

Detection and Characterization of Medication Administration and Dispensing Errors in a South Indian Tertiary Care Hospital: A Cross-Sectional Study

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Abstract

Background: Medication errors occur at every stage of the medication-use process, and dispensing and administration are consistently its most error-prone stages. Indian data characterizing both error types concurrently within one institution remain scarce. This study detected and characterized medication administration errors (MAEs) and dispensing errors in a tertiary care government hospital in Visakhapatnam, India.

Methods: A cross-sectional, prospective observational study was conducted over four months in the General Medicine ward and outpatient Drug Information Centre of a 1300-bed government hospital, following institutional ethics committee approval. Adult patients (>18 years) were consecutively screened; administration records were compared against physicians' orders to detect MAEs, and dispensed medicines against prescriptions to detect dispensing errors. Errors were classified by drug, dosage form, contributing factor, error type, and severity (NCC MERP index). Categorical distributions were tested against a uniform-frequency null using chi-square tests.

Results: Of 226 patients screened, 100 MAEs and 100 dispensing errors were identified across 80 patients. Patients aged 40–50 years accounted for the largest share of MAEs (35%); sex distribution did not differ significantly (54% vs 46% male, $p=0.42$). Pantoprazole (30%) and injectable formulations (83%) were the most frequently implicated drug and dosage form. Lack of drug availability was the leading contributing factor (42%), and omission the predominant error type (70%, $p<0.001$). Ninety-seven of 100 MAEs caused no patient harm (NCC MERP category A–C). Among dispensing errors,

metoprolol (47%) and tablets (92%) predominated; wrong-strength dispensing was the most common incident (63%), attributed chiefly to stock unavailability (38%) and a limited dosage-strength range (28%).

Conclusion: Administration and dispensing errors were both common but predominantly low-severity. Pharmacy supply-chain constraints, rather than clinician or nursing performance, appeared to be the dominant modifiable driver of error on both sides of the medication-use process, suggesting inventory management as a priority target for intervention.

Keywords: medication errors; medication administration errors; dispensing errors; patient safety; hospital pharmacy; India

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1. Introduction

The National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP) defines a medication error as any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of a healthcare professional, patient, or consumer ^[1]. Under this framework, an error can originate at any of several points in the medication-use cycle: prescribing, order transcription, dispensing, administration, or monitoring, and each stage carries a distinct error profile and a distinct set of contributing systems ^[2]. Administration and dispensing are singled out repeatedly in the literature as the two stages where the largest share of preventable harm accumulates, because they sit closest to the patient and offer the fewest remaining opportunities for a second check before a drug is taken ^[1,2].

The scale of the problem is substantial wherever it has been measured carefully. The World Health Organization's Medication Without Harm initiative estimated that medication errors cost health systems an estimated US\$42 billion annually worldwide and named them among the leading avoidable sources of patient injury ^[3]. A retrospective review of English general practice found that 18.7% of patients had at least one prescribing or monitoring error over a 12-month period, rising to 41.9% among patients aged 75 years and older and to 32.3% among those on five or more medicines ^[4]. A separate costing analysis for the English National Health Service put the annual burden at roughly 237 million medication errors, 66 million of them clinically significant, at a cost exceeding £98 million and an estimated 1,700 avoidable deaths a year ^[5]. Indian data, though sparser, point in the same direction: hospital-based studies from Uttarakhand and Karnataka have reported medication error rates of 25.7% and 15.34% respectively among hospitalized patients ^[6,7], a tertiary care hospital in South India recorded a 14.6% prevalence using the same NCC MERP index applied in the present study ^[8], and a 2025 systematic review of 40 Indian hospital-based studies placed the median incidence of medication errors at 34.1% (95% CI 20.5–54.6) ^[9]. The picture outside India is comparably variable: a systematic review of medication errors across Southeast Asian countries described marked heterogeneity in reported rates that the authors attributed largely to differences in detection method rather than genuine differences in underlying risk ^[10], a pattern consistent with what this study's own comparison of chart-review and incident-reporting evidence later suggests (Discussion, section 4.4). In the United States, the Institute of Medicine's landmark accounting put preventable-error costs at

approximately US\$17 billion of a total US\$37.6 billion in annual medical-error expenditure ^[11].

Health systems have responded with a recognizable toolkit: computerized physician order entry with embedded clinical decision support, barcode-assisted dispensing and administration, unit-dose packaging, high-alert medication protocols, and structured medication reconciliation at points of transition in care. These interventions measurably reduce error rates where they have been implemented and evaluated, but their reach is uneven. Ambwani et al. described medication errors as the hidden part of a submerged iceberg in health systems that lack the surveillance infrastructure to detect and report them systematically, a description that applies with particular force to government tertiary care hospitals in India, where electronic prescribing and barcode verification remain the exception rather than the rule ^[12]. In settings that still rely on handwritten charts and manual cross-checking, dispensing and administration errors are correspondingly more likely to go undetected until a clinical pharmacist or dedicated observer specifically looks for them.

Most of the direct-observation literature on this subject, however, addresses administration errors and dispensing errors as separate research questions, generating parallel bodies of evidence that are difficult to compare directly because they draw on different patient cohorts, settings, and detection methods ^[13–22]. Even within India, published work has tended to examine either administration errors in a single ward ^[13] or prescribing and dispensing irregularities in an outpatient pharmacy ^[23], rather than both error types within the same patients at the same institution. This leaves a practical gap for hospital pharmacy and nursing leadership, who need to know not just how often either error type occurs but how the two compare in frequency, severity, and root cause when measured concurrently, so that limited quality-improvement resources can be directed to the stage of the medication-use process where they will do the most good. The present study was undertaken to address this gap in the General Medicine department of a large government teaching hospital in Visakhapatnam, Andhra Pradesh.

The major objective of this study was to detect and analyse medication dispensing and administration errors among patients attending the study site. The minor objectives were to assess the factors associated with, and the severity of, these errors, and to determine the frequency of occurrence of each error type together with the drug classes most commonly responsible.

2. Materials and methods

2.1 Study design and setting

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This was a hospital-based, cross-sectional, prospective observational study conducted in the General Medicine inpatient department (for MAE detection) and the outpatient Drug Information Centre (for dispensing-error detection) of King George Hospital (KGH), Visakhapatnam, a 1,300-bed government tertiary care teaching hospital affiliated with Andhra Medical College. Data collection ran for four months. This study followed the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) reporting guideline for cross-sectional studies; a completed STROBE checklist is available on request.

2.2 Ethics approval

The study protocol, case report form, and bilingual (English and Telugu) patient information sheet and informed consent form were reviewed and approved by the Institutional Ethics Committee of King George Hospital (IEC-KGH; Reg. No. ECR/197/Inst/KGH/2013/RR-20) prior to the commencement of data collection (Protocol No. AU/AUCoPS/Pharm.D./2019–2025/02133236). All participants, or their attending caregiver where applicable, provided written informed consent before enrolment.

2.3 Study population and sampling

Patients of either sex, aged over 18 years, attending the inpatient General Medicine unit or the outpatient Drug Information Centre during the data collection period were eligible. A consecutive sampling approach was used: every patient attending either site who met the eligibility criteria below was screened and, if willing, enrolled, rather than a randomly or conveniently selected subset. No formal a priori sample-size or power calculation was performed, and no cohort-specific stopping rule was applied; screening continued across the full four-month window at both sites regardless of the cumulative error count. The MAE and dispensing-error cohorts each happened to comprise exactly 100 index events; given the absence of any count-based stopping rule, this equality was an incidental feature of the achieved sample rather than a pre-specified or capped target (see Section 4.6).

Inclusion criteria: patients over 18 years of age attending the inpatient or outpatient units of the study site who were willing to provide voluntary written informed consent.

Exclusion criteria: patients with mental disabilities or comatose patients; patients with an inpatient admission of less than 24 hours; patients who underwent early termination of the study or reached a study endpoint before data collection was complete; and pediatric or pregnant patients. No upper age limit was applied; patients over 60 years were eligible and are represented in the study population (Table 1).

Table 1. Demographic characteristics of patients affected by medication administration errors and dispensing errors

Characteristic	MAE cohort (n=100)	Dispensing-error cohort (n=100)
Age 20–30 y	10 (10%)	21 (21%)
Age 30–40 y	10 (10%)	16 (16%)
Age 40–50 y	35 (35%)	20 (20%)

Age 50–60 y	20 (20%)	17 (17%)
Age 60–70 y	19 (19%)	19 (19%)
Age 70–80 y	5 (5%)	7 (7%)
Age 80–90 y	1 (1%)	—
Mean age $\pm$ SD (years)	49.7 $\pm$ 13.67	46.8 $\pm$ 14.32
Age-distribution χ^2 (df), p-value	54.84 (6), p<0.001	7.76 (5), p=0.17
Male	54 (54%)	51 (51%)
Female	46 (46%)	49 (49%)
Sex-distribution χ^2 (df), p-value	0.64 (1), p=0.42	0.04 (1), p=0.84

2.4 Detection of medication administration errors

MAEs were identified by reviewing inpatient medication charts against the medication administration record for each patient. Any deviation between the physician's prescribed order and what was actually charted or administered was recorded as an MAE on a structured data collection form.

2.5 Detection of dispensing errors

Dispensing errors were identified by reviewing the case sheets of patients attending the Drug Information Centre, supplemented where necessary by counselling the patient or an accompanying caregiver. The medication name, dose, frequency, duration, quantity, and route documented on each prescription was matched against the dispensing label and the medicines actually dispensed.

2.6 Classification of errors

Each MAE was classified by patient age and sex; implicated drug; dosage form; contributing factor (lack of communication, frequent interruptions, lack of availability of drug, lack of availability of a healthcare professional, staffing, or training); error type (omission, wrong drug, wrong duration, wrong route, wrong strength/concentration, or wrong time); and severity, graded A–D on the NCC MERP index (A: circumstances with the capacity to cause an error; B: error occurred but did not reach the patient; C: reached the patient without harm; D: reached the patient and required intervention). Each dispensing error was similarly classified by patient age and sex, implicated drug, dosage form, nature of incident (no drug given, wrong drug, unprescribed drug, verbal disagreement, wrong dosage form, or wrong strength), and reason for incident (by mistake, confusion, illegible handwriting, interruptions, lack of knowledge, lack of stock, limited dosage-strength availability, miscommunication, unidentified prescription, verbal disagreement, or workload).

2.7 Data collection and management

Data were recorded on a structured, pre-piloted data collection form and entered into a Microsoft Excel spreadsheet for cleaning and analysis.

2.8 Statistical analysis

Descriptive statistics — frequencies, percentages, and, for continuous data, means with standard deviations — summarized patient demographics and error characteristics. Age was recorded in 10-year bands; mean and SD were calculated from these grouped data using mid-interval methods, which should be read as approximate given the underlying binning. Chi-square goodness-of-fit tests compared each categorical variable's observed distribution against a uniform-

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frequency null (significance set at $p < 0.05$); sex was tested against an expected 1:1 ratio. This uniform-null comparison is a reasonable approximation for the error-classification variables (contributing factor, error type, severity, nature and reason for incident), where categories had no a priori reason to differ in frequency, but a weaker one for implicated drug and age group specifically: neither prescribing volume nor ward age structure is itself uniform, so a non-uniform result for these two variables is also consistent with prescribing frequency or admission demographics alone rather than elevated per-exposure error risk (Section 4.6). Where the same variable was recorded for both cohorts (sex, age group, dosage form), chi-square tests of homogeneity additionally compared the two cohorts directly (Section 3.9), collapsing low-frequency categories to keep expected cell counts ≥ 3 . All analyses used Python (SciPy 1.17.1); charts were prepared in Python (Matplotlib).

3. Results

3.1 Study population overview

Over the four-month study period, 226 patients attending the General Medicine inpatient unit and the outpatient Drug Information Centre were screened. Two hundred medication errors were identified across 80 of these patients: 100 medication administration errors (MAEs) and 100 dispensing errors, each analyzed here as its own cohort of 100 index errors. Because MAEs were detected among inpatients on the General Medicine ward and dispensing errors were detected among outpatients attending the Drug Information Centre, the two error types were not necessarily observed in an identical set of patients, and a single patient could in principle contribute more than one error of either type. The source data record the combined total of 80 affected patients but do not distinguish how many experienced only an MAE, only a dispensing error, or both; consequently, this study reports the two error types as parallel cohorts of 100 index events each rather than claiming a fully patient-matched comparison, and no patient-level overlap statistic is presented.

3.2 Demographic profile of the MAE cohort

Patients aged 40–50 years accounted for the largest share of MAEs ($n=35$, 35%), followed by the 50–60-year ($n=20$, 20%) and 60–70-year ($n=19$, 19%) groups; patients aged 80–90 years contributed the smallest share ($n=1$, 1%) (Table 1, Figure 1A). Mean patient age was 49.7 ± 13.67 years (grouped-data estimate; see Section 2.8). The age distribution departed markedly from a uniform spread across the seven age bands ($\chi^2=54.8$, $df=6$, $p < 0.001$). Male patients accounted for a modest majority of MAEs ($n=54$, 54%) over female patients ($n=46$, 46%; $\chi^2=0.64$, $df=1$, $p=0.42$), indicating no statistically meaningful difference in error frequency by sex (Table 1, Figure 1C).

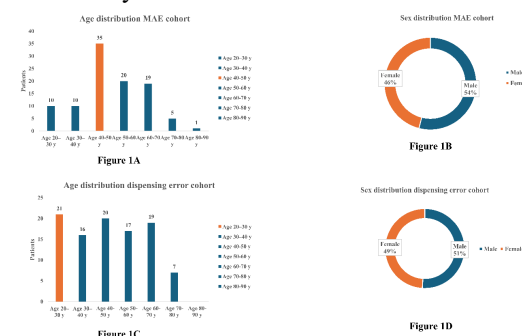


Figure 1. Demographic profile of patients affected by medication administration errors (MAE) and dispensing errors (DE).

3.3 Medications and dosage forms implicated in MAEs

Pantoprazole was the single most frequently implicated drug ($n=30$, 30%), roughly double the share of the next most common agents, ceftriaxone and thiamine ($n=13$ each, 13%) (Table 2, Figure 2A). Furosemide (11%), hydroxyurea, tramadol, and piperacillin–tazobactam (9% each), and sulbactam–cefoperazone (7%) accounted for the remainder. (As with the dispensing-error drug profile below, MAE product-level percentages sum to 101% rather than 100%; because the excess is exactly one count, this is arithmetically consistent with exactly one MAE having involved two implicated products rather than one, with the remaining 99 MAEs each involving a single product; Table 2.) The distribution across the eight implicated drugs differed significantly from chance ($\chi^2=29.8$, $df=7$, $p < 0.001$).

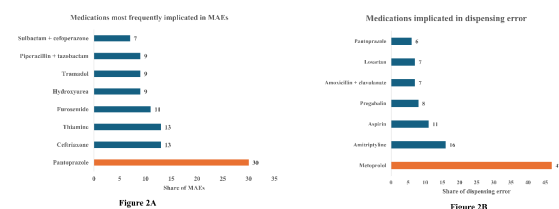


Figure 2. Medications most frequently implicated in MAEs and dispensing errors

Table 2. Medications most frequently implicated in medication administration errors and dispensing errors

MAE cohort — drug	n (%)	Dispensing-error cohort — drug	n (%)
Pantoprazole	30 (30%)	Metoprolol	47 (47%)
Ceftriaxone	13 (13%)	Amitriptyline	16 (16%)
Thiamine	13 (13%)	Aspirin	11 (11%)
Furosemide	11 (11%)	Pregabalin	8 (8%)
Hydroxyurea	9 (9%)	Amoxicillin + clavulanate	7 (7%)
Tramadol	9 (9%)	Losartan	7 (7%)
Piperacillin + tazobactam	9 (9%)	Pantoprazole	6 (6%)
Sulbactam + cefoperazone	7 (7%)	—	—

χ^2 (df), p-value	29.77 (7), p<0.001	χ^2 (df), p-value	89.06 (6), p<0.001
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Injectable formulations were implicated in the substantial majority of MAEs (n=83, 83%), against 16% for tablets and 1% for capsules (Table 3, Figure 3). This concentration in injectable products was highly significant ($\chi^2=114.4$, df=2, p<0.001).

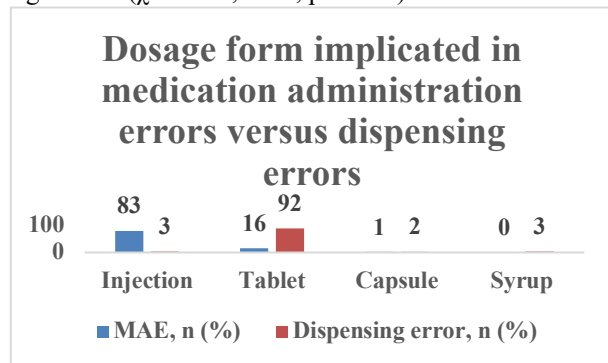


Figure 3. Dosage form implicated in medication administration errors versus dispensing errors (n=100 each)

Table 3. Dosage form implicated in medication administration errors and dispensing errors

Dosage form	MAE, n (%)	Dispensing error, n (%)
Injection	83 (83%)	3 (3%)
Tablet	16 (16%)	92 (92%)
Capsule	1 (1%)	2 (2%)
Syrup	—	3 (3%)
χ^2 (df), p-value	114.38 (2), p<0.001	239.44 (3), p<0.001

3.4 Contributing factors and error types in MAEs

Lack of availability of the prescribed drug was the single largest contributing factor, implicated in 42% of MAEs, roughly double the combined share of staffing (21%) and training (21%) (Table 4A, Figure 4A). Lack of availability of a healthcare professional accounted for a further 12%, while frequent interruptions and lack of communication each contributed 2%. This distribution across the six contributing-factor categories was far from uniform ($\chi^2=67.9$, df=5, p<0.001).

Omission was the predominant error type, accounting for 70% of all MAEs identified (Table 4B, Figure 4B). Wrong-time errors were the next most frequent (14%), followed by wrong route of administration (8%), wrong drug (4%), and wrong duration and wrong strength/concentration (2% each). This distribution was again highly non-uniform ($\chi^2=211.0$, df=5, p<0.001), consistent with omission — itself closely tied to the leading contributing factor of drug unavailability — as the dominant failure mode at this site.

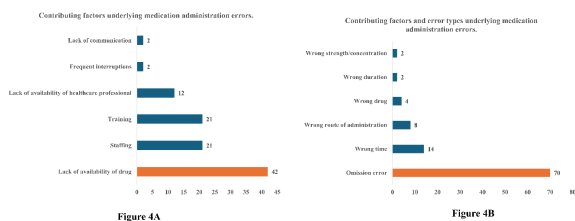


Figure 4. Contributing factors and error types underlying medication administration errors

Table 4A. Contributing factors for medication administration errors (n=100)

Contributing factor	n (%)
Lack of availability of drug	42 (42%)
Staffing	21 (21%)
Training	21 (21%)
Lack of availability of healthcare professional	12 (12%)
Frequent interruptions	2 (2%)
Lack of communication	2 (2%)
χ^2 (df), p-value	67.88 (5), p<0.001

Table 4B. Contributing Error type for medication administration errors (n=100)

Type of medication administration error	n (%)
Omission error	70 (70%)
Wrong time	14 (14%)
Wrong route of administration	8 (8%)
Wrong drug	4 (4%)
Wrong duration	2 (2%)
Wrong strength/concentration	2 (2%)
χ^2 (df), p-value	211.04 (5), p<0.001

3.5 Severity of MAEs

Applying the NCC MERP index, 49% of MAEs fell into category B (an error that occurred but did not reach the patient) and 46% into category C (an error that reached the patient without causing harm) (Table 5, Figure 5). Category A, representing circumstances with the capacity to cause an error, accounted for 2%, while category D, denoting an error that reached the patient and required clinical intervention, accounted for 3%. No MAE in this cohort was classified beyond category D; none resulted in permanent harm, life-threatening injury, or death. The severity distribution differed significantly from a uniform spread across the four categories ($\chi^2=81.2$, df=3, p<0.001).

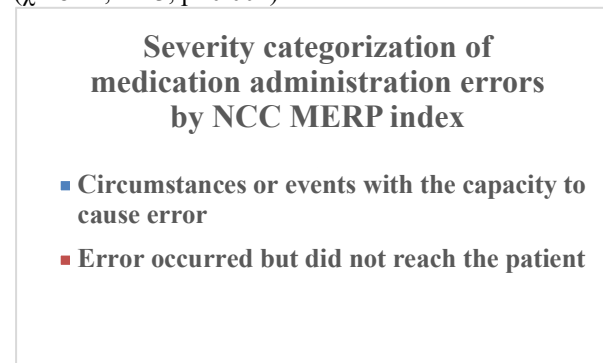


Figure 5. Severity categorization of medication administration errors by NCC MERP index (n=100)

Table 5. Severity categorization of medication administration errors (NCC MERP index, n=100)

NCC MERP category	Definition	n (%)
A	Circumstances or events with the capacity to cause error	2 (2%)
B	Error occurred but did not reach the patient	49 (49%)

C	Error reached the patient but did not cause harm	46 (46%)
D	Error reached the patient and required intervention	3 (3%)
χ^2 (df), p-value		81.20 (3), $p<0.001$

3.6 Demographic profile of the dispensing-error cohort

Among patients experiencing a dispensing error, the 20–30-year age group contributed the largest share ($n=21$, 21%), closely followed by the 40–50-year group ($n=20$, 20%) (Table 1, Figure 1B). Mean patient age was 46.8 ± 14.32 years. Unlike the MAE cohort, the age distribution of dispensing errors did not differ significantly from a uniform spread across the six age bands ($\chi^2=7.76$, $df=5$, $p=0.17$), indicating a comparatively even risk of dispensing error across adult age groups. Male and female patients were affected in near-equal proportion (51% vs 49%; $\chi^2=0.04$, $df=1$, $p=0.84$) (Table 1, Figure 1D).

3.7 Medications and dosage forms implicated in dispensing errors

Metoprolol accounted for close to half of all dispensing errors ($n=47$, 47%), a markedly larger share than any other agent (Table 2, Figure 2B). Amitriptyline (16%), aspirin (11%), pregabalin (8%), amoxicillin–clavulanate (7%), losartan (7%), and pantoprazole (6%) accounted for the remainder. (Product-level percentages summed to 102% in the underlying data, consistent with a small number of incidents in which more than one product was implicated.) The distribution across implicated drugs was highly non-uniform ($\chi^2=89.1$, $df=6$, $p<0.001$).

Tablets accounted for the substantial majority of dispensing errors ($n=92$, 92%), with injections and oral syrups each contributing 3% and capsules 2% (Table 3, Figure 3). This concentration was highly significant ($\chi^2=239.4$, $df=3$, $p<0.001$) and, in absolute and relative terms, considerably more pronounced than the corresponding dosage-form pattern observed for MAEs, where injectables rather than tablets predominated.

3.8 Nature and reasons for dispensing-error incidents

Dispensing of the wrong strength of a correctly identified drug was the most common type of incident, accounting for 63% of dispensing errors (Table 6A, Figure 6A). Wrong drug (12%), unprescribed drug (10%), and wrong dosage form (11%) followed; no drug being given at all accounted for 3%, and verbal disagreement between pharmacist and patient for 1%. This distribution differed markedly from chance ($\chi^2=160.6$, $df=5$, $p<0.001$).

Lack of stock of the prescribed strength was the leading reason recorded for these incidents (38%), followed by a limited range of available dosage strengths (28%) and workload (16%) (Table 6B, Figure 6B). Illegible handwriting on the prescription contributed a further 9%, while confusion, miscommunication, unidentified prescriptions, interruptions, verbal disagreement, lack of knowledge, and outright mistake collectively accounted for the remaining 9%. This distribution, too, departed significantly from a uniform spread across the eleven reason categories ($\chi^2=183.6$, $df=10$, $p<0.001$). Taken together, stock- and formulation-availability issues accounted for 66% of all recorded reasons for dispensing-error incidents at this site.

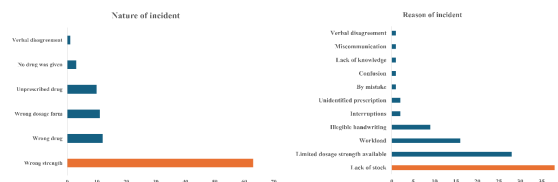


Figure 6. Nature and reasons for dispensing-error incidents.

Table 6A. Nature of incident and reason for incident in dispensing errors ($n=100$)

Nature of incident	n (%)
Wrong strength	63 (63%)
Wrong drug	12 (12%)
Wrong dosage form	11 (11%)
Unprescribed drug	10 (10%)
No drug was given	3 (3%)
Verbal disagreement	1 (1%)
χ^2 (df), p-value	160.64 (5), $p<0.001$

Table 6B. Nature of incident and reason for incident in dispensing errors ($n=100$)

Reason for incident	n (%)
Lack of stock	38 (38%)
Limited dosage strength available	28 (28%)
Workload	16 (16%)
Illegible handwriting	9 (9%)
Interruptions	2 (2%)
Unidentified prescription	2 (2%)
By mistake	1 (1%)
Confusion	1 (1%)
Lack of knowledge	1 (1%)
Miscommunication	1 (1%)
Verbal disagreement	1 (1%)
χ^2 (df), p-value	183.58 (10), $p<0.001$

3.9 Comparison between the MAE and dispensing-error cohorts

Because the two cohorts were drawn from different care settings (inpatient ward versus outpatient pharmacy counter) rather than from a single matched patient sample (Section 3.1), any comparison between them describes a difference in cohort-level error profile rather than a within-patient difference. With that caveat, three characteristics recorded identically for both cohorts — sex, age group, and dosage form — permit a direct statistical comparison (Table 7). Sex distribution did not differ meaningfully between the two cohorts (54% vs 51% male; $\chi^2=0.18$, $df=1$, $p=0.67$), indicating that whatever drives the roughly even sex split seen in each cohort separately (Section 3.2, 3.6) operates similarly regardless of error type. Age-group distribution showed a difference that did not reach conventional statistical significance ($\chi^2=9.70$, $df=5$, $p=0.084$): the MAE cohort's concentration in the 40–50-year band was visually more pronounced than the comparatively flat dispensing-error age profile (Figure 1A–B), but this study was not powered to detect a difference of this size with confidence. Dosage form, by contrast, differed sharply between the two cohorts ($\chi^2=130.6$, $df=2$, $p<0.001$ after collapsing capsule and syrup into a single ‘other’ category to satisfy minimum expected-cell-count assumptions): injectable formulations dominated the

MAE profile while tablets dominated the dispensing-error profile, a difference large enough to be visually obvious in Figure 3 and confirmed here as statistically robust rather than a product of chance sampling.

Table 7. Statistical comparison of sex, age group, and dosage form between the MAE and dispensing-error cohorts

Characteristic compared	Test	χ^2	df	p-value	Interpretation
Sex distribution	χ^2 test of homogeneity	0.18	1	0.67	No significant difference
Age-group distribution	χ^2 test of homogeneity	9.70	5	0.084	No significant difference (borderline)
Dosage form (collapsed)*	χ^2 test of homogeneity	130.57	2	<0.001	Significant difference

4. DISCUSSION

This study measured MAEs and dispensing errors concurrently within the same general medicine service, allowing direct comparison rather than reliance on separate studies with different detection methods. Errors of both kinds were common: 100 MAEs and 100 dispensing errors were identified among 80 of 226 patients screened. Both error types were predominantly low-severity, and both traced back most often to the same underlying driver — availability of drug stock and dosage strengths at the pharmacy — rather than to individual prescriber, nurse, or pharmacist performance.

4.1 Patient demographics

MAEs were concentrated in patients aged 40–50 years (35%), differing from Patel et al.'s Gujarat cohort, where the 12–32-year band was most affected [13]; published evidence linking MAE frequency to patient age (rather than to nursing demographics) is otherwise sparse. Sex was not a discriminating factor in either cohort (MAE: 54% vs 46%, $p=0.42$; DE: 51% vs 49%, $p=0.84$), consistent with Kumar et al.'s Karnataka findings [7]. The dispensing-error cohort skewed slightly younger (46.8 vs 49.7 years) with no significant age clustering ($p=0.17$), consistent with dispensing errors arising from pharmacy-side supply constraints that do not discriminate by patient characteristics. Patients over 60 years were well represented in both cohorts (25% and 26% respectively), unlike designs that exclude older adults outright — a strength given the elevated risk reported for this age group elsewhere (Section 4.6). The direct cross-cohort comparison (Section 3.9, Table 7) found no significant difference in sex ($p=0.67$) or age-group distribution ($p=0.084$, borderline), suggesting patient-level demographics are, at most, weak discriminators between who experiences an MAE versus a dispensing error here — consistent with both error types tracing chiefly to supply-side rather than patient-side factors.

4.2 Medications and dosage forms

Pantoprazole and injectable formulations dominated the MAE profile (30% and 83%). This differs in specifics from Abu-Farha et al.'s Jordanian cohort, where antimicrobials led (22.6%) [14], but aligns in principle with Brazilian ATC-classified data, where digestive-system/metabolism agents — pantoprazole's class — accounted for the largest share (30.5%) [18,19]. The 83% injectable concentration considerably exceeds the ~50% reported in the Brazilian series [19], plausibly reflecting the intensity of intravenous therapy and the additional discrete steps (reconstitution, rate calculation, line management) an injectable order requires relative to a tablet. Metoprolol accounted for nearly half of dispensing errors (47%), and tablets for the large majority of the dosage-form profile (92%) — more concentrated than the MAE dosage-form pattern, where injectables predominated. This is consistent with the different clinical contexts: the Drug Information Centre serves ambulatory outpatients on chronic oral therapy (for which metoprolol is first-line), while the inpatient ward manages more acute, injectable therapy. As Section 2.8 notes, however, none of these comparisons distinguish elevated per-exposure risk from simple prescribing volume, since exposure denominators were not available.

4.3 Contributing factors and error types

Lack of drug availability was the leading MAE contributing factor (42%), departing from Wondmienieh et al.'s Ethiopian cohort, where interruptions dominated (61%) [16] — plausibly because that study captured only nurse-reported factors and not supply-side variables. Omission was correspondingly the leading MAE error type (70%), well above the 35.9% adherence-error rate reported by Abu-Farha et al. [14] or the 32.9% time-error predominance in the Brazilian series [19]. This internal consistency — omission tracking directly with drug unavailability — suggests a single upstream cause (pharmacy stock-outs) manifesting downstream as a doses-not-given pattern. For dispensing errors, wrong-strength incidents predominated (63%), attributable chiefly to stock unavailability (38%) and a limited dosage-strength range (28%). This differs from the labelling-error pattern Dilsha et al. reported as dominant in Sri Lanka [21]; medicines at our site are dispensed in blister packs bearing only dosing-time information, without individually printed labels, which removes labelling as a category our method could capture. Workload contributed to 16% of incidents, broadly consistent with Sandeep et al.'s Trinidad findings [22], albeit at a lower share, again likely reflecting government-sector stock constraints not present in better-resourced comparator settings.

4.4 Severity

Ninety-seven of 100 MAEs fell within NCC MERP categories A–C (no harm reaching the patient, or harm-free); three (category D) required intervention, and none progressed to permanent harm or death. This is broadly consistent with Abu-Farha et al.'s finding that no MAE in their Jordanian cohort caused harm [14], but contrasts with the considerably higher harm rates in voluntary incident-reporting systems such as Norway's (62% harmful, 5.2% severe) [24] or Finland's supervisory-authority data on more serious errors [25]. This most

plausibly reflects detection method rather than underlying risk: concurrent chart review captures errors regardless of severity, whereas voluntary-reporting datasets are biased toward the more consequential incidents staff feel obliged to escalate. A Spanish mixed-method critical-care study combining chart review, direct observation, and staff interviews reported a comparably low 1.93% global error index, reinforcing that detection method and denominator choice shape the apparent severity profile as much as underlying clinical risk does [26].

4.5 Clinical and policy implications

The recurring pattern across both cohorts — omission linked to drug unavailability on the administration side, wrong-strength dispensing linked to stock-outs and a narrow dosage-strength range on the dispensing side — is consistent with pharmacy inventory management, rather than prescriber or nursing education, being a reasonable first target for intervention at this site, though the descriptive, single-centre design (Section 4.6) means this should be read as hypothesis-generating rather than established. Plausible next steps consistent with the data would include demand-forecasting for high-turnover agents such as intravenous pantoprazole and oral metoprolol, a broader stocked dosage-strength range for chronic outpatient medicines, and evaluating unit-dose dispensing or automated dispensing cabinets for high-turnover injectables, in line with ASHP guidance [2] and WHO's Medication Without Harm priorities [3]. Moving toward individually printed dispensing labels rather than blister-pack dosing times alone would directly address the labelling-adjacent incident types recorded here. Because errors at the inpatient–outpatient interface carry documented risk of their own — a systematic review reported a median 50% discrepancy rate following hospital discharge [27] — any such intervention would reasonably extend to the discharge-prescribing handoff rather than stopping at the ward or pharmacy counter.

4.6 Limitations

This study has several limitations. Four months is too short to capture seasonal variation in prescribing volume, staffing, or drug supply. No a priori sample-size or power calculation was performed, and the borderline cross-cohort age-group result ($p=0.084$) may reflect insufficient power rather than a genuine absence of difference. Neither prescribing-volume nor dispensing-volume denominators were available, so the chi-square comparisons for implicated drug and age group (Section 2.8) cannot distinguish elevated per-exposure risk from simple prescribing or ward-demographic frequency; this applies with less force to the error-classification variables (contributing factor, error type, severity, nature/reason for incident), which have no equivalent volume confound. Pediatric and pregnant patients were excluded, limiting generalizability to those groups, who carry distinct, well-documented risk elsewhere [28,29]. Patients over 60 years were well represented but not separately stratified, so this study cannot confirm whether risk factors reported for older or chronically ill patients elsewhere [30,31] apply with the same weight here. The study was single-centre, limited to the General Medicine department and Drug Information Centre, so findings should not be extrapolated elsewhere without

independent verification. Error detection relied on retrospective and concurrent record review rather than continuous direct observation, which will under-detect errors leaving no written trace and may understate the true error rate relative to direct-observation studies [14,17]. The two cohorts were drawn from different care settings rather than a single matched sample, and the data do not permit determining patient-level overlap (Section 3.1); the Section 3.9 comparisons should be read as comparing cohort-level profiles, not paired outcomes. Finally, all associations reported are descriptive; no multivariable adjustment was performed, so none of the comparisons above establish an independent or causal relationship.

4.7 Future directions

Larger, multi-centred, longer-duration studies incorporating direct observation alongside chart review, and ideally capturing prescribing- or dispensing-volume denominators, would yield more robust and generalizable estimates and would let per-exposure error rates be distinguished from prescribing-frequency effects. Studies powered for multivariable regression could help disentangle patient-, staffing-, and supply-level predictors that this descriptive design cannot separate. Given the consistency with which pharmacy stock availability emerged as a shared candidate root cause across both cohorts, a targeted before-after evaluation of an inventory-management or unit-dose dispensing intervention at this site would be a logical next step.

5. Conclusion

In this general medicine service of a government tertiary care hospital in southern India, MAEs and dispensing errors were each identified in 100 instances among 80 of 226 patients screened over four months. Both error types were dominated by a small number of implicated drugs and dosage forms — pantoprazole and injectables on the administration side, metoprolol and tablets on the dispensing side — and both were, in the great majority of cases, low in severity: 97% of MAEs reached NCC MERP category C or below, and no error in either cohort resulted in permanent harm or death. Lack of drug availability and a limited stocked dosage-strength range were the largest identifiable driver of error on both sides of the medication-use process. This is consistent with pharmacy inventory management and dosage-strength range, rather than individual prescriber, nursing, or pharmacist performance, representing a priority target for quality-improvement efforts at this institution, pending confirmation in the prospective, multi-centre studies outlined above.

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