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Medication Safety and Quality of Care on an Interprofessional Training Ward vs Conventional Care in Gastroenterology and Hepatology: A 2-Year Cohort Study

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Abstract

Background

Drug-related problems (DRPs) are a leading cause of preventable inpatient harm. Interprofessional training wards prepare future physicians and nurses for collaborative practice, but whether they also provide safe medication management is unknown. We therefore compared the need for clinical pharmacist interventions and the characteristics of DRPs between an interprofessional training ward and a conventional ward.

Methods

This retrospective cohort study analyzed prospectively documented pharmacist-led medication reviews from weekly interprofessional ward rounds on 2 gastroenterology and hepatology wards of a German university hospital (June 2024 to June 2026), including all adult inpatients with at least 1 review. On the interprofessional training ward A-STAR, final-year medical students and nursing trainees treat patients under supervision. The primary outcome was the rate of pharmacist interventions per prescribed drug; secondary outcomes were interventions per review and DRP characteristics according to the ATC, PCNE and NCC MERP classifications.

Results

A total of 946 medication reviews were analyzed (interprofessional training ward, 540 reviews in 351 patients; conventional ward, 406 reviews in 344 patients). Age, sex and length of stay were comparable, and liver cirrhosis was the leading diagnosis on both wards. Although more drugs were prescribed per review on the interprofessional training ward (mean, 13.8 vs 12.7; $P = .006$), fewer pharmacist interventions were required (11.8 vs 15.0 per 100 prescribed drugs; adjusted incidence rate ratio [IRR], 0.80; 95% CI, 0.72–0.90; $P < .001$), robustly across sensitivity analyses. Affected drug classes, DRP causes, acceptance of recommendations (58.6% vs 55.2%), problem resolution (98.9% vs 99.1%) and DRP severity were similar. Only excessive treatment duration, mainly of anti-infectives, was more frequent on the interprofessional training ward (6.8% vs 3.5% of causes; q = .03).

Conclusions

In this cohort study, care on an interprofessional training ward was associated with fewer pharmacist interventions and a DRP profile comparable to that of conventional care. Interprofessional training wards with embedded clinical pharmacists combine medication safety and high-quality care with the interprofessional education of future physicians; antimicrobial stewardship is a priority learning target.

Trial registration

Not applicable (retrospective observational study; approved by the Ethics Committee of the University of Regensburg, No. 26-4816-104).

Background

Drug-related problems (DRPs) are among the leading causes of preventable harm in hospitalized patients.[1] Approximately 3% of inpatients experience preventable medication-related harm, and about one quarter of these events are severe or life-threatening.[2] The World Health Organization has therefore declared medication safety a global patient safety challenge.[3]

Clinical pharmacists can prevent many of these problems. Pharmaceutical co-supervision of inpatients is associated with fewer medication errors, shorter length of stay and fewer readmissions and emergency department visits,[4–6] particularly when pharmacists are integrated into the ward team and take part in interprofessional ward rounds.[7–9] In Germany, however, ward-based clinical pharmacy is not yet standard of care, although the national action plan for medication safety explicitly calls for its expansion.[10–12]

High-quality care for complex inpatients depends on interprofessional collaboration, which is best learned early, before professional silos are established.[13–18] Interprofessional training wards, also known as interprofessional student wards, offer such workplace-based learning: students of different health professions jointly care for real patients under supervision.[19–21] In October 2019, the interprofessional training ward A-STAR (Ausbildungsstation Regensburg) was established in the Department of Internal Medicine I of the University Hospital Regensburg, Germany.[22, 23] Care on this interprofessional training ward is associated with very high patient satisfaction and with mortality, readmission and intensive care transfer rates comparable to those of conventional wards despite a higher case-mix index.[23] The ward also operates cost-efficiently, with lower medication costs per case.[24, 25]

For medical education, interprofessional training wards address a critical gap. Final-year medical students often lack prescribing competencies, and newly qualified physicians commit prescribing errors, especially when insufficiently supervised.[26–28] Interprofessional training wards allow future physicians to acquire medication management and collaboration skills in real patient care before they become responsible prescribers, and participation on the A-STAR ward significantly improved medical students' interprofessional competencies.[29] Whether this educational setting also provides safe medication management, however, has not been investigated, because previous outcome studies of interprofessional training wards focused on readmission, complications, mortality and patient satisfaction.[23, 30, 31] Evidence on patient-level outcomes of interprofessional education targeting medication therefore remains limited.[14, 15]

Medication safety is of special concern in gastroenterology and hepatology, where polypharmacy, hepatic and renal dysfunction and complex anti-infective and anticoagulant regimens accumulate risks.[32–35] We therefore compared the need for clinical pharmacist interventions, as an indicator of medication safety and quality of care, between the interprofessional training ward and a conventional gastroenterology and hepatology ward over 2 years, and characterized all DRPs using the classification of the Pharmaceutical Care Network Europe (PCNE) and the severity index of the National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP).[36, 37] We hypothesized that medication safety on the interprofessional training ward would be at least as high as on the conventional ward.

Methods

Study Design and Setting

This retrospective cohort study analyzed prospectively documented medication reviews from 2 general wards of the Department of Internal Medicine I (Gastroenterology, Hepatology, Endocrinology, Rheumatology and Infectious Diseases) at the University Hospital Regensburg, a German tertiary-care center, between June 2024 and June 2026. Both wards specialize in gastrointestinal and liver diseases and treat a comparable spectrum of patients (Table 1). The study was approved by the Ethics Committee of the University of Regensburg (registration No. 26-4816-104), which waived the requirement for informed consent because of the retrospective design and the use of pseudonymized routine data. The study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline.[38] On the A-STAR unit, each shift was staffed by up to 6 final-year medical students and 2 nursing trainees in their second or third year of training, whereas care on the conventional wards was provided by physicians and nurses with only supplementary involvement of students and trainees. Medical students, who had completed all theoretical coursework and the second of 3 state examinations, spent 8 to 16 weeks of their final year on the A-STAR unit, and nursing trainees, who had completed at least 1 of 3 years of training, spent approximately 4 weeks.[23] The A-STAR unit was thereby embedded in the regular ward structure and united medical students and nursing trainees in a shared base, following a structured daily routine of joint planning, interprofessional ward rounds, teaching sessions and reflective feedback.[23, 24] Senior physicians and registered nurses supervised the teams continuously and intervened whenever required for patient safety.[23] Students were not permitted to prescribe medications: they contributed to medication planning and discussed proposed changes with the team, whereas all drug orders were issued and signed by the supervising physicians.

On both wards, all patients present on the day of the weekly review received a pharmacist-led medication review followed by an interprofessional ward round. Two final-year pharmacy students, supervised by 3 experienced clinical pharmacists, prepared each review using medical records, the computerized physician order entry system (Avelios, Avelios Medical GmbH) and the hospital information system (SAP i.s.h.med, SAP SE). Potential DRPs and recommendations were identified using established references (UpToDate, AiDKlinik, Sanford Guide to Antimicrobial Therapy, Lexicomp and summaries of product

characteristics), agreed with the clinical pharmacists and discussed with the physicians during the ward round. On the interprofessional training ward, these rounds also served as a structured learning format in which medical, nursing and pharmacy students jointly discussed each patient's medication.[23]

Participants

All patients aged 18 years or older who were treated on either ward during the study period and received at least 1 pharmacist-led medication review were included. Reviews were excluded if they were performed outside the study period, if no medication was documented or if age or the patient identifier was missing or could not be linked to clinical data (Additional file 1: Figure S1).

Data Collection

After each ward round, the pharmacy team documented age, sex, patient identifier, length of stay, main diagnosis, prescribed drugs, time required for the review, pharmacist interventions and affected drugs. Drugs involved in DRPs were coded according to the Anatomical Therapeutic Chemical (ATC) classification,[39] and DRPs according to PCNE version 9.1 by problem (P), cause (C), proposed intervention (I), acceptance (A) and outcome (O).[36] For the present analysis, these data were retrospectively linked to the main diagnosis (ICD-10) via the patient identifier, and the severity of each DRP was graded according to the NCC MERP index[37] by consensus of the pharmacist team, with majority decision if no unanimous agreement was reached.

Statistical Analysis

Categorical variables are presented as frequencies and percentages and continuous variables as mean (SD). The number of prescribed drugs per review was compared using the Mann–Whitney U test and the time required per review using the χ^2 test. The primary outcome, pharmacist interventions per prescribed drug, was compared by negative binomial regression with the log number of prescribed drugs as offset, age and log-transformed length of stay as covariates and cluster-robust standard errors to account for repeated reviews within patients; interventions per review were analyzed as a secondary outcome. Results are presented as incidence rate ratios (IRRs) with 95% CIs. Sensitivity analyses modelled the number of prescribed drugs as a covariate instead of an offset, omitted length of stay, used generalized estimating equations with an exchangeable correlation structure or were restricted to the first review per admission (Additional file 1: Table S1). ATC groups were compared using a χ^2 test with Monte Carlo simulation and PCNE and NCC MERP categories using the Fisher exact test, with Benjamini–Hochberg correction within each PCNE domain (q values). All tests were 2-sided, and $P < .05$ ($q < .05$) was considered statistically significant. Analyses were performed using GraphPad Prism version 8.0.01 (GraphPad Software) and Python version 3.11.

During the preparation of this work, the authors used the large language model Claude Opus 5.5 (Anthropic; accessed September 2026) to assist with writing the statistical analysis code (Python), formatting tables and figures, and final language editing and revision of the manuscript. All analyses were reviewed and verified by the authors, who take full responsibility for the content of the publication.

Results

Of 1075 documented medication reviews, 946 were included: 540 reviews in 351 patients (399 admissions) on the interprofessional training ward and 406 reviews in 344 patients (385 admissions) on the conventional ward (Additional file 1: Figure S1). Exclusion rates were comparable (11.6% vs 12.5%). At least 1 pharmacist intervention was required in 76.1% (411 of 540) and 79.1% (321 of 406) of reviews, respectively.

Patients on both wards were comparable in sex, age and length of stay (Table 1). Liver cirrhosis was the leading main diagnosis on both wards (ICD-10 codes K70.3 and K74.6 combined, 24.5% vs 18.6%), and hepatobiliary diseases dominated the 5 most frequent main diagnoses, reflecting a highly complex therapeutic spectrum.

Table 1
Baseline Patient Characteristics, Interprofessional Training Ward (A-STAR) vs Conventional Ward (Control).

Total no. of patients		**A-STAR**	**Control**
	n (%)	**351 (100.0)**	**344 (100.0)**
Sex	Male n (%)	228 (65.0)	222 (64.5)
	Female n (%)	123 (35.0)	122 (35.5)
Age	mean (SD) [range] – years	58.7 (16.5) [18–90]	59.1 (16.1) [18–92]
Length of stay	mean (SD) - days	16.3 (14.6)	16.2 (15.6)
Top 5 main diagnoses	n (%)	Other and unspecified cirrhosis of liver (K74.6)	Other and unspecified cirrhosis of liver (K74.6)
		49 (14.0%)	35 (10.2%)
		Alcoholic cirrhosis of liver (K70.3)	Alcoholic cirrhosis of liver (K70.3)
		37 (10.5%)	29 (8.4%)
		Liver cell carcinoma (C22.0)	Liver cell carcinoma (C22.0)
		13 (3.7%)	14 (4.1%)
		Intrahepatic bile duct carcinoma (C22.1)	Acute-on-chronic liver failure (K72.10)
		9 (2.6%)	8 (2.3%)
		Obstruction of bile duct (K83.1)	Primary sclerosing cholangitis (K83.0)
		7 (2.0%)	7 (2.0%)

SD, standard deviation. Sex (χ^2 test, $P = .91$), age (Welch t test, $P = .75$) and length of stay (Welch t test, $P = .93$) did not differ significantly between wards.

The time required per review was similar on both wards, with most reviews completed within 10 to 30 minutes (Table 2). Although more drugs were prescribed per review on the interprofessional training ward (mean [SD], 13.8 [6.8] vs 12.7 [6.9]; $P = .006$), fewer pharmacist interventions were required, both per 100 prescribed drugs (11.8 vs 15.0; IRR, 0.79; 95% CI, 0.70–0.88; $P < .001$) and per review (mean, 1.6 vs 1.9; IRR, 0.86; 95% CI, 0.75–0.97; $P = .02$). After adjustment for age and length of stay, the rate of interventions per prescribed drug remained 20% lower on the interprofessional training ward (IRR, 0.80; 95% CI, 0.72–0.90; $P < .001$). This advantage was robust across all sensitivity analyses (IRR range, 0.78–0.88; Additional file 1: Table S1), including restriction to the first review per admission (IRR, 0.88; 95% CI,

0.78–0.98; *P* = .02). Longer length of stay was associated with fewer interventions per prescribed drug (IRR, 0.88 per log-unit of days; 95% CI, 0.82–0.93), whereas age was not.

Table 2
Pharmacist Intervention Rates and Incidence Rate Ratios, A-STAR vs Conventional Ward.

	A-STAR	**Control**	**IRR (95% CI)**	**P value***
Baseline data				
Patients (n)	351	344		
Medication reviews (n)	540	406		
Interventions (n)	881	773		
Prescribed drugs, cumulative (n)	7472	5166		
Prescribed drugs per review, mean (SD) [range]	13.8 (6.8) [2–40]	12.7 (6.9) [1–44]		**.006***
Intervention rate				
Interventions per 100 prescribed drugs	11.8	15.0	0.79 (0.70–0.88)	**< .001***
Interventions per prescribed drug, adjusted for age and length of stay			0.80 (0.72–0.90)	**< .001***
Interventions per medication review, mean (SD)	1.6 (1.5)	1.9 (1.7)	0.86 (0.75–0.97)	**.02***
Time required for medication check				
< 10 min (n, %)	186 (34.4)	151 (37.2)		
10–30 min (n, %)	323 (59.8)	218 (53.7)		.06
> 30 min (n, %)	31 (5.7)	37 (9.1)		

CI, confidence interval; IRR, incidence rate ratio; SD, standard deviation.

Interventions: pharmacist interventions per medication review; 1 intervention could address more than 1 DRP. Adjusted analysis: negative binomial regression with the log number of prescribed drugs as offset and age and log-transformed length of stay as covariates; covariate estimates and sensitivity analyses are shown in Additional file 1: Table S1.

**P* values from a Mann–Whitney U test (number of drugs per review), negative binomial regression with cluster-robust standard errors accounting for repeated medication reviews within the same patient and a χ^2 test of independence (distribution of time required per review). Bold *P* values indicate *P* < .05.

The lower intervention rate was not explained by a different drug spectrum. On both wards, drugs for the alimentary tract and metabolism (ATC A) were most frequently involved in DRPs, followed by anti-infectives for systemic use (ATC J) and drugs for blood and blood-forming organs (ATC B) (Fig. 1; Additional file 1: Table S2).

The individual drugs most frequently involved were largely identical on both wards (Additional file 1: Table S3): calcium supplements and ursodeoxycholic acid ranked first and second in ATC group A, piperacillin/tazobactam and meropenem dominated among anti-infectives, and low-molecular-weight heparins (tinzaparin, enoxaparin) were among the leading drugs in ATC group B.

Overall, the distribution of ATC groups did not differ significantly between wards (P = .07; Additional file 1: Table S2); anti-infectives accounted for a numerically larger share of affected drugs on the interprofessional training ward (23.8% vs 18.7%).

Causes of DRPs by ATC group (Additional file 1: Figure S2) showed similar patterns on both wards: inappropriate drug combinations (C1.3) and untreated indications (C1.5) predominated for alimentary tract and metabolism drugs, untreated indications (C1.5) for drugs acting on blood and blood-forming organs, and drug choice not in line with guidelines (C1.1), lack of indication (C1.2) or excessive treatment duration (C4.2) for anti-infectives.

Additional file 1: Tables S4 and S5 list the 10 drugs most frequently involved in DRPs on each ward with their leading causes. On the interprofessional training ward, piperacillin/tazobactam led the list, mainly because of excessive treatment duration (37.1% of its DRP causes); on the conventional ward, tinzaparin was most frequent, predominantly because of use not in line with guidelines (39.6%). Complete resolution rates were high on both wards (75.0%-100%).

Table 3
PCNE Classification of Drug-Related Problems, Interprofessional Training Ward (A-STAR) vs Conventional Ward (Control).

Domain	Code	Subdomain	A-STAR n (%)	Control n (%)	q value*
Problems	*Total*		**954 (100.0)**	**741 (100.0)**	
	Treatment effectiveness				
	P1.2	Effect of drug treatment not optimal	143 (15.0)	123 (16.6)	.59
	P1.3	Untreated symptoms or indication	134 (14.0)	112 (15.1)	.59
	Treatment safety				
	P2.1	Adverse drug event (possibly) occurring	431 (45.2)	345 (46.6)	.59
	Other				
	P3.1	Unnecessary drug treatment	226 (23.7)	149 (20.1)	.44
	P3.2	Unclear problem/complaint	20 (2.1)	12 (1.6)	.59
Causes	*Total*		**997 (100.0)**	**771 (100.0)**	
	Drug selection				
	C1.1	Inappropriate drug according to guidelines/formulary	110 (11.0)	77 (10.0)	.63
	C1.2	No indication for drug	149 (14.9)	98 (12.7)	.61
	C1.3	Inappropriate combination of drugs, or drugs and herbal medications or drugs and dietary supplements	253 (25.4)	182 (23.6)	.63
	C1.4	Inappropriate duplication of therapeutic group or active ingredient	0 (0.0)	2 (0.3)	.61
	C1.5	No or incomplete drug treatment in spite of existing indication	147 (14.7)	128 (16.6)	.63
	C1.6	Too many different drugs/active ingredients prescribed for indication	25 (2.5)	29 (3.8)	.61
	Drug form				

Domain	Code	Subdomain	A-STAR n (%)	Control n (%)	q value*
	C2.1	Inappropriate drug form/formulation (for this patient)	0 (0.0)	1 (0.1)	.63
	Dose selection				
	C3.1	Drug dose too low	34 (3.4)	43 (5.6)	.27
	C3.2	Drug dose of a single active ingredient too high	75 (7.5)	69 (8.9)	.63
	C3.3	Dosage regimen not frequent enough	2 (0.2)	1 (0.1)	> .99
	C3.4	Dosage regimen too frequent	4 (0.4)	5 (0.6)	.63
	C3.5	Dose timing instructions wrong, unclear or missing	74 (7.4)	66 (8.6)	.63
	Treatment duration				
	C4.2	Duration of treatment too long	68 (6.8)	27 (3.5)	**.03**
	Dispensing				
	C5.2	Necessary information not provided or incorrect advice provided	6 (0.6)	6 (0.8)	.88
	Drug use process				
	C6.1	Inappropriate timing of administration or dosing intervals by a health professional	9 (0.9)	4 (0.5)	.63
	Other				
	C9.3	No obvious cause	41 (4.1)	33 (4.3)	.97
Interventions	*Total*		**1745**	**1342**	
	Prescriber level				
	I1.1	Prescriber informed only	134 (14.0)	112 (15.1)	.71
	I1.2	Prescriber asked for information	3 (0.3)	0 (0.0)	.41
	I1.3	Intervention proposed to prescriber	803 (84.2)	625 (84.3)	.95
	I1.4	Intervention discussed with prescriber	14 (1.5)	4 (0.5)	.26
	Patient level				
	I2.1	Patient (drug) counselling	14 (1.5)	4 (0.5)	.26
	Drug level				

Domain	Code	Subdomain	A-STAR n (%)	Control n (%)	q value*
	I3.1	Drug changed to …	173 (18.1)	128 (17.3)	.72
	I3.2	Dosage changed to …	119 (12.5)	118 (15.9)	.26
	I3.3	Formulation changed to …	0 (0.0)	1 (0.1)	.60
	I3.4	Instructions for use changed to …	101 (10.6)	63 (8.5)	.35
	I3.5	Drug paused or stopped	239 (25.1)	159 (21.5)	.26
	I3.6	Drug started	145 (15.2)	128 (17.3)	.41
Acceptance	*Total*		**954 (100.0)**	**741 (100.0)**	
	Intervention accepted				
	A1.1	Intervention accepted and fully implemented	528 (55.3)	392 (52.9)	.43
	A1.2	Intervention accepted, partially implemented	31 (3.2)	17 (2.3)	.43
	Intervention not accepted				
	A2.1	Intervention not accepted: not feasible	377 (39.5)	322 (43.5)	.43
	A2.2	Intervention not accepted: no agreement	18 (1.9)	10 (1.3)	.45
Outcome	*Total*		**954 (100.0)**	**741 (100.0)**	
	O1.1	Problem totally solved	782 (82.0)	604 (81.5)	.85
	O2.1	Problem partially solved	161 (16.9)	130 (17.5)	.85
	O3.4	No need or possibility to solve problem	11 (1.2)	7 (0.9)	.85

**q value: Fisher exact test P value for each subdomain vs all other subdomains within the same domain, Benjamini-Hochberg false discovery rate (FDR) corrected within each domain. Bold q values indicate q < .05. Relative frequencies for all interventions (PCNE I) are based on the total number of documented DRPs (954/741); more than 1 cause and intervention was possible per DRP. Documented DRPs do not exactly*

match interventions from Table 2 *as in several cases, a pharmaceutical intervention was made without any or with > 1 related DRP.*

The distribution of PCNE problems, causes, interventions, acceptance and outcomes was similar on both wards (Table 3), with 1 exception: excessive treatment duration (C4.2) was documented more frequently on the interprofessional training ward (6.8% vs 3.5% of all causes; q = .03). Almost half of all problems concerned (potential) adverse drug events (P2.1; 45.2% vs 46.6%), and the majority of interventions were proposed directly to the prescriber (I1.3; 84.2% vs 84.3%). Pausing or stopping a drug (25.1% vs 21.5%) and starting a drug (15.2% vs 17.3%) accounted for 40.3% and 38.7% of all DRPs. Recommendations were accepted and fully or partially implemented in 58.6% and 55.2% of cases, respectively, and 98.9% and 99.1% of all problems were totally or partially solved, either because the intervention was directly implemented by the medical team or by finding an alternate solution during the interprofessional ward round.

According to the NCC MERP index (Table 4), most DRPs were category D, ie, errors that reached the patient and required monitoring or intervention to preclude harm (83.6% vs 82.6%), and the remainder were category A circumstances with the capacity to cause error (16.4% vs 17.4%; *P* = .60). Because a causal relationship between DRPs and harm could not be established reliably in this retrospective analysis, potential harm categories (E-I) were assigned to category D.

Table 4
NCC MERP Severity Classification of DRPs, Interprofessional Training Ward (A-STAR) vs Conventional Ward (Control).

Category	Explanation	A-STAR n (%)	Control n (%)	P value*
A	Circumstances or events that have the capacity to cause errors	156 (16.4)	129 (17.4)	.60
D	An error occurred that reached the patient and required monitoring to confirm that it resulted in no harm to the patient and/or required intervention to preclude harm	798 (83.6)	612 (82.6)	

**P value from the Fisher exact test comparing the distribution of categories A and D between wards. No DRP was attributed to categories B, C as well as E-I which are therefore not shown.*

Discussion

In this 2-year cohort study, care on an interprofessional training ward, where final-year medical students and nursing trainees cared for patients under supervision, was associated with high medication safety and quality of care in a complex gastroenterology and hepatology population. Compared with a conventional ward, the interprofessional training ward required 20% fewer pharmacist interventions per prescribed drug despite more prescribed drugs per review, whereas the type, severity, acceptance and

resolution of DRPs were similar. To our knowledge, this is the first study of medication safety on an interprofessional training ward, adding patient-level evidence on interprofessional education, which has rarely been studied.[14, 15]

Medication safety on the interprofessional training ward was high. The lower intervention rate was not explained by a different spectrum of drugs or problems, because affected drug classes and DRP causes were almost identical on both wards (Fig. 1 and Table 3; Additional file 1: Tables S2 and S3 and Figure S2); the DRP pattern thus reflected the hepatological and infectious disease case mix rather than team structure.[32–34] In a large PCNE-based study, 45.1% of hospitalized patients had at least 1 DRP[40]; the higher proportion in our cohort (76.1% and 79.1% of reviews) reflects the high medication burden and pharmacological complexity of advanced liver disease,[32, 33] and more than 80% of DRPs required monitoring or intervention (NCC MERP category D; Table 4). Patients in this high-risk population therefore benefit substantially from ward-based clinical pharmacy, which was an integral part of the interprofessional training ward.

Our results extend the evidence that interprofessional training wards deliver high-quality care. Previous evaluations of the same ward showed very high patient satisfaction and mortality, readmission and intensive care transfer rates comparable to those of conventional wards despite a higher case-mix index,[23] as well as cost-efficiency with lower medication costs.[24, 25] The present study adds medication quality as a further dimension: fewer medication-related problems required correction on the interprofessional training ward, and pharmacist recommendations were implemented to a similar extent on both wards. Overall acceptance (58.6% and 55.2%) was lower than in previous reports,[10, 40] mainly because some interventions were not feasible, for example because of imminent discharge or life-threatening infections. In most cases, however, non-implementation of interventions was a consensus-based decision of pharmacists and physicians, as shown in the particularly high level of final resolution (98.9%/99.1%).

Several features of the interprofessional training ward plausibly explain its lower intervention rate. First, medication management follows a four-eyes principle: students prepare and present medication plans, and supervising physicians review them before issuing any drug order, adding a safety layer that is not routinely present in conventional ward care. Second, a favorable ratio of patients to team members allows more time for individualized medication management, which patients perceive as attentive and well-explained care.[23] Third, the ward is built on an open error culture and daily interprofessional exchange, in which pharmacists' recommendations are discussed as learning opportunities rather than corrections.[7, 8, 17, 41] The lower intervention rate therefore most likely reflects the defining elements of a well-designed interprofessional training ward: close supervision, protected time and embedded interprofessional collaboration.

These results are highly relevant for medical education. Final-year medical students often lack prescribing competencies, and prescribing errors are common among newly qualified physicians.[26–28] On the interprofessional training ward, future physicians learn medication management in real

patient care through supervised treatment planning, weekly interprofessional medication rounds with pharmacists and pharmacy students and immediate feedback. Together with the significant gains in interprofessional competencies among medical students on the A-STAR ward,[29] this creates a learning environment in which patient safety and education reinforce each other. The only DRP cause that was more frequent on the interprofessional training ward—excessive treatment duration, mainly of anti-infectives such as piperacillin/tazobactam—identifies a concrete learning target: defining treatment duration, stop dates and reassessment points should become an explicit learning objective, embedded in antimicrobial stewardship programs with clinical pharmacists, which have already improved antimicrobial therapy in critically ill patients with liver disease.[42–44]

These findings have direct implications for health care systems. Demonstrating that student-led care is safe is a prerequisite for the broader implementation of interprofessional training wards.[19, 23] Integrating clinical pharmacists into these wards addresses 2 needs at once: the expansion of ward-based clinical pharmacy called for by the German action plan for medication safety[12] and the early development of collaborative medication management competencies.[15, 16] Interprofessional training wards may also strengthen the health care workforce, as graduates of the A-STAR ward were frequently recruited as physicians and nurses,[24] and good interprofessional collaboration is associated with lower psychological distress among health care professionals.[45]

Strengths and Limitations

Strengths of this study include the 2-year observation period, identical pharmacist-led review procedures on both wards, robust modelling with multiple sensitivity analyses and the detailed characterization of DRPs using 3 complementary classification systems. This study also has limitations. The analysis was retrospective, single-center and nonrandomized, although data were documented prospectively. Residual confounding by case complexity cannot be excluded; however, the interprofessional training ward previously treated patients with a higher case-mix index,[23, 24] which would bias against the observed advantage. Pharmacists were not blinded to ward allocation, and the intervention rate is a process measure; clinical end points such as adverse drug events were not assessed. Weekly reviews overrepresented longer stays and differed in frequency between wards, and NCC MERP severity was graded retrospectively and without consultation of physicians. Multicenter studies will show how far these findings apply to other specialties and training ward models.

Conclusions

In this cohort study, care on an interprofessional training ward with embedded clinical pharmacy was associated with high medication safety, reflected by fewer pharmaceutical interventions than on a conventional ward, and with a comparable DRP profile in a high-risk gastroenterology and hepatology population. Interprofessional training wards thus combine 3 benefits: safe medication management, high quality of care and interprofessional education that prepares future physicians for safe prescribing.

Clinical pharmacists should be core members of interprofessional training wards, and antimicrobial stewardship should be a priority learning objective. Prospective multicenter studies with patient-centered end points should now inform the broader implementation of interprofessional training wards. [19]

Abbreviations

ATC
Anatomical Therapeutic Chemical classification
CI
confidence interval
DRP
drug-related problem
GEE
generalized estimating equations
ICD-10
International Classification of Diseases,10th Revision
IRR
incidence rate ratio
NCC MERP
National Coordinating Council for Medication Error Reporting and Prevention
PCNE
Pharmaceutical Care Network Europe
SD
standard deviation
STROBE
Strengthening the Reporting of Observational Studies in Epidemiology.

Declarations

Ethics approval and consent to participate

The study was approved by the Ethics Committee of the University of Regensburg (registration No. 26-4816-104) and was conducted in accordance with the Declaration of Helsinki. The ethics committee waived the requirement for informed consent because of the retrospective design and the use of pseudonymized routine data.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and analyzed during the current study are not publicly available because they contain pseudonymized patient data protected under German and European data protection law, but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

DF and AK conceived and designed the study. DF, VG and AK acquired, analyzed and interpreted the data. DF performed the statistical analysis and drafted the manuscript. MM and AK supervised the study. SSH, HCT, SS and MM contributed to the interpretation of the data. All authors critically revised the manuscript for important intellectual content and read and approved the final manuscript.

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Figures

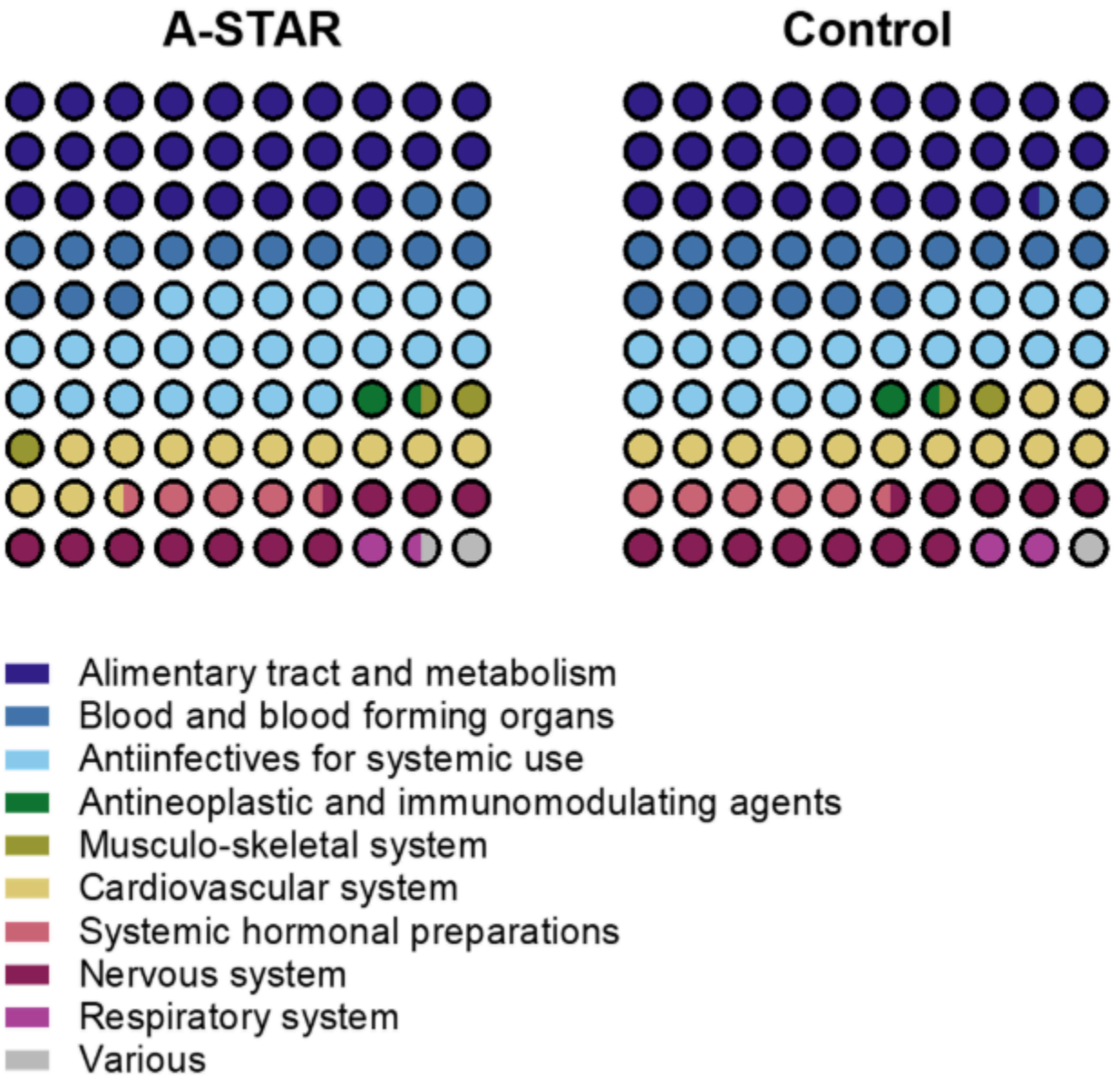


Figure 1

Distribution of ATC Drug Classes Involved in Drug-Related Problems, A-STAR vs Conventional Ward. Waffle charts; each circle of the 10 × 10 grid represents 1 percentage point of all drugs involved in DRPs

on the respective ward, and colors indicate the ATC class (Various = all remaining ATC classes combined).

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