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ORIGINAL RESEARCH ARTICLE

The Impact of a Structured Pharmacist Intervention on the Appropriateness of Prescribing in Older Hospitalized Patients

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Abstract
Background Throughout the literature, drug-related problems (DRPs), such as medication reconciliation issues and potentially inappropriate prescribing, have been reported to be associated with adverse outcomes in older individuals. Both structured pharmacist review of medication (SPRM) interventions and computerized decision support systems (CDSSs) have been shown to reduce DRPs.
Objective The objectives of this study were to (i) evaluate the impact of a specially developed SPRM/CDSS intervention on the appropriateness of prescribing in older Irish hospital inpatients, and (ii) examine the acceptance rates of these recommendations.
Methods We prospectively reviewed 361 patients, aged ≥65 years who were admitted to an Irish university teaching hospital over a 12-month period. At the point of admission, the patients received a SPRM/CDSS intervention, which screened for DRPs. Any DRPs that were identified were then communicated in writing to the attending medical team. The patient's medical records were reviewed again at 7–10 days, or at the point of discharge (whichever came first).
Results Of the 361 patients reviewed, 181 (50.1 %) were female; the median age was 77 years [interquartile range (IQR) 71–83 years). A total of 3,163 (median 9, IQR 6–12) and 4,192 (median 12, IQR 8–15) medications were prescribed at admission and discharge, respectively. The SPRM generated 1,000 recommendations in 296 patients. Of the 1,000 recommendations, 548 (54.8 %) were implemented by the medical teams accordingly. The SPRM/CDSS intervention resulted in an improvement in the appropriateness of prescribing as defined by the medication appropriateness index (MAI), with a statistically significant difference in the median summated MAI at admission (15, IQR: 7–21) and follow-up (12, IQR: 6–18); $p < 0.001$. However, the SPRM did not result in an improvement in appropriateness of underprescribing as defined by a modified set assessment of care of vulnerable elders (ACOVE) criteria.
Conclusion This study indicated that DRPs are prevalent in older Irish hospitalized inpatients and that a specially developed SPRM intervention supported by a CDSS can improve both the appropriateness and accuracy of medication regimens of older hospitalized inpatients.

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1 Introduction

Older individuals aged ≥65 years constitute approximately 12 % of the Irish population, with this figure expected to almost double by 2045 [1]. During the same period the

proportion of individuals ≥85 years is expected to almost triple [1]. Although older individuals constitute just in excess of 10 % of the population, they consume approximately 50 % of all prescription medications [2].

Drug-related problems (DRPs), such as poor compliance, medication reconciliation issues, potentially inappropriate prescribing (PIP), and adverse drug reactions (ADRs) are prevalent in older hospitalized patients [3–5]. Older individuals may be especially vulnerable to DRPs at the interface of care, particularly on admission to hospital. It is estimated that unintentional medication omissions and errors (i.e., medication reconciliation issues) may be present in up to 70 % of medication histories taken at this time [6–9] and that PIP prevalence may be as high as 96 % [10]. Medication reconciliation issues and PIP have both been highlighted repeatedly as major contributory factors in adverse drug events (ADEs), increased morbidity, mortality, and increased healthcare utilization in older individuals [11–13].

A medication reconciliation review is designed to ensure that the most accurate and comprehensive list of medications is maintained throughout the continuum of care [6, 8]. Medication reconciliation has been described as "the process of identifying the most accurate list of patient's current medications—including names, dosage, frequency, and route—and comparing them to the current list in use, recognizing any discrepancies and documenting any changes thus resulting in a complete list of medications" [14]. In 2007, the World Health Organization (WHO) expanded the scope of this definition by indicating that the medication reconciliation process should be accompanied by a review of appropriateness: "the medication reconciliation process provides an opportunity to reconsider the appropriateness of a patient's medications" [15]. To ensure that medications are prescribed appropriately and to minimize the risk of ADEs during the entire time in hospital, it is important that an up-to-date and accurate medication history is recorded at the point of admission [6, 16].

In older individuals, one approach to assessing appropriateness of prescribing is to use a set of validated PIP criteria. These may be either implicit (judgment based) criteria, such as the medication appropriateness index (MAI) [17] and Assessment of Care of Vulnerable Elders (ACOVE) [18], or explicit criteria, such as Beers criteria [19], the Screening Tool of Older Person Prescribing (STOPP) [20], the Screening Tool to Alert Prescribers to Right Treatment (START) [20], and the Priscus criteria [21].

Involvement of pharmacists in the prescription review and monitoring process is an efficient means of optimising prescribing and improving patient outcomes [11, 22]. Clinical pharmacy services are intended to be (i) patient centered, (ii) focused on optimization of pharmacotherapies, and (iii) at minimum cost [4]. Pharmacists are well positioned to perform a medication reconciliation and appropriateness review [9, 11, 23–25]. Structured pharmacist review of medication (SPRM) interventions focus on medication optimization and counselling of patients, and have the potential to identify and reduce DRPs [26, 27]. Computerized decision support systems (CDSSs), are designed to support healthcare professionals in the prescription ordering and review process. Studies investigating the use of CDSSs have reported that they can significantly reduce DRPs and can have a positive effect on ADE occurrence [9, 23, 24].

To date, the authors are not aware of any study that has examined the impact of SPRM intervention supported by a CDSS on appropriateness of prescribing in older Irish hospitalized inpatients. The objective of this study was to (i) evaluate the impact of a specially developed SPRM/CDSS intervention on the appropriateness of prescribing in older Irish hospital inpatients, and (ii) examine the acceptance rates of these recommendations.

2 Methods

2.1 Study population and setting

This study was conducted in an 810-bed hospital in the greater Cork region of Ireland. All patients aged ≥65 years admitted through the accident and emergency (A&E) department were eligible for this study. Patients who were terminally ill or admitted under the care of psychiatry or directly into the intensive care unit (ICU), or had an expected length of stay <48 h were excluded from this study. Each participant gave written informed consent. We prospectively studied 361 patients, aged ≥65 years who were admitted to an Irish university teaching hospital between June 2012 and June 2013.

The data presented in this article are part of a larger randomized control trial, and pertain to the intervention arm of the study. The primary outcome measure in the larger study is the incidence of ADRs in older hospitalized individuals. The trial protocol was approved by the regional ethics committee and was registered with the United States National Institutes of Health (NCT01467128) http://clinicaltrials.gov/show/NCT01467128.

2.2 Intervention

Within 48 h of admission, patients were reviewed by the research pharmacist (primary author of this report) for eligibility. A comprehensive review was made of the patient's medical notes and medication chart. The research pharmacist also conducted a consultation with the patient

and/or their caregivers at the point of recruitment; the format of this consultation was based on the questions outlined in Structured History taking of Medication use (SHIM) questionnaire [28]. The information gathered during this review process was recorded in the specially developed CDSS.

The SPRM is detailed in Fig. 1, and it was designed based on the structured pharmacist review proposed by Spinewine et al. in 2006 [4].

The CDSS was developed through collaboration between the pharmaceutical care research team from the School of Pharmacy and the Department for Geriatric Medicine of University College Cork. The data collected (patient demographics, current and past medical history, urea and electrolyte results, prescribed medications) was structured to reflect the data normally recorded during a medical history review in Irish hospitals. The system was designed to complement the SPRM and standardize the delivery of the SPRM intervention.

The reconciliation review element of the CDSS was designed to ascertain the most accurate and up-to-date information possible relating to each medication and the system prompted the research pharmacist to ask a number of questions relating to each medication. A medication reconciliation issue related to any undocumented discrepancy between the medications charted in the patient's medication charts and the list of medications that the patient was on prior to admission; that is, inadvertent omission, and dosage or frequency discrepancy. The system also included a section for recording omitted medications and over-the-counter medications. If unsure of matters relating to a specific medication, the research pharmacist could refer to the summary of product characteristics (SPC) for that medication, which was integrated into the CDSS. The system also included a PIP and potential prescribing omission (PPO) assessment element. Although not designed for decision making, the system could be used for decision support; that is, the research pharmacist could select a particular medication from the patient's list of medication and the system would highlight all the criteria from the STOPP and the Beers and Priscus criteria related to that particular medication. The research pharmacist could then record the PIP instances and decide whether to intervene based on clinical relevance. Similarly for the PPO assessment, the research pharmacist could select a particular condition from the patient list of conditions and the system would highlight the START criteria relevant to that condition. Based on clinical relevance of the PPO intervention at the time of review, the research pharmacist could decide whether to intervene on the PPO instance. For drug–drug interactions and renal and hepatic dosage adjustment recommendations, a similar process was followed, although the information was based on the British National Formulary (BNF) 61st edition [29]. Once

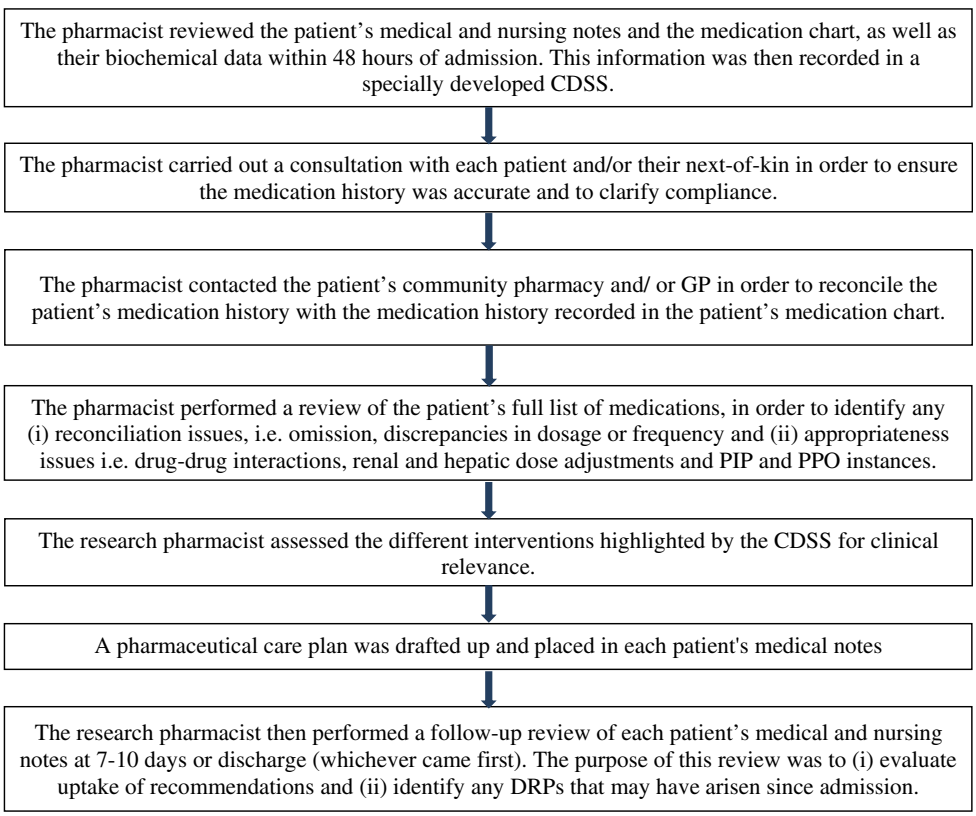

Fig. 1 Description of data collection and review process. *CDSS* computerized decision support system, *GP* general practitioner, *PIP* potentially inappropriate prescribing, *PPO* potential prescribing omission, *DRP* drug-related problems

all data were collected and the review process completed, a pharmaceutical care plan outlining all of the clinically relevant interventions was generated and inserted in the patient's medical notes. The research pharmacist was a postgraduate pharmacist with previous experience in geriatrics care, and was present at the hospital from 8 am to 5 pm, Monday to Friday. Because of the high volume of older patients attending A&E and to facilitate a full and comprehensive review and subsequent follow-up, recruitment was limited to the first three consecutive patients on the bed list each day who met the inclusion criteria.

Usual pharmaceutical care in the hospital involved the hospital pharmacists, who performed pharmaceutical reviews within 24–72 h of admission for the majority of patients (approximately two thirds) throughout the study period. The hospital pharmacists undertake these reviews independently of the attending medical team and communicate any identified DRPs to the medical team via written notes.

2.3 Assessment of Prescribing Appropriateness

PIP was assessed in this study using the STOPP [20], Beers (2003) [19], and Priscus [21] criteria. For the purpose of this study, the 2003 Beers criteria were used because the 2012 version had not been published prior to initiation of this study. The Beers independent of diagnosis (ID) medication criteria (medications deemed potentially inappropriate independent of the patient's diagnosis) and the Beers considering diagnosis (CD) medication criteria (medications considered potentially inappropriate taking the patient's underlying conditions into consideration) were applied. START [20] was used to assess potential underprescribing. Potential drug–drug interactions and PIP in individuals with renal and hepatic impairment were assessed using the BNF 61st edition [29].

2.4 Generation of Pharmaceutical Care Interventions

Interventions generated by the CDSS were reviewed by the research pharmacist and a pharmaceutical care plan was generated, outlining the clinically relevant interventions at the point of review (Fig. 1). Clinical relevance was assessed by the research pharmacist and was based on the clinical appropriateness/relevance of each intervention at the time of review. The review was performed at admission. The intervention focused on DRPs [4, 30]; that is, medication reconciliation issues and appropriateness issues relating to new and long-term medications prescribed on a regular or as-needed (PRN) basis. The interventions were communicated in writing to the hospital physicians with primary responsibility for patient care (where possible, recommendations were verbally communicated). Where necessary, the research pharmacist was also available to answer prescriber queries about specific medications or interventions.

2.5 Outcome Measures

The primary outcome of this study was the appropriateness of prescribing as defined by the medication appropriateness index (MAI) [17] and a modified subset of the ACOVE criteria [3] at follow-up (7–10 days) or discharge, whichever came first. The MAI and ACOVE were used as primary outcomes, because they are both considered comprehensive tools for assessing prescribing appropriateness with assessment based on a number of different aspects of prescribing [17, 18]. These two tools were used previously as an outcome measure in a study similar to ours undertaken by Spinewine et al. in 2007 [3]. The modified version of the ACOVE criteria (only including the indicators relating to underprescribing) was used, because the appropriateness of prescribing was already addressed by the MAI. The medical records of all patients recruited into the study were followed up. The primary outcome assessment was performed by the research pharmacist.

The secondary outcome measures were:

(i) Uptake or acceptance of interventions by hospital physicians with primary responsibility for patient care.
(ii) The prevalence of PIP and PPO [as defined by STOPP, Beers (2003), and Priscus criteria], the combined PIP criteria, and the START criteria at admission and follow-up.

2.6 Data Analysis

Statistical analysis was performed using PASW (Predictive Analytics SoftWare) version 19 for Windows (SPSS, Chicago, IL, USA). Descriptive statistics included median and interquartile range (IQR) for nonparametric data; for normally distributed data, mean and standard deviation were calculated. The Wilcoxon signed rank test was used to examine the difference in the median summated MAI score, the ACOVE frequency, the PIP frequency (as defined by STOPP, Beers ID, Beers CD, and Priscus criteria), PPO frequency (as defined by the START criteria), drug–drug interaction frequency, and the frequency of medications that required renal dosage adjustment at admission and follow-up. A Mann–Whitney *U*-test was used to examine the differences between each individual element of the MAI criteria between admission and follow-up. A probability value of <0.05 was considered statistically significant.

3 Results

3.1 Demographics

Three hundred and sixty one patients were consecutively recruited; 50.1 % were female, 93.6 % of the sample lived independently. Median (IQR) age was 77 (71–83) years. The median (IQR) Barthel Index score was 19 (18–20), the median (IQR) cumulative illness rating score (CIRS) was 5 (3–6), and the median (IQR) abbreviated mental test score (AMTS) was 10 (9–10). The median (IQR) number of prescribed medications was 9 (6–12) at admission and 12 (8–15) at follow-up (Table 1). Median (IQR) length of stay was 8 (5–13.5) days. Seventeen patients (4.7 %) died during the hospital stay.

3.2 Characteristics of Interventions

On review of these DRPs, 1,000 interventions were made by the research pharmacist in 296 (82.0 %) patients. Two hundred and sixty seven patients (74 %) had ≥1 appropriateness issue, while 161 patients (44.6 %) had ≥1 reconciliation issue. A median of 2 (IQR 1–4) interventions were made per patient. Five hundred and seventy seven (57.7 %) of these recommendations related to appropriateness issues, while 423 (42.3 %) of the recommendations related to reconciliation issues. The physicians with primary responsibility for patient care implemented 548 (54.8 %) of the overall interventions. The SPRM/CDSS highlighted 1,905 potential DRPs, but on review of the clinical relevance of each DRP instance, 1,000 of these DRPs were intervened on. Table 2 summarizes the main characteristics of all interventions made.

3.3 Potentially Inappropriate Prescribing

At admission, the STOPP criteria identified 449 instances of PIP relating to 232 (64.2 %) patients, the Beers ID criteria identified 90 instances of PIP in 76 (21.0 %) patients, the Beers CD criteria identified 188 instances of PIP in 115 (31.8 %) patients, and the Priscus criteria identified 197 instances of PIP in 153 (42.4 %) patients. When the criteria were combined and overlapping criteria were removed, 712 instances of PIP were identified in 275 (76.3 %) patients.

At follow-up, 362 instances of PIP were identified in 200 (55.5 %) patients using the STOPP criteria, 103 instances in 66 (18.3 %) patients using the Beers ID criteria, 179 instances in 114 (31.6 %) patients using the Beers CD criteria, and 190 were identified in 147 (40.6 %) patients using the Priscus criteria. When the criteria were combined and overlapping criteria were removed, 633 instances of PIP were identified in 257 (71.2 %) patients.

A Wilcoxon signed rank test revealed a statistically significant reduction in PIP as defined by the combined criteria [median at admission (M-Adm): 1 (IQR 1–3), median at follow-up (M-Fol): 1 (IQR 1–3); $z = -4.001$, $p < 0.001$], STOPP criteria [M-Adm: 1 (IQR 0–2), M-Fol: 1 (IQR 0–1); $z = -5.492$, $p < 0.001$]. A reduction in PIP as defined by the Beers CD and Priscus criteria was also reported, but this was not found to be statistically significant [Beers CD, M-Adm: 0 (IQR 0–1), M-Fol: 0 (IQR 0–1); $z = -1.075$, $p = 0.282$; Priscus, M-Adm: 0 (IQR 0–1), M-Fol: 0 (IQR 0–1); $z = -0.804$, $p = 0.421$]. A statistically significant increase in PIP as defined by the Beers ID criteria was reported [M-Adm: 0 (IQR 0–0), M-Fol: 0 (IQR 0–0); $z = -2.197$, $p < 0.05$].

Table 1 Frequency of medications prescribed for the 361 patients at admission and discharge

Variables	Admission	Follow-up
Number of medications	3,163	4,192
Number of medications, median (IQR)	9 (6–12)	12 (8–15)
Polypharmacy (≥5 medications), *n* (%)	305 (84.5 %)	346 (95.8 %)
Major polypharmacy (≥10 medications), *n* (%)	157 (43.5 %)	241 (66.8 %)

IQR interquartile range

Table 2 Breakdown of the interventions relating to the clinically relevant drug-related problems

Type of recommendations	No. of recommendations	Recommendations accepted, *n* (%)
Appropriateness issues	577	222 (38.5)
Indication	47	18 (38.3)
Interactions	73	29 (39.7)
Renal adjustment	25	13 (52)
Appropriateness tools (STOPP, Beers, Priscus)	297	135 (45.5)
Underprescribing assessment tool (START criteria)	44	13 (29.5)
Miscellaneous appropriateness issues	91	27 (29.7)
Reconciliation issues	423	326 (77.1)
Dosage	95	69 (72.6)
Missing medications	322	252 (78.3)
Miscellaneous reconciliation issues	6	5 (83.3)

STOPP screening tool of older persons' prescribing, *START* screening tool to alert prescribers to right treatment

Table 3 Number of medications with an inappropriate rating on admission and at follow-up as defined by the medication appropriateness index (MAI)

MAI criterion	Admission, *n*	Follow-up, *n*	*p* value
Indication	343	275	<0.001
Dose	16	6	0.011
Directions	57	64	0.741
Duration	177	102	<0.001
Practicality of directions	34	33	0.398
Drug–drug interaction	361	386	0.118
Drug–disease interaction	211	187	0.002
Duplication	39	32	0.114
Cost	1,762	2,085	0.752
Effectiveness	421	377	<0.001

3.4 Potential Prescribing Omissions

The START criteria identified 155 instances of PPO in 112 (31.0 %) patients at admission, and 150 instances in 114 (31.5 %) patients at follow-up. A Wilcoxon signed rank test reported a reduction in the PPO, but this was not found to be statistically significant [M-Adm: 0 (IQR 0–1), M-Fol: 0 (IQR 0–1); $z = -0.656$, $p = 0.512$].

3.5 Drug–Drug Interactions and Renal Impairment Dosage Adjustment

At admission, the E-Pharm-Assist system identified 405 potentially major drug–drug interactions in 208 (57.7 %) patients and 61 potentially inappropriate dosages in 35 (9.7 %) patients with renal impairment. At follow-up, the E-Pharm-Assist system identified 439 potentially major drug–drug interactions in 231 (63.9 %) patients and 43 potentially inappropriate dosages in 26 (7.2 %) patients with renal impairment. A Wilcoxon signed rank test found a statistically significant increase in the number of drug–drug interactions from admission to follow-up [M-Adm: 1 (IQR 0–2), M-Fol: 1 (IQR 0–2); $z = -1.964$, $p = 0.50$] and a statistically significant reduction in the number of medications requiring renal dosage adjustment [M-Adm: 0 (IQR 0–0), M-Fol: 0 (IQR 0–0); $z = -2.170$, $p < 0.05$].

3.6 Medication Appropriateness Index (MAI)

A Wilcoxon signed rank test revealed a statistically significant difference between the summated MAI score at admission and follow-up [M-Adm: 15 (IQR 7–21), M-Fol: 12 (IQR 6–18); $z = -7.486, p < 0.001$]. In total, 214 (59.3 %) patients had a lower MAI score at follow-up, 107 (29.6 %) had a higher MAI score, and 40 (11.1 %) had no change in their MAI score. Almost 65 % of the medications had at least one inappropriate rating at admission, while the figure was just over 55 % at follow-up. The SPRM intervention resulted in improvements in the majority of the MAI criteria (Table 3). There was a slight reduction in the number of patients with $\geq$1 inappropriately rated MAI criteria, with 357 (99.0 %) patients at admission and 354 (98.1 %) at follow-up; this reduction was not found to be significant ($p = 0.543$).

3.7 Assessing Care of Older Vulnerable Elders (ACOVE)

At admission and follow-up, 28.3 % and 26.9 % of the patients, respectively, had at least one inappropriately rated ACOVE criteria. Between admission and follow-up there was a slight improvement, but this was not found to be clinically significant ($p = 0.739$) (Table 4).

4 Discussion

This study showed that a SPRM intervention using a CDSS can produce improvements in appropriateness of

Table 4 Patients with at least one breach of an assessing care of vulnerable elders (ACOVE) underuse criteria at admission and follow-up

ACOVE underuse criteria	Patients with inappropriate rating on admission, *n* (%)	Patients with inappropriate rating at follow-up, *n* (%)	*p* value
Antiplatelet/ anticoagulant in atrial fibrillation	17 (4.7)	11 (3.0)	0.134
Antiplatelet in diabetes mellitus	17 (4.7)	16 (4.4)	0.655
Angiotensin-converting enzyme inhibitor in heart failure	29 (8.0)	31 (8.6)	0.564
Beta-blocker in heart failure	21 (5.8)	21 (5.8)	1
Antiplatelet in ischemic heart disease	17 (4.7)	17 (4.7)	1
Beta-blocker in myocardial infarction	17 (4.7)	16 (4.4)	0.564
Bisphosphate/calcium, and/or vitamin D in osteoporosis/ fracture	28 (7.8)	27 (7.5)	0.705

prescribing as defined by the MAI. This is the first Irish study to use a SPRM intervention supported by a CDSS to improve appropriateness of prescribing in older hospitalized individuals. In Irish hospitals, medication appropriateness and reconciliation reviews already exist. However, to date this review process is not standardized and delivery of such reviews is highly variable and is often dependent on the individual approach of the each pharmacist. In addition, the quality of the review is heavily reliant on the knowledge and expertise of each individual pharmacist.

In this study, we developed a SPRM intervention supported by a CDSS to standardize the delivery of in-hospital pharmaceutical care in Ireland; essentially, to make it more structured, time efficient, and consistent. Although a SPRM intervention alone may have resulted in an improvement in appropriateness, it was coupled with the CDSS in an effort to standardize both data collection and the review process. The CDSS was designed to provide structure to the medication reconciliation process by prompting the research pharmacist to ask questions that helped to ensure all relevant information was ascertained from each patient. It not only assisted in data collection, but also provided the research pharmacist access to additional information relating to each specific medication (the SPC and the PIP assessment tools). This allowed the research pharmacist to formulate a more informed decision on the appropriateness of a patient's medication regimen. A number of other studies have reported similar improvements in the prescribing appropriateness using pharmaceutical care interventions [3, 31, 32] and using CDSS [7, 33–35].

Although the intervention showed improvements in the overall median summated MAI score for the majority of patients, there was an increase in the number of medications that had an inappropriate rating in several of the criteria, including directions, cost, and drug–drug interaction. In addition, although the majority of patients showed an improvement in their MAI summated score, almost 30 % showed an increased MAI summated score postintervention. This may relate to the fact that the intervention not only addressed appropriateness issues, but also highlighted medication reconciliation issues; that is, inadvertent omission of medications. Therefore, while the SPRM/CDSS intervention was intended to improve appropriateness, it could also lead to an increase in the number of medications charted. However, if a physician recharted all the omitted medications, but did not address the appropriateness issues, this could lead to an increase in the number of medications with an increased inappropriate rating and therefore increase the median summated MAI score.

Although a statistically significant improvement in the MAI score was observed, the true clinical relevance of such an improvement has yet to be illustrated. Throughout the literature, a number of studies have demonstrated improvements in the MAI secondary to different intervention strategies, but few have demonstrated how these improvements can impact on key clinical outcomes, such as healthcare utilization, morbidity, and mortality. Our research group is currently working on a multicenter trial to examine the clinical significance of such improvements in prescribing appropriateness on such outcomes.

This study found that the intervention produced only a slight improvement in the number of patients who were underprescribed clinical beneficial medications according to the modified ACOVE criteria. This finding may relate to the low acceptance of recommendations relating to the START criteria, which may be secondary to the high rate of prescribing already present in this population. A number of studies have reported that polypharmacy can result in the underprescribing of clinically beneficial medications, which may be caused by doctors having reservations about initiating additional medications to already potentially complex regimes [36–38]. The low uptake of PPO recommendations may also relate to physicians deeming that the research pharmacist recommendations were not clinically relevant at that time. Other reasons may also be in play here, and our research group is currently undertaking some qualitative work to examine these reasons.

The intervention produced improvements in both PIP and PPO as defined by all of the screening criteria except for the Beers CD criteria. Similar findings have been reported in other intervention studies [3, 39, 40]. Although this study did find improvements in both PIP and PPO postintervention, as defined by the different criteria, high levels of PIP and PPO were still prevalent postintervention. Again as indicated above, this may relate to the reconciliation element of the intervention, which may have led to an increase in the number of charted medications and in the number of instances of PIP. Therefore, the medication reconciliation aspect of the intervention may have offset some of the improvements made by the appropriateness element of the review. It is crucial that a medication reconciliation review is performed initially before any appropriateness review to ensure that all of the patient's medications are considered in the appropriateness review, thereby ensuring that the most comprehensive review of the patient's medications is undertaken. In our study population, a high number of patients had a DRP, and 82 % of the patients had $\geq$1 DRP. Of these patients, 44.6 % had $\geq$1 medication reconciliation issues. Similar prevalence of medication reconciliation issues have been reported in the literature [6, 7, 41]. The high prevalence of DRPs identified in this study further supports the importance of carrying out a medication reconciliation and appropriateness review within 48 h of admission. These findings illustrate that the first and foremost step in any pharmaceutical care review

should be to ascertain an up-to-date and accurate medication history, a finding that has been echoed in a number of other studies [7, 42].

CDSSs have been reported to be useful tools that can support the delivery of pharmaceutical care [9, 41, 43], improve prescribing appropriateness [11, 24, 35, 43], and minimize the occurrence of ADRs [23, 43]. As stated above, the CDSS used was specially developed by our research group and was intended to provide structure to the patient review and data collection process. The research pharmacist was also able toaccess clinically relevant information at the point of review and perform comprehensive medication reconciliation and appropriateness reviews. Although CDSSs allow the user to perform a detailed review in a time-efficient fashion, they are only as good as the information that is entered into them and they are designed to complement/supplement the clinical judgement of the healthcare professional using them, and not to replace it [11, 40, 44]. This is reflected in the fact that the CDSS highlighted 1,905 potential interventions, but review of clinical relevance saw only 1,000 of these actually intervened upon. An intervention was considered not clinically relevant based on a review by the research pharmacist. A number of the interventions that were highlighted by the system that were not intervened on related to drug–drug interactions; for example, angiotensin conversion enzyme inhibitors in combination with potassium sparing diuretics (in these patients, their potassium was regularly monitored). A number of instances related to PIP were highlighted, but on review were deemed not clinically relevant (PIP of digoxin or doxazosin). Caution is advised when using these medications that they are not contraindicated in older patients and that all patients that were prescribed these medications had been on these medications long term and they were well tolerated. Although 905 DRPs were considered not to be clinically relevant in this group of patients, in a different group of patients, these interventions may have been deemed clinically relevant to intervene on. For example, in older individuals with a history of falls, for a patient who is a long-term user of neuroleptics with a history of schizophrenia, the risks associated with discontinuing the neuroleptic may outweigh the potential benefits of discontinuing the therapy. In contrast, in a patient who is being initiated on a neuroleptic, it would probably be more appropriate to highlight this recommendation to the physicians. Therefore, similar to routine practice, the decision of whether to intervene on a particular recommendation was based on a review of the clinical status of the patient and a risk–benefit evaluation of the consequences of discontinuing or initiation for each specific medication. As stated above, just because an intervention was deemed not to be clinically relevant in this population does not mean that these interventions are always deemed nonclinically relevant.

The most common DRPs intervened on related to instances of PIP or PPO. Three sets of PIP criteria were utilized for this study: STOPP, Beers (2003), and Priscus criteria. These three sets of criteria were used because all outline a number of clinically relevant PIP instances and all three have been previously validated by expert panels from different areas of geriatric medicine. Although in Ireland the STOPP criteria is probably considered the gold standard for PIP assessment, there are a number of criteria unique to the Beers and Priscus list that are not addressed by STOPP; these are (i) long-term benzodiazepines in patients with depression, (ii) fluoxetine, (iii) doxazosin, (iv) nitrofurantoin, (v) zolpidem $\geq$5 mg, and (vi) zopiclone $\geq$3.75 mg.

Upon commencement of our study, the STOPP and Beers (2003) criteria were the most commonly used for assessing PIP internationally and our research indicated that both sets of criteria were applicable for use in Ireland [44]. Although the Priscus criteria was not well established at the time our study was undertaken, we included it in the PIP assessment based on a review of the criteria. A major advantage of the Priscus over the other two sets of criteria is that it not only assesses PIP, but it also provides recommendations on alternatives to the potentially inappropriate medications (PIMs) and cautionary advice if a PIMs is to be used. Therefore, we decided that the most comprehensive assessment of PIP would be achieved if all three sets of PIP criteria were applied concomitantly. The high rate of PIP observed by each set of criteria individually or in combination was similar to PIP prevalences in older hospitalized patients nationally and internationally [45–47]. In addition, the PPO prevalence reported here was found to be similar to that reported in other studies in this setting [46–48]. The low rate of acceptance of the recommendations relating to PIP and PPO is concerning and requires further investigation. It may be that the physicians felt that the research pharmacist's recommendations were not clinically relevant or appropriate to implement at that moment in time; that is, while the patients were being treated for an acute illness. Therefore, delivery of this SPRM in primary care or communication of the pharmaceutical care plan to the patient's general practitioner may lead to improved implementation of the recommendations and a greater improvement in the appropriateness of prescribing.

The second most common DRP identified and intervened on during the medication reconciliation review related to medication omissions ($n = 322$), defined as the inadvertent/undocumented omission of at least one scheduled medication from a patient's medication regimen. A number of other studies have reported similar findings [6–

8, 42, 49]. Over three quarters of the discrepancies relating to omissions were rectified postintervention. As stated above, implementation of the recommendations relating to these omissions may have contributed to the substantial increase in the number of medications from admission and discharge and may have contributed to an increase in the prevalence of PIP, drug–drug interactions, and the median summated MAI scores from admission to follow-up.

This study found that 54.8 % of the interventions were accepted by the prescribing physicians, and this acceptance rate is the same as that reported recently in another Irish study by Galvin et al. [6]. The acceptance rate reported in the present study may reflect the means by which the recommendations were communicated. A number of studies have reported on the acceptance rates of pharmaceutical care interventions and have found that between 40 and 90 % of these are accepted [42, 49–51]. The majority of the studies that have reported high acceptance rates involved a scenario in which the pharmacist worked closely with the doctor and other healthcare professionals as part of a multidisciplinary team or participated in ward rounds [27]. However, studies that used primarily written recommendations have reported lower rates of acceptance, similar to those reported here [42]. Written recommendations were chosen as the main means of communication, because this reflects normal practice in Ireland. The patients involved in this study were also under the care of a number of different specialists, and logistically it was not feasible for verbal communication of all interventions for each patient. It was only possible to verbally communicate about one third of the recommendations. Verbal communication may have led to improved uptake of interventions. This is an area that requires further investigation and our research group is currently undertaking qualitative work to establish the factors that influence PIP, PPO, and uptake of recommendations.

A high prevalence of DRPs was reported in this patient population. Clinical pharmacists working in A&E are in prime position to perform both a medication reconciliation and appropriateness review [49, 52]. Although studies have shown that clinical pharmacists can reduce DRPs and improve appropriateness of prescribing [3, 27, 53], these services are often underutilized because of issues relating to limited workforce or reimbursement [11, 23, 24, 54, 55].

The medication reconciliation review included a patient consultation and patient counselling on their medications. The consultation was focused on ascertaining the most up-to-date information; the SHIM questionnaire was used to standardize this consultation process.

A number of studies have reported on the importance of performing an accurate medication reconciliation review at admission. Some studies have shown that failure to correctly reconcile a patient's list of medication at admission may perpetuate throughout the patient's entire stay from admission to discharge and beyond [8, 49]. It is reported that over 50 % of the medication discrepancies at discharge may originate at admission. Pharmacists are ideally positioned and have the knowledge and expertise to deliver such services. This study demonstrates that a pharmacist using a CDSS to supplement their knowledge and to standardize the medication reconciliation and appropriateness review process can significantly improve prescribing appropriateness in older hospitalized patients.

4.1 Limitations

This study has a number of important limitations. Our study was undertaken by a single research pharmacist working only 5 days a week in a single hospital, using a specially developed CDSS, so generalizations may not be possible. In addition, only the first three patients were recruited each day, and this may lead to some bias. However, due to the detailed nature of the initial review and the follow-up review process, it was not possible to recruit more patients on a daily basis. Another limitation and possible source of bias relates to the fact that the outcome assessment was performed by the same research pharmacist who conducted the intervention. Ideally, the outcome assessment should have been undertaken by an independent assessor, but this was precluded by resource and time constraints. Another limitation was that the same PIP criteria were used as an intervention and as a secondary outcome measure. However, the primary outcome measures used in this study were the MAI and modified ACOVE.

As stated above, the CDSS highlighted DRPs to the research pharmacist, who then decided whether to intervene. This approach may have resulted in some individuality in the intervention process and may limit the generalization of the intervention. However, it was considered that this intervention strategy best reflected routine practice. An alternative intervention strategy where all the recommendations relating to every DRP highlighted by the CDSS would inundate the medical teams and make them less receptive to the recommendations outlined in the pharmaceutical care plans.

Because the study participants were under the care of teams that looked after many patients throughout the hospital, it was not possible to verbally communicate the majority of the interventions to the doctors with primary responsibility for study participants. About only one third of the interventions were communicated verbally to the medical teams.

A number of studies have reported on the importance of a medication reconciliation review not only at admission, but also at discharge [8, 49, 50]. Because of resource and

time constraints in the intervention and follow-up review, coupled with the disjointed nature in which patients are discharged, it was not possible for the single research pharmacist to perform a detailed medication reconciliation and appropriateness review at both admission and discharge.

Because the intervention process was unblinded and the medical teams were aware of the purpose of the study, it is not possible to rule out the presence of the Hawthorne effect; that is, the doctors may have acted/performed differently than they would normally because they were aware that they were part of a study. Whether the intervention impacted on additional outcomes such as compliance and quality of life is outside the scope of this study. This study did not examine the impact that the SPRM/CDSS intervention had on key clinical outcomes such as healthcare utilization, morbidity, and mortality. However, as stated above, our research group is currently undertaking a larger multicentered controlled trial to examine the impact of a modified version of this SPRM/CDSS on the patient's quality of life, healthcare utilization, morbidity, and mortality.

5 Conclusion

This study illustrated that there is a high prevalence of DRPs in older Irish hospitalized individuals. A SPRM intervention supported by a CDSS can improve the appropriateness and accuracy of the medication regimens of older hospitalized patients. The SPRM/CDSS intervention standardized the medication review process and may prove to be a feasible method of reducing reconciliation issues and improving appropriateness of prescribing in this patient population. The allocation of additional resources focused on implementation of similar types of SPRM aimed at older individuals at the point of hospital admission and discharge may lead to significant improvements in both the safety and appropriateness of prescribing in these individuals in the future.

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