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Research Article

Participation in an Advanced Anatomy Capstone Project Facilitates Student Involvement in the Development of an Instructional Tool for Novel Dissection

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Introduction. Student-driven design of instructional tools within basic sciences curricula in general, and in anatomy in particular, has been shown to be both a positive educational experience for the student developers and a viable way to create quality materials for future courses. We present here a description of a student collaboration arising from participation in an advanced anatomy capstone research project, resulting in the creation of a new dissection protocol for the thoracolumbar junction dorsal primary rami and their branches. *Materials and Methods*. This project was initiated by two third-year doctor of physical therapy (DPT) students and involved participation from faculty and other DPT students of varying experience levels, in order to pilot and refine the tool over a two-year period. We describe the process by which the tool was developed, from the genesis of the original idea through the piloting stage. *Results and Discussion*. This collaboration resulted in a new instructional tool to be launched within our first-year DPT gross anatomy labs in 2022. Evaluation of the project through qualitative interviews demonstrated the learning impact on student participants. *Conclusions*. The success of this project shows the potential for students to be meaningfully involved in instructional tool design. The complete dissection guide, along with photos, is included and will be of particular relevance for medical and health science educators with an interest in orthopedics, neurosurgery, pain management, or physical therapy.

1. Introduction

Student-driven development of instructional tools in medical and allied health education has been increasingly recognized as a valuable way to both engage students in their learning and incorporate end-user perspectives into course design [1, 2]. One way to involve students in this process is through the creation of original instructional materials within the framework of advanced, elective, foundational sciences coursework [3]. Opportunities for advanced anatomy learning through electives or independent study have been shown to be an effective means of integrating anatomy into academic clinical content and as a way to prepare students for clinical experiences [4–6].

In this report, we describe the development of a dissection tool (Table 1) that arose from the work product of an advanced anatomy capstone research project within a Doctor of Physical Therapy (DPT) program. This tool describes two approaches to the dissection of the branches of the dorsal primary rami (DPR) of the spinal nerves. These are clinically relevant structures but are not commonly dissected in an introductory gross anatomy lab course.

The tool described herein was created through a unique collaboration involving four students and two faculty over a two-year period. The planning and execution of the initial dissection was done by two third-year DPT (DPT3) students and was followed by a piloting process of the original dissection guide by a third DPT3 student and completion of

Table 1: Dorsal primary ramus dissection guide.

General approach. When planning this dissection, it is important to recognize that the branches of the dorsal primary rami (DPR) pass not just dorsally, but quite inferiorly as they descend several vertebral levels from the bifurcation of the DPR and the ventral primary rami (VPR). To ensure preservation of the superficial nerve branches contained in the muscles of the low back, the approach detailed below begins inferiorly and superficially and follows the nerve branches back to their deeper, more superior origins.

Dissection step	Instructions
(1) Landmark identification and skin removal	*Basic dissection*: place the cadaver in prone. Remove the skin but preserve the subcutaneous fat in the lower thoracic, lumbar and upper gluteal regions. *Advanced dissection*: the skin should initially be preserved in order to identify the superior cluneal nerves (SCNs). Begin by labelling with marker key landmarks in the region of interest which will be useful as the dissection progresses. These include the spinous processes of T10 to L5, the posterior superior iliac spine (PSIS), the twelfth rib, and the iliac crest from the PSIS to the anterior superior iliac spine (ASIS). The SCNs typically pierce the thoracolumbar fascia (TLF) just superior to the rim of the iliac crest and continue inferiorly in the adipose tissue until they reach their target tissues in the skin of the upper gluteal region. You will, therefore, look for the SCNs in the subcutaneous fat and skin of the upper gluteal region beginning just below the iliac crest, in a zone between the PSIS medially and the tubercle of the iliac crest laterally.
(2) Identification and cleaning of superior cluneal nerves	*Advanced dissection* (Figure 1): make a vertical cut through the skin running from the PSIS superiorly to the level of the L4 spinous process and make a second parallel vertical cut laterally at the midaxillary line. Connect these two cuts with shallow horizontal scalpel cuts, which will result in a rectangular region in which the terminal branches of the SCNs can be found. Begin to peel the skin downwards while using a probe and forceps to identify the cutaneous branches of the SCNs passing through the subcutaneous fat. After you have identified the SCN branches, carefully clean the fat that surrounds each one. Making sure to preserve this region of skin and subcutaneous fat supplied by the SCNs, you can now remove all other proximal skin and subcutaneous fat up to the thoracolumbar junction (TLJ) exposing the TLF and superficial back muscles.
(3) Identification of lateral branches of dorsal primary rami piercing thoracolumbar fascia	*Basic and advanced dissection* (Figure 1): identify how the SCNs merge into the lateral branches of the T12 and L1 DPR, which penetrate the TLF and then pass deep into the iliocostalis (IC) lumborum muscle. Continue to trace the lateral branches of the DPR as they pass through the deeper layers of posterior spinal musculature proximally to their origin at the TLJ.
(4) Removal of thoracolumbar fascia	*Basic and advanced dissection*: to clear the dissection field, remove the TLF, except for the inferior portion through which the SCNs pass. Remove the serratus posterior inferior muscle and all superficial fascia from the surface of the ES muscles. Use your fingers and probe to define the borders between the IC, longissimus (LG), and spinalis muscles.
(5) Transection and reflection of erector spinae muscles	*Basic and advanced dissection*: the next part of the dissection involves cutting and reflecting the ES muscles inferiorly in order to identify the lateral and medial branches of T12 and L1. Begin by making a transverse cut through the IC and LG muscles at the level of T10. You do not need to transect or reflect the spinalis or the multifidus muscles. Then, carefully reflect IC and LG inferiorly using your hands and scissors as needed (Figures 2 and 3). You will need to cut LG away from spinalis in order to reflect it inferiorly. Palpate for the floating ribs in order to orient yourself to the correct spinal level.
(6) Cleaning and following the T12 lateral branch from the L1 transverse process distally towards the iliac crest	*Basic and advanced dissection*: as you peel back the IC and LG muscles inferiorly, you will see lateral branches of the higher spinal nerves (T9–T11) penetrating these muscles. Cut these higher branches in order to facilitate the downward reflection of these muscles. Use a probe and blunt scissors to hollow out the muscle tissue surrounding the lateral branches of T12 and L1 so that the nerve will not be stretched and torn as you reflect the muscles. Carefully clean and follow-up to 3 levels of lateral branches from where they exit the lateral foramen, pass over the transverse process of the vertebrae below, and continue into the IC muscle.

Table 1: Continued.

(7) Identification of the medial branch of T12	*Basic and advanced dissection*: identify the medial branch of the T12 DPR as it branches medially off of the DPR at about an 80-degree angle (Figures 2 and 4). Careful removal of connective tissue surrounding the nerve, using scissors and mosquito forceps, is required in order to expose the course of this delicate branch. *Advanced dissection*: however, before attempting the full dissection of the medial branch, identify and highlight the borders of the mamillo-accessory ligament (MAL).
(8) Cleaning and opening of tunnel under mamillo-accessory ligament	*Advanced dissection* (Figure 4): the MAL passes over the T12 medial branch running from the mammillary process of the superior articular facet of L1 to the accessory process of the transverse process (TP) of L1. Use the tip of the mosquito forceps to open the tunnel under the MAL and carefully clean and expose the medial branch on both sides of the MAL.
(9) Following the medial branch to its targets	*Basic and advanced dissection*: medial to the MAL, you can follow the medial branch as it passes into the multifidus (MF) muscle (Figure 5). In a very careful dissection, you may be able to identify the articular branches from the medial branch that pass into the superior and the inferior facet joints (Figure 5).
(10) Finishing cleaning of the T12 dorsal primary ramus	*Basic and advanced dissection*: follow the nerve superiorly, if possible cleaning the DPR up to its bifurcation with the ventral primary ramus (VPR) and the spinal nerve of T12. Although it is not strictly required for this dissection, removal of some portions of the multifidus muscle may aid in exposing more of the spinal nerve, as well as portions of the medial branch.
(11) Repetition of dissection with L1 dorsal primary ramus	*Basic dissection*: repeat the above steps for the L1 DPR so that you cleanly demonstrate DPR and medial and lateral branches. *Advanced dissection*: expose the superior cluneal nerves, associated with this spinal nerve.
(12) Exposure and cleaning of TPs and facet joints of T12 and L1	*Basic and advanced dissection*: clean tissues from the TPs of L1 and L2 and the T12/L1 and L1/L2 facet joints to clearly demonstrate their relationships to the nerve branches.

tool piloting by a first-year DPT (DPT1) student. Students worked independently with their cadavers to execute the dissection, with as-needed, hands-on faculty support available within the lab as they dissected. Student input was incorporated into the guide at every stage to increase the ultimate usability for our student end-users. Project evaluation entailed in-depth student interviews regarding their perceptions of the value of this process and their roles in the development of the tool (Table 2).

2. Materials and Methods

Authorization for the present research was received from the body donor program that provided our cadaver donors, and exemption from human subjects review was obtained from the Thomas Jefferson University Office of Human Research.

As part of a capstone research project, two DPT students were charged with performing a literature review and independent dissection on a topic of clinical relevance to them. The short-term goal was to create a research poster to use for peer-teaching within the department on their chosen topic. They selected Maigne's syndrome, a segmental dysfunction of the facet joints at the thoracolumbar junction (TLJ), with secondary referred pain to the ipsilateral iliac crest and buttock regions [7–9]. A literature review on the syndrome, as well as on the anatomy of the DPR and possible dissection approaches, was then conducted during this first semester. The following semester, the students performed a dissection of the T12 and L1 DPR, with as-needed guidance from anatomy faculty, and using a dissection plan they devised themselves, due to a dearth of coverage of these structures in traditional anatomy dissectors. During the third semester, they created a research poster on the project based on their literature review and photos from the dissection. This was presented internally at our institution at an annual student poster day, as well as at the annual meeting of the American Association of Anatomists later that year.

Based on positive feedback from faculty and encouragement from attendees at the anatomy conference, the students were motivated to transform their DPR dissection instructions into a formal dissection guide appropriate for use by other DPT and medical students. In general, our anatomy courses are developed using an approach based on the Analyze, Design, Develop, Implement, and Evaluate (ADDIE) model of instructional design. This intuitive model commonly used in nursing and medical education instructional design [10–12]starts with a baseline student needs analysis, and culminates in a formal evaluation stage. Importantly, it also threads formative evaluation and reassessment into the design and development stages of both course content and instructional materials [10]. We thus found it to be a useful framework for the iterative process by which we planned to create, pilot, and revise the dissection tool.

With faculty guidance, the description of the students' dissection methods was expanded and adapted into the dissection guide format used by core anatomy faculty within our academic department. This initial guide was piloted with

Table 2: Observations from the originator, the reviser, and the end-user: student reflections on their involvement in the development of a novel dissection and dissection guide educational tool.

Description of student roles

Although there were some overlaps, three distinct roles were identified during the interview process which characterized student involvement in the development of the dissection tool. These roles were *originator*, *reviser*, and *end-user*.

The originator was a 3rd year Doctor of Physical Therapy (DPT3) student who selected the topic for the literature review and dissection and led the team of two DPT3 students in planning and conducting the original dissection. The originator had successfully treated a patient with low back pain (LBP) on a prior clinical affiliation, who had presented with signs and symptoms consistent with a dorsal primary (DPR) syndrome. The students worked independently, with minimal guidance from the supervising anatomy instructor, to perform a literature review and the dissection described elsewhere in this manuscript. The originator worked subsequently with the supervising faculty member to develop a step-by-step checklist for the dissection.

The reviser was a DPT3 student who had participated in advanced anatomy coursework and had worked as a teaching assistant in the DPT1 gross anatomy lab. He performed the dissection independently using the checklist created by the originator and photos of the original dissection, with supervising faculty available in the lab for guidance as needed. The reviser then provided feedback and recommendations for changes and additions to the dissection checklist.

The end-user was a 1st year Doctor of Physical Therapy (DPT1) student who had completed the first-year anatomy course and worked as a graduate assistant on some research-related dissections with anatomy faculty. This student was given the revised draft of the dissection checklist, which included more detailed descriptions, and additional photos of the reviser's dissection. The end-user also received assistance from the anatomy instructor as needed during her dissection. She successfully completed the Basic dissection in two hours, using the revised checklist, photos, and moderate assistance from anatomy faculty.

Themes

Interviews from all three students were analyzed with four dominant themes emerging:

(1) The dissection process was very challenging, with the subtheme that the dissection checklist was useful in mitigating the difficulties inherent in the dissection process. All three students indicated that the dissection was difficult because they had not been exposed to the DPR structures in their DPT1 anatomy course. The reviser and the end-user felt, however, that the dissection checklist was very useful and that the opportunity to have explicit photos of the different stages contributed greatly to their successful completion of the dissection.

"When I went through the first year of anatomy courses we were only told to just know that the dorsal primary ramus innervates the erector spinae muscles. We didn't talk about . . . the branches and I never heard of the mammilo-accessory ligament before. So these are kind of new concepts and I didn't have a visual concept in my head of where they were, what they were, and how they went."— ***The reviser***

"I think that the checklist was helpful. . . I think the format was really good. It was clear and not too crowded. . . . The pictures of the dissection that had been done previously . . . were really helpful"— ***The end-user***

(2) The dissection process of a previously unexplored region had educational value with a subtheme that this dissection is more appropriate for advanced students or those with a strong interest in anatomy. All participants indicated that the dissection had great educational value for students studying anatomy and enhanced their developing knowledge of the evaluation and treatment of patients with LBP. A consistent perspective was that the checklist could be used in basic anatomy courses but would be more appropriate in an advanced course.

"This [dissection] is actually connecting three classes. It's biomechanics, it's anatomy, and it's exam skills . . . for me this experience has really opened my eyes to regional interdependency"— ***The reviser***

"You don't really cover those nerves in [first-year] anatomy . . . and you kind of skip over it when you're doing your dissection . . . [and] it's kind of hard for a novice dissector to not cut them."— ***The originator***

"I think it would have been maybe nice to see it [in first year anatomy], but I think with working in a group of six . . . new students, it would have been difficult to do."— ***The end-user***

(3) T**he dissection has clinical relevance with the subtheme of the importance of understanding the structures in the dissection and the relationship to LBP.** All participants agreed that the dissection had significant clinical application; and allowed the students to see the anatomical structures that could be the cause of LBP for some patients. They felt that completing the dissection increased their ability to understand the concepts of referred pain and the nuances of the different pain-generating structures in the region.

"I think it's interesting because for me personally, I love anatomy and I think it's really important for manual based orthopedic therapy . . . because you need to understand the anatomy and how it connects. It's such a complex [process and] . . . going forward clinically I think I have a tremendously greater understanding of the nerves which was my goal going into this anatomy dissection project. In general, looking at it in the book doesn't really do it justice until you can really get your hands in there, see it, feel it, and look at it . . . in 3D."— ***The originator***

"It could be a tool for introducing the concepts of referred pain. Because . . . you can actually better appreciate how something up in the spinal column can actually affect and travel down and cause pain elsewhere. And how it's important to assess where that source of pain could be coming from . . . [Students] should recognize that hip pain or buttock pain could actually be being caused by something in the back. Do you just look at the buttock? No, you look at the back to clear that. Good PTs clear the lumbar spine first.— ***The reviser***

(4) The process of performing the dissection and helping create this learning tool was exciting and intellectually demanding. All three students expressed that they considered involvement in this project to be a unique opportunity. Their descriptions of their learning processes as they moved through the dissection demonstrated a growing metacognitive awareness.

"I kept telling people about it because . . . it was so exciting . . . and I was really happy to do it. I'm especially interested in neurological type things, and so I think being able to see it and actually appreciate how small the nerve and ligament were . . . Dr. A. kept describing it as 'the width of two eyelashes' and it really was. So being able to see . . . these very small structures . . . was really beneficial for me."— ***The end-user***

"It was interesting to start with the checklist . . . distally and working up proximally. I thought that was very helpful for really helping me create a concept map in my head of where the nerves went. Starting from the end and following it all the way back to the beginning. Because I knew where the dorsal root ganglion was, I knew where the spinal nerve was, and I know where the superior cluneal nerves are . . . But I never saw all these components as a full picture. So that's what made this dissection different."— ***The reviser***

a third DPT3 student who had completed advanced anatomy coursework within the department and worked as a teaching assistant in the DPT1 anatomy lab course. As-needed assistance from the supervising anatomy instructor was provided during this dissection, which took four hours to complete. This student and instructor then revised the dissection guide for clarity and to make it more user-friendly and to allow for completion of the dissection with less faculty involvement. At this time, the dissection instructions were broken down into a basic and an advanced dissection based on available time and the abilities of the dissector. At the end of the third semester, further piloting of the revised guide was conducted with a DPT1 student who had completed the introductory gross anatomy course and who had advanced dissection skills gained through her work as a graduate assistant with anatomy faculty. She was able to perform the basic dissection in two hours, and additional revisions and refinement of the dissection checklist were made based on her feedback, with photos from her dissection added to the final dissection guide.

In the fourth semester, a separate inquiry was conducted by a second faculty member with extensive experience as a qualitative researcher, in order to explore student perceptions about their roles in, and the value of, the project. Three of the four involved students were available to participate in this process and were interviewed separately.

3. Results

3.1. Dorsal Primary Rami Dissection. Instructions for completion of the dissection are provided in Table 1, with explanatory photos of key steps and structures contained in Figures 1–5. The advanced dissection includes branches of the T12 and L1 DPR and can be performed by upper level medical or health sciences students or by highly motivated and skilled first-year students working under the supervision of anatomy faculty. It involves demonstration of the medial and lateral branches in their entirety up to and including the superior cluneal nerves (SCN), the mamillo-accessory ligament (MAL), and the branches to multifidus (MF) and the facet joint. This advanced dissection can take up to 4 hours even when performed by a skilled anatomist. A less complete, basic dissection, will expose most of the pathways of the medial and lateral branches, without preserving the SCNs or the MAL, and can be accomplished by a novice in less than 4 hours.

3.2. Qualitative Evaluation of Student Roles in Project. A detailed summary of the themes that emerged from our evaluation is contained in Table 2. During the interview process, it became clear that the experiences of the three students were widely divergent and separated both in time and by the different tasks and responsibilities they assumed or had been assigned. Three distinct student roles were thus identified: the originator, the reviser, and the end-user. Within the context of these different roles, four common themes emerged from the three interviews as follows: (1) the dissection itself was challenging; (2) both the dissection and the process of developing the tool had educational value; (3) the dissection itself was clinically relevant; and (4) participation in the process was both demanding and personally satisfying.

4. Discussion

The project described here combines a number of desired goals in anatomy teaching: student involvement in anatomy-related research; use of dissection for peer-to-peer teaching; and the application of anatomy knowledge to real world clinical scenarios. This multiyear project resulted in a lasting instructional tool, namely, a dissection guide for a clinically relevant dissection that had not been seen previously in the literature.

Anatomy dissectors routinely make only cursory reference to the DPR, and the existence of the branches of the DPR is all but ignored [13–16]. This is in spite of the fact that they are relevant to certain types of back and neck pain, including pain arising from facet joint arthropathy [17–19] and Maigne's syndrome [8, 20]. The DPR's potential clinical relevance is further demonstrated when one considers the role of the multifidus (MF) muscle in the etiology of low back pain (LBP). This deep stabilizer of the spine is innervated segmentally by the medial branches of the DPR and has been shown in a number of studies to atrophy in the presence of nonspecific LBP [21–23]. Furthermore, iatrogenic injury to the medial branches of the lumbar DPR during spinal surgeries [24, 25], causing denervation of the MF muscle, will also lead to MF atrophy and has been identified in failed back surgery syndrome [26]. A deeper understanding of the anatomy of the DPR and their branches is relevant to both medical and health sciences students. Spinal surgeons, pain management physicians, and anesthesiologists are particularly in need of a deeper understanding of the detailed anatomy of this structure in order to safely perform surgeries, corticosteroid injections, and radiofrequency ablations. Physical therapists also need to be familiar with the anatomy of the DPR in order to recognize potential underlying etiologies related to these nerve lesions in their patients with LBP, and to develop evidence-based treatments.

Based on the feedback we received during follow-up interviews with the students involved in the project, it is clear that they found it worthy and felt that they personally benefitted from their participation. In particular, they believed that the process was challenging and had educational value, and that the dissection was clinically relevant. They also felt excited about their role in the project and expressed an appreciation for the value of dissection in the learning process. They did, however, feel that, due to the complexity of the dissection and the advanced skills required to expose delicate structures without damaging them, this dissection may not be appropriate for all first-year students.

The ADDIE model was a useful framework to guide the creation of our dissection guide. In particular, the ongoing revision of materials based on student feedback and experiences, which are a hallmark of the ADDIE approach [27], led us to pilot and refine the tool with DPT students of

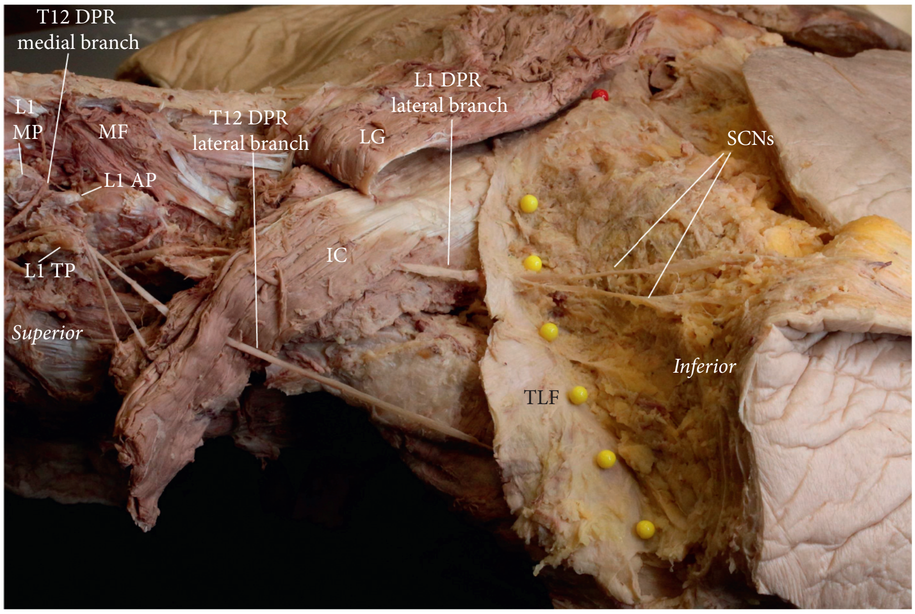

Figure 1: Advanced dorsal primary ramus dissection highlighting superior cluneal nerves. Pin heads indicate path of iliac crest. DPR, dorsal primary ramus; LG, longissimus muscle; IC, iliocostalis muscle; SCN, superior cluneal nerves; TLF, thoracolumbar fascia; TP, transverse process; PSIS, posterior superior iliac spine; MP, mammillary process of superior articular facet; AP, articular process of transverse process.

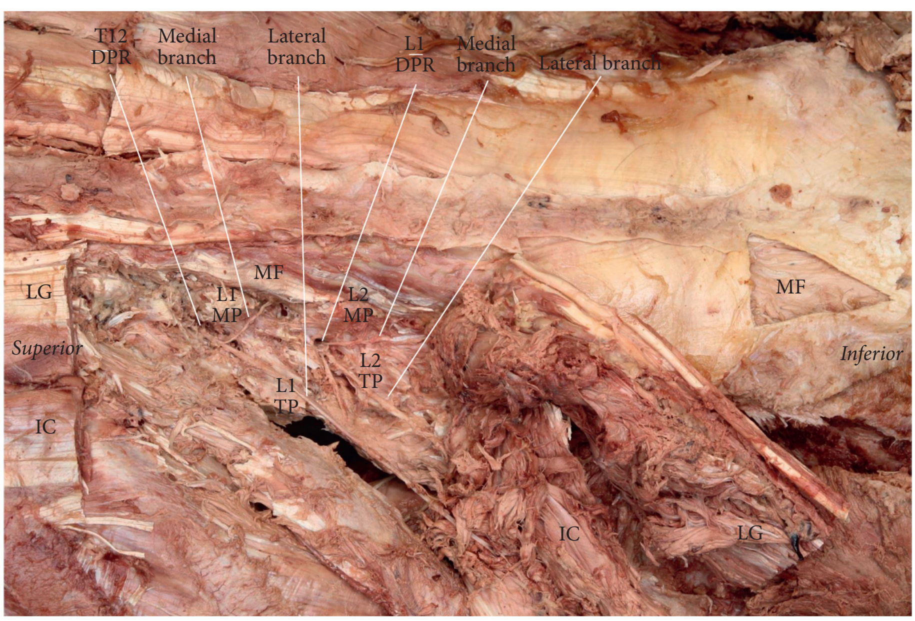

Figure 2: Basic dorsal primary ramus dissection. DPR, dorsal primary ramus; LG, longissimus muscle reflected; IC, iliocostalis muscle reflected; MF, multifidus muscle; MP, mammillary process of superior articular facet; TP, transverse process.

different skill levels. The detailed descriptions of the varying roles of our student collaborators contained in Table 2 highlight how the involvement of each student was built on the work of their peer(s) to achieve a cohesive final end product. ADDIE also supports a type of curation of instructional design that targets different student expertise levels, which guided our team to create two forms of the dissection: the basic and the advanced.

The dissection guide created as a part of this project is unique when compared to existing anatomy instructional materials. Firstly, it covers an area of gross anatomy dissection largely absent in existing resources such as Grant's Dissector [14]. Secondly, it provides two tiers of instructions to meet the needs of the differing ability levels of the students who might be working with the tool. Finally, the instructions within the tool were developed and refined using feedback

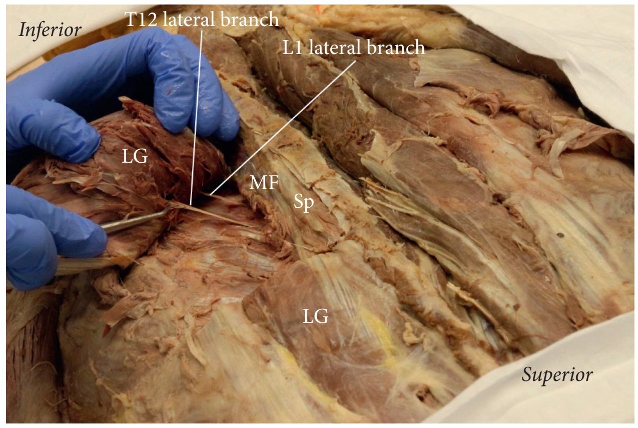

Figure 3: Reflection of erector spinae for basic dorsal primary ramus dissection. LG, longissimus muscle reflected; IC, iliocostalis muscle reflected; MF, multifidus muscle; Sp, spinalis muscle.

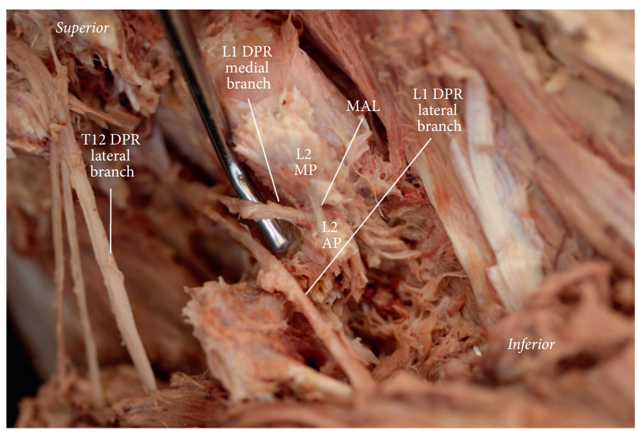

Figure 4: Medial branch of L1 dorsal primary ramus passing under mamillo-accessory ligament. DPR, dorsal primary ramus; MP, mammillary process; AP, accessory process; MAL, mamillo-accessory ligament.

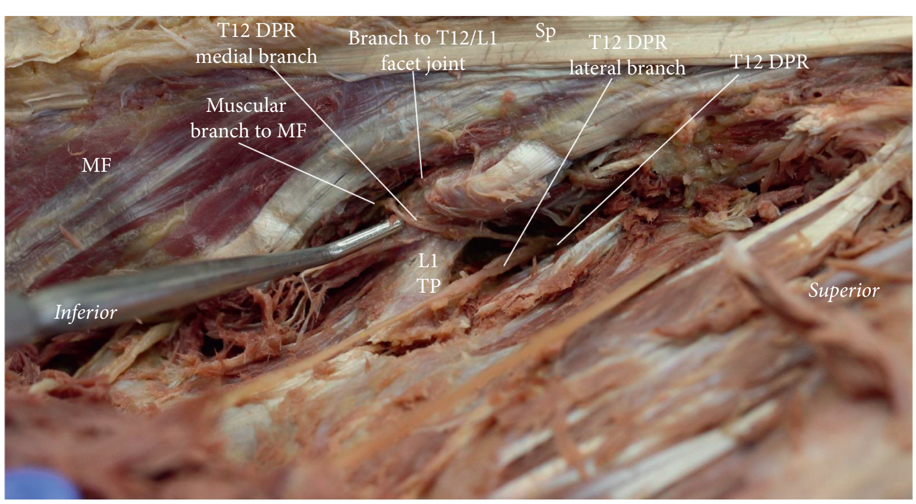

Figure 5: Medial branch of T12 dorsal primary ramus showing muscular branch to multifidus and articular branch to facet joint. DPR, dorsal primary ramus; MF, multifidus; TP, transverse process; Sp, spinalis muscle.

from our target audience of anatomy students to ensure that they were student-centered, appropriate, and user-friendly.

5. Limitations

The time required to develop the tool and pilot it over multiple semesters mandated that the involved students be highly motivated and committed to seeing the project through to a completion extending well beyond their graduation date. Additionally, the temporary move to virtual anatomy instruction in 2020 due to the Covid-19 pandemic prevented piloting of this tool with a large cohort of first-year DPT students. Future refinements of the tool are planned, including introducing it as a voluntary dissection in the gross anatomy lab for DPT1 students at our institution matriculating in the summer of 2022.

6. Conclusions

Student engagement in the development of instructional tools, such as this dissection guide, is feasible and appropriate, and the process can be rewarding for the involved students. A clinically relevant product can be created that is both useful and that fills a gap in available course materials. Ongoing, periodic reassessment of the tool can ensure that it continues to meet the changing needs of students enrolled in both health sciences and medical school anatomy courses.

Data Availability

The data are available through application to the corresponding author.

Disclosure

Authorization for the present research was received from the body donor program that provided our cadaver donors, and exemption from human subjects review was obtained from the Thomas Jefferson University Office of Human Research. No funding was received for this research.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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