Pharmacogenomics in the Professional Pharmacy Curriculum: Content, Presentation and Importance

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Abstract

The current study was designed to examine the types and quantities of pharmacogenomics (PG) content taught in U.S. and Canadian pharmacy schools as well as the methods of presentation used. It also assessed faculty perceptions of the adequacy and importance of PG content in their current curriculum. A four-page survey was mailed to the dean of each School of Pharmacy for distribution to the appropriate faculty member(s). The results of the study indicate that a majority (87%) of pharmacy schools included PG content in their curriculum. The role of PG in drug metabolism, drug transport and specific disease states were most frequently addressed by faculty teaching PG. The majority of faculty responders believed their current amount of PG content was inadequate but expected it to increase in the future. The scope and degree of PG coverage was highly variable with no clear consensus on courses, content or amount of coverage. In addition, definitive PG resources that might aid the teaching of PG appear to be lacking. The majority of both students and faculty in all areas of pharmacy considered knowledge in PG to be very important for their current and future practice.

Keywords. pharmacogenomics, pharmacy education, teaching methodologies, curriculum, survey

Introduction

Pharmacogenomics (PG) is the study of the genes that influence drug behavior and effects in individuals. While the genomes of any two individuals are essentially (99%) identical, there are still approximately 3 million nucleotides that differ between individuals. Most of these variations occur as *single nucleotide polymorphisms* (SNPs) in which one nucleotide is exchanged with another at a given position. Although seemingly minor genetic changes, these polymorphisms can have major effects on the way humans respond to drugs, disease, and toxins in the environment. Genetic polymorphisms are capable of altering drug target pathways as well as the enzymes that metabolize drugs. With completion of the Human Genome Project[1] and the advent of deoxyribonucleic acid (DNA) microarrays[2], it is now possible to rapidly analyze thousands of DNA segments from a patient for genetic variants. In recognition of the potential importance genetic variants may play in drug response, a private consortium of pharmaceutical companies (SNP Consortium)[3] have set out to map all human SNP's.

The ultimate goal of pharmacogenomics is to tailor drug therapy for an individual based on his or her genetic composition in order to maximize therapeutic effectiveness and minimize toxicity. Although still in an early stage, some of the findings from pharmacogenomic research have already begun to impact clinical practice and drug therapy. For example, genetic polymorphisms in CYP450 enzymes can significantly alter the rate at which patients metabolize a number of drugs from important classes such as antidepressants, anesthetics, antiseizure agents and anticancer drugs,[4,5] thereby markedly altering blood levels of these agents. Genetic variation in drug transporters, drug receptors and target enzymes can likewise alter the pharmacodynamic response of patients to various drugs[6]. Patient testing for specific genetic variants has been used to improve efficacy and reduce toxicity of chemotherapy[7], enhance statin therapy of hypercholesterolemia[8], and improve treatment of depression with SSRI's.[9]

As advances in pharmacogenomics increasingly influence clinical practice, pharmacists will need to become knowledgeable in various aspects of pharmacogenomics, including data interpretation, study methodologies and the application of specific genetic findings to the care of their patients. In 2001-2002, the charge of the Academic Affairs Committee of the American Association of Colleges of Pharmacy (AACP) was expanded to include consideration of the impact of the emerging knowledge of

pharmacogenetics, pharmacogenomics, proteomics and bioinformatics on the future role of the pharmacist[10]. A recent study by Latif[11] reported that while most schools of pharmacy were providing some instruction in PG, it was not to the depth recommended by AACP[10]. According to their findings, the average school of pharmacy was currently addressing only about half of the AACP recommendations pertaining to specific PG content such as the genetic basis of disease and only about one third of the AACP recommendations related to ethical, social and economic factors. A second recent article by Sansgiry[12] used a detailed survey to evaluate the confidence that community pharmacists had in their knowledge surrounding the human genome project, genetic testing and pharmacogenomics. Results of the study indicated that confidence levels were low. This suggests a need to educate existing community pharmacists as well as current students about the potential impact of PG on the practice of pharmacy now and in the future. Continuing education should be enhanced in these areas.

In light of these findings and the rapid growth occurring in the field of pharmacogenomics, we decided to examine pharmacogenomics content within the PharmD curricula of U.S. and Canadian Schools of Pharmacy. Questions included: what percentage of U.S. and Canadian schools of pharmacy include PG content in their curriculum; what specific content is presented and in what courses is PG content included; how is PG content delivered and what resources are utilized in its delivery? We were also interested in assessing whether pharmacy faculty teaching in this area felt the amount of PG content currently offered in their curriculum was sufficient and if they thought the amount of content would increase in the future. Finally we asked faculty how important they believed it was for students and pharmacists practicing in various areas to have a PG knowledge base.

Methods

To collect data for the study, a 23 question survey was developed (see Appendix A). The survey was sent to the dean of each School of Pharmacy in the U.S. and Canada (100 surveys total). The survey was accompanied by a detailed cover letter that stated the objectives of the study and asked the dean to forward the survey to the appropriate faculty member(s) within their school. The first page of the survey also listed the objectives of the current study along with instructions and contact information for the authors. Anonymity was assured. A self-addressed, stamped envelope was included with each survey to facilitate its return, which was requested within one month.

The survey was divided into 3 parts. The first series of questions focused on PG content, asking which specific courses included PG content, what specific content areas were addressed, in what year of the curriculum was this content offered and how many total contact hours were allotted for PG content. Questions were also asked in this section regarding PG electives that were currently offered or planned in the future. Survey recipients were asked if they believed the current amount of PG content in their curriculum was sufficient and if they expected the amount of content to change significantly over the next few years.

The second section of the survey contained questions on PG content delivery. Respondents were asked about delivery format, whether or not they used small-group discussion or case studies, and whether or not they gave written assignments. Subsequent questions were also asked regarding specific readings, texts, journals or Web sites that were assigned or used by the students.

The third section focused on the perceived importance of PG content in the pharmacy curriculum and in pharmacy practice. Survey respondents were asked how important they felt PG knowledge was for current pharmacy students, as well as for health-system and community practitioners. Finally, the survey asked respondents whether or not they agreed with the statement that in the future, only certain specialist pharmacists would need to know the principles of pharmacogenomics. The surveys contained no identifiers and were returned anonymously.

Results

A total of 100 surveys were sent out, 46 were received before the cut-off date, yielding a response rate of 46%. Of the schools responding to the survey, 85% reported including PG content in their current

curriculum (Table 1). In 95% of these schools, PG content was a required element. The majority of institutions offered between 1 and 26 teaching hours with the median content being 7 hours (mean = 10.1 hours with a S.D. ± 7.2). A single institution offered 60 hours (Table 1). The data in Table 1 shows that PG content was mainly distributed across the first 3 years of the professional curriculum with the majority of schools (68%) emphasizing this content in the second professional year. Of those schools with PG content, only 2.7% offered it during the fourth professional year. The reported number of PG elective courses also was low with only 8.5% of responding schools offering an elective related to PG.

Figure 1 lists the specific courses in which schools reported significant PG content. While PG content was found in a wide range of courses across the various schools of pharmacy, the most common courses including PG content were biochemistry, pharmacokinetics and pharmacology followed by medicinal chemistry. “Other” was the single largest category reported with 35% of schools offering PG content in a course other than the 10 listed on the survey. Some examples of “other” courses that included PG content were physiology, pharmaceutical biotechnology, molecular medicine, PG elective, drug interactions elective, biotechnology and biomedical sciences modules.

Figure 2 provides a breakdown of specific PG content areas that responding schools included in their curriculum. Six of the 9 PG content areas listed on the survey were included in the curriculum of at least 70% of the Schools of Pharmacy who included PG in their curriculum. Ninety percent of respondents included the role of pharmacogenomics in drug metabolism while 80% focused on the role of PG in drug transport. Approximately 20% of schools included other topic areas such as the impact of PG on pharmacy, the pharmacoeconomics of PG and the role of the pharmacist in PG.

Table 1. Pharmacogenomic (PG) content in the PharmD Curriculum of Schools of Pharmacy

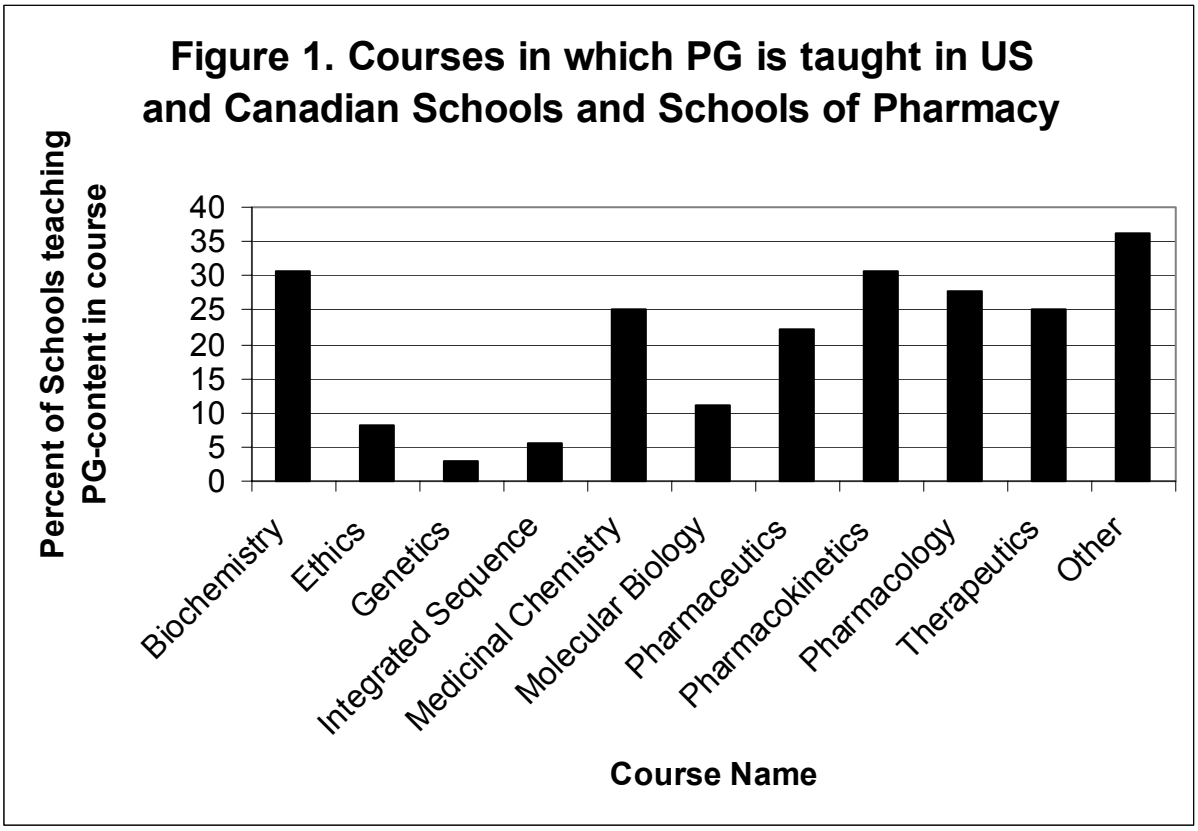
Survey Question	Yes	No
Is PG content included in the PharmD curriculum?	87% N=40*	13% N=6
Is the PG content required?	95% N=38 out of 40	NA
Hours of PG content included in the PharmD Curriculum	Mean = 10.1 Median = 7.0 Std. Dev. = 7.2	
What year of the PharmD curriculum is PG content offered?		
P1	52.6% N=20	NA
P2	68.4% N=26	
P3	57.9% N=22	
P4	2.7% N=1	

* For the group having PG content (Yes column), N = 40 for those not having PG content (No column) N = 6. U.S and Canadian responses were combined due to low response rate from Canadian schools.

As seen in Table 2, the primary method for delivery of PG content was didactic lecture. Over 90% of respondents who taught PG content supplemented their lecture with instructor handouts. Sixty-four percent of respondents used case presentations while 30% employed group discussions. Assigned reading in PG was given by 68% of respondents. Only 41% and 38% of faculty used a specific textbook or journal respectively as their primary reading source. When asked to list what specific text or journal was used for their PG course, no text or journal title appeared more than one time. Homework was assigned by 33% of respondents while 46% included some online materials to supplement their PG content.

When surveyed faculty were asked if they felt the current level of PG content in their curriculum was adequate, 60% of faculty responded that it was less than adequate, 37% felt it was adequate and none felt it was more than adequate (Table 3). Nearly 70% of respondents currently offering PG content believed the amount of content in their curriculum would increase in the future while 83% of respondents not currently offering PG content believed that it would be included in their curriculum in the future.

The last section of the survey was designed to gauge faculty opinion as to how important they believed PG knowledge is to current PharmD students and practicing community and health-systems pharmacists. As seen in Figure 3, greater than 80% of respondents believed such PG knowledge was either "very important" or "important" for both current PharmD students and health-systems pharmacists. Over 80% of respondents disagreed with the statement that "only specialist pharmacists will need to know PG."



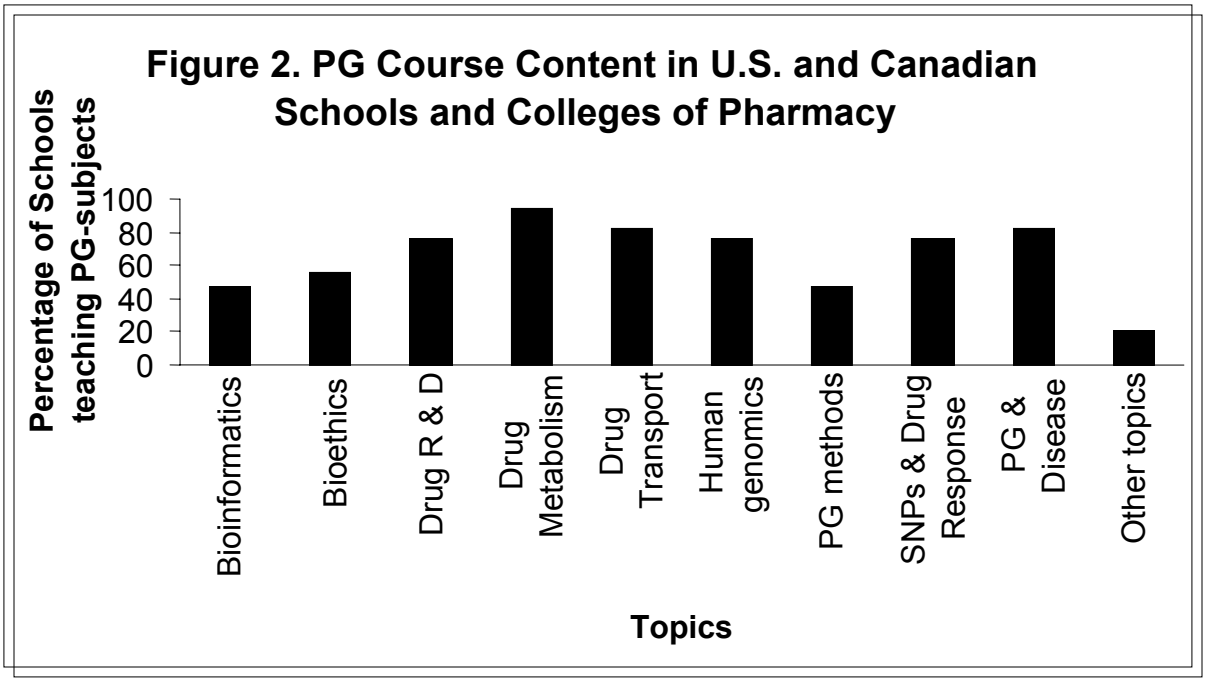


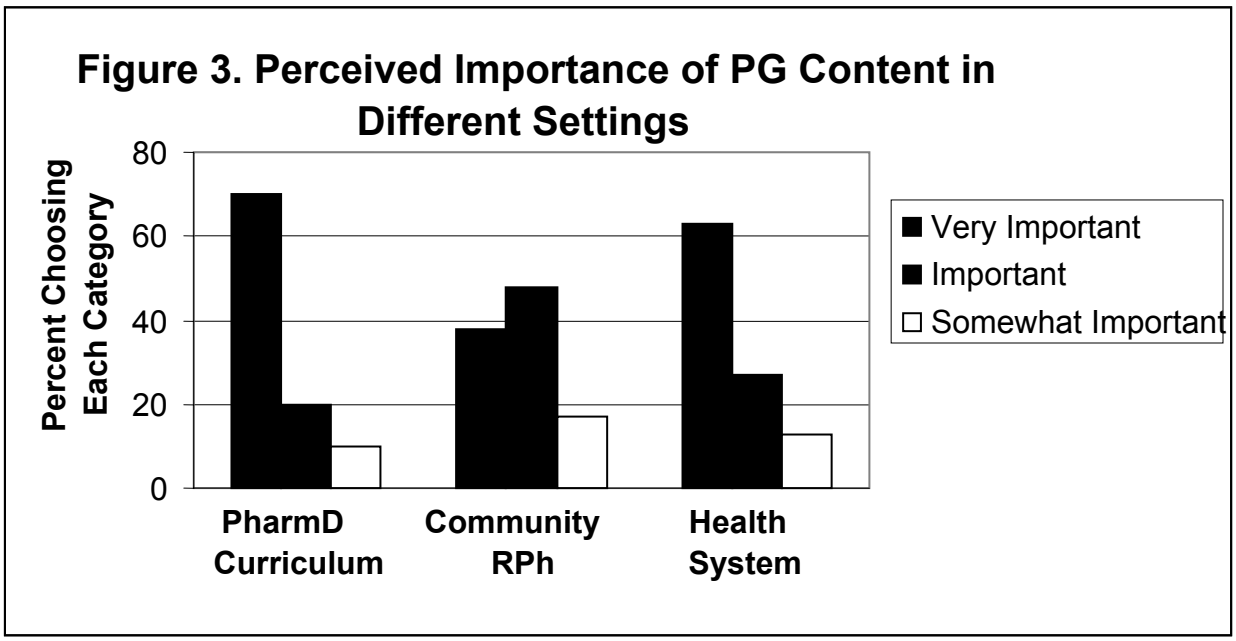
Table 2. Methods of PG content delivery in PharmD Programs

PG Content	Percent of Respondents	
Lectures	100.0	(40)*
Instructor Handouts	90.0	(36)
Case Presentations	62.5	(25)
Group Discussion	30.0	(12)
Written Assignments	32.5	(13)
Online Materials	45.0	(18)
Assigned Readings	67.5	(27)
Journals	37.5	(15)
Texts	40.0	(16)

*N = 40 responses total. Numbers in ( ) are number of responders who use each method.

Table 3. Faculty opinions as to the adequacy of PG content in their current programs.

Question	Those Including PG Content (N=39)	Those not including PG Content (N=7)
The current level of PG content is:		
Less than adequate	60%	NA
Adequate	37.5%	NA
More than adequate	0	NA
I believe that in the future the amount of PG content in the curriculum will:		
Decrease	0	0
Remain the Same	32.5%	16.7%
Increase	67.5%	83.3%



Discussion

It appears that the vast majority (nearly 90%) of schools of pharmacy in the U.S. and Canada currently offer PG content in their curriculum. Among 95% of responding schools, PG content was a required element. Recent studies by Latif[11] and Moridani[13] reported that 78% and 60% respectively of the schools of pharmacy responding to their survey offer pharmacogenomics content. Latif's study concluded that while the majority of pharmacy schools surveyed provide some instruction in PG, many do not provide the depth recommended by AACP. Both studies surveyed U.S. schools of pharmacy, which response rates were 48% and 34% respectively. The authors believe the overall response rate for our survey (46%) was good and we would like to think it might be in part due to the perceived interest and importance of the topic in pharmacy education.

In light of the high reported rate of PG content inclusion in the curriculum, it seems that schools of pharmacy have been proactive toward including emerging PG knowledge in the pharmacy curriculum. Interestingly, more than half of respondents who offered PG content felt the amount currently offered was less than adequate. On a positive note, most of those respondents who believed the current level of PG content was inadequate or who did not currently offer PG content, believed the amount would increase in the near future, which was a finding echoed in the study by Latif[11].

Most PG content was included in P1-P3 years of the pharmacy curriculum with very little during the P4 year. The vast majority of PG content was in required courses, with only a few courses being offered as an elective. There was wide variability in which course(s) PG content was taught. Biochemistry, pharmacokinetics, pharmacology and medicinal chemistry courses were most frequently listed. A smaller, but still significant percent of schools included PG content as part of clinical courses such as therapeutics. Little content appeared to be presented during the fourth professional year of most schools' curricula. This is most likely because students at that point are typically on rotations. Although PG was seldom taught formally during a student's final/rotation year, it would be interesting to investigate how much of the PG content students received during earlier didactic courses was actually utilized or expanded upon in the practice setting by preceptors or clinical faculty.

The actual range of PG-related topics was quite broad. Areas for which there is the greatest amount of published scientific information and current clinical application, such as the role of PG in drug metabolism, drug transport and specific disease states, were addressed with the highest frequency. A significant percentage (>70%) of schools with PG content also included information on human genomics as well as the role of PG in new drug development. It was interesting that more than half of the institutions that had PG content also included discussions related to bioethical issues, which is a topic of great importance. Teaching of actual PG methodologies received a less significant emphasis in the curriculum than did content related to the application of PG.

The overwhelming choice for delivering PG content was lecture. Almost all respondents reported supplementing lectures with instructor handouts. Interestingly, while nearly 70% of respondents assigned readings, there were no definitive textbooks, journals or even Web sites available to faculty. No single text, journal or Web site was listed more than once, a finding that clearly highlights the lack of appropriate written PG resources for pharmacists and pharmacy students. This lack of appropriate PG resources presents an excellent scholarship opportunity with regards to the development of PG-specific texts, journal articles and Web sites for pharmacists and pharmacy students.

Our final goal was to gauge the importance that faculty assign to students and pharmacy practitioners having knowledge in PG. The vast majority of respondents believed PG content was "very important" or "important" for all groups listed. The overwhelming majority of faculty believed it was "very important" for current PharmD students and health-systems practitioners to have PG knowledge; nearly as many felt it was likewise important or very important for community practitioners. Only 10% of our respondents agreed with the statement that only specialist pharmacists will need to know PG for their future practice; clearly most pharmacy faculty involved with PG believe PG knowledge will be important in the future practice of pharmacy.

The findings of this study are particularly timely given the recent commercial availability of pharmacogenomic testing that may be done directly by patients. Using a simple cheek swab, patients may obtain DNA tests by mail that detail their pharmacogenetic profile for drug classes such as antidepressants, anticoagulants and opioids in addition to their risk for certain drug reactions. Kits are also available to analyze a patient's CYP450 enzyme activity to determine if they are "fast," "slow" or "intermediate" metabolizers. It is likely that pharmacists will be asked to interpret test results and answer questions about adverse drug effects that might occur based on a patient's genetic CYP profile. It is also likely that additional home, Web or pharmacy-based tests for genetic variability will become available in the near future (e.g., the company marketing the home CYP test kits also plans to offer home test kits for N-acetyltransferase 2 in the near future). As a result, pharmacists must understand the basis of these pharmacogenomic tests along with their potential benefits and short-comings.

A recent interesting article by Brock[14] argued that genetic science and pharmacogenomics could revitalize the clinical role of pharmacists and generate new interest in pharmacy education and research. Brock stated that in order for current and future pharmacists to participate in the translation of pharmacogenomic advances into clinical practice, they will need to be trained in the interpretation, management, application and delivery of pharmacogenomic information. He also argued that as researchers, pharmacists can play a critical role in the implementation of novel drugs with highly specific, genetically-based targets, and new study methodologies tailored for pharmacogenetic research and development. This new PG-based drug development will require pharmacists to be well-educated in the ethical, social and legal issues of PG as they relate to clinical practice.

As a continuation of the current study, the authors intend to follow-up with additional surveys directed specifically at pharmacy preceptors and practicing pharmacists in community and hospital settings. These surveys will focus on how important these pharmacists believe PG knowledge is to their practice and to what extent they apply various aspects of PG in their daily practice. We also intend to repeat the original survey in approximately 3 years to identify whether or not the anticipated increase in PG content has occurred and to track additional changes.

The wide range of PG topics and the variation in curriculum placement suggest the need for a national dialogue focusing on 2 important questions. First, what PG topics are important for practicing pharmacists both now and in the future, and second, how can those topics best be integrated into pharmacy curricula?

Currently taught PG content is highly correlated with available published literature. While the topics of drug metabolism, drug transport, and specific disease states may be highly appropriate, others such as bioinformatics, the role of SNPs in drug response, and bioethics may be equally or even more important. It is important that we identify which topics are essential for practicing pharmacists, and then focus both research and educational efforts on those topics.

Finding the optimal curricular locations for these topics is also a critical issue. For example, should bioinformatics be included in current informatics courses or incorporated into discussions of the role of SNPs in drug response? Should PG-related ethical issues be concentrated within current bioethics courses or should they be addressed along with the role of SNPs in drug response, since SNP variations can have larger implications beyond that of drug metabolism?

Limitations

There are several limitations in the current study. While we did survey all schools of pharmacy in the U.S. and Canada, we did not separate compiled data based on the country from which it was returned. As a result we are unable to make any comparisons between PG content in U.S. and Canadian schools of pharmacy. Our survey was directed toward faculty actively involved in the presentation of PG content. It is likely these faculty might be biased in their opinions of how important this content is in the curriculum. We did not actively survey outside preceptors or other practicing pharmacists to gauge how important they felt PG knowledge was for current practice or what content would be most appropriate to include. Our survey package was sent directly to the deans of each of the various schools of pharmacy who were asked to forward the survey to the faculty best suited to complete the survey. In this respect the choice of who filled out the surveys was decided by the deans and not the survey authors. Finally, although we believe our survey response rate was good, results could differ significantly between responding and non-responding schools.

Conclusion

Schools of pharmacy appear to have been proactive in following the AACP guidelines for PG content in their curriculum. However, there was a wide scope of PG content and variable amounts of coverage across pharmacy curricula. The majority of respondents felt the amount of PG content in their current curriculum was inadequate; however, most believed the amount would increase in the future. There was

no clear consensus on what content should be included, nor on which course should include significant PG content. Definitive texts, reference journals or Web sites are not available or are not widely used by pharmacy instructors presenting PG content. With regards to the value of PG education, content knowledge in PG was considered important for students of pharmacy as well as for pharmacists practicing in all areas.

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Appendix A

START HERE

1. Does your school include pharmacogenomics/ pharmacogenetics (PG) content in your Pharm.D. curriculum?
   - ☐ No→ (skip to question 19)
   - ☐ Yes

2. In which of your Pharm.D. courses is the PG content being taught? (check all that apply)
   - ☐ Biochemistry
   - ☐ Ethics
   - ☐ Genetics
   - ☐ Integrated Sequence
   - ☐ Medicinal Chemistry
   - ☐ Molecular Biology
   - ☐ Pharmaceutics
   - ☐ Pharmacokinetics
   - ☐ Pharmacology
   - ☐ Therapeutics
   - ☐ Other course

   (Name of other course or courses).

   _____

3. Is the PG content required or is it elective?
   - ☐ Required
   - ☐ Elective

The following section asks about required PG content. If you do not require PG content, skip to question 7.

4. How many teaching hours are allotted for the teaching of PG material in required courses?
   _____ hours

5. During what year or years is the required PG content taught or offered? (check all that apply)
   - ☐ P1
   - ☐ P2
   - ☐ P3
   - ☐ P4

6. Which of the following content areas do you currently include in your required PG class(es)?
   - ☐ Bioinformatics
   - ☐ Bioethics
   - ☐ Role of PG in drug discovery and development
   - ☐ PG and drug metabolizing enzymes
   - ☐ PG and drug transporters/p-glycoprotein
   - ☐ Human genomics
   - ☐ PG methodologies
   - ☐ Role of single nucleotide polymorphisms (SNPs) in drug response
   - ☐ Role of PG in specific diseases
   - ☐ Other topics (please list)

   _____

   The next two questions ask about elective material.

7. Does your institution currently offer an elective in PG?
   - No
   - Yes

   If Yes, how many credit hours is it? _____ (skip to question 9)

8. If No, does it plan to offer one in the future?
   - No
   - Yes

Questions 9-15 seek to determine what methods you use to deliver material on PG to your students.

9. Do you use lectures?
   - No
   - Yes

10. Do you provide instructor handouts?
    - No
    - Yes

11. Do you use case presentations?
    - No
    - Yes

12. Do you use small group discussions?
    - No
    - Yes

13. Do you use written home work assignments?
    - No
    - Yes

14. Do you use online materials?
    - No
    - Yes (please list)

    _____

15. Do you assign readings?
    - No
    - Yes

16. Do you assign journal articles to read?
    - No
    - Yes

    If yes, what specific journal(s)?

    _____
    _____
    _____

17. Do you assign readings from textbooks?
    - No
    - Yes (please list texts)

_____

18. Do you think the amount of PG content in your current Pharm. D. curriculum is:
    - Less than adequate
    - Adequate

- More than adequate

19. Do you think that the amount of PG content in your curriculum will _____ in the next few years?
    - Decrease
    - Remain the same
    - Increase

20. How important is it to include PG within the Pharm. D. curriculum?
    - Very important
    - Important
    - Somewhat important
    - Not important

21. In the future, how important will it be for community pharmacists to know the basics of PG?
    - Very important
    - Important
    - Somewhat important
    - Not important

22. In the future, how important will it be for health-system pharmacists to know the basics of PG?
    - Very important
    - Important
    - Somewhat important
    - Not important

23. Please indicate how much you disagree or agree with the following:

    In the future only certain specialist pharmacists will need to know the basics of PG.

    - Strongly disagree
    - Somewhat disagree
    - Neither disagree nor agree
    - Somewhat agree
    - Strongly agree

Additional Comments:

_____

_____

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