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ORIGINAL RESEARCH

Heart Failure Readmission in Patients With ST-Segment Elevation Myocardial Infarction and Active Cancer

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ABSTRACT

BACKGROUND Although numerous studies have examined readmission with heart failure (HF) after acute myocardial infarction (AMI), limited data are available on HF readmission in cancer patients post-AMI.

OBJECTIVES This study aimed to assess the rates and factors associated with HF readmission in cancer patients presenting with ST-segment elevation myocardial infarction (STEMI).

METHODS A nationally linked cohort of STEMI patients between January 2005 and March 2019 were obtained from the UK Myocardial Infarction National Audit Project registry and the UK national Hospital Episode Statistics Admitted Patient Care registry. Multivariable Fine-Gray competing risk models were used to evaluate HF readmission at 30 days and 1 year.

RESULTS A total of 326,551 STEMI indexed admissions were included, with 7,090 (2.2%) patients having active cancer. The cancer group was less likely to be admitted under the care of a cardiologist (74.5% vs 81.9%) and had lower rates of invasive coronary angiography (62.2% vs 72.7%; $P < 0.001$) and percutaneous coronary intervention (58.4% vs. 69.5%). There was a significant prescription gap in the administration of post-AMI medications upon discharge such as an angiotensin-converting enzyme inhibitor/angiotensin receptor blocker (49.5% vs 71.1%) and beta-blockers (58.4% vs 68.0%) in cancer patients. The cancer group had a higher rate of HF readmission at 30 days (3.2% vs 2.3%) and 1 year (9.4% vs 7.3%). However, after adjustment, cancer was not independently associated with HF readmission at 30 days (subdistribution HR: 1.05; 95% CI: 0.86-1.28) or 1 year (subdistribution HR: 1.03; 95% CI: 0.92-1.16). The opportunity-based quality indicator was associated with higher rates of HF readmission independent of cancer diagnosis.

CONCLUSIONS Cancer patients receive care that differs in important ways from patients without cancer. Greater implementation of evidence-based care may reduce HF readmissions, including in cancer patients. (J Am Coll Cardiol CardioOnc 2024;■:■-■) © 2024 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

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ABBREVIATIONS AND ACRONYMS

ACE = angiotensin-converting enzyme

AMI = acute myocardial infarction

ARB = angiotensin receptor blocker

CABG = coronary artery bypass graft

DM = diabetes mellitus

HES = Hospital Episode Statistics

HES APC = Hospital Episode Statistics Admitted Patient Care Registry

HF = heart failure

MINAP = Myocardial Infarction National Audit Project

NHS = National Health Service

OBQI = opportunity-based quality indicator

ONS = Office for National Statistics

PCI = percutaneous coronary intervention

PVD = peripheral vascular disease

STEMI = ST-segment elevation myocardial infarction

Cardiovascular disease and cancer are the primary causes of death worldwide and account for approximately 70% of deaths in high-income countries.[1,2] The concurrent prevalence of cardiovascular disease in cancer patients has increased[3]; with the rate of cardiovascular death increasing, cancer-specific deaths decline.[4] Reports indicate that 1 in 5 cancer survivors faces the risk of cardiovascular death, particularly within the initial year after a cancer diagnosis.[5] Ischemic heart disease contributes to more than half of all cardiovascular deaths in cancer patients, and acute myocardial infarction (AMI) is a common cardiovascular presentation in patients with cancer.[6,7]

Unplanned readmission rates after AMI can be as high as 15% at 30 days, and heart failure (HF) stands out as a predominant cause of hospital readmission,[8] accounting for 20% of hospital readmissions, with about two-thirds occurring within the first 30 days postdischarge.[8] Although several studies have assessed HF readmission post-AMI, there are limited data on HF readmission in cancer patients post-AMI, and scant information exists regarding differences in processes of care, drug treatments, and their association with longer-term outcomes. Cancer patients admitted with ST-segment elevation myocardial infarction (STEMI) may face an elevated risk of HF readmission given the lower likelihood of invasive management and chemotherapy agents associated with an increased risk of left ventricular impairment.[1,9] Previous studies addressing HF risk post-STEMI in this patient group are limited, specifically concerning the evaluation of different cancer types and longer-term follow-up.[9-11]

Because most clinical trials excluded cancer patients, prospective clinical registries provide an opportunity to assess the quality of care, treatments received, and HF readmission after AMI in patients with cancer.[1] Therefore, we assessed the rate and predictors of HF readmission in STEMI patients with cancer using linked multisource electronic health care records from an integrated health care system in the United Kingdom. This analysis relied on data from the UK Myocardial Infarction National Audit Project (MINAP) heart attack registry, recognized as the world's largest heart attack registry.[12-14]

METHODS

STUDY DESIGN. This is a population-based, retrospective cohort study focusing on patients admitted with STEMI in England and Wales between January 2005 and March 2019. Data were obtained via linkages between the MINAP registry, hospital admission records from the Hospital Episode Statistics (HES) registry, and the National Deaths Registry from the Office for National Statistics (ONS).[12-14]

MINAP serves as a national AMI audit registry, which collects information on the characteristics and clinical care of patients diagnosed with AMI in England, Wales, and Northern Ireland. This registry plays a crucial role in auditing care quality, public reporting of AMI patients, and supporting academic research.[12,15,16] The database contains information on patient demographics, admission details and methods, cardiovascular comorbidities, clinical characteristics, relevant investigations, in-hospital pharmacologic and interventional treatments, in-hospital outcomes, and discharge treatments.[17-20]

The ONS, the largest independent producer of official statistics, houses the Hospital Episode Statistics Admitted Patient Care Registry (HES APC). This national registry covers all admissions to National Health Service (NHS) hospitals in England.[13] The ONS is responsible for collecting and publishing statistics related to the economy, population, and society at the national, regional, and local levels.[14] It includes all certified and registered deaths in England and Wales recorded in the Civil Registration Deaths Data of the ONS of England and Wales.[21] To obtain information about the date of death, as stated on the medical certificate of cause of death, we used the ONS database. An NHS identifier, a unique code for each patient, facilitated linking between the databases.

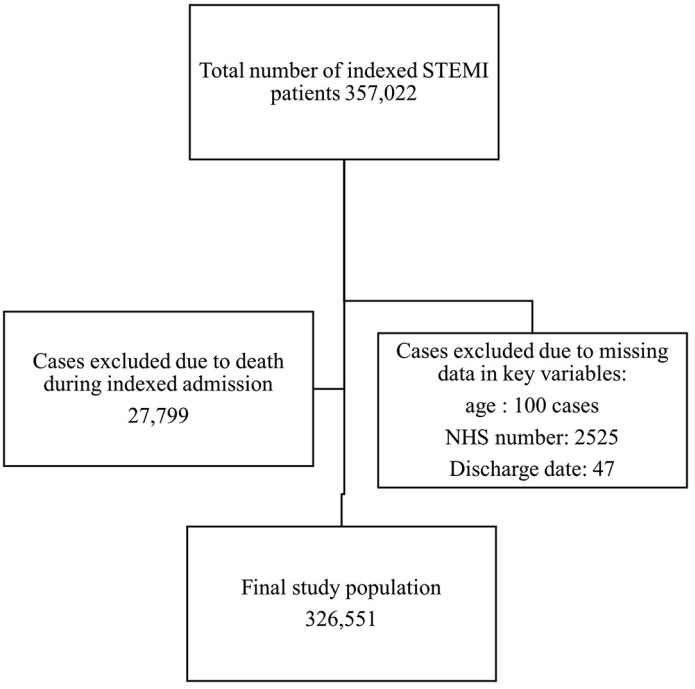
STUDY POPULATION. We identified all STEMI index admissions from the MINAP database linked with HES APC. Patients with a diagnosis of cancer were identified from the HES APC database using the International Classification of Diseases-10th Revision-Clinical Modification. Population-based studies from the national British registry have shown the reliability of the HES database in providing information on cancer, HF, and AMI diagnoses.[22,23] STEMI patients were then categorized into 2 cohorts: those with active cancer and those without. Active cancer was defined as patients who had cancer at the time of admission and were identified using the International Classification of Diseases-10th Revision codes from the HES database. The cancer conditions included

and their corresponding International Classification of Diseases-Tenth Revision codes used in this study are listed in Supplemental Table 1. We then used the NHS identifier and the date of subsequent readmissions from the HES APC database to identify the occurrence and date of the first readmission with decompensated HF. Cases with missing NHS identifiers, age, and date of discharge were excluded (Figure 1).[22,23]

ETHICAL APPROVAL. The study underwent formal ethical approval for the data linkages of the MINAP, HES, and ONS registries. Ethical approval was granted by the Health and Care Research Wales and the Health Research Authority (Research Ethics Committee reference 20/WA/0312).[24] Additionally, approval was obtained by the Confidentiality Advisory Group, an independent body providing expert advice on the use of confidential patient information for research.[25]

QUALITY INDICATORS. To evaluate the quality of care, we used the quality indicators of the European Society of Cardiology Association for Acute Cardiovascular Care for the relevant year concerning STEMI.[26,27] Specifically, the following indicators were used: reperfusion within 12 hours after presentation, door-to-balloon time, revascularization (percutaneous coronary intervention [PCI]/coronary artery bypass graft [CABG]), left ventricular ejection fraction evaluation before discharge, P2Y12 inhibitors at discharge, dual antiplatelet therapy received on discharge, high-intensity statin on discharge, angiotensin-converting enzyme (ACE) inhibitor or angiotensin receptor blockers (ARBs) on discharge for those with moderate and severe left ventricular systolic dysfunction, beta-blocker on discharge for those with moderate and severe left ventricular systolic dysfunction, and the composite opportunity-based quality indicator (OBQI).[26] The OBQI reflects the number of fulfilled care opportunities in each hospital (numerator) divided by the total number of care opportunities to provide care (denominator).[28] The score comprised 6 evidence-based care processes: the prescription of aspirin, thienopyridine inhibitor, beta-blocker, ACE inhibitor/ARB, 3-hydroxy-3-methylglutaryl coenzyme A reductase enzyme inhibitor (statin), and enrollment in a cardiac rehabilitation program at the time of discharge.[28] Care processes that were contraindicated, not applicable, not indicated in, or declined by individual patients were excluded from both the numerator and denominator. Higher values of the OBQI signify better inpatient quality of care.

FIGURE 1 Study Population Flowchart



The flowchart illustrates the cases excluded from the analysis. Exclusions were made for cases with missing National Health Service (NHS) identifiers, age, and date of discharge. STEMI = ST-segment elevation myocardial infarction.

CLINICAL OUTCOMES. The primary clinical outcome focused on HF readmission in STEMI patients who survived to discharge at both 30 days and 1 year.

STATISTICAL ANALYSIS. Continuous variables are expressed as mean ± SD or as median with 25th and 75th percentiles (Q1, Q3) for skewed data. Categoric variables are expressed as percentages. The Student's *t*-test or Kruskal-Wallis test was used to compare normally distributed and skewed continuous variables between groups, respectively. The chi-square test was applied to analyze categoric variables. To handle missing data, we used the multiple imputations by chained equations algorithm. The assumption was that the missing data were missing at random. Twenty imputed data sets were generated, and subsequent analyses were conducted on each imputed data set, with the results statistically combined.[29-31] Supplemental Tables 2 and 3 describe details on the missing and imputed data.

To address the competing risk of all-cause death postdischarge, the Fine-Gray competing risk regression model was used. This model calculates the

TABLE 1 Patients Characteristics and Processes of Care of STEMI Patients

	STEMI Without Cancer (n = 319,461)	STEMI With Cancer (n = 7,090)	*P* Value
Age at admission, y	64.6 (55.0, 75.0)	74.1 (66.4, 81.0)	<0.001
Sex			
Men	229,712 (71.9)	5,324 (75.1)	<0.001
Women	89,749 (28.1)	1,766 (24.9)	
Missing	0	0	
Ethnicity			
White	253,236 (91.3)	6,147 (95.9)	<0.001
BAME	24,101 (8.7)	260 (4.1)	
Missing	42,124	683	
BMI, kg/m^2	26.9 (24.1, 30.1)	25.7 (22.9, 28.9)	<0.001
Cardiac arrest			
No	281,671 (91.9)	6,378 (92.8)	0.005
Yes	24,928 (8.1)	495 (7.2)	
Missing	12,862	217	
Killip class			
Killip class I	116,888 (80.3)	2,703 (74.0)	<0.001
Killip class II	11,620 (8.0)	425 (11.6)	
Killip class III	4,521 (3.1)	153 (4.2)	
Killip class IV	12,531 (8.6)	372 (10.2)	
Missing	173,901	3,437	
Left ventricular ejection fraction			
Good	75,439 (52.9)	1,496 (48.6)	<0.001
Moderate/poor LV function	67,081 (47.1)	1,580 (51.4)	
Missing	176,970	4,014	
PMH of angina			
No	242,428 (86.3)	5,167 (81.9)	<0.001
Yes	38,550 (13.7)	1,143 (18.1)	
Missing	38,483	780	
Previous MI			
No	244,390 (85.9)	5,222 (81.6)	<0.001
Yes	40,026 (14.1)	1,177 (18.4)	
Missing	35,045	691	
Heart failure			
No	272,824 (97.8)	6,065 (96.7)	<0.001
Yes	6,006 (2.2)	206 (3.3)	
Missing	40,631	819	
DM			
No	254,123 (84.5)	5,573 (82.7)	<0.001
Yes	46,690 (15.5)	1,169 (17.3)	
Missing	18,648	348	
Hypertension			
No	161,994 (57.0)	3,373 (53.0)	<0.001
Yes	122,192 (43.0)	2,992 (47.0)	
Missing	35,275	725	
Hypercholesterolemia			
No	192,160 (69.3)	4,484 (72.1)	<0.001
Yes	85,215 (30.7)	1,733 (27.9)	
Missing	42,086	873	
Peripheral vascular disease			
No	268,699 (97.1)	5,977 (96.1)	<0.001
Yes	7,981 (2.9)	242 (3.9)	
Missing	42,781	871	

Continued on the next page

cumulative incidence and subdistribution HR (sHR) with a 95% CI. In comparison to the Cox regression model, the Fine-Gray competing risk model is designed to account for competing risks of death in time-to-event analyses for nonfatal outcomes, offering a more accurate estimation of the risk of the primary outcome when 1 or more competing risks are present. The Fine-Gray model produces a subdistribution HR that describes the relative effect of covariates on the subdistribution hazard function.[32] Therefore, predictors in this model can be interpreted as being associated with the probability of events occurring over time or the cumulative incidence function.[32]

Competing risk regression models were also used to identify the independent predictors of HF readmission. The models were adjusted for variables including age, sex, ethnicity, cardiac arrest, cardiogenic shock, left ventricular ejection fraction, history of angina, previous myocardial infarction, HF, diabetes mellitus (DM), hypertension, hypercholesterolemia, peripheral vascular disease (PVD), stroke, family history of coronary artery disease, smoking, chronic kidney disease, asthma or chronic obstructive pulmonary disease, PCI, previous CABG, and composite quality indicator. We ensured that the nonproportional hazards assumptions were not violated by examining the log-log plot and the Kaplan-Meier observed vs predicted survival from the model, as shown in Supplemental Figures 1 and 2. Martingale residual plots were used to check the linearity assumption for numeric covariates (age, OBQI), as shown in Supplemental Figure 3. Stata V16 software (StataCorp LLC) was used to complete the statistical analysis.[33]

RESULTS

PATIENT CHARACTERISTICS. A total of 326,551 STEMI indexed admissions survived to discharge between January 1, 2005, and March 30, 2019. Among them, 7,090 (2.2%) were diagnosed with active cancer. The cancer group was older (median age [Q1, Q3]: 74.1 years [66.4, 81.0 years] vs 64.6 years [55.0, 75.0 years]) and more likely to have Killip class II (11.6% vs 8.0%) and Killip class III (4.2% vs 3.1%) at presentation. The cancer group had a higher frequency of cardiovascular comorbidities such as angina (18.1% vs 13.7%), previous myocardial infarction (18.4% vs 14.1%), a history of HF (3.3% vs 2.2%), DM (17.3% vs 15.5%), hypertension (47.0% vs 43.9%), peripheral vascular disease (3.9% vs 2.9%), chronic kidney

disease (5.6% vs 2.5%), and stroke (7.5% vs 5.1%). Table 1 shows the baseline characteristics of patients with STEMI with and without a cancer diagnosis.

PROCESS OF CARE AND EUROPEAN SOCIETY OF CARDIOLOGY QUALITY INDICATORS. The cancer group was less likely to be admitted under a cardiologist (74.5% vs 81.9%) and had lower rates of invasive coronary angiography (62.2% vs 72.7%; $P < 0.001$), PCI (58.4% vs 69.5%), and CABG (0.8% vs 1.2%) (Table 2). Cancer patients were less likely to be prescribed dual antiplatelet therapy (67.3% vs 69.6%) and were less likely to be referred to cardiac rehabilitation services (83.1% vs 90.7%) at discharge.

A significant gap existed in inpatient administration of HF medications that have been shown to improve patient prognosis in patients with left ventricular systolic dysfunction, such as ACE inhibitors/ARBs (49.5% vs 71.1%) and beta-blockers (58.4% vs 68.0% in cancer patients) (Table 3). In contrast, cancer patients were more likely to receive loop diuretic agents (25.7% vs 18.5%) (Table 2).

READMISSION WITH HF AND INDEPENDENT PREDICTORS OF HF READMISSION. The cancer group was readmitted more frequently with HF at 30 days (3.2% vs 2.3%) and 1 year (9.4% vs 7.3%) (Figure 2A). Figure 2A shows the unadjusted cumulative incidence of HF readmissions. After adjustment for patient characteristics, comorbidities, and quality of care, a cancer diagnosis was not associated with an increased risk of readmission from HF at 30 days (sHR: 1.05; 95% CI: 0.86-1.28) or 1 year (sHR: 1.03; 95% CI: 0.92-1.16). Figure 2B shows the adjusted cumulative incidence for HF readmission in STEMI patients. Patients with hematologic malignancies had a higher risk of HF readmission (sHR: 1.35; 95% CI: 1.05-1.74) compared with the other common cancers, as shown in Table 4.

The main factors associated with HF readmission at 1 year were as follows: age (sHR: 1.02; 95% CI: 1.02-1.02); female sex (sHR: 1.09; 95% CI: 1.5-1.14); Black, Asian, or minority ethnicity (sHR: 1.20; 95% CI: 1.12-1.29); DM (sHR: 1.38; 95% CI: 1.32-1.45); hypertension (sHR: 1.10; 95% CI: 1.06-1.15); PVD (sHR: 1.28; 95% CI: 1.17-1.39); stroke (sHR: 1.15; 95% CI: 1.07-1.24); chronic kidney disease (sHR: 1.38; 95% CI: 1.27-1.51); chronic obstructive pulmonary disease (sHR: 1.22; 95% CI: 1.16-1.28); and moderate to severe left ventricular impairment at discharge (sHR: 1.69; 95% CI: 1.62-1.75). The OBQI was inversely associated with HF readmission, particularly at 30 days (sHR: 0.99; 95% CI: 0.99-0.99). Figure 3 shows the independent predictors of HF readmission at 30 days and 1 year, respectively.

TABLE 1 Continued

	STEMI Without Cancer (n = 319,461)	STEMI With Cancer (n = 7,090)	*P* Value
Stroke/TIA			
No	264,495 (94.9)	5,798 (92.5)	<0.001
Yes	14,199 (5.1)	467 (7.5)	
Missing	40,767	825	
FH of CAD			
No	156,597 (64.9)	4,010 (77.5)	<0.001
Yes	84,630 (35.1)	1,164 (22.5)	
Missing	78,234	1,916	
Smoking status			
Never smoked	99,089 (33.9)	2,359 (36.9)	<0.001
Ex-smoker	80,873 (27.6)	2,656 (41.5)	
Current smoker	112,711 (38.5)	1,382 (21.6)	
Missing	26,788	693	
Chronic kidney disease			
No	270,957 (97.5)	5,893 (94.4)	<0.001
Yes	6,983 (2.5)	349 (5.6)	
Missing	41,521	848	
Asthma/COPD			
No	244,790 (88.2)	5,279 (84.5)	<0.001
Yes	32,717 (11.8)	965 (15.5)	
Missing	41,954	846	
Previous PCI			
No	257,677 (91.9)	5,715 (90.6)	<0.001
Yes	22,801 (8.1)	590 (9.4)	
Missing	38,983	785	
Previous CABG			
No	272,954 (97.3)	6,043 (95.8)	<0.001
Yes	7,590 (2.7)	267 (4.2)	
Missing	38,917	780	

Values are median (Q1, Q3) or n (%).

BAME = Black, Asian, or minority ethnicity; BMI = body mass index; CABG = coronary artery bypass graft; CAD = coronary artery disease; COPD = chronic obstructive pulmonary disease; DM = diabetes mellitus; FH = family history; LV = left ventricular; MI = myocardial infarction; PCI = percutaneous coronary intervention; PMH = past medical history; STEMI = ST-segment elevation myocardial infarction; TIA = transient ischemic attack.

TEMPORAL TRENDS. The crude proportion of readmission from HF at 1 year in STEMI patients with cancer increased from 7.7% in 2005 to 15.8% in 2018. Similarly, the proportion of 1-year HF readmission in STEMI patients without cancer increased from 6.6% in 2005 to 11.3% in 2018 (Figure 4). The rate of 1-year HF readmission in STEMI patients with cancer (per 1,000 STEMIs) doubled between 2005 and 2018 (from 19 to 39 readmissions). Figure 5 illustrates temporal trends in the 1-year readmission rates with HF in STEMI patients based on the most common cancers in the United Kingdom, namely, prostate cancer, breast cancer, lung cancer, colon cancer, and hematologic

TABLE 2 Process of Care and Readmission With HF in STEMI Patients

	STEMI Without Cancer (n = 319,461)	STEMI With Cancer (n = 7,090)	*P* Value
Admitted by a cardiologist			
No	56,246 (18.1)	1,750 (25.5)	<0.001
Yes	254,360 (81.9)	5,107 (74.5)	
Missing	8,855	233	
Clopidogrel			
No	46,135 (15.7)	1,086 (16.4)	0.12
Yes	248,286 (84.3)	5,544 (83.6)	
Missing			
Glycoprotein IIb/IIIa inhibitors			
No	209,989 (82.7)	5,081 (88.5)	<0.001
Yes	43,800 (17.3)	661 (11.5)	
Missing	65,672	1,348	
Beta-blockers			
No	17,544 (6.6)	623 (10.6)	<0.001
Yes	249,847 (93.4)	5,253 (89.4)	
Missing	52,070	1,214	
Loop diuretics			
No	201,493 (81.5)	4,189 (74.3)	<0.001
Yes	45,884 (18.5)	1,448 (25.7)	
Missing	72,084	1,453	
Aldosterone antagonists			
No	153,495 (84.8)	3,811 (86.4)	0.005
Yes	27,430 (15.2)	602 (13.6)	
Missing	138,536	2,677	
Coronary angiogram			
No	80,260 (27.3)	2,341 (37.8)	<0.001
Yes	213634 (72.7%)	3,854 (62.2)	
Missing	25,567	895	
PCI			
No	89,075 (30.5)	2,555 (41.6)	<0.001
Yes	203,363 (69.5)	3,590 (58.4)	
Missing	27,023	945	
CABG			
No	289,933 (98.8)	6,183 (99.2)	0.009
Yes	3,449 (1.2)	51 (0.8)	
Missing	26,079	856	
Coronary revascularization			
No	86,162 (29.5)	2,513 (40.9)	<0.001
Yes	206,275 (70.5)	3,632 (59.1)	
Missing	27,024	945	
In-hospital outcomes			
Bleeding complications			
No	301,441 (99.2)	6,641 (98.5)	<0.001
Yes	2,512 (0.8)	99 (1.5)	
Missing	15,508	350	
Reinfarction			
No	280,082 (98.1)	6,252 (98.1)	0.93
Yes	5,333 (1.9)	118 (1.9)	
Missing			
HF readmission			
30 days HF readmission			
No	312,046 (97.7)	6,861 (96.8)	<0.001
Yes	7,415 (2.3)	229 (3.2)	
1-year HF readmission			
No	296,206 (92.7)	6,425 (90.6)	<0.001
Yes	23,255 (7.3)	665 (9.4)	

Values are n (%).
HF = heart failure; other abbreviations as in Table 1.

malignancies.[34] This is mainly because of the increase in HF readmissions in patients with prostate cancer (4.4 to 11.7 readmissions), hematologic malignancies (2.2 to 9.7 readmissions), and lung cancer (1.5 to 5.7 readmissions) (Figure 5).

DISCUSSION

Our analysis of STEMI care and post-STEMI HF readmission in patients with active cancer reveals several important findings. Patients with active cancer presenting with STEMI were older and had a greater burden of comorbidities compared with patients without cancer. Despite this, patients with cancer were less likely to undergo invasive evaluation and revascularization during their STEMI presentation. Furthermore, they were less likely to be discharged on guideline medical therapy, including antiplatelet agents, statins, and neurohormonal blockade. Although patients with cancer exhibited higher rates of 30-day and 1-year readmission for HF compared with patients without cancer, these readmission rates were no longer significant after adjusting for differences in baseline characteristics. Notably, lower-quality metrics on discharge from the STEMI hospitalization were associated with a higher risk of HF readmission irrespective of cancer presence. These results highlight opportunity gaps in managing patients with cancer presenting with STEMI, holding important clinical implications for the care of this growing patient population (Central Illustration).

We observed an increasing hospital readmission rate after AMI caused by HF over the years regardless of the cancer status. This trend can be explained by the aging population, increased comorbidities, and improved survival post-AMI caused by nationwide implementation of primary PCI services. High-risk patients now live longer, contributing to the development of HF. Unlike the United States, there is a lack of national programs in the United Kingdom, such as the Hospital Readmission Reduction Program on HF, which has proven effective in reducing HF readmissions.[35]

Our analysis builds on prior publications describing the care and outcomes of cancer patients presenting with acute coronary syndrome. Prior analyses have consistently shown lower rates of invasive evaluation and revascularization in patients with cancer vs those without cancer presenting with AMI, including those presenting with STEMI.[1,36] Despite revascularization being the gold standard for the care of patients with STEMI, revascularization rates in cancer patients presenting with STEMI, as reported in

prior U.S. data, fall in the 50% to 70% range, aligning with our current findings. A cancer diagnosis has also been identified as an independent predictor of all-cause readmissions after an AMI,[9] although limited data exist regarding the specific risk of concomitant cancer on readmission for HF.

Our results build on these prior publications and fill important knowledge gaps regarding the management of patients with active cancer who present with STEMI. Specifically, key new findings include not only reduced use of invasive intervention but also slower revascularization; lower rates of admission by a cardiologist; and decreased adherence to guideline-recommended treatment, such as antiplatelet agents, statin agents, and neurohormonal blockade in patients with systolic dysfunction. Taken together, patients with cancer and STEMI exhibited lower OBQI scores, indicating a disparity in global quality measures for STEMI care. The reasons for the lower use of invasive evaluation, revascularization, medications, and other quality metrics in cancer patients may be multifactorial. Clinicians and patients may have concerns about medication intolerance because of comorbid conditions, such as bleeding risk with antiplatelet agents or hypotension with neurohormonal blockade. Additionally, patients and clinicians may underestimate the crucial role of noncancer comorbidities, including coronary disease and HF, as contributors to prognosis in cancer patients, especially because prognosis from a cancer standpoint continues to improve over time.[5,37]

We found that gaps in guideline-recommended care and quality measures were associated with higher readmissions for HF among cancer patients compared with noncancer patients after the initial STEMI presentation, with HF being the most frequent cause of post-AMI readmissions in previous studies.[9] In multivariable analyses, lower quality of care as measured by OBQI was linked to greater HF readmission independent of cancer status. This implies that optimizing evidence-based interventions among cancer patients may lead to a reduction in HF readmissions. Therefore, our findings suggest that select cancer patients presenting with STEMI should be considered for optimal guideline-based therapies, including revascularization, medication optimization, and other OBQI measures, similarly to patients without cancer in an effort to improve postdischarge outcomes.

There may be additional factors contributing to the higher risk of HF readmission in patients with cancer presenting with STEMI. Advances in chemotherapy and immunotherapy for cancer care have introduced agents with potential direct cardiotoxicity, an increased risk for myocarditis, or other cardiac complications, such as arrhythmia or vasospasm leading to symptomatic HF.[37] Moreover, cancer and HF may share a bidirectional causal relationship in which

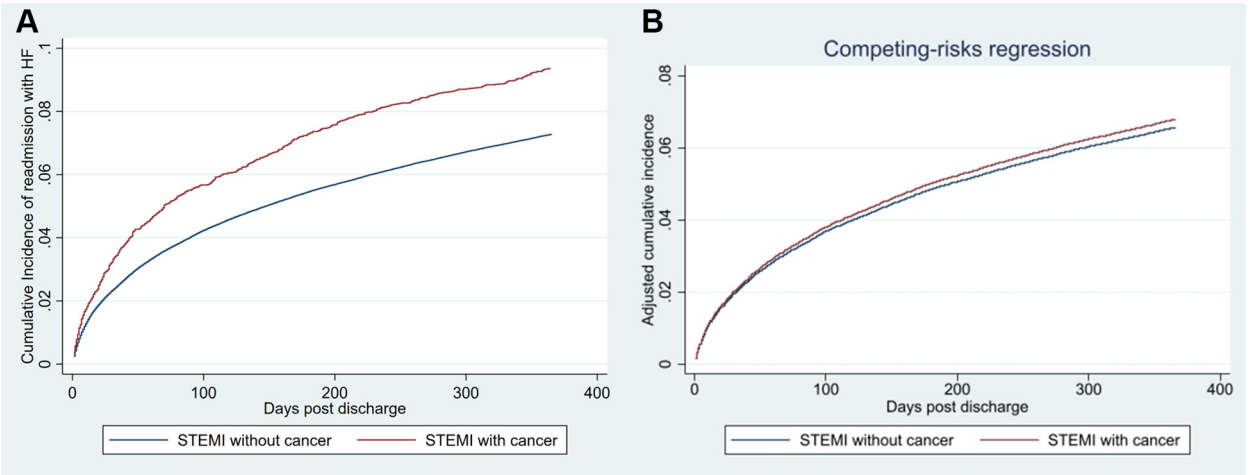
TABLE 3 ESC Quality of Care of Indexed Admissions of STEMI Patients With and Without Cancer

	STEMI Without Cancer (n = 319,461)	STEMI With Cancer (n = 7,090)	*P* Value
Reperfusion within 12 h of presentation			
No	3,003 (1.3)	133 (3.2)	<0.001
Yes	231,863 (98.7)	3,973 (96.8)	
Missing	84,595	2,984	
Door-to-balloon time <60 min			
>60 minutes	60,510 (25.8)	1,188 (28.9)	<0.001
<60 minutes	174,356 (74.2)	2,918 (71.1)	
Missing	84,595	2,984	
Door-to-balloon time <120 min			
No	18,593 (7.9)	410 (10.0)	<0.001
Yes	216,273 (92.1)	3,696 (90.0)	
Missing	84,595	2,984	
Coronary revascularization			
No	86,162 (29.5)	2,513 (40.9)	<0.001
Yes	206,275 (70.5)	3,632 (59.1)	
Missing	27,024	945	
Left ventricular ejection fraction assessed			
No	176,970 (55.4)	4,014 (56.6)	0.04
Yes	142,491 (44.6)	3,076 (43.4)	
P2Y12			
No	9,530 (4.6)	577 (11.7)	<0.001
Yes	197,392 (95.4)	4,344 (88.3)	
Missing	112,539	2,169	
DAPT received on discharge			
No	84,476 (30.4)	2,010 (32.7)	<0.001
Yes	193,229 (69.6)	4,139 (67.3)	
Missing	41,756	941	
High-intensity statin on discharge			
No	8,939 (3.2)	687 (11.1)	<0.001
Yes	269,277 (96.8)	5,530 (88.9)	
Missing	41,245	873	
ACE inhibitor or ARB on discharge for those with moderate and severe LVSD, %			
No	23,755 (28.9)	1,235 (50.5)	<0.001
Yes	58,375 (71.1)	1,212 (49.5)	
Missing	237,331	4,643	
Beta-blocker on discharge for those with moderate and severe LVSD (%)			
No	27,115 (32.0)	925 (41.6)	<0.001
Yes	57,685 (68.0)	1,296 (58.4)	
Missing	234,661	4,869	
OBQI	92.5 ± 19.8	85.0 ± 25.9	<0.001
Cardiac rehabilitation on discharge			
No	26,654 (9.3)	1,079 (16.9)	<0.001
Yes	260,754 (90.7)	5,296 (83.1)	
Missing	32,053	715	

Values are n (%) or mean ± SD.

ACE = angiotensin-converting enzyme; ARB = angiotensin receptor blocker; DAPT = dual antiplatelet therapy; ESC = European Society of Cardiology; LVSD = left ventricular systolic dysfunction; OBQI = opportunity-based quality indicator; STEMI = ST-segment elevation myocardial infarction.

FIGURE 2 Cumulative and Adjusted Cumulative Incidence for HF Readmission in STEMI Patients



(A) The cumulative incidence of heart failure (HF) readmission in ST-segment elevation myocardial infarction (STEMI) patients. Competing risk regression models were used to calculate the cumulative incidence, considering the competing risk of all-cause death postdischarge. The cancer group exhibited higher readmission rates with HF at 30 days (3.2% vs 2.3%) and 1 year (9.4% vs 7.3%). (B) The adjusted cumulative incidence for HF readmission in STEMI patients. To account for the competing risk of all-cause death postdischarge, we used the competing risk regression models to calculate the cumulative subdistribution HR (sHR). After adjustment for patient characteristics, comorbidities, and quality of care, a cancer diagnosis was not associated with an increased risk of readmission from HF at 30 days (sHR: 1.05; 95% CI: 0.86-1.28) or 1 year (sHR: 1.03; 95% CI: 0.92-1.16).

each has been associated with the development of the other mediated by the combination of cardiotoxicity, neurohormonal activation, and inflammation.[38] Although surveillance for cardiotoxicity is common, cardiac complications, including HF, may still develop and subsequently contribute to hospitalizations. Differences in chemotherapy use or other cancer-specific effects on post-STEMI care, such as the need for cancer-associated blood transfusion or prehydration for chemotherapy, may also explain variations in HF readmission rates among different types of active cancer. Our findings underscore the importance of cardiac, particularly HF, surveillance for post-STEMI patients with cancer, especially among those with high-risk features for HF readmission, such as patients with known systolic dysfunction, diabetes, or PVD or those intolerant of optimal post-STEMI medical care. Additionally, patients with colon cancer and hematologic malignancies may also benefit from extra monitoring for HF readmission post-STEMI because those populations had higher sHRs for readmission with HF. Such monitoring can involve closer echocardiographic[39] or biomarker-based monitoring[40] as well as an enhanced focus on multidisciplinary cardiovascular risk factor modification.[11] Our current results also highlight the need for further studies to identify evidence-based treatment approaches for the care of cancer patients who present with myocardial infarction.

TABLE 4 Risk of HF Readmission by Cancer Type

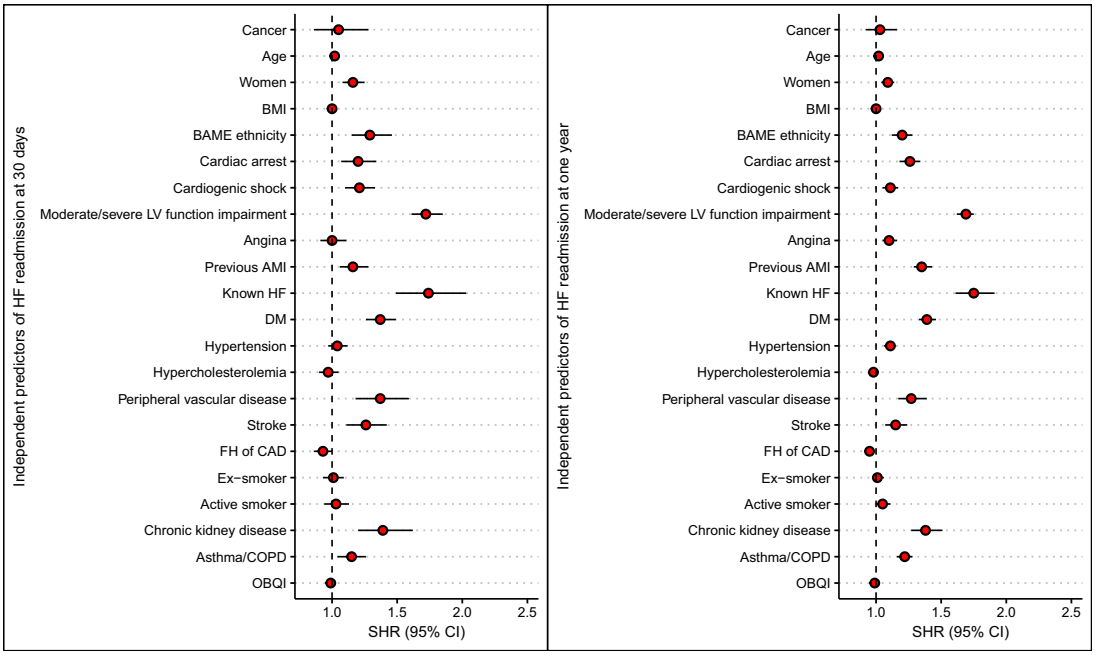
Cancer Type	1-Year HF Readmission[a] Subdistribution HR	95% CI	Comparator Group
Prostate cancer	0.94	0.77-1.16	Patients without prostate cancer
Lung cancer	0.83	0.58-1.19	Patients without lung cancer
Colon cancer	1.42	0.99-2.03	Patients without colon cancer
Hematologic malignancies	1.35	1.05-1.74	Patients without hematologic malignancies
Breast cancer	0.77	0.40-1.47	Patients without breast cancer

[a]Results of multivariable models with consideration of competing risks. The variables adjusted for in the models included age, sex, ethnicity, cardiac arrest, cardiogenic shock, left ventricular ejection fraction, history of angina, previous myocardial infarction, HF, diabetes mellitus, hypertension, hypercholesterolemia, peripheral vascular disease, stroke, family history of CAD, smoking, chronic kidney disease, asthma or chronic obstructive pulmonary disease, percutaneous coronary intervention, previous coronary artery bypass graft, and composite quality indicator.

HF = heart failure.

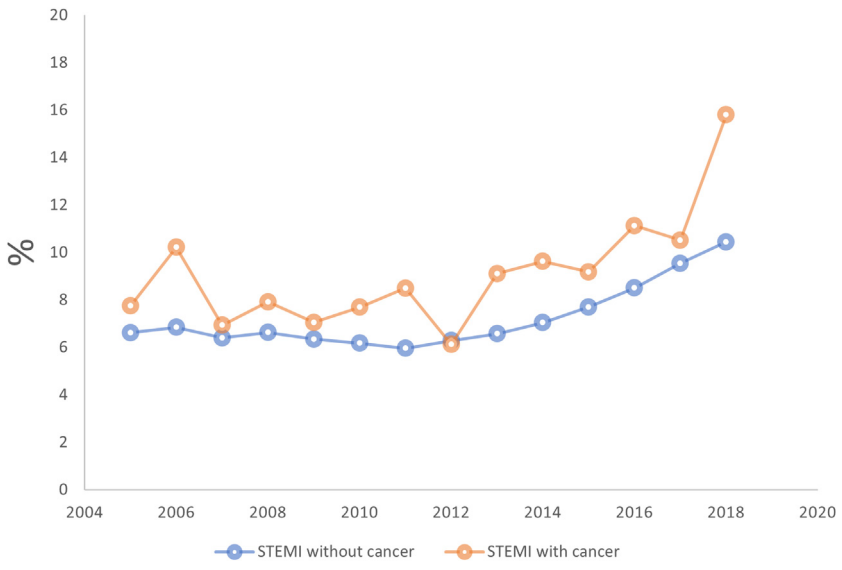
STUDY LIMITATIONS. Diagnoses for active cancer and STEMI were based on coded diagnoses, and

FIGURE 3 **Independent Predictors of HF Readmission**



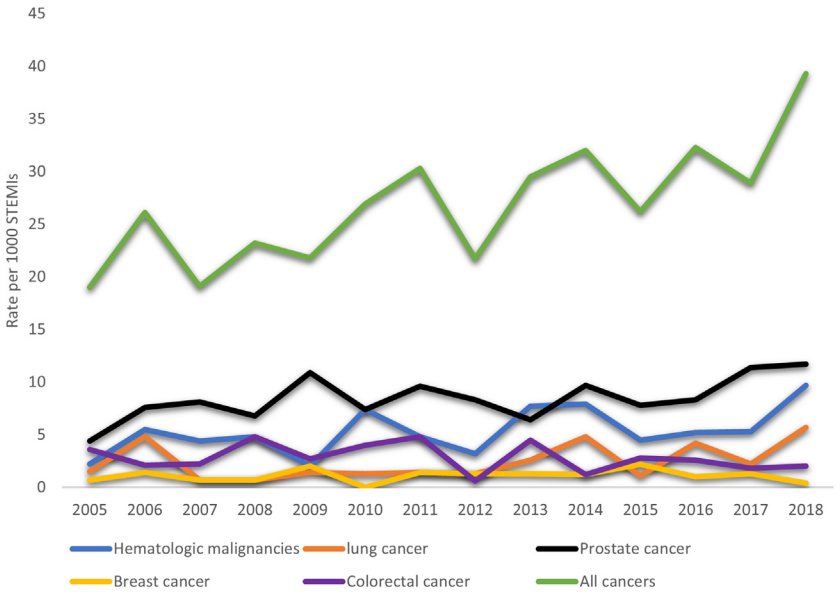
This figure shows the independent predictors of HF readmission at 30 days and 1 year, respectively. The key factors associated with HF readmission at 1 year were age (sHR: 1.02; 95% CI: 1.02-1.02), female (sHR: 1.09; 95% CI: 1.4-1.14), Black, Asian, or minority ethnicity ethnicity (sHR: 1.2; 95% CI: 1.12-1.28), diabetes mellitus (sHR: 1.39; 95% CI: 1.33-1.46), hypertension (sHR: 1.10; 95% CI: 1.06-1.15), peripheral vascular disease (sHR: 1.28; 95% CI: 1.17-1.39), stroke (sHR: 1.15; 95% CI: 1.07-1.24), chronic kidney disease (sHR: 1.38; 95% CI: 1.27-1.51), obstructive lung disease (sHR 1.22; 95% CI: 1.16-1.28), and moderate to severe left ventricular impairment at discharge (sHR: 1.69; 95% CI: 1.62-1.75). The composite care quality index demonstrated an inverse association with HF readmission, particularly at 30 days (sHR: 0.99; 95% CI: 0.99-0.99). Abbreviations as in Figure 2.

FIGURE 4 **The Unadjusted Crude Annual Incidence of 1-Year HF Readmission**



HF readmissions at 1 year in STEMI patients with cancer increased from 7.7% in 2005 to 15.8% in 2018. Similarly, 1-year HF readmissions in STEMI patients without cancer increased from 6.6% in 2005 to 11.3% in 2018. Abbreviations as in Figure 2.

FIGURE 5 Crude Rate of 1-Year Readmission With HF Based on Cancer Type



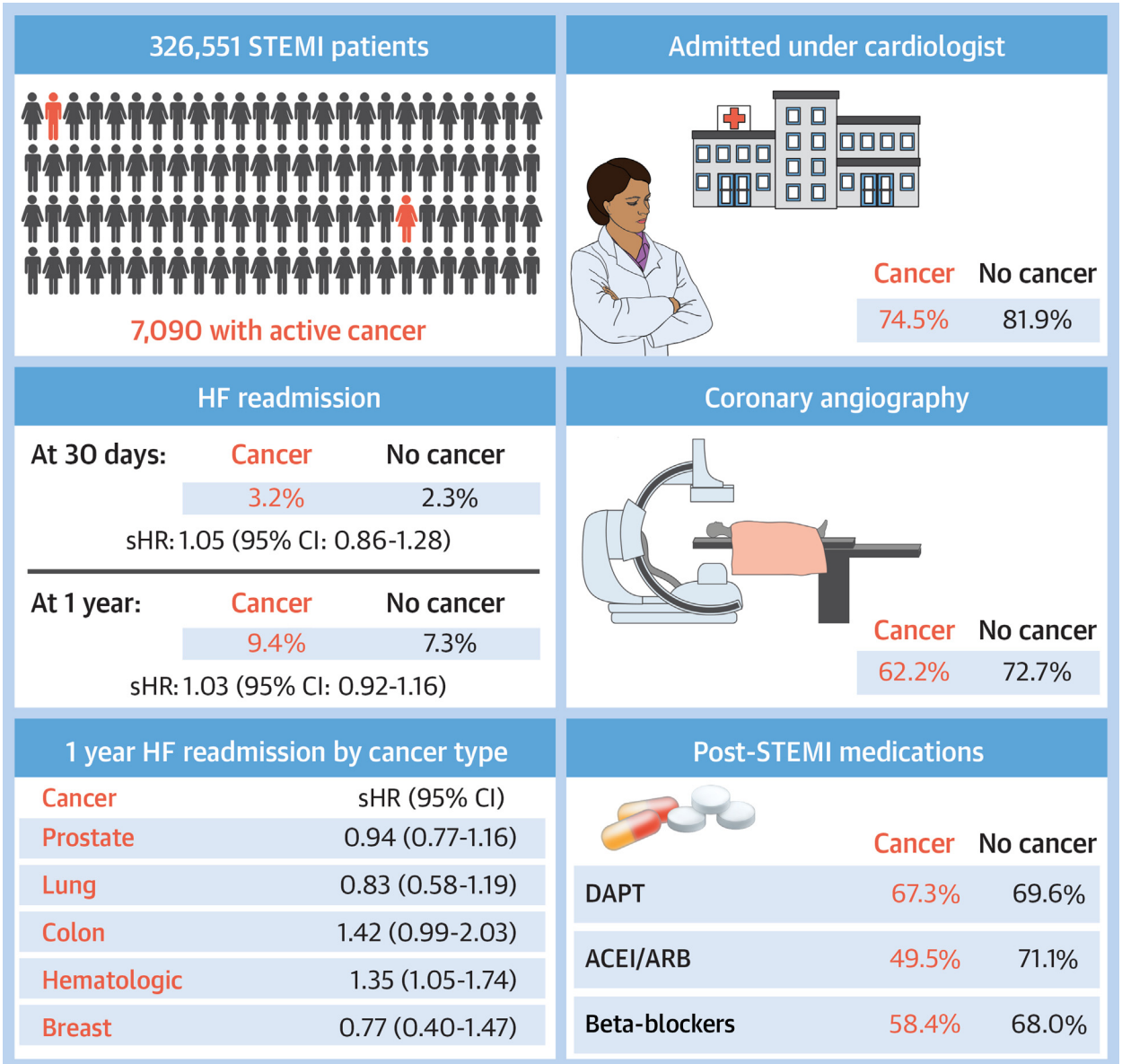
This figure shows temporal trends in the 1-year readmission rates with HF in STEMI patients categorized by the most common cancers in the United Kingdom, including prostate cancer, breast cancer, lung cancer, colon cancer, and hematologic malignancies.[35] The observed trends are primarily driven by increased HF readmissions in patients with prostate cancer (4.4 to 11.7 readmissions), hematologic malignancies (2.2 to 9.7 readmissions), and lung cancer (1.5 to 5.7 readmissions). Abbreviations as in Figure 2.

cancer chronicity, stage, and current or former cancer treatment could not be determined in our cohort. Although the current analysis presents sHRs, which consider competing risk for cancer mortality, medical decision making may depend on factors such as patient prognosis, life expectancy, and patient preferences (including hospice consideration), which are not well accounted for. HF readmission classification was based on coding, and accurate diagnosis of acute HF in patients with high comorbidity burden may be challenging. The diagnosis of HF may have changed over the study period (eg, with greater use of natriuretic peptides), which may affect the comparison in HF readmission rates over time. The prevalence of systolic dysfunction at the time of the STEMI presentation was known, but subsequent trends in ejection fraction and whether subsequent readmissions occurred in the setting of systolic dysfunction or preserved systolic function cannot be determined. Contraindications or medication side effects may limit the prescription of medications included in the OBQI, particularly in patients with significant comorbidities such as chronic kidney disease.

CONCLUSIONS

We demonstrate that patients with active cancer who present with STEMI undergo less invasive management and lower rates of medication optimization compared with patients without cancer. Cancer patients with STEMI had higher absolute rates of hospitalization for HF compared with STEMI patients without cancer, a finding attenuated in multivariable analyses. Nevertheless, lower-quality care was associated with higher HF readmissions irrespective of a cancer diagnosis, suggesting that select patients with cancer who present with STEMI should be considered for evaluation and management similar to the remaining population. Additional studies are needed to address important gaps in evidence-based care for the expanding

CENTRAL ILLUSTRATION **Heart Failure Readmission in ST-Segment Elevation Myocardial Infarction Patients With Active Cancer**



Dafaalla M, et al. J Am Coll Cardiol CardioOnc. 2024;■(■):■-■.

This illustration highlights significant gaps in evidence-based care for the expanding group of patients diagnosed with cancer who present with ST-segment elevation myocardial infarction (STEMI). ACEI = angiotensin-converting enzyme inhibitor; ART = angiotensin receptor blocker; DAPT = dual antiplatelet therapy; HF = heart failure; sHR = subdistribution HR.

group of patients with a cancer diagnosis who present with AMI.

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PERSPECTIVES

COMPETENCY IN MEDICAL KNOWLEDGE: STEMI patients with cancer were less likely to undergo invasive evaluation and revascularization and less likely to be discharged on guideline medical therapy. Lower-quality care was associated with higher HF readmissions irrespective of cancer. Select cancer patients presenting with STEMI should be considered for management similarly to the noncancer population.

TRANSLATIONAL OUTLOOK: Further studies are needed to address important gaps in evidence-based care for the growing group of patients with a cancer diagnosis who present with AMI.

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KEY WORDS **cancer, heart failure readmission, ST-segment elevation myocardial infarction**

APPENDIX **For supplemental tables and figures, please see the online version of this paper.**