RESEARCH PAPER

Discharge prescribing of four-pillar guideline-directed medical therapy in hospitalized patients with HFrEF: a multicentre retrospective cross-sectional study from Nasiriyah, Iraq

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Abstract

Optimising discharge prescribing for four-pillar guideline-directed medical therapy (GDMT) remains a critical therapeutic priority in heart failure with reduced ejection fraction (HFrEF). Data regarding current trends in inpatient prescribing is scarce in resource-limited settings. This study aimed to describe the incidence of complete four-pillar GDMT at discharge and to assess factors associated with incomplete prescribing among hospitalized patients with diagnosed HFrEF from five hospitals in Nasiriyah, Iraq. This study was a retrospective cross-sectional multicenter analysis of consecutive eligible hospital discharges from January 1, 2024, to December 31, 2025, involving patients from five public hospitals in Nasiriyah City, Thi-Qar Governorate, southern Iraq. Adults diagnosed with echocardiographically-confirmed HFrEF (left ventricular ejection fraction ≤40%) were included if a discharge prescription was available for examination. The principal outcome was the comprehensive four-pillar guideline-directed medical therapy (GDMT) at discharge, characterized by the prescription of at least one agent from each of the following categories: angiotensin-converting enzyme inhibitor, angiotensin receptor blocker, or angiotensin receptor-neprilysin inhibitor; evidence-based beta-blocker; mineralocorticoid receptor antagonist; and sodium-glucose cotransporter-2 inhibitor (SGLT2i). Prespecified multivariable logistic regression models were employed to assess factors correlated with the administration of complete guideline-directed medical therapy (GDMT) at discharge, adjusting for predetermined variables known to predict incomplete four-pillar prescribing, including enrolment centre, estimated glomerular filtration rate (eGFR), prescriber speciality group, type 2 diabetes mellitus, NYHA class, and serum potassium levels. Two hundred ten discharges were evaluated, leading to the inclusion of 160 eligible patients in the final analyses. The average age was 62.4 years (SD 10.9), with 102 (63.7%) of 160 patients being male, and the median left ventricular ejection fraction was 30.5% (IQR 26.1–34.6). At discharge, complete four-pillar GDMT was recommended to 52 patients (32.5%, 95% CI 25.3–40.4). At discharge, prescription rates for the four guideline-mandated pillars were as follows: 64.4% received an ACE inhibitor/ARB/ARNI, 71.2% received an evidence-based beta-blocker, 58.1% received a mineralocorticoid receptor antagonist, and 39.4% received an SGLT2 inhibitor. Receipt of comprehensive four-pillar GDMT was greater among patients prescribed by a cardiologist than by a non-cardiologist in the centre-adjusted multivariable model (adjusted OR 2.88, 95% CI 1.27–8.41; p=0.028). Elevated eGFR and the existence of type 2 diabetes mellitus correlated with increased likelihood of receiving complete GDMT, but elevated serum potassium levels and NYHA class were linked to decreased likelihood of complete GDMT at discharge. The most significant disparity in prescribing practices between specialists and non-specialists was noted for SGLT2 inhibitors (51.9% vs to 26.6%). In a cohort of hospitalized patients with proven HFrEF from five hospitals in Nasiriyah City, Iraq, less than one-third were discharged on comprehensive four-pillar GDMT. Prescribing by cardiologists was associated with a higher likelihood of completing guideline-directed medical therapy (GDMT) at discharge, with the most significant deficiency in four-pillar prescribing observed with SGLT2 inhibitors. These findings underscore a significant deficiency in the discharge-level application of modern HFrEF medication within this regional hospital system and guide future evaluations of optimization options, including pharmacist-assisted discharge review.

Keywords: Heart failure with reduced ejection fraction, guideline-directed medical therapy, hospital discharge, prescribing patterns, sodium-glucose cotransporter-2 inhibitors, prescriber specialty, Iraq, retrospective cross-sectional study

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INTRODUCTION

Heart failure affects more than 64 million people globally. It is linked to elevated rates of recurrent hospitalization, diminished quality of life, and premature mortality (1,2). The management of heart failure with reduced ejection fraction (HFrEF) currently comprises four essential pharmacotherapeutic pillars: renin–angiotensin system inhibition, evidence-based beta-blockade, mineralocorticoid receptor antagonism, and sodium–glucose cotransporter-2 (SGLT2) inhibition (3). All of these medicines are included in the latest heart-failure guidelines because of their beneficial impact on clinically significant outcomes in eligible patients (4,5).

Nonetheless, despite these advancements, the execution of guideline-directed medical therapy (GDMT) remains inadequate. International registries and surveys have revealed persistent deficiencies in the utilization and dosing of evidence-based treatments for HFrEF (6,7). Moreover, significant variability in practice is evident across different geographies and healthcare environments. Extensive international initiatives, such as QUALIFY, the ESC Heart Failure Long-Term Registry, and REPORT-HF, have elucidated real-world practice patterns; however, they cannot evaluate the prescription of contemporary four-pillar therapy at hospital discharge in resource-limited inpatient settings (8,9).

This knowledge deficit is therapeutically pertinent. Hospital discharge marks a critical phase of therapy for patients with HFrEF, during which long-term therapies may be initiated, discontinued, escalated, or deferred (10,11). Moreover, if essential prescriptions are overlooked before discharge, their administration may be postponed for the duration of the full index admission. Although the 4 Pillar Drugs were recently introduced in Iraq, there is no knowledge regarding their consistent prescription across inpatient settings and whether physician characteristics, such as specialty involvement, affect prescribing trends (12,13). Therefore, it is essential to gather local prescribing patterns to measure the disparity between published evidence and actual practice and to pinpoint opportunities for quality improvement initiatives focused on discharge (14).

The main aim of this study was to evaluate the percentage of hospitalized patients with documented HFrEF who were discharged on comprehensive 4 Pillar GDMT across five hospitals in Nasiriyah City, Iraq. Secondary objectives included identifying clinical and healthcare system characteristics associated with incomplete 4 Pillar therapy at discharge. Ultimately, we aimed to establish a region-specific standard for forthcoming enhancement activities focused on hospital discharge.

MATERIALS AND METHODS

Research design and setting

The research was a retrospective, cross-sectional, multicenter examination of consecutive eligible hospital discharges from five public hospitals in Nasiriyah, Thi-Qar Governorate, southern Iraq. The selected centres were deliberately chosen to reflect the diversity of cardiac care capacity throughout the governorate and to jointly serve a catchment population of about 1.2 million individuals from Nasiriyah city and its neighbouring regions. Analyses encompassed adult patients admitted to these institutions from January 1, 2024, to December 31, 2025, with echocardiographically verified heart failure with reduced ejection fraction (HFrEF).

The five hospitals are as follows: Al-Hussein Teaching Hospital (centre 1; a tertiary referral teaching hospital with cardiac speciality wards, a coronary care unit [CCU], and echocardiography services); Bent Al-Huda Teaching Hospital (centre 2; a tertiary referral teaching hospital offering general cardiology services and echocardiography); Al-Haboubi Teaching Hospital (centre 3; a secondary level teaching hospital providing general internal medicine and cardiology coverage); Al-Nasiriyah General Hospital with internal medicine and visiting cardiology services; and Al-Shatra General Hospital, a district general hospital with general internal medicine services.

Analyses were performed in accordance with a predetermined, date-locked statistical analysis plan established before data extraction at the initial centre. The reporting adheres to the STROBE guidelines for cross-sectional research.

Participants

Eligible patients were adults (age ≥18 years) admitted to any centre between January 1, 2024, and December 31, 2025, with echocardiographic evidence of heart failure with reduced ejection fraction (HFrEF), defined as a left ventricular ejection fraction ≤40% as evaluated by the Simpson biplane method and recorded in a

formal cardiology or echocardiography report. Patients were eligible if a discharge prescription was accessible for abstraction.

Centres implemented uniform exclusion criteria during screening: mortality before discharge; transfer to another facility before the issuance of a discharge prescription; heart failure with mildly reduced or preserved ejection fraction; absence of essential documentation needed to verify eligibility or determine outcomes; enrolment in an interventional trial upon admission; or end-stage renal disease, characterised by documented dialysis dependence or an estimated glomerular filtration rate of less than 5 mL/min per 1.73 m². No restrictions for comorbidities that could indicate a potential relative contraindication to components of guideline-directed medical therapy (GDMT) were made; rather, free-text notes regarding non-prescribing were systematically categorized using a predetermined taxonomy applied uniformly across sites.

Patient allocation at the site level

Out of 177 patients admitted to a participating center during the study period with echocardiographically confirmed heart failure with reduced ejection fraction, 160 eligible patients were enrolled across five centers based on admission volume and echocardiography capacity: 62 patients from Al-Hussein Teaching Hospital, 38 patients from Bent Al-Huda Teaching Hospital, 28 patients from Al-Haboubi Teaching Hospital, 20 patients from Al-Nasiriyah General Hospital, and 12 patients from Al-Shatra General Hospital. The enrolling centre for each patient was recorded to facilitate site-level descriptive reporting and to control for centre as a covariate in the study.

Outcomes

The main outcome was the prescription of a comprehensive four-pillar GDMT upon discharge. The outcome was characterized by the prescription at discharge of at least one medication from each of four categories: angiotensin-converting enzyme inhibitor (or angiotensin receptor blocker [ARB] or angiotensin receptor-neprilysin inhibitor [ARNI]); evidence-based beta-blocker; mineralocorticoid receptor antagonist; and sodium-glucose cotransporter-2 inhibitor. Patients were not required to be on a minimum medication dose to fulfil the criteria for the primary outcome.

Secondary outcomes included a predetermined assessment of the administration of 50% of the recommended target dosage for each qualifying GDMT prescription element. For excluded drug classes, free-text documentation of the rationale for non-prescription was classified according to the previously outlined taxonomy and applied consistently across all sites.

Exposure, determinants, and covariates

The main variable of interest was the specialty of the discharge prescriber, categorized as cardiologist or non-cardiologist based on the prescriber's signature on the discharge statement. The centre of enrolment was included as an additional covariate to account for inter-site variability in prescribing behaviour. Renal function was evaluated with the estimated glomerular filtration rate derived from the 2021 CKD-EPI creatinine equation. Serum potassium and sodium levels were obtained from the most recent inpatient measurement. Priority was assigned to values acquired within 48 hours preceding discharge.

The NYHA functional class was extracted from the discharge record wherever accessible. Glycated hemoglobin (HbA1c) was documented if assessed during hospitalization or within the preceding 90 days. Biomarker values for BNP or NT-proBNP were extracted if accessible.

Data were extracted at each location by two trained clinical pharmacy research assistants using a single, piloted, standardized abstraction form. This form was disseminated to each centre before data collection began. Concordance among abstractors for the primary outcome was assessed in a random 20% sample at each participating centre before the extraction of all data.

Sample size

The sample size calculations were predicated on the assessment of a comprehensive four-pillar GDMT at discharge for all eligible admissions within the multicenter cohort. With an expected complete-GDMT prevalence of 35%, two-sided 95% confidence intervals, and a precision of ±8 percentage points, the minimum necessary sample size was 137. Given the possibility of incomplete or ineligible records at each site, the total number of patients grew to 158. A total of 160 eligible patients were included in the final study sample across participating centres. To mitigate overfitting, given the number of events in the primary outcome, the multivariable model was kept parsimonious.

Statistical analysis

Continuous data are expressed as mean (SD) or median (IQR), as applicable, whereas categorical variables are reported as counts and percentages. Two-

sided exact 95% confidence intervals for proportions are supplied where applicable. Descriptive statistics at the site level were produced for the primary outcome and significant factors to analyze inter-centre variation. The primary investigation used multivariable logistic regression to assess parameters associated with the administration of comprehensive four-pillar GDMT at discharge. Six covariates were predetermined a priori and incorporated into the model concurrently: estimated glomerular filtration rate (modelled continuously per 10 mL/min per 1.73 m²), discharge prescriber speciality, type 2 diabetes mellitus (yes vs no), NYHA functional class, serum potassium (modelled continuously per 1 mmol/L), and center of enrolment (modelled as a categorical fixed effect to account for site-level confounding). No incremental variable-selection methods were employed.

All model assumptions were evaluated using predetermined diagnostic tests. Variance inflation factors were utilized to evaluate multicollinearity. The Box-Tidwell method was employed to evaluate linearity in the log-odds for continuous predictors. The model's calibration was evaluated using the Hosmer-Lemeshow goodness-of-fit test. Influential cases were identified utilizing Cook's distance. The discriminatory efficacy of the final model was summarised using the area under the receiver operating characteristic (ROC) curve, with a two-sided 95% confidence interval.

A predetermined subgroup analysis assessed whether prescribing complete GDMT varied significantly between centres, utilizing a likelihood-ratio test to compare the fit of models with and without the centre term. A set of predetermined interaction analyses was conducted as exploratory post-hoc assessments. Interactions were analyzedanalyzed in distinct models for eGFR type 2 diabetes, discharge prescriber specialtyspecialty, NYHA functional class, serum potassium eGFR, and discharge prescriber specialtyspecialty, and discharge prescriber specialtyspecialty and centre of enrolment. Models were evaluated by likelihood-ratio testing, and interaction parameters were awarded p-values. The results of these tests should be regarded as producing hypotheses.

Four predetermined sensitivity analyses were performed to evaluate the robustness of the primary results. The initial sensitivity analysis compared outcomes from the primary complete-case analysis with those obtained from a multiple imputation by chained equations model that addressed missing covariate data. In the second sensitivity analysis, the analysis was repeated using alternative definitions of treatment completeness to dichotomize the primary outcome. The final sensitivity analysis was limited to subjects without any recorded absolute contraindications to components of GDMT pertinent to renally dosed medicines (namely, eGFR <30 mL/min per 1.73 m²). The fourth sensitivity analysis replicated the primary study after eliminating high BNP values. An E-value was computed for the primary relationship to quantify the hypothetical minimal magnitude of unmeasured confounding necessary to account for the observed impact.

To mitigate the risk of over-interpreting the extensive exploratory comparisons, we employed a false-discovery-rate correction via the Benjamini-Hochberg procedure on the p-values from the predetermined exploratory bivariable testing panel. Both unadjusted and adjusted p-values are presented in the results. Confirmatory analyses utilized two-sided significance criteria of 0.05, whereas exploratory results were interpreted descriptively. All analyses were conducted utilizing R software (version 4.3. x). The Supplementary Appendix contains additional technical specifications, including package versions, site-level abstraction completion logs, and annotated analysis code.

Ethical consideration

Ethics approval for the project was secured from the National University Research Ethics Committee before data extraction commenced at the initial participating centre. Ethics approval was expressly obtained for all involved hospitals. Site-specific authorization was secured from the medical director of each institution before the commencement of data collection. The study, being a retrospective review of de-identified routine clinical information, posed minimal risk to patients and could not be completed feasibly without a waiver of consent; thus, the necessity for individual informed consent was waived. All data were anonymized before investigators accessed them, with hospital identifiers substituted by numeric codes in the analytic dataset. The research was conducted in compliance with the Declaration of Helsinki.

RESULTS

Study population and baseline characteristics

A total of 160 of 210 hospital discharges screened from January 1, 2024, to December 31, 2025, across five hospitals in Nasiriyah met the inclusion criteria and were included in the primary analysis. Patients were excluded if they died before discharge (n=11), had a confirmed left ventricular ejection fraction over 40%

on echocardiographic assessment (n=18), had essential qualifying documents (n=14), were participating in another clinical trial (n=4), or had end-stage renal disease (n=3). Patients included in the study were diagnosed with HFrEF at the following institutions: Al-Hussein Teaching Hospital (n=62), Bent Al-Huda Teaching Hospital (n=38), Al-Haboubi Teaching Hospital (n=28), Al-Nasiriyah General Hospital (n=20), and Al-Shatra General Hospital (n=12).

The average age was 62.4 years (SD 10.9), with 102 out of 160 patients (63.7%) being male, and the median left ventricular ejection fraction was 30.5% (IQR 26.1–34.6). The distribution of heart failure etiology was ischaemic (n=79, 49.4%), hypertensive (n=40, 25.0%), idiopathic dilated (n=24, 15.0%), and valvular or other. Comorbidities comprised type 2 diabetes mellitus (n=77, 48.1%), hypertension (n=128, 80.0%), ischaemic heart disease (n=98, 61.3%), and atrial fibrillation (n=41, 25.6%). Upon discharge, 93 patients (58.1%) presented with NYHA class III–IV heart failure. Prescriber specialty data were available for all patients: 81 of 160 patients (50.6%) were discharged by cardiologists, while 79 of 160 (49.4%) were discharged by non-cardiologists.

The baseline characteristics are summarised in Table 1. The concordance among abstractors was substantial for the primary outcome in the predetermined reliability sample (ICC = 0.94; 95% CI = 0.88–0.97). The rates of missing data for essential covariates in the multivariable model were minimal (eGFR: 1.3%; serum potassium: 3.1%), but were significantly higher for BNP (36.9%) and glycated hemoglobin (HbA1c; 51.2%). The patterns of missingness for these and other factors are reported in the Supplementary Appendix.

Principal outcome: comprehensive four-pillar GDMT at discharge

A complete four-pillar GDMT was prescribed at discharge in 52 of 160 analyzed hospital discharges, resulting in a prevalence of 32.5% (95% CI 25.3–40.4). The prescription rates for individual GDMT classes were as follows: ACEi/ARB/ARNI (n=103, 64.4%), evidence-based beta-blockers (n=114, 71.2%), mineralocorticoid receptor antagonists (n=93, 58.1%), and SGLT2 inhibitors (n=63, 39.4%). The SGLT2 inhibitor was the least frequently prescribed class of GDMT among the research sample.

In comparing the proportions of each GDMT class prescribed by different prescriber groups, 51.9% of discharges led by cardiologists received SGLT2 inhibitors, whereas 26.6% of discharges led by non-cardiologists received them, resulting in an absolute group difference of 25.3 percentage points. The highest absolute difference was recorded across the four GDMT therapy pillars; in comparison, the absolute differences were 12.2 percentage points for ACEi/ARB/ARNI, 4.8 percentage points for mineralocorticoid receptor antagonists, and 3.2 percentage points for beta-blockers. Information regarding the rationale for omitting therapies and dose achievement is provided in Supplementary Table S2.

Bivariate analyses

Out of 18 predetermined bivariable comparisons, five remained significant after applying the FDR correction for multiple testing ($q<0.10$): age ($q=0.033$; rank-biserial correlation coefficient $r=0.265$), eGFR ($q<0.001$; $r=-0.409$), serum potassium ($q=0.004$; $r=0.335$), NYHA class ($q=0.094$; $\varepsilon^2=0.025$), and CKD stage ($q<0.001$; $\varepsilon^2=0.095$). Patients discharged with comprehensive four-pillar GDMT were younger, had better renal function, had lower serum potassium levels, and experienced less severe functional impairment and a lower CKD stage at discharge than those discharged without complete GDMT. The prescriber's specialty was substantially correlated with the total four-pillar GDMT prescription at a nominal significance level ($p=0.021$). It was hence included in the multivariable model according to the predetermined analytic strategy. The complete findings from bivariable testing are displayed in Table 2.

Centre-adjusted multivariable analysis

Following adjustment for the enrolment centre and the five patient-level covariates that satisfied the predetermined FDR threshold, cardiologist-led prescribing was significantly correlated with increased odds of four-pillar GDMT prescription at discharge in comparison to non-cardiologist-led prescribing (adjusted OR 2.88, 95% CI 1.27–8.41; $p=0.028$). A greater eGFR was substantially correlated with the result (OR per 10 mL/min/1.73 m^2 1.30, 95% CI 1.12–1.58; $p=0.004$), as was reduced serum potassium (OR per 1 mmol/L 0.18, 95% CI 0.06–0.41; $p<0.001$).

The presence of type 2 diabetes mellitus was associated with a higher likelihood of receiving complete GDMT (OR 2.95, 95% CI 1.38–7.96; $p=0.018$), whereas a higher NYHA class was associated with a lower likelihood (OR 0.57, 95% CI 0.31–0.92; $p=0.040$). Model diagnostics indicated no serious multicollinearity. The model's AUC was 0.805 (95% CI 0.730–0.871), the Hosmer-Lemeshow test statistic was $\chi^2[8]=4.14$ ($p=0.845$), and the Nagelkerke R^2 was 0.348. All prespecified interaction items were excluded from the model after FDR-based selection. The

primary analysis results are presented in Table 3, while the interaction analyses are located in the Supplementary Appendix.

Sensitivity analyses

The outcomes of the sensitivity analyses were analogous to those of the original analysis (Table 5). The complete-case analysis employing multiple imputation produced a point estimate for the correlation between cardiologist-led prescribing and comprehensive GDMT that closely resembled that of the primary study (OR 2.76, 95% CI 1.26–7.91). Limiting the population to those without extreme contraindications to pharmacological treatments did not significantly modify the point estimate of the association (OR 2.87, 95% CI 1.30–8.06).

Alternative definitions of the outcome yielded diminished yet directionally consistent results, notably when complete ≥3-pillar GDMT was designated as the outcome (OR 2.21, 95% CI 1.11–4.86). Excluding patients with anomalous BNP values did not significantly affect the primary association estimate (OR 2.74, 95% CI 1.25–8.49). The E-value for the principal relationship was 5.21, with a matching lower confidence limit E-value of 1.85.

Data are mean (SD), median (IQR), or n (%). P values compare patients discharged on the complete four-pillar GDMT with those not discharged on it.

Table 1: Baseline characteristics of the multicentre study cohort, overall and stratified by complete four-pillar GDMT at discharge

Variable	Total (N= 160)	GDMT Complete (N=52)	GDMT Incomplete (N=108)	p-value	Effect size
Demographics					
Age, years — mean ± SD	62.4 ± 10.9	58.7 ± 10.1	64.1 ± 11.0	0.007*	r = +0.265
Male sex — n (%)	102 (63.7%)	35 (67.3 %)	67 (62.0 %)	0.819	V = 0.032
BMI, kg/m² — mean ± SD	27.9 ± 5.3	28.2 ± 5.2	27.7 ± 5.3	0.776	r = −0.029
Clinical severity					
NYHA class I — n (%)	10 (6.2 %)	6 (11.5 %)	4 (3.7%)		
NYHA class II — n (%)	57 (35. 6%)	26 (50.0 %)	31 (28.7 %)		
NYHA class III — n (%)	70 (43. 8%)	16 (30.8 %)	54 (50.0 %)	0.026*	ε² = 0.025
NYHA class IV — n (%)	23 (14. 4%)	4 (7.7 %)	19 (17.6 %)		
LVEF, % — median (IQR)	30.5 (26. 1–34.6)	31.4 (27.2 – 35.3)	29.9 (25.4–34.1)	0.193	r = −0.129
BNP, pg/mL — median (IQR)	1,456 (726 – 2,364)	1,150 (718 – 2,016)	1,638 (788–2,530)	0.210	r = +0.154
HF etiology — Ischaemic	79 (49. 4%)	27 (51.9 %)	52 (48.1 %)	0.269	V = 0.180
HF etiology — Hypertensive	40 (25. 0%)	15 (28.8 %)	25 (23.1 %)		

Variable	Total (N=160)	GDMT Complete (N=52)	GDMT Incomplete (N=108)	p-value	Effect size
HF etiology — Idiopathic	24 (15.0%)	7 (13.5%)	17 (15.7%)		
HF etiology — Valvular/Other	17 (10.6%)	3 (5.8%)	14 (13.0%)		
Comorbidities					
T2DM — n (%)	77 (48.1%)	30 (57.7%)	47 (43.5%)	0.131	OR 1.76 (0.90–3.41); φ = +0.133
Hypertension — n (%)	128 (80.0%)	44 (84.6%)	84 (77.8%)	0.423	φ = +0.080
Atrial fibrillation — n (%)	41 (25.6%)	14 (26.9%)	27 (25.0%)	0.650	φ = +0.051
Ischaemic HD — n (%)	98 (61.3%)	31 (59.6%)	67 (62.0%)	0.640	φ = −0.051
Admission vitals					
SBP, mmHg — mean ± SD	129.9 ± 18.9	130.5 ± 18.1	127.0 ± 22.1	0.271	r = −0.109
HR, bpm — mean ± SD	82.6 ± 19.7	81.0 ± 18.3	80.0 ± 19.6	0.641	r = +0.047
Laboratory					
eGFR, mL/min/1.73m² — mean ± SD	74.0 ± 26.5	86.4 ± 24.6	67.9 ± 25.4	<0.001*	r = −0.409
CKD G1 (eGFR ≥90) — n (%)	44 (27.5%)	25 (48.1%)	19 (17.6%)	<0.001*	ε^2 = 0.095
CKD G2 (60–89) — n (%)	62 (38.7%)	27 (51.9%)	35 (32.4%)		
CKD G3a (45–59) — n (%)	32 (20.0%)	7 (13.5%)	25 (23.1%)		
CKD G3b (30–44) — n (%)	18 (11.3%)	2 (3.8%)	16 (14.8%)		
CKD G4–5 (<30) — n (%)	4 (2.5%)	0 (0.0%)	4 (3.7%)		
K^+, mmol/L — mean ± SD	4.24 ± 0.49	4.02 ± 0.44	4.34 ± 0.47	<0.001*	r = +0.335; d = 0.699
Na^+, mmol/L — mean ± SD	139.7 ± 4.7	140.3 ± 4.7	139.4 ± 4.7	0.236	r = −0.116
Hyperkalaemia (K^+ >5.0) — n (%)	19 (11.9%)	2 (3.8%)	17 (15.7%)	0.178	φ = −0.137

Variable	Total (N=160)	GDMT Complete (N=52)	GDMT Incomplete (N=108)	p-value	Effect size
HbA1c, % — median (IQR)†	7.7 (6.6–8.8)	7.5 (6.8–9.0)	7.8 (6.4–8.8)	0.649	r = +0.050
Prescriber					
Cardiologist prescriber — n (%)	81 (50.6%)	34 (65.4%)	47 (43.5%)	0.037*	OR 2.14 (1.09–4.21); φ = +0.178

Abbreviations: BMI = body mass index; BNP = B-type natriuretic peptide; CKD = chronic kidney disease; eGFR = estimated glomerular filtration rate; HbA1c = glycated haemoglobin; HF = heart failure; HR = heart rate; IQR = interquartile range; LVEF = left ventricular ejection fraction; NYHA = New York Heart Association; SD = standard deviation; SBP = systolic blood pressure; T2DM = type 2 diabetes mellitus.

† HbA1c reported in patients with T2DM only; 82/160 records had missing HbA1c (51.3%). HbA1c values were available in a subset of patients and should be interpreted accordingly. Missing data per variable: age 0.6%, BMI 7.5%, LVEF 1.9%, eGFR 1.3%, K^+ 3.1%, Na^+ 1.9%, BNP 36.9%, SBP 2.5%, HR 3.8%. The cohort was drawn from five participating hospitals in Nasiriyah.

Statistical tests: continuous variables — Mann-Whitney U (non-normal) or Welch t-test (normal); categorical variables — Yates-corrected chi-squared or Fisher exact; ordinal variables — Kruskal-Wallis H. Effect sizes: rank-biserial r (Mann-Whitney U), Cohen's d (t-test), Cramér's V or phi (chi-squared), epsilon-squared ε^2 (Kruskal-Wallis). All 95% CIs for proportions: Clopper-Pearson exact binomial.

All 18 comparisons were prespecified in the statistical analysis plan. Benjamini-Hochberg false-discovery-rate adjustment was applied across the full bivariable testing set (q=0.10).

Table 2: Prespecified bivariable associations with complete four-pillar GDMT at discharge

Variable (T01–T18)	GDMT Complete n=52	GDMT Incomplete n=108	Test	p-value (raw)	p-value (BH-FDR q-adj.)	Sig? q<0.10
T01 Age, years	59.5 (51.0–66.4)	63.5 (56.3–71.3)	MWU	0.0072	0.0325	✓ YES
T02 BMI, kg/m²	28.2 (22.6–33.2)	27.7 (22.2–32.4)	MWU	0.776	0.819	No
T03 LVEF, %	31.4 (27.2–35.3)	29.9 (25.4–34.1)	MWU	0.193	0.378	No
T04 eGFR, mL/min †	87.0 (68.2–106.5)	65.0 (50.4–82.6)	MWU	<0.001	0.001	✓ YES
T05 K^+, mmol/L	4.0 (3.7–4.3)	4.3 (4.0–4.6)	MWU	0.0007	0.004	✓ YES
T06 Na^+, mmol/L	140.3 (137.2–143.8)	139.4 (136.3–143.2)	MWU	0.236	0.387	No

Variable (T01–T18)	GDMT Complete n=52	GDMT Incomplete n=108	Test	p-value (raw)	p-value (BH-FDR q-adj.)	Sig? q<0.10
T07 BNP, pg/mL	1150 (718–2016)	1638 (788–2530)	MWU	0.210	0.378	No
T08 SBP, mmHg	130.5 (115–145)	127.0 (112–142)	MWU	0.271	0.406	No
T09 HR, bpm	81 (65–95)	80 (65–95)	MWU	0.641	0.731	No
T10 Male sex	35 (67.3%)	67 (62.0%)	χ^2 (Y)	0.819	0.819	No
T11 T2DM	30 (57.7%)	47 (43.5%)	χ^2 (Y)	0.131	0.336	No
T12 Hypertension	44 (84.6%)	84 (77.8%)	χ^2 (Y)	0.423	0.585	No
T13 AF	14 (26.9%)	27 (25.0%)	χ^2 (Y)	0.650	0.731	No
T14 IHD	31 (59.6%)	67 (62.0%)	χ^2 (Y)	0.640	0.731	No
T15 Hyperkalaemia	2 (3.8%)	17 (15.7%)	FE	0.178	0.378	No
T16 Cardiologist‡	34 (67.3%)	47 (43.5%)	χ^2 (Y)	0.037	0.111	No
T17 NYHA class	III–IV: 20 (38.5%)	III–IV: 73 (67.6%)	KWH	0.026	0.094	✓ YES
T18 CKD stage	G3+: 9 (17.3%)	G3+: 45 (41.7%)	KWH	<0.001	0.001	✓ YES

Abbreviations: AF = atrial fibrillation; BH-FDR = Benjamini-Hochberg false discovery rate; BNP = B-type natriuretic peptide; CKD = chronic kidney disease; eGFR = estimated glomerular filtration rate; FE = Fisher exact test; HR = heart rate; IHD = ischaemic heart disease; KW H = Kruskal-Wallis H; LVEF = left ventricular ejection fraction; MWU = Mann-Whitney U; NYHA = New York Heart Association; OR = odds ratio; SBP = systolic blood pressure; T2DM = type 2 diabetes mellitus; χ^2 (Y) = Yates-corrected chi-squared.

Medians (IQR) reported for all continuous variables (all failed normality by KS+Lilliefors except age, eGFR, K^+, Na^+, SBP, HR, which passed; see Supplementary Table S1 for full normality testing results).

† eGFR: complete patients mean 86.4 ± 24.6; incomplete patients mean 67.9 ± 25.4 mL/min/1.73m².

‡ Prescriber specialty (T16): raw p=0.037 meets nominal significance but BH-FDR q=0.111 exceeds 0.10. This variable was included in the primary multivariable model on a priori theoretical grounds per SAP §4.3, independent of bivariate screening. OR = crude (unadjusted) odds ratio with Haldane-Anscombe continuity correction.

Primary prespecified model. Odds ratios and 95% CIs are adjusted for all other covariates in the model.

Table 3: Centre-adjusted multivariable logistic regression for complete four-pillar GDMT at discharge

Variable	β coef.	Adj. OR	95% CI Lower	95% CI Upper	p-value (Wald)	VIF
Intercept (β_0)	3.447	—	—	—	—	—
eGFR, per 10 mL/min/1.73m²	0.260	1.297	1.122	1.584	0.004	1.06
Cardiologist prescriber (vs non-cardiologist)	1.058	2.881	1.267	8.405	0.028	1.02
T2DM (yes vs no)	1.081	2.948	1.384	7.957	0.018	1.00
NYHA class (per unit increase)	−0.565	0.569	0.314	0.918	0.040	1.02
Serum K^+ (per 1 mmol/L)	−1.703	0.182	0.059	0.407	<0.001	1.03
EPV audit	Events (N=52) ÷ covariates (k=5) = 10.4 ✓ ≥10 threshold confirmed					
Nagelkerke R^2	0.348 (McFadden pseudo-R^2 = 0.226)					
AUC (C-statistic)	0.805 (95% CI 0.730–0.871) — good discrimination					
Hosmer-Lemeshow	χ^2 (8) = 4.14, p = 0.845 — good calibration ✓					
Overall LRT	χ^2 (5) = 44.26, p < 0.000001					
All VIF < 5	Confirmed (max VIF = 1.06) — no multicollinearity					
Box-Tidwell	eGFR p=0.215; NYHA p=0.900; K^+ p=1.000 — linearity confirmed ✓					
Complete cases	153/160 (95.6%); 7 excluded (missing K^+ or eGFR)					

Abbreviations: AUC = area under the receiver operating characteristic curve; CI = confidence interval; EPV = events per variable; eGFR = estimated glomerular filtration rate; LRT = likelihood ratio test; NYHA = New York Heart Association; OR = adjusted odds ratio; T2DM = type 2 diabetes mellitus; VIF = variance inflation factor.

ORs and 95% CIs are adjusted for all other covariates in the model. Highlighted rows (green shading) = covariates with p<0.05. Pre-specified ORs from SAP: eGFR/10 = 1.28; Cardiology = 3.40; T2DM = 1.75; NYHA = 0.55; K^+ = 0.42. All prespecified directions confirmed. No interaction reached p<0.10 threshold; additive main-effects model retained as primary.

All four sensitivity analyses were pre-specified in SAP v1.0 §5.6 before data access. Alternatively, = adjusted odds ratio for cardiologist vs non-cardiologist prescribers.

Table 4: Prespecified sensitivity analyses for the association between cardiologist-led prescribing and complete four-pillar GDMT at discharge in the centre-adjusted model

Analysis	N	Events	OR* (Cardiology)	95% CI	p (LRT)	Δ from Primary
SA0: PRIMARY — Complete case analysis	153	52	2.881	1.267 – 8.454	<0.001	Ref.
SA1: Complete case vs Multiple Imputation (MICE; m=20 datasets; Rubin's rules pooling)						

Analysis	N	Events	OR* (Cardiology)	95% CI	p (LRT)	Δ from Primary
eGFR/10 — primary	153	52	1.297	1.122 – 1.584	0.004	—
eGFR/10 — MICE pooled	160	52	1.300	—	—	−0.3%
T2DM — primary	153	52	2.948	1.384 – 7.957	0.018	—
T2DM — MICE pooled	160	52	2.612	—	—	−11.4%
Cardiology — primary	153	52	2.881	1.267 – 8.454	<0.001	—
Cardiology — MICE pooled	160	52	2.760	1.261 – 7.906	—	−4.2%
K^+ — primary	153	52	0.182	0.059 – 0.407	<0.001	—
K^+ — MICE pooled	160	52	0.200	—	—	−9.9%
SA2: Alternative outcome operationalizations						
SA2a: GDMT_3pillar (≥3/4 pillars)	153	66	2.209	1.108 – 4.859	—	−23.3%
SA2b: SA1a Ordinal pillar count (0–4)	153	—	—	—	—	—
SA2c: 3-pillar (pre-2021, excl. SGLT2i)	153	—	—	—	—	—
SA3: Restricted to pharmacologically eligible patients (eGFR ≥20 AND K^+ ≤5.5 mmol/L)						
SA3: Eligible population only	151	52	2.869	1.299 – 8.061	—	−0.4%
SA4: BNP outlier exclusion (Tukey outer fence: BNP >7,278 pg/mL; n=3 removed)						
SA4: Outlier-excluded sample	150	50	2.736	1.247 – 8.486	—	−5.1%

* OR = adjusted odds ratio for cardiologist vs non-cardiologist prescriber, from primary five-covariate logistic regression model unless otherwise noted. Δ = percentage change in OR relative to the primary complete-case estimate (SA0).

MICE imputation: IterativeImputer; m=20 datasets; predictive mean matching (continuous variables); logistic imputation (binary variables); auxiliary variables: ward type, admission year; Rubin's rules

pooling. Maximum observed change across covariates: T2DM −11.4%; all changes <20%.

DISCUSSION

Principal results

Complete adherence to the four-pillar guideline-directed medical therapy (GDMT) at discharge was infrequent across five hospitals in Nasiriyah, and the presence of a cardiologist was independently correlated with higher probabilities of achieving complete discharge GDMT after adjustment. In total, merely 32.5% of qualified patients were administered four-pillar GDMT at the time of discharge. Cardiologist-led prescribing was associated with a higher likelihood of complete four-pillar GDMT compared to non-cardiologist-led prescribing (adjusted odds ratio [aOR] 2.88, 95% confidence interval [CI] 1.27–8.41). The disparity in prescribing rates was most pronounced for SGLT2 inhibitors, which were prescribed 25.3 percentage points more frequently following cardiologist-led discharges compared to non-cardiologist-led discharges.

Implications of clinical pharmacotherapy

Clinicians seeking to enhance discharge optimisation of heart failure with reduced ejection fraction (HFrEF) medication in hospitals with differing specialist capabilities may derive many insights from this investigation(11,15). SGLT2 inhibitors were the least often prescribed category in absolute terms and exhibited the greatest disparity between expert and non-specialist teams. This pattern suggests that emerging therapeutic classes may be more challenging to implement consistently at discharge outside specialised cardiology settings than long-established treatments such as beta-blockers or RAAS inhibitors(16,17). Implementation efforts should thus take into account frontline clinicians' comfort and knowledge with novel HFrEF medicines as possible intervention targets(17). Pharmacists in mixed-service environments seeking to implement multidisciplinary discharge reviews may find it advantageous to formulate clear criteria for establishing, documenting, and categorising clinically valid exemptions to each of the four pillars(18).

These data indicate a readily actionable quality improvement objective upon discharge. Pharmacist-led discharge medication reviews are frequently used to optimise pharmacotherapy before hospital discharge; however, these initiatives may go unnoticed or unacknowledged if therapies are excluded without an explicit clinical rationale documented in the chart(19). Consequently, the discharge review should be organised to explicitly evaluate each of the four discharge GDMT pillars, with accompanying documentation for any excluded medication class, including an explanation of the contraindication, deferral, unavailability, or another clinically valid rationale(20). This technique would not elucidate the reasons for pharmaceutical omissions; nonetheless, it would immediately address silent omissions, enhance documentation quality, and facilitate more stringent auditing of prescribing decisions across institutions. Current evidence suggests that assessing SGLT2 inhibitor prescribing is the most promising area for improvement(21,22).

Generalisability and constraints

Our findings should not be construed as demonstrating or elucidating the reasons for the absence of SGLT2 inhibitor prescriptions for these patients. This study did not directly evaluate prescriber awareness of SGLT2 inhibitor indications, the availability of specific drugs at discharge, drug prices, discharge workflow, or clinical inertia, or undocumented clinical decision-making that may have varied between institutions(23–25). The most prudent interpretation of these findings is that they align with insufficient clinical expertise, ambiguity over the proper use of discharge, inadequate documentation, or resistance to the introduction of SGLT2 inhibitors into standard treatment beyond specialised cardiology settings(26).

While elevated potassium levels correlated with reduced LVEF, they were independently associated with a lower likelihood of achieving complete GDMT in multivariable analysis. The correlation between potassium levels and the probability of achieving complete guideline-directed medical therapy (GDMT) indicates that prescribers may exhibit increased reluctance as serum potassium rises, potentially leading to a reduction in the initiation of guideline-directed therapies before reaching potassium thresholds officially designated as contraindications for potassium-sensitive medications such as RAAS inhibitors and mineralocorticoid receptor antagonists (MRAs)(27–29). Clinicians should recognise that this study was observational, and so, the precise decision thresholds utilised by prescribers in real life remain unknown. This study underscores the potential benefit of developing clearer discharge procedures to enhance prescriber decision-making by more distinctly differentiating between "monitor and proceed" and "withhold and reassess" strategies(14,30).

Diabetic patients were independently more inclined to undergo comprehensive four-pillar GDMT upon discharge. Given that diabetes is inherently a criterion for SGLT2 inhibitors, prescribers may have been more inclined to initiate these drugs in diabetic patients compared to those with HFrEF lacking concurrent diabetes(31). Consequently, an educational implication is that multidisciplinary clinicians beyond cardiology should be informed that SGLT2 inhibitors constitute routine pharmacotherapy for HFrEF, rather than being viewed solely as glucose-lowering agents, when implementing guideline-directed recommendations at discharge(8,32).

Evaluation against current evidence

The findings of this study align with existing evidence indicating greater adherence to guideline-directed heart failure therapy following referral to specialists or care in specialised centres, compared with non-specialist care(33). This study is the inaugural investigation assessing this possible difference via a four-pillar outcome that includes SGLT2 inhibitors. This study was conducted across several hospitals within a single regional health system, rather than assessing variations within a single centre(8).

Implications of the study

The selected design for this analysis should not be seen as adequate to establish or negate a specialist-specific causal effect. Residual confounding from factors excluded from the adjusted model remains a possibility. The comfort of prescribers with evidence-based pharmacotherapy for HFrEF was not assessed, and unquantified variations in the documentation of absolute pharmacological contraindications across institutions could have affected prescribing completeness, irrespective of provider type(34). Throughout predetermined sensitivity tests, the adjusted correlation remained consistent, enhancing confidence that the conclusion was not solely influenced by disparities in absolute renal function or potassium-related contraindications between groups(35).

The findings of this trial should not be generalised to suggest that specialist engagement will enhance HFrEF medication at discharge in other hospitals. In multicenter cohorts such as these, centre-level factors can confound the association. These may encompass unrecorded disparities in ward discharge procedures, prescriber seniority or training, accessibility of cardiology consultation, formulary availability, medication accessibility at discharge, or other clinical variables that were inequitably allocated across centres but omitted from the adjusted regression model(36). Consequently, the most tenable conclusion derived from these data is that the inclusion of specialised teams was associated with a higher likelihood of complete discharge prescribing within this specific cohort of hospitals.

Multiple supplementary findings necessitate careful interpretation. The lack of importance attached to LVEF suggests that cardiologists' prescribing practices are likely effective for patients with proven HFrEF, as evidenced by the limited range of LVEF in this study population(37). The non-significance of BNP is challenging to evaluate due to substantial missing data; future studies should ensure a comprehensive collection of this routinely collected variable. The association between type 2 diabetes mellitus and complete GDMT was stronger than first hypothesised, suggesting that real-world outpatient prescribing may still reflect outdated paradigms about SGLT2 inhibitor utilisation in diabetes(38,39).

Mechanistic ramifications

Mechanistically, these observations may be elucidated by various aspects and should not be employed to conclusively validate or dismiss any single concept in favour of others. Variations in familiarity with contemporary HFrEF treatment guidelines, especially for newer medications such as SGLT2 inhibitors, may help explain discrepancies in prescribing practices between cardiologists and non-cardiologists(31,40,41). Nonetheless, the varying degrees of thoroughness in discharge medication reviews, documentation standards, and the propensity to initiate or maintain multiple medications within complex clinical workflows may also account for the observed outcomes and differ among hospitals with distinct internal service frameworks(18).

Our data indicate that prescribing patterns were more analogous across cardiologist-led and non-cardiologist-led discharges in patients with diabetes. Nonetheless, no statistically significant interaction was observed in the prespecified logistic regression model, and this investigation lacked the capacity to assess interactions. The lack of a substantial interaction term reinforces the conclusion that the association exists among all patients, irrespective of diabetes status; however, a post-hoc interaction analysis should not be construed as conclusive evidence that the mechanism underlying the observed association is uniformly informational and non-clinical for patients with and without diabetes(42,43).

Analyses of subgroups

All studied subgroups were predetermined; nonetheless, the data from these subgroups should be considered hypothesis-generating, given the exploratory nature of the criteria used. None of the three prearranged interactions met the predetermined exploratory significance threshold for assessing effect modification by cardiology team leadership across the strata of the covariate of interest (type 2 diabetes mellitus, Pinteraction = 0.235; CKD stage, Pinteraction = 0.650; NYHA class, Pinteraction = 0.593). Consequently, these findings do not yield statistically significant evidence that the independent relationship between cardiologist-led prescribing and comprehensive four-pillar GDMT differed substantially among the subgroups analysed in this study(41,44,45).

Nevertheless, prudent interpretation of the findings can yield feasible objectives for forthcoming prospective implementation studies. The correlation between cardiologist-led prescribing and comprehensive GDMT was more pronounced in patients with CKD stage G3 than in those with CKD stages G1–2, despite the latter subgroup being relatively small and imprecise(46). The connection seemed somewhat less, though not statistically significant, in people with diabetes compared to those without diabetes. Neither of these patterns can be deemed conclusive; nonetheless, they may guide future research goals aimed at bridging the discharge-prescribing gap for patients with mild renal impairment or those with HFrEF without diabetes(31,47).

Strength

This study possesses numerous significant strengths. Initially, five hospitals within a singular regional health system were incorporated. This enhances generalisability beyond a single specialist centre and facilitates the investigation of prescribing patterns across various inpatient treatment settings. The SAP was completed before data extraction. The principal multivariable model was predetermined and remains succinct given the observed number of primary outcome events. The rationale for the exclusion of each therapy class was extracted from patient records using a predetermined taxonomy, rather than defaulting to undocumented omissions or conducting post hoc analyses of recorded causes. Fifth, all elements of the primary study were consistently replicated in the predetermined sensitivity studies. Lastly, adjusted models incorporated enrolment centre as a covariate, reducing the likelihood that the observed association arises from patient-level characteristics and increasing the probability that it reflects a genuine disparity in prescription trends.

Limitations

This study could not establish causation because of its cross-sectional design. Secondly, all hospitals examined were situated within a single governorate and health system; therefore, these findings should not be presumed applicable to rural hospitals or health systems with differing frameworks. The study population was limited to patients who were discharged alive from the hospital and had sufficient medical record material for abstraction. Despite including LVEF as a covariate in the adjusted model, our findings may predominantly apply to stable patients rather than to those who succumb in the hospital, as the latter were excluded from the study. Ultimately, numerous chart-abstracted characteristics were not gathered in real time but rather retrospectively following patient discharge. This introduces the potential for information bias, especially with the recorded justifications for excluding drugs. Clinicians may have rightly considered certain drugs to be unequivocally contraindicated but neglected to register this determination. Likewise, certain therapeutic contracts listed in the chart may lack a stated rationale if the physician opted not to record one. The constraints of the rationale for medicine omission should be understood in the context that this study examines recorded reasons for omission rather than direct evidence of physician decision-making.

Prospective avenues for study

The observational nature of the data precludes definitive conclusions about the reasons for these results or potential measures to address the prescribing gap reported across five hospitals. Nonetheless, we can propose a plausible subsequent investigation. Future research should ideally be prospective and capable of assessing the effect of a specific intervention on clinician behaviour and patient outcomes. To determine whether focused implementation strategies can enhance the efficacy of comprehensive four-pillar GDMT upon discharge, the subsequent study should be an implementation experiment.

A viable strategy would involve implementing a stepped wedge cluster-randomised trial in general medical wards, contrasting standard care with a structured pharmacist-led discharge reconciliation process based on a standardised four-pillar chart

review, which includes explicit identification and documentation of contraindications, deferrals, unavailability, or other reasons for each omitted drug class. This study might assess the attainment of comprehensive four-pillar GDMT at discharge as an implementation outcome and evaluate its impact on post-discharge outcomes, including early readmission, treatment adherence, and class-specific prescribing trends across time.

CONCLUSION

The implementation of a complete four-pillar GDMT at discharge was rarely observed across the five hospitals in Nasiriyah, Iraq. Compared with non-cardiologist-led care, cardiologist engagement was independently associated with a higher probability of achieving complete four-pillar GDMT at discharge, after adjustment for patient-level confounders. SGLT2 inhibitors had the lowest overall prescription rates at discharge and demonstrated the greatest disparity between specialist and non-specialist care teams.

Discrepancies in adherence to guideline-directed prescribing are present at discharge in regional hospital settings, particularly notable for novel medication classes such as SGLT2 inhibitors. This analysis should not be construed as evidence that cardiologist engagement leads to more comprehensive prescribing or that a focused intervention will bridge the detected gap through the same mechanism. Additional study is required to determine whether structured multidisciplinary discharge protocols can enhance comprehensive four-pillar GDMT rates at discharge and subsequent patient-centred outcomes.

DECLARATIONS

Data dissemination

Upon request to the corresponding author (subject to institutional review and approval), the anonymized participant-level dataset and the annotated R code necessary to reproduce the reported analyses will be available to those seeking to replicate the results or reanalyze the data. The dataset behind these results cannot be publicly disclosed due to local research governance agreements that prohibit data sharing beyond the consortium without patient consent. Data access requests will be evaluated upon the submission of a completed data-access form.

Statement of interests

All authors disclose no conflicting interests. No authors disclose any financial assistance obtained from pharmaceutical industry sources. No authors disclose any involvement with advisory boards, consultancy, speaking fees, stock ownership, or other financial affiliations with the manufacturers of any pharmaceuticals or drug categories examined or contrasted in this study.

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Approval for ethical compliance

The National University Research Ethics Committee provided ethical permission for this investigation before the commencement of the study and data extraction. Due to the retrospective nature of this investigation, which involved a review of de-identified routine care records obtained by authorized personnel and posed minimal risk to patients, the Health Research Ethics Committee exempted the requirement for individual informed consent. Authors can verify that all raw data were anonymized before granting access to any investigators. All investigators had submitted Disclosure of Relationship with Industry forms (standard waivers) through the institution prior to the study commencing. This study adheres to the standards outlined in the Declaration of Helsinki.

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Additional resources

Wiley and Hindawi endorse the publication of extra materials related to papers in the Online Journal of Public Health Ethics. The supplied supplemental resources are intended solely for informational reasons. In the absence of a directive from the copyright holder, these works may be downloaded, printed, stored, and redistributed in any format by any individual for any purpose.

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APPENDICES

Table S1: Prespecified interaction analyses for the primary multivariable model

Interaction term	β interaction	OR interaction	LRT χ^2 (1)	p-interaction	Verdict
INT1: eGFR/10 × T2DM	+0.211	1.235	1.641	0.200	No interaction (p≥0.10)
INT2: Prescriber × NYHA class	−0.499	0.607	0.941	0.332	No interaction (p≥0.10)
INT3: K^+ × eGFR (MRA model)	+0.023	1.023	0.026	0.871	No interaction (p≥0.10)

Interaction terms were explored in separate models and assessed by likelihood-ratio testing. These analyses were exploratory.

Table S2: Exploratory subgroup analyses of the association between prescriber specialty and complete four-pillar GDMT at discharge

Subgroup	N	GDMT Complete Rate	OR* (Cardiologist vs Other)	95% CI	p-value	p-interaction †	Forest
OVERALL (Primary model)	160	32.5%	2.88	1.27–8.41	0.028	—	◆
Subgroup 1: T2DM Status [EXPLORATORY — hypothesis-generating only]							
T2DM present	77	39.0%	1.82	0.73–4.56	0.200	0.235	>
No T2DM	83	26.5%	2.59	0.95–7.09	0.063		"
Subgroup 2: CKD Stage [EXPLORATORY — hypothesis-generating only]							
CKD G1–2 (eGFR ≥60)	105	41.9%	1.97	0.90–4.31	0.126	0.650	>
CKD G3 (eGFR 30–59)	49	16.3%	2.73	0.56–13.2	0.331		"
CKD G4–5 (eGFR <30)	4	0.0%	—	—	—		—
Subgroup 3: Prescriber Specialty — Pillar-Specific Rates [EXPLORATORY]							

Subgroup	N	GDMT Complete Rate	OR* (Cardiologist vs Other)	95% CI	p-value	p-interaction †	Forest
Cardiologist — ACEi	91	70.4%	—	—	—	—	
Non-cardiologist — ACEi	69	58.2%	—	—	—	—	
Cardiologist — BB	91	72.8%	—	—	—	—	
Non-cardiologist — BB	69	69.6%	—	—	—	—	
Cardiologist — MRA	91	60.5%	—	—	—	—	
Non-cardiologist — MRA	69	55.7%	—	—	—	—	
Cardiologist — SGLT2i	91	51.9%	—	—	—	—	★★
Non-cardiologist — SGLT2i	69	26.6%	—	—	—	—	↓↓
Subgroup 4: HF Severity (NYHA) [EXPLORATORY — hypothesis-generating only]							
NYHA I–II	67	41.8%	2.68	1.00–7.16	0.078	0.593	"
NYHA III–IV	93	25.8%	2.00	0.77–5.17	0.217		>

* OR = odds ratio for cardiologist versus non-cardiologist prescriber in each subgroup; estimated by chi-squared with Haldane-Anscombe correction. † p-interaction = likelihood ratio test comparing model with vs without subgroup × prescriber cross-product term (one df); threshold p<0.10.

All subgroup analyses are hypothesis-generating per SAP v1.0 §5.2. No subgroup finding is interpreted as a primary conclusion.

★★ SGLT2i specialist–non-specialist gap = 25.3 percentage points (51.9% vs 26.6%) — largest pillar-specific gap across all four pillars. ↓↓ Non-cardiologist SGLT2i rate identifies knowledge-driven omission as the dominant barrier (see Discussion).

CKD G4–5 subgroup (N=4) has insufficient events for OR estimation; excluded from interaction test. Forest column: >= OR in same direction as overall;" = larger effect; — = not calculated; ◆ = primary model anchor.