TEACHERS' TOPICS

A Pharmacokinetics Module Taught Within a Pediatrics Pharmacotherapy Course

Patricia Gerber, PharmD,^a and Roxane Carr, PharmD^{a,b}

^aFaculty of Pharmaceutical Sciences, University of British Columbia, Vancouver, British Columbia, Canada

^bChildren's and Women's Health Centre of British Columbia, Vancouver, British Columbia, Canada

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Objective. To review the effectiveness of a pedagogical approach and methods used to teach pediatric pharmacokinetics to a large class of pharmacy students in a required course in the third-year of a bachelor of science in pharmacy program.

Design. The pharmacokinetic sessions emphasized facilitating student understanding of the basic pharmacokinetic principles learned in earlier courses and applying that knowledge to pediatric case scenarios. This was accomplished using lectures with PowerPoint slides followed by small-group, context-focused discussions that required students to apply the principles outlined in the lecture.

Evaluation. Student understanding of the pharmacokinetics concepts discussed within the course was assessed via a written examination.

Conclusion. The small-group context-focused approach to teaching pediatric pharmacokinetics in a large class size with minimal resources allowed opportunities for students to apply their foundational knowledge in an interactive and engaging atmosphere.

Keywords: pediatrics, pharmacokinetics, small group, pharmacotherapy

INTRODUCTION

Applying foundational science materials into patient care activities within the classroom can be challenging, especially with large class sizes and minimal resources and time to conduct smaller-group activities. The Association of the Faculties of Pharmacy of Canada and the Canadian Council for Accreditation of Pharmacy Programs' Accreditation Standards and Guidelines for the First Professional Degree have defined educational outcomes, and the need to align with the views of the Blueprint for Pharmacy, a collaborative initiative led by the Canadian Pharmacists Association that outlines a vision for the future of the profession in Canada.¹⁻³ These standards and guidelines establish that Canadian core pharmacy curricula must encompass pharmaceutical sciences content, including pharmacokinetics.

The Faculty of Pharmaceutical Sciences at the University of British Columbia offers a 4-year entry-to-practice bachelor's degree in pharmacy. Since 2005, the 3-credit-hour course Pediatric and Geriatric Drug Therapy

has been required in the third year of the program. In this course, students receive approximately 18 hours of pediatric pharmacotherapy instruction.

Others have described the extent of pediatric pharmacotherapy content in pharmacy curricula in Canadian and US colleges and schools of pharmacy.⁴⁻⁶ In a review of 65 US colleges and schools of pharmacy, Bahal-O'Mara and colleagues noted a range of 1-25 contact hours of pediatric topics in required courses within the various programs.⁴ Similarly, the extent of pediatric education varied extensively in Canadian faculties of pharmacy, with a range of 5 to 40 hours of pediatric topics in required courses.⁵ In a 2005 opinion paper about the quality and quantity of pediatric pharmacy education in US colleges and schools of pharmacy, the American College of Clinical Pharmacy Pediatrics Practice and Research Network recommended that pediatric content be introduced early on in the curriculum, with the provision of at least 25 hours of classroom instruction in core pediatric topics.⁷

With a limited amount of structured class time for students to develop the skills and knowledge to provide quality pharmaceutical care to this special population, the syllabus for the Pediatric and Geriatric Drug Therapy course was strategically developed and subsequently has been modified to ensure key topics are covered to prepare novice pharmacists to provide effective, quality

Corresponding Author: Dr. Patricia Gerber. The University of British Columbia, Faculty of Pharmaceutical Sciences, 2405 Wesbrook Mall, Vancouver, BC, Canada V6T 1Z3. Tel: 604-813-5390. Fax: 604-822-3035. E-mail: patricia.gerber@ubc.ca

pharmacotherapy outcomes to pediatric patients upon entering practice. In the pediatric population, understanding patients' pharmacotherapy needs requires an understanding of the pharmacokinetics and dynamics in a growing neonate, infant, and child; and the importance of a drug's palatability, appropriate formulation, dose calculations, and appropriate use.

Students are introduced to basic concepts in pharmacokinetics and pharmacodynamics in their first year of the program. In the second and third years, non-linear kinetics, 1-and 2-compartment models, and drug metabolism and metabolizing enzymes are taught. More in-depth clinical applications of pharmacokinetics are also part of the third-year curriculum. The course instructors observed, however, that pharmacy students often understood pharmacokinetic concepts but lacked the ability to apply these skills in clinical practice, including to dosage requirements.

In the pediatrics course, learning objectives related to pharmacokinetics included: defining the pediatric age groups and describing how at each stage, the pediatric patient differs from an adult patient; describing the pharmacokinetic and pharmacodynamic alterations on drug disposition and therapeutic outcome in the pediatric patient; and applying this knowledge to the management of drug therapy in the pediatric patient. Students develop a conceptual understanding from their previous pharmacokinetic course work as well as from specific classroom sessions regarding pediatric pharmacokinetics, and subsequently apply their knowledge to explain why the dosing of certain drugs differs between various pediatric age groups and/or adults. This paper describes the pedagogical approach and methods used to teach pediatric pharmacokinetics to third-year entry-to-practice bachelor of science pharmacy students.

DESIGN

The course met for 1-hour sessions, 3 times weekly, from January to April. Student enrollment in the class varied between 145 and 155 students. The course was divided into 2 independent sections: Pediatric Drug Therapy and Geriatric Drug Therapy. Students had to successfully complete both sections in order to pass the course.

The overall goals of the Pediatric and Geriatric Drug Therapy course were to provide students with the basic skills and knowledge to be able to provide pharmaceutical care to pediatric patients. The course addressed drug therapy considerations specific to the pediatric population (neonate, infant, child and adolescent), major medical conditions and drug-related issues affecting pediatric groups, and the social and pharmacological aspects of pediatric development. Instructional strategies employed

included lectures, case studies, assigned reading, literature retrieval, and group assignments and presentations. Over the years, the design of the course had changed significantly, both in terms of content and instructional strategies employed.

In *Educational Psychology: A Cognitive View*, David Ausubel reminds us "the most important single factor influencing learning is what students already know. Ascertain this and teach him accordingly."⁸ Thus, in this course, the course instructors attempted to build upon and make connections to what students already knew about pharmacokinetics. Pediatric pharmacokinetics had been covered in the course since its inception. However, the instructional strategies employed, the approach used in teaching the topic, and the time devoted to it were significantly changed over the years in various attempts to maximize the use of limited contact time with the students. In 2010, the course instructors began to podcast a series of 4 lectures on introductory general topics in pediatric pharmacotherapy, such as definitions and general concepts, regulatory and approval processes for pediatric medications, challenges in delivering pharmaceutical care to pediatric patients, adherence, medication errors, and drug information resources, in an attempt to free up some class time to provide students with active-learning opportunities.

In order for students to develop their pediatric pharmacokinetic knowledge base and be able to apply this knowledge, the course instructors designed a 2-part lecture series within the course: Pharmacokinetic Differences Between Adults and Children (part 1) and Clinical Applications (part 2), each 50 minutes long. The concept was to enable students, when presented with a scenario such as "why is the dosing of drug X twice daily in a neonate versus once daily in an adult," to be able to rationalize, using pharmacokinetic and pharmacodynamic principles, appropriate dosing regimens in various pediatric populations. Part 1 of the lecture series included a 50-minute lecture using PowerPoint slides and class handouts to describe how pharmacokinetic concepts differ within the pediatric population as a result of their physiological and developmental differences. Part 2 of the class series involved a 50-minute group activity where students worked through their class notes from part 1 and other provided references to explain why the dosing of certain drugs varies between different age groups.

The learning objectives for part 1 were to:

- Identify 4 limitations in conducting pharmacokinetic research in children.
- Define ways in which the absorption, distribution, metabolism, and elimination of drugs differ in a neonate compared to an older child or adult.

- Explain why co-trimoxazole is contraindicated in infants < 2 months old.
- Explain how the metabolism of acetaminophen and theophylline differs in neonates/young infants vs adults.
- List 4 drugs which display unique pharmacodynamics in the pediatric population.

To illustrate clinical implications of the physiological differences, the course instructors discussed a variety of scenarios (examples of these scenarios are provided in Appendix 1). Part 1 of the pharmacokinetics series concluded with a brief discussion on developmental difference in the pharmacodynamics of drugs. The course instructors used valproic acid, tetracycline, ciprofloxacin, and phenobarbital as examples of drugs with age-dependent adverse drug reactions.

The learning objectives for part 2 were to:

- Use common pediatric references to research the unique pediatric pharmacokinetic characteristics of drugs.
- Explain how the pharmacokinetic differences between neonates, infants, older children, and adults relate to differences in dosing regimens for many drugs.
- Explain how the unique pharmacokinetic differences in pediatrics can result in clinical challenges.
- Demonstrate how the pharmacist can work through a case of a neonate, infant, or child and a prescribed drug to determine the appropriateness of a dosing regimen based on what is known about the drug's pharmacology, pharmacokinetics, etc.

In part 2, students were randomly assigned to groups of 5 to 10 students and given a handout listing a series of drug-dosing scenarios that outlined the typical regimens used for particular drugs in, for example, a neonate compared to an older infant, or a child compared to an adult. Each group of students was given a copy of the *Pediatric and Neonatal Dosage Handbook* to use along with their class notes from part 1 to explain the series of drug dosage comparisons outlined on the handout.⁹ Each group was assigned 3 of the 10 scenarios to work on. Within their groups, students discussed each of their scenarios and developed pharmacokinetic explanations for the drug dosage scenarios presented. After giving the groups approximately 15-20 minutes to discuss the assigned scenarios, the class reconvened and each group described to the entire class their interpretation and rationale for each of their assigned scenarios. The instructors moderated the discussion to ensure students understood why it was important to consider the principles behind various dosing regimens within the pediatric age groups in clinical

practice. The instructors also discussed the approach that pediatric pharmacists take when making pharmacotherapy recommendations for a neonate, infant, or child who requires a drug that has poorly defined pediatric dosing regimens. The importance of understanding and applying pharmacokinetics and pharmacology was illustrated using the instructors' personal anecdotes from pharmacy practice. Examples of the types of scenarios the course instructors gave the groups to work through are given in Appendix 2.

Despite the challenges that teaching a large class presented, the course design attempted to engage students whenever possible in the higher-level thinking within Bloom's taxonomy and incorporate activities at different levels of the taxonomy. That is, the instructors provided students with opportunities to demonstrate their knowledge and skill by doing an activity that required them to critically think, synthesize, and apply information, and derive an explanation for a given clinical scenario.

The teaching style and approach used revolved around the famous Chinese Proverb "Tell me and I'll forget; show me and I may remember; involve me and I'll understand." We tried to "show them" and "involve them" by having them analyze daily dosing scenarios that required them to apply the basic concepts of pediatric pharmacokinetics learned in part 1.

Whenever possible, the instructors drew comparisons between the material discussed in class and clinical cases encountered in practice. The sessions were structured to engage different learning styles of students. The instructors delivered the content using a variety of teaching methods, moving around while talking, asking a lot of questions, and engaging students in debates with other groups regarding their rationale and explanations.

EVALUATION AND ASSESSMENT

Because of limited resources, in 2010 the assessment methods used in the pharmacokinetics portion of the course were reduced to a 10-question online quiz (5% of the overall mark for the course), 1 written examination (80%), and 1 group project (15%). The online quiz tested students' knowledge of the material covered in the podcast sessions that students were instructed to review prior to the start of the course. The written examination was administered at the end of the pediatrics section of the course and contained a mix of case-based multiple-choice, true-false, and case-based short-answer questions. The group assignment was called "Hot Off the Pediatric Press" and involved students working in groups of 5 to 6 students to research and select a news article that

dealt with pediatric pharmacotherapy and write a critique of it.

Student understanding of the pharmacokinetics concepts discussed within the course, including material covered in the lecture (part 1) and the concepts discussed during part 2 in the small groups and in the open discussion, is assessed via the written examination. In addition, each year at least 1 or 2 groups of students chose to focus their written assignment on a pharmacokinetic topic. Examples of topics selected by students included safety concerns with using topical corticosteroids in neonates, dosing guidelines for obese children, use of caffeine to manage apnea of prematurity, and safety concerns of codeine-containing cough products.

At the end of the course, students completed voluntary anonymous course and teaching evaluations online. Year after year the evaluations indicated that the most valued aspect of the course was the open discussion and application of topics. In fact, part 2 of the pharmacokinetics lecture series was one of the most-favored aspects of the course. In their comments about the strengths and usefulness of the learning environment, several students described the interactive environment of this lecture series as being engaging and enhancing their knowledge and comprehension of the material taught. Students also valued the real-life examples and personal experiences discussed because they felt that these added a practical dimension to the class and helped them to understand and apply the concepts. The evaluations consistently indicated that students appreciated the relevant and engaging way the course material was delivered despite the large class size.

Each year, when students were asked to comment on how the course could be improved, they suggested having more contact time, offering the course earlier in the curriculum (either in the first or second year), and integrating the pharmacokinetics content covered with that of the general pharmacokinetics course the students take in the second year.

DISCUSSION

This model for teaching pediatric pharmacokinetics to a large class of third-year students in a baccalaureate pharmacy program has been successful overall and well received by students. This model addresses the goal of teaching students the pharmacokinetic and pharmacodynamic alterations on drug disposition and therapeutic outcomes that are unique to the pediatric patient, and it does so within the boundary of current contact hours and the resources allocated for it. The main challenge to continued use of the model within the pharmacokinetics course is the pending increase in class size from 150 to

224 students in September 2013. The course will continue to evolve to maximize effective large group learning, while maximizing the use of available resources such as teaching assistants.

An unknown factor in the future planning of this course is the Faculty's plan to develop an entry-to-practice doctor of pharmacy (PharmD) program. The structure of the new curriculum, both horizontally and vertically, will dictate where and how the pediatric pharmacokinetics content will best fit. We see the potential value of integrating the content into a course in which general pharmacokinetic principles are taught. For example, such a course could have general introductory sessions followed by some which deal with special populations such as pediatrics, geriatrics, obese patients, hemodialysis patients, etc. Such a change would require careful thought about where in the curriculum the other unique aspects of the pediatric population and its special physiological and pharmacotherapeutic considerations should be taught in order not to lose the context provided by having a section of a course dedicated entirely to pediatrics.

As the bachelor of science in pharmacy curriculum is revised into that appropriate for an entry-to-practice PharmD program, we will continue to look for opportunities to employ a student-centered perspective by engaging the students with interactive class activities and discussions that allow them to apply their knowledge and skills, and by using a variety of assessment strategies that are relevant to practicing in various pharmacy settings.¹⁰

SUMMARY

A 2-part approach, combining PowerPoint lectures with hands-on group activities, was used to teach the clinical applications of pediatric pharmacokinetics to third-year bachelor of science students. This model allowed students to review and build on foundational knowledge learned in other courses and provided them with opportunities to apply it.

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Appendix 1. Scenarios used to illustrate the clinical implications of physiological differences in patients.

- A hospitalized neonate is receiving oral acetaminophen for pain but the nurse does not wait long enough after administering it for absorption to take place and a therapeutic effect to be evident before administering a repeated dose of the drug. The course instructors discuss delayed oral absorption in a neonate and the importance of being aware of this and not mistakenly deeming the drug ineffective.^a
- Gentamicin is commonly used to treat meningitis in neonates because of their increased permeability of the blood brain barrier, especially in premature neonates, and higher degree of movement of some antibiotics such as aminoglycosides across it. As well as the physicochemical properties of a drug, such as gentamicin, that make it a hydrophilic polar compound that can distribute readily into the extra-cellular fluid. In contrast, the course instructors discuss the reasons why this antibiotic would not be selected to treat meningitis in an adult patient.
- The differences in protein binding between neonates and older patients in the context of co-trimoxazole's (trimethoprim-sulphamethoxazole) was discussed because of the relative contraindication for use in neonates. Using graphics, the course instructors demonstrate how bilirubin displacement as a result of administration of this antibiotic can cause potentially harmful levels of the protein resulting in kernicterus.
- The delayed maturation in the activity of drug metabolizing enzymes and the resulting toxicity that may occur in pediatric patients was discussed using examples of codeine to treat pain in breastfeeding mothers and the potential adverse effects to the newborn. The course instructors also used graphics to depict how the metabolism of acetaminophen and theophylline are examples of distinct patterns of metabolism of drugs that rely on phase I (oxidation) and phase II (conjugation) metabolizing enzymes.
- The immaturity of renal processes in neonates compared to older children was described as well as the gradual maturation of glomerular filtration rate and tubular secretion in neonates. Using examples of renally eliminated drugs such as vancomycin and aminoglycosides, the course instructors illustrate the importance of age-appropriate selection of drug dosing regimens.

^a Isbister GK, Bucens IK, Whyte IM. Paracetamol overdose in a preterm neonate. *Arch Dis Child Fetal Neonatal Ed.* 2001;85(1):F70-F72.

Appendix 2. Examples of anecdotes used to illustrate the importance of understanding and applying pharmacokinetics and pharmacology.

Digoxin Dosing

Infant: 10 mcg/kg/day orally, divided twice daily

Adult: 0.125-0.25 mg orally daily

Commentary: in this scenario, students were expected to explain the dosing regimens by highlighting the developmental changes that occur in glomerular filtration rate and tubular secretion processes, as well as the differences in volume of distribution for digoxin in infants compared to adults.

Enoxaparin Dosing

1-month old infant: 1.5 mg/kg subcutaneously every 12 hours

Child: 1 mg/kg subcutaneously every 12 hours

Commentary: this scenario required students to consider the metabolic and renal mechanisms involved in the elimination of this drug, as well as how its mechanism of action relates to antithrombin III and its reduced levels in infants compared to adults.

Metronidazole Dosing

3-day old neonate: 7.5 mg/kg intravenously every 12 hours

Infant: 15 mg/kg intravenously every 12 hours.

Commentary: this example required students to consider that metronidazole is a drug whose clearance increases after the first few days of life. Its half-life in an older infant or adult is around 10 hours, whereas that in a neonate is between 25 and 75 hours, thus requiring a neonatal dose that is half of that administered to an older infant.

Clindamycin Dosing

Neonate: 15 mg/kg orally every 8 hours

Child: 10mg/kg orally every 8 hours

Commentary: when presented with the dosing regimen above, students were expected to recognize that the higher dose in a neonate reflects that this drug is mostly cleared by hepatic metabolism and must be hydrolyzed in the gastrointestinal track before it can be activated. This process is immature at birth and therefore a larger dose Clindamycin is required in this age group.