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Collaborative pharmaceutical care in an Irish hospital: uncontrolled before-after study

Tamasine C Grimes,^{1,2} Evelyn Deasy,^{1,2} Ann Allen,¹ John O'Byrne,¹ Tim Delaney,¹ John Barragry,³ Niall Breslin,³ Eddie Moloney,³ Catherine Wall³

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¹Pharmacy Department, Tallaght Hospital, Dublin, Ireland

²School of Pharmacy and Pharmaceutical Sciences, Trinity College Dublin, Ireland

³Medical Directorate, Tallaght Hospital, Dublin, Ireland

Correspondence to

Dr Tamasine C Grimes, Pharmacy Department, Tallaght Hospital, Dublin 24, Ireland, tagrimes@tcd.ie

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ABSTRACT

Background We investigated the benefits of the Collaborative Pharmaceutical Care in Tallaght Hospital (PACT) service versus standard ward-based clinical pharmacy in adult inpatients receiving acute medical care, particularly on prevalence of medication error and quality of prescribing.

Methods Uncontrolled before-after study, undertaken in consecutive adult medical inpatients admitted and discharged alive, using at least three medications. Standard care involved clinical pharmacists being ward-based, contributing to medication history taking and prescription review, but not involved at discharge. The innovative PACT intervention involved clinical pharmacists being team-based, leading admission and discharge medication reconciliation and undertaking prescription review. Primary outcome measures were prevalence per patient of medication error and potentially severe error. Secondary measures included quality of prescribing using the Medication Appropriateness Index (MAI) in patients aged ≥ 65 years.

Findings Some 233 patients (112 PACT, 121 standard) were included. PACT decreased the prevalence of any medication error at discharge (adjusted OR 0.07 (95% CI 0.03 to 0.15)); number needed to treat (NNT) 3 (95% CI 2 to 3) and no PACT patient experienced a potentially severe error (NNT 20, 95% CI 10 to 142). In patients aged ≥ 65 years ($n=108$), PACT improved the MAI score from preadmission to discharge (Mann–Whitney U $p<0.05$; PACT median -1 , IQR -3.75 to 0 ; standard care median $+1$, IQR -1 to $+6$).

Conclusions PACT, a collaborative model of pharmaceutical care involving medication reconciliation and review, delivered by clinical pharmacists and physicians, at admission, during inpatient care and at discharge was protective against potentially severe medication errors in acute medical patients and improved the quality of prescribing in older patients.

BACKGROUND AND INTRODUCTION

Periods of patient care that involve a transfer across organisations or transfer between professionals are more vulnerable with regard to medication safety than other periods.^{1–4} Medication error is more prevalent at these junctures and may result in harm: a type of adverse drug event (ADE). Medication reconciliation (here on referred to as MedRec) is a process advocated to prevent harm consequent to reconciliation error,^{5–9} and in some organisations MedRec is required to facilitate accreditation.¹⁰ MedRec was defined by the Institute for Healthcare Improvement (IHI) 2006 as “the process of obtaining and maintaining an accurate and detailed list of all prescribed and non-prescribed drugs a patient is taking, including dosage and frequency, through all healthcare encounters and comparing the physician’s admission, transfer, and/or discharge orders to that list, recognizing any discrepancies, and documenting any changes, thus resulting in a complete list of medications, accurately communicated”.⁶ It is time consuming and labour intensive,^{11 12} and scarce resources should be prioritised for it only where there is evidence of its value to care. Two recent systematic reviews investigating hospital-based MedRec practices concluded that while there is a need for further comparative studies, available evidence suggests benefits from interventions that involve pharmacy staff.^{3 13} There is evidence that MedRec interventions should focus on patients at high risk of ADEs,³ for example, those using increasing numbers of medication, having a higher comorbidity burden or being older.^{2 14–16} Additionally the prevalence rates of potentially inappropriate prescribing among older (≥ 65 years) patients

have been cited by authors as being in the range 35–60% of patients in acute hospitals.^{17 18} The financial and clinical consequences of poor prescribing, caused either by poor prescribing decisions or error, include impact on national drug and healthcare budgets^{19 20}; drug-related morbidity causing hospitalisation or mortality.^{14 21–24}

A number of recent controlled trials have investigated the benefits of complex interventions that involve collaborative medical care and clinical pharmacy activity at admission, during inpatient stay and at discharge.^{14 15 21 23 25 26} The interventions have involved close working between clinical pharmacy and medical staff, facilitating integrated management of medicines across the entire inpatient episode. Such integration has been proven to reduce the prevalence of medication error and (re)hospitalisation and to improve the quality of prescribing.^{14 23 26–28} This accords with statements from the International Pharmaceutical Federation (FIP) that describe a five-level model of Collaborative Pharmacy Practice (CPP) with advancing models involving closer collaboration with the medical team and greater responsibility for the pharmacist.²⁹ FIP have identified that examples of the most advanced levels of CPP are in place in the UK, USA and Canada, but few elsewhere.²⁹

In Ireland, few hospital pharmacy departments are involved in delivering MedRec at admission or discharge.^{30 31} Involvement of clinical pharmacists in multidisciplinary clinical activities, with the exception of specialist services, for example, haematology, is rare.³¹ To date, there has been no comparative study undertaken in Ireland to determine the benefits of integrating the clinical pharmacy service with medical care. Evidence is needed to support wider implementation of this model of collaboration in Ireland and worldwide. The purpose of this study was to investigate the benefits of a team-based collaborative model of clinical pharmacy and medical care, the Collaborative Pharmaceutical Care at Tallaght Hospital (PACT) service, on the prevalence per patient of medication error and the quality of prescribing. Standard care comprised a ward-based clinical pharmacy service. The study was undertaken in consecutive adult medical inpatients receiving acute care, admitted and discharged alive during the study period and using at least three regular medications on presentation to hospital.

METHODS

Study design, setting and sampling

Ambispective observational uncontrolled before-after study, undertaken at Tallaght Hospital, Dublin, Ireland: a 600-bed acute hospital managing >17 000 adult inpatient episodes annually. The study was undertaken with four medical teams with a standard care, washout and intervention period for each (table 1), between July 2010 and May 2011 (table 2). The teams all provided

Table 1 Key features of the Pharmaceutical Care in Tallaght Hospital (PACT) intervention and standard care

	Standard care	PACT intervention
Service arrangement	Aligned to a ward	Aligned to a medical team
Clinical pharmacists involved	Service delivered by routine clinical pharmacists	Service delivered by one of two PACT clinical pharmacists
Service at admission	Contributed to admission medication history taking	Led admission medication history taking and reconciliation
Service during admission	Made minor changes and endorsements to the drug prescription and administration chart (drug chart), for example, clarify an intended formulation or notate to facilitate appropriate administration, for example, 'before food' Delivered routine clinical pharmacy tasks (drug chart review; therapeutic drug monitoring; medication review; contribution of suggestions to optimise medication use and medication information queries)	Made minor and major changes to the drug chart, as required, and these were co-signed by a medical practitioner Delivered routine clinical pharmacy tasks (drug chart review; therapeutic drug monitoring; medication review; contribution of suggestions to optimise medication use and medication information queries)
Service at discharge	No service	Discharge medication reconciliation Made minor and major changes to the discharge medication list, as required, and these were co-signed by a medical practitioner

general medical care, with the leading consultants having recognised, certified, higher specialist training in endocrinology, gastroenterology, respiratory or renal medicine. In the study hospital, there is no cohorting of patients on wards according to the medical specialty. Adult medical patients, who used three or more regular medications, admitted to and discharged alive from the hospital were eligible for inclusion. Patients readmitted during the study period and staff members admitted as patients were excluded. Consecutive patients who fulfilled the inclusion criteria were recruited.

Standard care and intervention

The standard care and intervention activities are presented in table 1. Standard care clinical pharmacists were aligned to a ward, serving patients under the care of numerous treating consultants, consistent with Level 3 of the FIP model of CPP.²⁹ Approximately two-thirds of standard care clinical pharmacists held National Framework of Qualifications (NFQ) Level 9 (Master), the remainder held NFQ Level 8 (Bachelor). The PACT intervention comprised integrated medication management with the clinical pharmacist aligned

Table 2 Recruitment of patients and dates of study periods

	Standard	Intervention
Assessed for eligibility	431	403
Excluded, not meeting study criteria		
Admitted outside study period	29	33
Discharged outside study period	58	85
Died during hospital stay	9	9
Used less than three regular medications at admission	98	58
Transferred to another medical team during study period	111	84
Readmitted during study period, already recruited	5	22
Included in study and exposed to intervention	121	112
Follow-up, primary outcome not assessable	20	4
Primary outcome data analysed	101	108
Dates of study periods		
Team 1	Jul–Sep 2010	Oct–Dec 2010
Team 2	Oct–Dec 2010	Jan–Mar 2011
Team 3	Jan–early Mar 2011	Late Mar–May 2011
Team 4	Jan–early Mar 2011	Late Mar–May 2011

to one medical team, meaning she delivered service to patients of one treating consultant across multiple wards, enabling her integration into the medical team. Two clinical pharmacists contributed to PACT, one delivered service to teams 1, 2 and 3, and the other to team 4, with each providing holiday relief for the other. They both held a Masters in Hospital Pharmacy, NFQ Level 9, and the General Level Framework.³² The PACT intervention aligns with Level 4 of the FIP model of CPP.²⁹

Outcome measures

Primary outcomes measured comprised the prevalence per patient of

- ▶ any medication error identified by reconciliation or in the writing of a new prescription, following admission and discharge (here-on referred to as error);
- ▶ an error with the potential to cause severe patient harm.³³

MedRec was defined based on the IHI's process, identifying inclusion of unintentional changes and intentional but undocumented changes to medication as failure to reconcile.⁶ This study investigated errors identified at admission and discharge and not those between these two points. Error was defined as a prescription writing error that was identified by reconciliation or in the writing of new medication orders at admission or discharge.^{2 34} The clinical pharmacist's medication history was regarded as the gold standard preadmission medication list (GSPAML) against which reconciliation was assessed. The medication history was built using a

previously developed method.¹¹ Data from the following sources were used prospectively by the investigator to identify errors: GSPAML; drug chart; discharge medication list (prescription and summary); all entries in the healthcare record regarding medication use. Identified discrepancies were clarified as intentional or not, by reference to the medical team and/or clinical pharmacist. Every identified discharge error was presented, in the form of a case study outlining clinical, diagnostic and medication details, to six independent assessors, blinded to study allocation, who retrospectively scored the potential for harm using a validated, reliable visual analogue scale (VAS) (0=no harm, 10=death)³³ previously used for this purpose.^{2 35} Assessors included hospital and community pharmacists, hospital doctors and general practitioners. The mean score for each error was calculated from the individual VAS scores of the six assessors and categorised as minor (<3), moderate (3–7) or severe (>7). Where a patient experienced multiple errors, the highest scoring error was used to describe the potential for harm to that patient.

Secondary outcome measures were

- ▶ quality of prescribing in patients aged ≥ 65 years, using the Medication Appropriateness Index (MAI);³⁶
- ▶ frequency of acceptance of clinical pharmacists' documented suggestions.

MAI, a tool validated to assess prescribing quality in patients aged ≥ 65 years, has good inter-rater reliability.³⁷ It comprises ten weighted categories, allowing a total sum of 18 marks for each drug, with increasing scores representing inferior quality: (indication (3); population effectiveness (3); dosage correct (2); directions correct (2); directions practical (1); drug–drug interactions (2); drug–disease interactions (2); cost (1); unnecessary duplication (1) and duration (1)). The weighted score is applied if 'inappropriate' is selected. Where a medication was unintentionally omitted or intentionally stopped or withheld but not documented on the discharge list, it was categorised as 'directions correct—inappropriate'. MAI was applied retrospectively by one of two investigators, with quality assurance on the data entry for a randomly selected 10% of patient cases by a third investigator. The investigators were not blinded to study allocation and had access to all sources of medication and clinical details in the healthcare record. MAI was applied on three medication lists: preadmission, during admission and discharge. The summated score for each patient at each stage and the differences from preadmission to admission and from preadmission to discharge were calculated.^{27 38} Underuse of medication, that is, whether each of the patient's present medical conditions or risk factors was treated, was not assessed.

Data management

The sample size calculation was based on the primary outcome. Prevalence per patient of medication error on

discharge was previously identified as 50–66%.^{2 39} To demonstrate a reduction from 60% to 40%,^{21 40–42} 90% power, 5% significance level (two-sided) required 130 per group, total 260 patients. Review of hospital discharge statistics indicated that this sample size was achievable by allowing 2 months PACT service delivery for each of the four teams. The unit of assignment was the team, and the unit of analysis was the patient. Data collection was undertaken by clinical pharmacist investigators who were not involved in delivering the intervention. Data collection was ambispective happening during hospitalisation (error) and after discharge (MAI, VAS). Data were inputted into SPSS, V.18, and STATA, V.11, for support in analysis. Double data entry was undertaken by a second investigator on a randomly selected 10% of patient cases to assure quality. Errors at discharge were validated by two independent assessors, both clinical pharmacists, blinded to study allocation, and the level of agreement with the main investigator was measured using Cohen's κ coefficient. Data distribution was analysed using the Kolmogorov–Smirnov test. Differences between groups were identified using the χ^2 test for categorical data, Mann–Whitney U (reporting median and interquartile range) for non-parametric continuous data and the Student t test (reporting mean and SD) for parametric continuous data. Prevalence of error was analysed using multilevel logistic regression, adjusting for length of stay; Charlson comorbidity index⁴³; age and number of medications and accounting for any clustering effect at the level of the team. The number needed to treat (NNT) to prevent one patient

experiencing any error and a potentially severe discharge error was calculated using the Newcombe–Wilson hybrid score CI.⁴⁴ Extreme scenario analysis provided sensitivity analysis to account for cases of missing data for the primary outcome, providing 95% CIs around each extreme case.⁴⁵

Approval was obtained from the St James's Hospital/Tallaght Hospital Joint Research Ethics Committee (SJH/AMNCH REC ref 2010/03/11). It was considered an investigation of service delivery, all investigators were employed clinicians, contractually bound to maintain patient confidentiality. Patient consent was not required. Guidance for undertaking observational studies⁴⁶ and non-randomised designs⁴⁷ was followed. As this involved prospective observation, the investigators were ethically obliged to report any identified reconciliation errors at discharge to the treating team or clinical pharmacist to facilitate remedial action.

FINDINGS

A total of 233 patients were recruited (table 2). There were no differences in baseline clinical or demographic characteristics between the 121 standard care and 112 intervention patients (table 3). Some 2324 medications were surveyed, the majority were cardiovascular (33%), central nervous system (16%), respiratory (11%), gastrointestinal (11%) and endocrine (9%). For 24 patients (10.3%), the primary outcome was not assessable because the discharge documentation was not completed. These patients were identified as being younger and were more likely to receive standard care (see online supplementary file 1).

Table 3 Patients' demographic and clinical characteristics, intervention and standard care

Characteristic	Standard (n=121)	Intervention (n=112)	p Value
Gender, n (%), male	49 (40.5)	52 (46.4)	0.217
General medical service* status, (%) in receipt	72 (50.0)	61 (55.0)	0.260
Employment status, (%) working	56 (46.3)	49 (44.1)	0.423
Smoking status, (%) current user	36 (29.8)	37 (33.0)	0.690
Alcohol use, (%) current user	53 (43.8)	46 (41.1)	0.773
Age, years, median (IQR)	64 (52–75)	62 (54–77)	0.922
Age \geq 65 years, n (%)	60 (49.6)	48 (42.9)	0.369
Length of stay, days, median (IQR)	6 (4–12)	7 (4–12)	0.593
Charlson comorbidity index, median (IQR)	2 (1–3)	1 (1–3)	0.915
Number of medicines†, median (IQR)	10 (7–12)	9 (7–13)	0.727

*General Medical Service refers to government support for healthcare, including general practitioner visits and prescribed medication, eligibility is largely based on income.

†Relates to the total number of medicines prescribed before admission and those added during admission that remained active at discharge, exclusive of medications commenced and stopped within the hospital episode.

Primary outcome measures

Medication errors were identified in 25.4% of patients at admission and 34.8% at discharge. The two blinded assessors agreed with the identification of an error for 201 of the 202 implicated drugs, representing substantial agreement for each assessor with the main investigator ($\kappa=0.8$).⁴⁸

Patients receiving standard care were statistically significantly more likely to experience an error at admission (40.5% vs 9.0%, $\gamma^2=30.3$, df 1, p 0.000) and discharge (65.3% vs 13.9%, $\gamma^2=58.2$, df 1, p 0.000) than those receiving the intervention. Patients receiving standard care had a greater likelihood of experiencing a potentially severe discharge error (5.9% vs 0, $\gamma^2=6.6$, df 1, p 0.012) (table 4). The variable that dominated the logistic regression models for experiencing an error at admission or discharge was the study group, demonstrating a protective effect by the PACT intervention. The only other variable statistically significantly associated with experiencing an error in these models was the number of medicines used per patient. For every extra medicine used, there was a 17% increased likelihood of error (95% CI 6 to 29%). The NNT to prevent any discharge error was 3 (95% CI 2 to 3) and to prevent a potentially severe discharge error

Table 4 Primary outcome measures

Outcome	Prevalence Standard, n (%)	Intervention, n (%)	Goodness of fit (Hosmer & Lemeshow test, Nagelkerke's R ²)	Unadjusted OR, 95% CI	Adjusted OR accounting for clustering, 95% CI
Admission error, per patient	49/121 (40.5)	10/112 (9.0)	0.737, 0.239	0.15, 0.07 to 0.30	*0.14, 0.07 to 0.31
Discharge error, per patient	66/101 (65.3)	15/108 (13.9)	0.723, 0.418	0.09, 0.04 to 0.17	†0.07, 0.03 to 0.15
Extreme sensitivity analysis	86/121 (71.1)	19/112 (17.0)	0.406, 0.415	0.08, 0.04 to 0.16	†0.07, 0.04 to 0.14
Missing data treated as error present					
Missing data treated as error not present	66/121 (54.5)	15/112 (13.4)	0.759, 0.306	0.13, 0.07 to 0.25	†0.11, 0.06 to 0.23
Discharge: potential to cause harm‡, n (%)					
No error, no harm (VAS score 0)	35 (34.7)	93 (86.1)			
Minor harm (VAS score <3)	6 (5.9)	2 (1.9)			
Moderate harm (VAS score 3–7)	54 (53.5)	13 (12.0)			
Severe harm (VAS score >7)	6 (5.9)	0 (0)			
VAS score for potential harm‡ (median, IQR)	4 (0 to 5)	0 (0 to 0)	Mann–Whitney U p 0.000		

*Multilevel logistic regression, adjusted for Charlson comorbidity index, number of medicines (relates to the total number of medications prescribed before admission and those added during admission that remained active at discharge, exclusive of medications commenced and stopped within the hospital episode), age.

†Multilevel logistic regression, adjusted for Charlson comorbidity index, number of medicines (relates to the total number of medications prescribed before admission and those added during admission that remained active at discharge, exclusive of medications commenced and stopped within the hospital episode), age, length of stay.

‡Calculated across all 209 patients for whom the primary outcome measure was available, with a value of 0 applied for no error. VAS, visual analogue score.

was 20 (95% CI 10 to 142). (See online supplementary file 2 for examples of errors in each severity category.)

Extreme sensitivity analysis, accounting for missing primary outcome data, identified consistently that the PACT intervention protected against the occurrence of any error (table 4).

The drug categories most commonly implicated in error relative to their frequency of use, by British National Formulary (BNF) classification, were (%=percentage of errors of the total number of drugs surveyed in that BNF class, n=number of errors): anaesthesia (100%, n=1); ear, nose and oropharynx (33%, n=1); musculoskeletal and joint diseases (22%, n=11); obstetric, gynaecology and urinary tract (21%, n=4). However, medications that accounted for the greatest proportion of errors, owing to the higher prevalence of use, were cardiovascular (8.1%, n=55); central nervous system (11.3%, n=36), respiratory system (11.1%, n=25) and endocrine system (13.1%, n=24).

Secondary outcome measures

Medication Appropriateness Index

Of the 233 patients recruited to the study, 108 were aged 65 years or older (43% of the intervention group, 50% of standard care) and eligible to apply the MAI tool. MAI was applied to all 108 patients at the stages preadmission and admission, but to 102 patients' discharge lists (data missing for six standard care patients who did not have discharge medication lists prepared). There was no difference between the groups in the median summated MAI score applied to the GSPAML (table 5), indicating a similar quality of prescribing before admission to hospital. The quality

of prescribing during admission and at discharge deteriorated in patients receiving standard care and improved for intervention patients (table 5).

Clinical pharmacist suggestions

The PACT clinical pharmacists documented suggestions to optimise medication use more frequently than the standard care clinical pharmacists (table 5). The most common types of intervention were notification of an omitted medication (40.8% and 54.7% of the intervention and standard care suggestions, respectively); dose correction or clarification (34.2% and 26.9%); commission (the unintentional addition of a medication the patient was not actually using) (8.5% and 7.5%); frequency of administration correction or clarification (6.9% and 5.5%); and other (9.6% and 5.5%). These suggestions were more likely to be accepted for patients receiving the intervention and to be accepted earlier, during the admission rather than at discharge, in the hospital episode (table 5).

DISCUSSION

The main findings of this study are that the PACT intervention is effective at reducing the prevalence per patient of error at admission and discharge from adult medical inpatient care, preventing potentially severe error and facilitating clinical pharmacy input to improve medication use. PACT improved the quality of prescribing in medical patients aged 65 years and older.

The finding that PACT, integrating clinical pharmacy service with medical care, with a focus at admission and discharge, reduced the prevalence of error is consistent

Table 5 Secondary outcome measures

Outcome	Standard	Intervention	p Value
MAI, median (IQR)			
Summated MAI pre-admission	3 (1 to 6.8)	4 (1 to 7.5)	0.538
Summated MAI admission	4 (2 to 7)	2.5 (1 to 5)	0.013
Summated MAI discharge	6 (3 to 9)	2 (0 to 4)	0.000
Difference preadmission to admission, summated MAI	0 (−2 to 4)	−0.5 (−3 to 0)	0.006
Difference preadmission to discharge, summated MAI	1 (−1 to 6)	−1 (−3.8 to 0)	0.000
Process measures			χ^2 , p value, df
Clinical pharmacist suggestion made per patient, n (%)	73/121 (60.3%)	86/112 (76.8%)	7.3, =0.005, 1
Clinical pharmacist suggestion made per medication, n (%)	200/1231 (16.2%)	261/1093 (23.9%)	21.2, =0.000, 1
Acceptance of clinical pharmacist suggestions n (%) of suggestions			
Accepted during admission	111 (55.5%)	240 (92.0%)	91.9, =0.000, 2
Accepted at discharge	24 (12.0%)	16 (6.1%)	
Not accepted	65 (32.5%)	5 (1.9%)	

MAI, Medication Appropriateness Index (increase in score represents reduction in quality of prescribing).

with international findings.^{14 21 26 40 42 49–52} The PACT effect size seems larger than that achieved in other pharmacist-led interventions that measured medication error or discrepancy.^{21 40–42 53} The exception was Vasileff *et al*¹⁶, a study undertaken in an Australian emergency department in patients aged 60+ using 4+ drugs, identifying 72% absolute reduction in prevalence of unintentional discrepancy per patient. The observed effect size may be related to differences in the study populations and their underlying risk for medication misadventure. The evidence from this study supports the involvement of the clinical pharmacist in medication management across the entire inpatient episode, inclusive of discharge. Consistent with other studies, we identified that an increasing number of medications is associated with likelihood of experiencing an error.^{2 15} However, although previous studies targeted patients with increasing comorbidity burden or of advancing age,^{14 16 38 54} we did not identify a correlation between either of these variables and the presence of an error. The evidence from this study supports targeting the PACT intervention to patients using a greater number of medications.

We identified that the quality of prescribing deteriorated in patients receiving standard care and improved with the PACT intervention. A recent Cochrane systematic review identified that inappropriate polypharmacy is a particular concern in older people and is associated with negative health outcomes: complex, multifaceted pharmaceutical care demonstrated a mean difference of −6.78 in MAI score from pooled data of four studies.⁵⁵ Direct comparison to the effect size in our study is difficult because our data were not normally distributed; however, the PACT effect, in this regard, appears to be modest. Two of the four studies reported in the Cochrane review involved collaborative working between pharmacists and medical practitioners.^{28 56} The Integrated Medicines Management (IMM) services in Northern Ireland and Sweden achieved similar improvements in MAI score as our

study^{27 38} and these findings support the collaborative model of medicines management between physicians and pharmacists to improve prescribing quality for older hospitalised patients.

As with any complex intervention, it is difficult to attribute success to any single ‘active ingredient’ or component of the intervention.⁵⁷ However, the collaborative nature of this intervention is worthy of discussion. Collaborative prescribing requires a collegiate relationship between a pharmacist and a medical practitioner with legal authority to prescribe.⁵⁸ It has been identified as a form of dependent prescribing, that being where authority to prescribe is delegated from an independent prescribing professional to a healthcare professional without such authority.⁵⁸ The PACT intervention allowed for the clinical pharmacist, in consultation with the medical team, to make major and minor changes to the patient’s drug chart or the discharge medication list. These activities are consistent with the notion of collaborative prescribing. There is evidence that collaborative prescribing reduces the prevalence of medication error and unintentional discrepancy in the emergency department and perioperative settings.^{16 59}

⁶⁰ This is consistent with our finding that PACT patients experienced more clinical pharmacist’s recommendations that were accepted more frequently and earlier in the hospital episode than standard care, coupled with a reduction in error and an improvement in quality of prescribing. The lower frequency of, and delay in, standard care clinical pharmacist’s recommendation acceptance demonstrates an inefficiency in standard care. Possible contributing factors include an absence of physician recognition of the pharmacist’s contribution, as previously described in a London hospital,⁶¹ or inferior collaboration and teamwork in the ward-based model. However, this is countered by the estimation that PACT pharmacists were able to see approximately 70% the volume of patients as the standard service, meaning that PACT is 40% more

intensive in terms of clinical pharmacy resource. In times of budgetary constraint, it will be important to investigate the health economics of PACT and this is the focus of the current research. The findings of the study demonstrate that integration of a more advanced level of CPP as described by FIP, with greater responsibility for the pharmacist, yields benefits for patient safety.²⁹ It is important to say that this should be supported by appropriately qualified and credentialed pharmacists.^{58 62}

There are a number of limitations to this study. An uncontrolled before-after study is regarded as inferior to a controlled or a randomised study design: changes that occur over time make it difficult to attribute any observed change to the intervention; there is evidence that the results of such studies may overestimate the effects of quality improvement-like interventions.⁶³ It was not feasible to undertake a randomised controlled study at a single centre due to potential for contamination across the care of patients receiving standard or intervention care by either the pharmacists or the doctors. However, every effort was taken to minimise bias due to non-randomisation and no difference was identified in baseline demographic or clinical characteristics between the study groups. Extreme sensitivity analysis accounted for missing primary outcome data and the findings were consistent at each extreme, demonstrating the positive effect of PACT to prevent error. In this study, the GSPAML was held as the most accurate reflection of the patient's medication use and a rigorous process was followed to compose this list.^{11 64} Despite this, it is known that it is difficult to identify a patient's actual medication use and it is possible that the GSPAML was not always accurate, presenting a potential bias.⁶⁴ Target sample size was not achieved, largely because a large proportion of patients were transferred to another medical team following admission. Nonetheless, the study was adequately powered to identify the magnitude of change in the primary outcome measure with 90% power at the 5% significance level. The proportions of the study population who were male (46.6% nationally) and medical card holders (53.5% nationally) are comparable to adult inpatients receiving acute hospital care nationally.⁶⁵ However, the study population were older and had lengthier hospital stay than the national average. This is likely because we selected patients using at least three regular medications on admission, and it is known that length of stay⁶⁵ and number of drugs used per patient⁶⁶ increase with advancing age. This supports external generalisability of the efficacy of the intervention to older patients using at least three regular medications on admission rather than to all adult inpatients.^{65 67} Only two clinical pharmacists were involved in delivering the PACT intervention. This limits the generalisability of the study. However, both held Masters in Hospital Pharmacy and were certified General Level

Framework, which may support generalisability to other clinical pharmacists with equivalent credentials.³²

As is the case with most prospective observation, the main investigator was required to intervene to remediate and mitigate harm consequent to identified reconciliation errors at discharge. This limited the opportunity to assess the impact of the intervention on healthcare use or the presence of ADEs after discharge. Few studies^{51 68 69} have investigated the effect of MedRec interventions on ADEs, likely due to the complexity, high cost and resource intensiveness of identifying this outcome.⁵¹ ADE and healthcare use are regarded as ideal outcome measures in studies of medication management because they represent actual patient outcomes.⁷⁰ There is debate regarding the validity of ADEs or healthcare use as outcome measures of MedRec interventions: it is argued that the harm consequent to reconciliation error may not become apparent for months after discharge.¹³ Furthermore, the causality between MedRec interventions and ADE or healthcare use following discharge is difficult to establish, given the opportunities for medication change and other confounders that may occur in the interim. Therefore, we believe our choice of outcome measures is valid and pragmatic.

PACT improved the quality and safety of prescribing for medical patients receiving acute hospital care: it reduced the prevalence of all medication error and potentially severe error; it improved the quality of prescribing in patients aged 65 years or older. The recommendations are to implement collaborative models of medication management between medicine and pharmacy and to facilitate collaborative prescribing by pharmacists within this model.

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Contributors All authors had full access to all the data in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis. TCG, ED, AA, JO'B, TD, JB, NB, EM and CW were responsible for study design. TCG and MT were responsible for acquisition of data. All authors were responsible for analysis and interpretation of data. TCG and ED were responsible for drafting of the manuscript. TCG, ED, AA, JO'B, TD, JB, NB, EM and CW were responsible for critical revision of the manuscript for important intellectual content. TCG supervised the study.

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Patient's demographic and clinical characteristics, primary outcome data availability

Characteristic	Primary outcome data available (n=209)	Primary outcome data not available (n=24)	p
Gender, (%), male	92 (44.0)	9 (37.5)	0.350
General Medical Service* status, (%) in receipt of	121/207	12/24	0.281
Employment status, (%) Working	90 (43.3)	15 (62.5)	0.058
Smoking status, (%) current user	64 (52.9)	9 (37.5)	0.649
Alcohol use, (%) current user	87 (41.6)	12 (50.0)	0.587
Study group, (%) PACT intervention	108 (51.7)	4 (16.7)	0.002
Age, years, median (IQR)	64 (54-76)	58 (50-65)	0.034
Length of stay, days, median (IQR)	7 (4-12)	6 (3-12)	0.454
Charlson Co-morbidity index, median (IQR)	2 (1-3)	2 (1-3)	0.740
Number of medicines [§] , median (IQR)	10 (7-12)	9.5 (5-14)	0.940

IQR, Inter-quartile Range; NS, not statistically significant at 0.05.

* General Medical Service refers to government support for healthcare including GP visits and prescribed medication, eligibility is largely based on income.

[§] Relates to the total number of medications prescribed before admission and those added during admission that remained active at discharge, exclusive of medications commenced and stopped within the hospital episode.

Patients who experienced at least one error with potential to cause severe harm	Drug mean VAS score	Patient maximum mean VAS score
45 year old male admitted with headache and ataxia, left sided weakness and urinary incontinence, with poor vision. Diagnoses for this episode were neoplasm of uncertain behaviour of pituitary, steroid induced diabetes mellitus. Length of stay was 17 days. Background medical history of giant hyper-vascular pituitary adenoma.		8.3
Dexamethasone 2mg once daily was prescribed pre-admission, during admission and active on discharge. Discharge prescription error contained prednisolone 2mg once daily rather than dexamethasone 2mg once daily.	8.3	
41 year old female presented with abdominal pain and diarrhoea. Medical history included chronic pancreatitis secondary to alcohol, seizure disorder, asthma, recurrent electrolyte and metabolic disturbance. Diagnoses for this episode were alcohol induced pancreatitis, hypokalaemia, nausea and vomiting, urinary tract infection. Length of stay 18 days.		7.5
Sodium valproate controlled release 800mg twice daily was prescribed pre-admission. This was unintentionally changed to 600mg twice daily on admission, and this error continued through to the discharge prescription.	7.5	
Pain team consulted during admission and recommended addition of tramadol to analgesic regime. This was not prescribed during admission and not prescribed on the discharge prescription.	5	
Loperamide 2mg three times daily was prescribed pre-admission and during admission. It was recorded as "not administered" for 10 days before discharge because plain film x-ray of the abdomen identified slight faecal loading. Loperamide 10mg three times daily was prescribed on discharge.	4.3	
39 year old male presented for routine cardiovascular investigations during which an abnormal echocardiogram was noted and he was advised to attend the emergency department. He had a history of left arm numbness over the previous 8 weeks with intermittent chest pain and palpitations. Also had mild right leg swelling, and was treated for a suspected superficial clot with enoxaparin for one month pre-admission. Medical history included type 2 diabetes, obstructive sleep apnoea and anxiety. Hospital investigations identified that the chest pain was not cardiac related. Diagnosis for this episode was chest pain, unspecified.		8.2
Risperidone 2mg once daily was prescribed pre-admission and during admission. Risperidone 12mg once daily was prescribed in error on discharge.	8.2	
Aspirin 75mg once daily was prescribed pre-admission and intentionally stopped during hospital admission. This was prescribed in error on discharge.	3.5	

69 year old male presented with dizziness, headaches and nausea. His wife reported him having a number of falls within the previous year. Diagnosis during this episode of care was intracranial haemorrhage. Length of stay was 9 days. Medical history included hypertension, ischaemic heart disease, paroxysmal supraventricular tachycardia, stage III chronic kidney disease, cerebrovascular disease.		7.8
Aspirin 75mg once daily was prescribed pre-admission and withheld during admission. The discharge prescription did not communicate whether aspirin was to continue or to stop, or that it was withheld.	7.8	
Doxazosin controlled release was prescribed pre-admission and withheld during admission. The discharge prescription did not communicate whether doxazosin was to continue or to stop, or that it was withheld.	5	
62 year old female presented with left pleural chest pain. Medical history included hypertension, asthma/ chronic obstructive airways disease, cellulitis, previous left deep vein thrombosis 36 years earlier. Diagnosis for this episode of care was multiple pulmonary emboli. Length of stay was 6 days.		8.4
Warfarin lifelong was commenced in hospital. The discharge prescription did not list warfarin.	8.4	
Seretide® 250 Diskus inhaler (salmeterol/ formoterol) was prescribed pre-admission. This was unintentionally omitted during inpatient care and omitted on discharge.	4.6	
70 year old male presented with increasing confusion, headache, cough. Medical history included ischaemic heart disease (previous coronary artery bypass graft), type 2 diabetes, chronic anaemia, recurrent deep vein thrombosis, cerebrovascular accident, cognitive impairment, falls. Diagnosis for this episode of care was acute on chronic renal failure, lower respiratory tract infection. Length of stay was 5 days.		8.2
Insulin aspart was commenced during admission but omitted from the discharge list.	8.2	
Insulin detemir was prescribed pre-admission and during admission but omitted from the discharge list.	7.6	
Examples of patients who experienced at least one error with potential to cause moderate harm		
34 year old male presented having collapsed, experiencing chest pain and with a question of seizure activity. Medical history included type 1 diabetes (with neuropathy), asthma, previous intravenous drug misuse, methadone maintenance, heart murmur, hepatitis B and C positive. Diagnosis for this episode of care was hypoglycaemic episodes in type 1 diabetes. Length of stay 7 days.		6.8
Insulin aspart 10 units three times daily was prescribed pre-admission. This was changed to 10 units morning, 8 units lunch, 10 units evening because of hypoglycaemic episodes. Discharge prescription unintentionally stated 10 units three times daily.	6.8	

Beclomethasone inhaled 200 micrograms twice daily prescribed pre-admission and during admission. Seretide 250 Diskus (salmeterol/formoterol) was erroneously recorded as a pre-admission medication and prescribed during admission and at discharge.	4.2	
Zopiclone 7.5 mg at night used long term preadmission and prescribed during admission. Unintentionally omitted on discharge.	3.8	
34 year old male admitted with shortness of breath and production of green sputum. Medical history included shrinking lung syndrome secondary to systemic lupus erythematosus (SLE), recurrent chest infections, steroid dependent asthma. Diagnosis for this episode of care was asthma, shrinking lung syndrome secondary to SLE. Length of stay was 4 days.		4.2
Calcium/ Vitamin D3 was prescribed long term pre-admission but unintentionally omitted during admission and on discharge.	4.2	
Co-codamol was prescribed long term pre-admission and stopped during admission. There was no communication on discharge that this drug was intentionally stopped.	3.4	
Examples of patients who experienced at least one error with potential to cause minor harm		
77 year old female was admitted for observation following a polypectomy. Medical history included ischaemic heart disease, type 2 diabetes with neuropathy, hypertension, heart failure. Diagnosis for this episode of care was iron deficiency anaemia. Length of stay was five days.		3.2
Pregabalin 75mg twice daily was prescribed pre-admission and during admission. Unintentionally changed to 75mg once daily on discharge.	3.2	
66 year old female presented with acute severe onset headache. Medical history included hiatus hernia, hypertension, high cholesterol, vertigo, tinnitus, migraine, asthma. Diagnosis for this episode of care was aneurysm from the anterior communicating artery in the brain. Length of stay was 19 days.		2.7
Betahistine 16mg three times daily was prescribed long term pre-admission and during admission. Prescribed in error as 5mg once daily on discharge.	2.7	
Prochlorperazine 5mg three times daily was prescribed long term pre-admission. It was prescribed on the "as required" section of the drug chart during admission and was unintentionally omitted on discharge.	2.7	