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A Game-Based Approach to Teaching and Learning Anatomy of the Liver and Portal Venous System

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Abstract

Introduction: The use of games and game elements as teaching tools has received increasing attention in the medical education literature. Used formatively, games promote student engagement and satisfaction, and encourage collaboration and teamwork among students. They may also help students retain knowledge, although research supporting this notion is limited. This resource contains a 30-minute interactive lab station involving two different game-based activities aimed at teaching functional anatomy of the liver and portal venous system. **Methods:** The first activity is a flipped version of a traditional pinned anatomy practical, wherein students place their own pins on a body donor in response to application-level prompts. The second activity is an outlay-type card game where students assemble cards to depict the venous drainage of gut organs in a healthy patient versus one with portal hypertension. **Results:** In end-of-session reviews, several students volunteered feedback that the activities were effective and enjoyable. Additionally, average student scores on two subject exam questions increased by approximately 13% and 4%, compared with students who took the exam before the game elements were introduced. **Discussion:** These game-based activities may serve as a starting point for others wishing to deal with historically difficult topics in a more engaging way. The tools presented are low-cost, low-tech, and easy to modify for use with different student populations.

Keywords

Anatomy, Medical Education, Liver, Learning, Games, Portal Venous System

Educational Objectives

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

1. Describe the anatomical relationships of the liver, including its surface anatomy, surfaces, and peritoneal connections.
2. Describe the pathways of venous drainage from the foregut, midgut, and hindgut that contribute to the hepatic portal vein.
3. Describe the four main sites of portocaval anastomosis and correlate them with the clinical symptoms resulting from portal hypertension.

Introduction

Educational games are learning activities that have an element of competition and are constrained by preset rules.¹ In recent years, the use of games for educational purposes has received increasing attention from medical educators. Apart from promoting student engagement and satisfaction,² there is mounting evidence that using games in educational settings may actually help students retain knowledge.³ Games have been adapted from television quiz shows to increase engagement in large group settings,⁴ and numerous card and board games have been designed to teach specific topics in nursing, veterinary, and pre- and postgraduate medical programs.⁵⁻⁸

Due to their inherently interactive nature, games may be particularly useful vehicles of active learning. A well-designed game can address some of the main goals of active learning; specifically, to intentionally engage students and lead them to reflect about what they are doing.⁹ Games universally require decision-making, which is important for long-term recall of material.¹⁰ Using games as educational tools also

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Appendices

- A. Prewrite.docx
- B. Clinical Anatomy of the Liver.pptx
- C. Cards and Instructions.pptx
- D. Session Evaluation.pdf

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

encourages open dialogue among students and enhances their ability to communicate their thoughts and rationales with their peers.

The complex structure of the liver and portal venous system poses a substantial challenge to both pre- and postgraduate learners of anatomy. Many students find the concept of portocaval anastomosis (the dual venous drainage of certain abdominal structures) to be particularly confusing. The importance of this system to hepatobiliary surgeons has inspired both high-technology and low-technology solutions to teaching and learning among residents.^{11,12} Despite the rise in popularity of computer-based teaching tools, low-technology solutions may be just as effective as or even more effective than their digital counterparts.¹³ They also have the advantage of being less costly.

The anatomy laboratory provides an ideal environment for interactive, small-group learning. Beyond its obvious use for dissection, the laboratory is also ideally suited for experimentation with new and innovative teaching methods.¹⁴ We designed a 30-minute laboratory station with two interactive games in order to: (1) foster active learning, (2) maximize student engagement instead of didactic lecturing, (3) explore a low-cost, low-tech solution for use in anatomy education, and (4) provide a novel and memorable way to understand a historically complex topic of human anatomy.

This contribution adds to the small but growing collection of game-based approaches previously published in *MedEdPORTAL*.⁴ It is distinct in its coupling of a specimen-based activity with an abstract, conceptual tool for learning this particular body system.

Methods

The activity described here was part of an integrated laboratory session on normal and pathologic liver structure. It occurred during “Fueling the Body,” our integrated gastrointestinal course during the First 100 Weeks.¹⁵ The complete lab session entailed four complementary stations: clinical anatomy (described here), liver pathology, neoplasia, and imaging. Students rotated every 30 minutes until they visited all four stations (2 hours in total).

The anatomy station consisted of two games aimed at illuminating and clarifying the gross morphology and anatomic relationships of the liver and the anatomy and function of the portal venous system in health and disease. The exercise was designed to take approximately 30 minutes. A group of six students worked with one faculty facilitator toward a clear goal—to understand the anatomic structure of the liver and hepatic portal venous system.

Pework

Before class, students accessed a lab guide that contained the goal of the session and the learning objectives they were expected to achieve from their combined reading and lab activity (see educational objectives). They were given a reasonable¹⁶ amount of prework in the form of assigned textbook pages and videos (Appendix A). It was critical that they completed the prereading/viewing before the lab session so that they were prepared to discuss what they had read and apply it to a new and unknown situation.

Lab Session

A PowerPoint presentation was used as an outline to guide the students through the station’s different components (Appendix B). At the beginning of the session, the goal was explicitly reiterated. Students were then oriented to a prosected donor body and an isolated liver specimen from a second donor body. They were given colored pins and presented with a list of prompts in the form of anatomic descriptions. Students were required not merely to identify anatomic structures, but to infer from the description which structure fits each prompt, and then find that structure on the donor body. The initial game task was for students to work as a team to place pins in the anatomical structures that most closely match the descriptions.

Once students had placed all their pins in the specimens (approximately 6-7 minutes), the facilitator queried the group as to why they chose the structures they did. The functional anatomical relationships were further explored using Socratic questioning to challenge the accuracy and completeness of student thinking. Through this debriefing process, students could better understand their correct choices as well as any erroneously placed pins. There was usually more than one possible correct answer, and a student's individual response would dictate the direction of the discussion. For example, one prompt asked students to pin a remnant of an embryonic vein. If students correctly pinned the round ligament (remnant of the umbilical vein), the facilitator could then ask, "Where else could you have placed the pin?" Students would then recognize the possibility of another venous remnant, the ligamentum venosum. The placement of all pins was discussed and any questions resolved before proceeding to the next exercise.

The session then transitioned to the second learning objective, aimed at describing the functional anatomy of the portal venous system. A volunteer was asked to define a portal venous system, and the definition was refined through discussion. A slide clarified the generalities of a portal venous system (namely the configuration of two capillary beds separated by a vein). The differences between a portal system and general systemic circulation were thus illuminated. Students were asked to move from this general description to the specific anatomy of the hepatic portal system by labeling some of the structures. Importantly, they recognized that the liver represents the second capillary bed in this model.

The session next moves to the second game, which involved building a model of portal venous drainage with labeled cards (Appendix C). Students were presented with four digestive organ cards (esophagus, stomach, cecum, and rectum) and were shown two more cards representing the liver and heart. The remaining cards had the names of veins, and the students were instructed to assemble the cards such that they describe the path of venous drainage from each organ to the portal vein, through the liver, and to the heart. The students completed the activity as a group (lasting approximately 7 minutes), initially without the input of the facilitator.

Once the group members had finished arranging the cards, the facilitator again debriefed them on their work. This opportunity was used to illuminate the generalities of portal venous drainage (e.g., that the splenic and superior mesenteric veins form the portal vein) and to clear up misunderstandings about the smaller tributaries from the foregut, midgut, and hindgut. The possibility for certain anatomic variants was discussed. When students had reflected on the correct arrangement of the veins, the instructor played a red "no" card by placing it on top of the liver to represent portal hypertension. Students then received five additional vein cards and were asked to create detours to bypass the liver (approximately 5 minutes). These cards allowed them to model alternative drainage routes from the esophagus and the rectum. The students were again debriefed on how they arrived at their chosen pattern, and any misconceptions were again cleared up. The detours they built were revealed as specific cases of portocaval anastomosis.

At the end of the exercise, students were asked to predict clinical signs that would arise from engorgement of these veins along specific routes of portocaval anastomosis. A final slide tabulated this information along with other possible locations and clinical signs. The annotated PowerPoint (Appendix B) was released immediately after the lab session for student review and exam preparation.

Session Evaluation

After the session, approximately one third of the class ($N = 29$) was selected at random to receive an evaluation form (Appendix D). The form was deployed using One45 software and consisted of four questions on a 5-point Likert scale, aimed at assessing the strengths and weaknesses of the lab as a whole, rather than any one particular station. There was also a field for open comments. This standard form is also used to assess other lab sessions throughout the First 100 Weeks.

Results

This station was one of four stations in an integrated lab session on liver structure. We received 29 responses to the postsession evaluation form (100% response rate). Respondents overwhelmingly found the lab to be a positive experience (Table 1). Ninety-three percent of respondents either agreed or strongly agreed that the learning objectives and assigned prework prepared them to apply their knowledge in the session. Moreover, 100% of respondents either agreed or strongly agreed that the session fostered active learning, balanced individual facts with larger concepts, and enhanced their learning relative to other content presented that week. There were no specific questions about the anatomy station; however, many students chose, unsolicited, to mention the anatomy station and games as helpful:

- “Yet another fun and elucidating structure session. Liver anatomy was a fun station in which [faculty] gave me a much better understanding of the surface anatomy and ligaments of the liver, the subdivisions, and the alternate venous pathways used in portal hypertension - I really enjoyed the interactive pinning of the gross liver specimen and the index card ‘game’ for the blood pathways.”
- “Great session! [The card game] was very effective.”
- “[The card game] was an engaging way to cover the concepts of the station.”
- “One of my favorite structure labs. I felt prepared with my prework and the actual stations hammered in key concepts and definitely increased my understanding of the liver.”
- “I really enjoyed the anatomy station with the two games - I thought it was very interactive and will help me remember liver anatomy and vasculature well.”
- “The pin exercise at the anatomy station was particularly useful.”
- “The clinical anatomy station did a great job of allowing us to use our readings.”
- “Loved the creative learning games at the liver anatomy station. Very effective and challenged me to think about the portosystemic shunts in a different visualization.”

None of the students polled volunteered any specific negative criticism of the game.

Table 1. Session Evaluation of Liver Structure Lab (*N* = 29)

Statement	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree	<i>M</i>
The learning objectives and prework prepared me for this session.	0	0	2	14	13	4.4
The faculty fostered active learning (i.e., did not simply lecture, but asked questions and interacted with students).	0	0	0	8	21	4.7
Session appropriately balanced individual facts and conceptual knowledge as related to the goals of the session.	0	0	0	12	17	4.6
Session appropriately complemented/enhanced my learning relative to this week's theme.	0	0	0	10	19	4.7
Total	0	0	2	44	70	4.6

Assessment

We assessed learning at this station by way of open-ended essay questions on the summative final examination. Two questions specifically related to the portal venous system and tested learning of educational objectives 2 and 3 above. The first question asked students to explain the anatomical basis for portocaval anastomoses, and why they occur in the locations they do. The second asked students to describe the venous drainage of the rectum, and then to describe an alternate path of venous drainage without going through the liver (i.e., a portocaval anastomosis). These questions were essentially unchanged between 2015 and 2016, when the games were introduced. The item analysis is summarized in Table 2. Students overall performed better on both questions in 2016. In addition, students who scored in the upper 25% performed better on both questions. Those in the lower 25% improved dramatically on the first question, but not on the second. Unfortunately, by 2017, we had combined these topics into a single question, and are unable to further elaborate on this trend. Nevertheless, the quantitative data we have are consistent with our students' qualitative assessment and our own observations of the effectiveness of this learning activity. We plan to follow the performance of questions on future exams that are relevant to learning in this subject area.

Table 2. Student Performance on Open-Ended Final Exam Portocaval Anastomosis Questions

Metric	2015 (n = 100)		2016 (n = 101)	
	%	r	%	r
Q1: Anatomic basis of portocaval anastomoses.				
Difficulty	78.50		91.75	
Lower 25%	64.00		85.33	
Upper 25%	92.00		97.33	
Discrimination		.28		.12
Q2: Alternate paths of rectal venous drainage.				
Difficulty	74.00		78.22	
Lower 25%	68.00		60.00	
Upper 25%	84.00		92.00	
Discrimination		.16		.32

Discussion

Based on the session evaluation, we found that the two games were effective in promoting student engagement with the material. Taken as a whole, the station presented at least four opportunities for reflection: (1) after reading the prework, (2) after the initial pin game, (3) after the first outlay of cards, and (4) after the outlay of the detour cards. The structure of the station ensured that the students would reflect after each game component. Importantly, reflection allowed students to correct misconceptions, adapt their understanding of a topic, and extract more meaning from what they experienced.¹⁷

The pin game builds upon traditional pin-based (or “spotter”) anatomy practical exams. In such exams, students are typically asked to identify pinned structures only by name (although a drive to include higher levels of Bloom’s taxonomy¹⁸ is gaining momentum¹⁹). Our pin game differed from a pinned lab practical in several ways. First, it was a purely formative exercise, and therefore no grade or credit was assigned. Second, it required students to recognize structures based on abstract descriptions. This corresponded to the application level of Bloom’s taxonomy, wherein students are asked to apply their knowledge to a new situation.¹⁸

The portal system card game can be considered an outlay game, which requires the identification and assembly of parts to reveal a larger pattern.⁵ It can be further classified as a three-stage game, because it involves an initial experience, reflection, and planning.⁵ A similar game, designed for teaching immunology, was favorably reviewed by students, and even showed a significant increase in student test scores.²⁰ We plan to further assess the effectiveness of this and similar games in the future.

Both the pin game and the card game are universally applicable in the anatomy lab. We have implemented similar pin games for a number of other organ systems, including coronary circulation, laryngeal anatomy, and musculoskeletal anatomy. One could implement a similar card game by applying it to other vascular structures, including anastomotic networks in the limbs. The universality of these approaches makes them worthwhile approaches to teaching that promote student engagement, active learning, and higher-order thinking in the anatomy laboratory setting.

Limitations and Lessons Learned

The tools and techniques presented here are of narrow scope and utility in their present form; however, there is opportunity to adapt them for other purposes. As presented, the activity requires access to body donors or prosections, which may not be feasible for all programs. A model of the liver and colored stickers can serve as a substitute for the pin game. Dissection-based anatomy programs that follow a specific method may also not have the flexibility to add a station like this to their curricula. One method of addressing this is to design the station as a “pull-out” activity in lab, wherein small groups of students are called to the station while the remainder of the group continues to dissect.

A lesson we learned from implementing this activity is that small groups are key to engagement with the activity. A group of five or six students is ideal; groups larger than this will invariably leave some students out of the process. This is another possible limitation for other programs, which may not have a curricular

or personnel structure that allows this ratio. Larger groups can be split up and race to solve the card game on their own, introducing some additional friendly competition into the session and ensuring uniform participation.

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Ethical Approval

Reported as not applicable.

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