ORIGINAL ARTICLE

Evaluation of Medication Errors among Inpatients in a Tertiary Government Hospital's Pulmonary Medicine Service: A Cross-sectional Retrospective Study

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ABSTRACT

Background and Objective. Medication errors pose substantial risks in hospitals, particularly concerning patient safety. These errors, occurring throughout the medication use process, are one of the most common causes of morbidity and mortality in clinical practice. In the Philippines, there is a lack of evidence on the prevalence and effects of medication errors, emphasizing the need for further investigation. This study evaluated the prescribing, transcribing, and monitoring errors among inpatients under the Pulmonary Medicine Service of the Department of Medicine in the Philippine General Hospital.

Methods. This cross-sectional retrospective records review used the total population purposive sampling technique to examine eligible charts of inpatients with asthma and/or COPD from August 1 to December 31, 2022. The frequency, type, and severity of medication errors were determined. Linear regression and Cox proportional hazards models were used to examine the relationship between patient-related factors and medication errors, and length of hospital stay and mortality.

Results. Fifty (50) out of 226 medical records were processed and analyzed. Included patients were predominantly older male adults. More than two-thirds of the patients were diagnosed with COPD while approximately one-fourth suffered from asthma. All patients were practicing polypharmacy and the vast majority presented with comorbidities. A total of 6,517 medication errors, predominantly prescribing errors (99.1%), were identified. Despite the high prevalence of medication errors, the majority were classified as "error, no harm" (98.8%), while only 1.17% were deemed as "error, harm." As the frequency of prescribing errors increases in the power of three (rough approximation of e), from 1 to 3 to 9 to 27, etc., the expected hospital stay increases by 2.078 days ($p < 0.001$) (e.g., $3^2 = 9$ errors with LOS of around 4 days); meanwhile, more severe transcribing errors increase the length of stay by 4.609 days ($p = 0.034$) All independent variables were noted to have a lack of significance and thus no meaningful patterns in the data related to patient mortality were identified, primarily due to the insufficient amount of observed mortality in the included sample.

Conclusion. All eligible patient charts had at least one medication error, with the majority being prescribing errors. Among the variables, prescribing errors significantly affected the length of stay, while severity of transcribing errors had a marginally significant effect. It is essential to develop comprehensive education and training initiatives and adopt a systematic approach to mitigate medication errors and promote patient safety.

Keywords: medication errors, patient safety, pulmonary medicine

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INTRODUCTION

Overview of Medication Errors and their Significance in Healthcare

Medication errors pose substantial concerns in global healthcare, especially in aspects of patient care and healthcare costs. One of the primary contributors to injuries and preventable harm in healthcare systems worldwide are unsafe and irrational medication practices and errors, wherein medication harm accounts for more than half of the overall preventable harm in medical care.[1,2] Although consequences of medication errors in the Philippines have not yet been fully examined due to the lack of literature characterizing their clinical or economic impact, such medication errors are associated with high mortality rates in the United States of up to 9,000 deaths per annum and alarming costs estimated up to $42 billion annually.[3,4]

The National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP) defines 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 the healthcare professional, patient, or consumer. Such events may be related to professional practice, health care products, procedures, and systems, including prescribing; order communication; product labeling, packaging, and nomenclature; compounding; dispensing; distribution; administration; education; monitoring; and use.[5] Medication errors can occur due to a multitude of factors such as fatigue, poor communication, inconducive environmental factors, inexperienced staff, complex treatment regimen, multimorbidity, and others which affect the different stages of the medication use process including prescribing, transcribing, dispensing, administration, and monitoring practices.[3,4,6] Such errors in the patient's treatment process can lead to or have the potential to harm patients, most of which lead to severe harm or potentially life-threatening situations while some result in disability and even death.[3,4,7]

Medication errors are a complex problem that requires a broader understanding and a systematic approach to fully comprehend and address its underlying factors. Medication errors are not due to a single cause but a result from a combination of a wide variety of individual and systemic factors. A thorough examination of the medication use process shows that ineffective workflows, poor communication among healthcare professionals, lack of standardized protocols, inadequate training, and ineffective use of technology frequently result in medication errors.[8,9] These multiple interconnected factors within the healthcare system can be addressed through the implementation of effective strategies such as standardized communication tools, workflow redesign, continuous professional education and training, interprofessional collaboration, and effective integration of technology.[10,11] Through appropriate consideration of all these factors, the healthcare system can efficiently mitigate medication errors and promote patient safety. Employing a system perspective on medication errors reveals that errors are not solely because of healthcare professionals, but due to a multitude of factors.[12] Thus, a holistic approach should be adapted to minimize errors and optimize treatment outcomes.

Background on Asthma and Chronic Obstructive Pulmonary Disease (COPD)

Respiratory diseases have a significant impact on public health globally, including in the Philippines. Pulmonologists play a crucial role in managing chronic respiratory diseases, such as asthma and COPD,[13] which have a significant burden in the Philippines. Additionally, since the treatment regimens of respiratory conditions are complex more often than not, clinical pharmacists can provide specialized expertise in medications, optimizing drug therapy for patients with respiratory conditions. Both the pulmonologist and pharmacist can provide personalized treatment plans and help them effectively manage symptoms and medications for long-term control and improved quality of life, making them indispensable in the healthcare team.[13,14]

According to the Global Asthma Report 2022, 74% of global deaths were due to NCDs with approximately 4 million deaths due to chronic respiratory diseases. In the same year, it was noted that approximately 262 million people worldwide were affected by asthma with 461,000 deaths – more than 1,000 per day. Meanwhile, an estimated 384 million individuals were diagnosed with COPD. It is known as the third leading cause of death worldwide, causing approximately 3.23 million deaths in 2019.[15,16]

In the local context, it has been reported that approximately one out of ten Filipinos suffer from asthma, with a prevalence amounting to about 12% of the Philippine population.[17] Meanwhile, COPD ranks 5th in terms of leading causes of mortality in the Philippines.[18]

With the given background, it is imperative to determine and examine the medication errors involved with patients diagnosed with asthma and COPD in the Philippines due to their intricate treatment regimens, encompassing diverse medication classes and delivery modalities. These respiratory conditions pose various challenges due to polypharmacy and patient-specific needs. These conditions' prevalence, coupled with the potential for drug interactions and adverse events, underscores the need for a thorough investigation and comprehension of the factors contributing to medication errors in their management.

Prevalence of Medication Errors in Hospitals

The existing literature on medication errors in Pulmonary Medicine is limited, and there are several gaps in establishing the relationship between medication errors and clinical outcomes of patients with asthma and/or COPD, especially in the Philippine setting. In the hospital setting, medication errors are considered as one of the most common causes of morbidity and mortality, and have become a serious problem

worldwide in clinical practice.[19] Studies involving tertiary care hospitals and public hospitals in different countries have shown that medication errors happen all throughout the medication use process with either the physician, nurse, or pharmacist playing a significant role in the occurrence of these errors.[19-23] The prevalence of medication errors in tertiary hospitals vary, and data from the Southeast Asia region are still limited. Despite this, the high patient load in these hospitals, in addition to other pressing factors, contribute to the greater impact of medication errors in inpatient settings.[24]

In the Philippines, the culture of patient safety among health workers is just beginning to be explored. The overall prevalence of medication errors in the country is still yet to be determined; however, WHO has identified key factors contributing to medication errors which include staff shortage, high workload, and lack of health-worker experience.[25] Few studies have also been conducted on some hospitals such as in the case of Philippine General Hospital (PGH) which is known to be the biggest tertiary hospital in the country.[26] In the study of Pasco et al.,[22] it was found that there is a high prevalence of medication errors in the main service wards with prescribing as the most common type of medication error (e.g., illegible order, incorrect abbreviation, no dose, no route, and no duration).

A study by Pasco et al.[22] highlights the need for determining the frequency and specific types of medication errors in PGH due to the observable increasing trend in the number of deaths from medication errors in the United States. The impact of medication errors extends across a wide variety of outcomes including health and economic consequences. Medication errors contribute to approximately one out of every 131 deaths among outpatients and one out of every 854 deaths among inpatients.[27] Aside from mortality, these errors greatly influence the hospital stay of patients. Consequently, prolonged hospital stay disrupts overall patient recovery and increases risk for other complications, especially in low- to middle-income countries.[28] In line with this, patients who experienced medication errors may require further treatment and additional interventions which may lead to increased economic burden. These consequences emphasize the necessity to establish efficient cultures of safety across healthcare organizations in order to promote system improvement and develop effective interventions towards recognizing and reporting safety concerns.[3,29]

Essentially, this emphasizes the need to address the possible medication errors related to patients' admissions, investigate the factors influencing mortality rate and patients' length of hospital stay (LOS), and provide significant insights on the medication safety practices in the PGH. Specific types of medication errors such as dispensing and administering errors were not studied due to the possible lack of documentation for such processes. Thus, the researchers only selected prescribing, transcribing, and monitoring errors, as well as the specific subtypes of these medication errors which can be identified in the patients' medical charts. Nonetheless, there is a compelling need to investigate the prevalence of medication errors among inpatients in the Pulmonary Medicine of the Department of Medicine at PGH in order to help explore the impact of such errors and provide substantial insights on opportunities for improvement in the tertiary government hospital's current medication safety protocol and practices.

OBJECTIVES

This study aims to evaluate the medication errors (i.e., prescribing, transcribing, monitoring) among inpatients provided with services from the Pulmonary Medicine Service of the Department of Medicine in the Philippine General Hospital. Specifically, it aims to: (1) describe the characteristics of diagnosed inpatients with asthma and/or COPD, (2) identify the frequency, types, and severity of medication errors, and (3) examine the relationship between medication errors and patient-related factors, and clinical outcomes (i.e., length of hospital stay and mortality).

MATERIALS AND METHODS

Study Design

This study utilized a cross-sectional retrospective records review study design. The retrospective approach involved the review and analysis of existing patient medical charts in the Philippine General Hospital's RADISH from August 1, 2022 to December 31, 2022 to reach a minimum of 50 eligible charts. This allowed for the collection of data without directly interfering with the healthcare processes or patient care. By retrospectively examining these charts, the study gathered comprehensive data on the types, frequency, and severity of medication errors that had previously taken place within the Pulmonary Medicine Service. The records review aspect of the study involved the objective collection and analysis of data without any direct intervention or manipulation of variables since the researchers observed and documented medication errors as recorded in the medical charts (RADISH).

Study Setting

The study site was the Philippine General Hospital which is considered to be the biggest tertiary hospital in the country. It is located in Metro Manila, and provides services to approximately 800,000 patients annually from different areas of the Philippines.[26] The study focused primarily on the service of the Pulmonary Medicine division of PGH.[30]

Sampling Design

Population and Sampling Technique

In this study, the target population was derived from the patient medical charts of inpatients diagnosed with asthma or COPD who were provided with services from the Pulmonary Medicine Service of the PGH from August 1,

2022 to December 31, 2022. Since the steps in conducting a records review are similar to the procedures of a drug utilization review, the researchers made use of the WHO[31] recommended minimum number of medical records to obtain meaningful results. Thus, the researchers utilized a sample size of at least 50 patient medical charts.

The inclusion criteria of the study are: (1) inpatients with documented medical records in RADISH available for review; (2) admitted during a defined period of December 1, 2022 to December 31, 2022 or even earlier within the preceding period (going back to November 30) until a minimum of 50 eligible charts have been reached; (3) diagnosed with asthma and/or COPD; (4) aged 18 years or above who were provided with services from the Pulmonary Medicine Service of the Department of Medicine of the Philippine General Hospital for a minimum of 24 hours; and (5) received at least one prescribed medication during the hospital stay from the Pulmonary Medicine Service of the Department of Medicine of the Philippine General Hospital. Meanwhile, the exclusion criteria are: (1) patients admitted before the institution of RADISH in PGH (before 2020); (2) decided to go home against medical advice (i.e., HAMA) during the hospital stay; and (3) second and succeeding admissions of patients who were provided with services more than once by the Pulmonary Medicine Service on or before December 31, 2022.

This exclusion criteria minimized potential bias of historical changes due to possible differences in protocols or interventions prior to and following the institution of RADISH. In addition, this study focused only on the first admission for patients admitted multiple times to help maintain independence of observations, avoid duplication of data, and reduce bias associated with the previous hospitalizations of the same patient.

The study utilized the total population sampling technique to identify and select eligible patient medical charts based on the aforementioned inclusion and exclusion criteria, wherein the total charts screened served as the total population used for the study. This type of purposive sampling was used to treat and consider the whole population of interest (i.e., all charts fulfilling the inclusion criteria) as a sample which enabled the study to meet the required minimum number of patient records to obtain meaningful results and to reduce risks of missing potential insights. The purposive sampling procedure was performed through the evaluation and review of the electronic medical charts (RADISH) in order to select eligible patient charts admitted on or before December 31, 2022 with Pulmonary Medicine Service as the primary or as a co-managing service.

Data Collection Procedure

Medical Records Access and Retrieval

The medical records were acquired from the Health Information Management Division (HIMD) of the PGH Expanded Health Research Office (EHRO), and prior to accessing and reviewing these, necessary approvals and permits were obtained from the University of the Philippines Manila Research Ethics Board (UPMREB) and the hospital's EHRO. The medical records from PGH were accessed electronically through RADISH, which records patient charts within the said hospital.

The researchers were only able to access the records of specific inpatients with case numbers and passcodes provided by PGH-HIMD for a limited duration of time. This enabled the HIMD to oversee the extraction of patient information from the database. Furthermore, the researchers were strictly prohibited from sharing the database entries from the RADISH database through photography (e.g., mobile camera) to ensure the confidentiality of the viewed patient information.

Screening and Extraction

The initial screening of the medical records was conducted with the assistance of an HIMD personnel who gave the list of case numbers and respective passcodes of inpatients with a diagnosis of asthma and/or COPD and were admitted in PGH from December 1, 2022 to December 31, 2022. The researchers further screened the cases according to the inclusion and exclusion criteria, and in order to meet the minimum number of 50 eligible charts, records of inpatients admitted in PGH were extended from December 2022 to August 2022. Following this, the researchers de-identified the patient charts for data extraction. The charts were only accessed one at a time and were only viewed to extract pertinent information needed in the study. Afterwards, the cases were transcribed by the researchers into a spreadsheet in an electronic workbook created through Microsoft Excel which was used throughout for screening, extraction, processing, and analysis of data.

Firstly, the assigned service was checked to confirm if the patient has asthma and/or COPD and was provided with services from the Pulmonary Medicine Service. Then, the admission date was checked. After this, only patients aged 18 or above who received at least one prescribed medication during the hospital stay were included. It was also noted that only patients admitted and provided with services from Pulmonary Medicine Service for a minimum of 24 hours between the study period were included. After comparing the provided charts for December 2022 with the study's inclusion and exclusion criteria, it revealed a shortfall of 50 charts. Thus, the researchers requested additional patient charts from the HIMD extending up to the month of August 2022.

Upon reviewing individual RADISH charts, if a patient's chart did not meet the prior inclusion criterion, the subsequent information was no longer added to the Raw Summary of Patient Information spreadsheet (Appendix A). The eligible cases, on the other hand, were coded and transferred to the Summary of Processed Data spreadsheet. The coding was manually entered, with a drop-down list on

some, according to the order done for the initial screening using the Coding Manual. Following this, data was processed to assess the frequency, type, and severity of medication errors present using the checklist and NCC MERP flowchart in the same workbook. These were then encoded back into the said spreadsheet.

Instrumentation

The study utilized Microsoft Excel to access the workbook containing the collected data. This includes the spreadsheets for the raw summary of patient information, self-developed checklist, summary of processed data, coding manual, and the flowchart for the classification of severity of medication errors based on the NCC MERP algorithm. The access was restricted by encrypting it with a password known only to the researchers.

The workbook was designed with specific columns to gather information from patients' medical charts, including age, sex, patient status, admission date and time, discharge date and time, pulmonary diagnosis, medications, comorbidities/assessments, and monitoring parameters (e.g., SpO_2, RR, HR). For classifying medication errors according to the medication use process, the study utilized a self-developed checklist. Additionally, the severity of medication errors was categorized using the Flowchart for Classification of Severity of Medication Errors based on the NCC MERP algorithm (Appendix B), which has been internationally validated.[32,33] The NCC MERP has four degrees of error, namely no error; error, no harm; error, harm; error, death. These degrees were used for classifying the severity of the medication errors identified during the study, except for the degree "error, death" as this could lead to perfect correlations with death cases when assessing the relationship of the variables of the study with mortality. The actual index Categories A to I of the NCC MERP classification was not utilized due to the inherent limitation of a retrospective records review wherein the severity cannot be further investigated and classified. Therefore, only three degrees of error were included.

The checklist used to classify the stage of medication use where medication errors occurred was developed by the researchers based on previous studies assessing medication errors in other countries[23,34,35] and inputs from SMEs (i.e., PGH pharmacists). This checklist served as a guide to identify and categorize medication errors within individual medical charts. The checklist was divided into three main types of errors corresponding to different stages of the medication use process, excluding dispensing and administering due to study limitations. Therefore, the study specifically focused on errors occurring during: (a) prescribing, (b) transcribing, and (c) monitoring. Each type of error within the checklist contained entries detailing subtypes of errors that could occur within the respective stages of the medication use process (e.g., drug interaction, wrong patient, not monitored for safety).

Data Processing and Analysis

Identifying Frequency, Type, and Severity of Medication Errors

A one-day observer training session provided researchers with adequate knowledge and skills to identify and analyze various types and severities of medication errors. Additionally, researchers assessed the appropriateness of treatment regimens based on CPGs such as Global Initiative for Asthma (GINA) and Global Initiative for Chronic Obstructive Lung Disease (GOLD), as well as other reliable references such as UpToDate. The researchers utilized the self-developed checklist to document the observed errors from each patient chart and identify the different types of medication errors throughout the medication use process (Appendices B and C). The eligible cases were individually examined by two researchers, and the third researcher served as the arbiter when disagreements arose, and no consensus was reached between the two. Consultations with the co-investigator were also conducted to assist the researchers in identifying and analyzing medication errors and addressing other concerns in the study when discrepancies were found.

To streamline the process, a separate sheet within the MS Excel workbook was designated for the checklist itself (Appendix D). This enabled the researchers to mark the relevant cells corresponding to each patient's medical chart. For instance, if there was an issue with the frequency of medication administration for a particular patient, the researcher responsible for that patient's chart would record the number of errors corresponding to the cell labeled "inappropriate frequency" under the category of "prescribing errors."

As mentioned, the Flowchart for Classification of Severity of Medication Errors based on the NCC MERP algorithm was used to determine the severity of medication errors. Similar to the checklist sheet, a distinct sheet was created in the MS Excel workbook specifically for the flowchart. However, unlike the interactive nature of the checklist sheet, this separate sheet solely served as a reference guide for choosing the severity level of medication errors on the main sheet. In the MS Excel workbook, the Summary of Processed Data spreadsheet was dedicated to summarizing processed data, such as the patient's record number, patient status, age, sex, number of medications, pulmonary diagnosis, presence of comorbidities, and LOS. The corresponding codes of the attributes were input into the appropriate cells (Appendix E).

The same sheet also included separate columns for recording the frequency, type, and severity of medication errors. The frequency of errors was based on the exact number of medication errors found in each medical chart using the self-developed checklist. It should be noted that multiple errors could be identified under one type of medication error. For instance, one medical chart had multiple errors

in the prescribing process (e.g., inappropriate dosage form, duplicate therapy, and no indication). Each error was counted as one medication error; thus, such a medical chart had three prescribing errors in total. Meanwhile, the type of medication error was recorded as is. Then, to input the severity level, which corresponded to one of the three degrees of severity, the researchers selected the appropriate classification from a drop-down list in the cell, following the NCC MERP algorithm.

Statistical Analysis

Frequency statistics and percentages were used to describe sociodemographic variables and the presence of medication errors and their corresponding type and severity. After identifying the cases with medication errors, the frequency and percentage of the corresponding attributes of the independent variables were presented. The overall prevalence rate of medication error was calculated by identifying the number of cases in which medication error had been identified divided by the total number of medical charts, and multiplied by 100.

Multiple linear regression was also used in the study to examine the relationship between the LOS, a continuous dependent variable, and multiple independent variables which include age, sex, number of medications, diagnosis, comorbidities, frequency of prescribing errors, frequency of transcribing errors, frequency of monitoring errors, severity of prescribing errors, severity of transcribing errors, and severity of monitoring errors. The use of such analysis allowed the researchers to examine the combined effect of the independent variables identified in the study on the LOS of patients provided with services from Pulmonary Medicine Service in the Department of Medicine at PGH, creating an accurate prediction on the level of effect these independent variables have on the outcome.

To account for another important consideration in the study which is patient mortality, a survival model was necessary for analysis. The study utilized Cox Proportional Hazards model, a general linear model which is similar to a regression model, but makes use of time-to-event (mortality) hazard rates as the dependent variable. The hazard rates for different groups, which were determined by the covariates, were proportional over time. This model aimed to explain how the predictor variables—termed as covariates—influence the hazard function which represents the instantaneous probability of death occurring at a given time, assuming that it has not happened until that time.[35] Contrary to the four classifications of severity of medication errors that was used in Multiple Linear Regression, the severity for the Cox Proportional Hazards consisted only of three groups wherein "Error, Harm" and "Error, Death" were combined.

Ethical Considerations

The information gathered from all medical charts was treated with utmost privacy and confidentiality in accordance with the Data Privacy Act of 2012 or RA 10173. Personal information obtained from the study was not disclosed to third parties or other individuals outside the research group. Patients' demographics were kept anonymous as evidenced by the use of codes in data extraction (e.g., Record 001, Record 002). All information gathered was used for this study only.

The research proposal of this study was sent and reviewed by the University of the Philippines Manila Research Ethics Board (UPMREB) as well as the Expanded Hospital Research Office (EHRO) for approval with an approval code of UPMREB 2023-0794-UND. In close coordination with these authorities and with collaboration with the Health Information Management Division (HIMD), the research study was conducted in PGH through accessing and screening patients' medical records.

All data was saved in an encrypted file where the password for such file and passcodes for all included medical records were provided to the investigators only. The investigators' personal devices, which were used to access the encrypted file, were also protected with strong passwords. Data was saved in a flash drive for the duration of the study until five years from the date of submission of the final manuscript to ensure validity and reliability of collected data. After which, the data will be destroyed for security purposes through permanently deleting all files pertaining to the records and not keeping any copies of them.

This study posed a minimal risk due to the use of personal computers and gadgets for viewing medical records. Such risk can be attributed to data storage, use, and protection. However, the researchers ensured that the data was accessible to themselves only and such data was used only for the purpose of this study.

RESULTS

Figure 1 shows the flow of screening of eligible medical records. The researchers were able to screen 226 medical records of patients admitted during August 2022 to December 2022. Among the 226 medical records individually reviewed, 57 (25.22%) charts remained after the preliminary screening. However, further screening led to the removal of seven charts, six of which were identified to be patients who opted to go home against medical advice (HAMA) and one patient who was handled by the Pulmonary Medicine service for less than 24 hours. With this, only 50 out of 226 (22.12%) medical charts met the inclusion criteria, and were therefore processed and analyzed.

In Table 1, a preliminary analysis was performed on the cohort data with an overview of their general demographic indicators. Provided in this table are the count and percentage frequency distributions of their age, sex, pulmonary diagnosis, number of medications, comorbidity status, and status as either expired or improved.

Age distribution among the patients indicates that a significant majority are older, with 72% being over the age of 60. Those aged between 40 and 59 comprise 20% of the

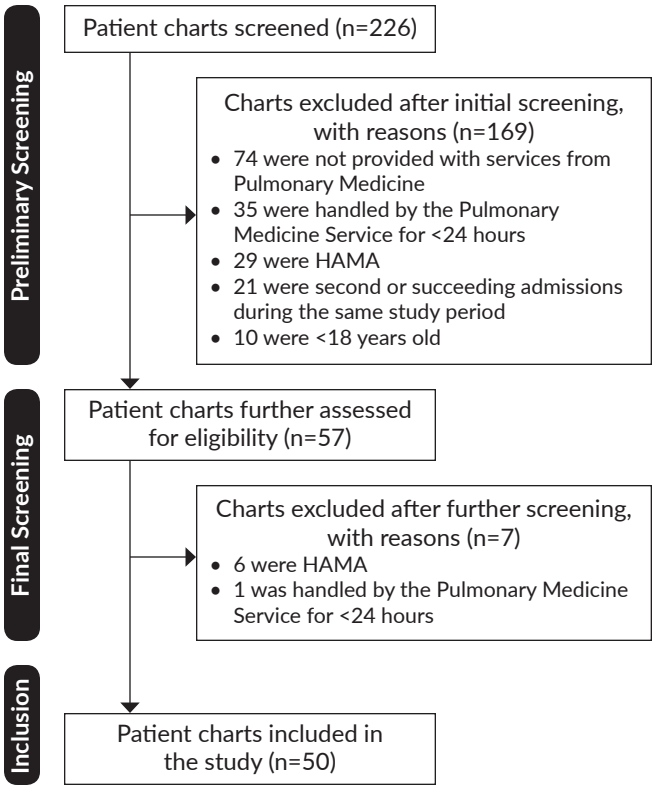

Figure 1. Identification of eligible medical records.

Table 1. General Demographic Indicators (n = 50)

Indicator	Level	Frequency	%
Age	Younger than 40	4	8.0
	40 to 59 years	10	20.0
	60 or older	36	72.0
Sex	Female	16	32.0
	Male	34	68.0
Diagnosis	Asthma	13	26.0
	COPD	32	64.0
	Asthma and COPD	5	10.0
Number of medications	Less than 5	0	0.0
	5 or more	50	100.0
Comorbidities	With	48	96.0
	Without	2	4.0
Status	Expired	2	4.0
	Improved	48	96.0

cohort, while the youngest group, under 40, makes up 8%. Gender distribution shows a notable imbalance, with males representing 68% of the cohort and females making up 32%. In terms of diagnosis, a substantial proportion of patients, 64%, are diagnosed with COPD. Patients with asthma alone constitute 26%, while those diagnosed with both asthma and COPD account for 10%. When examining comorbidities, a striking 96% of the patients have additional health conditions, indicating that comorbidity is highly prevalent in this cohort. Regarding patient outcomes, the data reveals a highly positive trend, with 96% of patients showing improvement and only 4% resulting in death.

Also focusing on some overview of general descriptive statistics, Table 2 shows some summary measures of the LOS in days, as well as the total frequency per patient of medication errors. The mean LOS is 8.4 days, with a standard deviation of 4.2 days. The shortest recorded stay is 2.6 days, while the longest extends to 18.1 days. This range highlights significant differences in individual patient experiences, potentially influenced by the severity of their conditions, the presence of comorbidities, and the occurrence of medication errors. The mean number of errors per patient is 130.3, with a substantial standard deviation of 94.9. The minimum recorded number of errors is 2.0 while the maximum number of errors recorded for a single patient is an alarming 392.0, underscoring the potential for significant patient safety issues.

In Table 3, the frequency and number of patients that experienced medication errors, divided into its three major types: prescribing error, transcribing error, and monitoring error are shown. It can be observed that prescribing errors dominate the landscape, constituting 99.1% of the total recorded errors. This indicates that nearly all medication errors are related to the prescribing process, highlighting a significant area for potential intervention. The universal presence of prescribing errors, experienced by 100% of the patients, underscores a systemic issue that may impact patient safety and outcomes substantially. However, transcribing errors are exceptionally rare, accounting for only 0.046% of the total errors. Monitoring errors, occur in 0.8% of the total cases. These errors are experienced by 38% of the patients, indicating that while they are less frequent than prescribing errors, they are not uncommon.

Table 4 looks at the major types of errors again, but this time cross-classifying them with the level of harm that occurred. Notably, prescribing errors are the most

Table 2. Summary of Length of Hospital Stay and Frequency of Medication Errors

	Length of Stay	Frequency of Medication Errors
Mean	8.4	130.3
SD	4.2	94.9
Min	2.6	2.0
Max	18.1	392.0

Table 3. Frequency and Patient Counts per Type of Error

	Total Errors		Patients	
	Frequency	%	Frequency	%
Prescribing Error	6459	99.1	50	100.0
Transcribing Error	3	0.0	3	6.0
Monitoring Error	55	0.8	19	38.0
Total	6517	100.0		

Table 4. Patient Counts per Severity and Type of Error (n = 50)

	Did Not Occur		Error, No Harm		Error, Harm	
	Frequency	%	Frequency	%	Frequency	%
Prescribing Error	0	0	39	78	11	22
Transcribing Error	47	94	3	6	0	0
Monitoring Error	31	62	19	38	0	0

Table 5. Frequency per Severity and Type of Error (n = 6517)

	Error, No Harm		Error, Harm	
	Frequency	%	Frequency	%
Prescribing Error	6383	98.8	76	1.2
Transcribing Error	3	100.0	0	0.0
Monitoring Error	55	100.0	0	0.0
Total	6441		76	

pervasive—0.0% of patients were error-free in this category. Among these patients, 78.0% experienced prescribing errors that did not result in harm, indicating that while errors are common, most do not cause immediate adverse effects. However, the remaining 22.0% of patients suffered harm due to prescribing errors. Transcribing errors are comparatively rare, with 94.0% of patients unaffected by such errors. For the 6.0% of patients who did experience a transcribing error, none resulted in harm, pointing to a relatively benign nature of these errors within this cohort. Monitoring errors were absent in 62.0% of the patients, indicating that almost two-thirds of the cohort did not encounter such errors. However, for the 38.0% of patients who experienced monitoring errors, none of these errors resulted in harm.

In Table 5, the level of harm was cross-classified with the type of error in terms of raw frequency. Prescribing errors are overwhelmingly the most common, with a total of 6,383 instances where these errors occurred without causing harm. However, there were still 76 instances where prescribing errors led to harm. In contrast, transcribing errors are exceedingly rare, with only 3 instances recorded where the error occurred without harm. Monitoring errors, similar to transcribing errors, are infrequent, with 55 total instances of such errors occurring without harm.

In Table 6, the typology of errors is expanded to their specific subtypes and to identify which among them are more pervasive in terms of frequency. Beginning with prescribing errors, the most prevalent subtype is incomplete prescription, where 4,052 instances, or 62.7% of all prescribing errors, involve missing elements such as generic names, dosage strength, dose, dosage form, route, or frequency. Drug interactions are the second most common subtype, with 1,176 instances, accounting for 18.2% of prescribing errors. Unofficial abbreviations also constitute a notable proportion, with 891 instances (13.8%), which poses risk due to possible misinterpretations. This is followed by incomplete review of medications (145 instances, 2.2%), reflecting discrepancies in encoding medication orders across different healthcare providers. Meanwhile, transcribing errors are relatively rare compared to prescribing errors, but they still pose significant risks. Among the subtypes, double entry in RADISH inpatient charts accounts for all three recorded transcribing errors (100.0%). On the other hand, the most common monitoring error subtype is the failure to monitor for safety, with 27 instances, representing 49.1% of monitoring errors. Similarly, 14 instances each (25.5%) involve failures to monitor for effectiveness and results not being available.

A regression analysis is performed on the LOS with the patients' demographic indicators, as well as whether they experienced a number of, or a level of severity of the three types of errors discussed in the preceding results. The results of the regression analysis, as well as some tests for diagnostics and model fit, are provided in Table 7.

First, the results of the full model are discussed. This represents the model proposed in the methodology, including all factors and without removing any insignificant indicators. In this model, the intercept estimate is -1.772 with a p-value of 0.651. This value represents the baseline LOS when all other variables are zero, although it is not statistically significant, indicating that the baseline LOS is not reliably different from zero. The log frequency of prescribing errors has a coefficient of 1.779, meaning that as the frequency of prescribing errors increases in the power of three (rough approximation of e),

Table 6. Frequencies over Specific Subtype of Errors

Type	Subtype	Frequency	%
Prescribing	Unclear or no medical indication	4	0.1
	Contraindication	0	0.0
	Inappropriate dosage strength	24	0.4
	Inappropriate dose	5	0.1
	Inappropriate dosage form	6	0.1
	Inappropriate frequency	33	0.5
	Inappropriate duration	3	0.0
	Duplicate therapy	36	0.6
	Drug interaction	1176	18.2
	Brand prescribing	10	0.2
	Incomplete prescription	4052	62.7
	Incomplete review of medications	145	2.2
	Unofficial abbreviations	891	13.8
	Others	74	1.1
	Total	6459	100.0
Transcribing	Wrong patient	0	0.0
	Double entry in RADISH inpatient charts	3	100.0
	Total	3	100.0
Monitoring	Not monitored for safety	27	49.1
	Not monitored for effectiveness	14	25.5
	Results not available	14	25.5
	Total	55	100.0

Table 7. Regression Model on Length of Hospital Stays

Variable	Full Model			Restricted Model		
	Est	S. Err.	*P*	Est	S. Err.	*P*
Intercept	-1.772	3.890	0.651	-1.274	2.459	0.607
Age	0.009	0.047	0.849			
Female	0.471	1.398	0.738			
Diagnosis: Asthma	1.111	1.849	0.552			
Diagnosis: COPD	0.002	2.316	1.000			
With Comorbidities	0.428	3.078	0.890			
Log (Prescribing: Frequency)	1.779	0.766	0.026	**2.078**	0.535	<0.001
Monitoring: Frequency	0.098	0.381	0.799			
Prescribing: Severity	2.283	1.371	0.104			
Transcribing: Severity	4.763	2.366	0.051	**4.609**	2.113	0.034
Monitoring: Severity	-0.801	1.599	0.619			
Model Fit						
R^2	0.397			0.333		
Adjusted R^2	0.242			0.304		
F Test	2.564		0.017	11.710		<0.001
Breusch-Pagan	2.490		0.991	0.258		0.879
Shapiro-Wilk	0.965		0.148	0.959		0.082

[a] *Frequency of Transcribing Errors omitted since max is only 1, all with same severity. This will cause a collinearity issue if both severity and frequency are in the equation.*

from 1 to 3 to 9 to 27, etc., the expected hospital stay increases by 1.779 days or ~2 days (e.g., $3^2 = 9$ errors with LOS of around 4 days). This effect is statistically significant with a p-value of 0.026, indicating a significant impact of prescribing errors on the LOS. Meanwhile, the severity of transcribing errors has a large estimate of 4.763, indicating a substantial increase in hospital stay by 4.763 days for more severe transcribing errors. The p-value is 0.051, which is marginally significant, suggesting that the severity of transcribing errors might have a considerable impact on the LOS.

In terms of model fit, the model explains a moderate portion of the variance in hospital stay length, with an R^2 value of 0.397, and an adjusted R^2 of 0.242. This suggests that approximately 39.7% of the variability in LOS can be explained by the model. However, the adjusted R^2, which accounts for the number of predictors, indicates that about 24.2% of the variability is explained when adjusting for the number of predictors in the model, making this more suitable for interpretation. The F-test statistic is 2.564 with a p-value of 0.017, indicating that the model as a whole is statistically significant and provides a better fit than a model with no predictors.

However, it is noted that given the limited number of observations in the data (50 patients overall), it is important to restrict the model as a robustness measure since the inclusion of many insignificant variables takes up degrees of freedom that might otherwise prove the significance of a few, strong predictors in the set. In the Restricted Model, the insignificant demographic indicators were removed, keeping only pairs of frequency and severity measures for the types of error. Thus, only the frequency of prescribing errors remains significant with an effect of 2.078 ($p < 0.001$) which means that every increase in errors to the power of three generally adds (+) 2 days to a patient's expected hospital stay. Meanwhile, the severity of transcribing errors is now much more significant ($p = 0.034$) than its baseline status in the full model, wherein harm caused by such errors has been found to increase expected hospital stays by (+) 5 days.

Overall, the model retains its strong fit, even retaining more Adjusted R^2 to 0.304, and a significant Overall F Test ($p < 0.001$). It should also be noted that the model passes a heteroskedasticity test using the Breusch-Pagan method ($p = 0.991$ for the Full model, $p = 0.879$ for the Restricted model). The Shapiro-Wilk test shows some slight deviation from normality, but failure to meet our threshold means that this has not entered into a region that might render our analysis invalid.

A notable observation to be made in the model is that the frequency of prescribing errors has been log-transformed as a predictor. This is to address the non-linearity present in the association between prescribing errors and hospital stay. Figure 2 shows the fitted regression line for this covariate, which shows how the log-transformed predictor changes the linear regression model into one that accommodates this nonlinearity better.

The log-transformation over frequency allows the regression line to be much more flexible and accommodate this non-linearity in the relationship. As the frequency of errors increases to the power of three, the expected hospital stay increases by two days. However, the implication is that

the LOS increases rapidly until about 100 prescribing errors, but up to that point, the impact of frequency of errors slows down. At 100 prescribing errors, LOS is approximately eight days, but when the number of prescribing errors increases further to 400 instances, there is only a marginal increase of approximately 12 days.

Part of the objectives of the study has been to identify as well if demographic indicators, frequency of errors, and severity of errors can be associated with patient mortality. However, as noted in the demographics study, only 2 out of the 50 patients had their cases resulting in mortality. This implies two important facts: the first is that there is little evidence in the data that there is a significant deviation from 100% survival among patients that experience any type of medication errors, and the second is that this means that a survival analysis may not be possible to conduct as proposed.

In Table 8, the estimates of the Cox Proportional Hazards model are provided. However, the lack of any significant variables is noted here. Two variables: Comorbidity Status and Age, had to be removed as this results in the model fitting procedure to not converge due to the near-100% censoring status of the data. A Wald's test for overall significance has statistic 1.81, p = 0.999. The Log-Rank test also returns a statistic of 10.16, p = 0.3. All of these suggest that the model has failed to find any useful patterns in the data contributing to patient mortality, largely due to a lack of such mortality being observed in the first place.

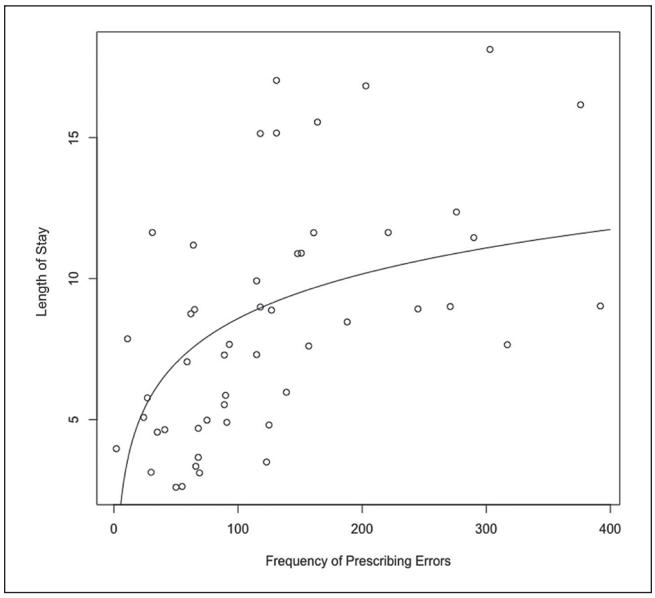

Figure 2. Scatterplot of prescribing error frequency against length of stay.

Table 8. Cox Proportional Hazards Model on Patient Mortality

Variable	Full Model		
	Est	S. Err.	P
Diagnosis: Asthma	-1.290	2.939	0.661
Diagnosis: COPD	22.470	103700.000	1.000
Female	1.526	115500.000	1.000
Prescribing: Frequency	-0.025	0.019	0.202
Monitoring: Frequency	0.184	17360.000	1.000
Prescribing: Severity	-20.570	66250.000	1.000
Transcribing: Severity	4.561	3.639	0.210
Monitoring: Severity	-22.190	97520.000	1.000

** Comorbidities and Age removed due to model non-convergence.*

DISCUSSION

This study is the first retrospective study discussing the type, frequency, and severity of medication errors and their impact on the LOS among COPD and asthma inpatients in the Philippines. Although the study of Pasco et al.,[22] conducted previously in PGH, evaluated the frequency and type of medication error in PGH, the severity of medication errors had not been characterized in any of the wards included.

Among the 50 patients included in the current study, the average error per patient was calculated to be 130.3, with 28 of the patients (56%) experiencing at least one unique type of medication error, while 22 (44%) patients experienced at least two unique types of medication error. The prevalence rate of medication errors was 100%, with the most common type being prescribing errors as also seen in other studies.[2,37] Among these prescribing errors, incomplete prescription and drug interactions were the most common, similar to most studies.[22,38] Furthermore, this study has determined that an increase of prescribing errors to the power of three per patient increases their LOS by 1.779 days (adjusted: 2.078 days).

Type and Frequency of Medication Errors

Prescribing Errors

Out of 6,517 medication errors identified, prescribing errors were the most prevalent with 6,459 (99.1%) identified. This study concurs with the prospective study of Dorothy et al.[39] wherein among all identified medication errors, prescription errors were determined to have had the highest frequency (42.31%). In addition to this, Fjin et al. [40] had similar results indicating that multiple errors in the prescribing stage such as inconsistencies in drug characteristics (e.g., dosage form, continuation of pre-admission treatment, and therapeutic area) were associated with significant medication errors. This finding also aligns with similar observations in two separate studies where prescribing errors were also identified as one of the most frequent types of errors.[2,37]

In contrast, Zeraatchi et al.'s study,[41] where prescribing errors were also highlighted as the most prevalent, revealed that only nearly 22% of patients experienced at least one medication error in an academic emergency department in Iran, with an average rate of medication errors calculated at 0.41 errors per patient. The majority of errors (over 60%) were attributed to prescribing errors by physicians, while the

remaining percentages were transcription or administration errors by nurses. Notably, more than 35% of prescribing errors occurred during drug dose and frequency selection.

Additionally, the findings from this study are consistent with Pasco et al.'s review conducted at PGH,[22] which also identified a high prevalence of medication errors, particularly within the main service wards, with an alarming rate of 97.8%. Among the medication errors observed, prescribing errors were the most common. Examples of these prescribing errors included cases where the route of administration was not specified and assumed to be oral (per orem) for medications in capsule or tablet form, as well as instances where brand names were used instead of generic names for medications containing multiple components (e.g., Tramadol + Paracetamol).

Among all medication errors identified in this study, incomplete prescription (62.7%) and drug interactions (18.2%) were the most common. An incomplete prescription is characterized by missing specific elements such as generic name, dose, dosage strength, dosage form, route, and frequency. Across all cases, physicians often fail to input the appropriate route of the prescribed medication, especially if it should be taken orally (PO). Another common occurrence is the lack of dosage strengths for inhaled medications such as Ipratropium + Salbutamol, Budesonide + Formoterol, Indacaterol + Glycopyrronium, and Tiotropium + Olodaterol.

In a retrospective cohort study conducted by Abukhalil et al.[42] involving older adults hospitalized in Palestine, they identified 221 instances of potentially inappropriate prescribing, among which seven cases involved patients with COPD who were prescribed oral corticosteroids instead of inhaled corticosteroids (ICS). Notably, out of 247 patients included in the sample, approximately 5% of all potential prescribing omissions (the prescriber did not reorder a medication that was previously ordered) were observed in older patients with respiratory diseases such as COPD. In congruence, the current study found that incomplete review of medications across different services is also notable, with 145 instances (2.2%), reflecting discrepancies in medication management across different prescribers. For the incomplete review error, this is mainly identified as a discrepancy in review of medications of the primary service (Pulmonary Medicine) from another service. For instance, when the Pulmonary Medicine service, who acts as the primary service handling the patient, fails to reconcile all medications from other services such as Cardiology, Infectious Diseases, etc. This emphasizes the importance of appropriate medication selection and reconciliation to optimize therapeutic outcomes and minimize the risk of adverse effects.

In terms of drug interactions, only drug-drug interactions were noted, accounting for 18.2% of the total prescribing errors. Drug interactions were identified using the UpToDate drug interaction checker, wherein only classes C (monitor therapy), D (consider therapy modification), and X (avoid combination) were included as these were the only classes of drug interactions requiring relevant actions. Furthermore, these are the same classes utilized by the PGH pharmacists in noting medication errors in RADISH inpatient charts. The most evident interactions were between two inhaled anticholinergic/sympathomimetic agents (e.g., Glycopyrronium + Formoterol and Tiotropium + Olodaterol, Tiotropium + Olodaterol and Ipratropium + Salbutamol, etc.), resulting in significant adverse events such as tachycardia and tachypnea.

The use of unofficial abbreviations was also prevalent across all cases, accounting for 13.8% of all prescribing errors. The researchers utilized the PGH's Hospital Memo 2018-42: Guidelines for the Use of Terminologies, Abbreviations, and Symbols in Prescribing in assessing the inpatient charts for the presence of unofficial abbreviations. This guideline does not qualify common abbreviations such as SC/SQ (subcutaneous), RTC (round the clock), neb (nebule), cc (cubic centimeter), and shorter versions of medicines like salb + ipra (Salbutamol + Ipratropium) as official abbreviations. Therefore, these abbreviations accounted for a significant portion of the total medication errors encountered during the study period.

Meanwhile, the rest of the prescribing errors encountered include inappropriate frequency (0.5%), inappropriate dosage form (0.1%), inappropriate dosage strength (0.4%), brand prescribing (0.2%), and others (1.1%). Concurrently, inappropriate frequency of medications was identified, specifically in the overuse of SABAs. It was observed that some physicians fail to revise the current inhaler plan of patients from round the clock administration to as needed administration despite the resolution of the patient's exacerbations, dyspnea, and other conditions. Such prescribing error could potentially lead to increased risk for exacerbations, moderate to severe nasal symptoms, reduced bronchodilator response, and overall poor clinical outcomes.[43,44]

In relation to this, the systematic review conducted by Boylan et al.[45] identified five studies that highlighted errors associated with the inappropriate use of inhaled corticosteroids (ICS) in patients with COPD. It was emphasized that not all patients with COPD are suitable candidates for ICS therapy, with potential benefits observed in individuals with comorbid asthma, frequent exacerbations of COPD (ECOPD), or eosinophilia. The authors in the systematic review also discussed a plausible reason for inappropriate ICS prescribing, suggesting that prescriber familiarity with and commercial availability of ICS/LABA combination therapies—widely recommended for asthma treatment—might contribute to this practice, given their longer presence in the market compared to long-acting muscarinic antagonists (LAMAs) and LABA/LAMA combinations. Notably, short-acting inhalers and oral bronchodilators are prescribed more frequently internationally than long-acting inhalers due to cost considerations. The review suggested that future research should reference current clinical practice guidelines, such as the GOLD Report, to provide contextual information on the appropriateness of inhaled medications

during the study period, enhancing transparency and understanding of treatment decisions in COPD management.

On the other hand, errors on brand prescribing, though infrequent, were notable since all government hospitals must adhere to generic prescribing.[46] Some examples of brand prescribing include Moriamin Forte (Multivitamins + Amino acids), Symbicort (Budesonide + Formoterol), and Spiolto (Tiotropium + Olodaterol). Other prescribing errors include wrong spelling of medications, typographical errors, no reliever medications, etc.

Essentially, the lack of specificity in the prescription can lead to confusion for pharmacists, nurses, and other healthcare professionals, potentially resulting in medication errors and patient harm. Thus, it is crucial for prescribers to clearly provide all relevant medication information to facilitate optimal therapeutic management and reduce the prevalence of errors.

Transcribing Errors

On the other hand, transcribing errors accounted for only 0.046% of the total number of errors in this study. These results concurred with the findings of Hodkinson et al.,[2] noting that the transcribing stage had one of the lowest rates of medication errors and preventable medication harm (3%, 95% 0 to 9%, n = 8, I2 = 78%). In this current study setting, however, documentation was largely being taken care of by nurses, specifically in encoding administered medications in the therapeutic sheet. Nevertheless, given that this study's scope lies within the Pulmonary Medicine service, the researchers were not able to account for transcribing errors conducted by nurses and other healthcare professionals. The transcribing errors included in the total number of medication errors only accounted for Pulmonary Medicine physicians who had encoded duplicate entries in the RADISH chart. Nonetheless, the researchers were able to encounter common transcribing errors by nurses including wrong administration time, omission of medications, duplicate entries, and wrong spelling of medications in the therapeutic sheet. Although the adoption of electronic health records and electronic prescribing has helped avert medication errors and preventable harm at the prescribing and transcribing stages of the medication use process, underlying system and individual factors facilitate errors which can lead to subpar patient care and even serious harm.[2,39] In congruence, the study of Fahimi et al.[47] noted that approximately 30% of 287 charts resulted in transcribing errors, highlighting the need for comprehensive surveillance systems to help decrease the prevalence of medication errors. Thus, improved safeguarding practices that recognize the impact of individual and system-based factors on patient safety should be employed at all stages of the medication use process.[2,48]

Monitoring Errors

In terms of monitoring errors, the assessment had been limited only to what was found to be lacking from inpatient charts and inpatient attachments. In total, monitoring errors accounted for only 0.8% of the total number of errors identified in the current study. Similarly, in the study by Avery et al.,[34] 55 out of 6048 (0.9%) prescription items reviewed, 0.9% are monitoring errors with the most common type being failure to request monitoring.

A common observation found in the current study is the lack of monitoring for possible side effects such as anticholinergic effects (e.g., urinary retention, constipation, tachycardia, dry mouth) brought about by drug-drug interactions (e.g., antimuscarinic agents indicated for asthma and COPD) constituting 49.1% of the total monitoring errors. Although the rate of anticholinergic side effects for drugs in this class appears to be low,[15] the concurrent administration of antimuscarinic agents have been classified by the drug interaction checker UpToDate as Rating X such as in the case of Glycopyrronium + Formoterol with Tiotropium + Olodaterol and Ipratropium + Salbutamol with Tiotropium + Olodaterol. Drug interactions belonging in the said rating necessitate monitoring for evidence of anticholinergic-related toxicities if such combinations cannot be avoided.

As for monitoring errors due to lack of monitoring for effectiveness of medications, these account for 25.5% of the monitoring errors. The specific monitoring parameters commonly monitored by the Pulmonary Medicine Service include symptoms of exacerbation and vital signs, such as respiratory rate, heart rate, blood pressure, and oxygen saturation. Vital signs have been included both in the inpatient chart entries of the said service and in inpatient attachments, while symptoms of exacerbation are mainly found in inpatient chart entries.

Monitoring these parameters is vital in evaluating for clinical signs of asthma and COPD exacerbation and in assessing for the effectiveness and safety of medicines prescribed. In the case of asthma exacerbation, part of the management includes assessing the exacerbation severity from the degree of dyspnea, respiratory rate, pulse rate, oxygen saturation, and lung function.[49] Similarly, it is recommended for patients with COPD exacerbations to monitor for their respiratory rate, oxygen saturation, and symptoms of exacerbation such as shortness of breath, wheezing, and cough.[15] Additionally, monitoring of blood pressure, heart rate, and respiratory rate is important in monitoring for effectiveness and possible side effects or drug-drug interactions of medicines such as in the case of concurrent administration of sympathomimetics (e.g., short-acting and long-acting beta$_2$-agonists).

Other monitoring errors observed are due to unavailable results accounting for 25.5% of the total monitoring errors. Despite having lung function as one of the parameters to monitor for exacerbation, it has not been considered a standard practice in PGH due to the limited resources available. However, in some inpatients included in the study, it has been observed that the Pulmonary Medicine

Service explicitly ordered the use of incentive spirometry in inpatient chart entries to which there had been no results available following their order. Consequently, this was also considered in the study as a monitoring error especially since measurement of lung function is strongly recommended in patients with asthma exacerbations.[49]

Severity of Medication Errors

The findings of the current study show that 6,441 out of 6,517 errors are classified as "error, no harm," while 76 out of 6,517 errors are categorized under "error, harm." Although the classification was limited to the three degrees of severity (no error; error, no harm; error, harm), there were no errors from Pulmonary Medicine Service which resulted to the death of the patient which is similar with the findings of Sheikh et al.[50] and Gebremariam et al.[51] Most of the errors identified in the current study did not result in harm, while those which resulted in harm did not cause permanent harm (Category G) or required intervention necessary to sustain life (Category H). Examples of such errors which resulted in harm, although not life-threatening, include hyperventilation, tachycardia, tachypnea, constipation, and others.

In a systematic review and meta-analysis of observational studies[2] comparing the prevalence of preventable medication harm across different healthcare settings, it has been found that the proportion of mild preventable medication harm was 39%, moderate preventable harm was 40%, and severe or potentially life-threatening preventable harm was 26%. In contrast, the current study did not have an error which resulted in severe harm or death.

In three other studies determining the severity of medication errors, the NCC MERP classification was also used[50-52] with most of the medication errors falling within the classification of "error, no harm." Al Harbi et al.[52] observed that most of the medication errors identified were determined to be under Category A (43.61%), B (45.36%), or C (7.02%). Only 1.75% of errors were classified under Category D to I with no further characterization to differentiate which errors were solely categorized under Category I (i.e., death). Meanwhile, in the study conducted by Sheikh et al.,[50] 87.5% of the medication errors were classified under Category C. Other levels of harm such as 'no error' (Category A) and 'error, death' (Category I) were not observed in the study. Consequently, Gebremariam et al.[51] identified a total of 491 medication errors, the majority of which were classified under category D (64.56%), followed by category C (17.31%), both belonging under "error, no harm." None of the errors were classified as Category G, H, or I. Similarly, the findings of the current study show that most errors (98.83%) encountered in the Pulmonary Medicine Service of PGH are classified under "error, no harm." Only a few (1.17%) have resulted in harm, none of which resulted in death.

According to WHO, an estimate of one death per 1 million of population is caused by medication errors.[53] Furthermore, it was discussed by Duthie et al.[54] that out of the medication errors reviewed, 18% of them resulted in permanent harm, 48% accounted for near-death errors, and 23% were associated with patient death. In contrast to these findings, none of the errors in the current study led to permanent harm, near-death, or death. Although this has been the case, it is still important to note that only 50 inpatient charts have been reviewed. Additionally, assessment was only limited to the available information included in the inpatient charts and attachments.

Patient-related Factors and Mortality

In terms of mortality, it was discussed in a retrospective cohort study conducted by Lüthi-Corridori et al.[55] among patients admitted for acute exacerbation of COPD in a district general hospital in Switzerland that the age of patients was associated with higher mortality within 12 months of admission. Additionally, having active cancer as a comorbidity was also positively associated with an increased risk of death. Similarly, in a retrospective review of hospital records conducted by Ibrahim et al.[56] among asthma patients who presented with exacerbations, it was found that predictors of acute severe asthma mortality include older age and more than three comorbidities. However, no medication error in the current study has resulted in death or a life-threatening situation. Thus, findings of the study failed to find any patterns in the data which might contribute to patient mortality, mainly because of the lack of such mortality being observed in the first place.

Patient-related Factors and Length of Hospital Stay

In the study by Lüthi-Corridori et al.,[55] a cohort of 170 patients, predominantly male with a median age of 75 years, was analyzed. Similarly, the distribution of comorbidities in their study sample mirrors that of the broader COPD population, with 84% of patients having at least one chronic condition, consistent with previous findings where this proportion was around 80%. Over the past 15 years, there has been a significant decline in the LOS for COPD patients in Switzerland. The average LOS in this study (8 days) aligns with this national trend. Similarly, the current study has an average LOS of 8.4 days, which is also aligned with the existing studies' data. This suggests that, on average, patients stay in the hospital for just over a week, although the LOS can vary significantly. Comparably, in Li et al.'s study,[57] the average LOS was approximately 12 days. Factors such as age, gender, hemoglobin levels, smoking history, presence of comorbidities, and utilization of non-invasive ventilation (NIV), pulmonary rehabilitation (PR), and inhaled medications were identified as contributors to increased LOS. Three out of every five COPD inpatients in this study had at least one comorbidity, consistent with findings from previous research. In the current study, however, 48 patients, regardless of their pulmonary diagnosis, were found to have at least one comorbidity. These findings emphasize the importance of an integrated and interdisciplinary healthcare approach for older patients,

given the possible implications of age and comorbidities on hospitalization duration and healthcare provision.

Medication Errors and Length of Hospital Stay

According to Bates et al.,[58] an additional 4.6 days in LOS were observed among 207 admissions due to preventable adverse drug events (ADEs). In a case-control study by Classen et al.,[59] as cited by Kohn et al.,[27] adverse drug events affected 2.43 out of every 100 hospital admissions. Experiencing an ADE was associated with an increased LOS of 1.91 days. Additionally, Sheikh et al.[50] demonstrated a positive correlation between the number of medication errors and prolonged hospital stay, indicating that as the number of medication errors increased, so did the LOS. In comparison, the current findings of this study showed that drug interactions possibly leading to harm accounted for 18.2% of the total medication errors. Prescribing errors, including drug interactions, were found to be associated with an increase in LOS, wherein an estimated increase to the power of three increases the LOS by 2 days.

Limitations of the Study

Despite this study being the first to examine the relationship of type, frequency, and severity of medication errors, and the LOS and mortality of COPD and asthma patients, there remain several limitations. First, the researchers had limited access to RADISH, the medical record system of PGH. The researchers were only able to access the inpatient charts and inpatient attachments for a limited period of time. Moreover, the researchers were not able to access and review the laboratory findings and other test results done per patient, thus limiting the comprehensive analysis of the patient's conditions and other factors contributing to medication errors.

Due to the retrospective nature of this study and the sole reliance on medical records, a conclusive causality between patient-related factors, type and severity of medication errors, and mortality cannot be definitively established, essentially warranting further prospective research in this field. Also, errors related to transcribing and patient monitoring rely more on accurate and real-time observations and assessments, which may not be as evident through retrospective reviews alone. Specific types of medication errors such as dispensing and administering errors were not studied due to the lack of accurate documentation for such processes. Hence, evaluation of medication errors was only limited to the stages of prescribing, transcribing, and monitoring. The tertiary government hospital has an Open Enterprise Resource Planning (OpenERP) system which details the medications ordered and time of order; however, the researchers were not able to access such a system.

Furthermore, the use of only one drug interaction checker limits the detailed assessment of drug interactions and may not capture all interactions that could contribute to medication errors and affect patient care. Additionally, the transcribing and monitoring practices of nurses and other healthcare professionals were not assessed in this study. Since the scope of this study focuses on the Pulmonary Medicine Service alone, only transcribing errors and monitoring errors conducted by physicians under such service were processed. Due to the lack of standardization in these stages of the medication use process, the Pulmonary Medicine Service cannot be held solely responsible for the occurrence of medication errors.

In terms of patient-related factors, the study only accounted for age, sex, number of medications taken, pulmonary diagnosis, and presence of comorbidities as the patient-related factors. Other factors such as smoking history and family history of COPD or asthma were not included.

As for the sample size, only 50 inpatient records were assessed. It is worth noting, however, that an increase in the sample size can provide more observations for each variable, ultimately increasing the power of the study. Moreover, since the study was limited to one study site, the findings may not be generalizable to a larger population. This means that the unique clinical practices, patient population, protocols, and the health database (i.e., RADISH) of PGH may not accurately represent those in other healthcare settings. Therefore, such limitations may raise concerns about the external validity of the results as these may not be entirely applicable to other settings. Thus, interpretation of findings should be made with caution due to the low sample size.

CONCLUSION

In PGH, inpatients provided with services from the Pulmonary Medicine Service were predominantly older male adults. More than two-thirds of the included patients were diagnosed with COPD while approximately one-fourth suffered from asthma. All included patients were practicing polypharmacy, and the vast majority presented with comorbidities, emphasizing the complex conditions and healthcare needs of each patient. Among the 50 patients studied, all experienced medication errors. Prescribing errors were the most prevalent, followed by monitoring errors and transcribing errors. Most medication errors did not result in harm, indicating that while medication errors are common, most do not cause immediate adverse events on patients. Prescribing errors were found to have an effect on the LOS, such that an increase in prescribing errors to the power of three increases the LOS by 2 days until it reaches 100 errors, at which point the increase in LOS begins to slow down. The severity of transcribing errors was also found to be marginally significant, suggesting that the severity of such errors might have a considerable impact on LOS. On the other hand, all independent variables were noted to have a lack of significance which implies the inability to identify any meaningful patterns in the data related to patient mortality, primarily because there is an insufficient amount of observed mortality in the included sample.

The current study presents substantial insights on opportunities for improvement in the PGH's current medication safety protocol and practices, specifically in the stages of medication use where medication errors were identified. It is recommended to conduct prospective studies on the same topic to address the limitations of the current study. Additionally, other patient-related factors, such as smoking history and family history of COPD or asthma, may contribute to the occurrence of medication errors. The researchers also acknowledge the need for further investigation on the administering and dispensing stages to provide a more in-depth understanding of medication errors in a hospital setting, as well as its effect on patient care and safety. It is recommended that future researchers delve deeper into medication safety concerns in similar healthcare settings and other medical specialties, reviewing a greater number of cases to allow detection of errors not identified in the current study.

Since a significant number of prescribing errors were attributed to the use of unofficial abbreviations, it is highly recommended that the tertiary government hospital update its current list of approved abbreviations for prescribing medications. It is also highly recommended that monitoring guidelines be established for consistency since monitoring errors have been observed in the current study. Considering that there is usually more than one service on board in the provision of care, the primary service should take the lead in ensuring that there is proper monitoring of the patient's status and that possible causes of harm are minimized.

Also, there is a critical need to prioritize targeted education and training initiatives to prevent medication errors. Continuing education programs must address specific challenges related to medication management in asthma and COPD, including recognizing potential drug interactions, properly and completely writing medication orders, and ensuring proper monitoring of treatment responses. A department-wide approach may then be adopted to develop standardized training programs that address medication safety and management practices applicable to different specialties. Aside from training for proper prescribing practices, protocols on double-checking and implementing alert systems in the current electronic prescribing/recording system (RADISH) is also imperative to possibly minimize transcribing errors.

Statement of Authorship

All authors certified fulfillment of ICMJE authorship criteria.

Author Disclosure

All authors declared no conflicts of interest.

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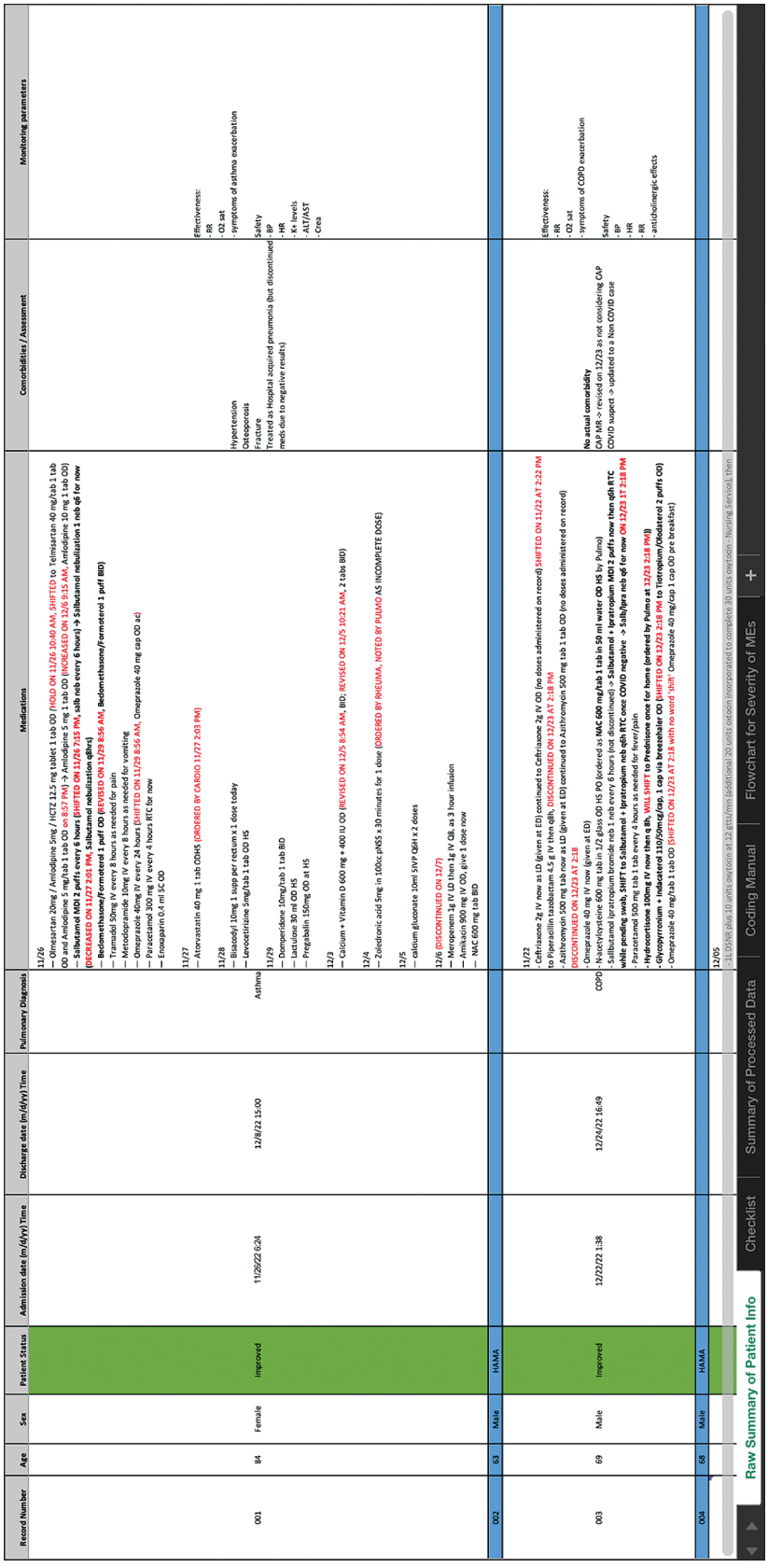
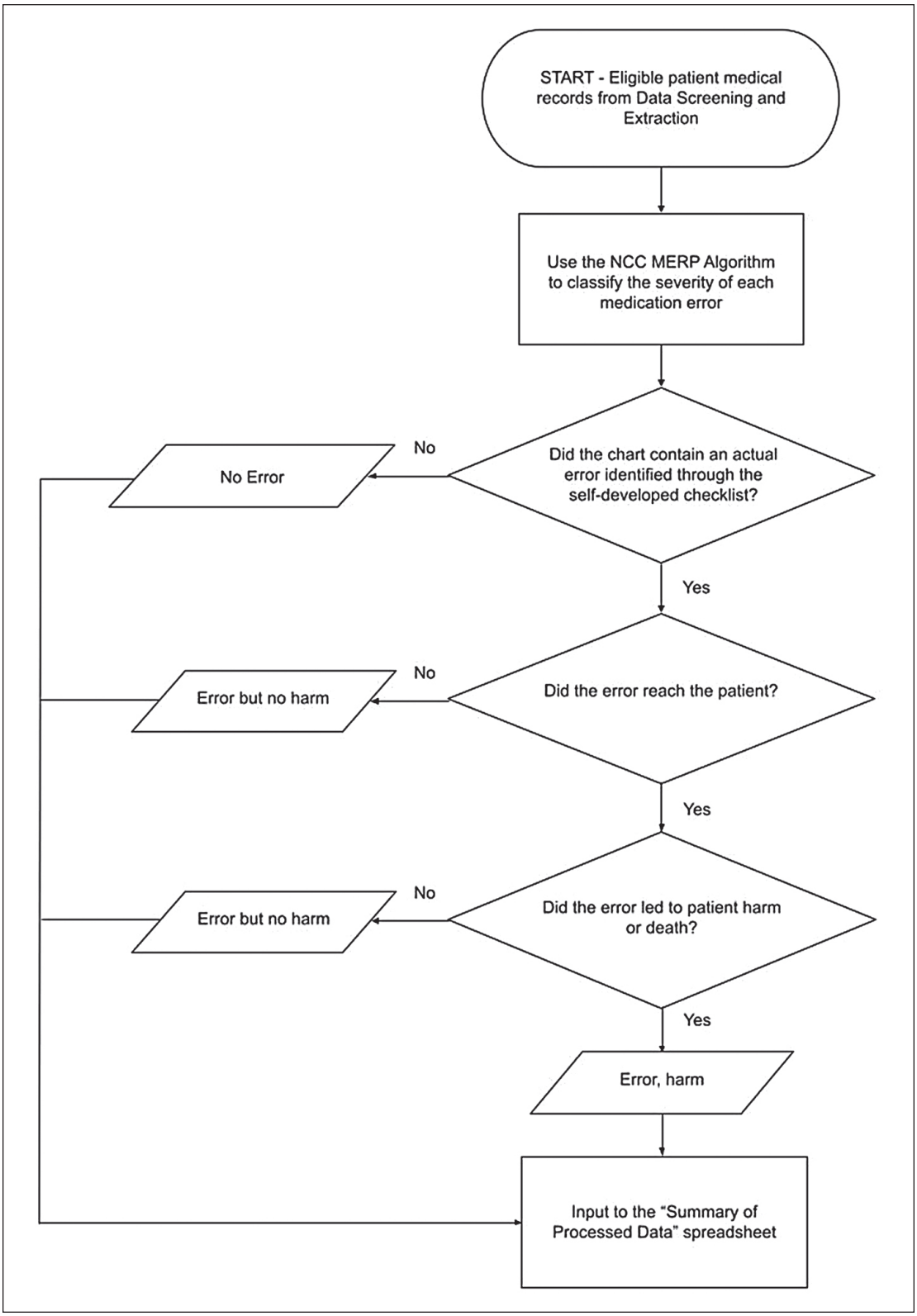
APPENDICES



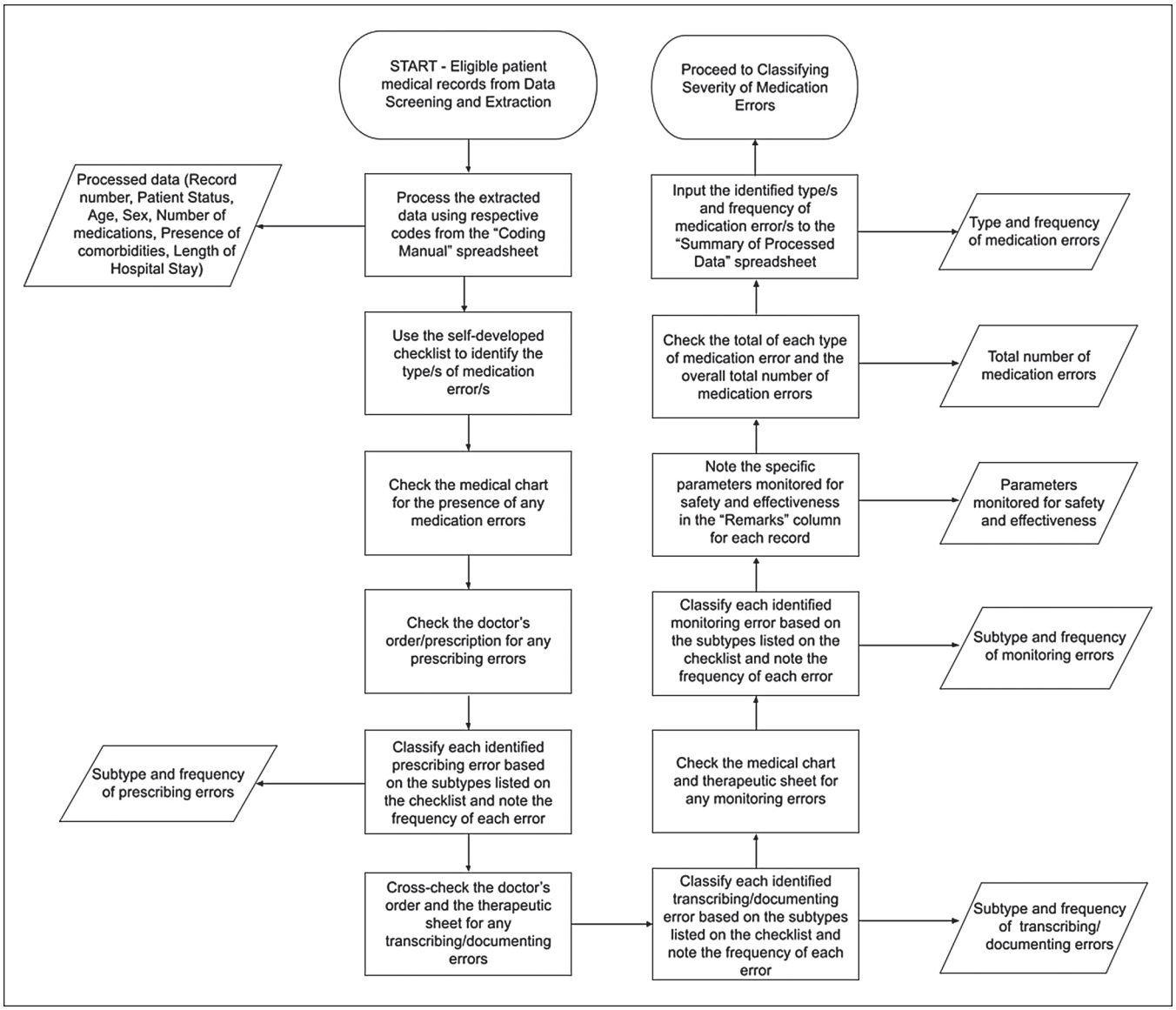
Record Number	Age	Sex	Patient Status	Admission date (m/d/yy) Time	Discharge date (m/d/yy) Time	Pulmonary Diagnosis	Medications	Comorbidities / Assessment	Monitoring parameters
001	84	Female	Improved	11/26/22 8:24	12/8/22 15:00	Asthma	11/26 — Olmesartan 20mg / Amlodipine 5mg / HCTZ 12.5 mg tablet 1 tab OD (HOLD ON 11/26 10:40 AM, SHIFTED to Telmisartan 40 mg/tab 1 tab OD and Amlodipine 5 mg/tab 1 tab OD on 8:57 PM) -> Amlodipine 5 mg 1 tab OD (INCREASED ON 12/6 9:15 AM, Amlodipine 10 mg 1 tab OD) — Salbutamol MDI 2 puffs every 6 hours (SHIFTED ON 11/26 7:15 PM, salb neb every 6 hours) -> Salbutamol nebulization 1 neb q6 for now (DECREASED ON 11/27 2:01 PM, Salbutamol nebulization q8hrs) — Beclomethasone/Formoterol 1 puff OD (REVISED ON 11/29 8:56 AM, Beclomethasone/Formoterol 1 puff BID) — Tramadol 50mg IV every 8 hours as needed for pain — Metoclopramide 10mg IV every 8 hours as needed for vomiting — Omeprazole 40mg IV every 24 hours (SHIFTED ON 11/29 8:56 AM, Omeprazole 40 mg cap OD ac) — Paracetamol 300 mg IV every 4 hours RTC for now — Enoxaparin 0.4 ml SC OD 11/27 — Atorvastatin 40 mg 1 tab ODHS (ORDERED BY CARDIO 11/27 2:03 PM) 11/28 — Bisacodyl 10mg 1 supp per rectum x 1 dose today — Levocetirizine 5mg/tab 1 tab OD HS 11/29 — Domperidone 10mg/tab 1 tab BID — Lactulose 30 ml OD HS — Pregabalin 150mg OD at HS 12/3 — Calcium + Vitamin D 600 mg + 400 IU OD (REVISED ON 12/5 8:54 AM, BID; REVISED ON 12/5 10:21 AM, 2 tabs BID) 12/4 — Zoledronic acid 5mg in 100cc pNSS x 30 minutes for 1 dose (ORDERED BY RHEUMA, NOTED BY PULMO AS INCOMPLETE DOSE) 12/5 — calcium gluconate 10ml SIVP Q6H x2 doses 12/6 (DISCONTINUED ON 12/7) — Meropenem 1g IV LD then 1g IV Q8. as 3 hour infusion — Amikacin 900 mg IV OD, give 1 dose now — NAC 600 mg tab BID	Hypertension Osteoporosis Fracture Treated as Hospital acquired pneumonia (but discontinued meds due to negative results)	Effectiveness: - RR - O2 sat - symptoms of asthma exacerbation Safety - BP - HR - K+ levels - ALT/AST - Crea
002	63	Male	HAMA						
003	69	Male	Improved	12/22/22 1:38	12/24/22 16:49	COPD	11/22 - Ceftriaxone 2g IV now as LD (given at ED) continued to Ceftriaxone 2g IV OD (no doses administered on record) SHIFTED ON 11/22 AT 2:22 PM - Azithromycin 500 mg tab now as LD (given at ED) continued to Azithromycin 500 mg tab 1 tab OD (no doses administered on record) DISCONTINUED ON 12/23 AT 2:18 - Omeprazole 40 mg IV now (given at ED) - N-acetylcysteine 600 mg tab in 1/2 glass OD HS PO (ordered as NAC 600 mg/tab 1 tab in 50 ml water OD HS by Pulmo) - Salbutamol ipratropium bromide neb 1 neb every 6 hours (not discontinued) -> Salbutamol + Ipratropium MDI 2 puffs now then q6h RTC while pending swab, SHIFT to Salbutamol + Ipratropium neb q6h RTC once COVID negative -> Salb/ipra neb q6 for now ON 12/23 1T 2:18 PM - Paracetamol 500 mg tab 1 tab every 4 hours as needed for fever/pain - Hydrocortisone 100mg IV now then q 8h, WILL SHIFT to Prednisone once for home (ordered by Pulmo at 12/23 2:18 PM) - Glycopyrronium + Indacaterol 110/50mcg/cap, 1 cap via breezehaler OD (SHIFTED ON 12/23 2:18 PM to Tiotropium/Olodaterol 2 puffs OD) - Omeprazole 40 mg/tab 1 tab OD (SHIFTED ON 12/23 AT 2:18 with no word 'shift' Omeprazole 40 mg/cap 1 cap OD pre breakfast)	No actual comorbidity CAP MR -> revised on 12/23 as not considering CAP COVID suspect -> updated to a Non COVID case	Effectiveness: - RR - O2 sat - symptoms of COPD exacerbation Safety - BP - HR - RR - anticholinergic effects
004	68	Male	HAMA						
							12/05 -1l DSNR plus 10 units oxytocin at 12 gtts/min (additional 20 units oxtocin incorporated to complete 30 units oxytocin - Nursing Service), then		

Raw Summary of Patient Info | Checklist | Summary of Processed Data | Coding Manual | Flowchart for Severity of MEs | +

Appendix A. Data Collection Tool: Raw Summary of Patient Information.



Appendix B. Flowchart for Classification of Severity of Medication Errors.



Appendix C. Flowchart for Identifying Types and Frequencies of Medication Errors.

Type of Medication Error	001	Remarks	003	Remarks	005	Remarks	006	Remarks	007	Remarks
Prescribing Error										
Unclear or no medical indication										
Contraindication										
Inappropriate dosage strength										
Inappropriate dose										
Inappropriate dosage form										
Inappropriate frequency	1	Salbutamol not changed to prn (as needed)					1	Salbutamol + ipratropium neb q6h RTC despite "asthma exacerbation resolved"		
Inappropriate duration							1	Salbutamol + ipratropium neb q6h RTC despite "asthma exacerbation resolved"		
Duplicate therapy			1	Two orders of Salbutamol+Ipratropium w/o dc of one					9	Both LABA - Formoterol
		Beclomethasone and salbutamol; Tramadol and levocetirizine; Tramadol and pregabalin;						Salmeterol + Fluticasone with		Bilastine WITH Azithrom Budesonide + Formoterc Tiotropium + Olodaterol Methotrexate WITH Om Methotrexate WITH Pipe Tazobactam; Insulin Isophane WITH I Prednisone WITH Calciu Prednisone WITH Insulir Prednisone WITH Insulir Metformin WITH Insulin Metformin WITH Predni Insulin Isophane WITH H Insulin HR WITH Hydroc

Raw Summary of Patient Info | Checklist | Summary of Processed Data | Coding Manual | Flowchart for Severity of MEs | +

Appendix D. Data Collection Tool: MS Excel Checklist.

Record Number	Patient Status	Age	Sex	Number of medications (num	Pulmonary Diagnos	Presence of Comorbidities (com	Length of Hospital stay (los)	Frequency of Medication Error (freq)	Type of Medication Error (type)	Severity of Medication Error (sev)
001	Improved	84	1	2	1	1	12.35833333	276	1	2
									1	2
									1	2
									1	2
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									1	2

Raw Summary of Patient Info | Checklist | Summary of Processed Data | Coding Manual | Flowchart for Severity of MEs | +

Appendix E. Data Collection Tool: Summary of Processed Data.