ORIGINAL ARTICLE

# Failure of a pharmacist-initiated antimicrobial step-down protocol to impact physician prescribing behaviour or patient outcomes: A quasi-experimental, cross-over study

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## Abstract

**Background:** Intravenous (IV) to oral (PO) conversion may expedite hospital discharge and decrease costs. Most IV-to-PO programs include antimicrobials with highly-bioavailable PO formulations, allowing sequential interchanges. Our aim was to evaluate clinical and economic outcomes of a pharmacist-initiated antimicrobial step-down protocol whereby IV antimicrobials were switched to different PO antimicrobials.

**Methods:** A 12-month quasi-experimental, cross-over study was conducted on a 45-bed adult general medicine ward in two populations (A & B) receiving an IV antimicrobial for $\geqslant$ 48 hours in three phases: baseline (Phase 1); step-down protocol in Group A only (Phase 2); and step-down protocol in Group B, withdrawn from Group A (Phase 3). A step-down conversion form was used by pharmacists to screen patients for eligibility. If eligible, the form was placed in the medical record to be completed by the physician. Outcomes reported after step-down eligibility included percent receiving step-down conversion; length of stay; therapy duration; IV complications; clinical cure; and antimicrobial and hospitalization costs.

**Results:** 2,635 patients were screened. Of 595 included patients, 33.6% (n=98) and 32% (n=97) were eligible for step-down in Groups A and B, respectively. During Phase 2, 42.1% of the eligible Group A and 28.6% of the eligible Group B patients were switched to step-down therapy ($p$=0.12). No significant difference existed between the groups for length of stay; duration of therapy; IV complications; clinical cure; and costs. Similar results were observed in Phase 3. Post hoc analyses showed those receiving step-down conversion had shorter stays ($p$=0.02) and decreased hospitalization costs ($p$=0.006).

**Conclusions:** Approximately 60%-75% of eligible patients did not receive step-down conversion. The step-down protocol was labor-intensive and poorly accepted. Successful step-down programs must anticipate these challenges. Step-down was associated with shorter stays and decreased costs.

## Key words

Intravenous to oral, Antimicrobials, Outcomes, Quasi-experimental

# 1 Introduction

Healthcare systems are facing increased pressure to shorten inpatient stays to decrease costs, minimize morbidity, and increase patient satisfaction. One mechanism to expedite discharge and decrease costs is intravenous (IV) to oral (PO) conversion of antimicrobials. Potential advantages of IV to PO conversion include decreased utilization of IV catheters leading to decreased risk of catheter-associated adverse events, increased quality of life, decreased length of stay, less labor for nursing and pharmacy staff, and economic benefit. Several studies have demonstrated cost savings with IV to PO conversion of antibiotics [1-4]. It has been suggested that universal implementation of early IV to PO conversion and hospital discharge for treatment of community-acquired pneumonia in the United States could result in a reduction of 440,000 hospital days and savings of $400 million annually [5].

Unfortunately, several misconceptions hamper acceptance of IV to PO conversion, particularly step-down conversion, which occurs when the prescribed IV antimicrobial is changed to a PO antimicrobial of a different name or class (e.g., cefepime changed to ciprofloxacin). The primary obstacle is the belief that PO therapy is less effective than IV therapy. These concerns have been abated by several studies documenting equivalent therapeutic outcomes with IV to PO conversion [1, 6-12]. Another misconception is that the same antimicrobial must be used orally as that used intravenously, in other words, a sequential interchange. However, step-down conversions are possible as long as the spectrum of activity and tissue penetration are adequate. Finally, many providers wait to convert patients to PO therapy until discharge, under the misconception that patients receiving PO therapy will not qualify for inpatient status according to third-party payer policies. Many of the agencies that determine criteria for hospital admission now recognize that IV or PO antimicrobials can be used as long as severity of illness dictates hospitalization [4]. Because of the potential advantages to the patient and institution, clinicians should be encouraged to change from IV to PO therapy as soon as appropriate.

The purpose of this study was to evaluate the impact of a pharmacist-initiated antimicrobial step-down protocol on clinical and economic outcomes.

# 2 Patients and methods

## 2.1 Study design

Our hypothesis was that implementation of a step-down protocol for antimicrobials would lead to increased IV to PO conversion with resultant positive clinical outcomes and decreased costs. This hypothesis was evaluated using a quasi-experimental study in two patient populations (A & B) on a general medicine ward.

Patients admitted to Family Medicine or Internal Medicine services comprised Group A, and patients admitted to General Surgery and Hematology/Oncology services comprised Group B. Groups were based on admitting service because the primary outcome (IV to PO step-down conversion) was dependent on physician behavior. Therefore, study groups were comprised of two different groups of physicians, including attending physicians, fellows, and residents.

The study was conducted in three four-month phases from August 2006 to July 2007. In phase 1, baseline characteristics of Groups A and B were established. In phase 2, the intervention, a step-down conversion form (Table 1), was introduced to the paper chart of eligible patients in Group A and withheld from Group B. In phase 3, the assignments were reversed. Phase 1 established the rate of eligibility for step-down conversion and comparability of the groups. Phase 2 tested the impact of the step-down protocol on physician prescribing behavior and subsequent outcomes, and phase 3 assessed reproducibility.

**Table 1.** Step-down conversion form

Date_____ Time_____

**Your patient is eligible to be switched from intravenous _____ to an oral agent of your choice based on the following criteria:**

**Inclusion Criteria**

□ received intravenous therapy for at least 48 hours
□ receiving other oral medications
□ receiving enteral feeding
□ not experiencing nausea, vomiting, or significant diarrhea (more than 3 stools/day)
□ showing clinical improvement, with all of the following:
 □ temperature less than 38°C for 24 hours
 □ SBP greater than 90 mmHg
 □ HR less than 100 bpm
 □ normal white blood cell count (between 4,000-11,000 cells/mcl) OR a decrease of at least 2,000 cells/mcl over the last 24 hours

**Important Consideration**

□ An Infectious Disease consult is recommended for patients with infections complicated by bloodstream infection or with primary bloodstream infection.
*Other important considerations include site of infection, host immune status, and antimicrobial susceptibility of organisms.*

Physician Signature_____ Pager # _____

**Physician Orders**

NOTE: Oral therapy is not recommended for treatment of endocarditis or central nervous system infections.
□ Discontinue _____. Start _____

*Refer to back of this form for some potential oral alternatives.*

□ No step-down conversion (Indicate reason below.)
___ has not received intravenous therapy for at least 48 hours
___ is not receiving other oral medications
___ is not receiving enteral feeding
___ experiencing nausea, vomiting, or significant diarrhea
___ not clinically improving
___ endocarditis
___ central nervous system infection
___ Other: _____

□ Infectious Disease consult (Indication:_____)

Physician Signature_____ Pager # _____

**Possible Conversions by Type of Infection**

This list is not all-encompassing but provides recommendations that may be appropriate. Importantly, the hospital antibiogram should be utilized to choose empiric therapy. If a microorganism has been identified, susceptibility reports should be used to tailor therapy.

| Type of Infection | Possible Oral Options |
|---|---|
| Community-acquired pneumonia | Amoxicillin/clavulanate |
| | Azithromycin |
| | Cefuroxime |
| | Doxycycline |
| | Moxifloxacin |
| Intra-abdominal infection | Amoxicillin/clavulanate |
| | Ciprofloxacin + metronidazole |
| | Moxifloxacin |
| Osteomyelitis | Please consult Infectious Diseases. |
| Skin/soft tissue infection | Amoxicillin/clavulanate |
| | Cefuroxime |
| | Cephalexin |
| | Clindamycin |
| | Dicloxacillin |
| | Linezolid |
| | Moxifloxacin |
| | Trimethoprim/sulfamethoxazole |
| Urinary tract infection | Amoxicillin/clavulanate |
| | Cephalexin |
| | Ciprofloxacin |
| | Trimethoprim/sulfamethoxazole |

During phase 1, baseline population characteristics and step-down eligibility were determined by study personnel. After implementation of the intervention in phases 2 and 3, patients included in the intervention group were screened by ward pharmacists for eligibility for IV to PO step-down conversion using a form as a decision support tool (Table 1). If the pharmacist determined the patient was eligible, the form was placed in the orders section of the medical record. The bottom section of the form, authorizing the proposed IV to PO conversion, was to be completed by the physician.

## 2.2 Setting and patient selection

The study was conducted over a 12-month period on a 45-bed general medicine ward at a 689-bed academic medical center. All patients admitted to the ward for $\geqslant$ 24 hours, who received an IV antimicrobial for $\geqslant$ 48 hours that was not in the currently existing sequential IV to PO interchange protocol, were included. The existing sequential IV to PO protocol included azithromycin, ciprofloxacin, clindamycin, fluconazole, linezolid, metronidazole, moxifloxacin, rifampin, trimethoprim-sulfamethoxazole, and voriconazole. In order to be eligible for step-down conversion, the patient must have met all of the following criteria: received an IV antibiotic for $\geqslant$ 48 hours, receiving other oral medications or enteral

feeding; no nausea, vomiting, or diarrhea; and clinical improvement with temperature less than 38℃, systolic blood pressure > 90 mmHg, heart rate < 100 bpm, and normal white blood cell count (4,000-11,000 cells/$\mu$L) or a decrease of at least 2,000 cells/$\mu$L over the last 24 hours (Table 1).

The following information was collected in a prospective manner from the medical records using a standardized case report form: medical record number, demographic information, antimicrobial allergies, infectious disease diagnosis, principal diagnosis, Charlson score, eligibility for oral therapy, date of eligibility, antimicrobial therapy, IV catheter complications, length of stay, 30-day readmission, intensive care unit admission, and mortality. Costs associated with antimicrobial therapy (acquisition and preparation costs) and hospitalization were obtained from the institutional financial database.

The study was approved by the Institutional Review Board with a complete waiver of informed consent.

## 2.3 Outcome measures

The primary outcome measure was the percent of step-down eligible patients who were switched to PO therapy. Secondary outcome measures included length of stay, duration of therapy, duration of IV therapy, IV catheter complications, clinical success, and costs of antimicrobial therapy and hospitalization. Clinical success was defined as any patient who met criteria for IV to PO step-down conversion (received an IV antibiotic for ⩾ 48 hours, receiving other oral medications or enteral feeding; no nausea, vomiting, or diarrhea; and clinical improvement with temperature less than 38℃, systolic blood pressure > 90 mmHg, heart rate < 100 bpm, and normal white blood cell count or a decrease of at least 2,000 cells/$\mu$L over the last 24 hours) and did not meet our definition of failure. Failure was defined as any patient who had an IV antimicrobial re-started, was transferred to the intensive care unit, expired, or was readmitted within 30 days. Secondary outcome measures were evaluated after step-down eligibility criteria were met.

## 2.4 Statistical analysis

The primary comparison of interest was between Groups A and B during Phase 2. Secondary comparisons were between Groups A and B during Phases 1 and 3. Wilcoxon rank-sum or t-tests were used for continuous variables, and Chi-squared or Fisher's exact test for categorical variables. All analyses for primary and secondary binary outcomes utilized generalized estimating equations (GEE) for logistic regression to account for correlation within each physician group. Patients within the same physician group may be more likely to display similar, correlated values on covariates and outcomes. If the within group correlation was not accounted for in the analysis, the standard errors may be biased, rendering inflated Type I or Type II errors. Hence, GEE analysis was performed to account for correlation within each physician group. Allowance for possible confounding factors was included in the model for the primary outcome measure. Continuous outcomes were transformed using a natural logarithm to meet normality and constant variance assumptions, except for duration of IV therapy, total duration of therapy, and antibiotic costs, which were not transformable to meet model assumptions. Thus, these variables were dichotomized based on the median of the overall sample and analyzed using GEE for logistic regression; all other log-transformed outcomes were analyzed by GEE for linear regression.

Using a cluster randomized design; we needed to sample 7 clusters (physicians) in each group with 10 patients for each physician for a total of 70 patients per group per time period in order to have 80% power to detect a difference in the proportion of patients switched from IV to PO of 0.25. This assumes a significance level of 0.05 and an intra-cluster correlation coefficient of 0.02. We expected that only half of the patients would be eligible to be switched from IV to PO; therefore, we needed 140 patients in each group at each time period, for a total of 840 patients.

Due to poor compliance with the intervention, a post hoc analysis was conducted to compare all eligible patients receiving step-down therapy, regardless of study phase, group assignment, or use of the form, versus eligible patients who were not changed to step-down therapy. The analysis was conducted utilizing GEE with logistic regression for binary outcomes and linear regression for continuous outcomes. Continuous variables were transformed using a natural logarithm to meet

normality and constant variance assumptions, except for duration of IV therapy, total duration of therapy, and antibiotic costs, which were not transformable to meet model assumptions. Thus, these variables were dichotomized based on the median of the overall sample and analyzed using GEE.

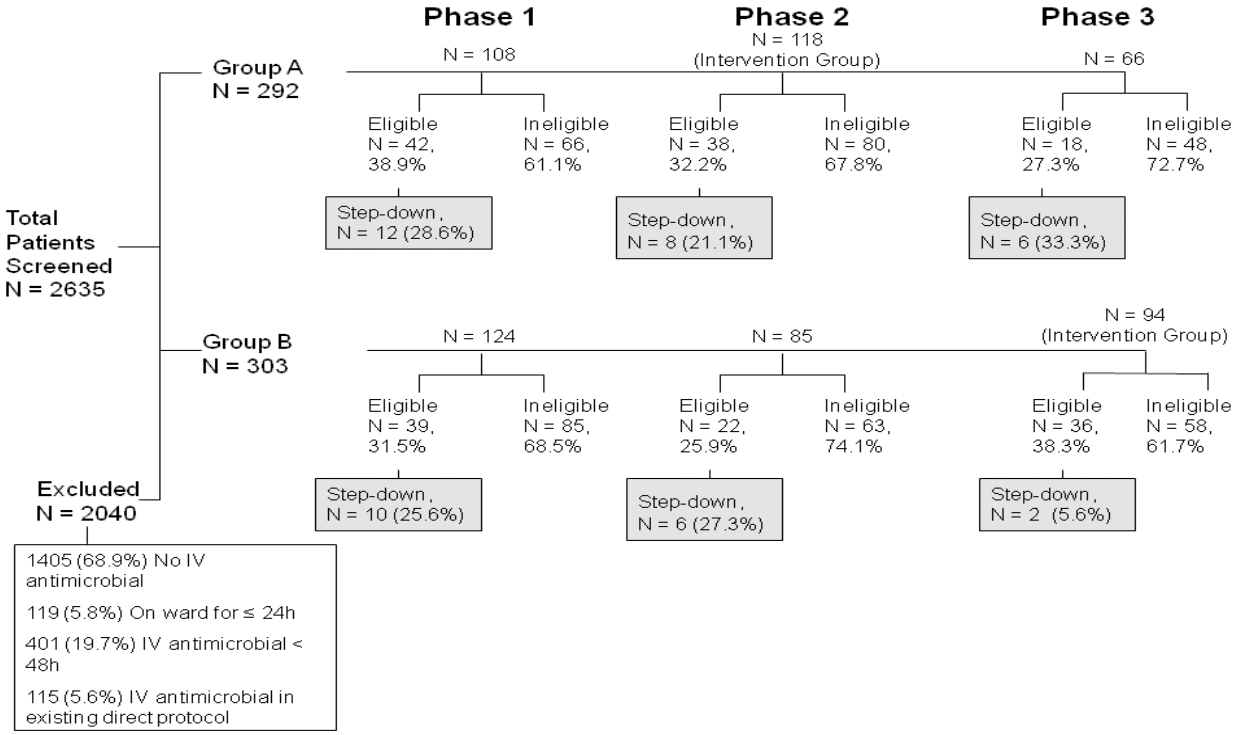


**Figure 1.** Patient Enrollment Schematic

# 3 Results

A total of 2,635 patients were screened for inclusion, of which 2,040 were excluded. The most common reason (n=1405) for exclusion was that the patient did not receive IV therapy (Figure 1). Overall, 595 patients were included, 292 in Group A and 303 in Group B (Figure 1).

No statistically significant differences existed for the demographics of Groups A and B, with the exception of age ($p$=0.02) in Phase 1 and Charlson score ($p$=0.03) in Phase 2 (Table 2). Thus, the statistical analyses for outcomes in Phase 1 and 2 controlled for age and Charlson score, respectively.

For the primary comparison of Group A versus B during Phase 2, 32.2% (n=38) of patients in Group A and 25.9% (n=22) of patients in Group B were eligible for step-down conversion. However, 10.5% (n=4) and 4.5% (n=1) of patients in Group A and B, respectively, became eligible for step-down conversion on the date of discharge and were excluded because inpatient conversion was not possible. Phase 2 included 40 prescribing physicians with an average of 1.4 patients included in the study for each physician. Twenty-five percent of the physicians had at least two patients included in the study.

Overall, 21.1% and 27.3% of eligible patients underwent step-down conversion in Groups A and B, respectively, during Phase 2 (Figure 1). The step-down conversion form was placed in the chart for only 50% (n=19) of the eligible patients in Group A. Of the forms placed in the patient chart, only 21% (n=4) were completed by the physician. Step-down

conversion was declined by the physician in all four of these cases (n=1, endocarditis; n=2, osteomyelitis; n=1, therapy discontinued). Despite the presence of the step-down conversion form in Group A, no significant difference in step-down conversion was observed between Groups A and B ($p$=0.12). The median duration of IV therapy after all eligibility criteria were met was 2-3 days (Table 2). Results from phase 3 were similar to those from phase 2, revealing low rates of step-down conversion for eligible patients in Groups A and B at 33.3% and 5.6%, respectively (Figure 1).

**Table 2.** Phase 1 -3 Demographics and Outcomes[a]

| Variable | Phase 1 | | | Phase 2 | | | Phase 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Group A, n=38 | Group B, n=34 | *p* | Group A, n=19 | Group B, n=21 | *p* | Group A, n=18 | Group B, n=8 | *p* |
| Age (median, years) | 73.5 | 64 | 0.02[b] | 71 | 64 | 0.73 | 75 | 73 | 0.84 |
| Male gender (n, %) | 18 (47.4) | 20 (58.8) | 0.33 | 8 (42.1) | 8 (38.1) | 0.80 | 10 (55.6) | 4 (50) | 0.99 |
| Caucasian (n, %) | 30 (79.0) | 28 (82.4) | 0.72 | 17 (89.5) | 17 (80.9) | 0.66 | 15 (83.3) | 8 (100) | 0.53 |
| Charlson score (n, %) | | | | | | | | | |
| 0 | 11 (28.9) | 17 (50) | 0.18 | 3 (15.8) | 12 (57.1) | 0.03[c] | 5 (29.4) | 5 (62.5) | 0.23 |
| 1 | 9 (23.7) | 5 (14.7) | | 5 (26.3) | 2 (9.5) | | 7 (41.2) | 1 (12.5) | |
| >1 | 18 (47.4) | 12 (35.3) | | 11 (57.9) | 7 (33.3) | | 5 (29.4) | 2 (25) | |
| Switched to step-down (n, %) | 12 (31.6) | 10 (29.4) | 0.57 | 8 (42.1) | 6 (28.6) | 0.12 | 6 (33.3) | 2 (25) | 0.99 |
| Length of stay[d] (median, days) | 4 | 4 | 0.51 | 4 | 2 | 0.16 | 2.5 | 2 | 0.65 |
| Duration of IV therapy[d] (median, days) | 2.5 | 2 | 0.42 | 3 | 2 | 0.31 | 2 | 2 | 0.73 |
| Duration of antimicrobials (median, days) | 3 | 3 | 0.2 | 3 | 2 | 0.93 | 2 | 2 | 0.93 |
| IV complications (n, %) | 15 (39.5) | 4 (11.8) | 0.004 | 4 (21) | 4 (19) | 0.85 | 6 (33.3) | 3 (37.5) | 0.99 |
| Clinical cure (n, %) | 29 (76.3) | 23 (67.7) | 0.13 | 11 (58) | 15 (71.4) | 0.56 | 13 (72.2) | 6 (75) | 0.99 |
| Total cost of hospitalization[d] (median, $) | 6,757 | 6,719 | 0.33 | 6,500 | 3,545 | 0.23 | 5,478 | 4,820 | 0.93 |
| Antimicrobial costs[d] (median, $) | 228 | 204 | 0.85 | 158 | 116 | 0.32 | 254 | 138 | 0.89 |

[a]Excludes patients who became eligible for step-down on date of hospital discharge (Phase 1: Group A = 4, Group B = 5; Phase 2: Group A = 4, Group B = 1; Phase 3: Group A = 0, Group B = 2) or did not have form placed in chart (Phase 2: Group A = 15; Phase 3: Group B = 26)
[b]Phase 1 outcomes adjusted for age
[c]Phase 2 outcomes adjusted for Charlson score
[d]After step-down eligibility criteria were met

Vancomycin and piperacillin/tazobactam were the antimicrobials most frequently converted. Moxifloxacin, amoxicillin/clavulanate, and cefuroxime were the most frequently chosen oral alternatives. Pneumonia, skin and soft tissue infections, and urinary tract infections were the most common infections among those switched to step-down therapy.

Overall, no statistically significant differences between groups were found for primary or secondary outcomes in any phase of the study, with the exception that more IV complications occurred in Group A in Phase 1. The post hoc analysis comparing all eligible patients receiving step-down therapy, regardless of study phase, group assignment, or use of the form, to eligible patients who were not changed to step-down therapy showed no statistically significant differences in demographics (Table 3). Similar clinical success rates were achieved for patients who were switched to step-down therapy compared to those who were not switched (74.6% versus 66.7%, respectively; $p$=0.31; Table 3). Patients who were switched to step-down therapy had a significantly shorter length of stay (median of 1 day, $p$=0.02) and lower total cost of hospitalization (median savings of $2,136 per patient, $p$=0.006) compared to patients who were eligible but not converted

to step-down therapy, although no statistically significant difference was found for duration of IV antimicrobial therapy ($p$=0.14) or antimicrobial costs ($p$=0.77; Table 3).

**Table 3.** Step-Down versus No Step-Down Demographics and Outcomes

| Variable | No Step-down, n=117 | Step-down, n=63[a] | *p*-value |
|---|---|---|---|
| Age (median, years) | 66 | 67 | 0.38 |
| Male gender (n, %) | 53 (45.3) | 28 (44.4) | 0.89 |
| Caucasian (n, %) | 95 (81.2) | 55 (87.3) | 0.37 |
| Charlson score (n, %) | | | |
| 0 | 41 (35.7) | 31 (49.2) | |
| 1 | 27 (23.5) | 11 (17.5) | 0.18 |
| >1 | 47 (40.9) | 21 (33.3) | |
| Length of stay[b] (median, days) | 4 | 3 | 0.02 |
| Duration of IV therapy[b] (median, days) | 3 | 2 | 0.14 |
| Duration of antimicrobials[b] (median, days) | 3 | 3 | 0.83 |
| Clinical cure (n, %) | 78 (66.7) | 47 (74.6) | 0.31 |
| Total cost of hospitalization[b] (median, $) | 7,337 | 5,201 | 0.006 |
| Antimicrobial costs[b] (median, $) | 179 | 197 | 0.77 |

[a]Includes 22 patients from Phase 1 with no step-down form, 22 patients in Phases 2 and 3 for whom the form was used, and 19 patients in Phases 2 and 3 for whom the form was not used (i.e., patients included regardless of whether intervention was used);
[b]After step-down eligibility criteria were met

# 4 Discussion

Our experience with a failed attempt at an antimicrobial step-down protocol is important for a number of reasons. This project suggests that a potential benefit for antimicrobial step-down exists. On the general medicine ward studied, approximately 47% of patients received an IV antimicrobial agent and only about 9% of the patients receiving an antibiotic were included in our pre-existing sequential IV to PO conversion program. Unfortunately, of those who met objective criteria for clinical improvement and other eligibility requirements for step-down conversion, only 35% underwent conversion. In the post-hoc analysis, patients switched to oral therapy experienced similar clinical success rates, significantly shorter lengths of stay, and lower cost of hospitalization compared to patients who met criteria but were not switched. Our study supports three key findings from the literature regarding step-down conversion: 1) approximately half of patients receiving IV therapy are eligible to receive PO therapy, 2) substantial opportunity exists for step-down conversion, and 3) IV to PO programs may lead to cost savings [2, 4, 13-18].

Reasons for failure of our program should be examined, and others contemplating antimicrobial step-down programs may learn from our experience. The screening process for determining step-down eligibility was laborious, and, in many cases, the form was not placed in the charts of eligible patients. Pharmacists were responsible for the screening process, and their lack of compliance most likely was due to several factors. The information needed to perform screening was not readily available in the electronic medical record at the time of our project, and this inaccessibility of data precluded efficient screening. In addition, a new formalized process for medication reconciliation, requiring significant time from the pharmacists, was introduced shortly before our study began. Undoubtedly, competing priorities existed and may have limited the pharmacists' ability and/or enthusiasm for rigorously screening patients for step-down conversion. Furthermore, use of the step-down conversion form was adversely impacted by lack of physician compliance with completion of the form. We attempted to mitigate this by securing support from physician leadership through face-to-face meetings prior to study initiation. However, our institution is an academic medical center with continual rotation of medical staff. Thus, all physicians may not have been familiar with the form, since it was being used on only one hospital unit. However, at the beginning of each month, an email was sent to all physicians, including attending physicians,

fellows, and residents, scheduled to be on the intervention services. The email included a description of the pharmacist screening process, an attachment with the step-down conversion form, and an appeal for compliance with completion of the form. The lackluster performance of this project emphasizes the importance of effective communication, leadership, and a means to motivate pharmacists, housestaff, and attending physicians. In summary, this program failed due to the laborious, manual screening process, conflicting pharmacy priorities, and lack of physician participation.

Therefore, to be successful, an antimicrobial step-down protocol should address these issues. Developing a program whereby screening for eligibility is possible via electronic means would increase efficiency, particularly if this were accompanied by decision-support software in which some or all eligibility requirements were automatically screened. Similarly, the need for physician cooperation was demonstrated, and the failure of a passive, paper-based reminder system was observed. An actionable, electronic alert in a computerized physician order entry (CPOE) system may be an optimal means of intervention. Emphasizing improved patient outcomes and shorter length of stay should serve to generate enthusiasm from healthcare professionals.

This study has three primary limitations. First, use of the step-down conversion form was limited, which in turn limited the sample size. Ultimately, we did not reach the necessary sample size to achieve adequate statistical power for the primary outcome measures. In an attempt to compensate, a post-hoc analysis was performed which likely introduced bias. Patients in whom step-down conversion was performed could be predisposed and biased toward the secondary outcomes. In this non-randomized, observational study, results from the post hoc analysis should be interpreted with caution. However, potential benefits of shorter length of hospital stay and decreased total hospitalization cost demonstrated in the post hoc analysis have been corroborated in other published literature [1-4]. Second, the intervention was implemented on only one hospital unit, and questions regarding generalizability may arise. The chosen unit was a general medicine ward with an occupancy rate of 76% and an average of 155 admits and approximately 1,000 patient days each month. The unit housed patients seen by a variety of medical services, with approximately half consisting of internal medicine or family medicine patients and the other half consisting of patients seen by other services. In general, approximately half of the patients admitted to this unit received an IV antimicrobial. Third, although the primary comparison was between groups A and B during phase 2, it is possible that prescribers in group A may have learned to consider step-down therapy without the pharmacist's reminder which could have carried over to phase 3. However, this effect was most likely quite minimal as during the study period, few attending physicians or housestaff were assigned to the same inpatient service.

In conclusion, our study suggests that step-down conversion for antimicrobial therapy may be an effective method for decreasing length of stay and cost of care for patients who are eligible for oral administration of antimicrobials. However, use of a manual screening process and a passive mechanism for communication with the prescriber are unlikely to be effective in increasing step-down conversion rates.

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## Conflicting interests

Authors report no relevant conflicting interests.

# References


[1] Chan R, Hemeryck L, O'Regan M, Clancy L, Feely J. Oral versus intravenous antibiotics for community acquired lower respiratory tract infection in a general hospital: open, randomised controlled trial. BMJ. 1995; 310: 1360-1362. PMid:7787537 http://dx.doi.org/10.1136/bmj.310.6991.1360

[2] Hunter KA, Dormaier GK. Pharmacist-managed intravenous to oral step-down program. Clin Ther. 1995; 17: 534-540; discussion 516. http://dx.doi.org/10.1016/0149-2918(95)80119-7

[3] Walters DJ, Solomkin JS, Paladino JA. Cost effectiveness of ciprofloxacin plus metronidazole versus imipenem-cilastatin in the treatment of intra-abdominal infections. PharmacoEconomics. 1999; 16: 551-561. PMid:10662480 http://dx.doi.org/10.2165/00019053-199916050-00011

[4] Wong-Beringer A, Nguyen KH, Razeghi J. Implementing a program for switching from i.v. to oral antimicrobial therapy. Am J Health-Sys Pharm. 2001; 58: 1146-1149. PMid:11449860

[5] Ramirez JA. Managing antiinfective therapy of community-acquired pneumonia in the hospital setting: focus on switch therapy. Pharmacotherapy. 2001; 21: 79S-82S. PMid:11446522 http://dx.doi.org/10.1592/phco.21.10.79S.34530

[6] Ahkee S, Smith S, Newman D, Ritter W, Burke J, Ramirez JA. Early switch from intravenous to oral antibiotics in hospitalized patients with infections: a 6-month prospective study. Pharmacotherapy. 1997; 17: 569-575. PMid:9165561

[7] Castro-Guardiola A, Viejo-Rodriguez AL, Soler-Simon S, et al. Efficacy and safety of oral and early-switch therapy for community-acquired pneumonia: a randomized controlled trial. Am J Med. 2001; 111: 367-374. http://dx.doi.org/10.1016/S0002-9343(01)00868-3

[8] Cohn SM, Lipsett PA, Buchman TG, et al. Comparison of intravenous/oral ciprofloxacin plus metronidazole versus piperacillin/tazobactam in the treatment of complicated intraabdominal infections. Ann Surg. 2000; 232: 254-262. PMid:10903605 http://dx.doi.org/10.1097/00000658-200008000-00016

[9] Ramirez JA, Bordon J. Early switch from intravenous to oral antibiotics in hospitalized patients with bacteremic community-acquired *Streptococcus pneumoniae* pneumonia. Arch Int Med. 2001; 161: 848-850. http://dx.doi.org/10.1001/archinte.161.6.848

[10] Ramirez JA, Srinath L, Ahkee S, Huang A, Raff MJ. Early switch from intravenous to oral cephalosporins in the treatment of hospitalized patients with community-acquired pneumonia. Arch Int Med. 1995; 155: 1273-1276. http://dx.doi.org/10.1001/archinte.1995.00430120050006

[11] Ramirez JA, Vargas S, Ritter GW, et al. Early switch from intravenous to oral antibiotics and early hospital discharge: a prospective observational study of 200 consecutive patients with community-acquired pneumonia. Arch Int Med. 1999; 159: 2449-2454. http://dx.doi.org/10.1001/archinte.159.20.2449

[12] Solomkin JS, Reinhart HH, Dellinger EP, et al. Results of a randomized trial comparing sequential intravenous/oral treatment with ciprofloxacin plus metronidazole to imipenem/cilastatin for intra-abdominal infections. The Intra-Abdominal Infection Study Group. Ann Surg. 1996; 223: 303-315. PMid:8604912 http://dx.doi.org/10.1097/00000658-199603000-00012

[13] Fox ER, Beckwith MC, Tyler LS. Pharmacy-administered IV to oral therapeutic interchange program: development, implementation, and cost-assessment. Hosp Pharm. 2003; 38: 444-452.

[14] Kuti JL, Le TN, Nightingale CH, Nicolau DP, Quintiliani R. Pharmacoeconomics of a pharmacist-managed program for automatically converting levofloxacin route from i.v. to oral. Am J Health-Sys Pharm. 2002; 59: 2209-2215. PMid:12455304

[15] Laing RB, Mackenzie AR, Shaw H, Gould IM, Douglas JG. The effect of intravenous-to-oral switch guidelines on the use of parenteral antimicrobials in medical wards. J Antimicrob Chemother. 1998; 42: 107-111. PMid:9700538 http://dx.doi.org/10.1093/jac/42.1.107

[16] Przybylski KG, Rybak MJ, Martin PR, et al. A pharmacist-initiated program of intravenous to oral antibiotic conversion. Pharmacotherapy. 1997; 17: 271-276. PMid:9085318

[17] Sevinc F, Prins JM, Koopmans RP, et al. Early switch from intravenous to oral antibiotics: guidelines and implementation in a large teaching hospital. J Antimicrob Chemother. 1999; 43: 601-606. PMid:10350396 http://dx.doi.org/10.1093/jac/43.4.601

[18] Zamin MT, Pitre MM, Conly JM. Development of an intravenous-to-oral route conversion program for antimicrobial therapy at a Canadian tertiary care health facility. Ann Pharmacother. 1997; 31: 564-570. PMid:9161649