RESEARCH

Pharmacy Students' Knowledge and Confidence of Penicillin Allergies Following Focused Didactic Instruction and Simulation

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Objective. To evaluate pharmacy students' knowledge and confidence regarding penicillin allergy assessment and skin testing (PAAST) before and after a focused didactic instruction and simulation (FDIS).

Methods. A multicenter, quasi-experimental, cross-sectional survey study was performed among pharmacy students before and after FDIS on PAAST at two schools of pharmacy. The FDIS on PAAST consisted of an infectious disease faculty-led seminar, student-led penicillin allergy counseling interviews, penicillin skin testing simulation, and case studies to assess penicillin allergy scenarios and management. An anonymous, voluntary, electronic survey was distributed to students (n=159) before and after the FDIS. The pre- and post-intervention survey contained ten PAAST knowledge-based questions and multi-step, 5-point Likert scale statements related to confidence of PAAST. The post-intervention survey also evaluated students' perceptions of the FDIS on PAAST. Descriptive statistics were performed, and the Student *t*-test was used to compare pre- and post-intervention responses.

Results. One-hundred and forty-three surveys were completed resulting in a survey response rate of 90%. PAAST knowledge scores (mean±SD) increased overall following the FDIS on PAAST (6.67±1.51 vs. 7.81±1.39). Knowledge scores increased considerably for questions related to penicillin allergy consequences, cross-reactivity, and correct steps of PAAST. Pharmacy students' PAAST confidence scores (mean±SD) also improved following the interactive instruction and simulation (2.30±0.70 vs. 3.22±0.67) with considerable confidence increases in penicillin skin testing. Pharmacy students' perceptions of the FDIS on PAAST were also positive overall.

Conclusion. Pharmacy students' knowledge and confidence of PAAST improved following FDIS. This may be an effective strategy to implement PAAST education during pharmacy school.

Keywords: penicillin allergy, simulation, penicillin skin test, pharmacy students, antimicrobial stewardship

INTRODUCTION

Penicillin allergy is the most commonly reported antibiotic allergy with approximately 10% of the United States population being labeled as penicillin allergic; however, approximately only 1 in 10 of these individuals are truly allergic.¹⁻³ Documentation of inaccurate penicillin allergies often leads to the use of alternative antibiotics that are more broad-spectrum or less effective.⁴ This practice has been associated with several untoward consequences including *Clostridioides difficile*-associated diarrhea, increased development of resistant bacteria, increased medical costs, increased surgical site infections, and poorer clinical outcomes.⁵⁻¹² Given the complications of penicillin allergies, antimicrobial stewardship programs (ASP) can be a critical resource to encourage penicillin allergy assessment and skin testing (PAAST) to identify and manage individuals who are not truly penicillin allergic.¹³⁻¹⁵

Pharmacists are well positioned to evaluate, manage, and de-label penicillin allergies as part of ASP initiatives.¹⁶⁻¹⁸ Pharmacists are frequently relied upon for their drug expertise within ASPs,¹⁹ and are involved in several activities related to PAAST in the inpatient setting such as leading penicillin allergy interviews, performing penicillin skin testing,

evaluating cross-reactivity potential among beta-lactam antibiotics, and providing other types of allergy evaluations or challenges.²⁰⁻²⁵ Pharmacist opportunities and involvement in PAAST are also expanding to outpatient settings.²⁶

Given the significant impact pharmacists can have in PAAST, appropriate education is essential.^{24,26} Schools of pharmacy should educate and train pharmacy students about PAAST as they may frequently be involved in such practices as future pharmacists. However, there are currently no reports of PAAST training in the PharmD curricula or other healthcare disciplines to our knowledge. Thus, we sought to evaluate the impact of a focused didactic instruction and simulation (FDIS) class on PAAST on pharmacy students' knowledge and confidence.

METHODS

This was a multicenter, quasi-experimental, cross-sectional survey study among pharmacy students before and after the FDIS on PAAST at Binghamton University School of Pharmacy and Pharmaceutical Sciences in Binghamton, New York, and Saint John Fisher College Wegmans School of Pharmacy in Rochester, New York. Pharmacy students were included in survey distribution if they attended and participated in the FDIS on PAAST. Pharmacy students were excluded if they did not complete or had an incomplete pre- and/or post-survey response.

This study was deemed exempt by the Institutional Review Boards at Binghamton University and Saint John Fisher College. A survey invitation letter with the appropriate informed consent information was attached to the survey instrument and distributed electronically via email. By selecting to enter the survey, the respondent agreed to participate.

The required 3-hour skills lab course is run concurrently with the infectious diseases (ID) pharmacotherapeutics course at both schools of pharmacy. The FDIS on PAAST occurred in the skills lab course during February 2020 of the second and third professional year at Binghamton University School of Pharmacy and Pharmaceutical Sciences and Saint John Fisher College Wegmans School of Pharmacy, respectively. Allergy basics were taught during the ID pharmacotherapeutics course prior to this intervention, but within the same week of the skills lab course. Instruction for these allergy topics was general and briefly introduced compared to this intervention's structure and content delivery.

During this session, pharmacy students were exposed to several concepts and areas within PAAST. These included a brief, 30-minute lecture on PAAST delivered by an ID pharmacist faculty member, student-led penicillin allergy interviews and activities, a simulated scratch test component of penicillin skin testing, and case studies to assess penicillin allergy scenarios and management strategies. The brief lecture on PAAST provided education on various topics related to penicillin allergies including penicillin allergy epidemiology, Centers for Disease Control and Prevention penicillin allergy statistics,²⁷ penicillin allergy consequences, types of allergic reactions, penicillin allergy interview questions, cross-reactivity between beta-lactam antibiotics, and allergy reconciliation strategies including penicillin skin testing, direct/graded challenges, and desensitization (induction of drug tolerance). ID pharmacist faculty used the same presentation materials at both schools of pharmacy to optimize consistency in content delivery. The student-led penicillin allergy interviews and activities facilitated appropriate questions to ask patients who are labeled with a penicillin allergy. The ID pharmacist faculty member also provided a brief simulation session on the appropriate steps to complete a penicillin skin test, and then pharmacy students performed the scratch component of the penicillin skin test on fellow students as part of this activity. Lastly, pharmacy students worked in groups to complete four graded case studies to evaluate penicillin allergy management strategies with the goal of providing the correct reconciliation strategy and supporting rationale.

A 25-item pre-intervention survey and a 31-item post-intervention survey were designed to evaluate pharmacy students' knowledge and confidence of PAAST before and after FDIS. The survey was anonymous and students were not required to complete this, but participation was encouraged. The survey was developed using the expert opinion of the ID pharmacist faculty members. Qualtrics (Qualtrics, Inc., Provo, UT, USA) was used to design and collect survey responses.

The pre-intervention survey included 10 knowledge-based PAAST questions including penicillin allergy statistics, penicillin allergy consequences, types of allergic reactions, cross-reactivity between beta-lactam antibiotics, and penicillin allergy management scenarios. The pre-intervention survey also included 15 confidence statements for various aspects of PAAST measured on a 0 (strongly disagree) to 4 (strongly agree) scale. The post-intervention survey included the same knowledge questions and confidence statements as those on the pre-intervention survey as well as six additional items that measured students' perceptions of the FDIS on PAAST, also measured on a 0 (strongly disagree) to 4 (strongly agree) scale. Reliability analysis of the pre- and post-intervention scale score demonstrated that the scale had excellent internal consistency with a Cronbach's alpha value of 0.92 and 0.97, respectively.

The survey instrument was pilot tested by an ID pharmacist and fourth year pharmacy student. Feedback was then incorporated before dissemination to ensure validity, logistical integrity, and question clarity. The pre-intervention survey was distributed electronically via email to pharmacy students shortly prior to the start of class and subsequently closed before instruction began. The post-intervention survey was distributed electronically via email to pharmacy students at the

conclusion of class and was left open for 48 hours after. No reminder emails were sent given the relatively short time the survey remained open.

Survey responses were collected via Qualtrics survey software and statistical analyses were performed using R (R Foundation for Statistical Computing, Vienna, Austria). Survey responses were matched based on unique, anonymous survey codes to align pre- and post-survey responses. Descriptive statistics were performed to characterize survey responses. Comparisons of continuous data within the survey were performed using a Student *t*-test. All statistical tests were 2-tailed, and a *p*-value less than 0.05 was considered to indicate a statistically significant difference.

RESULTS

One hundred and forty-three out of 159 pharmacy students completed the survey resulting in a response rate of 90%. Thus, 16 out of 159 pharmacy students were excluded because of incomplete or unsubmitted survey responses. Seventy-seven (54%) and 67 (46%) pharmacy students responded from Binghamton University School of Pharmacy and Pharmaceutical Sciences and Saint John Fisher College Wegmans School of Pharmacy, respectively. More respondents were female (63%) compared to male (37%).

Overall mean knowledge scores on ten PAAST-related questions significantly improved from pre-intervention to post-intervention (6.67 ± 1.51 versus 7.81 ± 1.39 , $p < .001$). Table 1 displays the pre- and post-survey PAAST knowledge scores by item. All questions demonstrated statistically significant improvement following FDIS. Knowledge scores increased by an average of one point overall following the intervention ($p < .001$). Furthermore, 59% of pharmacy students' knowledge scores improved with 37% of them improving by ≥ 2 points.

Overall mean confidence agreement with PAAST statements using a 5-point (0-4) Likert scale significantly improved from pre-intervention to post-intervention (2.3 ± 0.7 versus 3.22 ± 0.67 , $p < .001$). Table 2 shows the mean improvement in confidence agreement scores for PAAST following FDIS. Pharmacy students' confidence increased significantly in all PAAST areas assessed. Confidence scores increased the most for penicillin skin testing, specifically with the steps to perform penicillin skin testing, the scratch test component, the intradermal component, and management of potential adverse reactions.

Table 3 displays pharmacy students' perceptions of the FDIS on PAAST. Pharmacy students' perceptions of the class were positive overall. On a 0-to-4-point scale, the mean agreement for each statement was above 3.4. Based on anecdotal information, pharmacy students were interested in having additional FDIS sessions in the future, and believed that participation will better prepare them for their clinical rotations and future practice as a pharmacist. They found the class enjoyable and that it generally improved their knowledge and comfort level for evaluation and management of PAAST.

DISCUSSION

Given the importance of pharmacists as drug experts and educators for ASP, pharmacy graduates involved in antimicrobial stewardship roles will likely engage in PAAST in both inpatient and outpatient settings.^{19,24,26} Postgraduate training opportunities for pharmacists specializing in ID are available, but a limited number of programs currently exist.²⁸ A 15-hour continuing education certificate program is offered by the University of South Carolina College of Pharmacy to specifically train and certify pharmacists and other clinicians in PAAST, which also includes a four-hour live component with hands-on teaching and practice with penicillin skin testing.²⁹ Given these limited opportunities for pharmacy graduates, PAAST education and training should be considered to begin in schools of pharmacy.

We describe the implementation of FDIS on PAAST at two schools of pharmacy during a skills lab course. This interactive class was designed to teach and apply key components of the PAAST process including, but not limited to basic penicillin allergy knowledge, penicillin allergy statistics, beta-lactam antibiotic cross-reactivity, types of allergic reactions, penicillin allergy interview assessments, penicillin skin testing, and penicillin allergy management. Our goal was to provide pharmacy students with the necessary education and training to evaluate and manage penicillin allergies. We observed a statistically significant increase in overall knowledge scores on a ten-question PAAST assessment, and also on specific items, most notably those involved with penicillin allergy consequences, cross-reactivity, and correct steps of PAAST. We also observed a statistically significant increase in pharmacy students' confidence related to PAAST. Although pre-intervention to post-intervention confidence increased significantly on all items, the confidence boosts were particularly large on items related to penicillin skin testing. Furthermore, students generally enjoyed this interactive focused class on PAAST and found this educational initiative useful to their practice as a future pharmacist.

Current literature outlines the success of simulation experiences for various clinical pharmacy activities including medication reconciliation, patient counseling, and pharmacokinetic dosing.³⁰⁻³² To our knowledge, this is the first report to describe and evaluate PAAST education and simulation training in the PharmD curricula. It is unknown if and to what

extent PAAST education and training exists in PharmD programs. While allergies and drug hypersensitivities would be expected in the PharmD curricula,³³ it is unclear if this also includes PAAST. Kufel and colleagues evaluated the inclusion and extent of antimicrobial stewardship education among schools of pharmacy in the United States, and identified that only approximately 68% of respondents included antimicrobial stewardship in their required didactic curricula. However, it is still unknown if this education specifically included PAAST. As such, we hope our experience will further encourage pharmacy educators to consider prioritizing PAAST education and training within the PharmD curricula.

One of the strengths of our study was the high survey response rate of 90% to potentially minimize the risk of selection bias. Nevertheless, our study is not without important limitations to consider. First, we surveyed pharmacy students soon after the FDIS on PAAST was delivered. Therefore, it is unclear if students will have retained the content and application upon graduation for future practice. Future studies should perform follow-up assessments to evaluate if the content and skills learned were retained. Second, our surveyed population is only representative of pharmacy students from two schools of pharmacy and may not be generalizable to pharmacy students at other schools of pharmacy. Third, our instruction was delivered by two different ID pharmacist faculty members at each school of pharmacy, and thus, the content delivery may have varied. However, we utilized the same lecture content and activities for teaching to be as consistent as possible. Lastly, given the limited number of knowledge-based questions asked, there is a potential wide range for significance where small changes in the number of correct or incorrect responses could impact results.

CONCLUSIONS

Our study demonstrated that delivery of a FDIS on PAAST to pharmacy students led to significant improvements in knowledge scores and confidence for performing PAAST. Pharmacy students also described that they enjoyed this educational experience and desired more FDIS in other areas. Future evaluations of PAAST education and training within the pharmacy school curricula are needed since it is unclear if and to what extent such exists. We hope our structure and delivery can serve as a model for schools of pharmacy to increase PAAST education for pharmacy students.

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Table 1. Pre- and Post-Intervention PAAST Knowledge Scores by Item (n=143).

Question Number	Question Topic	Pre-Intervention (Percentage Correct)	Post-Intervention (Percentage Correct)	P-value ^a
1	Symptoms of IgE-mediated allergic reactions	94%	98%	<.001
2	Percentage of individuals labeled as penicillin allergic	73%	87%	<.001
3	Percentage of individuals truly allergic to penicillin	65%	71%	<.001
4	Percentage of individuals with IgE-mediated allergic reactions to penicillin who lose sensitivity at ten years	82%	97%	<.001
5	Untoward consequences of labeled penicillin allergies	42%	82%	<.001
6	Beta-lactam antibiotic cross-reactivity based on R-1 side chain	66%	88%	<.001
7	Rashes in children with Epstein Barr virus infections who receive penicillin-type antibiotics	96%	99%	<.001
8	Recommend penicillin skin testing for an appropriate patient	29%	37%	<.001
9	Graded challenge versus desensitization	27%	42%	<.001
10	Identifying the correct steps in the PAAST process	80%	95%	<.001

^ap-values are from t-test analyses of pre- to post-intervention improvement.

Abbreviations: Immunoglobulin E, IgE; PAAST, penicillin allergy assessment and skin testing.

Table 2. Mean Pre- to Post-Intervention Improvement in Confidence Agreement Scores for PAAST

Following the Focused Didactic Instruction and Simulation Class (n=143).

Question number	PAAST category or topic	Mean improvement ^a (95% CI)
1	Penicillin allergy statistics and epidemiology	0.62 (0.46-0.79)
2	Untoward consequences of penicillin allergies	0.45 (0.29-0.62)
3	Cross-reactivity between beta-lactam antibiotics	0.79 (0.59-0.99)
4	IgE-mediated allergic reactions	0.38 (0.22-0.54)
5	Ability to perform a penicillin allergy interview	0.86 (0.67-1.05)
6	Provide penicillin allergy education to patients	0.67 (0.51-0.84)
7	Provide penicillin allergy education to clinicians	0.93 (0.74-1.12)
8	Differentiate desensitization versus graded challenges	1.05 (0.84-1.25)
9	Recommend penicillin skin testing for an appropriate patient	0.96 (0.75-1.17)
10	Correct steps to perform a complete penicillin skin test	1.45 (1.24-1.65)
11	Correct steps to perform the scratch test component	1.78 (1.56-1.99)
12	Correct steps to perform the intradermal component	1.42 (1.20-1.64)
13	Management of potential adverse reactions during a penicillin skin test	1.41 (1.20-1.61)
14	Interpretation of penicillin skin test results	0.67 (0.45-0.89)
15	Delabeling the penicillin allergy following a negative penicillin skin test	0.45 (0.67-1.24)

^ap-values were derived from t-test analyses of pre- to post-intervention improvement and all were statistically significant ($p < .05$).

Abbreviations: Immunoglobulin E, IgE; PAAST, penicillin allergy assessment and skin testing.

Table 3. Post-Intervention Perceptions of the Focused Didactic Instruction and Simulation Class on PAAST (n=143).

Item	Mean (SD) ^a
I am interested in having more focused instruction and simulation sessions for infectious disease education in the future.	3.58 (0.69)
I feel that participation in this penicillin allergy instruction and simulation will better prepare me for my clinical rotations.	3.57 (0.70)
I feel more comfortable performing an evaluation and providing recommendations for a patient with a penicillin allergy following penicillin allergy instruction and simulation.	3.61 (0.69)
I learned content in the penicillin allergy instruction and simulation that will be useful in my future practice as a pharmacist.	3.52 (0.72)
Penicillin allergy instruction and simulation was an enjoyable active learning experience.	3.55 (0.72)
Penicillin allergy instruction and simulation improved my knowledge of penicillin allergies.	3.47 (0.79)

^aItems are measured on a 0 (strongly disagree) to 4 (strongly agree) scale.

Abbreviations: PAAST, penicillin allergy assessment and skin testing; SD, standard deviation.