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ORIGINAL ARTICLE

How would final-year medical students perform if their skill-based prescription assessment was real life?

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Aims: Prescribing errors occur frequently, especially among junior doctors. Our aim was to investigate prescribing errors made by final-year medical students. Information on these errors can help to improve education on and assessment of clinical pharmacotherapy (CPT).

Methods: This was a retrospective cohort study amongst final-year medical students at Erasmus Medical Centre, The Netherlands. Errors made in the final prescribing assessment were analysed. Errors were categorized by type, possible consequence and possibility of reaching the patient in real life.

Results: A total of 381 students wrote 1502 analysable prescriptions. Forty per cent of these contained at least one error, and 54% of errors were of the inadequate information type. The rating of prescriptions for children was lower than for other question categories ($P = <.001$). Fifty per cent of errors were classified as "would have reached the patient but would not have had the potential to cause harm". In total, 253 (29%) errors would not have been intercepted by an electronic prescribing system or a pharmacist. Ten (4%) of these would probably have caused harm in the patient.

Conclusions: There is a high rate of errors in prescriptions written by final-year medical students. Most errors were of the inadequate information type, indicating that students had difficulties determining the content and amount of information needed to make treatment successful. Prescriptions for children contained most errors. Curricula could be improved by offering more case-based CPT education, focusing on the practical issues of prescribing, especially for paediatric cases, and offering more practice time for prescribing during clerkships.

KEYWORDS
education, medical education, medical student, pharmacotherapy, prescribing

The Principal Investigator for this paper is Floor van Rosse.

1 | INTRODUCTION

Prescribing errors occur frequently. Studies have found errors in 7.5 to 27.4% of prescriptions.[1–3] Especially young doctors, in the first few years after graduation, are prone to make prescribing errors as this is when they prescribe most frequently.[2] The PROTECT study showed that first-year postgraduates were responsible for half of all prescribing and had errors in 7.4% of their prescriptions.[3] Possibly contributing to this number of prescribing errors in junior doctors is that the majority of final-year medical students felt their medical curriculum had not adequately prepared them for their future prescribing responsibilities as a junior doctor.[4–9]

During the training of medical students at Erasmus Medical Centre, Rotterdam, the Netherlands, the education on clinical pharmacotherapy (CPT) is continually interlaced in the master phase of the curriculum. Students participate in blended learning by using the flipped classroom model[10] where they take e-learning modules in preparation for interactive classes. Additionally, students can practise their skills regularly by taking compulsory and non-compulsory e-learning modules relevant to their next clerkship in the online program P-scribe[11] and watch short online videos called 'Drug of the week'.[12]

After 3 years of bachelor's (undergraduate) curriculum, students start their 3-year master's (graduate) curriculum. During the fourth year of medical school, the basic skill of writing a prescription is taught and the WHO six-step model for rational pharmacotherapy[13] is explained and practised. After the first clerkship of internal medicine, students have to take a formative skill-based prescription assessment, as shown in Figure 1. This assessment is a digital assessment, taken in the online program P-scribe.[11] This assessment consists of six knowledge questions and calculations and two separate exercises in which students have to write a case-based prescription. Students are not graded on this assessment, but students receive standardized feedback on the knowledge questions and calculations and personalized feedback on their prescriptions by a CPT teacher.

During their fifth year, students train their digital prescribing skills during a 2-hour class in which they practise prescribing in a copy of the electronic patient record and electronic prescribing system (EPS). Also during this year, students are tested on their drug knowledge by means of a summative Dutch National Pharmacotherapy Assessment[14,15] as shown in Figure 1. This knowledge-based assessment consists of 60 multiple-choice questions on pharmacotherapy.

During their final year, students are assessed on their prescribing skills by means of a summative skill-based prescription assessment (see Figure 1). This assessment is also a digital assessment, taken in the online program P-scribe.[11] In this program, students type their free-text prescriptions in a blank prescription format (see Appendix 1 for an example of the assessment). During this assessment students are allowed to use online information sources, which would be used in real medical practice.[16–19]

This final skill-based prescription assessment consists of four questions at junior doctor level, of which three are cases with a predefined drug to prescribe (e.g., "write a prescription for nystatin for an oral candidiasis"). The fourth question is an open case in which students have to use the WHO six-step model to choose a drug and write a prescription for this self-chosen drug. All questions are developed by CPT teachers (pharmacists and medical doctors) and evaluated yearly to check for compliance to the national guidelines. The assessments are individually composed for each assessment date. Each assessment consists of at least one opioid case, a paediatric case and a case in which the dose needs to be adjusted to the kidney function. However, within these categories, different questions were asked on different assessment dates.

For marking, there is a predefined answer model and the assessment is graded by CPT teachers from the hospital pharmacy using a rubric form, which is evaluated annually. Teachers grade the assessment by stating the error after which the corresponding number of points are deducted. Students can get a maximum score of nine points per prescription. For the fourth case, students can receive one point for each step of the WHO six-step and three for the final prescription. Thus students can receive a maximum score of 36 points for the whole assessment. Students are graded on this assessment; the assessment can be marked "insufficient" (≤21 points), "pass" (22–30 points) or "well done" (≥31 points). After grading, each student has the possibility to check their personalized feedback given by the teachers during marking.

Literature has extensively described the problem of prescribing errors by junior doctors.[2,3,6,20] For medical students, there is a considerable amount of knowledge on confidence in prescribing, attitude towards prescribing and CPT knowledge.[4,5,7,8,21] When research on

What is already known about this subject

- Prescribing errors occur frequently, especially among junior doctors.
- The majority of final-year medical students felt their curriculum had not adequately prepared them for their prescribing responsibilities.
- There is limited knowledge on what kind of prescribing errors medical students make; however, this insight is necessary to evaluate the current CPT education.

What this study adds

- Most prescribing errors made by final-year medical students were of the inadequate information type.
- Students had difficulties determining the content and amount of information needed to make treatment successful.
- Curricula could be improved by offering more case-based CPT education and offering more practice time for prescribing during clerkships.

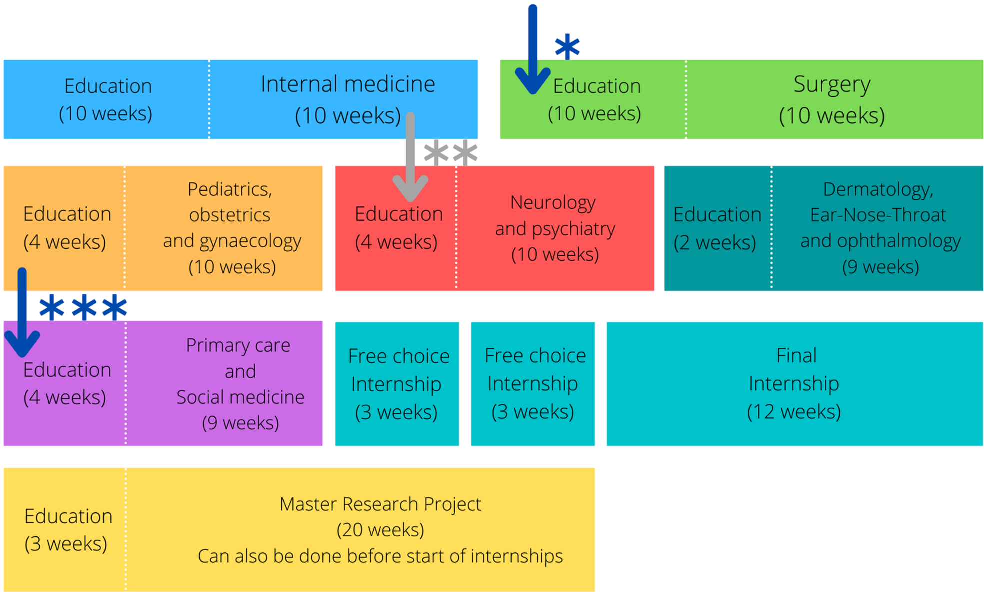

FIGURE 1 Medical curriculum including skill and knowledge assessments at Erasmus Medical Centre. * Formative skill-based prescription assessment, ** Dutch National Pharmacotherapy Assessment, *** Summative skill-based prescription assessment

medical students focuses on assessing CPT knowledge, it is often done through questionnaires. However, studying medical students' prescribing errors has not been done before. The aim of our study was to investigate the prescribing errors made by medical students by looking at the quality of their prescriptions. This adds to the current available literature, since it is not only important to know what kind of prescribing errors junior doctors make, it is just as important to know what kind of prescribing errors medical students make. Information on the type, amount and seriousness of the prescribing errors made by final-year medical students can help in assessing and improving education on CPT and build towards a solution to the high number of prescribing errors made by medical students, which translates into errors made by junior doctors. By having this knowledge, we will hopefully be able to fill knowledge gaps and prepare future students better for their graduation.

2 | METHODS

This retrospective cohort study was conducted among final-year medical students at Erasmus Medical Centre, Rotterdam, the Netherlands. All students who started their master curriculum between 1 September 2018 and 31 August 2019 were included. The students' first regular attempt at the summative prescribing assessment was done between 14 February 2020 and 4 October 2021. Students who did not do the summative prescribing assessment between these dates were excluded. Resit assessments were also excluded. Each student had a personal account in the P-scribe program for educational purposes prior to the study. On registering in P-scribe, students agreed to have their data stored and used for research. We coded student data to ensure anonymity. Data extraction from P-scribe took place from June 2021 to October 2021.

The research proposal was reviewed by the Medical Ethics Committee Erasmus MC. It was determined that the Medical Research Involving Human Subjects Act was not applicable to this research.

The data extracted from P-scribe included the grade for the assessment, the number of points scored for the complete assessment, the number of points scored per question, the question category (children, opioids, adjustment for kidney function, residual) and the teachers' feedback given during marking of the assessment. The categorization on type of errors, possible consequences of the errors and the possibility of the errors reaching the patient had to be deduced from the teachers' feedback on the prescriptions. The prescriptions themselves were not checked separately for errors which were not included in the teachers' feedback. A total of 12 CPT teachers marked these assessments. Using these data, a database was made using Castor EDC (Electronic Data Capture).[22]

Figure 2 shows the categorization of the errors. These categories were based on previous research, literature and the Erasmus Medical Centre guidelines to report an incident.[1,23] Table 1 displays a more detailed description of the type of errors within each category.

Next to the primary categorization of type of errors, a second categorization was applied, based on the possible consequences of the errors. To register the possible consequences of the errors, the errors were assessed as if they would have occurred in real prescriptions. This second categorization was derived from the classification of the National Coordinating Council for Medication Error Reporting and Prevention (NCCMERP).[24] However, due to the questions asked on the assessment, a modified categorization was implemented, which excludes categories: A (Circumstances or events that have the capacity to cause error), F (Error occurred, reached the patient, may have contributed to or resulted in temporary harm, caused or prolonged hospitalization) and H (Error occurred, reached the patient, required intervention to sustain life). The remaining categories are shown in Figure 3.[23]

Finally, we evaluated whether the errors were likely to reach a non-fictional patient, i.e., whether existing safety checks would have

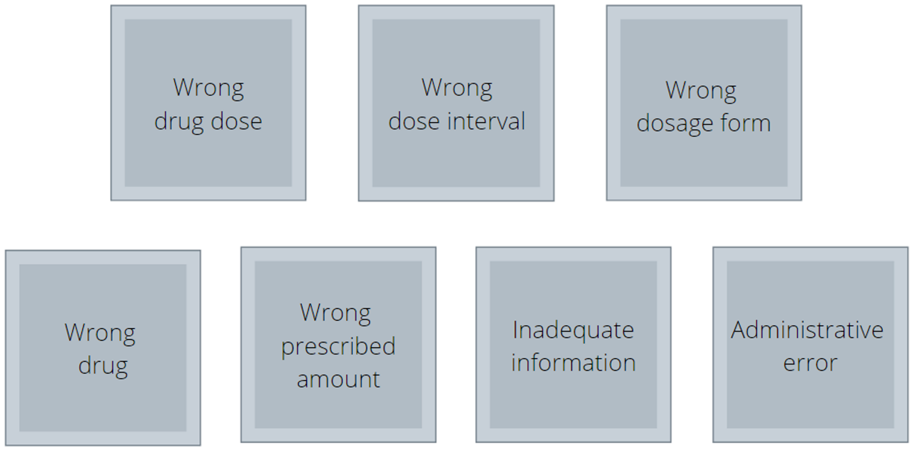

FIGURE 2 Categorization of prescribing errors in summative prescribing assessment

TABLE 1 Error types within each category

Inadequate information	No weight of child No indication stated when necessary No concentration or dosage stated No dosage form stated No amount to supply stated Missing maximum use Dose not measurable (e.g., 3.67 mL) Wrong usage instructions Missing usage instructions No "with controlled release" stated with the drug name when prescribed as a "with controlled release" product No duration of treatment stated
Wrong drug dose	Dose too low/high
Wrong drug interval	Incorrect drug interval "With controlled release drugs" prescribed in an interval as if not "with controlled release"
Wrong dosage form	Incorrect or less than desirable dosage form
Wrong prescribed amount	Insufficient prescribed which makes the prescription patient-unfriendly (e.g., student prescribed only one sildenafil tablet) Insufficient prescribed to finish treatment (e.g., student prescribed amoxicillin/clavulanic acid three times a day for 5 days, but only prescribes 10 tablets) Too much prescribed for newly started chronic drugs (e.g., enalapril for more than 15 days) Too much prescribed for necessary treatment (e.g., nystatine 300 mL, while 100 mL is sufficient)
Wrong drug[a]	Wrong drug

[a]Only in the 4th test question did students have to choose a drug.

alerted the prescriber. At Erasmus Medical Centre, drug safety alerts are organized as follows: firstly, the prescription is checked during the prescribing itself by the electronic prescribing system (EPS). A second check is done by the pharmacy management system (PMS), which checks the prescribed drugs with the current medication taken by the patient, patient characteristics and comorbidities. The PMS will be able to produce additional notifications (see Appendix 2 for examples of notifications). Thirdly, a pharmacy technician will then check all these notifications according to protocol. Lastly, only in case of unclear notifications or uncertainties will the prescription be checked by a pharmacist. This process of drug safety alerts may vary between different hospitals, it may vary with the primary care setting and it may vary between different retail pharmacies.

For each prescribing error made in the summative assessment, the occurrence of notifications in the EPS was checked. If the EPS could not warn the prescriber of his/her error, it was discussed whether a pharmacist would have been able to intercept the error made. Since the cases used in the summative assessment are largely primary care cases or cases in an outpatient clinic, the role of the supervisor or nurses have been excluded from this categorization. Additionally, literature has shown that in practice hierarchical structures and medical culture prevents junior doctors from seeking help or receiving supervision.[20,25]

All categorizations were made with the expert opinions of a medical doctor and a pharmacist. In case of uncertainty, the error was discussed through the expert opinion of an independent pharmacist until consensus was reached.

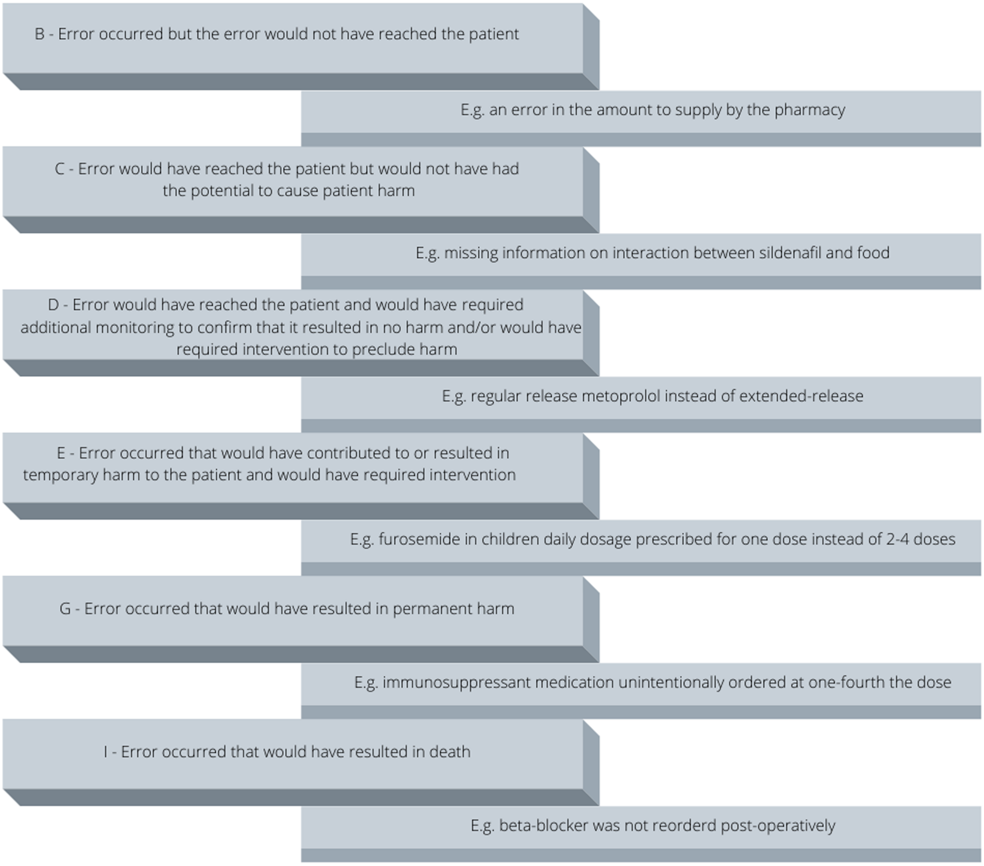

FIGURE 3 Categorization of possible consequences of prescribing errors in summative prescribing assessment

Data was transferred from Castor to the statistical package IBM SPSS statistics 25.0[26] for analysis. Data analysis was done with descriptive statistics. The number of points per question category was compared through Tukey's HSD test for comparison of multiple means. A level of 0.05 was used to detect differences.

3 | RESULTS

A total of 400 students started their master's curriculum in the academic year 2018–2019. Between 14 February 2020 and 4 October 2021, a total of 381 of these students made their first attempt at the summative prescription assessment. These students had an average age of 25.4 years and 65% were female. Each assessment contained three predetermined drug questions and one WHO six-step, including a prescription for a drug of the students' choice. A total of 1135 predetermined drug prescriptions and 379 complete WHO six steps including 367 prescriptions (see Figure 4) were suitable for analysis.

The predetermined drug questions ($n = 1135$) were divided into the following categories: prescriptions for children 312 (27%), opioids 244 (21%), adjustment to kidney function 208 (18%) and residual questions 372 (33%). The last prescription ($n = 367$), following the WHO six-step, contained one adjustment to kidney function question (0.2%) and the rest of the questions were categorized as residual questions ($n = 366$, 99%). The discrepancy between the number of WHO six-steps (379) and the prescription following the WHO six-step (367) is due to 12 students missing data on the kind of errors, as the teacher did not document this.

3.1 | Errors per question category

From a total of 1502 prescriptions, 603 contained at least one error (40%). In these 603 prescriptions a total of 884 errors occurred. In Table 2, the mean number of points (NOP) per question category is described. Most errors were made in the prescriptions for children. In 64% of these prescriptions at least one error could be found. Tukey's HSD test for multiple comparisons showed that the mean value of the NOP of the prescriptions for children was statistically significantly lower compared to all other categories ($P < .05$, child *vs* opioids 95% CI [−1.5;-0.6], child *vs* kidney function 95% CI [−1.4; −0.5], child *vs* general 95% CI [−1.1; −0.4]).

3.2 | Type of errors

The errors made were categorized into different types of errors. Figure 5 shows the percentage of all errors by error type. Most errors were classified as inadequate information (53%, $n = 474$).

FIGURE 4 Number of students and prescriptions excluded

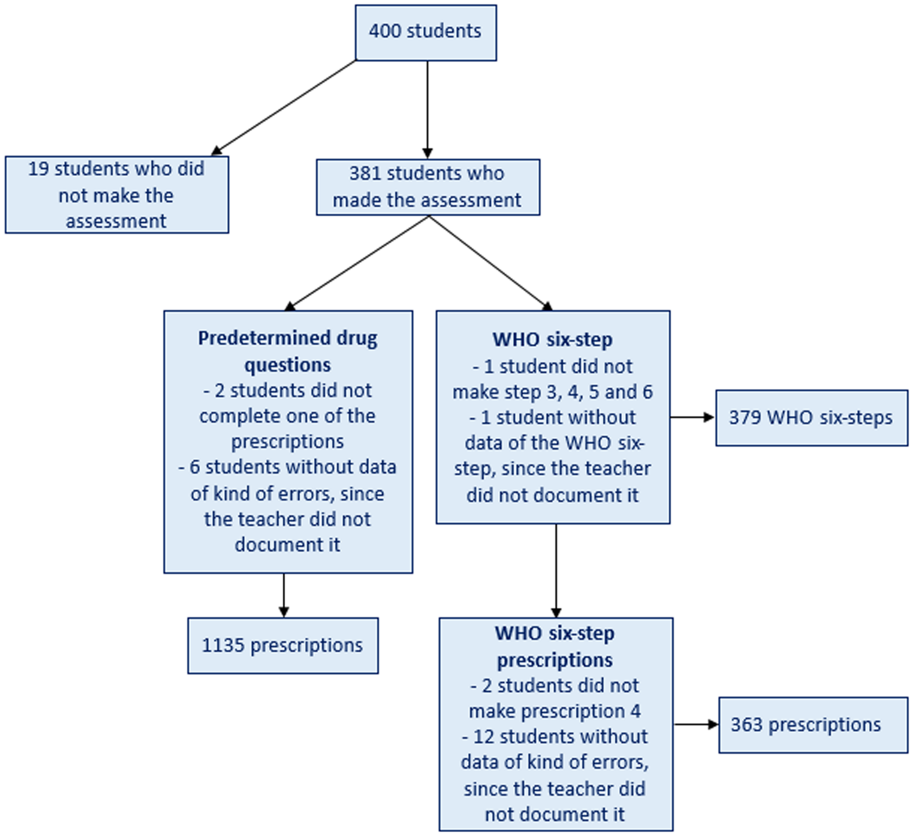

TABLE 2 Number of points (NOP) per question category (opioids, prescriptions for children, adjustment to kidney function, residual questions)

Question category		Mean NOP	Std. deviation	Tukey HSD test: Opioids	Children	Kidney function	Residual questions
		(Max. 9)					
Predetermined drug questions	Opioids (*n* = 244)	8.2	1.9	-	.00 [0.7,1.5]	.90 [−0.3,0.6]	.13 [−0.1,0.7]
Total 1135	Children (*n* = 312)	7.2	2.2	.00 [−1.5,-0.7]	-	.00 [−1.4,-0.5]	.00 [−1.1,-0.4]
	Kidney function (*n* = 208)	8.1	1.4	.90 [−0.6,0.3]	.00 [0.5,1.4]	-	.56 [−0.2,0.6]
	Residual questions (*n* = 372)	7.9	1.7	.13 [−0.7,0.1]	.00 [0.4,1.1]	.56 [−0.6,0.2]	-
		(Max. 3)					
WHO-six step prescriptions	Kidney function (*n* = 1)	2.0					
Total 367	Residual questions (*n* = 366)	2.7	0.6				

NOP, number of points scored by students on the prescription.
Mean NOP per question category is compared to the mean NOP of all other question categories.
Numbers for Tukey HSD test are presented as *P*-value [95% confidence interval]. Negative confidence intervals mean a lower mean NOP compared to other categories.

The errors classified as inadequate information were divided into several categories (Figure 6). Of the 474 errors, 302 were missing usage instructions, e.g., not stating that the patient should complete their antibiotics treatment.

The error of prescribing a wrong drug could only occur in the WHO six-step prescriptions since the other prescriptions were based on a predetermined drug. In Table 3 the types of errors are shown for each question category.

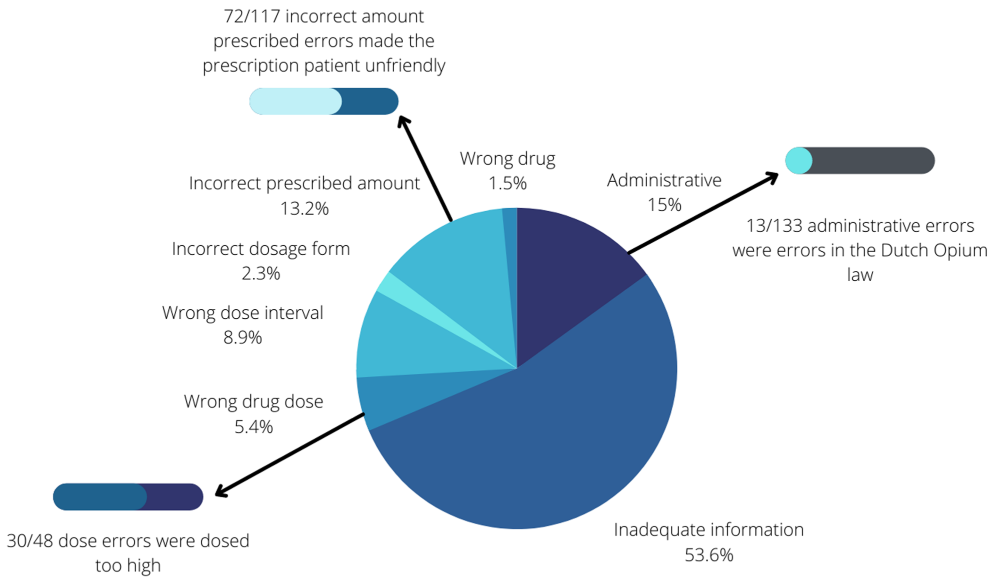

FIGURE 5 Percentage errors by type error

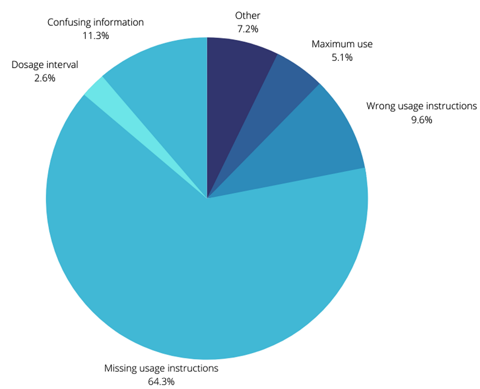

FIGURE 6 Inadequate information categorized by type. Category "other": weight of child (0.5%), no concentration stated (1%), no dosage form stated (0.1%), no amount to supply stated (0.7%), no duration of treatment stated (1%), dose not measurable (0.2%), no "with controlled release" stated (0.3%).

TABLE 3 The type of errors for each question category

Errors in the predetermined and WHO-six step prescriptions (Total 884)	Administrative	Inadequate information	Wrong drug dose	Wrong dose interval	Incorrect dosage form	Incorrect prescribed amount	Wrong drug
Opioids (*n* = 69)	26 (38%)	23 (33%)	12 (17%)	8 (12%)	0	0	n.a.
Children (*n* = 315)	47 (15%)	136 (43%)	17 (5%)	55 (17%)	7 (2%)	52 (17%)	n.a.
Kidney function (*n* = 118)	14 (12%)	69 (58%)	5 (4%)	7 (6%)	11 (9%)	12 (10%)	0
Residual questions (*n* = 382)	46 (12%)	246 (64%)	14 (4%)	7 (2%)	2 (1%)	53 (14%)	13 (3%)

Numbers are presented as *n* (rounded percentage of type of error per question category).
Prescribing the wrong drug only occurred in the WHO six-step prescriptions, these prescriptions only had two question categories.

3.3 | Possible consequences of the errors

The errors were classified based on the classification of the NCCMERP. In Table 4, the number of errors by NCCMERP classification are shown for each question category and for each type of error. Most errors (*n* = 445, 50%) were classified as category C; "an error occurred and would have reached the patient but would not have had the potential to cause patient harm".

TABLE 4 Number of errors captured by either EPS or pharmacy assistant/pharmacist

Errors in the predetermined and WHO six-step prescriptions (Total 884)	B taxonomy (n = 157)	C taxonomy (n = 445)	D taxonomy (n = 199)	E taxonomy (n = 83)
Opioids (n = 69)	25 (36%)	13 (19%)	7 (10%)	24 (35%)
Children (n = 315)	57 (18%)	191 (61%)	39 (12%)	28 (9%)
Kidney function (n = 118)	16 (14%)	78 (66%)	19 (16%)	5 (4%)
Residual questions (n = 382)	59 (15%)	163 (43%)	134 (35%)	26 (7%)
Type of errors				
Administrative (n = 133)	129 (97%)	3 (2%)	1 (1%)	0
Inadequate information (n = 474)	12 (2.5%)	256 (54%)	164 (35%)	42 (9%)
Wrong drug dose (n = 48)	0	6 (12.5%)	11 (23%)	31 (65%)
Wrong drug interval (n = 79)	0	61 (77%)	11 (14%)	7 (9%)
Incorrect dosage form (n = 20)	8 (40%)	11 (55%)	0	1 (5%)
Incorrect prescribed amount (n = 117)	2 (2%)	107 (91.5%)	8 (7%)	0
Wrong drug (n = 13)	6 (46%)	1 (8%)	4 (31%)	2 (15%)

Numbers are presented as n (rounded percentage of errors within the taxonomy/total errors within each question category or type of errors).
B taxonomy: error occurred but the error would not have reached the patient.
C taxonomy: error would have reached the patient but would not have had the potential to cause patient harm.
D taxonomy: error would have reached the patient and would have required additional monitoring to confirm that it resulted in no harm and/or would have required intervention to preclude harm.
E taxonomy: error would have contributed to or resulted in temporary harm to the patient and would have had required intervention.

TABLE 5 Taxonomy of prescribing errors after control by EPS and pharmacist/pharmacy technician

	Total amount of errors (n = 884)	Errors remaining after notification check by EPS (n = 611)	Errors remaining after check by a pharmacist (n = 253)
B taxonomy	157 (18%)	9 (1.5%)	0 (0%)
C taxonomy	445 (50%)	373 (61%)	171 (68%)
D taxonomy	199 (23%)	167 (27%)	72 (28%)
E taxonomy	83 (9%)	62 (10%)	10 (4%)

Numbers are presented as number errors not giving an EPS notification and probably not having been intercepted by a pharmacist.
B taxonomy: error occurred but the error would not have reached the patient.
C taxonomy: error would have reached the patient but would not have had the potential to cause patient harm.
D taxonomy: error would have reached the patient and would have required additional monitoring to confirm that it resulted in no harm and/or would have required intervention to preclude harm.
E taxonomy: error would have contributed to or resulted in temporary harm to the patient and would have had required intervention.

For the final categorization, the errors were categorized by whether the EPS could have warned the prescriber through a notification. If this was not the case, it was discussed whether a pharmacy technician/pharmacist would have been able to intercept the error made. Of all 884 errors, the EPS would have warned the prescriber through a notification in 273 of cases (31%). Of the remaining 611 errors, 358 errors (40.5%) would probably have been intercepted by a pharmacy technician or pharmacist, resulting in 253 (29%) errors actually reaching the fictional patients (see Table 5). An example of an error which would have been able to reach the patient is the prescription of a wrong drug for the case specified (e.g., paracetamol instead of amoxicillin), but prescribed in the correct way for the chosen drug.

Table 5 shows the number of errors without notifications from the EPS divided by NCCMERP classification. Most errors without notifications from the EPS (n = 373, 61%) were classified as a category C error ("an error occurred and would have reached the patient but would not have had the potential to cause patient harm"). Errors had the possibility to reach the patient if the error would not have alerted the prescriber through a notification by the EPS and would probably not have been intercepted by a pharmacy technician. Of all 884 errors, 253 (29%) would have had the possibility to reach the fictional patient, and of these, 10 (4%) could have caused temporary harm (see Table 5, taxonomy E). Most of the errors (n = 171, 68%) that reached the fictional patient had a C taxonomy ("an error occurred and would have reached the patient but would not have had the potential to cause patient harm").

4 | DISCUSSION

The aim of this study was to evaluate the type, amount and severity of prescribing errors final-year medical students make. Data of more than 1500 prescriptions were analysed. The results of this study provide valuable detailed information which can be used to improve education on clinical pharmacotherapy.

The key result of this study is that in all question categories, most errors were classified as inadequate information. Only 9% of these inadequate information errors could have caused harm in non-fictional patients because the information missing on the prescription was crucial for effective treatment. However, in 35% of all inadequate information errors, monitoring of the patient would have been necessary to confirm that the error would not result in any harm. Even though our study was done in an assessment setting, these results are similar to the study by Devine et al. in a real-life setting, who also found the majority of errors to be categorized as inadequate, or missing, information.[1]

In our study we found the most prescribing errors in prescriptions for children. In line with the study of Ghaleb et al.,[27] the main source of errors in prescriptions for children was inadequate information. In prescriptions for children, it is often necessary to prescribe a different and more complex dosage than for adults, leading to an additional need for information or instructions for parents, which caused students to make errors in the additional usage instructions in the prescriptions.

Despite also having to obey the Dutch Opium law, students scored the highest grades on prescriptions for opioids, indicating appropriate coverage in the curriculum. Nevertheless, errors made in these prescriptions had a large possibility to cause harm. In all these errors, a wrong drug dose was the most likely to have caused harm, compared to the other error types. Pharmacy technicians and pharmacists would have been most likely to capture errors with an E classification, and therefore prevent most harm.

The rate of prescribing errors in this study is higher than the rate found in the research by Devine et al., Ashcroft et al. and Ryan et al.[1–3] A first possible explanation for this could be the different study groups. While the research of those studies included graduated doctors, our research focused on prescriptions by final-year medical students. A second possible explanation could be the lack of supervision and checkpoints in our assessment compared to the supervision and checkpoints in real life. In our assessment, students prescribe as if done in writing, without the notification given by an EPS or PMS. Lastly, the assessment focuses on specific difficulties in prescribing (e.g., adjusting the dose to kidney function) in three out of the four questions, which might not be a fair representation of the reality where less difficult cases might be more common.

Kaushal et al.[23] found most medication errors in paediatric prescriptions were of the wrong drug dose type. In our study, the students also had to adjust dosages to body weight; however, we did not see this type of error frequently.

Although we considered our curriculum able to prepare students well for prescribing medication for children, it was with these prescriptions that students struggled the most. We hypothesized that the problem would be in the calculation of the right doses when prescribing for children; however, surprisingly most students were able to dose correctly, but had trouble with passing on the necessary information with these prescriptions for a safe and correct execution of the prescription. It could very well be possible to improve education on this matter. After discussing these results with a group of medical students and teachers, it was suggested that education should be more case-based. The students were not able to estimate the amount of practical information needed by a paediatric patient or by the parents of a paediatric patient to have treatment executed successfully.

Our research provides detailed information about the specific difficulties final-year medical students encounter when prescribing medication. Our hypothesis was that students would score the lowest grades on opioid prescriptions since they additionally have to adhere to the Dutch Opium laws. This information is often emphasized in our CPT classes and that clearly shows in the results.

Besides even more case-based education than currently given, to prepare young doctors better for their prescribing responsibilities, practice possibilities for students during their clerkships should be extended. In a study by Geoghegan et al., 62% of students had written fewer than five drug prescriptions during medical school.[6] Unfortunately, in most hospitals students are not able to practise their prescribing skills due to a lack of supervised prescribing authorizations in the different hospital information systems. Nevertheless, research shows that feedback by pharmacists on prescribing errors reduces the error frequency in a hospital setting.[28] One great way to implement more practice time during clerkships is through a student-run clinic.[29] A student-run clinic has been a mandatory part of the curriculum in the Erasmus University now for several years, in which students perform consultations during their clerkship internal medicine, including a treatment plan based on the WHO six-step method, and are able to prescribe medication under supervision. The aim is to expand this to all clerkships. It would therefore be interesting for future research to see if more supervised practice time during the clerkships supplemented with regular feedback reduces the error frequency for final-year medical students.

There are some potential drawbacks associated with our study. For example, for this study the prescriptions written by the students were not checked separately for errors, the data was solely based on the feedback given by the teachers during marking of the assessment, which can lead to errors being missed during the correction of the assessment and therefore being subsequently missed in our data. Furthermore, the potential to cause harm was subject to possible interpretation errors. Only fictional patients were included, so all possible consequences were categorized based on speculation, without facts on outcomes. During the evaluation of the potentiality of errors to reach the patient, we assumed that EPS notifications would have led to change in the prescription, while factors such as alert fatigue causes alerts to be overridden in a real-life setting.[30] Also, the single centre study design might be a limitation. However, due to the current extensive CPT program at Erasmus MC, the results are generalizable, especially to less robust CPT education programs. A final limitation of this study is the technical discrepancy between the summative skill-based prescription assessment and prescriptions for real patients. In the assessment, students had to write a prescription as if it were handwritten, whilst young doctors will mostly be using an EPS when prescribing in real life. Prescribing in an online hospital information system (HIS) or EPS has shown to reduce the number of prescribing errors.[31,32]

A strength of our study was the multidisciplinary approach to the sometimes complicated error classifications in the prescriptions. In case of a debatable error category, consensus about the classification was reached in a multidisciplinary consultation with hospital pharmacists and medical doctors. Secondly, due to the setting of the current prescription assessment, errors such as wrong drugs because of 'read-a-likes' are less likely to be made.[33] Thirdly, analysing the results of assessments is a great way to scrutinize a curriculum; it gives new insights on how to optimize the education given. This way of assessing a curriculum is applicable and recommendable for all faculties.

Future research should focus on the effects of more practice time for prescribing during clerkships. Also, for future education and research it would be important to test students in an EPS with proper checks by the EPS and a pharmacy technician/pharmacist, in addition to the current digital simulated handwritten assessment, so the assessment will be as authentic as possible and prescribing errors made by medical students will be more comparable to a hospital setting.

5 | CONCLUSIONS

This study shows a high rate of prescribing errors in prescriptions written by final-year medical students. Most of all errors were of the inadequate information type, indicating that students had difficulties determining the content and amount of information needed to make treatment successful. Prescriptions for children contained most errors. Curricula could be improved by offering more case-based clinical pharmacotherapy education focusing on the practical issues of prescribing, especially in paediatric cases, with emphasis on the execution of prescriptions by patients and offering more practice time for prescribing during clerkships.

COMPETING INTERESTS

The authors declare no conflicts of interest.

CONTRIBUTORS

L.K., F.R. and J.V. designed the study. The classification of errors was done by L.K., K.H., F.R., J.V. and C.B. L.K. and K.H. processed the data, performed the analysis and drafted the manuscript. L.K. interpreted the results with help of F.R. and J.V.. All authors discussed the results and commented on the manuscript.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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APPENDIX A: EXAMPLE OF SKILL-BASED ASSESSMENT IN P-SCRIBE; ONE PRESCRIPTION QUESTION AND ONE WHO SIX-STEP QUESTION

Question 1

You are a general practitioner. A dad comes in with his nine year old boy (30 kg). The boy is suffering from motion sickness and will go on a schooltrip by bus (about a one-hour drive). His dad asks you to write him a prescription to help with the motion sickness. Write a prescription for chlorcyclizine/cinnarizine for the boy with adequate instructions.

0 tekens | 0 woorden

Prescription for question 1

Name doctor:

Adress:

Phone number:

Date: 2021-07-06

Question 4

You are a general practitioner. You see a 40-year old female, with no documented medical history. She does not use any medication. She comes to see you for a first episode of heartburn. She has tried out several non-medical treatments, but they have not helped her enough. Fill out the 6-step and write a prescription.

Step 1

Define the patient's problem. Describe the preliminary diagnosis, the seriousness, cause and possible consequences.

0 tekens | 0 woorden

Step 2

Specify the therapeutic objective.

0 tekens | 0 woorden

Step 3

Describe the treatment possible for this diagnosis.

0 tekens | 0 woorden

Step 4

Choose the treatment which is most suitable for this patient and argue why you make this decision. (For example: comedications, contraindications, interactions)

0 tekens | 0 woorden

Step 5

Write a prescription for the choosen treatment and write which information you would give your patient. (For example, how does the medication work, side-effects, instructions for use, precautions)

0 tekens | 0 woorden

Step 6

What is your follow-up?

0 tekens | 0 woorden

Prescription for 4

Name doctor:

Adress:

Phone number:

Date: 2021-07-06

APPENDIX B: HIX ('HEALTHCARE INFORMATION EXCHANGE'; THE EPS USED IN ERASMUS MC) NOTIFICATION PER DRUG

Acenocoumarol

Swallow tablets whole, do not chew, crush, break or dissolve the tablets.

Usage according to scheme of thrombosis control service.

Take medication in the evening during dinner.

The prescribed dose exceeds the upper or lower dosage limits (>8 mg).

This dosage frequency is not registered (other than once per day).

Algeldrate/magnesium hydroxide

Chew thoroughly before swallowing.

This dosage frequency is not registered (other than 4 times per day).

The prescribed dose exceeds the upper or lower dosage limits (>2 tablets).

Amoxicillin

Finish treatment entirely.

This dosage frequency is not registered (other than; once, one time per 6, 8 or 12 hours, 2, 3 or 4 times per day).

The prescribed dose exceeds the upper or lower dosage limits (250–2000 mg).

Amoxicillin/Clavulanic acid

Finish treatment entirely.

Take medication BEFORE eating.

This dosage frequency is not registered (other than once, or 2 or 3 times per day).

The prescribed dose exceeds the upper or lower dosage limits (>1 capsule).

Chlorcyclizine/Cinnarizine

Be careful with alcohol.

Can affect the reactive capacity.

If prescribed in mg: with the chosen units, no dose control can be done. Converting to other units is not possible.

The prescribed dose exceeds the upper or lower dosage limits (>1 pill).

This dosage frequency is not registered (other than 1, 2 or 3 times per day).

Digoxin

Assess potassium blood value.

The prescribed dose exceeds the upper or lower dosage limits (0 to 0.062 mg, absolute maximum of 0.125 mg).

This dosage frequency is not registered (other than 1, 2 or 3 times per day).

Dimeticone

No notifications.

Enalapril

Assess potassium blood value.

This dosage frequency is not registered (other than 1 or 2 times per day).

The prescribed dose exceeds the upper or lower dosage limits (>40 mg).

Fentanyl

Advise: add a laxans to prevent constipation during opioids use.

Notifications for oral form: Be careful with alcohol.

Can affect the reactive capacity.

Usage according to usage information.

Throat lozenge: This dosage frequency is not registered (>8× per day).

The prescribed dose exceeds the upper or lower dosage limits (>1800 μg).

Transdermal patch: This dosage frequency is not registered (other than once per 3 days).

The prescribed dose exceeds the upper or lower dosage limits (>1 patch).

Furosemide

Assess potassium blood value.

This dosage frequency is not registered (other than 1, 2 or 3 times per day, or once per 2 days).

The prescribed dose exceeds the upper or lower dosage limits (>500 mg).

With controlled release:

Swallow tablets whole, do not chew, crush, break or dissolve the tablets.

This dosage frequency is not registered (other than once per day).

The prescribed dose exceeds the upper or lower dosage limits (>60 mg).

Hydrocortisone eardrops 1%

If prescription in drops: with the chosen units, no dose control can be done. Converting to other units is not possible.

This dosage frequency is not registered (other than 3, 6, 7 or 8 times per day).

The prescribed dose exceeds the upper or lower dosage limits (>999 g).

Shelf life 6 months after opening.

Read usage information before using.

Levonorgestrel

The prescribed dose exceeds the upper or lower dosage limits (>1.5 mg).

This dosage frequency is not registered (other than once per day).

Methformin
Take medication DURING or soon AFTER eating.
Normal:
The prescribed dose exceeds the upper or lower dosage limits (0–1000 mg).
This dosage frequency is not registered (other than 1, 2 or 3 times per day).
With controlled release:
Swallow tablets whole, do not chew, crush, break or dissolve the tablets.
The prescribed dose exceeds the upper or lower dosage limits (>1000 mg).
This dosage frequency is not registered (other than 1 or 2 times per day).

Methylphenidate
Can affect the reactive capacity.
Normal:
The prescribed dose exceeds the upper or lower dosage limits (>19 995 mg).
This dosage frequency is not registered (other than 2 or 3 times per day).
With controlled release:
Swallow tablets whole, do not chew, crush, break or dissolve the tablets.
Take medication in the morning.
The prescribed dose exceeds the upper or lower dosage limits (0–60 mg, absolute maximum of 160 mg).
This dosage frequency is not registered (other than once per day).

Miconazole
This dosage frequency is not registered (other than once or one time per week).
The prescribed dose exceeds the upper or lower dosage limits (>1200 mg).

Morphine
Advise: add a laxans to prevent constipation during opioids use.
Be careful with alcohol.
Can affect the reactive capacity.
Normal oral tablets: This dosage frequency is not registered (other than 1, 2, 3, 4 or 5 times per day).
The prescribed dose exceeds the upper or lower dosage limits (>180 mg).

With controlled release:

Swallow tablets whole, do not chew, crush, break or dissolve the tablets.

This dosage frequency is not registered (>2× per day).

Rectal: The prescribed dose exceeds the upper or lower dosage limits (>50 mg).

Nystatin
Finish entire treatment.
The prescribed dose exceeds the upper or lower dosage limits (3 times 500 000 to 1 000 000 units, 4 times 400 000 to 600 000 units, newborns 4 times >200 000 units, prematures 4 times >100 000 units).

This dosage frequency is not registered (other than 3 or 4 times per day).
Gently shake before using.
After opening, limited shelf life, see usage instructions.

Paracetamol
The prescribed dose exceeds the upper or lower dosage limits (>3000 mg).

This dosage frequency is not registered (more than 6 times per day).

Sildenafil
This dosage frequency is not registered (more than 3 times per day).
The prescribed dose exceeds the upper or lower dosage limits (>100 mg).

Valaciclovir
Finish entire treatment.
This dosage frequency is not registered (other than 1–4 times per day).
The prescribed dose exceeds the upper or lower dosage limits (>4 times 2000 mg or other than 1 time 500/1000 mg, 2 times 500/1000 mg, 3 times 500/1000 mg depending on indication, kidney function and immune status).