Original Research

Pharmacist-led education curriculum for fourth-year medical students: a single-center experience

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Abstract

Background: Doctors are usually challenged by the transition between theoretical basic science knowledge and actual clinical practice. Thus, a critical educational intervention is the early incorporation of pharmacists into the pharmacotherapy courses for undergraduate medical students from their college years and moving to the practice setting. **Objective:** We sought to determine if a pharmacist-led education course would improve medical students' knowledge of general pharmacotherapy topics. **Methods:** All fourth-year female medical students were invited to enroll in the pharmacy practice curriculum between January and March 2022. The program was divided into three main domains: formal lectures, a hands-on prescription writing skills session, and on-site pharmacy practice sessions. The pharmacy practice session was divided into three sections: first section pharmacy practice, second section pharmacy innovation, and the third section clinical pharmacy. Those who completed the curriculum were requested to complete pre- and post-session assessments and curriculum evaluations. **Results:** One hundred fourteen medical students enrolled in the pharmacy practice module. One hundred eleven (97.4%) completed the pre-and post-course assessment. After completing the module, the medical students' knowledge scores improved from pre- to post-course. A significant difference in the overall knowledge was observed between the pre-course and post-course scores (9.51 versus 16.04; p<0.001). The difference between the pre-course and post-course scores was also significant when comparing the knowledge per each part of the assessment, showing an average score of 2.78 versus 4.05 (p<0.001) for the first section; 3.39 versus 5.49 (p<0.001) for the second section; 3.34 versus 6.48 (p<0.001) for the third section. The program received overall positive feedback; the experience was rated overall as "Excellent" by 73% of the participants. **Conclusion:** We have demonstrated the impact of a pharmacist-led curriculum for medical students on improving their knowledge of fundamental pharmacy practice areas.

Keywords: pharmacist-led education; curriculum; medical students; knowledge; interprofessional education

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INTRODUCTION

Healthcare interprofessional education is a cornerstone in promoting effective cooperation, enhancing care provision, and optimizing patients' health-related outcomes. This was advocated by the World Health Organization (WHO) Framework for Action on Interprofessional Education and Collaborative Practice in 2010.[1,2] Globally, using medications is a dominating therapeutic approach to different disease states. Hence, the prescribing pattern of medications is directly related to the treatment outcomes and might lead to patient harm if errors occur.[3,4] In parallel, medication errors can be increased as a significant number of medications are prescribed by junior doctors.

Moreover, these doctors are usually challenged by the transition between theoretical basic science knowledge and actual clinical practice.[3,5] Thus, a critical educational intervention is the early incorporation of pharmacists into the pharmacotherapy courses for undergraduate medical students from their college years and moving to the practice setting.[3,5] This has been endorsed by the American College of Clinical Pharmacy (ACCP).[6]

Pharmacists are recognized as medication experts who receive specialized comprehensive education and training in various pharmacotherapy aspects.[3,7] Furthermore, their role has expanded to directly impact patient outcomes as multidisciplinary rounds professionals.[3] Thus, they can enhance the medication-based knowledge of other professions and translate it into a practice setting. This is particularly vital for medicine students.[4,7] The impact of pharmacist-led education has positively influenced the pharmacotherapy-related knowledge and practice of medical residents and physicians in various areas, as demonstrated in several studies.[3,8,9] However, little evidence on the impactful contribution of pharmacists to undergraduate medical students has been published, particularly on implementing structured formal programs.[4,10]

Hence, we sought to determine if a pharmacist-led education course would improve medical students' knowledge of general pharmacotherapy topics. We hypothesized that the pharmacist-led education curriculum would significantly improve medical students' knowledge of pharmacotherapy topics discussed within the curriculum. We also examined the students' overall

satisfaction.

METHODS

Aim

To evaluate the impact of pharmacist-led educational curriculum on the medical student's knowledge in general pharmacotherapy topics.

Design and setting

A pre- and post-intervention (quasi-experimental) study that was conducted in a tertiary care teaching hospital, Khobar, Eastern Province, Saudi Arabia.

Study population

All fourth-year female medical students were invited to enroll in the pharmacy practice curriculum between January and March 2022. Those who completed the curriculum were requested to complete pre-and post-session assessments and curriculum evaluations.

Program learning objectives

Seven learning objectives were set to be achieved by the program participants: 1) Describe the pharmacy practice aspects, including clinical pharmacy, 2) Explain the basis of the medication review process, 3) Summarize the medication error reporting process and analysis, 4) Recognize the pharmacy and therapeutic committee activities, 5) Discuss dosing methods in different patient populations, 6) Define the principles of pharmacokinetics and therapeutic drug monitoring, and 7) Describe the total parenteral nutrition indications and calculations.

Program structure

The program was divided into three main parts: formal lectures, a hands-on prescription writing skills session, and on-site pharmacy practice sessions.

Six formal online lectures were given to the medical students through Zoom (Zoom Video Communications, Inc., Santa Clara, California, United States). The lectures were chosen based on the pharmacists' areas of expertise, the medical students' curriculum, and the medical school's request. The lectures included an overview of major medication classes such as antidiabetics, antihypertensive, and direct oral anticoagulants. Furthermore, some essential concepts were introduced through those formal lectures, including an introduction to antimicrobial stewardship, considerations of medication dosage in special populations, and drug information safety guards.

Prescription writing skills are considered a critical aspect of our program and were given in the skills lab at the university campus, of which all the students were gathered in one session. The aim was to provide the medical student with the necessary skills to write medication prescriptions formally, integrating with the new technology skills using computerized prescribing order entry (CPOE). The program covered the

following: different types of prescription and the classification of medications, comparison and contrast between the schedules of controlled substances, component elements of the prescription, component elements of a controlled-substance prescription, controlled-substance classification and schedules, examples of look-alike and sound-alike prescription medications, and confusing abbreviations used in prescription writing. The program also highlights the importance of the usage of CPOE and its rule in minimizing prescribing errors.[11,12] Finally, it covered the national law and regulation requirements on prescription writing.[13]

The final part is the pharmacy practice sessions conducted three times weekly for seven weeks at the hospital and pharmaceutical care department. The medical students were divided into groups; each group had 16 students. We had a new group of medical students each week for three full days (Sunday, Tuesday, and Thursday). The days were divided into three domains: pharmacy practice, pharmacy innovation, and clinical pharmacy.

Domain 1: Pharmacy Practice

The domain of pharmacy practice provided an overview of three areas of pharmaceutical services: outpatient pharmacy, inpatient pharmacy, and intravenous (IV) room principles.

Outpatient pharmacy

It was meant to shed light on the workflow within the outpatient pharmacy department, from receiving the prescriptions to medication dispensing and counseling. There was an emphasis on prescription content and how to write a proper prescription, with many examples. Some counseling points and scenarios were discussed as well.

Inpatient pharmacy

This session was designed to aid medical students in understanding the importance of interprofessional interactions between pharmacy and medicine. It provided an overview of how pharmacists work in parallel with other professions to achieve the broad goal of optimizing patient outcomes. The session covered multiple aspects of the inpatient pharmacy, including the unit-dose system, the medication review process, the extemporaneous compounding, and the active role of the pharmacy in emergency codes. Moreover, the review and processing of medication orders and related integral collaboration and interactions between physicians and pharmacists were heavily discussed. Interactive case-based learning was exploited to present the medication-related problems, including the appropriateness of medication and its pertinent information, the indication of the medication, missing medication therapies, duplicate therapies, contraindications, adverse drug reactions, allergies, and drug-drug interactions.[1,2,14-16] Furthermore, some medication references were introduced to the students, and their utility in their future profession as doctors was emphasized.

IV room principles

It focused on introducing the concept of sterile products compounded in the IV room and listing some preparations that should be sterile, like eye drops, total parenteral nutrition (TPN), intravenous, intrathecal, intravesical, and intravitreal preparations.[17] It was essential to highlight the responsibilities of the IV room staff, including order verification, choosing the compatible diluent for each medication, minimizing the volume of dilution if needed, and compounding to ensure sterility. Explaining these roles to medical students will assist them in the future in making the best use of IV room services.[2] Furthermore, reviewing the orders was explained, aiming to improve prescribing, teamwork, communication, and conflict resolution.[1]

Domain 2: Pharmacy Innovation

The domain of pharmacy innovation provided an overview of three areas of pharmacy operation: pharmacy informatics, medication safety, and drug information.

Pharmacy informatics

This session aimed to give an overview of the concept of health informatics regarding medication-related information in electronic health records, pharmacy information systems, and automated systems. The students were introduced through a physical tour to all the automated systems related to medication in our hospital and how this can serve us as healthcare providers to minimize medication errors.[18-20]

Medication safety

In the pharmacy quality and safety module, the students were introduced to the importance of quality in health care and implanting the patient safety culture and non-punitive approach to reporting medication events.[21] Moreover, they were introduced to high-alert, look-alike, and sound-alike medications and how the mistakes may or may not be more common with these drugs; however, the consequences of an error are more devastating to the patient.[22,23] In addition, all strategies used to avoid errors were listed. Finally, the national and international hospital accreditations body were discussed briefly, emphasizing the importance of accreditation as a process used by healthcare organizations worldwide to accurately assess their performance with established standards.

Drug information

The drug information services lecture aimed to relay the importance of pharmacist/physician integration in the management of the formulary, creating and implementing medication management policies and procedures following evidence-based medicine. The drug information services portion of the training was divided into two aspects: a lecture given to the students followed by a practical part that focuses mainly on applying the knowledge gained. An important concept covered was hospital policies and procedures and how they aid healthcare providers in appropriately providing patient care services. Moreover, they were acquainted with utilizing these policies when requesting certain pharmaceutical services. Lastly, they were divided into two groups and given various practice scenarios that required them to search through the hospital drug information website (Lexi-Comp®),

read different policies, and use various forms (non-formulary, unlicensed, formulary addition request form).

Domain 3: Clinical Pharmacy

The domain of clinical pharmacy provided an overview of the following areas: total parenteral nutrition, therapeutic drug monitoring (TDM), warfarin TDM, and antimicrobial stewardship activities.

Total Parenteral Nutrition (TPN)

Parenteral Nutrition refers to providing nutrients through a venous access device for the basic metabolic functioning of the body when patients cannot receive adequate oral nutrition.[24,25] Physicians are likely to encounter parenteral nutrition in clinical practice. Thus, they must have a solid background in this area. Therefore, the objectives of this session were to 1) discuss the appropriate indications for the use of parenteral nutrition, 2) recommend a patient-specific parenteral nutrition formula based on the patient's nutritional needs, comorbidities, clinical condition, and the type of intravenous access used, and 3) discuss the monitoring parameters and the strategies for preventing complications associated with parenteral nutrition.

Therapeutic Drug Monitoring (TDM)

This session aimed to discuss the application of therapeutic drug monitoring in clinical settings. Examples of the medications needing TDM were included so students practice timing when to order drug concentration levels and factors affecting measured concentrations. Moreover, the students were enabled to apply their knowledge and practice in interpreting measured drug concentrations and adjusting doses accordingly to make clinically appropriate recommendations and monitor therapeutic drug dosing. By the end of this session, students could have skills in optimizing clinical outcomes of drug therapy by appropriate drug dosing in various clinical situations.

Warfarin TDM

This session aimed to equip undergraduates with the background knowledge and basic practical skills to manage anticoagulation with warfarin. That included a description of the pharmacological action, dosing, monitoring, managing clinically significant drug-drug or food-drug interactions, and reversal of warfarin. The effect of patient compliance and knowledge on the quality of warfarin therapy was also discussed. The lecture was combined with case studies showing the challenge of warfarin therapy.

Antimicrobial Stewardship (ASP)

This session aimed to incorporate the basic principles of antimicrobial stewardship program (ASP) and the appropriate use of antimicrobials into the education of undergraduate medical students. Through the formal lecture week, the drivers of antimicrobial resistance, the basic principles of ASP, the importance of preserving antimicrobials, and the types of ASP interventions were described. During the practical part, hands-on activities were conducted by reviewing the ASP principles and interventions[26] implemented at our institution, including restriction/preauthorization, prospective audit and feedback,

de-escalation/streamlining, pharmacokinetic dosing service, intravenous to oral conversion, and antibiotic home infusion pump.

Pre- and post-module assessment

The program included pre-course and post-course assessment tests consisting of 20 items to test the participants' knowledge of pharmacy practice. The questions were divided into three sections according to the pharmacy specialty areas. The first section includes medication distribution, inpatient pharmacy, outpatient pharmacy, and IV room principles; it contains five questions. The second section includes pharmacy quality, drug information, and pharmacy automation; it contains seven questions. Lastly, the third section includes clinical pharmacy aspects; it contains eight questions (Additional file 1).

Statistical analysis

Data analysis was performed using Statistical Package for the Social Sciences (SPSS) version 25 (IBM Corporation, Armonk, New York, United States). The data were summarized as frequencies (n) and percentages (%) for the categorical variables. Mean, and standard deviation were used to present the continuous variables. Paired t-test was utilized to test for a significant difference in knowledge after medical students' exposure to the pharmacy practice educational module. The level of significance was set at 0.05.

RESULTS

One hundred fourteen medical students enrolled in the pharmacy practice module. All the enrolled students were females (100%). One hundred eleven (97.4%) completed the pre-and post-course assessment.

Pre- and post-module assessment

After completing the module, the medical students' knowledge scores improved from pre- to post-course (Table 1; Figure 1). A significant difference in the overall knowledge was observed between the pre-course and post-course scores (9.51 versus 16.04; p<0.001). The difference between the pre-course and post-course scores was also significant when comparing the knowledge per each part of the assessment, showing an average score of 2.78 versus 4.05 (p<0.001) for the first section; 3.39 versus 5.49 (p<0.001) for the second section; 3.34 versus 6.48 (p<0.001) for the third section.

Student satisfaction survey and comments

One hundred ten medical students completed the course satisfaction survey. The experience was rated overall as "Excellent" by 73%, "Very Good" by 15%, and "Good" by 11% of the participants (Figure 2). The pharmacy practice sessions received an average rating of 3.66 (Standard deviation [SD], 0.12) out of 4. The inpatient pharmacy and antimicrobial stewardship sessions received the highest rating of 3.78, while the introduction to pharmacy automation session received the lowest rating of 3.36 (Figure 3).

Moreover, the program received overall positive feedback from

Table 1. Comparison of participants' knowledge score pre-course and post-course			
Time of Assessment	**Knowledge Score (Score out of 20)**		**P-Value**
	Mean	**Standard Deviation**	
Overall knowledge score			
Pre-Course	9.51	2.07	< 0.001**
Post-Couse	16.04	4.38	
The first section knowledge score [a]			
Pre-Course	2.78	0.72	<0.001**
Post-Couse	4.05	1.26	
Second section, knowledge score[‡]			
Pre-Course	3.39	1.25	<0.001**
Post-Couse	5.49	1.62	
Third section knowledge score*			
Pre-Course	3.34	0.79	<0.001**
Post-Couse	6.48	1.63	

†Includes areas of medication distribution, inpatient pharmacy, outpatient pharmacy, and IV room. ‡Includes areas of quality and medication safety, drug information, and pharmacy automation. *Includes areas of clinical pharmacy. **Significance level at 0.05.
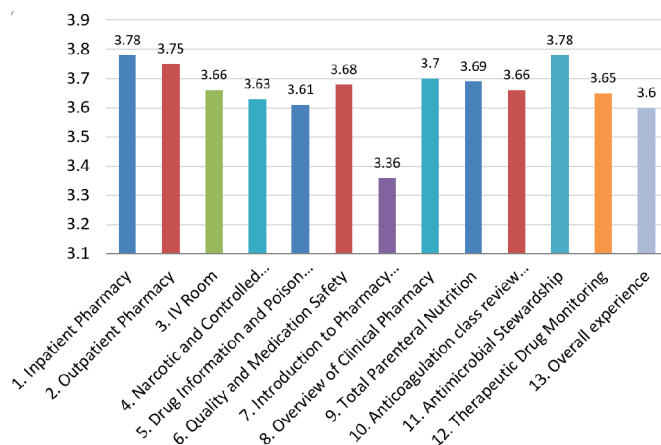

Figure 1. The percentages of the correct answers pre-and post-course exposure

Figure 2. Overall experience rating

the participants. Their comments addressed the importance of the program topics to the participants' future practice, complemented the program's organization and structure, and raised some concerns about its drawbacks. A collection of the participants' comments is presented in Table 2.

Figure 3. The rating of the sessions based on the participants' experience

DISCUSSION

Our study demonstrated the impact of a pharmacist-led module for medical students in improving their knowledge about the essential aspects of pharmacy practice. This impact has been demonstrated by the significant difference between the study participants' pre-course and post-course assessment test scores. Our findings are consistent with the study by Miesner and colleagues, which reported a two-fold increase in the post-assessment aggregate scores among medical residents after completing eight pharmacotherapy podcast modules developed by fourth-year pharmacy students.[27] The effect of such a module, however, may extend beyond the mere improvement in knowledge, as it was reported in a previous systematic review and meta-analysis of twelve studies involving 115,058 participants, in which educational programs led by a pharmacist were associated with significant reductions in the overall rate of medication errors occurrence (Odds ratio [OR], 0.38; 95% confidence interval [CI], 0.22 to 0.65).[28]

Prescribing errors are common and a known cause of adverse patient outcomes. The causes and frequency of prescribing errors include a lack of prescribing knowledge and skills, lack of error awareness, hindering cultural and behavioral prescribing norms, systems failures, and individual pressures such as workload and fatigue. Although the prescription writing skills session was a core part of our module structure, it was not included in the pre-and post-module assessment. However, previous studies on educational interventions and prescription writing errors identify generally positive results.[7,29]

The structure of our program included on-site pharmacy practice sessions. Since the pharmacology course is often only taught to medical students at a basic science level, our approach might add benefit to the medical students to connect the provided knowledge with real-world practice. This can be more impactful than delivering a didactic lecture in a classroom, primarily when it is taught by pharmacists who are ideally suited for this job based on their extensive education through didactic coursework and clinical training. However, our study has not developed a formal assessment that explicitly evaluates this approach's outcomes.
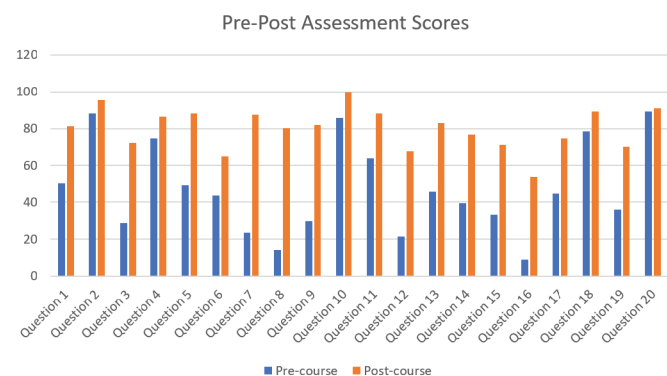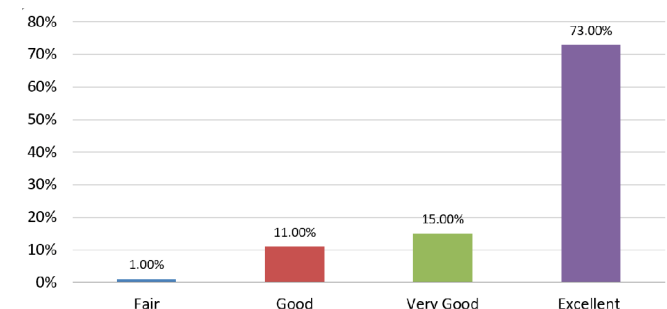
The feedback from the students was overwhelmingly positive and supportive of the program, with 73% of the participants giving an "Excellent" overall rating. Also, the comments from the participants demonstrated a positive attitude toward the program. Our findings support those of others that have found a positive impact of pharmacist-led teaching of junior doctors and medical students.[29,30] Also, the pharmacy practice sessions in our curriculum received a high rating, similar to a previous study that found a pharmacist-led session consistently received the highest rating score with an average of 4.7±0.5 on a 5-point scale.[3]

Our study has several limitations. First, the study has a small sample size that consists entirely of females, which could affect the generalizability of our findings. However, the inclusion of only female participants was not intentional. Instead, the program underwent some modifications after getting participants' feedback. Hence, only the participants in the program's first phase were included in the study to remove that variable. Second, the assessment method used in the program might not accurately reflect its learning outcomes since we used a knowledge-based assessment test for modules that follow the demonstration and hands-on approach.

CONCLUSION

Interprofessional education is essential in decreasing medical errors and improving patient outcomes. We have demonstrated the impact of a pharmacist-led curriculum for medical students on improving their knowledge of fundamental pharmacy practice areas. The program also received a high level of satisfaction from the participants. Our findings add to the current body of literature to emphasize the importance of involving pharmacists in teaching clinical pharmacology and pharmacotherapy courses to medical students.

LIST OF ABBREVIATIONS

ACCP	American College of Clinical Pharmacy
ASP	Antimicrobial stewardship Program
CPOE	Computerized Prescribing Order Entry
IV	Intravenous
OR	Odds Ratio
SD	Standard Deviation
SPSS	Statistical Package for the Social Sciences
TDM	Therapeutic Drug Monitoring
TPN	Total Parenteral Nutrition
WHO	World Health Organization

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Not applicable

CONFLICTS OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

ETHICAL APPROVAL AND CONSENT TO PARTICIPATE

The ethical approval was obtained from institutional review board (IRB) at Imam Abdulrahman bin Faisal University [ethics review ID: IRB-2023-484-KFUH]. The informed consent was waived by [institutional review board at Imam Abdulrahman bin Faisal University] as neither patients were involved nor intervention was done. All methods were carried out in accordance with Declaration of Helsinki.

CONSENT FOR PUBLICATION

Not applicable

AVAILABILITY OF DATA AND MATERIALS

All data generated or analyzed during this study are included in this published article [and its supplementary information files].

FUNDING

The project received no funding.

AUTHORS' CONTRIBUTIONS

BA has designed the idea, planned and conducted part of the course, supervised all of the activities, and contributed substantially to the drafting and revision of the manuscript. HW has contributed substantially to the interpretation of data, writing a major part of the manuscript, and revising the submitted version. ZA has contributed to the design of the study, ensured the consistency of collected data, written a major part of the manuscript, and substantially revised the submitted version. NA has analyzed the data collected, and substantially contributed to drafting and revising the manuscript. All authors contributed to the conduction of the course, acquisition of data, and drafting the manuscript. All authors have read and approved the submitted version of the manuscript.

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Table 2. Participants' feedback about the program	
Response ID	**Response**
139621771	I really enjoyed this experience; to be honest, it is one of the favorite rotations. **Pros:** 1- Pharmacy department tours. 2- Learning more about available facilities and aiding tools that will help us in the future. 3- Understand my part in drug-related issues as a future physician. 4- Raised more emphasis on the importance of physicians and pharmacists working together as a team to ensure a safe and understanding environment. **Cons:** 1- Number of lectures 2- The attendance time Thank you all for your efforts and for being genuinely nice and welcoming.
139621694	Honestly, it was one of the best rotations in the block. I enjoyed it so much, especially the tours.
139621633	Organized rotation filled with interested pharmacists in their field.
139211290	Very organized
139206464	Everything was perfect, and the staff was well prepared and well organized
139206205	I think it is possible to decrease the time for lectures with the same benefits (timesaving)
139205005	Thank you so much for this informative rotation
138581740	It has been a great experience with the team and a very well-organized and timely schedule. It would have been more exciting if we could do more hands-on work with you in. The pharmacy. As for lectures, all were really valuable and important; however, I sense that the areas of deficiencies in our knowledge should be covered also
138523485	Everything was good, but if we could take the lectures All and then go down to see the pharmacy would be a lot easier
138520738	The three tours should be together at the same time. It was not convenient to leave the class 3 time and return
138520722	I expected the rotation to be about medications with their mechanism of action, effects, and clinical uses, but the rotation was excellent, and the doctors were amazing. It would have been better if it was not until 4 o'clock. Thank you for all your efforts.
138520242	It was a great rotation with very helpful and optimistic staff
138519978	Thank you for this informative rotation
138519184	It is better to have all the lectures then the tour instead of having a lecture then going to the other building and the lecture and so on. It was uncomfortable.
137830161	One of the best rotations I have ever attended. The doctors' teaching skills are extraordinary
137810625	The rotation was great. We need all the slides for future reference. Thank you all for your efforts and kindness.
137809318	Very informative rotation, thank you.
137809285	Everything was extremely organized, and the instructors were welcoming our questions. The rotation gave me an insight on how important communication between physicians and pharmacists is and how this reflected on the patient's wellbeing. I do have one suggestion regarding the rotation. I think it would be even greater if there were a focus on topics covering what medical students in our university seems to have problems within pharmacology, based on the consultants' and pharmacists' opinions. (Lacking the knowledge in fluid resuscitation, for example) Other than that, everything was great and really informative, and the team was even greater. Thank you.
137181668	Excellent rotation, very organized. I learned a lot about how the work is done.
137181363	Focusing on drug monitoring, dosing, and all the information that benefit us as a medical student when giving a drug to our patients is what we want from this rotation. So, I think it will be best if all lectures or rotations are the same as warfarin, therapeutic drug monitoring, TPN, and lectures like this that teach us the formulas and dosage. I would like to advise a lecture on how to do unit conversions. Reporting lectures and DIC was also very beneficial for us in the future.
137180871	It would be great if the lectures were more relatable to our major.
136896725	It is not a recommendation. I just wanted to say that I really enjoyed this experience with the pharmacy department, so thank you so much.
136896712	Many lectures and kind of a heavy material for medical students and so if you can kindly combine some lectures together by mentioning the most imp points. Thank you, all great rotation.
136896708	One of the best rotations, a very healthy and welcoming environment.
136896705	The best department ever. Thanks for your hard work.
136896692	Thank you so much for your efforts. It was a nice experience. I just have a comment regarding time. I think that having from 8-4 was kind of tired otherwise, everything was amazing
136896690	Very interesting rotation. We really enjoyed it.
136896689	Best department ever. Very nice people!