Original Publication

Teaching Spinal Cord Neuroanatomy through Drawing: An Interactive, Step-Wise Module

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Abstract

Introduction: This interactive, case-based module was created to provide medical students with self-guided practice to improve their confidence with, and understanding of, neuroanatomy. The module was created to supplement neuroanatomy instruction. It is based on the idea that pictures and drawings are effective tools for teaching clinical neuroanatomy, especially when paired with a step-wise approach to solving clinical cases. **Methods:** The learning module focuses on the basics of spinal cord anatomy and lesion localization, topics fundamental to neuroanatomy. Students who have had a basic introduction to these topics in their neuroanatomy course will find this module a useful educational supplement. A full version of the module, which includes a self-drawing component for additional reinforcement, can be completed in approximately an hour. A shorter version without the self-drawing component, can be completed in less time. The materials associated with the module include an answer packet to use as a guide through the module cases, and both pre- and postmodule practice questions for self-evaluation. Both modules were tested at our institution by separate groups of second-year medical students in the early portion of their neuroanatomy course. **Results:** Both module versions showed significant improvement in confidence levels when describing spinal cord anatomy and lesion localization. Furthermore, students were highly satisfied with the material and reported they were likely to reuse it for additional studying. **Discussion:** The use of this module by medical students during their neuroanatomy course provides a step-wise, case-based approach that simplifies the learning of learning neuroanatomy, and improves their confidence through pictures and drawings.

Keywords

Lesion Localization, Neuroanatomy, Case-Based, Neurology, Spinal Cord Anatomy, Drawing

Educational Objectives

By the end of this session, learners will be able to:

1. Recognize the three major tracts of the spinal cord: spinothalamic, corticospinal, and dorsal column-medial lemniscus.

2. Draw the location of each of these tracts within the spinal cord.

3. Describe the type of information carried by each of the three tracts.

4. Determine the motor or sensory loss that would be expected from interruption of each of the three tracts.

5. Determine the location of a spinal cord lesion from a given motor and/or sensory loss.

6. Determine the motor and/or sensory losses that would result from a specific spinal cord lesion.

7. Practice a step-wise approach to lesion localization of the spinal cord.

Introduction

Neuroanatomy is a difficult topic. Medical students report low levels of perceived knowledge and confidence in learning neuroanatomy.[1] This is attributed largely to difficulty mastering the 3D spatial structures and their relation to 2D sectional representations. Mastering this sectional anatomy is fundamental to lesion localization, a core skill of neuroanatomy and neurology.[2] We have developed a

Appendices

A. Neuroanatomy Module Cases with Drawing.pptx

B. Fill-In Answer Packet Cases with Drawing.docx

C. Neuroanatomy Module Cases Only.pptx

D. Fill-In Answer Packet Cases Only.docx

E. Premodule Practice Questions.docx

F. Premodule Practice Questions with Answers .docx

G. Postmodule Practice Questions.docx

H. Postmodule Practice Questions with Answers .docx

I. Premodule Survey.docx

J. Postmodule Survey.docx

All appendices are peer reviewed as integral parts of the Original Publication.

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self-guided learning module to supplement current medical school neuroanatomy instruction. The module promotes learning and mastery of spinal cord anatomy and lesion localization.

A number of approaches exist to improve learning and retention of neuroanatomy and clinical localization principles. Some studies have explored computer-based methods as a teaching format. In two instances found on MedEdPORTAL, interactive 3D anatomical models of the nervous system, accompanied by tutorials, allow students to identify the levels of the central nervous system as they correspond to a specific set of symptoms.[2,3] Students perceived these methods to be more effective and more enjoyable for learning when compared to print-only materials.[2-5] Another module available on MedEdPORTAL provides students with two cases to review and with questions to answer. Students are expected to work in groups where they must provide written answers for later review.[6] Hands-on methods have also been developed, in which students are guided to create clay models. This approach has been shown to improve testing performance.[7] Other education tools for learning neuroanatomy that are accessible to students include textbooks and online videos that offer explanations, drawings, illustrations, practice questions, and additional guidance in order to provide additional practice in drawing the structures and pathways themselves.[8,9] In developing our module we sought to combine and expand upon these current interventions, to develop a practical and novel approach for improving student understanding of spinal cord anatomy and lesion localization.

First, we wanted to incorporate the idea of learner-generated visualizations as a tool to facilitate learning. Learning is likely to be more meaningful and enduring when students engage with pictorial representations along with verbal explanations.[10] Drawing is an ideal learning strategy for neuroanatomy given the field's high visual-spatial demands, as the activity requires students to directly visualize the anatomy and check their understanding at the same time.[11] In addition, creating visual explanations has been shown to benefit students who have varying levels of spatial abilities.[12] Our module focuses on simplified drawings, and prompts students to draw their own depictions of the spinal cord and its major tracts. By doing so we have incorporated the idea of using a hands-on method that has been seen in previously stated interventions, using learner-generated drawings rather than a computer program or clay as the medium. Some researchers have suggested that complex computer instruction, such as multiple 3D views of the brain, can actually hinder learning by exerting undesirable cognitive load and distraction.[13-15] For this reason, we use basic PowerPoint slides to present simple pictures and directions to students. This allows for the use of an enjoyable technology-based format,[2-5] while also ensuring simplicity.

Second, we wanted to use clinical case-based questions. A great deal of medical education literature calls for the integration of basic science and clinical application to facilitate learning. Many students find that clinical case studies promote interest and help solidify the complex structure-function relationships of neuroanatomy. Furthermore, practice with clinical problems allows medical students to develop essential diagnostic aptitude, a core competency of medical education.[16-18] Our module has students work through three clinical cases with questions that are complemented by active drawing prompts. These provide students the opportunity to apply their anatomical knowledge to clinical situations using learner-generated drawings to guide the connection.

Finally, we incorporated scaffolding into our module to further facilitate student learning. Scaffolding is a well-known instructional theory based on providing students with support to complete tasks. It was a term originally described as a process that enables the learner to problem solve or complete a task that is initially beyond the learner's understanding and capability by guiding the learner to focus on smaller components of the problem or tasks that are within his or her capabilities.[19] This concept of scaffolding has led to the building in of such supports into the fabric of activities and artifacts used during learning.[20] Providing this guided assistance helps the learner to recognize the steps required to reach a solution, so that he or she can go on to solve problems of the same type without assistance. Our module has students approach both prompted drawings and clinical case questions in a scaffolded, step-wise and simplified manner, with the goal of improving student understanding of spinal cord anatomy and establishing greater independence in solving lesion localization problems.

The main target audience of the module is medical students in the early portion of their neuroanatomy course. Nevertheless, its implementation could easily be broadened to include physician assistant, nursing student, medical resident, and other health professions curricula that require knowledge and understanding of neuroanatomy. A basic understanding of spinal cord anatomy and lesion localization is a prerequisite to implementation of the module.

Methods

A self-guided module was created to supplement traditional neuroanatomy instruction of spinal cord anatomy and lesion localization. It utilizes a step-by-step approach, visualizations, and clinical cases to facilitate student learning and confidence in neuroanatomy. It targets medical students currently enrolled in a neuroanatomy course or curricular block, who have had a basic introduction to spinal cord anatomy, spinal cord lesions, and lesion localization.

There are two versions of this module. The Neuroanatomy Module: Cases With Drawing version (Appendix A) includes a review of the three major spinal cord tracts followed by three clinical cases with associated questions and answers. As students work through the review and the case sections, they are prompted to draw their own pictures depicting spinal cord anatomy and nerve tracts to guide their learning and understanding of the material. Premade pictures are also provided within the module for students to reference after completing their own drawings. Answers to the associated questions are provided at the end of the module.

The first section of the Cases With Drawing version of this module is titled "Practice Drawing." In this section, students are instructed to draw out various components of spinal cord anatomy. Designated space for drawing is provided and labeled on the associated answer packet (Appendix B). Premade images for students to compare their own drawings to are provided within the slides of the PowerPoint presentation. The second section of the Cases With Drawing version is titled "Clinical Cases." In this section, students are presented with three different case scenarios. They work through the cases one at time, and are asked to answer clinical-based questions pertaining to the case at hand. They are also prompted to create drawings that pertain to understanding and learning each case. Designated space to record answers and drawings is provided and labeled in the associated answer packet. All spaces are numbered to match the question numbers in the module for easy use and order. Once students have reached the end of the third case, they will encounter slides containing the correct answers to the case questions. They can compare their recorded answers to these for self-evaluation.

As stated previously, we provide students with a printed fill-in answer packet (Appendix B) to be used in conjunction with this version of the module. This packet contains numbered spaces for students to write down their answers to the questions associated with the review and clinical cases sections of Appendix A. It also contains blank spaces for their drawings. This helps students to stay organized as they progress through the module and eliminates the need for additional paper for drawing/scratch paper. In addition, they can review and compare their answers to the correct answers provided at the end of the module in an orderly fashion.

A second, shorter version of the module was created in which the drawing prompts are omitted (Appendix C). The first section of this version is titled "Review Images." In this section, students are simply instructed to review the premade images provided. No practice drawing is involved. The second section of this version is titled the same as in the Cases With Drawing module, (i.e., "Clinical Cases"), and is essentially the same with the omission of drawing prompts. It should be noted that this version of the module was used alongside the full version with the original targeted audience for comparison. It contains the same review, clinical cases, questions and answers, and premade pictures included in the full version. A fill-in answer packet (Appendix D) is available for this version as well.

Both versions were created using Microsoft PowerPoint. Students can navigate through the review and case sections at their own pace, allowing for self-guided learning. This format also allows for easy

accessibility at a later date for additional studying and review. The module can also be converted to PDF format without interrupting the organization and flow.

To use either module, students should open the designated file in PowerPoint. The first slide of the module is a title slide. Upon advancing, the next slide provides a brief overview of the module and contains instructions for completion. Students will advance through the module slides, following the directions found on each slide. Both versions of the module are composed of two sections, to be completed in the order that they are presented.

Regardless of version administered, students also complete six premodule (Appendix E) and six postmodule practice questions (Appendix G). The questions are in multiple-choice format and reflect information related to basic spinal cord anatomy and lesion localization. They may be provided separately as-is or can be combined to create a single set of practice questions for self-evaluation. Both the premodule and postmodule questions have associated answer keys (Appendix F, H) that were provided after completion of the module session.

Students complete a premodule survey (Appendix I) before attempting practice questions or accessing the module. A 5-point Likert-scale is used to assess prior exposure to neuroanatomy education and to establish premodule levels of confidence with spinal cord neuroanatomy and localization. Students also complete a postmodule survey (Appendix J) after completion of practice questions and the module. On this survey, students use a 5-point Likert-scale on the same set of questions to determine changes in confidence with spinal cord neuroanatomy and localization. We also measure the following: perceived difficulty with the activity, perceived satisfaction with the activity, and likeliness of students to reuse the module. Perceptions and comments about the module are also obtained. Any of these can be used in conjunction with the premodule survey to measure changes following use of the module.

At our institution, a single session was held in the afternoon for students to attend. Those who did completed the module and associated materials listed above. The students worked through and completed the module on their own. However, the module and materials may easily be offered to students as a self-guided exercise to complete at home or as a group-based learning session in which students discuss and complete the module together.

Twenty-eight students attended the session. Students were randomly assigned to two groups. One group of 14 completed the Cases With Drawing version; the other group of 14 completed the Cases Only version. The Cases With Drawing version took approximately 50-70 minutes to complete, as compared to the Cases Only version which took approximately 30-50 minutes. Students reported slightly higher satisfaction with the full version, however, there was no difference between the two versions with respect to improved confidence in the material.

A basic introduction of spinal cord anatomy and lesion localization is a prerequisite to the module, but no additional preparation by the students prior to the session is required. Access to computers or tablets is recommended for viewing the module (unless a printed version of the PowerPoint is going to be provided). Students will need pencils or pens for writing down answers and drawings.

If pre- and postsurveys are to be used by the institution, the presurvey should be completed by students before any practice questions or modules are accessed. The postsurvey should be completed by students after completing the practice questions and module.

If practice questions provided in the submission materials are to be used as a pretest, students should complete them before accessing the module. If practice questions are to be used as a posttest, students should complete them after completing the module.

To use either module, students should open the designated file in PowerPoint. The first slide of the module is a title slide. Upon advancing, the next slide provides a brief overview of the module and contains instructions for completion. Students will advance through the module slides, following the directions found on each slide. Both versions of the module are composed of two sections, to be completed in the order that they are presented.

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Results

Twenty-eight, second-year medical students enrolled in the neuroanatomy curricular block at our institution attended a one-time session to test out the module. The session was held early in the block, following traditional lectures on spinal cord anatomy, spinal cord lesions, somatosensory systems, and upper and lower motor neurons. During the session, the students completed pre- and postsurveys in addition to the module and associated materials described above. A 5-point Likert scale was used in the surveys for student scoring of confidence, overall satisfaction, and likeliness to reuse the module. Student confidence levels in the ability to describe spinal cord anatomy and locate lesions were obtained in both the pre- and postsurvey for comparison. Student overall satisfaction with the module and likeliness to re-use the module scores were obtained in the postsurvey.

Overall student reported confidence levels improved significantly in their ability to describe spinal cord anatomy ($F(1, 26) = 37.03$, $p \leq .05$) and locate spinal cord lesions ($F(1, 26) = 27.81$, $p \leq .05$), with no significant difference between the two module versions (Figure 1 and Figure 2). Students ranked overall satisfaction with the module as 3.79 (± 0.77), with slightly higher satisfaction in the group who completed the full version with drawing prompts (Figure 3). Students also indicated a high likelihood of reusing the module (Figure 4).
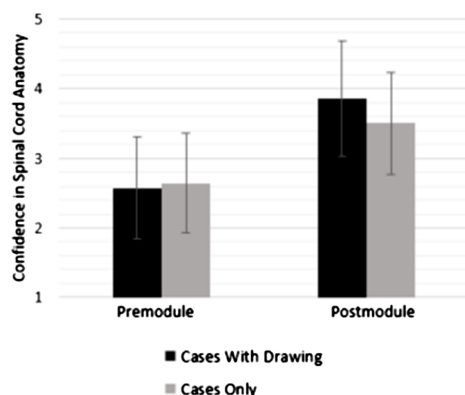

Figure 1. Mean confidence level reported for describing spinal cord anatomy on pre- and postmodule surveys for both module versions (cases with drawing, $n = 14$; cases only, $n = 14$). For all surveys, 5-point Likert scales were used (1 = *not at all confident,* 5 = *extremely confident*). Error bars represent standard deviations.
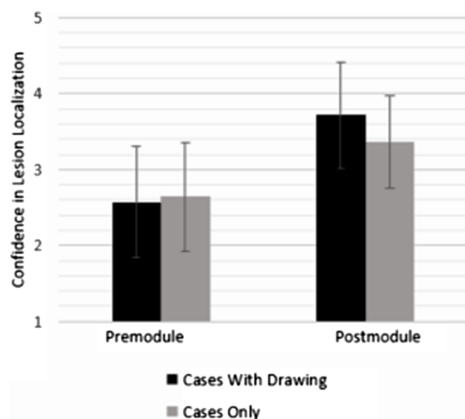
Figure 2. Mean confidence level reported for ability to locate spinal cord lesions on pre- and postmodule survey for both module versions (cases with drawing, $n = 14$; cases only, $n = 14$). For all surveys, 5-point Likert scales were used (1 = *not at all confident,* 5 = *extremely confident*). Error bars represent standard deviations.
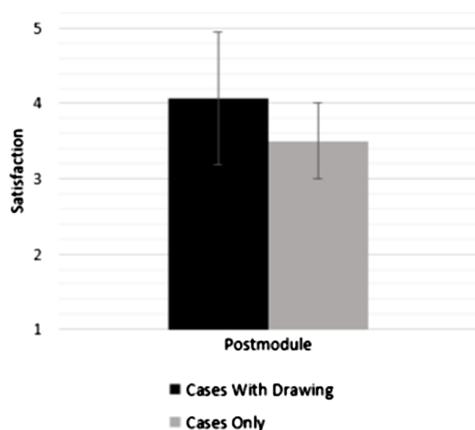
Figure 3. Mean satisfaction reported on postmodule survey for both module versions (cases with drawing, $n = 14$; cases only, $n = 14$). For all surveys, 5-point Likert scales were used (1 = *not at all satisfied*, 5 = *extremely satisfied*). Error bars represent standard deviations.
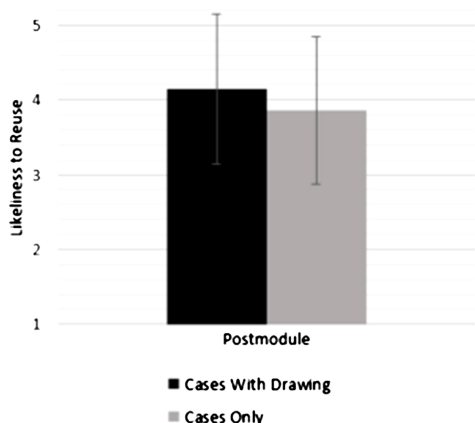
Figure 4. Mean likelihood of reusing module material as reported on postmodule survey for both module versions (cases with drawing, $n = 14$; cases only, $n = 14$). For all surveys, 5-point Likert scales were used (1 = *not at all satisfied*, 5 = *extremely satisfied*). Error bars represent standard deviations.

Students participating in the study, overall, felt that the cases were relatively simple. The average response as to the degree of difficulty was 2.2 and no participants rated the module as a "5" level of difficulty (the scale was graded 1-5 from "not at all difficult" to "extremely difficult").

Subjective open-ended responses were also obtained in the surveys to gather information about beneficial aspects of the module and suggestions for improvement. All of the comments were positive. The Table lists the major themes that emerged in the comments about the most helpful parts of the activity. They differed somewhat between the Cases With Drawing group and Cases Only group, but the most prevalent comments (reported by ≥ 50% of students) related to either self-drawing or viewing the premade hand drawings and practice with cases. The number of comments corresponding to each theme is reported by group, and is accompanied by the percentage of students this number represents in the specified group. Some comments contained more than one theme. Each group had a total of 14 students.

Sixteen of the 28 subjects responded to the open-ended request for suggestions to improve the module. From both groups, the most prevalent comment (8 out of 16) was to provide more practice questions and cases. Several students (5 out of 16) also suggested adding more detailed explanations for the answers within the module.

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Table. Themes and Number of Comments Elicited by the Question "What Was the Most Helpful Part of the Session?"

Theme	Cases With Drawing[a] n (%)	Cases Only[a] n (%)
Step-by-step practice	3 (21)	2 (14)
Drawing things out	7 (50)	0 (0)
Viewing the premade drawings	3 (21)	8 (57)
Practice cases/questions	6 (43)	7 (50)

[a]$N = 14$

Discussion

This module was developed to supplement current traditional neuroanatomy curriculum with the goal of facilitating student learning and confidence in spinal cord anatomy and lesion localization. The module was developed out of an interest in using drawing as a learning tool, and accompanied by an extensive literature review on teaching neuroanatomy and instructional theory. We incorporated scaffolding and step-by-step directions to promote learning of the principles of solving neuroanatomy clinical cases.

The module was tested for its effectiveness with second-year medical students enrolled in neuroanatomy. This student cohort had attended traditional lectures on spinal cord sensory and motor pathways, and spinal cord syndromes. The module represented the students' first experience with the principles of lesion localization in neurology within this course.

The results showed that students responded very positively to the module. Subjective ratings were very high regarding confidence in solving lesion-based problems, satisfaction with the module, and student likeliness to reuse the materials for studying. These measures are important for projecting future receptiveness and success of the module when incorporated into neuroanatomy curriculum. We did not measure actual performance on tests, which is a limitation of the study further described below. Nevertheless, improved learner confidence is essential to sustaining interest and engagement in those tasks, and therefore might ultimately lead to improved performance.[10] Future studies would need to address the question of whether the module promoted faster, or better abilities in localizing lesions.

The open-ended question asking what was the most helpful part of the session in the postmodule surveys provide much insight into which features of the modules provided the most benefit. Irrespective of which module was used, many students reported that going through cases promoted their understanding of lesion localization. Using clinical cases to problem solve in various basic science topics is a widely used teaching method because the cases are inherently relevant and involve problem-solving.[17,21] That these were so well-received in the early part of a neuroanatomy course suggests that, even with very little knowledge, students were eager and able to apply problem-solving methods to aid their learning. Several students in both groups indicated that the drawings were the most helpful part of the module. Whereas students in the Cases Only group commented on the helpfulness and clarity provided by the hand-drawn pictures that preceded and accompanied the cases those in the Cases With Drawing group were more likely to comment on the helpfulness of the active drawing component. We did not explore learning styles among participants, but learning preferences may have been a factor in how students responded to this question. Based on the various student responses, we recommend that students receive descriptions of the modules and be given the choice of which to use.

We encountered two challenges when testing the module because of varying knowledge level among students. First, the premodule questions were simpler for students than expected. We opted to keep these components as part of this resource because it may draw preparatory attention to the previously learned material and because students commented that they appreciated the extra practice (including the quizzes). In a similar vein, the second challenge arose when some students felt that more difficult cases could have been included.

There were several limitations to this resource. The module is confined to spinal cord anatomy and spinal cord lesions. Many students requested additional practice questions and cases as well as expansion to

cover brainstem and cortex anatomy and lesion localization. This highlights an area in which the module can be further developed and applied to other areas of neuroanatomy. This also suggests that this module design and approach may be applied to the learning of anatomy outside of the nervous system.

Our measurements were related to self-reported subjective measures of confidence and satisfaction. These measurements are subjective and may have been biased by subject expectations. Future studies should measure outcomes on objective measures such as quizzes or exams.

We studied the perceived effectiveness of this module in students at one medical school. Whether or not the modules are helpful may depend on the neuroanatomy curricula and the timing of the module as well.

In summary, we developed a module that was beneficial to learners in a medical school setting. It may be used for medical students or students of other medical professional programs in neuroanatomy courses. The module provides a step-wise, case-based approach to spinal cord anatomy and lesion localization, while simplifying a complex topic, improving learner confidence, and maintaining overall learning satisfaction. We recommend using this module as a homework activity for independent learning, or within a scheduled small group exercise.

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