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Pharmacist-assisted electronic prescribing at the time of admission to an inpatient orthopaedic unit and its impact on medication errors: a pre- and postintervention study

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Abstract

Background: Prescribing and administration errors related to pre-admission medications are common amongst orthopaedic inpatients. Postprescribing medication reconciliation by clinical pharmacists after hospital admission prevents some but not all errors from reaching the patient. Involving pharmacists at the prescribing stage may more effectively prevent errors. The aim of the study was to evaluate the effect of pharmacist-assisted electronic prescribing at the time of hospital admission on medication errors in orthopaedic inpatients.

Methods: A pre- and postintervention study was conducted in the orthopaedic unit of a major metropolitan Australian hospital. During the 10-week intervention phase, a project pharmacist used electronic prescribing to assist with prescribing admission medications and postoperative venous thromboembolism (VTE) prophylaxis, in consultation with orthopaedic medical officers. The primary endpoint was the number of medication errors per patient within 72 h of admission. Secondary endpoints included the number and consequence of adverse events (AEs) associated with admission medication errors and the time delay in administering VTE prophylaxis after elective surgery (number of hours after recommended postoperative dose-time).

Results: A total of 198 and 210 patients, pre- and postintervention, were evaluated, respectively. The median number of admission medication errors per patient declined from six pre-intervention to one postintervention ($p < 0.01$). A total of 17 AEs were related to admission medication errors during the pre-intervention period compared with 1 postintervention. There were 54 and 63 elective surgery patients pre- and postintervention, respectively. The median delay in administering VTE prophylaxis for these patients declined from 9 h pre-intervention to 2 h postintervention ($p < 0.01$).

Conclusions: Pharmacist-assisted electronic prescribing reduced the number of admission medication errors and associated AEs.

Keywords: adverse drug events, electronic prescribing, medication errors, medication reconciliation, medication safety, orthopaedics, pharmacist

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Introduction

It is important that orthopaedic patients continue to receive their regular medications for pre-existing medical conditions when they are admitted to hospital, given that they are typically an older population with multiple comorbidities and multiple medications.[1] It is also essential that they receive venous thromboembolism

(VTE) prophylaxis following surgery in a timely manner, given their high risk of postoperative VTE.[2,3] Omissions or delays in administering patients' regular medications or VTE prophylaxis increases the risk of postoperative complications and adverse events (AEs).[3–7]

Prescribing errors are common when patients are admitted to hospital. A major contributing factor is that up to 83% of medication histories obtained by medical officers contain at least one unintentional discrepancy.[8] Numerous studies have shown that having pharmacists undertake medication reconciliation can detect and correct many of these errors.[9] Medication reconciliation is a systematic process that involves obtaining a best possible medication history and comparing it with what has been prescribed to identify and resolve unintended discrepancies.[10] There is, however, limited evidence that this improves clinical outcomes.[9–12] This may be due to the timing of such interventions, with delays in medication reconciliation placing patients at risk of exposure to medication errors. A study of orthopaedic patients in an Australian hospital where pharmacists obtained medication histories and undertook reconciliation a median of 24 h after admission found that approximately 90% of patients were exposed to one or more medication errors relating to their pre-admission medications prior to pharmacist review, with a median of six errors per patient.[7] Around 8% of patients had an AE that was potentially related to these errors.[7] This highlights the importance of ensuring that medications are prescribed correctly at the time of hospital admission.

A report titled '*To err is human: building a safer health system*', by the Institute of Medicine (US) Committee on Quality of Health Care in America, described human errors in the healthcare system and highlighted the importance of having pharmacists at the point of prescribing.[13] There has since been emerging evidence demonstrating that pharmacists involved at the point of prescribing can significantly reduce medication errors on admission to hospital, however its subsequent impact on clinical outcomes is unclear.[14–16] The terminology for this process has been variously termed 'partnered pharmacist charting', 'partnered pharmacist prescribing', 'pharmacist-assisted prescribing' and 'supplementary or collaborative prescribing', but each are essentially equivalent processes.

Most studies exploring this area have used paper medication charts, which are increasingly being replaced with electronic medication management systems (eMMS). The introduction of eMMS has changed the way medical officers and pharmacists work. Whilst eMMS reduce procedural prescribing errors such as unclear or incomplete orders, in isolation they are less likely to reduce clinical prescribing errors such as omission of medications.[17] eMMS can, however, be used to improve collaboration between pharmacists and hospital medical officers at the point of prescribing to reduce clinical prescribing errors and improve efficiency.[18,19] Pharmacists can electronically order medications after verbal authorization by the medical officer who can subsequently review and electronically co-sign the order. This reduces delays in obtaining a correct order as medical officers can verbally authorize, review and co-sign orders remotely, even when they are away from the ward (e.g. in theatre or clinic). A study evaluating the use of pharmacist-assisted prescribing at the time of hospital discharge reported fewer discharge prescription errors, faster discharge times and greater staff satisfaction compared with medical-officer prescribing.[19] No studies to our knowledge have evaluated whether pharmacists can utilize eMMS to assist in prescribing medications on admission to reduce errors and AEs.

The objective of this pre- and postintervention study was to evaluate medication errors associated with pharmacist-assisted electronic prescribing at the time of hospital admission compared with usual care (i.e. medical-officer prescribing on admission and pharmacist medication reconciliation a median of 24 h postadmission), in orthopaedic surgery patients. The pre-intervention (usual care) data have been previously published.[7]

Methods

A pre- and postintervention study was undertaken at a 980-bed public teaching hospital in Melbourne, Australia over two 10-week periods (July–September and October–December 2015). There was a 2-week run-in prior to the intervention period. The orthopaedic unit was serviced by five junior medical officers, seven surgical registrars and 25 surgeons. The clinical pharmacy service consisted of one pharmacist per 32 inpatients (5 days per week). This study was approved by the Human Research Ethics Committee at the study hospital and university.

Patients were included in the study if they were admitted to the orthopaedic unit for at least 24 h. Patients who were not taking any regular medication prior to admission or admitted to the short-stay ward or the paediatric ward were excluded (as these patients are generally less complex than those admitted to the general orthopaedic ward and there was no regular clinical pharmacy service provided to these areas).

During both the pre- and postintervention periods, medications were prescribed electronically using Cerner Millennium (Cerner Corporation, Kansas City, MO, USA). During both periods, patients were reviewed by the ward-based clinical pharmacist, usually within 24–72 h of admission. The clinical pharmacist obtained a best-possible medication history, performed postprescribing medication reconciliation, reviewed medication orders and coordinated the supply of inpatient medications.

During the intervention period, a project pharmacist (PP) with 3 years of clinical hospital pharmacy experience was recruited to work Monday–Friday (08:00–17:00) alongside the orthopaedic surgery team in addition to the usual clinical pharmacy service. The PP's roles were to obtain and document a best possible medication history and, after consultation and verbal authorization from the orthopaedic medical officers, chart pre-admission medications on the electronic medication administration record. The medical officer who provided verbal authorization was required to co-sign electronically orders that had been placed by the PP. For elective surgical patients, this was undertaken pre-operatively and for emergency surgical patients it occurred either pre-operatively or postoperatively depending on the time of surgery. Nursing staff were able to administer medications before the medical officer co-signed, as verbal authorization from the medical officer had been given for all orders. The clinical pharmacist was not required to obtain a best possible medication history if this had already been documented by the PP, but they were required to use the documented pre-admission medication list to independently reconcile the medications charted by the PP. Patients who were not seen by the PP had their medications charted by the medical officer and reconciled by the clinical pharmacist as per usual practice.

For elective surgical patients, the PP also assisted in prescribing (if not already done) VTE prophylaxis according to hospital policy and surgeons' postoperative orders. This involved charting the order or rescheduling the administration time. VTE prophylaxis for nonelective patients was not included, as their surgeries were often unplanned and may have occurred outside the working hours of the PP. Enoxaparin was the hospital's anticoagulant of choice and the hospital protocol recommended administration 6 h after surgery unless specified by the surgeon, or if the patient had spinal surgery (in which case it was commenced 48 h after surgery).

Prior to commencing the role, the PP was required to have worked on a surgical ward, completed a performance review using the Society of Hospital Pharmacists of Australia Clinical Competency Assessment Tool and undertaken inhouse training on prescribing using Cerner. Upon commencement, the PP was required to prospectively review and discuss with the senior clinical training and education pharmacist (TT) five cases for which they had prescribed.

The primary endpoint was the number of medication errors per patient related to regular pre-admission medications during the first 72 h of hospital admission. Medication errors(s) were deemed to have occurred if there were one or more of the following: (a) unintentionally omitted doses; (b) unintended dose delays (delayed by more than 50% of the prescribed dose-interval); (c) incorrect dose regimen given (wrong amount or frequency of administration); (d) incorrect medication administered. Secondary endpoints were: (a) proportion of patients who experienced one or more admission medication errors in the first 72 h of hospitalization; (b) the nature of medication errors (prescribing or administration); (c) the number and consequences of preventable AEs associated with medication errors; (d) the delay (hours) in the administration of VTE prophylaxis in the first 24 h after surgery for elective patients.

Data collection

All data were collected retrospectively by two experienced pharmacists (EM and TT) not involved in the patients' care. Patient demographics, admitting unit and time of admission were obtained from the electronic patient management system, Trakcare (InterSystems Corporation, Cambridge, MA, USA). The American Society of

Anesthesiologists physical status classification was obtained (for patients who underwent surgery) from the anaesthetic records.[20] The patients' regular pre-admission medication lists were obtained from their pharmacist-completed 'Medication history on admission' forms. 'As required' (prn) medications were not included in this analysis as it was not possible to identify retrospectively whether they were needed by the patient and therefore whether a medication error had occurred. A regular medication was defined as any medication that was used at regularly scheduled intervals by the patient prior to admission.

The data collection methods used to identify medication errors and preventable AEs have previously been described in detail.[7] They were identified by EM who determined when the patient was due for their first scheduled dose after presentation to hospital and then reviewed the electronic medication record to see when it was administered. We only evaluated actual medication errors that reached the patient as opposed to 'near misses' so that we could determine their impact on patient clinical outcomes. Admission medication errors were classified as either prescribing or administration in nature. Prescribing errors occurred if the medication was prescribed incorrectly or unintentionally omitted. An administration error occurred if the medication was prescribed correctly but was not given by nursing staff with no documented valid reason. Pharmacy and nursing medication dispensing or selection errors were not evaluated.

The medical records for patients who experienced a medication error were retrospectively reviewed by TT to determine whether the patient developed a preventable AE that could have been related to the medication error. A preventable AE was defined as 'harm caused by the use of a drug as a result of an error' and was considered only if the clinical symptom of the harm was documented by medical staff in the patient's progress notes.[21] A summary of the potential AE cases was presented to a panel consisting of two independent reviewers (a senior clinical pharmacist and a clinical pharmacologist) blinded as to whether the AE occurred in the pre- or postintervention period. Information presented to the panel included the medication involved, type of error, number of affected doses, AEs documented and other relevant clinical information. The panel determined, *via* consensus, the causality of the event (using a modified version of the World Health Organization–Uppsala Monitoring Centre system) and the consequence (using a modified version of the Society of Hospital Pharmacists of Australia consequence matrix).[22,23] Modifications to these tools were required as there are currently no validated tools to assess causality or consequences of AEs from omitted medications (Appendices 1 and 2).

Data relating to delays in administering VTE prophylaxis after surgery were obtained by EM and TT. They were evaluated by determining (from the nursing operation report) the time the patient completed their surgery and (from the electronic medication record) when they received their first dose of anticoagulant. Delays (in hours) were calculated by evaluating the number of hours that had elapsed beyond the recommended 6 h after surgery completion (e.g. if enoxaparin was administered 7 h after surgery, the delay was 1 h). Patients were excluded from this analysis if their surgeon had specified in postoperative orders that they were not to receive anticoagulation (e.g. due to postoperative wound ooze) or if VTE prophylaxis was intentionally delayed (e.g. after spinal surgery).

Statistical analysis

Statistical analysis was performed using SPSS, version 25 (IBM Corporation, Armonk, NY, USA). Median and interquartile range were used to describe nonnormally distributed data, while mean and standard deviation were used to describe normally distributed data. A p value of less than 0.05 was considered statistically significant for all comparisons. Chi-square test was used to compare differences in proportions. Student's t test was used to compare differences in means for normally distributed data, while Mann–Whitney U test was used to compare distributions of nonnormally distributed and nonparametric data.

The study time-frame, and therefore the sample size, was determined by the funding available to conduct the study. *Post hoc* sample size calculation, after completion of the baseline study, indicated that with a sample size of 200 patients the study would be powered (power $\geq$ 80%) to detect a 33% reduction in the mean number of medication errors, which was deemed to be more than a minimally clinically significant reduction.

Table 1. Demographic characteristics.

	Pre-intervention[7] *n* = 198	Postintervention *n* = 210	*p*
Age (years), mean (SD)	70 (16.6)	70.2 (18.4)	0.19
Gender			
Male, *n* (%)	82 (41.4)	91 (43.3)	0.7
Length of stay, median (IQR)	7 (4–10)	6 (4–11)	0.84
Number of regular pre-admission medications, median (IQR)	7 (4–10)	6 (4–10)	0.38
Admitted on a weekend. *n* (%)	30 (15.2)	41 (19.5)	0.24
Reason for admission, *n* (%)			0.12
Upper limb fracture	19 (9.6)	12 (5.7)	
Total knee arthroplasty	17 (8.6)	18 (8.6)	
Total hip arthroplasty	10 (5.0)	7 (3.3	
Spinal injury	32 (16.2)	21 (10.0)	
Laminectomy	15 (7.6)	22 (10.5)	
Shoulder surgery	3 (1.5)	6 (2.9)	
Lower limb fracture	84 (42.4)	88 (41.9)	
Joint infection	7 (3.5)	17 (8.1)	
Other	11 (5.6)	19 (9.0)	
ASA physical status, *n* (%)			0.36
1	8 (4.0)	5 (2.4)	
2	51 (25.8)	46 (21.9)	
3	91 (46.0)	96 (45.7)	
4	12 (6.1)	21 (10.0)	
5	0 (0)	1 (0.5)	
NA*	36 (18.2)	41 (19.5)	

*Patients who did not undergo surgery during their admission.
ASA, American Society of Anesthesiologists; IQR, interquartile range; NA, not applicable; SD, standard deviation.

Results

Pre- and postintervention, 198 and 210 patients were included in the study, respectively. There were no significant differences in age, gender, length of stay or median number of regular medications on admission between the two groups (Table 1).

During the postintervention period, the PP obtained a medication history for 162 (77.7%) patients and was involved in prescribing for 155 (73.8%) patients (52 elective, 103 nonelective). The remaining patients were not able to be seen by the PP and received usual care (medical-officer prescribed admission medications without input from the PP).

Table 2. Admission medication errors.

	Pre-intervention[7] *n* = 198	Postintervention *n* = 210	*p*
Median (IQR) number of admission medication errors per patient	6 (3–10)	1 (0–4)	< 0.01
Number (%) patients with one or more admission medication errors*	176 (88.9)	128 (61.0)	< 0.01
Total number of admission medication errors	1506	526	
Types of medication error*			
Omitted dose, *n* (%)	1370 (91.0)	471 (89.5)	
Incorrect dose *n* (%)	100 (6.6)	33 (6.3)	
Incorrect medication *n* (%)	34 (2.3)	18 (3.4)	
Dose delay of > 50% of dosing schedule *n* (%)	2 (0.1)	4 (0.8)	
Sources of admission medication error			
Prescribing errors, *n* (%)	1369 (90.9)	390 (74.1)	
Administration errors, *n* (%)	137 (9.1)	136 (25.9)	

*Prescribing and administration errors combined.
IQR, interquartile range.

Admission medication errors

There was a statistically significant reduction in the median number of admission medication errors per patient and in the proportion of patients who experienced one or more medication errors in the postintervention period, compared with the pre-intervention period (Table 2). Fewer prescribing errors accounted for most of the decline in medication errors, as the number of administration errors remained relatively static (Table 2). The types of medication errors were similar during both time periods, with omitted doses being the most common.

Preventable AEs

During the pre-intervention period, 17 preventable AEs involving 24 medications and affecting 16 (8.1%) patients were classified by the independent panel as potentially related to an admission medication error (details previously published).[7] Of these errors, 6 (30%) were classified as being 'of moderate clinical consequence', while the remaining 11 (70%) were classified as 'of minor clinical consequence'. Postintervention, the panel classified one AE as 'possibly' related to an admission medication error. This involved three missed doses of regular acetaminophen, resulting in poorly controlled pain postoperatively. This AE was classified as 'minor in severity'.

Delays in administering VTE prophylaxis

Pre- and postintervention, there were 54 and 63 elective surgery patients, respectively, of which 30 and 41 patients in each group required and were prescribed VTE prophylaxis within 24 h postsurgery. Most patients who did not require VTE prophylaxis within 24 h had undergone spinal surgery (15 and 20 patients pre- and postintervention, respectively). Others had undergone upper limb surgery or minor surgical procedures (e.g. manipulation under anaesthesia). During the postintervention period, the PP assisted in the prescribing of VTE prophylaxis for 19/41 (46.3%) elective surgery patients (8 orders charted and 11 orders rescheduled to correct the administration time). There was a statistically significant reduction in the proportion of patients who experienced a delay in the administration of VTE prophylaxis in the postintervention period (Table 3).

Table 3. Delays in the administration of VTE prophylaxis.

	Pre-intervention ($n = 54$)	Postintervention ($n = 63$)	p
Patients requiring VTE prophylaxis within 24 h postsurgery	30 (55.6)	41 (65.1)	0.05
Number (%) of patients with a delay	27 (90.0)	18 (43.9)	< 0.01
Median (IQR) delay* (h)	9 (2–13)	2 (0–6)	

*Postoperative delay beyond 6 h.
IQR, interquartile range; VTE, venous thromboembolism.

Discussion

The traditional role of pharmacists has been to review and correct medication orders retrospectively after they are prescribed by medical officers. However, in a hospital setting, delays in correcting orders may result in medication errors and AEs. In our organization, where pharmacists undertake postprescribing medication reconciliation, medication errors during the first 72 h were prevalent in orthopaedic patients, with a small number resulting in AEs.[7] The current study demonstrates that having a pharmacist utilize an eMMS to assist with electronically prescribing admission medications significantly reduced the number of medication errors and AEs that patients experienced. Importantly, it allowed the pharmacist to be proactive in ensuring that medications were prescribed correctly as early as possible, which was demonstrated by the PP being able to chart admission medications for 74% of patients. The PP was not able to chart medications for all patients as she only worked 0800–1700 Monday–Friday. If the hours were extended and the service was provided at the weekends we would expect a further reduction in medication errors. Although we did not collect data on potential time-savings, anecdotal feedback from medical officers and the ward pharmacist indicated that the intervention reduced the amount of time spent reviewing and correcting prescribing errors.

The results of this study support previous research that has shown a significant reduction in medication errors when pharmacists are involved at the point of prescribing.[14–16] Our study demonstrates how pharmacist-assisted admission prescribing using an eMMS can facilitate interdisciplinary communication and reduce delays in correcting orders when the medical officer is not present on the ward (e.g. in the operating theatre). Another benefit of using electronic prescribing is that it facilitates a transparent audit trail, ensuring all involved in the prescribing process are clearly identifiable and accountable.

A novel feature of this study is that we examined the impact of pharmacist-assisted prescribing on actual patient outcomes by following up medication errors and determining whether they resulted in AEs. During the postintervention period, only one AE was observed that was possibly caused by an admission medication error and it was classified by the panel as minor in consequence. In comparison there were 17 events caused by an admission medication error during the pre-intervention period, with six classified as of moderate consequence (i.e. moderate injury or harm, increased length of stay or cancelled/delayed planned treatment). These results demonstrate that ensuring there is an accurate medication chart from the start of admission improves patient safety by reducing the number of AEs caused by admission medication errors.

Compliance with postoperative VTE prophylaxis administration guidelines for elective surgery patients was also evaluated. Failure to comply may occur as a result of delays in prescribing VTE prophylaxis (e.g. prescribed the day after surgery) or as a result of incorrect dose scheduling in relation to the completion of surgery. The median delay (from the recommended dose-time) in receiving the first dose of VTE prophylaxis was reduced from 9 h pre-intervention to 2 h postintervention. The PP reduced these delays by assisting in the prescribing of VTE prophylaxis and rescheduling the timing. Although our study was not powered to evaluate changes in VTE clinical outcomes, previous studies have shown that delayed administration of VTE prophylaxis postoperatively

increases the risk of developing thromboembolic complications.[3] Although the PP did not assist in prescribing VTE prophylaxis orders for emergency surgery patients in this study, we would expect similar results if the PP was able to do so. Whilst previous studies have shown that pharmacists can improve compliance with prescribing VTE prophylaxis, no studies have evaluated whether pharmacists can improve the timing of its administration.[15,24,25]

This study had some limitations. Firstly, in relation to the study design, it was not blinded. We minimized potential bias by not informing medical officers and the clinical pharmacist that medication errors during the pre-intervention period would be evaluated, to ensure they did not change their practice in prescribing and reconciling admission medications. It was not practical to blind medical officers and the clinical pharmacist during the postintervention period, however we anticipate the impact would have been minimal given the PP was responsible for the charting of almost two-thirds of admission medications and did this independently of the clinical pharmacist.

Medication errors in this study were identified retrospectively and therefore did not include administration error-types that could only be identified by direct observation (e.g. wrong dose or method of administration). Dispensing errors were also not evaluated. Given the high number of recorded prescribing errors compared with administration errors, the impact on our study is likely to be minimal.[26] The study was not a randomized controlled study and therefore the potential effects of confounding factors such as seasonal variations and staff changes cannot be ruled out.

The study was conducted within a single orthopaedic unit and only used one PP for the intervention, which may affect the generalizability of the results. The PP had 3 years hospital pharmacy experience and was required to have completed competency assessments to practise as a clinical pharmacist and training specific to the prescribing of medications. Tong and colleagues, when evaluating partnered pharmacist charting in general medical and emergency short-stay units, utilized pharmacists with at least 2 years of hospital pharmacy experience and who were also required to undertake an accreditation programme.[16] Further research is required as to the specific experiential and training requirements for such a role.

Lastly, our study did not evaluate the cost-effectiveness of this model of care. We recruited an additional pharmacist, rather than use the existing ward-based clinical pharmacist, to ensure the PP was able to see newly admitted patients in a timely manner and so that medication orders prepared by the PP were reviewed by a second pharmacist, as per standard care. Further studies are required to evaluate whether the roles of the PP can be incorporated into those of the usual ward clinical pharmacist. The cost and feasibility of such a change in practice needs to be further evaluated.

Conclusion

Pharmacists utilizing eMMS to assist with prescribing admission medications in orthopaedic patients reduced the number of medication errors and AEs, and improved the timeliness of VTE prophylaxis administration.

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Conflict of interest statement

The authors declare no conflicts of interest in preparing this article.

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Appendix 1. Adverse drug event causality assessment.

Likelihood that the medication error(s) caused the adverse event			
Level	**Descriptor**	**Description**	**Probability**
A	Very likely/certain	• Clinical event with a plausible time relationship to medication error(s) • Cannot be explained by concurrent disease or other drugs • Response to correction of medication error(s) plausible (pharmacologically, pathologically)	>90%
B	Probable/likely	• Clinical event with a reasonable time relationship to medication error(s) • Unlikely to be attributed to concurrent disease or other drugs • Response to correction of medication error(s) clinically reasonable	51–90%
C	Possible	• Clinical event with a reasonable time relationship to medication error(s) • Could also be explained by concurrent disease or other drugs • Information on response to correction of medication error(s) may be lacking or unclear	11–50%
D	Unlikely	• Clinical event whose time relationship to medication error(s) makes a relationship improbable (but not impossible) • Underlying disease or other drugs provide plausible explanations • Correction of medication error(s) does not resolve the event	1–10%
Based on the World Health Organization–Uppsala Monitoring Centre system for standardized causality assessment.[23]			

Appendix 2. Adverse drug event consequence assessment.

Consequence or impact		
Level	**Descriptor**	**Description**
1	Insignificant	No harm or injury
2	Minor	Minor injury or harm or minor treatment required AND unlikely to have increased length of stay
3	Moderate	Moderate injury or harm OR may have increased length of stay or led to cancellation or delay in planned treatment/procedure
4	Major	Major injury or harm OR likely to have increased length of stay or morbidity at discharge
5	Catastrophic	Death
Based on the Society of Hospital Pharmacists of Australia consequence matrix.[22]		