ORIGINAL ARTICLE

An online catalog of muscle variants: *Student perceptions of a new opportunity for self-directed learning*

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Objective: Muscle variants are common findings in dissection laboratories. These anomalous structures can be relevant in the diagnosis and management of certain conditions and therefore could be incorporated into anatomy curricula at chiropractic colleges. We aimed to create an online resource of muscle variants to facilitate student self-directed learning within this area of study.

Methods: At the time of their discovery during routine educational dissection, muscle variants included in the catalog were documented and subsequent case reports written. All content created for this resource, including photographs and videos, was hosted on the institution's learning management system. Students enrolled in our doctor of chiropractic program were invited to view the catalog and encouraged to leave feedback by completing an online survey.

Results: Student responses to Likert-style survey questions generally indicated high levels of satisfaction regarding the utility and features of the catalog. Open-ended and Likert-style survey questions were used to help guide the future directions of this developing resource. Concurrent anatomy students were not more likely to contribute to the catalog compared to students who had previously completed the university's anatomy course series ($p = .75$, 2-tailed Fisher exact test).

Conclusion: An online supplement to graduate-level gross anatomy courses can aid in the instruction of muscle variants by providing an opportunity for student self-directed learning. This resource will be updated continually and will be expanded on to include neurovascular and visceral variants. Student participation will be sought in developing future content to be included in this catalog.

Key Indexing Terms: Anatomy; Cadaver; Chiropractic; Dissection; Education; Surveys and Questionnaires

J Chiropr Educ 2018;32(2):131–140 DOI 10.7899/JCE-17-18

INTRODUCTION

Gross anatomy instruction tends to emphasize the "Vesalian" view of the human body, whereby teaching is focused on the typical anatomy of each structure.[1] Anatomical variants, naturally occurring deviations from the textbook standard, are routinely encountered in the dissection laboratory. Despite their abundance, variants are given little credence in conventional anatomy texts and atlases. Academic journals and specialty texts focused on anatomical variations exist, but collections of clinically important variations per medical specialty do not.[2]

Muscle variants are relevant to the chiropractic profession for several reasons: they may be encountered during physical examination or through medical imaging, muscle variants can alter surface anatomy landmarks or mimic soft tissue masses, and their presence may lead to or complicate clinical conditions. The proper diagnosis and treatment of a patient may rely on the chiropractor's understanding of a specific muscular anomaly. Interestingly, Chapman and colleagues reported that practicing chiropractors, compared to anatomists teaching in chiropractic programs, suggest that undergraduates should be taught a higher standard of anatomy in several curricular areas, including "variations."[3]

Educators face many challenges when they incorporate anatomical variations into gross anatomy curricula. The number of reported anomalies in the human body is substantial; for example, nearly 100 documented variations exist for the brachial plexus.[1] It has been suggested that medical anatomy courses have a "too much too soon" effect; students are tasked with a significant amount of information to master without the proper opportunity to appreciate the relevance of the material.[4] Because of these concerns, an instructor may feel wary of incorporating any additional content into a gross anatomy course that is already oversaturated. Furthermore, it is difficult for an educator to prioritize the teaching of variant anatomy at the expense of removing content focused on the form, relationships, and function of typical anatomical structures. Over the past few decades, the general trend in medical sciences education has involved a reduction of time allotted to teaching anatomy, a fact that could potentially place further restrictions for dedicated instruction of anatomical variations.[5] Within the realm of chiropractic education, there is little information in the literature pertaining to specific learning objectives and assessment of anatomical anomalies. An international survey focused on gross anatomy courses at chiropractic colleges reported on the design, delivery, and instructional methods at various institutions.[6] While useful in comparing and contrasting anatomical curricula at different chiropractic colleges, this survey did not address the inclusion or exclusion of anatomical variants within gross anatomy courses for chiropractic students.[6] Currently, variants are not addressed in the General Anatomy or Spinal Anatomy test plans for the National Board of Chiropractic Examiners Part I examinations.[7]

An additional difficulty encountered in the teaching of anatomical variants is the inability to retain unique cadaveric specimens in perpetuity. Limited space, variable retention permissions among donors, the challenge of eventual disposal of human tissues, and departmental pressures to shift away from cadaveric material can complicate the creation of an inventory of specimens that exhibit noteworthy variations. Digital archiving provides an alternative means of preservation when permanent storage is not an option. Several different technologies have been used to document cadaveric specimens that exhibit anatomical variations.[8–11] Here we describe an online catalog of muscle variants comprised primarily of case reports and videos. Student surveys were administered to gauge the utility and future directions of this project.

METHODS

Development and Description of Online Catalog

University of Western States (UWS) students participate in cadaveric dissection during the first 3 quarters of a 12-quarter Doctor of Chiropractic Program (DCP). Anatomical variations are inevitably encountered as students perform routine cadaveric dissection in the anatomy lab. Over the course of several quarters, noteworthy variations were documented and assembled into an online catalog titled *Anatomical Variants*. The catalog was hosted on UWS webCampus, a Moodle-based learning management system (LMS). The *Anatomical Variants* resource was designed to augment the traditional lecture and laboratory methods used in gross anatomy instruction by facilitating student self-directed learning of muscle variants. The content included in this online catalog was not directly assessed in any course at UWS.

To promote ease of use, the *Anatomical Variants* resource employed a simple layout. A brief written overview was featured at the top of the home page, including an introduction and the standard warning used at UWS regarding the distribution of files that contain cadaveric images or video. Each digitally archived muscle variant was identified by a heading. A case report (or reports) and additional files were linked below the heading (Fig. 1). Case reports included a gross description of the muscle variant, photographs of the relevant region of the body (Fig. 2), a review of the literature, and a summary of the clinical relevance of the variant structure. All case reports were uploaded in Portable Document Format (PDF). Brief, narrated videos (18–50 seconds in duration) were embedded as hyperlinks using the Panopto Video Platform (Panopto, Seattle, WA) (Fig. 3). This platform is an effective management system that is used to store and share educational videos created by UWS faculty and staff. Video files that are hosted onto the Panopto Video Platform can be integrated into the LMS and streamed on a variety of devices. Netter plates (anatomical drawings by Frank H. Netter, MD) were downloaded from the Netter Presenter (Elsevier, Amsterdam, Netherlands) online database and then uploaded to the LMS to foster comparisons between variant structures and the typical regional anatomy relevant to the case reports. All usage of images from the Netter Presenter was in accordance with the institutional license agreement between the publisher and UWS. When first made live, the *Anatomical Variants* online resource featured 22 case reports of 13 different muscle variants (Table 1). Where possible, the case reports were written to emphasize the potential clinical importance of the muscular anomaly.

Student Assessment of Online Catalog

This study was reviewed and approved by the UWS institutional review board. Students enrolled in the DCP at UWS as of January 2017 ($n = 451$) were notified by e-mail that a new catalog of muscle variants had been created by faculty members of the Department of Basic Sciences. Students were encouraged to reply to the e-mail if they wished to view the catalog of variants. A second e-mail was sent 1 week later. Students who expressed interest in viewing the resource could do so through the LMS, either on campus or remotely. A total of 96 students indicated that they were interested in viewing the catalog. User participation, which can be monitored on the LMS, showed that 17 students did not access the online catalog. An anonymous online survey was included on the LMS with the following text listed below the link: "Please provide feedback on this resource. Thank you." In the second e-mail seeking student enrollment, a link to the survey was included to prompt users already familiar with the resource to provide feedback. A reminder notification that included the survey link was sent via the LMS news forum 2 weeks after the catalog was first hosted online. The survey, which consisted of Likert-type and open-ended questions, was designed to gather feedback pertaining to the value, overall features, and future directions of the *Anatomical Variants* catalog. A total of 40 students completed surveys.

Statistical Analysis

Statistical analysis was performed using GraphPad Prism software version 6 (GraphPad, San Diego, CA). Nominal data were analyzed using the Fisher exact test to

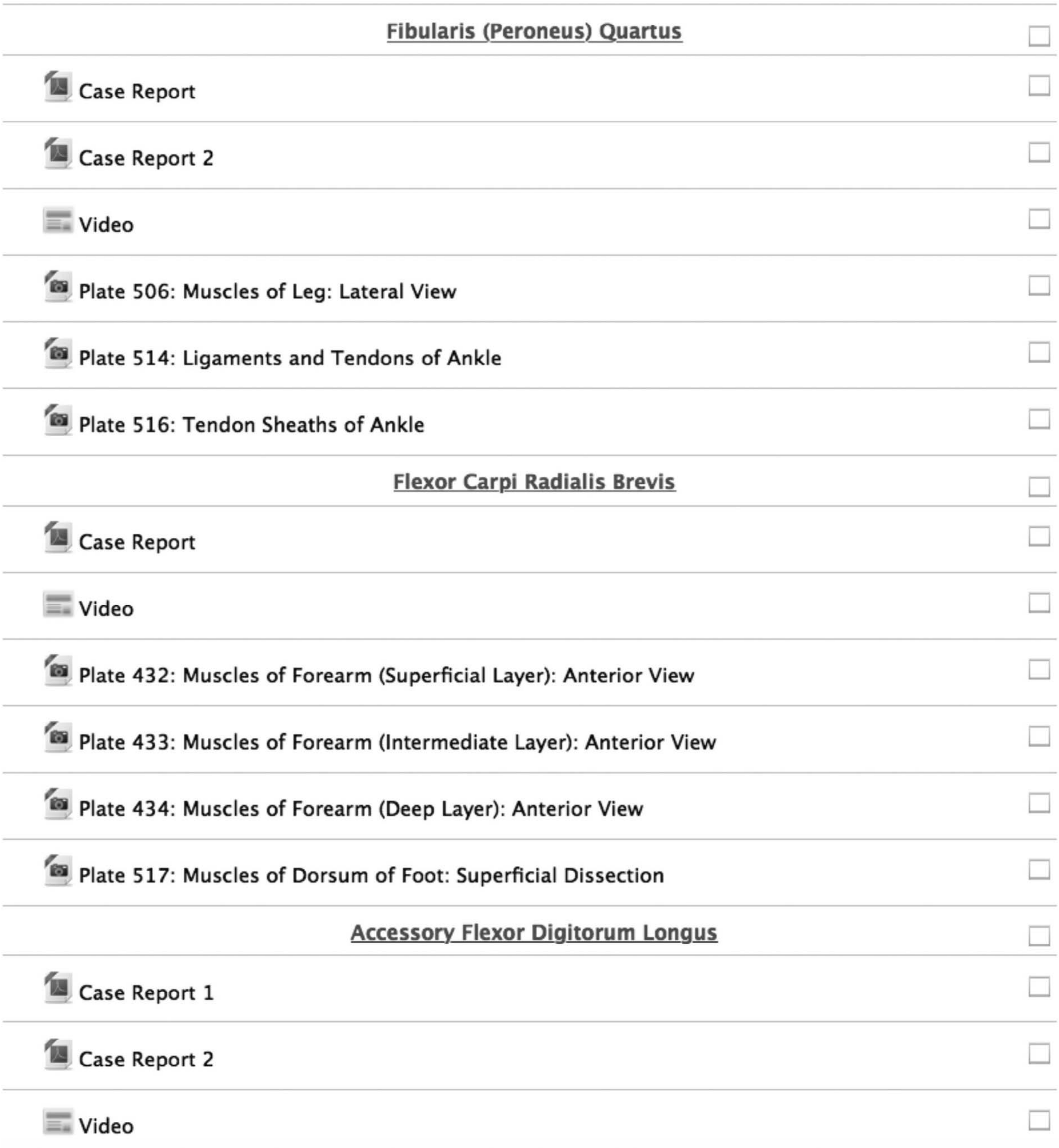

Figure 1 - Excerpt from home page of the *Anatomical Variants* online resource.

compare differences between groups. Data were considered significant when $p \leq .05$.

RESULTS

Respondent Demographics

Data were collected over a 3-week window following the day the *Anatomical Variants* resource was made live. In that time frame, of the 79 students who accessed the online catalog, 40 students completed surveys (50.63%). Of these 40 participating students, 23 (57.5%) were in quarters 1–3, 7 (17.5%) were in quarters 4–6, 7 (17.5%) were in quarters 7–9, and 3 (7.5%) were in quarters 10–12 of the DCP. At the time of survey dissemination and completion, students in quarters 1–3 were enrolled in 1 of the gross anatomy courses offered at UWS (BSC 5103: Gross Anatomy I, BSC 5203: Gross Anatomy II, or BSC 5304: Gross Anatomy III). Students in quarters 4–12 were not enrolled in a gross anatomy course at the time of survey completion.

Assessment of Utility

The survey included 5 Likert-type questions that pertained to the utility of the online catalog of muscle

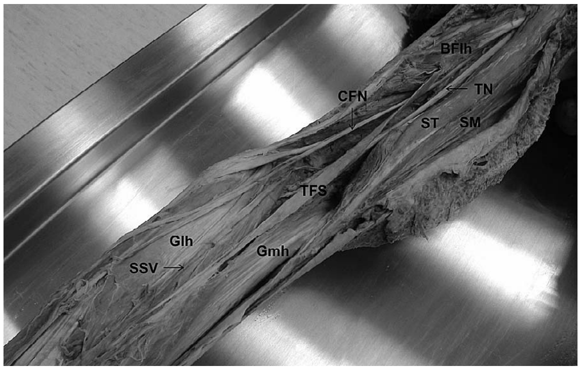

Figure 2 - Sample photograph of a muscle variant included in the online catalog. Posterior view of left thigh, popliteal fossa, and leg (TFS, tensor fasciae suralis muscle variant; Glh, lateral head of gastrocnemius muscle; Gmh, medial head of gastrocnemius muscle; SSV, small saphenous vein; TN, tibial nerve; CFN, common fibular nerve; ST, semitendinosus muscle; SM, semimembranosus muscle; BFlh, long head of biceps femoris).

variants (Fig. 4A). Overall, student responses indicated that the catalog was educationally valuable: 97.5% strongly agreed/agreed that the resource helped enhance their awareness of muscle variants, 100% strongly agreed/agreed that knowledge of muscle variants will be useful in future clinical practice, 100% of respondents strongly agreed/agreed that the resource was easy to use, 95% strongly agreed/agreed that they could learn at their own pace using this resource, and 97.5% strongly disagreed/disagreed that muscle variants are not interesting.

Figure 3 - Screenshot from video created to document an accessory soleus muscle.

Assessment of Features

Four Likert-type survey questions prompted students to assess components of the *Anatomical Variants* resource (Fig. 4B). Student feedback validated the merit of specific features: 100% strongly agreed/agreed that the videos helped advance their understanding of muscle variants, 100% strongly agreed/agreed that the cadaveric photos were of satisfactory quality, 87.5% strongly agreed/agreed that atlas images aided in the comparison of normal and variant structures, and 45% disagreed that the case reports were too brief (17.5% strongly agreed/agreed and 37.5% neither agreed nor disagreed).

Table 1 - List of Muscle Variants Initially Included in the *Anatomical Variants* Resource

Muscle Variant	Number of Case Reports	Associated Conditions
Accessory anterior belly of the digastric	4	May mimic a mass or lymph node on imaging or physical examination[12]
Accessory tendon of extensor hallucis longus	3	Hallux valgus deformity[13,14]
Fibularis quartus	2	Ankle pain[15] and/or instability,[16] fibularis tendon tears,[17,18] tenosynovitis[19]
Flexor carpi radialis brevis	1	Compression of the median nerve,[20] tenosynovitis[21–23]
Accessory flexor digitorum longus	2	Tarsal tunnel syndrome,[24–27] clubfoot,[28] flexor hallucis syndrome[29]
Accessory head of flexor pollicis longus	1	Anterior interosseous syndrome,[30–35] pronator teres syndrome[34–36]
Gracillimus orbitis	1	Unknown (possible role in certain types of strabismus)[37]
Reversed palmaris longus	2	Compression of the median nerve[38–44] and/or ulnar nerve[38]
Pectoralis minimus	1	Speculated to cause compressive injuries of the thoracoacromial vessels[45,46]
Accessory soleus	1	Painful/painless soft mass,[47–49] compression of the tibial nerve,[50] tarsal tunnel syndrome,[51] speculated to cause localized compartment syndrome[49,52]
Absent sternothyroid	1	Unknown, possible implications for speech, swallowing, and/or mastication[53]
Tensor fasciae suralis	2	May mimic a Baker's cyst,[54] speculated to cause compressive injuries of the popliteal vein[55] and the sciatic, tibial, and/or sural nerves[56]
Sternalis	1	May be misdiagnosed as a breast mass during mammography[57,58]

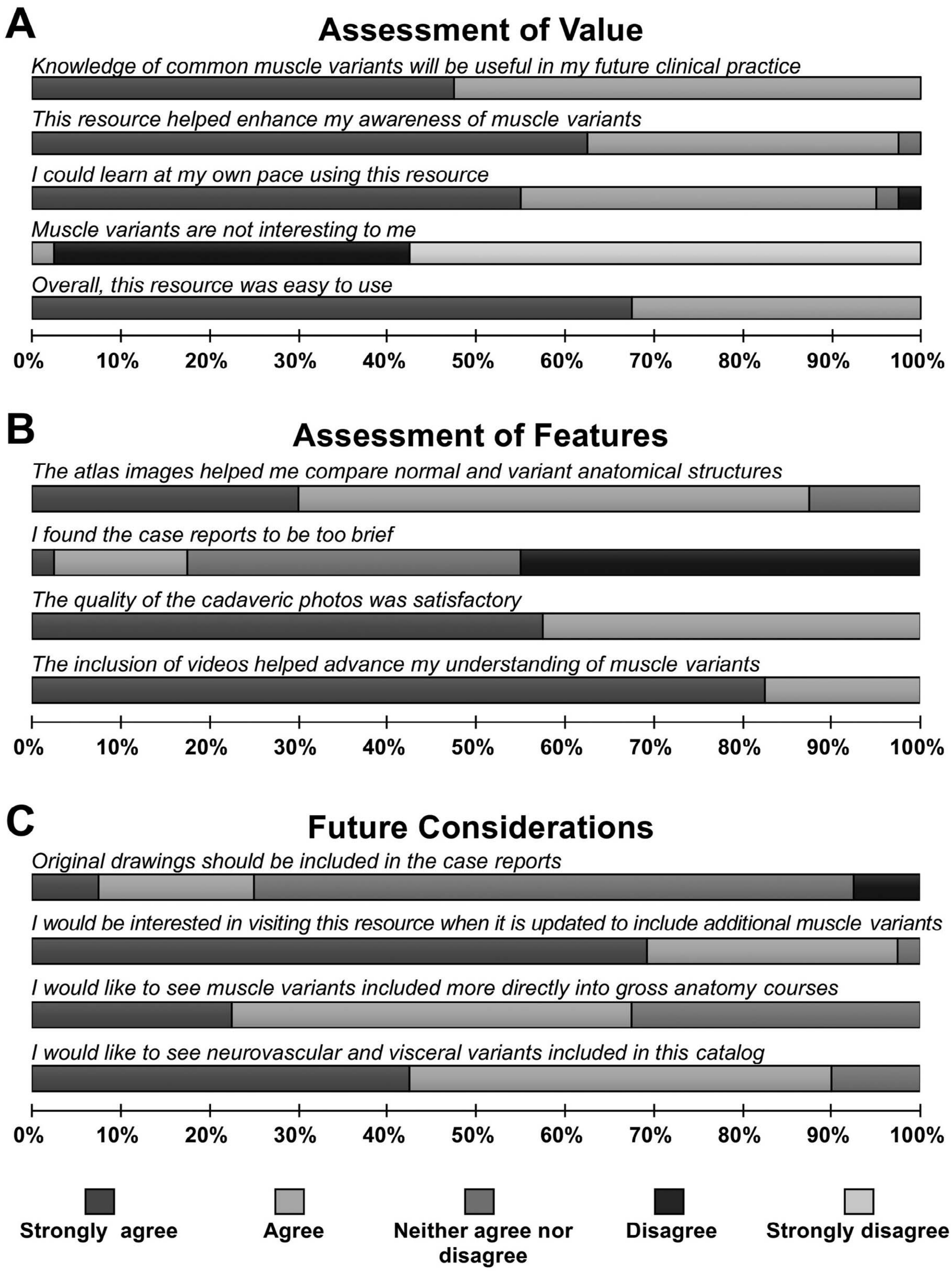

Figure 4 - Student responses to Likert-type survey questions focused on the value, utility, and future directions of the online catalog of muscle variants ($n = 40$).

Table 2 - Open-Ended Survey Questions

Question	Answered	Sample Comment
What are the strengths of the online muscle variants resource?	30	"I really like the videos and the case reports. If I didn't quite get the whole picture of the variant from the written report, the video immediately made it clear for me."
How could the *Anatomical Variants* webCampus resource be improved?	17	"A photo from another cadaver that lacked an anatomical variant could be added to each set . . . to help deepen the appreciation for the anatomical variants."
Please leave any other comments/feedback in the space below:	12	"I'd definitely like to play a part in future case studies."

Future Considerations

Four Likert-type questions that focused on the future development of the *Anatomical Variants* online catalog were included in the survey (Fig. 4C). Responses to these questions helped inform the manner in which the catalog will be expanded in the future: 90% of students strongly agreed/agreed that they would like to see neurovascular and visceral variants included in the catalog, 97.4% strongly agreed/agreed that they would be interested in visiting the resource again when additional muscle variants are included, 67.5% of students strongly agreed/agreed that they would like to see gross anatomy courses include muscle variants (32.5% neither agreed nor disagreed), and 25% strongly agreed/agreed that original drawings should be included in the case reports (67.5% neither agreed nor disagreed, and 7.5% disagreed).

Gauging Student Interest for Future Participation

All materials included in the first iteration of the *Anatomical Variants* resource were instructor created. The following yes/no survey question was used to gauge interest in the possibility of involving students in the creation of future content: "Would you be interested in contributing to the *Anatomical Variants* resource (writing case reports, performing literature searches, sketching diagrams, etc.) when new muscle variants are discovered in the anatomy laboratory?"

For this question, 23 students (57.5%) replied yes, while 17 (42.5%) replied no. Responses were not significantly associated with concurrent enrollment within an anatomy course ($p = .7492$, 2-tailed Fisher exact test).

Student Responses to Open-Ended Questions

Three open-ended questions were included in the survey (Table 2). Of the 30 responses to question 1, the following categories were mentioned as strengths: multimedia features (11 responses, 36.7%), organization/ease of accessibility (8 responses, 26.7%), clinical relevance/appropriateness for the chiropractic profession (6 responses, 20%), and learning/applying anatomy in a different way (5 responses, 16.7%). For question 2, 23 students contributed feedback to help improve the *Anatomical Variants* resource; however, 6 responses were deemed not applicable and were excluded. Replies were grouped into the following categories: modifications to the layout/organization of the catalog and its features (5 responses, 29.4%), inclusion of a greater amount of content (5 responses, 29.4%), suggestions for more effective comparison techniques between normal and variant structures (4 responses, 23.5%), and augmentation of the aspects focused on clinical relevance and applicability for chiropractors (3 responses, 17.6%). Question 3 elicited the fewest number of responses of the open-ended questions. A total of 12 students contributed comments, which were categorized as statements of encouragement regarding the catalog (7 responses, 58.3%), further suggestions for improvement (3 responses, 25%), or offers of future participation (2 responses, 16.7%).

DISCUSSION

From Vesalius in *De Humani Corporis Fabrica* to Bergman in his landmark *Compendium of Human Anatomic Variation: Text, Atlas, and World Literature*, anatomists have long been interested in documenting human variability. We created case reports and brief videos to document muscle variants found during routine educational dissection. The content was hosted on an online interface to provide students an opportunity for self-directed learning. Student feedback was solicited; 40 students completed surveys, and the data revealed that respondents found the catalog to be a beneficial adjunct to their gross anatomy programming. More than half of the respondents indicated that they would actively participate in the continued development of the resource. The willingness to create content for the catalog was not dependent on concurrent enrollment in an anatomy course.

The way in which variations are taught in medical anatomy curricula is, not surprisingly, variable. A survey that focused on the formal inclusion of anatomical variations in undergraduate medical curricula, sent to anatomy faculty from 110 accredited allopathic medical schools in the United States, showed that consensus exists among faculty members related to the benefits of students learning anatomical variations; however, the inclusion of variations was found to be highly inconsistent across the schools surveyed.[59] Most educational leaders of surgical and radiology residency programs in Canada and Australia report that resident doctors would benefit from increased instruction in anatomical variations during undergraduate medical education.[2] Willan and Humpherson have argued that content related to anatomical variation should be included early in undergraduate medical education, with the anatomy laboratory designated as the ideal venue for learning.[60] Although we were unable to directly integrate the teaching of anatomical variants into existing courses and dissection laboratories (because of curricular restraints), our approach enabled students to access in depth content in an online catalog that included images and videos of well-dissected specimens.

A survey of anatomy faculty at institutions of chiropractic education indicated that faculty members from 62% of the polled schools have published articles in the "normal variants and anatomical anomalies" category.[6] The reported percentage in this category was higher than any other publication area included in the survey, demonstrating that anatomy faculty members at chiropractic institutions are aware of the scholarly opportunities that anatomical variations can present. Indeed, 2 case reports that were first created for inclusion within our online catalog have been published in anatomical journals.[53,61]

As exemplified as early as the works of Vesalius, the desire to document unique anatomical variations has existed among anatomists for centuries.[62] Digital preservation of cadaveric material is a natural manifest of this same spirit, as it serves as a more modern means of documenting variation. Where once the anatomist relied on drawings or wet specimens, greater options exist today for preserving unique cadaveric samples. Since the creation of the Visible Body Project,[63] various technologies have been used to digitally archive noteworthy specimens. Nieder and colleagues suggested that photorealistic virtual reality could be used to create an online resource of variants.[11] An array of technologies, including photogrammetry, object virtual reality, and interactive PDF, were utilized by Jocks and colleagues to document both typical and variant specimens.[9] Three-dimensional modeling technologies, such as magnetic resonance imaging[8,10] and microcomputed tomography, have been used to digitally preserve examples of variant anatomy.[8] The multimedia aspects included in the *Anatomical Variants* resource are not intended to replace the dissection lab. Rather, the intent in creating this catalog was to augment the learning opportunities afforded by cadaveric dissection by documenting interesting and relevant specimens. In this manner, specimens have the potential to serve as teaching resources long after they have been returned to the body donation program for cremation. Additionally, by hosting specimens on the campus LMS, there is the potential for a greater number of students to learn from a given variant example rather than limiting the educational impact to the lab attendees at the time of discovery.

Various studies have been published regarding the usability of cadaveric dissection videos, either to substitute or supplement dissection[64–71] or to reduce anxiety associated with the dissection experience.[72,73] The videos created for this project were designed to be as brief as possible and therefore focused mainly on the structure and regional relationships of the specific muscle variant. In a massive study of the online viewing habits of students, Guo and colleagues found that shorter videos were more effective than longer videos in retaining student attention.[74] In addition to videos, case reports of each anomaly were included in the online catalog. Case reports are considered a time-honored vehicle for teaching others. Among other things, case reports should document unusual findings, be succinct, and add value to diagnosis or management.[75] Anatomical case reports have identified novel structures for centuries, a statement that is evident in the tremendous work of Bergman and colleagues whereby case reports from 884 journals (14th century to modern times) were incorporated into a centralized source.[1] With respect to our project, the majority of students found the case reports included in the *Anatomical Variants* resource to be of adequate length, and respondents revealed an interest in having access to case reports that will be created in the future.

Multiple academic journals publish case reports focused on anatomical variation; however, it is unfair to expect students to peruse these reports in addition to their expected academic load. By creating the *Anatomical Variants* online catalog, we aimed to facilitate student self-directed learning of human variability by creating a manageable amount of content. Initially, this resource was focused on muscle anomalies, as the authors believe them to be the most relevant type of variation for the chiropractic profession. Student feedback was generally positive regarding the utility of this project and the individual features that are included within it.

Future Directions

Student feedback was helpful in determining how the catalog of variants could be developed most effectively in the future. In general, survey responses indicated high levels of agreeability in student interest in visiting the resource again later. As such, there are plans to continuously update the online catalog with additional content when noteworthy muscle variants are identified in the UWS anatomy laboratory. Survey responses indicated that 57.5% of students would be interested in contributing to the online resource in the future. There was no difference in the level of interest between students enrolled in an anatomy course at the time of survey completion compared to students who were not enrolled. Student involvement, beyond the dissection of specimens, will be sought in the future development of content for the *Anatomical Variants* catalog. Between the end point of data collection and the time of publishing, 2 students were invited to contribute anatomical drawings to be incorporated within existing case reports (Figs. 5 and 6). It is predicted that student participation, combined with quality control review by current anatomy faculty, will benefit the educational impact of the catalog while providing a framework for self-directed learning.

Perhaps the most exciting possibility for this project is the inclusion of material beyond the realm of gross anatomy. With respect to the *Anatomical Variants* resource, collaboration with faculty who teach in the basic, clinical, and chiropractic sciences could help integrate both normal and variant anatomy into many subject areas of the DCP by encouraging student self-directed learning. For example, case reports integrating content related to human development, genetics, histology,

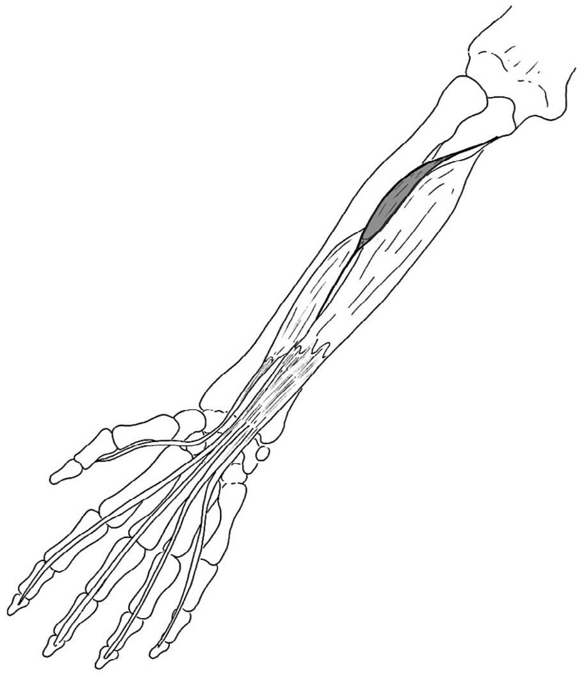

Figure 5 - Student-drawn diagram of right forearm, wrist, and hand. Flexor carpi radialis brevis muscle outlined in red.

pathology, surface anatomy, biomechanics, radiology, physical examination, diagnosis and management, and/or manipulation are possible. The benefit of teaching in a multidisciplinary approach is a worthwhile educational opportunity afforded by anatomical variants.[76] Additionally, this resource may benefit academic programming offered at UWS outside of the DCP, such as massage therapy, sports medicine, or diagnostic imaging and residency.

CONCLUSIONS

The *Anatomical Variants* catalog available to UWS DC students was designed with the goal of providing an opportunity for student self-directed learning of human muscular anomalies. The authors do not present a solution to the place that human variability should hold within medical education. Rather, the goal of this project was to instill future chiropractic physicians with an understanding that anatomical variations are abundant and often clinically relevant despite their limited inclusion in gross anatomy courses. Student responses in an online survey indicated that the catalog was useful. Additional content, including conspicuous and clinically relevant neurovascular and visceral anomalies, will be developed to augment the existing materials.

ACKNOWLEDGMENTS

The authors wish to thank individuals who donate their bodies and tissues for the advancement of education and research.

Figure 6 - Student-drawn diagram of anterior neck to document an absent left sternothyroid muscle.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare. Funding provided by the University of Western States.

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This article was received August 14, 2017; revised October 26, 2017; and accepted November 14, 2017.

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