Medication Prescribing Errors on a Surgery Service – Addressing the Gap with a Curriculum for Surgery Residents: A Prospective Observational Study

Journal of Medical Education and Curricular Development
Volume 11: 1–9

DOI: 10.1177/23821205241226819

Justine Ring[1], Jesse Maracle[2], Shannon Zhang[3], Michelle Methot[4] and Boris Zevin[5]

[1]Division of Plastic Surgery, University of Manitoba, Winnipeg, Manitoba, Canada. [2]School of Medicine, Queen's University, Kingston, Ontario, Canada. [3]Department of Family Medicine, University of Ottawa, Ottawa, Ontario, Canada. [4]Kingston Health Sciences Center, Kingston, Ontario, Canada. [5]Department of Surgery, Queen's University, Kingston, Ontario, Canada.

ABSTRACT

OBJECTIVES: Educational interventions with proven effectiveness to reduce medication prescribing errors are currently lacking. Our objective was to implement and assess the effectiveness of a curriculum to reduce medication prescribing errors on a surgery service.

METHODS: This was a prospective observational cohort study at a Canadian academic hospital without an electronic order entry system. A pharmacist-led medication prescribing curriculum for surgery residents was developed and implemented over 2 days (2 h/day) in July 2019. Thirteen (76%) out of 17 surgery residents contributed pre-implementation data, while 13 (81%) out of 16 surgery residents contributed post-implementation data. Medication prescribing errors were tracked for 12 months pre-implementation and 6 months post-implementation. Errors were classified as prescription writing (PW) or decision making (DM).

RESULTS: There were a total of 1050 medication prescribing errors made in the pre-implementation period with 615 (59%) PW errors and 435 (41%) DM. There were a mean of 87.5 (SD = 14.6) total medication prescribing errors per month in the pre-implementation period with 51.3 (11.9) PW and 36.3 (6.0) DM errors. There were a total of 472 medication prescribing errors made in the post-implementation period with 260 (55%) PW and 212 (45%) DM errors. There were a mean of 78.7 (10.3) total medication prescribing errors per month in the post-implementation period with 43.3 (9.5) PW and 35.3 (4.2) DM errors. In the first quarter of the academic year, there were significantly fewer mean total errors per month post-implementation versus pre-implementation (77.7(12.7) versus 107.3(8.1); $P = .035$), with significantly fewer PW errors per month (40.7(13.2) versus 68.7(9.3); $P = .046$) and no difference in DM errors per month (37.0(2.0) versus 38.7(5.7);$P = .671$). There were no differences noted in the second quarter of the academic year.

CONCLUSION: Medication prescribing errors occurred from PW and DM. Medication prescribing curriculum decreased PW errors; however, a continued education program is warranted as the effect diminished over time.

KEYWORDS: Education, general surgery, inappropriate prescribing, medication errors, residency

RECEIVED: June 5, 2023. **ACCEPTED:** December 22, 2023.

TYPE: Original Research Article

FUNDING: The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the Physicians' Services Incorporated Foundation Resident Research Grant, (grant number R19-08)

DECLARATION OF CONFLICTING INTERESTS: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

CORRESPONDING AUTHOR: Boris Zevin, Division of General Surgery, Kingston Health Sciences Centre, 76 Stuart Street, Burr 2, Kingston, ON, Canada K7L 2V7.
Email: boris.zevin@kingstonhsc.ca

Introduction

Medication prescribing errors are a source of morbidity and occasionally mortality in the hospital setting[1], previously shown to account for 8–16% of all adverse events on Canadian surgery wards.[2,3] One to two percent of in-patients have experienced harm as a result of a medication error[4,5]; however, the actual proportion of medication prescribing errors is much greater as only 20% actually reach the patient.[6] The causes of medication prescribing errors are numerous, with distraction from multiple simultaneous tasks, lack of feedback on errors, and writing orders for patients not well known to the prescriber as some of the contributing factors.[7,8]

Medication prescribing errors can be classified into prescription writing (PW) or decision making (DM) errors.[9] DM errors are related to mistakes in selecting appropriate medication for a clinical problem, or not adjusting the dose for renal function, weight, age, etc. PW errors are related to the process of transcribing the chosen order, including omission of frequency or route, prescribing a drug for the incorrect patient, and ambiguous medication orders. Medication prescribing errors in a non-electronic order entry (EOE) (paper-based) system have been shown to be associated with 'knowledge deficits' and 'other' factors, such as mistakes made during the process of order writing.[10] In a pilot study of medication prescribing errors in a Canadian academic hospital, without an EOE system, we demonstrated that surgery trainees made errors in 3% to 9% of medication prescription orders with 1/3 of errors related to DM and 2/3 to PW.[9] EOE systems can decrease adverse events related to medication prescription errors by 48–50%[11,12]; however, EOE systems do not appear to address all types of medication prescribing errors as medication prescribing errors can occur during both DM and PW phases.[13]

This suggests that educational interventions aimed at improving prescribing practices of healthcare providers are needed irrespective of the method of order entry.

Several educational interventions aimed at improving prescribing competency have been described in post-graduate family medicine training programs.[8,14–17] These include online modules, didactic or case-based teaching sessions,[15,16] pharmacist feedback,[17] or longitudinal programs with reduced prescribing privileges until completed.[14] However, similar educational interventions have yet to be described, implemented or evaluated in post-graduate surgery training programs. As prescribed medications classes often vary by discipline, it is important to develop a curriculum that improves the prescribing competency of surgery trainees.

The objectives of our study were (a) to implement a pharmacist-led medication prescribing curriculum for surgery trainees, (b) to evaluate the effectiveness of the curriculum by examining medication prescribing errors pre- and post-curriculum implementation, and (c) to identify specific times during the academic year when surgery trainees are more susceptible to making medication prescribing errors.

Methods

We conducted a prospective, observational cohort study on a general surgery service at a tertiary academic hospital (Kingston Health Science Centre, Kingston, Ontario, Canada) without EOE between July 1, 2018 and December 31, 2019. Research Ethics Board approval was obtained prior to commencement of the study (#6020195). Written informed consent was obtained from all participants. Preprint of this manuscript was submitted to Research Square in 2021.

Setting

Academic hospital with 440 inpatient beds, over 22,000 inpatient and over 9000 outpatient operations per year. Post-graduate residency training programs in general surgery, orthopaedic surgery and urology, as well as most medical specialties.

Development and implementation of a medication prescribing curriculum

We modified (with permission) a prescribing curriculum developed by Ginzburg et al[14] and used the data collected during the 12-month pre-implementation period to inform and develop the Medication Prescribing Curriculum for surgery residents at our institution. This curriculum was designed to specifically address different types of medication prescribing errors, strategies to mitigate these errors, as well as to provide specific examples of common prescribing errors in surgery. The Medication Prescribing Curriculum discussed the information to include in a medication prescription, inappropriate abbreviations and other habits to avoid, and how to correctly adjust medication dosing for weight and renal function. It addressed specific medication classes that were identified as weakness for surgery residents in a prior study from our group,[9] such as dosing of respiratory inhaler prescriptions, and antibiotic use. Based on this information, we modified Ginzburg et al's[14] curriculum and provided resources such as antibiograms, electronic drug-–drug interaction tools and contacts for hospital pharmacists. The Medication Prescribing Curriculum was delivered in person by two pharmacists over 2 days (2-h per day) to surgery residents in our program in July 2019. July was chosen as this is the beginning of the academic year at our institution. There were no other curricula focused on medication prescribing during the study period.

Process for ordering medications

In our institution, routine medication orders are written on carbon-copy papers, which are processed by the hospital pharmacy, and a copy of the original order remains in the patient's paper chart. Free-text fillable, computer-based forms are used in specific situations, such as admission orders and post-operative orders; however, these forms do not auto-populate medication doses and do not provide any clinical decision support. As such, the prescriber is allowed to omit dose, route, or frequency of medications on the computer-based forms. Medication orders (carbon-copy paper and computer-based forms) are reviewed by the pharmacists, who document any concerns on a medication memorandum (MM). The MM is sent back to the ward and placed in the patient's medical record (paper chart). For example, when the order 'Vit B12 1000 mg po daily' was written, the corresponding MM stated 'Please rewrite this order to clarify dose as 1000 mcg. We have interpreted it as such and have entered it into the patient profile'.

Outcome definitions

Medication prescribing error: any medication prescribing order which resulted in the generation of a MM by pharmacy, for any reason.

DM error: Any medication prescribing error classified, based on the consensus decision of two reviewers (JR, JM), as DM based on criteria in a previously published medication errors taxonomy.[9]

PW error: Any medication prescribing error classified, based on the consensus decision of two reviewers (JR, JM), as PW based on criteria in a previously published medication errors taxonomy.[9]

Medication prescribing errors

All orders meeting the definition of a medication prescribing error were collected. We classified each error using our previously described taxonomy as either an error in DM or PW,[9] and recorded the general class of the medication (ie, antibiotic,

anticoagulant). For medication prescriptions with more than one type of error (ie, omitting both route and frequency), we classified each error separately. We included all admission, in-patient and post-operative orders, as well as co-signed suggest orders on patients who were admitted under the care of a general surgeon as the most responsible physician. We did not have any restrictions on the time of day the medication order was written. We excluded orders written by trainees who did not consent to participate in this study. We also excluded orders written by surgery trainees on patients admitted to a non-general surgery service, including the intensive care unit, as these orders required co-signature by the primary service and may not have accurately captured errors made by the surgery trainee. We excluded verbal orders, orders written by non-surgery services such as the acute pain management service, orders for intravenous (IV) fluids, total parenteral nutrition (TPN), oxygen, diet, and activity, orders for an automatic therapeutic interchange (TI) of a prescribed medication, as well as MMs informing of limited supply or backorder medications. We were not able to collect information on the total number of medication prescribing orders written per month during the study period as this data was not available at our institution. The only available data included all orders processed by the pharmacy, which included non-medication prescribing orders for IV fluids, TPN and TI. Non-medication prescribing orders were excluded from our study. Lastly, we excluded MMs informing that a patients' home medication is non-formulary at our institution.

We did not collect prescriber information, such as name, year and level of training, or residency program. MMs were matched to the medication order written in the patient's chart by using the time stamp and medication dose to determine if the prescriber consented to study participation. Orders written by residents who did not participate in our study were excluded. We also did not collect patient identifying data, including the name, birthday and medical identification number. We were not able to identify the specific time for the medication prescribing errors as this information was not collected by our institution. All MMs for non-urgent medication prescribing errors were processed the following morning, so it was not possible to determine the exact time of the error which occurred at night.

Pre-curriculum implementation (baseline) data collection

Two independent reviewers (JR, JM) classified and recorded medication prescribing errors documented in MMs on all patients admitted to a general surgery service from July 1, 2018 to June 30, 2019. Only prescriptions written by residents who had consented to participate in our prior study were included in the analysis.[11] All MMs were reviewed by a minimum of one reviewer, with randomly selected months reviewed by both reviewers to identify any discrepancies in classification. Discrepancies in classification of errors as either PW or DM between the two independent reviewers were resolved by consensus. We also recorded the number of trainees (general surgery and off-service) rotating on the surgery service each month.

Post-curriculum implementation data collection

Two independent reviewers (JR, JM) classified and recorded all medication prescribing errors documented in MMs on patients admitted to a general surgery service post-curriculum implementation (July 1, 2019 to December 31, 2019) using the same methodology as for pre-curriculum implementation data collection. Information on the number of trainees (general surgery and off-service) rotating on the general surgery service each month was also recorded.

Statistical analysis

Descriptive statistics were calculated for the number and types of medication prescribing errors per month pre- and post-curriculum implementation. Normality testing was conducted on all data prior to analysis. Data was grouped into 3-month intervals as quarters of the academic year (Q1:July–September, Q2: October–December, Q3:January–March, and Q4: April–June) for comparisons within and between academic years (pre- and post-curriculum implementation). Independent sample t-tests were used to compare pre versus post-curriculum implementation data using 3-month interval data. One-way ANOVA and post-hoc Tukey tests were used to compare 3-month interval data within the academic year pre-curriculum implementation (July 2018 to June 2019). All statistics were performed using SPSS Version 26. Statistical significance was set to $P < .05$.

Results

The Medication Prescribing Curriculum was delivered to 13 out of possible 16 (81%) surgery trainees (Table 1). There were no significant differences in the number of surgery and off-service trainees on the surgery service each month pre-

Table 1. Year of training of post-graduate trainees who were eligible to participate and participated in the medication prescribing curriculum.

YEAR OF TRAINING	ELIGIBLE	PARTICIPATED
PGY 1	5	5
PGY 2	3	2
PGY 3	3	2
PGY 4	5	4
PGY 5	0	0
Total	16	13

PGY, post-graduate year.

and post-curriculum implementation (Table 2). Furthermore, the number of residents accepted per year into our general surgery residency training program does not change year-to-year. As such, the mix of senior versus junior residents was not expected to change from one academic year to the next.

Pre-curriculum implementation (baseline) data

Baseline data was collected on 13 (76%) out of 17 eligible surgery trainees. There were a total 1050 medication prescribing errors made over 12 months between July 1, 2018 and June 31, 2019 with 615 (59%) PW errors and 435 (41%) DM errors (Table 3). The mean number of errors per month was 87.5 (SD = 14.6), with significantly more PW compared to DM errors per month (51.3 (11.9) versus 36.3 (6.0); $P = .001$). The mean number of medication orders written for all patients on a surgery service per month was 4405.0 (141.4).

The most common PW errors were 'Omission of frequency/ not specifying PRN orders' with 12.7 (5.5) errors per month, followed by 'Prescribing one tab/ 1 puff of a drug that is available in more than one strength' with 11.6 (4.4) errors per month (Table 4). The most common DM errors were 'Prescribing a dose not recommended for the formulation prescribed' with 7.5 (2.3) errors per month followed by 'pharmaceutical issues' with 7.0 (2.8) errors per month, such as prescribing medication only available in IV formulation to be given orally. The highest number of medication errors per month was recorded in July (n = 116) and August (n = 106), while the lowest was recorded November (n = 66).

The mean number of errors per month for each quarter of the academic year were 107.3 (8.08) for Q1 (July–September), 83.3 (15.0) for Q2 (October–December), 77.7 (4.7) for Q3 (January–March) and 81.7 (7.1) for Q4 (April–June) (Figure 1). The mean number of errors per month was significantly higher in Q1 versus Q3 ($P = .02$) and Q4 ($P = .04$). The most common classes of medications involved in medication prescribing errors were 'other', 'gastrointestinal', 'respiratory' and 'narcotic' medications (Table 5).

Post-curriculum implementation data

There were a total 472 medication prescribing errors made over 6 months between July 1, 2019 and December 31, 2019 with 260 (55%) PW and 212 (45%) DM errors (Table 3). The mean number of total errors per month was 78.7 (10.3), with no significant difference between PW and DM errors per month (43.3 (9.8) versus 35.3 (4.2); $P = .13$). The mean number of medication orders written for all patients on a surgery service per month was 4313.7 (240.6).

The most common PW errors were 'Omission of frequency/ not specifying PRN orders (ie, morphine 2 mg PRN instead of q4h prn)', with 10.8 (6.2) errors per month, followed by 'Prescribing one tab/ 1 puff of a drug that is available in more than one strength' with 10.3 (5.1) errors per month. The most common DM errors were 'Pharmaceutical issues' with 10 (2.7) errors per month, and 'Prescribing two drugs for the same indication when only one is necessary' with 7.5 (4.1) errors per month. The highest number of medication errors per month was recorded in August (n = 92) and October (n = 87), while the lowest was recorded in July (n = 68) and December (n = 68) (Table 3).

The mean number of errors per month for each quarter of the academic year were 77.7 (12.7) for Q1 and 79.7 (10.2) for Q2 with no significant difference between Q1 and Q2 ($P = .84$) (Figure 1). The most common classes of medications involved in medication prescribing errors post-curriculum implementation were 'gastrointestinal', 'respiratory' and 'other (Table 5)'.

Effectiveness of the medication prescribing curriculum

There were significantly fewer medication prescribing errors committed per month in Q1 post-curriculum implementation versus pre-curriculum implementation (77.7(12.7) versus 107.3(8.1); $P = .04$). There were also significantly fewer PW errors committed per month in Q1 post-curriculum implementation as compared to pre-curriculum implementation (40.7(13.2) versus 68.7(9.3); $P < .05$); however, there was no significant difference in DM errors committed per month in

Table 2. Complement of post-graduate trainees on a surgery service pre- and post-curriculum implementation.

MONTH	PRE-CURRICULUM IMPLEMENTATION		POST-CURRICULUM IMPLEMENTATION		*P*-VALUE
	SURGERY RESIDENTS	OFF-SERVICE RESIDENTS	SURGERY RESIDENTS	OFF-SERVICE RESIDENTS	
July	13	0	8	2	.92
August	11	1	8	2	.43
September	10	1	8	2	.48
October	9	4	6	4	.65
November	8	4	7	3	.87
December	8	3	10	1	.27

Table 3. Number of medication prescribing errors per month pre- and post-curriculum implementation.

	PRE-CURRICULUM			POST-CURRICULUM		
MONTH	TOTAL ERRORS	PW ERRORS	DM ERRORS	TOTAL ERRORS	PW ERRORS	DM ERRORS
July	116	79	37	68	29	39
August	106	61	45	92	55	37
September	100	66	34	73	38	35
October	93	54	39	87	47	40
November	66	44	22	84	52	32
December	91	50	41	68	39	29
January	83	48	35	NA	NA	NA
February	74	39	35	NA	NA	NA
March	76	42	34	NA	NA	NA
April	74	43	31	NA	NA	NA
May	88	46	42	NA	NA	NA
June	83	43	40	NA	NA	NA
Total	1050	615	435	472	26	212

PW, prescription writing; DM, decision making.

Q1 pre- and post-curriculum implementation (37.0(2.0) versus 38.7(5.7); $P = .67$). The mean number of medication prescription orders written for all patients on a surgery service per month was not significantly different pre- and post-curriculum implementation (4405.0(141.4) versus 4313.7(240.6); $P = .66$).

There were no significant differences for medication prescribing errors committed per month pre- versus post-curriculum implementation in Q2 (83.3(15.0) versus 79.7(10.2); $P = .75$). There were no significant differences in PW errors per month (46.0(6.6) versus 49.3(5.0); $P = .53$) and DM errors per month (33.7(5.7) versus 34.0(10.4); $P = .96$) in Q2 pre- and post-curriculum implementation.

There were significantly fewer errors committed per month related to antibiotic prescribing post-curriculum implementation versus pre-curriculum implementation (3.8 (1.7) versus 8.0 (3.1), $P < .01$).

Discussion

In this study, we developed and implemented a pharmacist-led *Medication Prescribing Curriculum* for a surgery service in a tertial academic hospital without EOE system, and evaluated the effectiveness of this curriculum using a prospective observational cohort study design. We identified specific times during the academic year when surgery trainees are most susceptible to making medication prescribing errors and observed that both the total number of medication errors per month and PW errors per month were significantly reduced post-curriculum implementation for the first quarter (Q1) of the academic year (July–September). However, the *Medication Prescribing Curriculum* had no effect on the number of DM errors committed per month. We confirmed that there was no difference in the mean total number of medication prescription orders written per month pre- and post-curriculum implementation. This suggests that the 2-day (2-h per day) *Medication Prescribing Curriculum* was effective in mitigating the usual increase in medication prescribing errors seen in the first quarter of the academic year.

We observed a significant reduction in PW errors and no change in DM errors following participation in a 2-day educational intervention - *Medication Prescribing Curriculum*. Our *Medication Prescribing Curriculum* differs from previously published prescribing curricula in that it was developed to specifically address the most common medication prescribing errors made by surgery residents, as described by our group.[9] This was a modification (with permission) of a curriculum developed by Ginzburg et al and shown to be effective at educating medical residents on proper prescribing practices.[14] To address prescribing errors, components of a correct prescription (route, dose, frequency, etc.) were reviewed, with specific examples of prescriptions containing errors. Electrolyte replacement, with specific examples, was also added in our curriculum as these were common errors previously identified on surgery wards.[9] Given that we identified only a significant reduction in PW errors, it would appear that our curriculum is effective in addressing PW errors. DM errors may be related to gaps in participants' clinical knowledge of the condition being treated, rather than a lack of knowledge about prescribing a medication.

Table 4. Number and types of medication errors per month pre- and post-curriculum implementation.

	ERRORS PER MONTH (PRE-CURRICULUM IMPLEMENTATION)	ERRORS PER MONTH (POST-CURRICULUM IMPLEMENTATION)
Total errors	87.5 (14.6)	78.7 (10.3)
Decision making (total)	36.3 (6.0)	35.3 (4.2)
Pharmaceutical issues	7.0 (2.8)	10.0 (2.7)
Prescribing two drugs for the same indication when only one is necessary	5.3 (2.3)	7.5 (4.1)
Prescribing a dose not recommended for the formulation prescribed	7.5 (2.3)	7.3 (2.8)
Dosing of drug with a narrow therapeutic index outside of the predicted range (above or below)	3.3 (2.6)	4.0 (2.3)
Dosing of drug below what is recommended for patient's clinical condition	4.1 (2.0)	2.3 (1.5)
Documented significant allergy	1.7 (1.2)	1.3 (1.2)
Prescription inappropriate for patient concern	1.7 (1.3)	0.7 (0.8)
Drug is contraindicated for a co-existing condition of a patient	1.8 (1.2)	0.7 (1.2)
Prescribing a drug without adjusting for weight / body size	1.0 (1.0)	0.7 (0.8)
Dosing of drug inappropriate for patient's renal function (both overdosing / underdosing)	2.2 (1.9)	0.5 (0.5)
Continuing a drug in the event of a clinically significant adverse drug interaction	0.0 (0.0)	0.2 (0.4)
Continuing a prescription for longer duration than necessary	0.0 (0.0)	0.2 (0.4)
Prescribing a drug without adjusting for age	0.2 (0.4)	0.0 (0.0)
Prescribing a drug when there is no indications to	0.1 (0.3)	0.0 (0.0)
Prescribing a drug at a concentration greater than recommended for peripheral IV administration	0.3 (0.7)	0.0 (0.0)
Not taking to account a significant drug interaction	0.3 (0.6)	0.0 (0.0)
Prescription writing (total)	51.3 (11.9)	43.3 (9.8)
Omission of frequency/not specifying PRN orders (ie, morphine 2 mg PRN instead of q4h prn)	12.7 (5.5)	10.8 (6.2)
Prescribing one tab/ 1 puff of a drug that is available in more than one strength	11.6 (4.4)	10.3 (5.1)
Writing an ambiguous medication order	7.5 (4.4)	7.2 (1.5)
Wrong unit (milligrams vs micrograms)	4.8 (1.6)	5.0 (2.4)
Omission of route for a drug that can be given by more than one route	6.8 (2.8)	3.3 (1.8)
Error in prescribing a home medication on admission	1.5 (1.6)	2.3 (1.4)
Gross misspelling of medication names	1.8 (1.5)	1.7 (1.5)
Writing prescriptions using non-standard nomenclature / abbreviations/ trailing zero, not putting zero in front of decimal	2.3 (1.9)	1.5 (1.2)
Prescribing a drug, dose, or route that is not intended	1.3 (1.6)	0.8 (1.6)
Writing illegibly	0.3 (0.6)	0.2 (0.4)
Omission of duration over drug to be infused via IV	0.4 (0.9)	0.2 (0.4)

(continued)

Table 4. Continued.

	ERRORS PER MONTH (PRE-CURRICULUM IMPLEMENTATION)	ERRORS PER MONTH (POST-CURRICULUM IMPLEMENTATION)
Omission of signature	0.2 (0.4)	0.0 (0.0)
Drug intended for wrong patient	0.0 (0.0)	0.0 (0.0)
Transcription errors	0.1 (0.3)	0.0 (0.0)
Unintentionally not prescribing a drug patient was taking prior to admission	0.0 (0.0)	0.0 (0.0)

IV, intravenous.

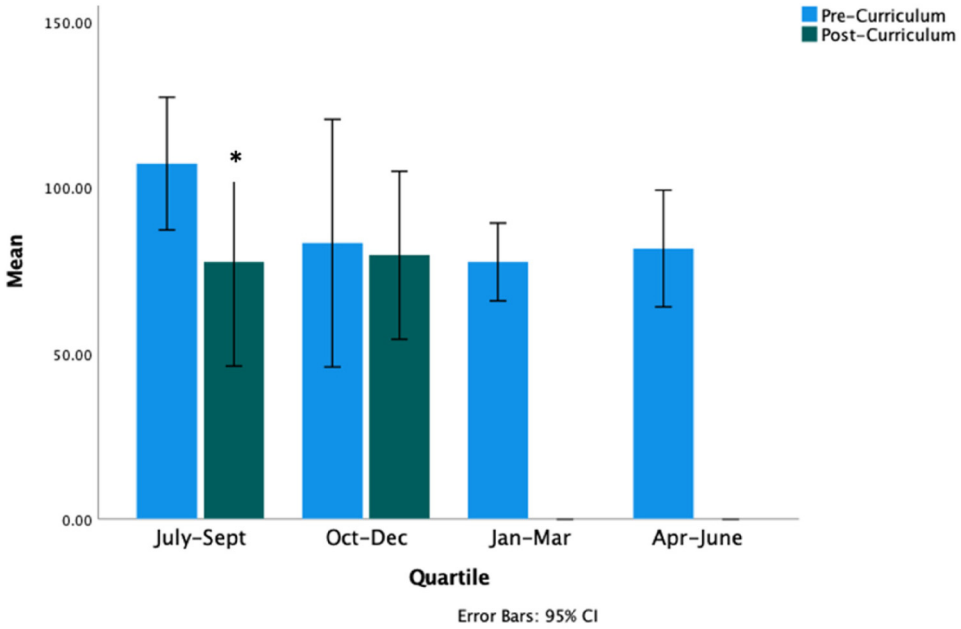

Figure 1. Mean number of monthly errors per quarter of the academic year; pre-curriculum and post-curriculum implementation.

Table 5. General classes of medications implicated in prescription writing errors.

MEDICATION CLASS	ERRORS PER MONTH (PRE-CURRICULUM)	ERRORS PER MONTH (POST-CURRICULUM)	*P*-VALUE
Gastrointestinal	11.6 (2.9)	11.3 (5.2)	.90
Respiratory	9.3 (4.9)	10.5 (6.9)	.67
Narcotic	8.8 (2.9)	7.3 (3.7)	.36
Cardiac	8.4 (4.1)	7.5 (2.1)	.62
Antibiotic	8.0 (3.1)	3.8 (1.7)	.007
Psychiatric	6.6 (2.7)	7.0 (1.4)	.74
Non-narcotic pain	5.4 (2.7)	4.2 (3.1)	.41
Electrolytes	5.1 (3.3)	6.7 (3.1)	.39
Anticoagulants /antiplatelet	5.1 (3.1)	4.5 (1.8)	.67
Vitamins	4.8 (2.8)	5.7 (3.3)	.55
Other	14.5 (4.4)	10.2 (3.5)	.054

As such, DM errors may require different, more intensive and prolonged educational interventions.

PW errors are common, accounting for over half of all errors in our study, and result from mistakes in PW (medication ordering) rather than a knowledge deficit. While PW errors can be reduced with implementation of an EOE system,[11,12] potentially serious DM errors such as failing to adjust dosing for weight or renal function continue to occur frequently in institutions with EOE.[13] As such, implementation of EOE should not be expected to eliminate DM errors and future research efforts should focus on specifically reducing the DM errors. One approach may be using examples of DM errors from our study to create vignettes for online case-based learning, which can be delivered longitudinally over the duration of the academic year.

As surgery trainees progressed through the academic year in our study, the effectiveness and the impact of our curriculum diminished over time. This is an expected finding as educational interventions often need to be repeated or refreshed on multiple occasions to avoid degradation in knowledge, skills and attitudes over time.[18] We suggest administering a 'refresher' *Medication Prescribing Curriculum* every 3 months during the academic year, as knowledge and skills of surgery trainees have been shown to degrade after a 3 month period.[18]

Baseline data for 12 months prior to the implementation of the *Medication Prescribing Curriculum* demonstrated that the greatest number of errors occurred in July with significantly greater number of errors per month in Q1 versus Q3 and Q4. This result is consistent with what Phillips termed the 'July Effect' where an increase in fatal prescribing errors was observed in American teaching hospitals in July.[19] Chaitoff et al showed a similar trend in errors throughout the academic year on a general surgery service.[13] As such, our finding of the absence of an expected increase in the number of errors per month in the first quarter of the academic year post-curriculum implementation suggests that the *Medication Prescribing Curriculum* may help mitigate the 'July Effect'.

The classes of medications involved in prescribing errors were compared on a monthly basis in the pre and post-curriculum years. We found that mean monthly errors in prescribing antibiotics were reduced post-curriculum from 8.0 (3.1) to 3.8 (1.7) ($P = .007$). Antibiotic selection, dosing and stewardship were specifically addressed in the *Medication Prescribing Curriculum* suggesting that targeted teaching about common classes of drugs, in addition to general prescribing principles, is effective. No significant differences for other classes of medications were observed.

Our study has several limitations. First, we were not able to capture medication prescribing errors that were of a highly acuity as such errors in our institution are communicated directly by the pharmacist to the post-graduate trainee by telephone without completing a MM. As such, the incidence of such errors at our institution is currently unknown; however, the potential influence of this practice on our results was likely minimal as this practice occurred both pre and post-curriculum implementation. Second, while the *Medication Prescribing Curriculum* was delivered only to surgery trainees, orders written by off-service residents were also included in our study. We were not able to separate orders written by surgery and off-service residents due to institutional limitations; however, the proportion of off-service residents rotating on the surgery service was not significantly different pre- and post-curriculum implementation (Table 2). Third, we did not determine our sample size based on a power calculation as it would have been unethical to exclude residents from participating in this educational intervention. Rather, we elected to include all eligible residents as participants in our study. Fourth, the decrease in errors noted in Q2 post-implementation could have been due to 'chance'. Future studies should attempt to collect post-implementation data for 1-year post-curriculum implementation to confirm our results. Fifth, it would have been ideal to calculate an error rate (number of errors per prescription per month); however it was not possible to calculate as the exact number of medication prescription orders entered per month was not recorded by our institution. Finally, it is possible that a Hawthorne effect contributed to the reduction in errors observed in Q1 of the academic year as trainees may have been aware of our study and may have adjusted their prescribing practices.

Conclusions

Implementation of a structured *Medication Prescribing Curriculum* in a surgery training program was associated with a reduction in the total number of medication prescription errors and PW errors in the first quarter of the academic year. The effectiveness of the *Medication Prescribing Curriculum* appears to decrease over time, and a 'refresher' curriculum could be offered at regular intervals during the academic year to mitigate this. Further research is needed to develop and evaluate educational interventions targeting DM errors in PW.

Author Contributions

Study conception and design: Ring, Zhang, Methot and Zevin; acquisition of data: Ring and Maracle; analysis and interpretation of data: Ring, Maracle, Zhang and Zevin; drafting of manuscript: Ring and Zevin; critical revision: Ring, Maracle, Zhang, Methot and Zevin.

Author's Note

Boris Zevin, Kingston Health Sciences Center, Kingston, Ontario, Canada.

Availability of Data and Materials

The datasets generated and/or analysed during the current study are not publicly available due to confidentiality concerns (unedited data contains specific information regarding

prescription medications and our institution is located in a relatively small community), but are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate

Research Ethics Board approval was obtained prior to commencement of the study from Queen's University (#6020195).

All methods were carried out in accordance with relevant guidelines and regulations.

Written informed consent was obtained from all participants.

REFERENCES

1. Brennan TA, Leape LL, Laird NM, et al. Incidence of adverse events and negligence in hospitalized patients: results of the Harvard medical practice study I. 1991. *Qual Saf Health Care*. 2004;13(2):145-152.
2. Baker GR, Norton PG, Flintoft V, et al. The Canadian adverse events study: the incidence of adverse events among hospital patients in Canada. *CMAJ* 2004;170(11):1678-1686.
3. Wanzel KR, Jamieson CG, Bohnen JM. Complications on a general surgery service: incidence and reporting. *Can J Surg*. 2000;43(2):113-117.
4. Bates DW, Cullen DJ, Laird N, et al. Incidence of adverse drug events and potential adverse drug events. Implications for prevention. ADE Prevention Study Group. *J Am Med Assoc*. 1995;274(1):29-34.
5. Dean B, Schachter M, Vincent C, et al. Prescribing errors in hospital inpatients: their incidence and clinical significance. *Qual Saf Health Care*. 2002;11(4):340-344.
6. Hug BL, Witkowski DJ, Sox CM, et al. Adverse drug event rates in six community hospitals and the potential impact of computerized physician order entry for prevention. *J Gen Intern Med*. 2010;25(1):31-38.
7. Franklin BD, Reynolds M, Shebl NA, et al. Prescribing errors in hospital inpatients: a three-centre study of their prevalence, types and causes. *Postgrad Med J*. 2011;87(1033):739-745.
8. Ross S, Bond C, Rothnie H, Thomas S, Macleod MJ. What is the scale of prescribing errors committed by junior doctors? A systematic review. *Br J Clin Pharmacol*. 2009;67(6):629-640.
9. Zhang S, Ring J, Methot M, Zevin B. Medication errors in surgery: a classification taxonomy and a pilot study in postcall residents. *J Surg Res*. 2021;264:402-407.
10. Larson KA, Wiggins EF, Goldfarb MA. Reducing medication errors in a surgical residency training program. *Am Surg*. 2004;70(5):467-471.
11. Nuckols TK, Smith-Spangler C, Morton SC, et al. The effectiveness of computerized order entry at reducing preventable adverse drug events and medication errors in hospital settings: a systematic review and meta-analysis. *Syst Rev*. 2014;3(1):1-12.
12. Radley DC, Wasserman MR, Olsho LE, et al. Reduction in medication errors in hospitals due to adoption of computerized provider order entry systems. *J Am Med Inform Assoc*. 2013;20(3):470-476.
13. Chaitoff A, Strong AT, Bauer SR, et al. Educational targets to reduce medication errors by general surgery residents. *J Surg Educ*. 2019;76(6):1612-1621.
14. Ginzburg R, Cohrssen A. Demonstrating prescribing competence: a successful pilot of a prescription competency curriculum for family medicine residents. *Fam Med*. 2007;39(10):703-705.
15. Kozer E, Scolnik D, Macpherson A, Rauchwerger D, Koren G. The effect of a short tutorial on the incidence of prescribing errors in pediatric emergency care. *Can J Clin Pharmacol*. 2006;13(3):e285-e291.
16. Howell RR, Jones KW. Prescription-writing errors and markers: the value of knowing the diagnosis. *Fam Med*. 1993;25(2):104-106.
17. Shaughnessy AF, D'Amico F. Long-term experience with a program to improve prescription-writing skills. *Fam Med*. 1994;26(3):168-171.
18. Madani A, Watanabe Y, Vassiliou MC, et al. Long-term knowledge retention following simulation-based training for electrosurgical safety: 1-year follow-up of a randomized controlled trial. *Surg Endosc*. 2016;30(3):1156-1163.
19. Phillips DP, Barker GE. A July spike in fatal medication errors: a possible effect of new medical residents. *J Gen Intern Med*. 2010;25(8):774-779.