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INSTRUCTIONAL DESIGN AND ASSESSMENT

A Hybrid Jigsaw Approach to Teaching Renal Clearance Concepts

Adam M. Persky, PhD, and Gary M. Pollack, PhD

School of Pharmacy, University of North Carolina at Chapel Hill

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Objectives. To evaluate the effectiveness of using a jigsaw cooperative learning approach to teach basic concepts of renal clearance to pharmacy students.
Design. Students collected information on the mechanisms of renal clearance for a particular drug and proposed a methodology for circumventing a urine drug screen. Attitudinal surveys, an online quiz, and course examinations were used to assess student learning.
Assessment. The majority of students felt apprehensive toward a group assignment prior to the exercise, and afterwards still preferred individual work over group work. Post-exercise quiz and final examination scores showed students successfully learned the material.
Conclusions. Students were successful in learning from each other and there was no difference in examination performance compared to years when the technique was not used. In addition, the relative negative experiences of previous group work decreased the subjective attitudes related to the current learning experience.

Keywords: pharmacokinetics, problem-based learning, group work, kidney, renal clearance

INTRODUCTION

Pharmacokinetics is a quantitative discipline that involves the application of mathematical principles to describe input into, distribution within, and elimination from a system, with subsequent utilization of that information to predict drug behavior in patient populations. Fundamental to the mathematical principles of pharmacokinetics is an understanding of physiology; interpretation of pharmacokinetic parameters must be made in the context of a biologic system to fully appreciate the utility of the discipline. Knowledge and application of pharmacokinetic concepts and equations are valuable tools in the design of optimal drug dosing regimens, but without an underlying understanding of the fundamental physiologic processes involved, pharmacokinetics loses much of its predictive power. Pharmacy students typically do not enjoy their basic pharmacokinetics coursework either because it is mathematical in nature or they fail to see the application of these basic concepts within the framework of their clinical education.

One approach to teaching pharmacokinetics is to incorporate real-world examples that involve problem solving and interactive instruction between student and instructor and/or among students. Problem-based learning (PBL) works well in other healthcare fields and many pharmacy educators have called for this type of learning to be more widely used/developed in the pharmacy curriculum. Renal clearance concepts are ideal topics for implementation of PBL because they require both a basic understanding of and an application to physiology within the pharmacokinetic framework.

We describe implementation of a learning approach that combined PBL with a cooperative learning technique called the *jigsaw* to teach renal clearance concepts in a basic pharmacokinetic course. In the jigsaw approach, which is framed around a given topic, learners are divided into small groups with each group member responsible for learning a part of the overall "puzzle." Students then learn about their part of the puzzle by meeting with other students who have identical parts of the puzzle. This group, called the *expert group*, meets as a team to gather information and become experts on their topic (ie, their part of the puzzle) to ensure that everyone has the correct information. Eventually students come back to their original jigsaw group (also referred to as the *teaching group*) and teach what they learned to the other members of the group. The topic is structured so that the only access any member has to the other parts of the puzzle is through the other group members.

We designed a pharmacokinetic problem/puzzle to test students' ability to read and interpret information,

Corresponding Author: Adam M. Persky, PhD, Clinical Associate Professor, 109G Beard Hall, CB#7360, Division of Pharmacotherapy and Experimental Therapeutics, School of Pharmacy, University of North Carolina at Chapel Hill, Chapel Hill NC, 27599-7360. Tel: 919-966-9104. Fax: 919-966-0197. E-mail: apersky@unc.ed

apply concepts, and make appropriate "real-world" decisions. The example we explored was related to the methodology used to produce a false-negative during a urinary drug screen, ie, to decrease the renal excretion of a drug to reduce the amount of drug excreted to below the limits detectable by quantitative analysis. Given the news stories related to drug testing of athletes competing in the Olympic games, the Tour de France, and professional sports, it was an ideal time to discuss issues about athletes' "doping," drug tests, and off-label use of medications. In addition, given the availability of "at home" drug testing kits, an understanding of how urine drug screens work and how they can be circumvented is an important component of clinical and community pharmacy. As part of their professional program, students learn how to interpret laboratory tests (eg, pros vs. cons, things to look out for in the interpretation process). What they may not realize is that evaluation of a standard urine drug screen is no different.

The jigsaw approach was used to provide students with individual accountability as they had to teach other members of their group what they learned while researching a problem. Only through collaboration could each student learn about all of the mechanisms of drug clearance via the kidney. The exercise was utilized during the first day of renal clearance material covered in the foundational pharmacokinetics course to help students learn the basic concepts of renal clearance. Objectives for students were (1) to be able to list the mechanisms of renal elimination; (2) to describe the factors that impact each mechanism of renal elimination and graphically depict these relationships and predict how changes in these factors will alter the concentration-time profile and excretion rate-concentration profile; and (3) to determine the predominant mechanism of renal elimination of a drug based on protein binding and renal clearance data.

DESIGN

Foundations in Pharmacokinetics is offered in the fall semester of the second year of the professional pharmacy program. The majority of this course is taught sequentially by 2 instructors. The renal clearance section of the course consists of 2 days of course material delivery, with the first day dedicated to basic concepts (ie, mechanisms of renal elimination) and the second day focused on recovering estimates of renal clearance from concentration-time and/or excretion-time data.

With respect to the semester, the renal clearance material was presented approximately 3 weeks after the first course examination and 1 week prior to the second course examination. Prior to this course, students had little exposure to renal clearance concepts other than the basics of renal physiology. Because second-year pharmacy students typically do not encounter group work within large, lecture-type courses within the pharmacy curriculum, prior to this assignment students were exposed to group work in a large, lecture class through the use of simple exercises like "think-pair-share."

Teaching groups" were formed on the basis of the first course examination scores and consisted of 3 students with 1 member each from the top, middle, and bottom of the grade scale; there were 39 groups formed. In addition, due to the disproportionate number of females to males (approximately 3 to 1), each group was balanced with respect to gender, with no more than 1 male student per group. The teaching group met only once during the assigned class period (50 minutes), at which time the students taught each other what they learned.

Approximately 2½ weeks prior to the designated class time, students were given the assignment along with a 15-minute overview of why the assignment was being given, as well as scientific and educational expectations. The assignment included reasons for the assignment, learning objectives, basic instructions, and background information for the drugs investigated. In general, each group member was assigned a drug that corresponded to a representative mechanism of renal elimination (ie, filtration, active tubular secretion, passive tubular reabsorption). The list was composed of drugs banned by the International Olympic Committee (IOC) and the National Collegiate Athletic Association (NCAA), with atenolol, methamphetamine, and nandrolone representing filtration, reabsorption, and secretion, respectively. For nandrolone, however, students were asked to focus on glucuronide conjugates, as the glucuronide conjugates of steroids secreted by the kidney are used to detect anabolic steroid use.[1] The students' goal was to propose a general way to beat a urine screen for their particular drug, and to teach other members of their teaching group about what they had learned and how they came to their conclusions regarding the mechanism of elimination and methodology proposed to influence this process. This goal required that students learn about the mechanisms of renal elimination and what factors impact these mechanisms, as well as how their particular drug was eliminated by the kidney. This class did not use a published textbook. To aid the students in finding information, the following resources were provided as a starting point for their investigation: reading assignments posted on Blackboard (version 6.1, Blackboard Inc., Washington, DC) in the form of an e-book designed by the first author (AMP); pharmacokinetic textbooks made available by the faculty members; and a posted list of references, including journal articles, books (eg, *Goodman and Gilman's Pharmacological Basis of Therapy*[2]) and databases (eg, Micromedex, MEDLINE) where relevant information could be found. Faculty members and teaching assistants were instructed to assist the students in finding information, but not to actively teach concepts related to renal clearance.

The jigsaw component of this exercise was incorporated by having students with a particular drug meet with members of other groups that were assigned the same drug to collectively find information and discuss what they were learning. This group was the "expert group" as it was their job to become experts in their particular topic. Although students were encouraged to form expert groups, participation was voluntary. Since many of the students had families or did not live or work in town, it was more convenient to allow the students to find classmates with similar schedules with whom to form groups and arrange meeting times. On the first day on which the renal clearance material was presented, students were given a brief breakdown of what should happen during the class period and approximately 40 minutes to form their teaching groups and teach their particular drug to the other members.

Assessment Methods

Pre-exercise assessment. The assignment was evaluated by the University of North Carolina's Center for Teaching and Learning to optimize the design and identify any potential pitfalls. Subsequently, a draft of the assignment was given to a group of 7 students who served as a "feedback" committee during the course of the semester. This committee provided general input to the course instructors, especially with regard to potential pitfalls associated with the assignment. After revisions of the assignment based on this feedback, and prior to the actual exercise, a multiple-choice, anonymous survey instrument was administered to capture students' attitudes and experiences regarding group work.

Post-exercise assessment. After students completed their teaching, they were asked to list 1 to 2 of the "muddier points" remaining after their group session, [3] which would be answered in the next class period or on Blackboard. In addition, an 8-question quiz was posted on Blackboard to help the students voluntarily assess what they learned from their groups. This quiz was available for 2 weeks after this class session and did not count toward the final course grade. In addition, an anonymous survey instrument was used to assess students' attitudes toward this type of learning exercise.

Assessment compared to traditional approaches. Short-term retention regarding foundational renal clearance concepts was assessed via examination score evaluation. The final examination scores, which included the renal clearance material, and the scores on the subsection of the examination related to the renal clearance content were summarized as medians and interquartile ranges because the grade distribution failed the normality test (SigmaStat 2.03, Sysstat Software Inc., Gmbh, Germany) and demonstrated leftward skewness. The final examination was worth 150 points (40% of total points). A Mann-Whitney test was used to compare the examination scores (as a raw score) and renal clearance scores (as a percentage) from the year the jigsaw approach was used (2004) to control years (2005, 2006), when more traditional approaches were used to teach the material. The Bonferonni adjustment was used for multiple comparisons. Statistical significance was set at $p \leq 0.05$.

ASSESSMENT

Pre-Group Work Survey

The class enrollment during the study year was approximately 120 students located on a single campus. The response rate for the pre-group work survey was 105 out of 118 students (89%). All responders had been involved with group work during either undergraduate training or pharmacy school. Overall, the students' prior attitude towards group work was favorable or very favorable (39% of responders), followed by neutral (32% of responders) and unfavorable or very unfavorable (29% of responders). Of the responders who stated they did not have a favorable experience, the most prominent reasons were the "inability to get groups together to meet" (34% of responders), "failure for group members to do their respective part" (28% of responders), "group parts were not equal" (25% of responders), "poor group dynamic" (8.6% of responders), and "other reasons" ($<$ 6% of responders). Despite the planning associated with and provision of a description of this assignment, students still had apprehensions about group work, with the main reason cited as "they prefer to work alone" (54% of responders) and "you must depend on others to do their part" (29% of responders). Conversely, 29% of responders noted they enjoyed group work because they got to interact with others. Nearly 9% of responders thought group work was a way for instructors to get out of doing their own work. All responders agreed that they would have to work as part of groups in their future role of pharmacist.

Day of the Assignment Findings

On average, 30 minutes were needed for the triads to complete their teaching. Groups submitted their "muddiest" points either as a group or as individuals. Various teaching methods were used by the student-teachers. The teaching tools ranged from PowerPoint presentations on personal laptop computers to handouts that summarized major points about the drug and on renal clearance in general. Several groups asked for clarification during the exercise, with most questions related to the specific method (eg, drug, substance) that could be used to alter these processes. They were asked to describe a general method to circumvent a drug screen (eg, reduce filtration rate, increase urine pH), but were not asked to find explicit means as the students did not yet have the pharmacologic knowledge or experience to select an appropriate drug or intervention.

Post-Group Work Assessments

The majority of students completed the post-group work survey instrument (78.6%). Of the responders, approximately half (55.4%) felt they learned less during this exercise than in a more typical lecture and 34% felt they learned about the same as in a traditional lecture. Students enjoyed this style of learning but still preferred traditional lectures (43.5%), and 11% wanted to see more of this type of exercise in the classroom. The amount of work required for the students was challenging but not considered burdensome (62% of responders). Some students (20%) felt that work in other classes suffered because of the amount of work required. When asked how much time they spent on this assignment, most students spent either 1 to 2 hours (30%) or 2 to 3 hours (29.3%). Forty-four percent of students would have given themselves an A letter grade for their effort and performance, and 48% would have given their classmates an A for their effort. Overall, the students felt they learned a modest amount and that the exercise was well structured and somewhat enjoyable (45.7%).

The post-assignment quiz was designed in Blackboard and consisted of 8 items, including 5 true/false and 3 multiple-choice questions. To correctly answer these questions, the student needed to hypothesize on the mechanism of renal elimination based on values of protein binding and renal clearance and describe the factors that impact the major mechanisms of renal elimination. These questions did not pertain to the specifics of individual drugs per se, but rather were based on the objectives of the exercise and were more generalized and representative of typical examination questions. One hundred twelve (95.7%) students completed the online quiz. The average score was 6.2 out of 8 (78%). The majority of students completed the quiz the week following the exercise; however, due to the proximity of this exercise to their examination week, students requested more time for quiz completion.

On the 2004 final examination (the year the jigsaw approach was used), the renal clearance subsection was worth 10 points (approximately 3 questions) and covered the material related to this exercise. The assessment items required students to interpret graphs, answer multiple-choice questions, and determine the mechanism of renal elimination. The average score on the renal subsection was 8.7 out of 10 (87%) with a median of 100% (Figure 1). Most of the points deducted from students' scores resulted from misinterpretation of the graphs. Although most students provided the correct reasoning in their side notes, they did not utilize this reasoning when interpreting the graph. There were no significant differences (Table 1, Mann-Whitney test with $p < 0.017$ based on the Bonferroni correction for 3 statistical comparisons) in student performance on the renal clearance section of the final examination when the total examination scores were compared to the results of the examinations administered in subsequent years (when more traditional approaches were used to teach this material in 2005 and 2006).

DISCUSSION

This exercise was designed to incorporate cooperative learning in the form of peer-teaching as a component of student mastery of concepts related to the renal clearance of drugs. Students were apprehensive about participation in a group project, based on their previous experience of difficulty meeting as a group or of group members failing to share responsibility.

Given the vast array of lifestyles and time commitments of students in a typical pharmacy class, these were reasonable concerns. The present project overcame this obstacle by allowing students to form their own "expert group" for consultation on their particular drug outside of class. If these expert groups were assigned by instructors, the issue of time management and student schedules

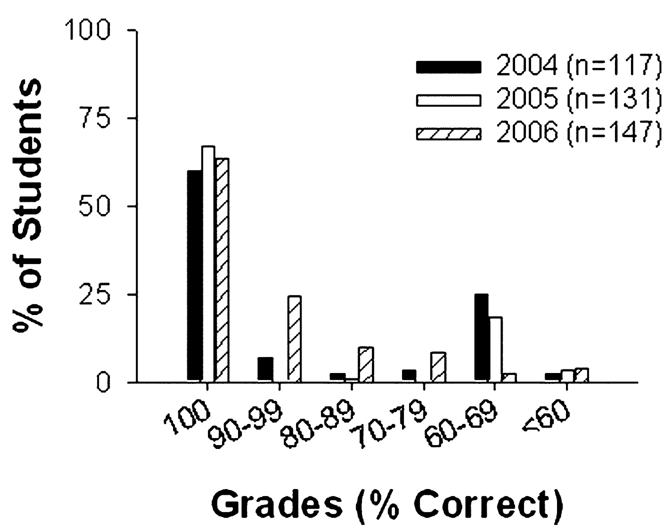

Figure 1. Distribution of scores on the renal clearance subsection of the final examination

would have had a larger and possibly negative impact. Second-year pharmacy students typically have established networks in the class; they are in a better position to identify classmates with the same time commitments and schedule flexibility. Since the assigned groups only met once during class time, organization of the "teaching group" was not subject to the constraints associated with student scheduling.

The second pitfall of group work identified by the students was that group members did not do their part. This exercise was designed as a cooperative learning project, and therefore established positive interdependence of the group. As with any cooperative learning structure, students needed to believe that they "sink or swim" together.[4,5] In this project, no group member could answer the question for all 3 drugs without a large time commitment. Students had to rely on other members to do their part to gather information on all of the mechanisms of renal clearance. The post-group work survey confirmed that all members performed their roles in an above-average manner.

Throughout their high school and undergraduate education, students often are evaluated on their individual work (graded on an absolute scale) and placed in competition with their classmates (graded on a performance-based scale). It is not surprising that, based on "individualistic" needs and their distain for group work, students would be apprehensive about a cooperative learning project. In addition, this technique requires active participation and is different from a traditional passive lecture. Although student opinion did not change even after the project was successfully completed, the students understood that they would someday work in groups as clinicians; however, they had not yet realized the importance of establishing a group mentality for learning purposes.

The post-quiz scores and performance on the examination demonstrated that students learned the material. When student performance was compared to subsequent years when the jigsaw approach was not used, there was no difference. It is difficult to assess the true impact of the jigsaw approach on learning since this exercise was meant to develop not only factual knowledge but also problem-solving skills and communication skills, and enhance long-term retention, and students' ability to become self-learners. These latter skills are better assessed through more authentic assessment-type approaches for example during the experiential part of the curriculum.

Although post-quiz scores demonstrated learning, students did not feel their understanding of the material was different than if they had received a more traditional lecture. One method to overcome this apparent disconnect may be to repeatedly inform the class of the rationale for the exercise. Another approach may be to debrief the class after the exercise and describe what was observed during the session as well as the results from the assessments. This would reinforce the points they learned from the experience that they then clearly communicated to the rest of their group.

The apparent disconnect between perceived learning and actual learning (as determined by the Blackboard quiz and final examination) that has been noted by others may relate to Perry's Scheme for intellectual development.[6] Students may correlate learning with memorization, consistent with Perry's Dualism category.[7] Students in this developmental category are at the lowest level of intellectual development; want instructors to provide information; and resist thinking independently, drawing their own conclusions, stating their own points of view, and discussing ideas with peers. The jigsaw approach is more closely associated with Perry's Relativism category in which the student's role is to think independently, analyze problems, and synthesize a response. In addition, this exercise increased the role of peers in the information acquisition process and reduced the instructors' role from distributor of knowledge to facilitator. The lack of notes taken on factual material may therefore be construed by the student as a "lack of learning," yet the assessment results provide a different conclusion. A large portion of students responded that they enjoyed this style of learning but would still prefer a traditional lecture. This also may relate back to Perry's schema that students easily associate learning with length of notes and factual material and less so with more transcendental learning.

Since the workload (ie, credit hours) for pharmacy students is typically highest in the second professional year, a concern of instructors when designing this exercise was to avoid overburdening the student. On the other hand, for cooperative learning to be effective, the work assigned has to warrant the need for a group effort in order to promote interdependence (ie, no individual could do the whole assignment alone). Most students felt the amount of work associated with this assignment was not burdensome, yet was not low enough that they could complete the assignment themselves. In general, students did not ask for assistance in preparing teaching materials. The majority of student questions involved feedback as to whether they were on the right track and/or what specifically was required of them to teach (ie, the objectives). The students gave themselves and their group members high marks for their efforts, with only 1 group providing a side note that indicated that 1 member performed/contributed less than the other group members. The increased variability seen in examination scores related to the renal clearance material during the year the jigsaw approach was used may be a function of the variability of peer-teaching approaches. Further work would be needed to assess the quality of the peer-instruction in addition to simply rating how their peers performed.

Overall, although students were apprehensive about group work and did not believe they learned more through cooperative learning, examinations and quiz results indicated the students learned the material. Students felt they should have been given more notice about this exercise or it should have been incorporated into the syllabus. The relatively short notice may have impacted the students' overall attitude toward this exercise.

The jigsaw approach was not repeated in subsequent years for 2 primary reasons: the instructor was interested in piloting different learning approaches for the material (eg, partially completed notes, incorporation of case studies), and a general feeling that the amount of student preparation time compared to the class time spent on the material was disproportionate. This latter impression was based on the feeling that students spent considerable time on the project for material that only represented a small part of the course (ie, only 10 points on the final examination). This hybrid jigsaw approach may be better suited for material that spans multiple classes. If the exercise was simplified to a more traditional jigsaw, then it could be used in a single class session (eg, have students teach other mechanisms of renal clearance without the drug testing portion). Although designing this exercise required many hours of preparation, it is infinitely reusable within pharmacokinetics or any other content area with minor modifications to correct any issues from previous experiences (eg, grades for individual accountability). This technique will be reused by the authors in various contexts in future courses.

SUMMARY

This group project applied pharmacokinetic principles in a real-world context beyond the field of clinical pharmacy. PBL and cooperative learning have been incorporated successfully into other heath education disciplines (ie, medicine), and this project is the first step in the evolution of the pharmacokinetics curriculum into a more interactive learning environment.

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