Reductions in Medication-Related Hospitalizations in Older Adults with Medication Management by Hospital and Community Pharmacists: A Quasi-Experimental Study

Karen L. Pellegrin, PhD, MBA,a Les Krenk, RPh,b Sheena Jolson Oakes, PharmD, RPh,c Anita Ciarleglio, PhD, RPh,d Joanne Lynn, MD,e Terry McInnis, MD, MPH,f Alistair W. Bairos, MD,g Lara Gomez, PharmD,h Mercedes Benitez McCrary,i Alexandra L. Hanlon, PhD,j and Jill Miyamura, PhDk

OBJECTIVES: To evaluate the association between a system of medication management services provided by specially trained hospital and community pharmacists (Pharm2Pharm) and rates and costs of medication-related hospitalization in older adults.

DESIGN: Quasi-experimental interrupted time series design comparing intervention and nonintervention hospitals using a mixed-effects analysis that modeled the intervention as a time-dependent variable.

SETTING: Sequential implementation of Pharm2Pharm at six general nonfederal acute care hospitals in Hawaii with more than 50 beds in 2013 and 2014. All five other such hospitals served as a contemporaneous comparison group.

PARTICIPANTS: Adult inpatients who met criteria for being at risk for medication problems (N = 2,083), 62% of whom were aged 65 or older.

INTERVENTION: A state-wide system of medication management services provided by specially trained hospital and community pharmacists serving high-risk individuals from hospitalization through transition to home and for up to 1 year after discharge.

MEASUREMENTS: Medication-related hospitalization rate per 1,000 admissions of individuals aged 65 and older, adjusted for case mix; estimate of costs of hospitalizations and actual costs of pharmacist services.

RESULTS: The predicted, case mix–adjusted medication-related hospitalization rate of individuals aged 65 and older was 36.5% lower in the Pharm2Pharm hospitals after implementation than in the nonintervention hospitals (P = .01). The estimated annualized cost of avoided admissions was $6.6 million. The annual cost of the pharmacist services for all Pharm2Pharm participants was $1.8 million.

CONCLUSION: The Pharm2Pharm model was associated with an estimated 36% reduction in the medication-related hospitalization rate for older adults and a 2.6:1 return on investment, highlighting the value of pharmacists as drug therapy experts in geriatric care. J Am Geriatr Soc 65:212–219, 2017.

Key words: pharmacist; medication management; medication-related hospitalization; cost avoidance; geriatric care model
previous research has shown that pharmacists can have a positive effect on care of older adults, including reducing hospital use,\(^5\) no research has estimated the effect of targeted state-wide all-payer models implemented across diverse provider groups on population metrics.

Selected in 2012 to receive a Health Care Innovation Award from the Centers for Medicare and Medicaid Services (CMS) Innovation Center, the University of Hawaii and its partners designed the Pharm2Pharm model to reduce preventable medication-related hospital care by strategically deploying the medication expertise of pharmacists across the continuum of care (a collaboration between hospital and community pharmacists: Pharm2Pharm). In this model, hospital consulting pharmacists identify inpatients who are at risk of medication problems and transfer responsibility for medication management to community consulting pharmacists who work with these individuals for up to 1 year after discharge. In the hospital and community settings, these consulting pharmacists engage patients and collaborate with prescribers to identify and resolve drug therapy problems, aiming to improve health and reduce potentially avoidable hospital use. This model leverages the recent increase in supply of pharmacists (as those who hire pharmacists regularly report),\(^6\) formalizing a more-proactive and integrated role than the traditional dispensing pharmacist role, which is especially valuable in places with physician shortages.\(^7\)

Previous research on care coordination models informed the development of the Pharm2Pharm model. In particular, of 15 randomized trials of care coordination programs for Medicare beneficiaries, only two showed significant reductions in hospitalizations and Medicare expenditures. Both of these programs included a medication education component and close collaboration with local hospitals. Only one of 10 of the other programs with sufficient sample size for evaluation included medication education. The most successful program risk-stratified its participants at enrollment and identified significant differences between the intervention and control groups only in the highest-risk group. None of the programs generated net savings.\(^8\)

Thus, the Pharm2Pharm model was conceptualized as a care transition and care coordination service but focused on medications. In this model, hospital consulting pharmacists use evidence-based criteria to identify inpatients at risk of medication problems (enrollment criteria available upon request) and formally transfer them after discharge to a community consulting pharmacist that the individual selects from among the available participating pharmacists. All Hawaii Community Pharmacist Association member pharmacies were eligible to participate. Participant visits were conducted in person, unless the participant preferred a telephone visit. Most of the in-person visits were conducted in the pharmacy where the community consulting pharmacist was employed, although some pharmacists offered and conducted home visits. Because this was an all-payer intervention, insurance type and ability to pay were not considered in the enrollment decision. These specially trained consulting pharmacists reconcile medications and, based on clinical information, systematically identify and resolve drug therapy problems, specifically indication, effectiveness, safety, and adherence problems. This comprehensive approach with extended follow-up was considered to be important, because previous research has found no effect of medication reconciliation alone on hospital use within 30 days of discharge.\(^9\)

This study aimed to evaluate the effect of this coordinated hospital and community pharmacist intervention to improve medication management for high-risk older adults. A secondary aim was to assess effect on costs from a payer perspective. It was hypothesized that this change in the medication management system would improve care at the population level, specifically medication-related hospitalization rates per 1,000 admissions of people aged 65 and older.

**METHODS**

The Pharm2Pharm model was implemented in Hawaii sequentially at six nonfederal, general, acute care hospitals with 50 or more beds in 2013 and 2014. All five other such hospitals in Hawaii served as a quasi-experimental comparison group. This approach excluded from both groups the Veterans Affairs hospital, specialty hospitals (e.g., women’s and children’s hospitals, psychiatric hospitals, rehabilitation hospitals), and very small hospitals (e.g., critical access hospitals). The six intervention hospitals included the four largest hospitals in the state’s three rural counties (Maui, Kauai, Hawaii) and two hospitals in urban Honolulu County. Three of the six intervention hospitals are public hospitals, and the other three intervention hospitals and the five nonintervention hospitals are private nonprofit organizations.

The four intervention hospitals in the more-rural counties were included in the Health Care Innovation Award application as operating partners. The intervention was launched sequentially at these hospitals based on availability of hospital and community pharmacists to complete the training and begin delivering the services. The program was then expanded to the more-urban island of Oahu, launching at the first two hospitals outside of Honolulu City that expressed interest and commitment to implement Pharm2Pharm quickly. This resulted in six intervention hospitals and one nonintervention hospital outside of Honolulu City and four nonintervention hospitals in Honolulu City. In summary, the intervention hospitals tended to be located in less-urban areas of Hawaii that had higher frequencies of preventable hospitalizations per population. In addition, the intervention hospitals tended to be smaller (mean licensed beds 135) than nonintervention hospitals (mean licensed beds 245). The first intervention hospital launched in the first quarter of 2013, followed by the second hospital in the second quarter of 2013, the third and fourth hospitals in the third quarter of 2013, the fifth hospital in the second quarter of 2014, and the sixth hospital in the third quarter of 2014. Implementation at all six intervention hospitals continued through the fourth quarter of 2014.

The Pharm2Pharm intervention was implemented as a quality collaborative\(^{10,11}\) among the participating hospitals and community pharmacies. This included standard operating procedures (Available upon request), mandatory training, tools to support implementation, monthly monitoring of performance, and ongoing implementation of
process changes designed to improve the model’s performance. The Health Care Innovation Award funded the pharmacist services. With this funding, the University of Hawaii hired the hospital pharmacists as employees. The community pharmacies were paid a per-participant fee that was prorated based on the length of time that the participant received services up to 1 year after discharge. At the end of the first year of implementation, minimum performance standards for payment were established.

The training focused on medication management processes across the continuum of care but also addressed special needs of the target population, including health literacy, cultural practices, and social services issues. This mandatory 8-hour training was provided in live sessions for all participating pharmacists in person or a webinar and included medication reconciliation, review of clinical information, and systematic review of each medication to identify and resolve the following categories of drug therapy problems based on best practice for medication management by pharmacists: indication, effectiveness, safety, and adherence. This training included focus on categories of high-risk medications, particularly those most commonly implicated in emergency hospitalizations of older adults and potentially inappropriate medications in older adults according to the American Geriatrics Society Beers Criteria. An online, self-guided, interactive training module has been adapted from this mandatory training and focuses on identifying and resolving drug therapy problems in high-risk individuals in inpatient and outpatient settings: http://pharmacy.uhh.hawaii.edu/ce/irdtp.php.) In addition, health information technology was phased in, along with training in the use of the technology, beginning in the last quarter of the first year, to support identified needs for electronic exchange of health information, including secure messaging, electronic access to laboratory results, and medication fill history query.

Process measures were monitored monthly, including percentage of participants for whom the hospital consulting pharmacist completed medication reconciliation during hospitalization, participants with all discrepancies resolved by discharge, participants receiving medication education from the hospital consulting pharmacist, participants with first visit with a community consulting pharmacist within 3 days of discharge, participants for whom the community consulting pharmacist completed medication reconciliation within 30 days of discharge, frequency of visits after discharge, drug therapy problems identified and resolved, and pharmacist communication with the prescriber at least quarterly. The project team tracked and reviewed these measures using statistical process control charts and implemented changes in response to performance variations or trends in an effort to achieve improvements. The pharmacists also received reports on their individual process performance relative to the aggregate performance.

To evaluate the primary outcome measure, a quasi-experimental interrupted time series design was used with quarterly measures including 3 years of baseline data, seven quarters during which Pharm2Pharm was launched sequentially at the intervention hospitals, and one quarter with full implementation at all six hospitals. Although this design does not include randomization, it includes some controls, namely comparative baseline time periods, use of nonintervention comparison hospitals, and staggered implementation schedule across the intervention hospitals. This staggered implementation (vs simultaneous implementation) across intervention hospitals further reduces the possibility of a confounding variable causing an effect.

Hawaii Health Information Corporation (HHIC), the private nonprofit corporation that maintains the only all-payer hospital database in the state, provided the medication-related admission rate per 1,000 admissions of individuals aged 65 and older according to quarter for each hospital from 2010 through 2014 using ICD codes. Although ICD codes probably do not capture all admissions that are medication related, this measure was used because previous research has shown that the medication-related hospitalization rate based on ICD codes of individuals aged 65 and older is more than double the rate of those younger than 65 in Hawaii and because the majority of Pharm2Pharm participants were aged 65 and older. Nationally, approximately 5% of all admissions of individuals of any age are medication related based on ICD codes. The Pharm2Pharm intervention did not aim to reduce all admissions or only admissions within 30 days after discharge. Rather it was focused on reducing medication-related admissions at any time after the index hospitalization. Thus, medication-related admission rate based on ICD code was considered the most-appropriate and -sensitive measure available to detect an effect if one existed. Specifically, the numerator was the count of admissions in individuals aged 65 and older with any of the following ICD-9 injury codes:

- 357.6 (neuropathy due to drugs)
- 692.3 (contact dermatitis due to drugs and medicines in contact with skin)
- 693.0 (dermatitis due to drugs or medicines taken internally)
- 960.0–964.9, 965.02–969.5, 969.8–979.9 (poisoning by drugs, medicinal and biological substances, including overdose of these substances and wrong substances given or taken in error)
- E850.1–E858.9 (accidental poisoning by drugs, medicinal substances, and biologicals, including accidental overdose, wrong dose given or taken in error, and drug taken inadvertently)
- E930.0–E934.9, E935.1–E949.9 (drugs, medicinal substances, and biologicals causing adverse effects in therapeutic use, including correct drug properly administered in therapeutic or prophylactic dosage as the cause of any adverse reaction including allergic or hypersensitivity reactions)

CMS recommended these codes for calculating adverse drug event rates for their healthcare innovation awardees with medication-focused interventions for high-risk populations; the codes are based on the medication-related ICD codes used in the Healthcare Cost and Utilization Project sponsored by the Agency for Healthcare Research and Quality. The denominator was the count of admissions of individuals aged 65 and older. This ratio was multiplied by 1,000 to produce the medication-related hospitalization rate per 1,000 admissions of individuals aged 65 and older for each hospital each quarter.
Analyses

Changes over time in the medication-related admission rate for the group of Pharm2Pharm intervention hospitals and the group of nonintervention hospitals were compared using a linear mixed-effects model. A random intercept and random slope were included to account for within-hospital correlation of medication-related admissions over time. The parameter of interest in terms of statistical inference was the interaction between study group and time, which tests for a difference in the slope of hospital admission trajectories over time according to study group. The Pharm2Pharm intervention was modeled as a time-dependent variable to account for the implementation dates at each intervention hospital. The nonintervention hospitals were coded as "no intervention" for all quarters over the 5-year period. The intervention hospitals were coded as "no intervention" during the quarters before implementation. The quarter during which the first participant was enrolled at a given hospital was used as the implementation quarter for that hospital, regardless of when during the quarter the first participant was enrolled, and was coded as "intervention" for that hospital from that quarter to the end of the 5-year period. Thus, the quarter after the implementation quarter was considered full implementation for each hospital. In addition, the model adjusted for CMS case mix index17 at each hospital. All analyses were performed using SAS version 9.3 (SAS Institute, Inc., Cary, NC), and statistical significance was taken at the .05 level.

CMS cost-to-charge ratios18 from 2014 were applied to the mean charges at each intervention hospital to estimate the average cost of a medication-related hospitalization in this age group during the last quarter, which reflected full implementation at all six intervention hospitals. This cost estimate does not include other categories of use (e.g., emergency department, ambulatory care, prescription medication). Actual costs of the pharmacist services were also tracked from July 2014 through June 2015 to capture investment with full implementation across hospitals. This included the salary plus benefits for the hospital consulting pharmacists and payments for the community consulting pharmacist services as described previously.7 This did not include the project administration costs or the cost of the health information technology that Hawaii Health Information Exchange phased in to support the Pharm2Pharm model from the last quarter of 2013 through the second quarter of 2015, because these would not reflect ongoing costs in sustaining the model and would differ in replication settings. The University of Hawaii institutional review board approved this research as exempt using existing data collected for this quality improvement initiative.

RESULTS

During the 2-year implementation period, 2,083 high-risk inpatients were enrolled in Pharm2Pharm at the intervention hospitals. Of those enrolled, 62% were aged 65 and older. The grand mean (mean of quarterly means) baseline medication-related hospitalization rates per 1,000 admissions of individuals aged 65 and older from 2010 through 2012 was 77 for the intervention hospitals and 82 for the comparison hospitals. The baseline range was 54 to 115 for intervention hospitals and 61 to 127 for comparison hospitals. For the last two intervention quarters, which reflected implementation at all six intervention hospitals, the grand mean quarterly rate was 49 at the intervention hospitals and 67 at the comparison hospitals, and the range was 26 to 81 for the intervention hospitals and 39 to 138 for the comparison hospitals.

Mixed-effects model results demonstrate that the medication-related admission rate over time in this age group, adjusted for case mix, differed significantly between the study groups (P < .01). Admission rates decreased significantly more rapidly in the Pharm2Pharm hospitals after implementation than in the nonintervention hospitals (P = .01, Table 1). Greater patient complexity was associated with higher medication-related hospital admissions (P = .03).

Predicted model values are presented in Figure 1, which shows all 11 hospitals combined during the 3-year baseline period, followed by the 2-year period during which the Pharm2Pharm model was implemented sequentially at the six intervention hospitals. The predicted rate in the last quarter after full implementation was 46 medication-related admissions per 1,000 admissions at intervention hospitals and 72 medication-related admissions per 1,000 at the nonintervention hospitals, reflecting a 36.5% lower rate associated with the Pharm2Pharm intervention.

To examine the potential bias due to greater patient complexity in the comparison hospitals (1.45 comparison vs 1.15 intervention hospitals, P = .008), the data were further analyzed after excluding the three comparison hospitals with the highest case mix index. With the remaining two comparison hospitals, the mean case mix index was 1.22. The mixed model results remained consistent with those of the original model; medication-related admission rates decreased significantly more rapidly in the Pharm2Pharm hospitals after implementation than in the nonintervention hospitals (P = .02, Table 2).

To determine whether there were significant differences between hospital groups during the 12 baseline quarters in rates of medication-related hospitalizations per 1,000 admissions of individuals aged 65 and older, a t-test for two independent groups was conducted using the rates not adjusted for case mix. The mean rates were not significantly different between the groups during this baseline period. The t-test was performed using the standard error for the quarterly means. The grand mean quarterly rate was 49 at the intervention hospitals and 67 at the comparison hospitals, and the range was 26 to 81 for the intervention hospitals and 39 to 138 for the comparison hospitals.

| Variable | Parameter Estimate | Standard Error | 95% Confidence Interval | P-Value |
|----------|--------------------|----------------|------------------------|---------|
| Intervention | -60.83 | 29.80 | -119.60 to -2.06 | .04 |
| Time | -4.74 | 1.73 | -8.58 to -0.90 | .02 |
| Case mix | 37.13 | 16.97 | 3.67 to 70.59 | .03 |
| Intervention by time | 4.43 | 1.71 | 1.07 to 7.80 | .01 |

*The decrease in medication-related hospitalization rate per 1,000 admissions of participants aged 65 and older over time in intervention hospitals was 4.4 per quarter greater than in nonintervention hospitals.
period (intervention hospital group mean 77.4, nonintervention hospital group mean 81.9, \(P = .78\)). Using a general linear model to adjust for case mix, the mean rates during the 12 baseline quarters were not significantly different between groups (case mix adjusted intervention hospital group mean 76.9, case mix adjusted nonintervention hospital group mean 82.5, \(P = .81\)).

Based on this statistical model as illustrated in Figure 1, the rate of medication-related hospitalizations in individuals aged 65 and older was 36% lower in the intervention hospitals by the last quarter of 2014 than in the nonintervention hospitals. Predicted rates are reported to reflect the adjustment of case mix that was used in the mixed-effects model. Because of the observational nature of the study (the study did not rely on randomization), accounting for selection bias in terms of case mix is important. Specifically, hospitals varied according to case mix, so it is important to estimate and report intervention effects after adjustment for potential confounding between case mix and intervention. Using actual total hospitalizations in this age group at intervention hospitals in 2014, the model estimates 394 avoided hospitalizations annually because of the Pharm2Pharm intervention. The annual cost estimate of these avoided admissions is $6,626,913 (Table 3).

The actual annual cost of the pharmacist services, including services for enrolled individuals younger than 65, was $1,820,454. Because it is not known whether the per-person cost of the pharmacist services was different for enrolled individuals aged 65 and older, the total cost of the service for all patients enrolled was used as a very

**Table 2. Mixed-Model Results for Medication-Related Hospital Admissions After Excluding Three Comparison Hospitals with Greater Patient Complexity**

| Variable               | Parameter Estimate | Standard Error | 95% Confidence Interval | \(P\)-Value |
|------------------------|--------------------|----------------|-------------------------|-------------|
| Intervention/C0        | 62.97              | 32.83          | –127.87–1.94            | .06         |
| Time/C0                | 4.64               | 1.92           | –9.19 to 0.10           | .047        |
| Case mix               | 51.85              | 22.06          | 8.24–95.46              | .02         |
| Intervention by time   | 4.63               | 1.88           | 0.91–8.36               | .02         |

**Table 3. Calculation of Estimates of Avoided Cost Associated with Pharm2Pharm and Return on Investment**

| Predicted Medication-Related Admission Rates 2014-Q4 | Value |
|-----------------------------------------------------|-------|
| A. Comparison group rate per 1,000 admissions       | 72.14 |
| B. Intervention group rate per 1,000 admissions     | 45.83 |
| C. Difference between comparison group and intervention group rates (A-B) | 26.31 |
| D. Actual number of admissions of individuals aged 65 and older at intervention hospitals 2014 | 14,966 |
| E. Predicted number of avoided medication-related admissions per year of individuals aged 65 and older associated with the intervention (C x (D/1,000)) | 393.75 |
| F. Average cost of a medication-related hospitalization for an individual aged 65 and older at intervention hospitals in 2014 based on Medicare cost-to-charge ratio, $ | 16,830.02 |
| G. Estimated annual cost of avoided medication-related admissions for individuals aged 65 and older associated with the intervention (E x F), $ | 6,626,913 |
| H. Actual annual cost of pharmacist services to deliver the intervention | 1,820,454 |
| Estimated return on investment in pharmacist services ((G–H)/H), % | 264% |

Figure 1. Case mix–adjusted predicted medication-related hospitalization rates per 1,000 admissions of individuals aged 65 and older, baseline through postimplementation, intervention hospitals versus comparison hospitals.
have lower rates of follow-up care and higher rates of care in rural areas,20 and Medicare beneficiaries in rural areas has shown a decrease in the number of pharmacies in rural counties of Hawaii has been more severe than in the urban county of Honolulu.19 Previous research showed that a more-limited pharmacist intervention did not reduce clinically important medication errors.24 In addition, the cost of pharmacist services provided was not tracked separately for individuals aged 65 and older; rather, the cost of the services for all patients (the majority of whom were aged ≥65) are reported, which represents an overestimate of the actual cost in the target age group. Finally, it is likely that the use of ICD codes, which does not capture all types of medication-related problems,2 underestimates the number of hospitalizations avoided.

This study design also did not include an evaluation of the relative effect of the various components of the Pharm2Pharm model on reducing medication-related hospitalization rates. Thus, dismantling studies would be needed to determine the more-important components of the intervention, which would support improvements in the efficiency of the model. Such research is important because one report showed that a more-limited pharmacist intervention did not reduce clinically important medication errors.24

Finally, differences in the skills and resources of the pharmacists providing the services were not evaluated. Although all participating pharmacists were required to complete at least 8 hours of training before providing the Pharm2Pharm services, the range of experience and implementation styles among the pharmacists was substantial. Future research should examine what competencies and context are necessary and sufficient to produce the best possible improvements in outcomes and cost.

An important challenge to the sustainability and spread of this model is how to pay for the pharmacist services. In traditional roles, pharmacists are paid for dispensing medications. Under Medicare Part D plans, pharmacists are paid a fee for providing medication therapy management (MTM) services, but the pharmacist in Medicare MTM typically has little access to clinical information about the patient, which greatly limits the pharmacist’s ability to identify and resolve drug therapy problems. Outside of MTM, pharmacists currently cannot bill Medicare for their services directly, although physicians can bill for pharmacist services that are provided incident to the physician service, including office visits and transitional care management. Accountable care organizations that have quality and cost incentives may currently be in a good position to fund the Pharm2Pharm model.

This study is also relevant to broader efforts to improve quality and reduce cost of care. For example, it was reported that National Committee for Quality Assurance (NCQA) recognition as a Patient Centered Medical Home (PCMH) was not associated with quality improvement in 91% of measures or with any cost reduction.25 NCQA criteria pertaining to medication management
might contribute to these findings. First, although NCQA PCMH standards include medication management (Element D in the “Plan and Manage Care” section), it is not a “must-pass” element and constitutes only 3% of the total possible points. Thus, a practice can achieve the highest level of NCQA PCMH recognition without meeting a single medication management requirement. Second, even if implemented, the current medication management requirements are unlikely to produce meaningful cost reductions or quality improvements because they are not focused on identifying and resolving medication problems that cause substantial hospital use. The Pharm2Pharm model demonstrates that expert medication management may be essential to improving quality and reducing costs and supports reforms achieving better integration of pharmacists into care teams, including medical homes.

The perspective of front-line physicians further emphasizes relevant lessons about the importance of care coordination: that care coordination is a safety matter and that the concept of teamwork must be expanded beyond a single clinical setting.26 The Pharm2Pharm model incorporates both lessons, addressing medication safety across settings. Medication errors, including prescribing errors and errors in taking medications, are common and preventable.27 The consulting pharmacists in the Pharm2Pharm model are trained to intervene beyond catching errors—they aim for drug therapy optimization, that is, making sure each medication is indicated, effective, safe, and taken properly and that there are no untreated indications for which medication is indicated, effective, safe, and taken properly and that are not focused on identifying and resolving medication problems that cause substantial hospital use. The Pharm2Pharm model demonstrates that expert medication management may be essential to improving quality and reducing costs and supports reforms achieving better integration of pharmacists into care teams, including medical homes.

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CONCLUSIONS

The Pharm2Pharm model was associated with a reduction in the medication-related hospitalization rate in older adults and substantial return on investment in the pharmacists deployed in this model. This study highlights the value of pharmacists as drug therapy experts and managers, particularly for high-risk individuals and across the continuum of care, adding to the evidence supporting integration of pharmacists in hospital and community settings to optimize drug therapy. The Pharm2Pharm model shows substantial promise in helping to solve the challenges of complex medication management amid a shortage of primary care physicians through strategic deployment of pharmacist expertise.

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