Renal Replacement Therapy

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The prevalence of medication-related problems in kidney transplant recipients at a tertiary care hospital in Saudi Arabia

Danyah Katlan[1,2], Hani Hasan[2], Mohammed Aseeri[2], Abrar Alsubhi[2] and Sherin Ismail[2,3*]

Abstract

Background Limited data are available regarding the prevalence of medication-related problems (MRPs) in kidney transplant recipients. This study aimed to determine the prevalence and types of medication-related problems.

Methods A cross-sectional study was conducted including kidney transplant recipients aged ≥ 18 years who were receiving immunosuppressive agents for at least 3 months post-transplant. The primary outcome was to determine the prevalence of MRPs. The secondary outcomes were to identify the pharmacological classes, categories of medications contributing to MRPs, and predictors of developing > 3 MRPs.

Results We enrolled 107 kidney transplant recipients. The mean ± standard deviation (SD) of age and body mass index (BMI) were 50 ± 15.8 years and 28.9 ± 5.3 (kg/m^2), respectively, and 66.3% were male. The prevalence of MRPs was 28.97% [95% confidence intervals (CI) 19.68%, 41.125] in 1393 prescriptions. The frequent types of MRPs were drug–drug interactions (46.1%), duplication (12%), and medication use without an indication (11.7%). Immunosuppressive agents and cardiac medications were the main classes causing MRPs. The number of medications and the years post-kidney-transplant were significant predictors of developing > 3 MRPs.

Conclusion The results showed that drug–drug interactions were the most frequent MRPs, with immunosuppressive agents being the most common class causing MRPs.

Keywords Medication-related problems, Kidney transplant recipients, Immunosuppressive agents, Post-transplant

Introduction

Chronic kidney disease (CKD) is a worldwide public health problem. Globally, the estimated number of disability-adjusted life years attributable to kidney disease has increased significantly from 1990 to 2015 [1]. In 2016, more than 726,000 patients in the USA required dialysis or a renal transplant, and more than 240 patients requiring dialysis died daily [2].

In the Kingdom of Saudi Arabia, according to the annual report of the Saudi Center for Organ Transplantation, the total number of kidney transplants in 2017 was 921, and the total number of kidney transplant recipients (KTRs) from 1979 to 2017 was 11,509 [3].

KTRs have a complex medication regimen, including immunosuppressive drugs, which require therapeutic drug monitoring (TDM) for appropriate dosing of calcineurin inhibitors (cyclosporine and tacrolimus) and the mammalian target for rapamycin inhibitors (sirolimus). TDM aims to optimize the efficacy, prevent

*Correspondence:
Sherin Ismail
sismail-atta@unc.edu
[1] Pharmaceutical Care Department, King Fahad Armed Forces Hospital, Jeddah, Saudi Arabia
[2] Pharmaceutical Care Department, Ministry of National Guard-Health Affairs, King Saud Bin Abdul-Aziz University for Health Sciences, King Abdullah International Medical Research Center, Jeddah, Saudi Arabia
[3] Department of Epidemiology, Gillings School of Global Public Health, University of North Carolina, Chapel Hill, USA

rejection episodes, minimize interindividual variability and concentration-dependent side effects related to drug dosing, and prolong graft survival [4]. Calcineurin inhibitors have unique pharmacokinetic parameters, including absorption through the P-glycoprotein efflux pump and metabolism by the liver through cytochrome P-450 enzymes. Consequently, calcineurin inhibitors cause many drug–drug interactions, which require careful drug-dosing adjustment or the selection of alternative regimens that do not interact with calcineurin inhibitors [5]. A comprehensive medication review by the pharmacist is required to optimize the medication regimen [6].

KTRs usually have chronic comorbidities that require the use of other medications and pose significant risk factors for the development of medication-related problems (MRPs). According to the literature, MRPs include improper dosing, drug–drug interactions, duplication, adverse drug reactions, and the requirement of renal and hepatic dosage adjustments [7].

A study reported that KTRs with MRPs, compared with the group without MRPs, had a doubling in the incidence of developing cytomegalovirus infection (CMV), and three times higher episodes of rejection and 30-day readmission [8]. Graft survival was significantly lower in the MRPs group [8]. Good communication between the transplant team improves patient-centered outcomes [9].

Pharmacists play a crucial role in the assessment of MRPs by evaluating the therapeutic regimen of KTRs and communicating with healthcare professionals to optimize medication regimens [10]. Pharmacists also provide counseling for KTRs to improve their medication adherence [7]. In addition, pharmacists participate in designing and implementing therapeutic protocols, serve as drug therapy experts to the transplant team, ensure appropriate dosing, provide pharmacokinetic services, and document therapeutic interventions [11].

Several studies have emphasized the impact of pharmacists in improving adherence and clinical and therapeutic outcomes and minimizing costs and medication errors among KTRs [12]. A study reported that a greater proportion of patients were adherent to their immunosuppressive medication at 1 year post-transplant when a pharmacist was involved [13]. Another study demonstrated that clinical pharmacy services had a major impact on achieving target therapeutic levels compared with patients not receiving such services [14]. Finally, a study reported that 81.8% of the interventions made by clinical pharmacists were clinically significant, and the physician acceptance rate of the recommendations was 96% [15]. The therapeutic interventions improved the patient outcomes, as 94.2% improved in terms of renal function, blood glucose control, total cholesterol and triglycerides, blood pressure, uric acid, adverse drug reactions (ADR), and compliance [15].

Our hospital provides a clinical pharmacy service for nephrology and transplant recipients, focused on inpatient, dialysis, and new KTRs during their inpatient admission for the kidney transplant procedure. However, there is a paucity of data related to the prevalence of MRPs in KTRs, types, and predictors. Such evidence will support future opportunities for the expansion of pharmaceutical care services to the ambulatory transplant setting.

Materials and methods

The study aimed to assess the prevalence of MRPs in KTRs and identify the types of MRPs, the most prevalent class of medication causing the MRPs, and the predictors for developing more than three MRPs. The study design was a retrospective electronic health record (EHR) review. The study was conducted at King Abdulaziz Medical City, Jeddah, Saudi Arabia, with patients attending the outpatient clinics at the Ambulatory Care Center from June 2016 to June 2017.

We used a convenience sampling method of all available patients in our center ($n=129$). Patients were included if they were KTRs, 18 years of age and above, receiving immunosuppressive agents, and had their kidney transplant for at least 3 months prior to June 2016. We excluded patients who received their kidney transplant after June 2016 or those who did not attend the clinic regularly during the study period.

A list of KTRs was identified through the kidney transplant coordinator at the Nephrology Department. A pharmacist screened all patients according to the eligibility criteria. We recorded the demographic characteristics, chronic comorbidities, laboratory results, and list of prescribed medications, as documented by various healthcare providers in the EHRs. A pharmacy resident reviewed each patient's prescription to identify MRPs and referred the patient to the nephrology and transplant pharmacists (two of the coauthors) for any inquiries or the need for any therapeutic interventions with the prescribing physician to optimize the care for the KTRs.

The primary outcome was the prevalence of MRPs. The secondary outcomes included identifying pharmacological classes of the medications contributing to MRPs, the categories of medications causing MRPs, and the predictors for more than three MRPs. A sample of 80 patients was estimated to detect a prevalence of MRPs of 31%, similar to literature reports [7]. We used a 95% confidence interval (CI), 5% precision, and an alpha of 0.05 [16].

We use descriptive statistics to report baseline demographics, classes, and types of MRPs, and the data are

presented as the mean ± standard deviation (SD) or median , interquartile range (IQR) for continuous variables and (*n*/*N*) and percentages for binary and categorical variables as deemed necessary. We determined the primary outcome of the prevalence of MRPs as a proportion of the number of MRPs per patient divided by the total number of prescribed medications for that particular patient and calculated the 95% confidence interval (CIs) using the Poisson Exact test. We categorized MRPs for each patient to less than or equal to 3 or more than 3 MRPs. To identify predictors of MRPs, we used logistic regression for the univariate, multivariate analyses, and a stepwise logistic regression selection algorithm, using a *p*-value of 0.01 for entry into the model. We used two-sided tests and STATA 16.1 (StataCorp LP, College Station, TX, USA) for all analyses.

Definitions

An MRP involves a medication that compromises the optimum outcome for a particular patient, as defined by the American Society of Hospital Pharmacists [17]. There are several categories of MRPs, such as drug–drug interactions, improper dosing, and adverse drug reactions [17].

(a) Drug–drug interactions were identified through the drug database LexiComp®. We focused on the drug–drug interactions of classes D and X in our study, as these types of interactions require therapy modification (class D) or should be avoided (class X) [18]. Any interaction detected was reported to the physician.
(b) Adverse reactions were assessed through documentation in the EHRs by various healthcare providers and institutional electronic reports of adverse drug events.
(c) For renal drug dosing, we assessed kidney function by estimating creatinine clearance using the Cockcroft–Gault equation [19], identified the required demographic characteristics and laboratory parameters through the EHRs and compared the prescribed doses to the dose-adjustment recommendations as per LexiComp® databases for each drug monograph [18].
(d) Regarding hepatic-dosing adjustment, we evaluated the need for hepatic dosage adjustment by the Child–Turcotte–Pugh (CTP) score using the LexiComp® databases for each drug monograph [18,20].
(e) Improper drug dosing includes subtherapeutic and supratherapeutic doses. We assessed for renal, hepatic drug-dose adjustments, and any improper drug dosing using the recommendations for dosing and dosing in special populations in the LexiComp® drug databases [18].
(f) Duplication was checked by reviewing the duplicated prescribing medication orders in the EHRs.
(g) Medication classes were classified on the basis of the indication for the treatment of a specific disease. For example, cardiovascular medication includes medication used to treat heart failure, ischemic heart disease, or arrhythmias.

Results

Data description

In total, 129 patients were screened, 107 of whom were included. The exclusion of the 22 patients was due to no active outpatient visits during the study period. The mean age ± SD was 50 ± 15.8 years, and males represented 66.36% of the cohort. The majority were either overweight (32.71%) or obese (42.99%), and the mean ± SD of the estimated glomerular filtration rate (eGFR) was 72.5 ± 21.80 ml/min/1.73 m^2. The median duration (IQR) post-kidney-transplant was 8.65 (4.79, 12.50) years. Hypertension was the most frequent comorbidity in our cohort (62.62%), followed by diabetes mellitus (42.99%). The mean frequency ± SD of the number of prescribed medications was 11.8 ± 4.29. The details of the baseline characteristics stratified by the MRPs are presented in Table 1.

Statistical analysis

In total, we reviewed 1393 prescriptions and identified 384 MRPs. The prevalence of MRPs was 28.97% [95% CI of (19.68%, 41.13%)]. The median number of MRPs was 3 [IQR (1, 5)]. The most frequent MRPs identified were drug–drug interactions ($n=177$; 46.1%), followed by duplicate therapy ($n=46$; 12%). The majority (65%) of the duplications were due to multiple prescriptions of the same medication, 17% to prescribing medications with the same effect, 11% to prescribing medications of two different strengths, and 7% to prescribing medications in the same class. Figure 1 displays the frequency and types of MRPs. Duplicate prescribed therapies included (1) cardiac medications (28%) including angiotensin converting enzyme inhibitors (ACEI), calcium channel blockers, beta-blockers, statins, and antiplatelets duplications; (2) immunosuppressants (22%) including tacrolimus, mycophenolate, azathioprine, and prednisolone; (3) gastrointestinal drugs (22%) including proton pump inhibitors, H_2 receptor antagonists and antidiarrheal drugs; and (4) others including ergocalciferol (13%), antihistamine (4%), anti-infective (4%), urology-related (4%), and respiratory drugs (2%).

During our assessment of ADRs, we identified a total of 11 reported adverse drug reactions (ADRs). Out of these,

Table 1 Baseline characteristics

	Total ($N=107$) (Mean ± SD), *n* (%), Median (interquartile range)	≤ 3 MRPs ($n=63$)	> 3 MRPs ($n=44$)
Age, years	50 ± 15.75	48 ± 14.83	53.14 ± 16.70
Sex, males	71 (66.36%)	42 (66.67)	29 (65.91)
Body mass index, (kg/m^2)			
Underweight	2 (1.87%)	0 (0)	2 (4.55)
Normal weight	24 (22.43%)	15 (23.81)	9 (20.45)
Overweight	35 (32.71%)	21 (33.33)	14 (31.82)
Obese	46 (42.99%)	27 (42.86)	19 (43.18)
Estimated glomerular filtration rate (eGFR)[a], ml/min/1.73 m^2	72.5 ± 21.80	75 ± 19.63	68.54 ± 24.26
Years post-kidney-transplant [b]	8.65 (4.79, 12.50)	6.14 (3.64, 10.31)	11.34 (7, 15.4)
Type of transplant[c]			
Living-related	20 (18.69%)	14 (22.22)	6 (13.63)
Living non-related	40 (37.38%)	24 (38.1)	16 (36.36)
Comorbidities			
Number of comorbidities	2 (1, 2)	1 (0, 2)	2 (1, 3)
Hypertension	67 (62.62)	35 (55.56)	32 (72.73)
Diabetes mellitus	46 (42.99)	22 (34.92)	24 (54.55)
Dyslipidemia	19 (17.76)	4 (6.35)	15 (34.09)
Hepatitis	13 (12.14%)	8 (12.70)	5 (11.36)
Others[d]	10 (9.34%)	7 (11.11)	3 (6.82)
Ischemic heart disease	8 (7.48)	3 (4.76)	5 (11.36)
Thyroid disorders	7 (6.54%)	3 (4.76)	4 (9)
Number of prescribed medications	11.8 ± 4.29	10.12 ± 3.64	14.22 ± 4.02

[a] eGFR was estimated using the modified diet in renal disease equation

[b] Two patients had missing date of kidney transplantation

[c] There were 47 missing observations (49.93%) for type of transplant

[d] Others includes asthma, epilepsy, heart failure, atrial fibrillation, and dementia

six ADRs were associated with immunosuppressant use that included reports of gastroenteritis, electrolyte disturbances, and hyperglycemia (Table 2 has a detailed description of these adverse events). Additionally, three ADR reports were associated with antimicrobial use, leading to elevation of liver function tests; one report was associated with insulin use leading to hypoglycemia; and one was associated with levothyroxine use leading to diarrhea.

Many classes of drugs were involved in more than one category of MRPs. The most frequent class involved in the MRPs were immunosuppressive agents ($n=122$), followed by cardiac medications ($n=37$), multivitamins and minerals ($n=29$), gastrointestinal medications ($n=24$), statins ($n=23$), anti-infectives ($n=19$), antiplatelets ($n=12$), and genitourinary medications ($n=10$). Figure 2 presents the details related to the medication classes involved in MRPs.

The results of the univariate analysis of the predictors indicated that the number of medications, number of comorbid conditions, years post-kidney-transplant, diabetes, and dyslipidemia were significantly associated with the development of more than three MRPs ($p<0.05$). Table 3 presents the details of the univariate and multivariate analyses. However, the stepwise logistic regression algorithm demonstrated that the number of medications and the years post-kidney-transplant were the most significant predictors for the development of more than three MRPs, with an area under the receiver operator characteristic curve of 0.83 (Table 4).

Discussion

Our study demonstrated a high prevalence of MRPs, which requires additional actions to minimize and support the improvement of therapeutic outcomes of KTRs in the ambulatory care setting. The median of 3 MRPs [IQR (1, 5)] in our study is consistent with a mean rate of 3.6 MRPs per patient reported in a previous study [7]. Although our study and the previous study included patients with similar baseline characteristics and comorbidities, there were differences in the frequency and types of MRPs [7]. In our study, drug–drug

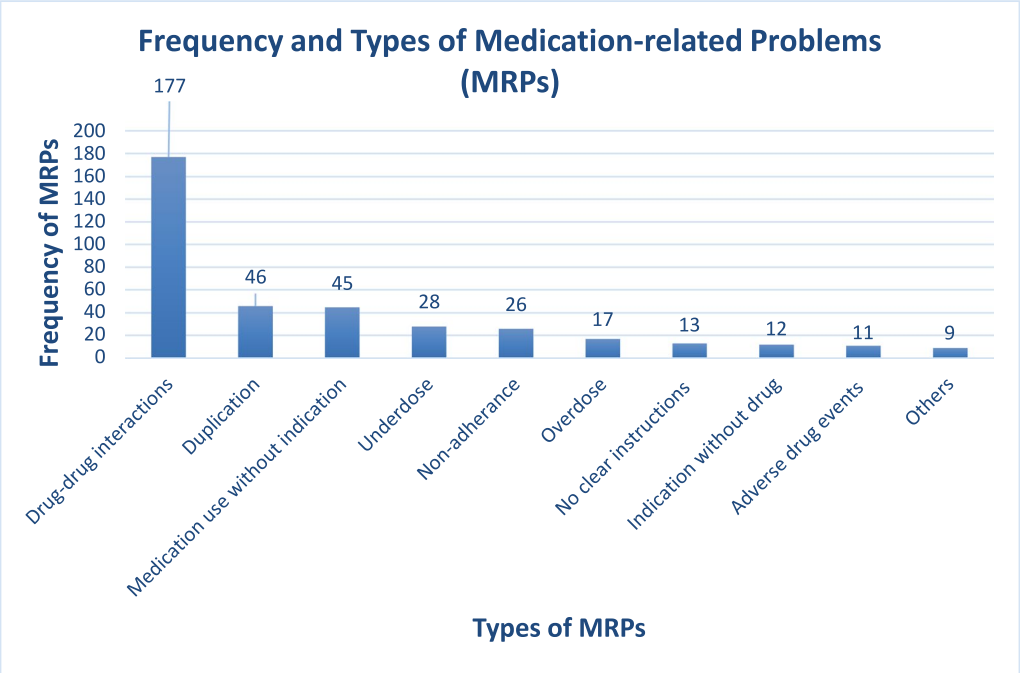

Fig. 1 Frequency and types of medication-related problems (MRPs). The total number of MRPs was 384 MRPs. Others include improper duration ($n=4$), discontinued with no clear reason ($n=3$), and miscellaneous including wrong medication selection and dose reduction with no clear reason ($n=2$)

interactions were the most frequent compared with the erroneous use of medications (discrepancies between the prescribed medication and what the KTRs were actually administered) in the previous study [7]. This difference highlights the importance of face-to-face interviews with patients to identify MRPs, as was done in the previous study compared with the current study, which was based on EHRs [7]. Nonadherence to medications was the second most frequent MRP reported in their study, and it was the fifth most frequent MRP in our study [7]. This may be attributed to the insurance status of the KTRs, as only 62% of their study had Medicaid coverage or social security disability insurance, compared with our cohort of patients who were fully insured [7]. Furthermore, our findings related to nonadherence were based on the physician's assessment and documentation in the EHRs that may underestimate nonadherence, as reported in the literature, compared with patient self-reports or objective measures or a combined method for the assessment of nonadherence in KTRs [21,22]. Although findings of our previous study assessing nonadherence among KTRs in the same cohort of patients demonstrated a low prevalence of nonadherence of 5.9% using the Immunosuppressant Therapy Adherence Instrument Scale (ITAS) [23] and 14.7% using average serum blood therapeutic drug levels [24].

A study including 97 KTRs reported 170 MRPs of 1178 prescribed medications (12.4%), in contrast to 384 MRPs of 1393 prescribed medications in our study [25]. Although these differences may be justified by the study duration (12 months in our study versus 3 months in the other study), both studies had the same average number of medications of 12 and similar baseline characteristics such as age, eGFR, mean BMI, and comorbidities [25]. The variability in the results may be explained by the differences in the practice setting and the utilization of Pharmacotherapy Assessment in Renal Transplant Patients (PART) criteria to assess MRPs in outpatient KTRs and the expert judgment of the kidney transplant pharmacists in their study compared with ours [25]. The number of medications administered by each patient was consistently associated with 1.45 times the odds of developing more than three MRPs in our study, compared with their study, as the number of medications (per an increase of five medications) was associated with the number of MRPs with a $\beta=0.27$ [95% CI (0.005, 0.547)]. [25].

From a patient-centered care perspective, we chose a cutoff of three or more MRPs for the assessment of the predictors, as it was the median number of MRPs per patient for the assessment of the predictors. Covert et al. (2017) designed a prediction model to identify KTRs with > 6 MRPs to prioritize the assessment by transplant

Table 2 Detailed description of adverse events related to immunosuppressant medications

Immunosuppressant	Type of ADR	Description	Action plan
Tacrolimus	Drug–drug interaction with clarithromycin	Increased tacrolimus level leading to acute kidney injury and hyperkalemia	Calcium resonium for 5 days, and then repeating of tacrolimus and potassium levels
			Clarithromycin stopped after 10-day course for *Helicobacter pylori*
Cyclosporine	Drug–drug interaction with trimethoprim-sulfamethoxazole	Hyperkalemia (serum potassium 5.7 mEq/L)	Given two doses of calcium resonium
			Stopped trimethoprim-sulfamethoxazole after 3-day course for UTI
			Repeated serum potassium level was 4.6 mEq/L after finishing the course of trimethoprim-sulfamethoxazole
Prednisolone	Side effect	Hyperglycemia, as indicated by increasing glycosylated hemoglobin A1c (HgbA1c) to 6.9 (pre-diabetic)	Prednisolone 5 mg continued as part of immunosuppression
			Added metformin 500 mg twice daily; HgbA1c of 5.9 after 6 months
Mycophenolate mofetil	Side effect	Diarrhea, initially > 5 times	Initially, switched from mycophenolate mofetil to mycophenolate sodium, and diarrhea decreased to 3 times daily
			Patient could not tolerate it, so eventually was switched to azathioprine
Mycophenolate mofetil	Side effect	Diarrhea, upon increasing the dose 750 mg twice	Dose reduced to 500 mg twice with improvement in diarrhea
			Further assessment of the intensity of immunosuppressive regimen in the follow-up visits
Mycophenolate mofetil	Side effect	Diarrhea with hypokalemia and hypomagnesemia after increasing the dose to 1 gm twice daily, which required an emergency department visit	Received potassium and magnesium replacement infusions, and reduction of the dose of mycophenolate mofetil by 50% upon discharge
			Further assessment of the intensity of the immunosuppressive regimen was planned in the follow-up visits

pharmacists in the ambulatory setting with limited resources [7]. We think that the selection of 6 MRPs is a high cutoff value, as the study reported an average of 3.6 MRPs per patient. The model requires further validation, as most of the included variables were related to accessibility to medication and insurance status, which may limit the generalizability to other healthcare settings with different medication insurance coverage [7]. Furthermore, it is essential to distinguish between the qualitative types of MRPs and their potential impact on various therapeutic outcomes for KTRs compared to the quantitative approach to prioritize the pharmaceutical care services.

The consistently reported high prevalence of MRPs among KTRs provides opportunities to engage transplant pharmacists in the ambulatory care settings [10,26]. Similar to previous studies demonstrating the influence of the pharmacists on identifying and mitigating MRPs among people with chronic kidney disease receiving maintenance hemodialysis [27–30]. The use of standardized assessment tools to identify and mitigate MRPs among KTRs is important. For example, these tools, which include the utilization of the PART criteria or medication therapy management and motivational interviews to manage interindividual variability associated with the use of calcineurin inhibitors, drug–drug interactions, and nonadherence, are indispensable. In addition, these tools will provide opportunities to target the most frequent comorbidities in KTRs, such as hypertension, diabetes mellitus, and cardiovascular diseases, to improve the clinical outcomes, in both inpatient and outpatient settings [25,31–34]. Furthermore, some of the MRPs, such as medication use without an indication, support deprescribing opportunities, specifically for drugs highly implicated with MRPs, including multivitamins, minerals, and gastrointestinal medications, as reported in the current study. [35].

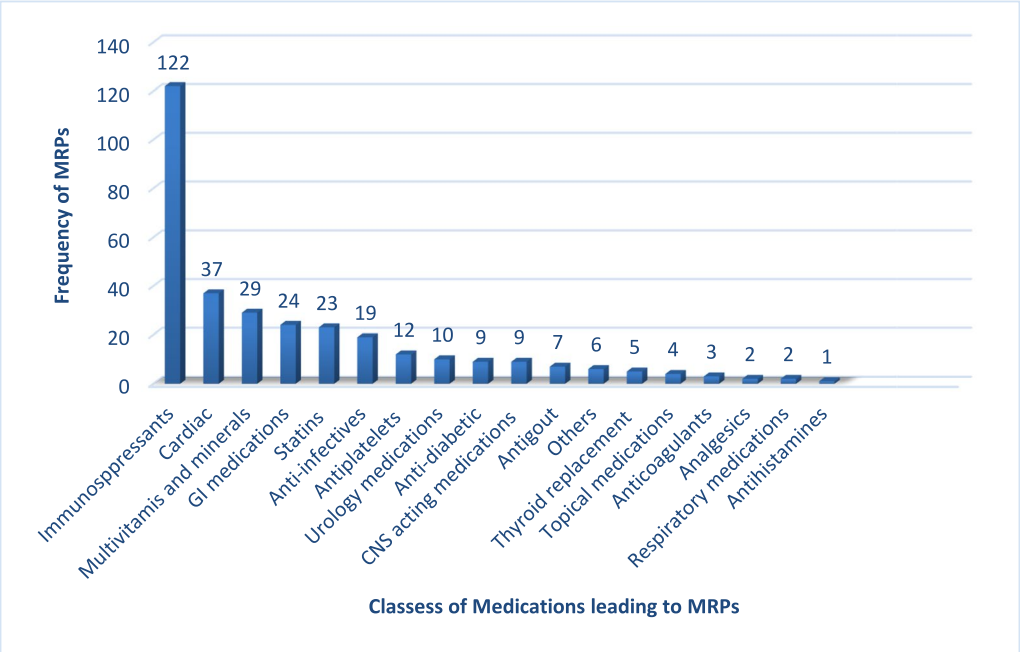

Fig. 2 Frequency and classes of medications involved in MRPs

Table 3 Univariate and multivariate analysis for the predictors of developing more than three MRPs

Variables[a]	Univariate analysis		Multivariate analysis	
	OR, 95% CI	*p*-value	OR, 95% CI	*p*-value
Age (years)	1.02 (1, 1.04)	0.100	NA	NA
Body mass index (kg/m^2)	1.01 (0.94, 1.09)	0.758	NA	NA
eGFR[b] (ml/min/1.73 m^2)	0.99 (0.97, 1)	0.119	NA	NA
Duration post-kidney-transplant (years)	1.10 (1.0, 1.18)	0.008	1.19 (1.07, 1.31)	0.001
Number of comorbidities	1.66 (1.16, 2.35)	0.005	0.83 (0.44, 1.57)	0.567
Number of medications	1.31 (1.16, 1.48)	< 0.001	1.48(1.23, 1.78)	< 0.001
Diabetes mellitus	2.24 (1.02, 4.92)	0.045	0.88 (0.21, 3.64)	0.865
Hypertension	2.13 (0.93, 4.89)	0.073	NA	NA
Dyslipidemia	7.63 (2.32, 25.06)	0.001	7.44, (1.45, 38.03)	0.016
Asthma	0.71 (0.06, 8.07)	0.782	NA	NA
Ischemic heart disease	2.56 (0.58, 11.3)	0.215	NA	NA
Epilepsy	0.71 (0.06, 8.07)	0.782	NA	NA
Hepatitis B virus	1.46 (0.28, 7.61)	0.651	NA	NA
Hepatitis C virus	0.55 (0.10, 2.99)	0.491	NA	NA
Hypothyroidism	1.46 (0.28, 7.61)	0.651	NA	NA

OR, odds ratio; CI, confidence interval; NA, not applicable; eGFR, estimated glomerular filtration rate

[a] A univariate analysis for atrial fibrillation, asthma, heart failure, hyperthyroidism, and dementia was not feasible due to the low number of observations

[b] eGFR: estimated glomerular filtration rate was calculated using the modified diet and renal disease equation

We acknowledge the following limitations. First, our study had a retrospective design using EHRs and thus was subject to information bias and lack of accurate documentation, which may further cause inaccuracies in the estimation of the MRPs. Second, there were no face-to-face interviews with the patients to assess adherence and identify other potential MRPs. Third, due to the retrospective design, we could not communicate directly with the prescribing physician to discuss some of the therapeutic interventions happening in the past. Fourth,

Table 4 Predictors of developing more than three MRPs

Predictors[a]	OR, 95% confidence intervals	*p*-Value
Number of medications	1.45 (1.24, 1.69)	< 0.001
Duration post-kidney-transplant (years)	1.19 (1.08, 1.31)	< 0.001

OR, odds ratio

[a] Stepwise logistic regression model ($p = 0.01$ for entry)

our study presented a single-center experience with limited generalizability to other populations and settings. Fifth, we faced possible challenges in the Computerized Prescriber Order Entry allowing the prescribing of duplicate medication, which may have exaggerated our estimate of the prevalence of MRPs without a viable patient harm.

The study has the following strengths. First, to our knowledge, this is the first study to assess the prevalence of MRPs in KTRs in Saudi Arabia. Second, the observation period was 1 year in the ambulatory care setting. Third, the study provides opportunities for the active participation of transplant pharmacists to identify and mitigate MRPs in KTRs. Fourth, the study offers insights regarding the predictors of MRPs to prioritize KTRs who requires a face-to-face interview in a practice setting with limited resources.

Future studies should assess the impact of the direct engagement of transplant pharmacists in the ambulatory care services of KTRs to conduct a comprehensive medication review to optimize therapeutic outcomes.

Conclusion

Our results demonstrated that MRPs are highly prevalent among KTRs. The most frequent type of MRPs were drug–drug interactions, duplication, medication use without indication, and underdosing. The most frequent classes associated with MRPs were immunosuppressant and cardiovascular drugs. The number of medications and the duration post-kidney-transplant were significant predictors for developing more than three MRPs.

Abbreviations

CKD	Chronic kidney disease
KTRs	Kidney transplant recipients
TDM	Therapeutic drug monitoring
MRPs	Medication-related problems
CMV	Cytomegalovirus infection
ADR	Adverse drug reactions
EHR	Electronic health record
eGFR	Estimated glomerular filtration rate
PART	Pharmacotherapy Assessment in Renal Transplant

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Author contributions

D.K. participated in the design, collected data, and wrote the first draft of the manuscript. M.A. participated in study design and reviewing the proposal. A.S. participated in data collection. H.H. participated in study design, data collection, and coordination. S.I. participated in study design, statistical analysis, and data interpretation; gained access to the patient list; reviewed the manuscript; and supervised the project. All authors read and approved the final version of the manuscript.

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Declarations

Ethics approval and consent to participate

The study received Institutional Research Board approval on the 22nd of May 2017 from King Abdullah International Medical Research Center (IRBC/634/17).

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of interest

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

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