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MAJOR ARTICLE

Change in the Perception of Oral Antibiotics Among Medical Students After Participating in a Parenteral-to-Oral Conversion Program for Highly Bioavailable Antibiotics

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Background. Appropriate conversion of antibiotics from a parenteral to the oral route can lower the risk of catheter-associated infections, reduce medical costs, and shorten hospitalization. This study investigated the effect of a parenteral-to-oral conversion program for highly bioavailable antibiotics on the perceptions of medical students regarding oral antibiotics.

Methods. In 2021, the parenteral-to-oral conversion program was implemented as one of the activities of an antimicrobial stewardship program at a tertiary-care hospital in South Korea. This program was also implemented for fifth-year medical students in the hospital's infectious diseases department as a core clinical practice course. Medical students reviewed the medical records of patients taking antibiotics with a high oral bioavailability and wrote a recommendation for oral conversion after confirmation by an infectious disease specialist. A survey on the perception of oral antibiotics was administered to medical students before and after clinical practice to evaluate the educational effect of the program.

Results. A total of 923 cases were reviewed, and more than one-fifth of the antibiotics with a high oral bioavailability were administered parenterally despite their oral conversion (20.6%, 190/923). Of these, 24.2% (46/190) accepted the written proposal within 48 hours, and 43.7% (83/190) declined the proposal. Through this program, students gained a proper perception of oral antibiotics.

Conclusions. The parenteral-to-oral conversion program demonstrated an acceptance rate of oral antibiotic conversion in the hospital of 24.2% and had significant educational benefits for medical students, giving them the ability to construct an appropriate perception of oral antibiotics.

Keywords. antibiotics; South Korea; education; medical student; stewardship.

Although parenteral antibiotics are still widely used for inpatients, most infectious diseases can be treated with oral antibiotics [1, 2]. As oral antibiotics are absorbed in the gastrointestinal tract and subsequently metabolized by the liver, they take longer to reach the optimal antibiotic blood concentration than parenteral antibiotics. Thus, the use of oral antibiotics is prioritized, except for critical infectious diseases in which high blood concentrations are required in a short period, such as severe sepsis and neutropenic fever, or for some infections that require consistent maintenance of a high blood antibiotic concentration [3, 4]. In particular, antibiotics with a high oral bioavailability, including trimethoprim/sulfamethoxazole, clindamycin, linezolid, and metronidazole, reach the blood efficiently, and their therapeutic effects are expected to be similar to those of parenteral antibiotics [5].

Parenteral treatment requires a catheter for the intravenous injection, and the long-term intravenous injection can cause phlebitis, catheter-related bloodstream infections, catheter-related venous thrombosis, increase in medical costs, and discomfort to patients. For that reason, the guidelines for antimicrobial stewardship programs (ASPs) issued by the Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America, as well as those in South Korea, recommend the timely conversion of parenteral antibiotics to oral antibiotics, as this can shorten hospitalization and duration of antibiotic use and reduce medical costs and complications related to parenteral injection [5, 6]. However, it seems that there is still a lack of awareness regarding the necessity of timely oral conversion of parenteral antimicrobial agents among health care workers in South Korea. In a multicenter point prevalence study in South Korea, ~40% of

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parenterally administered highly bioavailable antibiotics were not adequately converted to oral antibiotics [7].

Because a lack of knowledge about infectious diseases and antibiotics leads to inappropriate antibiotic prescriptions, it is important to enhance the understanding of antimicrobial resistance and ASP among physicians through robust education [8]. Furthermore, the education of medical students should also be emphasized because they will lead the medical field in the next generation [8, 9].

To enhance students' learning, strategies are necessary to obtain knowledge from both a source (didactic learning) and an experience (experiential learning) [10]. The infectious diseases department at Hanyang University Hospital implemented the parenteral-to-oral conversion program as a clinical clerkship course for medical students in 2021. This study investigated the effect of a parenteral-to-oral conversion program for highly bioavailable antibiotics on the perceptions of medical students regarding oral antibiotics.

METHODS

Study Setting

Hanyang University College of Medicine is a medical school in South Korea with 2 university-affiliated hospitals: Hanyang University Hospital and Hanyang University Guri Hospital. Approximately 110 students are in each year, and 2–3 students were assigned to 1 group to conduct clinical practice programs throughout the year in the fifth year (a total of 109 students were in the fifth year in 2021). The clinical practice course of the infectious disease department is a 1-week course and is held in the fifth year. Each student group visits Hanyang University Hospital or Hanyang University Guri Hospital for clinical practice in the infectious disease department. The place of clinical practice, including that in the infectious disease department for each student, was determined by the annual academic schedule; students could not select the hospital for their clinical practice program. According to the academic schedule, half of the fifth-year students participated in the clinical practice program in the infectious diseases department at Hanyang University Hospital, whereas the rest in the same year participated in the program at Hanyang University Guri Hospital. As a result, a group of students visited Hanyang University Hospital every 2 weeks, and a practical clinical program was conducted for them.

At Hanyang University College of Medicine, the characteristics of oral antibiotics and the importance of their use are introduced to fourth-year medical students as a didactic lecture in the standard curriculum (Block Lecture of Infectious Diseases). However, there has been no specific didactic lecture on the parenteral-to-oral conversion program for all students.

In 2021, the parenteral-to-oral conversion program was implemented as one of the activities of an ASP at Hanyang University Hospital, an 846-bed tertiary-care hospital in South Korea. As a core clinical practice course, this program was applied to fifth-year medical students who participated in the infectious diseases department at Hanyang University Hospital (50.5%, 55/109). Students assigned to Hanyang University Guri Hospital (49.5%, 54/109) did not participate in the program. Half of the students in the fifth year participated in the program from January 2021 to October 2021 (Figure 1).

Parenteral-to-Oral Conversion Program

Considering the burden of medical record review for medical students, we selected 4 departments where highly bioavailable antibiotics were usually prescribed (pulmonology, gastroenterology, general surgery, and neurology) for the intervention. The number of prescriptions of highly bioavailable antibiotics for inpatients by department are shown in Supplementary Figure 1. Adult patients (age ≥19 years) hospitalized in these departments were screened by medical students. Patients who received parenterally administered highly bioavailable antibiotics, including ciprofloxacin, levofloxacin, moxifloxacin, metronidazole, linezolid, and trimethoprim/sulfamethoxazole, for >3 days, were selected for further review. There was no specific training or education for the students with regards to the review process. However, a structured form for the review was developed by a researcher (B. Kim) and distributed to students to minimize the differences between students (Supplementary Data 1).

If the patients did not meet the exclusion criteria for the intervention, the medical students wrote a structured recommendation of switching to oral antibiotics in their medical records without direct contact with the prescribers after this recommendation was confirmed by an infectious disease specialist (Supplementary Data 2). Students and infectious disease specialists were not involved in prescribing antibiotics in each department, and acceptance of the recommendation was entirely dependent on the prescriber. Supplementary Table 1 shows the definition of cases considered "impossible for oral conversion" who were thus excluded from the intervention (Figure 2).

Data Collection and Analysis

We retrospectively reviewed the medical records of hospitalized patients who underwent parenterally administered highly bioavailable antibiotics in the departments of pulmonology, gastroenterology, general surgery, and neurology from January 2021 to October 2021. The retrospective review process was conducted from December 2021 to February 2022, after students in their fifth year finished clinical practice programs in 2021.

Those with medical records that were created during the period when clinical practice in the infectious disease department at Hanyang University was not held were excluded from the review. The review was performed on a daily basis, and if the same patient used parenterally administered highly bioavailable antibiotics for 2 or more days, these cases were considered to be separate.

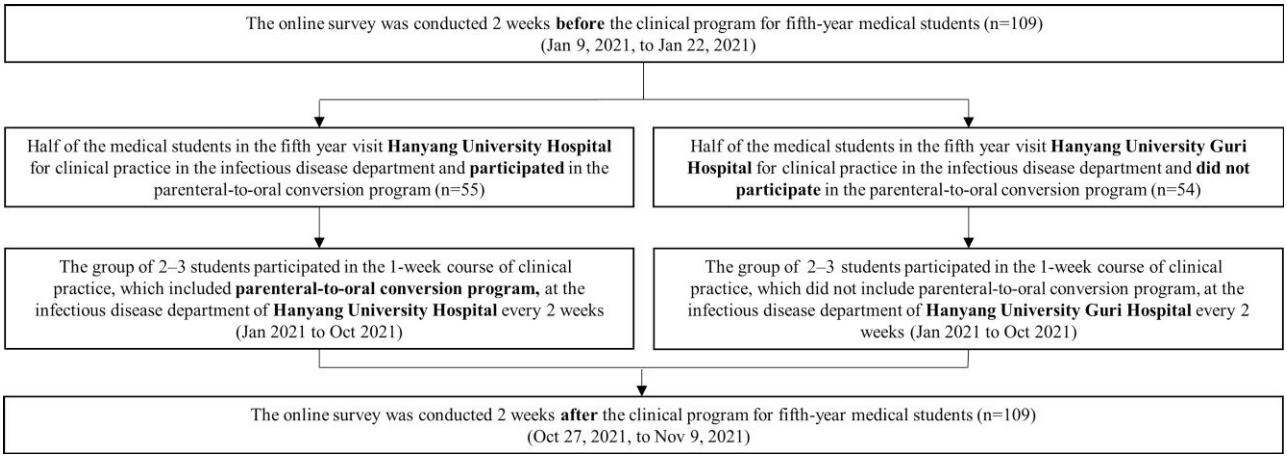

Figure 1. Flowchart of the study procedure.

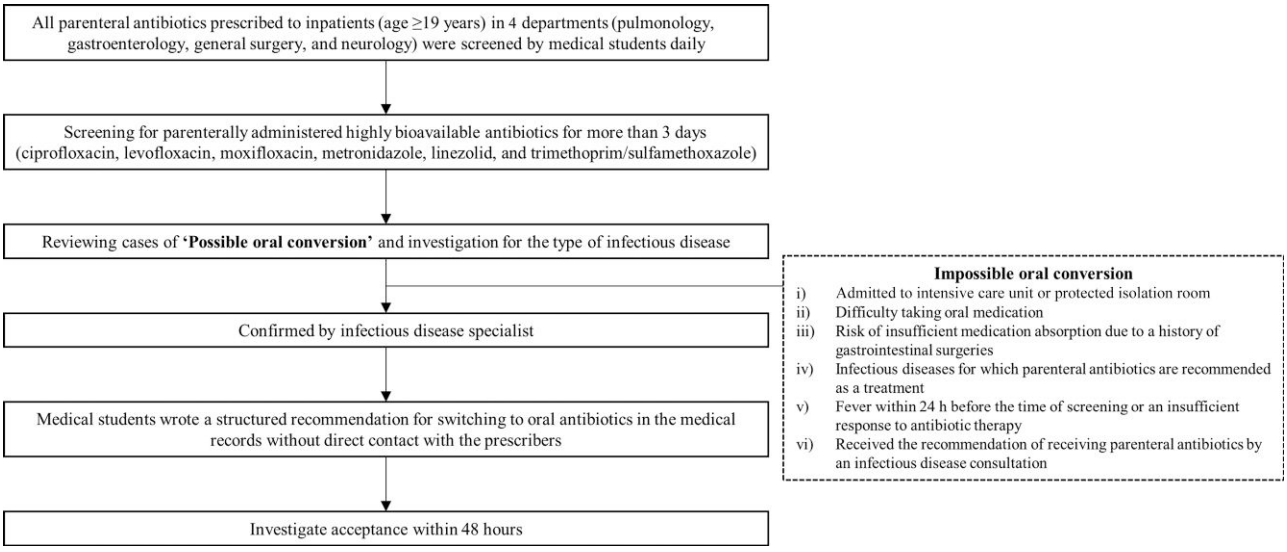

Figure 2. Flowchart of the parenteral-to-oral conversion program.

We collected data on age, sex, infection site, possibility of oral conversion, reason for impossibility of oral conversion, and response of the physicians after receiving a recommendation to switch to oral antibiotics. Of the patients with a recommendation to switch to oral antibiotics in their medical records, we defined cases as "intervention adherent" if parenteral antibiotics were converted to oral antibiotics within 48 hours of writing the recommendation. On the other hand, we defined cases as "intervention nonadherent" if parenteral antibiotics were continuously used for 48 hours after writing the recommendation (Figure 2).

Conducting the Survey

A survey on the perception of oral antibiotics was conducted to evaluate the educational effect of participation in the parenteral-to-oral conversion program. The questionnaire consists of 2 demographic questions and 15 questions related to the evaluation of the educational effect (3 questions about "perception of oral antibiotics," 4 questions about "knowledge of oral antibiotics," and 8 questions about "perception of criteria of possible oral conversion cases"). Each question related to the evaluation of the educational effect was measured using a 5-point Likert scale, which scored the degree of consent for each statement (Supplementary Data 3).

A link to the online survey was forwarded to all fifth-year medical students (n = 109) via email. The survey was conducted from 2 weeks before to 2 weeks after the clinical practice program for fifth-year medical students (January 9, 2021, to January 22, 2021; and October 27, 2021, to November 9, 2021). The same questionnaire was used for each survey. A

reminder was sent on the seventh day of each survey to encourage participation, and no incentives for participation were provided. The respondents were anonymized, and they voluntarily participated in the survey. Only 1 response was accepted from each participant; we could distinguish duplicate answers by the identification number entered in the survey by the respondents (Figure 1).

Statistical Analysis

Categorical variables were analyzed using the chi-square test or Fisher exact test, as appropriate, and continuous variables were analyzed using the Mann-Whitney *U* test or independent-samples *t* test. Moreover, changes in the perception of oral antibiotics among medical students before and after participating in the program were analyzed using the Wilcoxon signed-rank test or paired *t* test. All statistical analyses were performed using SPSS for Windows, version 24.0 (IBM Corporation, Armonk, NY, USA). Variables with a *P* value of <.05 were considered statistically significant.

Ethics Statement

The protocol for this study was approved by the institutional review board (IRB) of Hanyang University Hospital (IRB no. 2019-05-036-001), and the study was conducted in compliance with the guidelines of the Declaration of Helsinki, Belmont Report, CIOMS, and International Practice (ICH-GCP). All methods were performed in accordance with these guidelines and regulations. The requirement for written informed consent from the patients was waived because of the retrospective nature of the study.

RESULTS

Screening of Parentally Administered Highly Bioavailable Antibiotics

Table 1 shows the number of parenterally administered, highly bioavailable antibiotics screened in the program. A total of 1244 parenterally administered, highly bioavailable antibiotics were screened, of which 607, 400, 148, and 89 antibiotics were administered in the pulmonology, gastroenterology, general surgery, and neurology departments, respectively. For the 4 departments investigated in this program, levofloxacin and metronidazole were most commonly administered parenterally (41.8% and 37.8%, respectively). Levofloxacin was the medication most commonly administered, especially in the pulmonology and neurology departments (71.2% and 64.0%, respectively). In the gastroenterology and general surgery departments, metronidazole was administered most frequently (81.0% and 32.4%, respectively).

Effect of the Parenteral-to-Oral Conversion Program

The results of the parenteral-to-oral conversion program are presented in Table 2. In the 4 departments, 20.6% of the cases could be switched to oral antibiotics. In particular, in the pulmonology and gastroenterology departments, 24.8% and 21.2% of cases, respectively, could be switched to oral antibiotics. Regarding the response of the physicians after receiving a recommendation of switching to oral antibiotics, 24.2% of possible oral conversion cases (5.0% [46/923] of the patients reviewed) and 22.3% and 31.7% of cases in the pulmonology and gastroenterology departments, respectively, accepted the recommendation within 48 hours. However, 43.7% of the proposals were not accepted, and 48.8%, 33.3%, 40.0%, and 50.0% of the proposals were not accepted by patients in the pulmonology, gastroenterology, general surgery, and neurology departments, respectively.

A total of 79.4% of the patients could not be switched to oral antibiotics, and there were several reasons for the impossibility of oral conversion (Table 2). An insufficient response to antibiotic therapy and difficulty in taking oral medication were the most common reasons for impossibility (51.7% and 50.5%, respectively).

The demographic and clinical characteristics of patients who could be converted from parenteral antibiotics to oral antibiotics with high bioavailability are provided in Supplementary Tables 2 and 3.

Perceptions of Oral Antibiotics Before and After Participation in the Parenteral-to-Oral Conversion Program

Of the fifth-year medical students, 56.9% (62/109) responded to the survey. Among them, 66.1% (41/62) participated in the parenteral-to-oral conversion program, and 33.9% (21/62) did not. Of the participants, 74.5% (41/55) and 38.9% (21/54) who did and did not participate in the program responded to the survey.

Table 1. The Number of Parenterally Administered Highly Bioavailable Antibiotics Screened in the Program

…	Pulmonology	Gastroenterology	General Surgery	Neurology	Total
Metronidazole	7 (1.2)	324 (81.0)	122 (82.4)	17 (19.1)	470 (37.8)
Ciprofloxacin	6 (1.0)	52 (13.0)	14 (9.5)	14 (15.7)	86 (6.9)
Levofloxacin	432 (71.2)	23 (5.8)	8 (5.4)	57 (64.0)	520 (41.8)
Moxifloxacin	122 (20.1)	1 (0.3)	0 (0)	0 (0)	123 (9.9)
Trimethoprim/sulfamethoxazole	36 (5.9)	0 (0)	2 (1.4)	1 (1.1)	39 (3.1)
Linezolid	4 (0.7)	0 (0)	2 (1.4)	0 (0)	6 (0.5)
Total	607	400	148	89	1244

Table 2. Results of the Parenteral-to-Oral Conversion Program

…	Pulmonology (n = 487)	Gastroenterology (n = 283)	General Surgery (n = 79)	Neurology (n = 74)	Total (n = 923)
Possible oral conversion	121 (24.8)	60 (21.2)	5 (6.3)	4 (5.4)	190 (20.6)
Impossible oral conversion[a]	366 (75.2)	223 (78.8)	74 (93.7)	70 (94.6)	733 (79.4)
Admitted to the intensive care unit or a protected isolation room	128 (35.0)	14 (6.3)	7 (9.5)	13 (18.6)	162 (22.1)
Difficulty taking oral medication	210 (57.4)	94 (42.2)	23 (31.1)	42 (60.0)	370 (50.5)
Risk of insufficient medication absorption due to history of gastrointestinal surgeries	37 (10.1)	43 (19.3)	49 (66.2)	14 (20.0)	143 (19.5)
Infectious diseases for which patients are recommended to use parenteral antibiotics	2 (0.5)	1 (0.4)	1 (1.4)	4 (5.7)	8 (1.1)
Fever within 24 h before the time of screening	101 (27.6)	65 (29.1)	30 (40.5)	22 (31.4)	218 (29.7)
Insufficient response to antibiotic therapy	202 (55.2)	99 (44.4)	47 (63.5)	31 (44.3)	379 (51.7)
Recommendation of using parenteral antibiotics by infectious disease consultation	54 (14.8)	13 (5.8)	14 (18.9)	36 (51.4)	117 (16.0)
Response of physicians after receiving a recommendation of switching to oral antibiotics[b]					
Intervention adherent[c]	27 (22.3)	19 (31.7)	0 (0)	0 (0)	46 (24.2)
Intervention nonadherent[d]	59 (48.8)	20 (33.3)	2 (40.0)	2 (50.0)	83 (43.7)
Discontinuation of antibiotics within 48 h	35 (28.9)	21 (35.0)	3 (60.0)	2 (50.0)	61 (32.1)

Data are presented as No. (%).

[a]These values are the ratio among the cases designated impossible oral conversion.

[b]These values are the ratio among the cases designated possible oral conversion.

[c]Accepted the recommendation within 48 hours.

[d]Continuously prescribed parenteral antibiotics >48 hours from the time of writing the recommendation.

Table 3 presents the results of a survey on oral antibiotic recognition by medical students before and after participating in the parenteral-to-oral conversion program. Before participating in the clinical practice program, there was no significant difference in the perception of oral antibiotics, regardless of the participating group.

However, there were significant differences between the 2 groups after participating in the clinical practice program and before and after participating in the parenteral-to-oral conversion program in the participation group (Figure 3). As for the perception of oral antibiotics, students who participated in the parenteral-to-oral conversion program were more familiar with which patients could be administered oral antibiotics ($P = .004$ and $P < .001$, respectively). Regarding knowledge of oral antibiotics, students expressed deeper disagreement with the statements of "Parenteral antibiotics are more effective than oral antibiotics if the ingredient is the same" ($P < .001$) and "The price of parenteral antibiotics and oral antibiotics is almost the same if the ingredient is the same" ($P = .005$), after participation in the program.

As for the perception of criteria for possible oral conversion cases, students who participated in the parenteral-to-oral conversion program understood that there should be no structural abnormality in the patient's gastrointestinal tract that could cause malabsorption for oral conversion ($P = .039$). Among the students who participated in the program, the perception was that the causative bacteria of infection and antibiotic susceptibility results were more appropriate in the post-participation evaluation than in the preparticipation evaluation ($P = .016$). In addition, those who participated in the program more appropriately understood the following statements after the program: oral antibiotics with the same ingredients as parenteral antibiotics must be present ($P = .007$ and $P < .001$, respectively); fever should not exist for more than 24 hours ($P < .001$ and $P < .001$, respectively); inflammatory markers should be normalized ($P = .001$ and $P < .001$, respectively); and vital signs should be stable ($P < .001$ and $P = .034$, respectively).

DISCUSSION

In this study, 20.6% of the highly bioavailable antibiotics administered via the parenteral route could be converted to oral antibiotics, and the proportion of possible oral conversion antibiotics was different in each department. In addition, the compliance rate of the oral conversion intervention was 24.2%, and there was a difference in conversion compliance among departments. According to previous studies, compliance in implementing parenteral-to-oral conversion programs has been reported in various ways depending on the application and operation of the program and the type of applied medical institution [11–13]. In a single-center prospective study at a large teaching hospital in the United States, the oral conversion rate was raised from 54% to 83% through direct contact with the attending physician to promote the possibility of conversion from intravenous antibiotics [11]. In a multicenter cluster-randomized controlled trial in the Netherlands, the oral conversion rate of antibiotics used in community-acquired pneumonia patients was reported to be ~58%, and the oral

Table 3. Results of a Survey About the Perception of Oral Antibiotics Before and After Participation in the Parenteral-to-Oral Conversion Program

…	Before Participation in Clinical Practice Program				After Participation in Clinical Practice Program				Students Participated in Parenteral-to-Oral Conversion Program		
	Total (n = 62)	Participation (n = 41)	Nonparticipation (n = 21)	*P*	Total (n = 62)	Participation (n = 41)	Nonparticipation (n = 21)	*P*	Pre (n = 41)	Post (n = 41)	*P*
Demographic data											
Age	23.81 ± 1.81	23.68 ± 1.90	24.05 ± 1.63	.164	23.81 ± 1.81	23.68 ± 1.90	24.05 ± 1.63	0.164	23.68 ± 1.90		
Male sex	44 (71.0)	29 (70.7)	15 (71.4)	.954	44 (71.0)	29 (70.7)	15 (71.4)	0.954	29 (70.7)		
Perception of oral antibiotics											
I am familiar with which patients can be given oral antibiotics	3.05 ± 0.73	3.02 ± 0.72	3.10 ± 0.77	.751	3.69 ± 0.74	3.90 ± 0.58	3.29 ± 0.85	0.004	3.02 ± 0.72	3.90 ± 0.58	<.001
When oral antibiotics are available in the hospital, oral antibiotics are beneficial to patients compared to parenteral antibiotics	3.94 ± 0.79	4.00 ± 0.81	3.81 ± 0.75	.367	4.16 ± 0.61	4.22 ± 0.61	4.05 ± 0.59	0.218	4.00 ± 0.81	4.22 ± 0.61	.136
Patients will likely have a lot of complaints if oral antibiotics are used for inpatients	2.52 ± 0.86	2.37 ± 0.73	2.81 ± 1.03	.127	2.56 ± 0.99	2.61 ± 1.05	2.48 ± 0.87	0.760	2.37 ± 0.73	2.61 ± 1.05	.127
Knowledge of oral antibiotics											
Parenteral antibiotics are more effective than oral antibiotics if the ingredient is the same	3.08 ± 1.06	3.15 ± 1.11	2.95 ± 0.97	.478	2.40 ± 1.03	2.17 ± 0.86	2.86 ± 1.20	0.027	3.15 ± 1.11	2.17 ± 0.86	<.001
Parenteral antibiotics have a faster effect than oral antibiotics if the ingredient is the same	4.05 ± 0.66	4.07 ± 0.61	4.00 ± 0.77	.940	4.15 ± 0.65	4.10 ± 0.74	4.24 ± 0.44	0.630	4.07 ± 0.61	4.10 ± 0.74	.868
The price of parenteral antibiotics and oral antibiotics is almost the same if the ingredient is the same	2.21 ± 0.63	2.24 ± 0.70	2.14 ± 0.48	.425	1.87 ± 0.76	1.78 ± 0.85	2.05 ± 0.50	0.092	2.24 ± 0.70	1.78 ± 0.85	.005
Parenteral antibiotics have similar or fewer side effects than oral antibiotics if the ingredient is the same	2.08 ± 0.80	2.05 ± 0.84	2.14 ± 0.73	.471	2.05 ± 0.64	2.10 ± 0.77	1.95 ± 0.22	0.601	2.05 ± 0.84	2.10 ± 0.77	.822
Perception of criteria of possible oral conversion cases											
Patients should be able to swallow oral drugs	4.50 ± 0.50	4.51 ± 0.51	4.48 ± 0.51	.790	4.56 ± 0.56	4.59 ± 0.59	4.52 ± 0.51	0.516	4.51 ± 0.51	4.59 ± 0.59	.491
There should be no structural abnormality in the patient's gastrointestinal tract that could cause malabsorption	4.26 ± 0.63	4.32 ± 0.69	4.14 ± 0.48	.156	4.21 ± 0.87	4.39 ± 0.74	3.86 ± 1.01	0.039	4.32 ± 0.69	4.39 ± 0.74	.665
Chronic diseases such as diabetes mellitus or hypertension should not exist	2.45 ± 0.72	2.41 ± 0.74	2.52 ± 0.68	.585	2.18 ± 0.61	2.20 ± 0.68	2.14 ± 0.48	0.752	2.41 ± 0.74	2.20 ± 0.68	.101
Oral antibiotics with the same ingredients as parenteral antibiotics must be present	2.94 ± 1.02	2.95 ± 1.09	2.90 ± 0.89	.816	3.65 ± 1.03	3.88 ± 1.00	3.19 ± 0.93	0.007	2.95 ± 1.09	3.88 ± 1.00	<.001
The causative bacteria of infection and antibiotic susceptibility results must exist	3.98 ± 0.84	4.07 ± 0.82	3.81 ± 0.87	.205	3.63 ± 1.04	3.54 ± 1.05	3.81 ± 1.03	0.286	4.07 ± 0.82	3.54 ± 1.05	.016
Fever should not exist for more than 24 h	3.27 ± 0.85	3.29 ± 0.87	3.24 ± 0.83	.962	3.61 ± 1.03	4.00 ± 0.87	2.86 ± 0.91	<0.001	3.29 ± 0.87	4.00 ± 0.87	<.001
Inflammatory markers such as CRP and procalcitonin should be normalized	2.97 ± 0.89	2.95 ± 0.95	3.00 ± 0.77	.813	3.47 ± 1.08	3.78 ± 1.04	2.86 ± 0.91	0.001	2.95 ± 0.95	3.78 ± 1.04	<.001
Vital signs such as pulse rate, respiratory rate, and blood pressure, etc., should be stable	3.48 ± 0.82	3.54 ± 0.87	3.38 ± 0.74	.560	3.60 ± 0.90	3.90 ± 0.77	3.00 ± 0.84	<0.001	3.54 ± 0.87	3.90 ± 0.77	.034

Data are presented as No. (%) or mean ± SD. These were collected and analyzed as follows: "strongly disagree" was 1 point, "disagree" was 2 points, "neutral" was 3 points, "agree" was 4 points, "strongly agree" was 5 points.

Abbreviation: CRP, C-reactive protein.

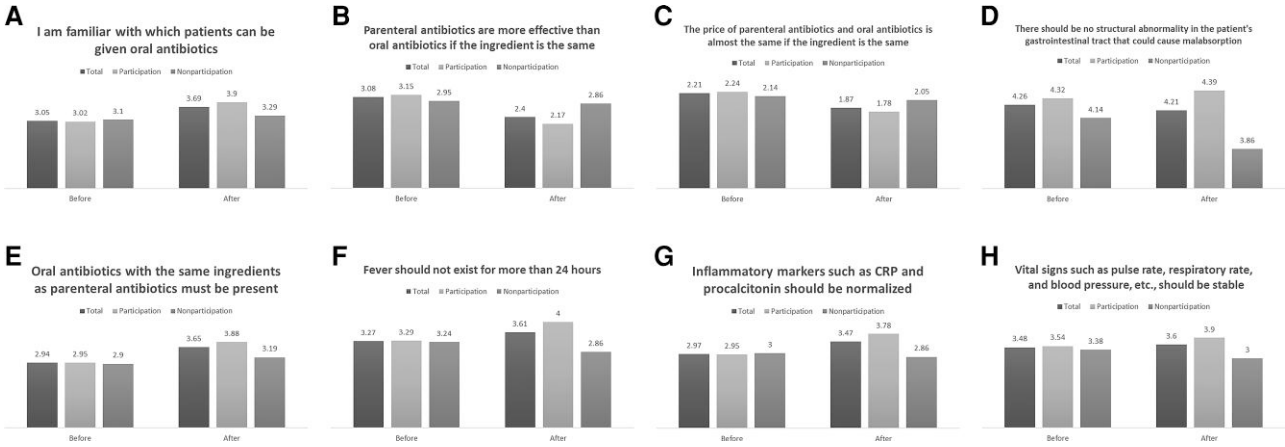

Figure 3. The significant results of the survey about the perception of oral antibiotics before and after participation in the parenteral-to-oral conversion program. *A*, I am familiar with which patients can be given oral antibiotics. *B*, Parenteral antibiotics are more effective than oral antibiotics if the ingredient is the same. *C*, The price of parenteral antibiotics and oral antibiotics is almost the same if the ingredient is the same. *D*, There should be no structural abnormality in the patient's gastrointestinal tract that could cause malabsorption. *E*, Oral antibiotics with the same ingredients as parenteral antibiotics must be present. *F*, Fever should not exist for more than 24 hours. *G*, Inflammatory markers such as CRP and procalcitonin should be normalized. H, Vital signs such as pulse rate, respiratory rate, and blood pressure, etc., should be stable. Abbreviation: CRP, C-reactive protein.

conversion rate varied from 22% to 94%, depending on the type of medical institution [12]. In a single-center retrospective study of intravenous-to-oral conversion intervention for fluoroquinolone at a large teaching hospital in South Korea, the compliance rate of an oral conversion intervention was reported to be 79.8% [14].

The compliance rate for the oral conversion intervention in this study was lower than that reported in previous studies. The possible explanations are as follows: (i) oral conversion was recommended only through medical records without direct communication; and (ii) preliminary education on the necessity of oral conversion was not conducted by the physicians of each department. Some studies show the effect of direct communication in ASP interventions [15, 16]. A single-center study in the United States demonstrated that the acceptance rate of ASP intervention was higher when using direct phone calls with prescribers [15]. Similarly, a single-center study in South Korea showed that direct communication with prescribing physicians and infectious disease clinicians was essential for reducing inappropriate continued use of vancomycin [16]. In the present study, compliance with oral conversion recommendations was higher in the pulmonology and gastroenterology departments, where communication with the infectious disease department is frequent, than in general surgery and neurology (data not shown). Therefore, direct communication between prescribers and antimicrobial stewardship teams should be emphasized to enhance the compliance rate of parenteral-to-oral conversion programs.

Another interesting finding of this study is that the perception of oral antibiotics was improved in the group that participated in the program during clinical practice. This is a good example of the effectiveness of an experiential program in ASP education for both students and trainees. The development of a robust undergraduate curriculum on ASP in medical schools has been emphasized because building a solid knowledge base is necessary for later prudent antimicrobial prescriptions [8]. To achieve this, many educational methods, mainly didactic teaching, have been applied for ASP training in medical schools. They seem to have a positive effect on students' understanding of antimicrobial resistance and appropriate antibiotic use [17–19]. However, attempts to incorporate experiential education methods into ASP education in medical schools have not been commonly tried and have not yet existed in the literature. In comparison, some experiential education programs, such as de-escalation of antibiotics and parenteral-to-oral conversion programs, were employed in the curriculum of some pharmacy schools in the United States; there was evidence of an increase in the understanding and application of ASP techniques among students who participated in the experiential programs [20–22]. Given that experiential education has proven to be more effective than didactic education in several medical fields, experiential education such as that in our study should be considered in ASP education for undergraduates [23–25]. Based on our experience, we suggest that it would be desirable to expand experiential programs in which medical students who will lead future health care systems directly participate in the ASP in order to know about the appropriate use of antibiotics and understand the importance of ASPs. Furthermore, participation of medical students might be helpful in resource-limited medical institutions, especially due to the workforce shortage in ASPs [26, 27].

This study had several limitations. First, the frequency of intervention does not allow for evaluating real-life situations.

Some patients eligible for the parenteral-to-oral conversion program might have been missed, and the physicians' response might not have been evaluated exactly. Second, the definition of "impossible for oral conversion" cases in the present study might be controversial. For instance, some randomized trials have shown that oral antibiotics can be used safely for osteomyelitis and infective endocarditis [28, 29]. Also, there is insufficient evidence to avoid oral administration when CRP levels are elevated. Despite this, we applied these criteria to select cases where oral conversion was possible. This may be the main reason for the relatively low proportion of cases who received the recommendation of "oral conversion." Third, there is a possibility that students may have understood only the criteria and assessment of the parenteral-to-oral conversion program and that they did not understand the more significant messages. For instance, there is no difference in answer to the question "When oral antibiotics are available in the hospital, oral antibiotics are beneficial to patients compared to parenteral antibiotics" (true/false) between before and after participating in the parenteral-to-oral conversion program. Because the question was intended to measure the perception of oral antibiotics, the question was somewhat vague, and no definite answer existed. Therefore, the interpretation of the question might have differed from student to student. Despite this, students seemed to know that "oral antibiotics are beneficial for cases that fulfill the criteria of possible oral conversion," considering the answers to the questions in the "knowledge of oral antibiotics" section. Fourth, the investigator who established the parenteral-to-oral conversion program was also involved in survey creation. Therefore, there might have been bias in the survey questions, and an objective assessment of the perception may have been limited. Fifth, this study did not evaluate the long-term educational effects of appropriate use of antibiotics on medical students. Further studies are necessary to evaluate the long-term effect of the parenteral-to-oral conversion program operated by medical students on the appropriateness of antibiotic use. In addition, an analysis of whether implementing the parenteral-to-oral conversion program has an educational effect on the prescription of oral antibiotics for physicians will be necessary in the future. Finally, this study was conducted in a university-affiliated tertiary care hospital. Therefore, the results cannot be generalized to other settings.

In conclusion, our parenteral-to-oral conversion program demonstrated an acceptance rate of oral antibiotic conversions in the hospital of 24.2%, and it had a significant educational effect on medical students and their ability to construct an appropriate perception of oral antibiotics.

Supplementary Data

Supplementary materials are available at *Open Forum Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

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Patient consent. The protocol for this study was approved by the institutional review board (IRB) of Hanyang University Hospital (IRB No. 2019-05-036-001) and was conducted in compliance with the guidelines of the Declaration of Helsinki, Belmont Report, CIOMS, and International Practice (ICH-GCP). All methods were performed in accordance with these guidelines and regulations. The requirement for written informed consent from patients was waived because of the retrospective nature of the study.

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