross anatomy: impacts on medical student performance

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Abstract

Objectives: The human gross anatomy course offered at the University of California, Davis, School of Medicine, is part of a partially integrated foundational block in the first year of the medical curriculum. The block organization was implemented in 2006 in part to foster the horizontal integration of four basic science courses. However, simultaneous instruction in multiple courses presented a challenging workload to students, especially considering the large amount of information covered in anatomy. In an attempt to improve student outcomes, the gross anatomy course was compressed and frontloaded to the first 13 weeks of the foundational block while instructions of other courses were shifted later to make room for the frontloaded gross anatomy course. To assess the effect of frontloading of anatomy on students' performance, we retrospectively compared the anatomy examination scores between before and after frontloading of the anatomy content.

Methods: Student performance in the gross anatomy course was compared between the pre-frontloading (2013–2015) and post-frontloading (2016–2018) cohorts. Average scores of each examination category (quizzes, midterms, practical and written finals, and overall grades) were calculated and compared between the two cohorts.

Results: Scores on the written final and practical final examinations and the overall grade in gross anatomy improved significantly ($p<0.05$) in the post-frontloading cohort (n=323) compare to the pre-frontloading cohort (n=343).

Conclusion: Moving gross anatomy forward and offering a compressed course may be an option for educators looking to improve student performance without increasing student contact hours, concomitantly allowing focused learning and mastery of anatomy content.

Keywords: anatomical education; assessment; curriculum reorganization; gross anatomy; student performance

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Introduction

The University of California, Davis, School of Medicine offers the four-year Doctor of Medicine (MD) program for students with a bachelor's degree. The program discussed in this report consists of 2 years of preclinical curriculum and 2 years of clinical curriculum. In 2006 the preclinical curriculum was revised from a traditional discipline-based organization with free-standing, department-based courses taught for the length of a quarter (10 weeks) to a more integrated, block-based organization with multiple courses taught in parallel for the length of a block created by the fusion of two quarters (18 weeks). Blocks of differing lengths allowed multiple courses to be taught simultaneously, improving opportunities for horizontal integration. The first 18-week Foundation Block concentrated on providing foundational knowledge in the basic sciences and included courses in gross anatomy, physiology, histology and biochemistry. These courses were offered in parallel with a course entitled Doctoring, which emphasized the physical examination, doctor-patient communication and biostatistics.[1] After the two introductory blocks, which filled most of the first academic year, the curriculum shifted to a pathophysiology and organ systems-based curriculum. This curriculum reorganization permitted us to coordinate content delivery between multiple basic science courses and integrate basic sciences with clinical experiences taught in Doctoring. Its organization was aligned with the nationwide movement towards integrated medical curriculum[2] and was favorably reviewed by the accredit-

ing authority, Liaison Committee on Medical Education (LCME) in 2014.

The perceived benefits of the integrated curriculum for medical student's performance are improved knowledge retention and clinical reasoning skills enhanced by conceptual integration.[2] This is likely the product of deep learning stimulated by applying principles of basic science in the context of clinical problem solving.[3] It has been shown that problem-based learning (PBL) is an effective pedagogy to enhance the integration of basic and clinical sciences.[4] When the effectiveness of PBL was investigated in anatomy education, however, it was indicated that the main determinant of students' performance outcome was not necessarily the format of instruction, but rather the context in which students learned anatomical knowledge. In one study, levels of anatomical knowledge gain were compared between two groups of students, one taught in PBL-based curricula and the other taught in traditional medical curricula, and no significant differences were found between the two groups.[5] The authors suggest that the crucial element for successful anatomy education is teaching anatomy in a clinical context, and as long as this condition is fulfilled, a traditional curriculum was capable of achieving high student performance. The importance of teaching anatomy linked to clinical contexts was reiterated by another report by Doomernik et al.[6] In this study, long-term (~1.5 years) anatomy knowledge retention was assessed in the student body attending an integrated, problem-based medical curriculum. The authors showed that traditional knowledge recall based on radiology imaging declined more rapidly than knowledge gained through clinical cases.[6] More recently, the positive effect of learning anatomy in clinical contexts in compressed instructions was reported.[7] To compensate for a reduced instructional duration, the authors emphasized correlating the functions with the anatomical structures. Although the instructional content was abbreviated, using clinical symptoms as an instructional focal point maintained students' performance.[7] Together, these reports highlight that the context in which anatomy knowledge is learned by students is the principal determinant of students' learning outcome.

When the horizontally integrated curricular reorganization was implemented at our school in 2006, we encountered an unintended consequence; the new curriculum required incoming students, many of whom had been away from the classroom for many years, to rapidly develop study skills at the very beginning of medical school to be successful in five large courses taught in parallel. From the cognitive learning theory standpoint, this circumstance could place these students who likely possess less pre-existing knowledge bases into a disadvantageous position, because a high volume of unfamiliar materials taught simultaneously would easily overwhelm those individuals' working memory capacity.[8] This situation could lead to a highly stressful, uncongenial learning condition.[9] A logical solution to this unintended consequence was to decrease the volume and complexity of materials taught concurrently, thereby reducing the cognitive load the first-year students have to confront at the very beginning of the curriculum.[10] Accordingly, the instructors of the basic science courses agreed in 2016 to move much of the content of the gross anatomy course into the first 13 weeks of the block and to reduce the content of other courses while the gross anatomy course was running. Much of this displaced content was moved to the final 6 weeks of the block, after the completion of gross anatomy. As the result of frontloading of the anatomy content, on the one hand, horizontal integration with the rest of basic science courses and Doctoring was reduced. On the other hand, intra-disciplinary integration[11] within the anatomy course was enhanced because of more focused integration of regionally taught gross anatomy content with embryology, ultrasound, and radiology.

In this report, to address the effect of frontloading of anatomy on students' performance, we retrospectively examined the scores of multiple-choice written examinations and laboratory practical examinations recorded in 2013–2015 (pre-frontloading) and in 2016–2018 (post-frontloading) in the gross anatomy course at the University of California, Davis, School of Medicine.

Materials and Methods

Human subjects research exemption was granted by the Internal Review Board (IRB) at the University of California, Davis (IRB ID: 1613920-1). The compliance with the Family Educational Rights and Privacy Act (FERPA) was approved by the Office of Medical Education (OME) at the University of California, Davis. All student data in this study were analyzed independently from any student identifiers using spreadsheets provided by the OME. Medical College Admission Test (MCAT) scores and undergraduate grade point averages (GPAs) were found on the School of Medicine's publicly available current and cached web pages. The student cohorts analyzed in this report were not subdivided based on gender or age, based on our previous observation that these characteristics did not affect students' examination scores in gross anatomy at UC Davis.[12]

The courses described here as gross anatomy and histology are officially titled Developmental, Gross and Radiographic Anatomy (CHA400, 7.5 units) and Cell and

Tissue Biology (CHA402, 4.5 units). The course of gross anatomy integrates clinically relevant anatomy, human embryology, surface anatomy, radiographic anatomy, and ultrasound anatomy. The latter three components are taught by physicians with appointments in the departments of Pediatrics, Radiology, and Emergency Medicine, respectively. The course consists of 55 lecture hours (35 in gross anatomy, 10 in embryology, 9 in radiographic anatomy, and one in ultrasound anatomy) and 81 laboratory hours during which students dissect a human cadaver in teams of 4 or 5, learn surface anatomy, and apply ultrasound anatomy in group sessions. Student's performance assessed in this report consists of the following four components: (1) quizzes - multiple choice questions offered approximately biweekly based on learning objectives from gross anatomy, embryology and radiographic anatomy lectures, (2) midterms - three midterm laboratory practical examinations that include questions on anatomical structures and functions based on dissected cadavers, animated ultrasound images and surface anatomy questions with a standardized patient, and one oral presentation given to an instructor and the student's dissection partners, (3) practical finals - a comprehensive laboratory practical examination with the same components as midterm practical, and (4) written finals - a comprehensive written multiple choice examination. The weight of each component in the overall course grade is as follows: the 70 total quiz questions are worth 20%, the midterms each 10% (total of 30%), the oral presentation 10%, and the final examination 40% (practical final 20%, written final 20%). All preclinical courses at UC Davis School of Medicine are pass-fail with no letter grades, and a grade of 75% or higher is used as a passing grade for the gross anatomy course. This cutoff score was selected empirically based on the past student performance as it corresponded to the letter grade C before the transition to the pass-fail grading occurred.

In the years of 2013 to 2015 the gross anatomy course was instructed over 18 weeks, with lectures and laboratory sessions primarily offered on Tuesdays and Thursdays, and in the years of 2016 to 2018 when the course was frontloaded the course was instructed in 13 weeks on Tuesdays, Thursdays and Friday. The content of the gross anatomy course remained nearly the same (a new embryology lecture on the development of the palate and face replaced a formal embryology review session starting in 2017), and the total number of student contact hours remained the same after frontloading. The other basic science courses in the foundational block accommodated the frontloading of gross anatomy by reducing their content while gross anatomy was in progress and increasing their student contact hours after the gross anatomy course was complete. For comparison, the monthly contact hours for the 2015 (pre-frontloading) and 2016 (post-frontloading) are presented in **Table 1**.

To evaluate the effect of the frontloading on the outcome of students' course performance, the past examination scores in the gross anatomy and histology courses were retrospectively collected and compared between pre- and post-frontloading student cohorts. The first-year medical students who took the gross anatomy course in 2013–2015 were grouped into the pre-frontloading cohort

Table 1

Number of student contact hours the year before (2015) and the year after (2016) frontloading gross anatomy.

	Month*	Anatomy	Physiology	Histology	Biochemistry
2015	August	31	21	19	14
	September	31	23	12	6
	October	29	16	15	10
	November	29	20	13	10
	December	16	4	8	4
	Total	136	84	67	44
2016	August	47	12	7	6
	September	44	20	13	10
	October	40	13	16	10
	November	5	20	15	17
	December	0	15	16	4
	Total	136	80	67	47

*Since the first day of classes varies from year to year, months are defined here as 4-week periods, with the first 4 weeks being August, the second 4 weeks being September, etc.

(n=323) and those in 2016–2018 (n=343) were grouped into the post-frontloading cohort. Examination scores of quizzes, midterms, practical finals, and written finals were calculated and analyzed as separate categories using Excel spreadsheet. To examine the unpaired data sets of the pre-frontloading and the post-frontloading cohorts, averages and standard deviations of scores of the cohorts in each examination category were calculated and statistical differences were determined using a Student's t test assuming equal variance and a two-tailed distribution. Significance was set at $p<0.05$. We chose to focus on the student data of these 6 years to keep potential effects of variables such as significant class-size expansion and the replacement of an instructor which occurred in 2019.

Results

The results of the curriculum changes showed to provide a more supportive learning environment for students by: (1) reducing the overall complexity and quantity of learning materials introduced during the first few months, (2) allowing concentration on learning activities in anatomy laboratories, radiology and ultrasound sessions, and (3) giving an opportunity to redevelop study skills while concentrating on anatomy. Likely reflecting these positive aspects, the mean scores of the practical finals, the written finals, and the overall course grades of the post-frontloading cohort (2016–2018) were statistically higher than those of the pre-frontloading cohort (2013–2015), and the mean scores of quizzes and midterms maintained the equivalent levels between the two cohorts (**Table 2**). Effect size (Cohen's d)[13] for each of practical finals, written finals, and the overall course grade was 0.33, 0.17, 0.17, respectively. Albeit the effect size was relatively small, statistically significant improvement in students' performance indicates that the frontloaded schedule helped to improve students' learning of gross anatomy without detrimental effect.

Discussion

Frontloading of the gross anatomy course reported here allowed us to achieve the focused integration within the anatomy related content and reduce hours of non-anatomy courses in the first half of the block. In a previous study, we found that only one in three first year students at the University of California, Davis, School of Medicine had taken an undergraduate course in human anatomy prior to matriculation.[12] Most students, therefore, are unfamiliar with human anatomy when they begin classes. Combined with the sheer volume of information they need to master in the course, gross anatomy is perceived as challenging, or even daunting as previously reported.[14] That frontloading of gross anatomy improved student performance on the anatomy practical final and written final examinations shows that designating focused time for mastering anatomy content had positive effect. The gross anatomy course described in this report experienced a 25% reduction in lecture hours in 2001. When the effect of this hour-reduction was investigated, it was shown that characteristics including age, gender, MCAT, GPA, and undergraduate coursework in anatomy did not correlate with the course performance.[12] Corroborating this report, the prematriculation academic records of the pre- and post-frontloading cohorts of this study are also comparable - the MCAT scores (averaging the 81st percentile in both 2013–2015 and 2016–2018) and the undergraduate grade point averages (3.69 in 2013–2015 and 3.64 in 2016–2018), indicating it is unlikely that the test score improvement was due to the academic or innate characteristics specific to the cohorts. Although the class size has increased steadily between 2013 and 2018 (the average class size of the pre-frontloading, 110 students; that of the post-frontloading, 115 students), the larger class size of the post-frontloading cohort did not appear to have negative effect on the performance in gross anatomy. Together, we consider the improved student performance in the post-

Table 2

Class performance in gross anatomy prior to frontloading (2013–2015) and after frontloading (2016–2018) in the medical curriculum.

Assessment	n	p-value	2013–2015 grade (percentage mean+SD)	n	2016–2018 grade (percentage mean+SD)
Quizzes	343	n.s.	85.7±8.4	343	86.6±7.4
Midterms	343	n.s.	90.0±7.0	343	90.2±5.6
Practical finals	343	<0.001	86.0±8.5	343	88.5±6.8
Written finals	343	<0.05	88.1±8.0	343	89.4±7.0
Overall grade	343	<0.05	88.8±5.7	343	89.6±4.8

n.s.: not significant (p>0.05); **SD:** standart deviation.

frontloading cohort in general was likely the result of students having more study time at the beginning of the block dedicated to gross anatomy and not having other final examinations competing with their study for the gross anatomy final examinations.

Improvements may also have come from students having an opportunity to develop good study habits earlier on during a less impacted curriculum. Though not measured empirically, the collaborative learning environment fostered in the gross anatomy dissection laboratory appeared to cultivate a strong sense of camaraderie among students in the early part of the foundational block. This may contribute to students developing the habit of studying in groups and helping each other's learning.[15] The collaborative atmosphere of the class nurtured by the frontloaded gross anatomy course may also help students reduce stress, which has been shown to negatively affect academic performance of medical students and aid them in navigating through the heavy academic demands.[16,17]

Removing the gross anatomy examinations from the final examination week may have also contributed to improved student performance in other courses. In this study we chose to analyze the final examination grades for the histology course, since this course was relatively unchanged during the six-year period analyzed in this report. The format of the physiology final examination changed significantly in 2017 (from an examination prepared by course instructors to that selected from the National Board of Medical Examiners Question Bank). The manner in which the biochemistry course grade was calculated also changed significantly during the study period by increasing the weight of attendance at journal clubs in final grades. These changes led us to preclude these two courses from our analysis. In histology, the post-frontloading cohort performed significantly better than the pre-frontloading cohort on their histology final examination - overall course grade: 2013–2015, 87.2±8.2, n=325; 2016–2018, 88.6±7.4, n=345 ($p<0.05$). This improvement on the histology final examination associated with frontloading gross anatomy may be the result of more time being available to study histology content during the final examination week. Since study time dedicated to the anatomy final examination in December was no longer needed in the frontloaded curriculum, the other courses gained a week to provide additional instructions and review sessions prior to their final examinations.

Studies by others have shown that the best way of improving gross anatomy knowledge is to spend more time teaching anatomy, and to revisit anatomy during the clinical years.[18] However, turning back the clock to increase time spent teaching anatomy is unlikely to be a viable option as schools consider ways of improving student performance.[19] McBride and Drake[20] reported that students spend on average 129 contact hours in gross anatomy classroom activities and dissection laboratories at North American medical schools. Our course has a total of 116 gross anatomy contact hours (35 lecture and 81 laboratory hours), and the contact hours available to teach this discipline have been capped. Others seeking to improve student performance in gross anatomy without increasing contact hours should consider the potential benefits of frontloading their content within an otherwise integrated foundational block, since as reported previously, the score on a gross anatomy comprehensive examination is positively correlated with scores on the USMLE Step 1 and passing the examination.[21] It is also possible that offering gross anatomy as a compressed, stand-alone course would result in similar improvements in student outcomes, as suggested by numerous studies in other disciplines.[22]

Where to place gross anatomy in the medical school curriculum has been a topic of heated debate for generations. In a thoughtful and entertaining review of the subject, Sinclair[23] argues that integrating anatomy with other foundational courses is probably irrelevant to student learning, as only basic anatomical concepts are needed for successful learning of physiology and biochemistry. Nevertheless, integrating gross anatomy with other foundational courses is a popular curricular approach,[20] though upon closer examination it is unclear if courses attempting integration are not merely being taught at the same time. Muller et al.[24] discussed how the integrated "foundations of human care" block offered at the start of the University of California, San Francisco's medical curriculum served as an example. Student evaluations of the block noted that histology and gross anatomy were, in fact, only well integrated with other foundational courses when they were studying cardiovascular systems, and for the bulk of the block the anatomical sciences were taught independently.[24] In addition, integrated curricula often present challenges to providing adequate levels of anatomical knowledge to medical students due to the general trend of reducing contact hours of basic science disciplines including anatomy.[2,25,26] One attractive solution for this challenge could be vertical integration of basic sciences into the clinical curricula;[3] however, this approach often faces the practical challenge of how to blend basic sciences into tightly scheduled clerkship schedules.[27]

Alternatively, one might argue that gross anatomy can be better integrated with certain applied clinical coursework than other foundational courses, as this would per-

mit lessons in the clinical relevance of the subject matter and earlier experiences with clinical problem solving. The recent study investigating preferred timing of cadaveric dissection in the curriculum by medical students (enrolled and graduated) reports the preclinical years as above all the most preferred time.[28] The main reasoning behind this preference was students' view of cadaveric dissection as a fundamental exercise to develop anatomical knowledge before transitioning to the clinical curriculum. The fact that the gross anatomy course at the University of California, Davis is fully integrated with surface, radiographic and ultrasound anatomy, taught by clinicians, may help it succeed as a quasi "stand-alone" course near the beginning of the curriculum to provide comprehensive anatomical knowledge foundation. This organization exemplifies the "intra-disciplinary integration of content" that delivers learning materials in an ordered, cohesive manner within a discipline.[11] The authors argue that curriculum design employing an inter-disciplinary integration model would likely present a challenge to gross anatomy because of the regional approach it takes for instruction. In this sense, the success of our current frontloaded gross anatomy course relies upon well-integrated intra-disciplinary instruction and the streamlined sequence of anatomical material presentation made possible by all-inclusive cadaver dissection laboratory sessions. An alternative way of maintaining the regional approach ideal for instruction of gross anatomy was achieved by the Morehouse School of Medicine integrated curriculum employing gross anatomy as the backbone of the curricular design.[29,30] Others have found that the benefits of an integrated curriculum became most evident at the later phase of the curriculum and led to improved mastery of knowledge in both basic and clinical sciences.[31]

Our report has limitations. First, the effect of frontloading on long-term retention of anatomical knowledge was not assessed. Evaluating anatomical knowledge of third year students rotating in relevant clerkships such as surgical rotation would be ideal to gain direct correlation between the frontloading curriculum and knowledge retention. In addition, because of the curriculum structure at our institution, we do not have the opportunity to compare the frontloaded format and the fully integrated curriculum within the context of our student body.

Conclusion

We have shown that frontloading a gross anatomy course in a compressed foundational curriculum can improve student outcomes both in the anatomy course as well as in the histology course being taught in the same block. This approach would be especially applicable to a gross anatomy course in which intra-disciplinary integration of content is well-established. Beginning of summer 2021, the University of California, Davis, School of Medicine rolled out a new integrated and learner-oriented curriculum. In this curriculum design we retained the frontloading format; the gross anatomy discipline is housed with histology and clinical skills disciplines as a single course to allow cohesive integration of the fundamentals in gross anatomy, micro anatomy and physical examination. This well-woven structure provides an excellent knowledge building block for the first-year students, functioning as the "pre-integration" foundational knowledge base[11] that prepares students for the subsequent courses revolving around integrated problem based and case-based learning sessions.

Conflict of Interest

No conflicts declared.

Author Contributions

RPT: project development, data collection/analysis, manuscript writing/editing; HA: data analysis, manuscript writing/editing; KAB: data collection/analysis, manuscript editing.

Ethics Approval

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