Hospital readmission after heart valve surgery in the United Kingdom

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ABSTRACT

Objective: To evaluate hospital readmission rates in the United Kingdom within the first 12 months following heart valve surgery.

Methods: All patients who underwent heart valve surgery between January 2013 and April 2023 were included in the study. Readmission to any National Health Service hospital within 12 months after discharge was captured. Trends in readmission, primary and secondary diagnoses, and related procedures were evaluated.

Results: A total of 44,467 patients (median age, 69.3 years; 61% male) were included, of whom 44.6%, 23.15%, and 11.95% experienced 1, 2, and 3 readmissions, respectively, within 12 months of discharge following the index procedure. The overall 30-day and 12-month readmission rates were 12.9% and 44.6%, respectively, with a total of 42,151 readmissions. The median time from discharge to readmission was 61 days (interquartile range, 14-168 days). The overall 12-month readmission rate remained consistently above 40% throughout the study period, with a slight drop in 2020 during the COVID-19 pandemic. Cardiovascular-related readmissions accounted for 10,318 (24.5%) of the total readmissions. Arrhythmia was the most common primary diagnosis (37.6%; atrial fibrillation/flutter in 82.4% of the cases), followed by heart failure (16.1%) and valve-related dysfunction (15.2%). Surgical valve procedure-related readmissions accounted for 24.9% of the total, with chest pain of noncardiac origin (41.0%), respiratory tract infections (16.0%), and pleural effusions (10.0%).

Conclusions: Nearly one-half of the patients required at least 1 readmission within 12 months of heart valve surgery, placing significant strain on the healthcare system. Cardiovascular- and procedure-related causes accounted for one-half of all readmissions. (JTCVS Open 2025;24:239-55)
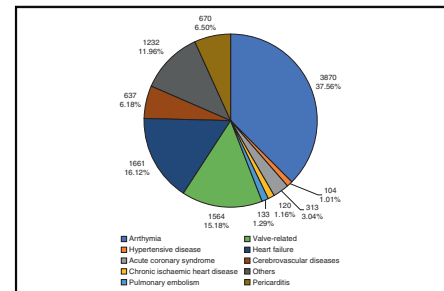
Primary cardiovascular-related readmissions.

CENTRAL MESSAGE

Nearly one-half of heart valve surgery recipients in the United Kingdom require at least 1 hospital readmission within 12 months of their operation.

PERSPECTIVE

Unplanned emergency admissions following cardiac surgery are associated with significant morbidity and place a high burden on the healthcare system. We highlight the need for better out-of-hospital monitoring and care to improve patient outcomes as well as to alleviate financial burdens on the healthcare system.

Hospital readmission after cardiac surgery is associated with increased morbidity and mortality and a huge burden on the healthcare system.[1] The 30-day unplanned readmission rate is now one of the quality metrics monitored closely across all specialties, including cardiothoracic surgery, in the United Kingdom. The reported readmission rate worldwide, mostly from the United States, is between 10% and 20% within 30 days of discharge.[2] Little data are available in the literature from Europe, where a universal healthcare model is commonly adopted.

During the study period (2013-2023), the Coronavirus disease 2019 (COVID-19) pandemic was declared in March

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Abbreviations and Acronyms

CABG	= coronary artery bypass grafting
CI	= confidence interval
COVID-19	= Coronavirus disease 2019
HES	= Hospital Episode Statistics
ICD-10	= International Classification of Diseases, Tenth Revision
IQR	= interquartile range
NHS	= National Health Service
SHR	= subdistribution hazard ratio
TAVI	= transcatheter aortic valve intervention

2020, with a significant impact on cardiac surgical and healthcare practice, and cardiac surgical volume has yet to return to the prepandemic level in the United Kingdom.[3] We aimed to report the trends in, short-term clinical outcomes of, and predictors of 12-month hospital readmission after heart valve surgery performed between January 2013 and April 2023 in the United Kingdom.

METHODS

Data were accessed in the National Health Service (NHS) Secure Data Environment service for England via the BHF Data Science Centre's CVD-COVID-UK/COVID-IMPACT Consortium. All patients who underwent first-time heart valve surgery between January 2013 and April 2023 were identified from the UK National Adult Cardiac Surgery database. This was linked with the NHS Hospital Episode Statistics (HES) (up to August 2023) and the death registry from the Office for National Statistics to identify any readmission and date of death via anonymized patient IDs generated from NHS numbers. Readmission was defined as an admission following discharge after heart valve surgery to any NHS hospital captured by the HES dataset. All readmissions within 12 months after discharge from the index operation were included. Patients who underwent any concomitant procedures (ie, coronary artery bypass grafting [CABG] and/or major aortic operation) and had previous cardiac surgery were excluded. Furthermore, patients who died before discharge from the hospital (n = 1355) and those with an unknown date of death (n = 28) were excluded from the follow-up study. Figure E1 provides a patient flow diagram.

The patients were divided into 2 groups, those with 1 or more readmissions and those with no readmissions after discharge from the index valve operation. Perioperative characteristics, risk factors predicting readmission, and 12-month survival, were compared between the 2 groups. The 12-month readmission rate during several phases of COVID-19 lockdown/relaxation as defined by the UK government also was evaluated.

Each readmission had a primary diagnosis and up to 19 secondary diagnoses. The primary and secondary diagnoses were reported using the International Classification of Diseases, 10th Revision (ICD-10), fifth edition.[4] The primary and secondary diagnoses related to postsurgical valve intervention were classified into cardiovascular causes (Chapter IX, Diseases of the circulatory system) and surgical valve procedure–related causes (Chapter X, Diseases of the respiratory system; Chapter XVIII, Symptoms, signs, and abnormal clinical and laboratory findings not elsewhere classified; and Chapter XIX, Injury, poisoning, and certain other consequences of external causes) based on the ICD-10 chapters listed above. In addition, the top 20 primary diagnoses of noncardiovascular, non–procedure-related readmissions were examined as well. The ICD-10 codes used in this study are included in Tables E1, E2, and E3.

Ethical Statement

The North East-Newcastle and North Tyneside Research Ethics Committee provided ethical approval for the CVD-COVID-UK/COVID-IMPACT research program (REC 20/NE/0161; approved May 27, 2020) to access, within secure trusted research environments, unconsented whole-population deidentified data from electronic health records collected as part of patients' routine healthcare. The need for individual patient consent was waived. The deidentified data used in this study were made available to accredited researchers only.

Statistical Analysis

Continuous variables are reported as mean ± SD or median and interquartile range (IQR), pending the normality of the data. Categorical variables are reported as frequency and percentage. The normality of the distribution of continuous data was assessed using the Shapiro-Wilk test.

The Pearson χ^2 test and Wilcoxon rank-sum test were used for comparisons of 2 categorical variables and comparisons of 2 means of continuous independent samples, respectively. We calculated the cumulative incidence of readmission at 1, 3, 6, and 12 months using Fine-Gray subdistribution hazard models accounting for the competing risk of death. To investigate factors associated with 12-month readmission, we performed a competing risk regression analysis using the Fine-Gray subdistribution hazard models with mortality as a competing event during the 12-month follow-up. Several articles have previously described the method in detail.[5-7]

Data completeness was satisfactory, with only 1% to 3% of missing data in each factor input into the model. Missing data were replaced using median and mode imputation, with mode for categorical variables and median for continuous variables. The trend in readmission by year was evaluated using the Cochran-Armitage test for trend. A *P* value < .05 was deemed statistically significant. This analysis was performed according to a prespecified analysis plan published on GitHub, along with the phenotyping and analysis code (https://github.com/BHFDSC/CCU007_11). R version 4.2.3 (R Foundation for Statistical Computing) and RStudio version 1.4.1103 (RStudio) were used for statistical analysis. Graphs and tables were created using R version 4.2.3 and Microsoft Office 365 version 16.0.14026).

RESULTS

A total of 44,467 patients were included in our analysis. The median patient age was 69.3 years (IQR, 59.6-75.9 years), and cohort was 61.0% male. Patient characteristics are summarized in Table E4. Preoperative atrial fibrillation was noted in 5842 patients (13.1%).

Eighty-nine percent of the cohort underwent a single-valve intervention, and 10% had a double-valve operation. Of those who underwent a single-valve operation, 26,441 (72.0%) had an aortic valve operation, 9921 (27.0%) had a mitral valve repair/replacement, and 1.0% had a tricuspid or pulmonary valve repair/replacement. The majority of operations (88%) were performed via median sternotomy. Overall, 30-day mortality was 2.6% (n = 1188, including in-hospital mortality), 4.3% of patients were returned to the operating theater, 1.8% had a neurologic event, and 1.9% required dialysis postoperatively (Table 1). There were no major differences in hospital clinical outcomes between patients who underwent surgery before the COVID-19 pandemic and those operated on after the pandemic (Table E5).

TABLE 1. Perioperative characteristics of the whole cohort and in patients with and without readmission and no readmission at 12 mo after heart valve surgery in the United Kingdom

Characteristic	Overall (N = 44,467)	No readmission (N = 24,844)	Readmission (N = 19,623)	P value
CPB time, min, median (IQR)	96 (76-124)	96 (76-122)	97 (76-126)	<.001
Cross-clamp time, min, median (IQR)	71 (56-92)	71 (57-91)	72 (56-93)	.21
Number of valves repaired/replaced, n (%)				<.001
1	36,713 (89)	20,849 (90)	15,864 (87)	
2	4197 (10)	2116 (9.1)	2081 (11)	
3	453 (1.1)	201 (0.9)	252 (1.4)	
4	5 (<0.1)	1 (<0.1)	4 (<0.1)	
Incision, n (%)				.40
Median sternotomy	24,936 (88)	14,312 (87)	10,624 (88)	
Hemi-sternotomy	1863 (6.3)	1081 (6.6)	782 (6.52)	
Mini thoracotomy	1487 (5.2)	886 (5.4)	601 (5.0)	
Other	135 (0.5)	78 (0.5)	57 (0.5)	
Return to theatre, n (%)	1831 (4.3)	928 (3.9)	903 (4.9)	.94
Neurologic events, n (%)				.017
Transient ischemic attack	327 (0.8)	161 (0.7)	166 (0.9)	
Cerebrovascular accident	431 (1.0)	225 (1.0)	206 (1.1)	
Dialysis postoperatively	823 (1.9)	332 (1.4)	491 (2.6)	<.001
Deep sternal wound infection, n (%)	138 (0.4)	62 (0.3)	76 (0.5)	.008

CPB, Cardiopulmonary bypass; *IQR*, interquartile range.

The cumulative incidence of readmission was 12.9% (95% confidence interval [CI], 12.6%-13.2%) at 1 month, 24.3% (95% CI, 23.9%-24.7%) at 3 months, 33.43% (95% CI, 33.0%-33.9%) at 6 months, and 44.6% (95% CI, 44.2%-45.1%) at 12 months (Figure 1). Forty-four percent of patients had 1 readmission, 21.9% had 2 readmissions, and 11.3% had 3 readmissions, resulting in a total of 42,151 readmissions. The median time from discharge to readmission was 61 days (IQR, 14-168 days). The overall readmission rate was consistently above 40%, ranging from 41.2% to 47.4% during the study period (2023 readmission rate included up to the third quarter only) (Figure 2). When specifically looking at the 12-month readmission rate during the COVID-19 pandemic, the rate remained consistently above 40% (range, 40.4%-46.9%) (Figure E2).

Primary and Secondary Cardiovascular- and Valve Surgery Procedure–Related Diagnoses

Cardiovascular-related readmissions accounted for 10,304 (24.5%) of the total readmissions, of which the most common primary diagnosis was arrhythmia (n = 3870; 37.6%), with atrial fibrillation/flutter accounting for 82.4%. This was followed by heart failure (n = 1661; 16.12%) and valve-related dysfunction (n = 1564; 15.2%), including residual regurgitation/stenosis, endocarditis, thrombosis, and mechanical complications (Figure 3).
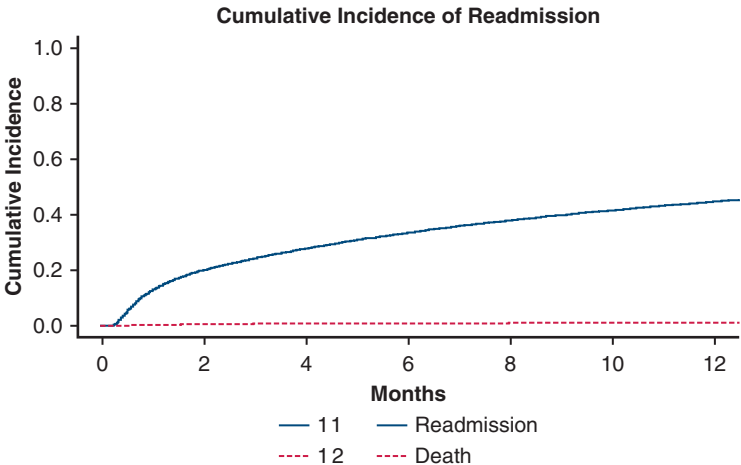

FIGURE 1. Cumulative incidence of readmission (n = 11) competing with death (n = 12).
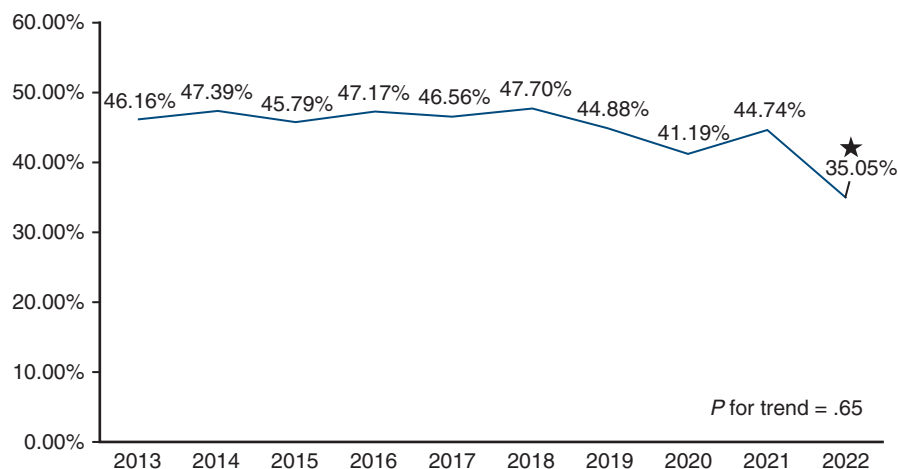
FIGURE 2. Twelve-month readmission rates in patients who underwent heart valve surgery between 2013 and 2022 (up to the third quarter) in the United Kingdom. *x*-axis, year; *y*-axis, readmission rate.

The primary diagnosis related to the surgical valve procedure (but not cardiovascular-related) accounted for 24.99% of the total readmissions, with wound pain of noncardiac origin accounting for 41.0%, respiratory tract infection for 16.0%, and pleural effusion for 10.0% (Figure 4). The most common secondary cardiovascular-related diagnosis of all readmissions was hypertensive disease (n = 23,506), followed by arrhythmia (n = 22,418) and valve-related dysfunction (n = 11,915) (Figure E3,

Table E2). The remaining primary readmissions (not cardiovascular- or surgical valve procedure–related) accounted for one-half of all readmissions and were for a variety of causes, the most common of which are reported in Table E3.

Predictors of Readmission

Several predictors were associated with 12-month readmission. Perioperative characteristics, including (but not limited to) age (subdistribution hazard ratio [SHR], 1.01; 95% CI, 1.01-1.01; $P < .001$), urgent (SHR, 1.10; 95% CI, 1.07-1.14; $P < .001$) and emergency (SHR, 1.24; 95% CI, 1.12-1.36; $P < .001$) operations, diabetes requiring medication (SHR, 1.06; 95% CI, 1.02-1.11; $P = .008$), hypertension (SHR, 1.06; 95% CI, 1.03-1.09; $P < .001$), and pulmonary disease (SHR, 1.07; 95% CI, 1.03-1.11; $P < .001$) were significant independent predictors of readmission (Table 2).

DISCUSSION

Our study demonstrates a high level of hospital readmission rate in the first 12 months after patients underwent heart valve surgery in the United Kingdom. The most common cardiovascular cause of readmission was arrhythmia, followed by heart failure and valve-related dysfunction. Furthermore, there was a similar percentage of surgical valve procedure–related readmissions, the most common of which were wound pain of noncardiac origin, respiratory tract infection, and pleural effusion. In addition, patients with a higher comorbidity profile and nonelective surgery were more likely to have an unplanned readmission. COVID-19 did not seem to have an impact on the trend and short-term clinical outcomes.

The 30-day readmission rate reported in the literature is approximately 7% to 23%.[2,8-11] Most studies were conducted in the Unted States, where the main health care
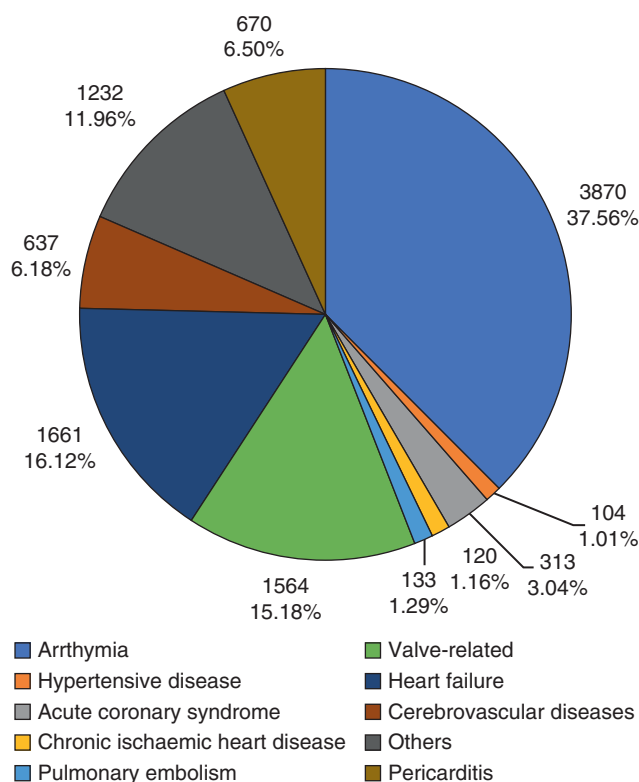

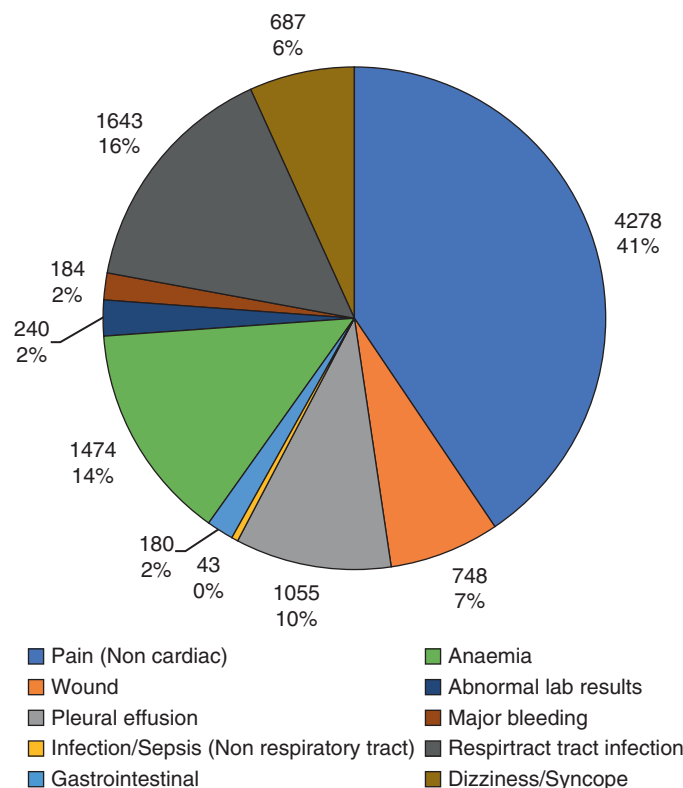**FIGURE 3.** Primary cardiovascular-related readmissions.

FIGURE 4. Primary surgical valve procedure–related readmissions.

is primarily provided by the private sector. This is unlike Canada, Australia, and the United Kingdom, where healthcare is provided mostly through a government-funded system. A systematic review by Shawon and colleagues[2] found that the 30-day readmission rate after isolated CABG is higher in studies conducted in the United States compared to the rest of the world (13.6% vs 10.5%). Another study by Iribarne and colleagues[12] showed a readmission rate of 18.3% at 30 days after isolated valve surgery in 10 North American centers, similar to the rate observed in our study (12.92%). This might be explained by the fact that our study was conducted using administrative data, and the higher readmission rate is related, at least in part, to better capturing of readmissions.[2]

Although data on readmissions following valve surgery in the United Kingdom are scant, several studies have reported readmission rates after CABG. Blackledge and colleagues[13] reported adjusted 30-day and 12-month readmission rates of 11.6% and 26.1%, respectively, from 1995 to 2004. Although the 30-day readmission rate in our study was similar, the 12-month readmission rate was nearly twice as high. This likely can be explained by the worse risk profile of patients undergoing cardiac surgery over the last 2 decades.[14-16] Narain and colleagues[17] examined their single-unit results from 2012 to 2017 and reported

a 30-day readmission rate of 11.9%, although this could be underestimated, as patients readmitted to other institutions were not captured. Other European studies included a single-center study in Denmark revealing an 18.85% 30-day readmission rate. Similar results were reported (an 18.3% 30-day readmission rate) in a Turkish cardiovascular center.[18,19] The higher readmission rates seen in our study compared to other European studies potentially could be related to a lack of rehabilitation facilities in the United Kingdom, which are common in Europe. The increased complexity of secondary care practice, which has been under considerable pressure over the last 2 decades, also could have contributed to the exponential rise in readmission rate. A lower threshold for operating on elderly patients, with their greater predisposition to develop arrhythmias after valve procedures, might have influenced the higher readmission rates.[20]

The most common primary cardiovascular cause of readmission in our study was arrhythmias, which accounted for approximately 9.2% of all readmissions. In addition, 53.2% of readmissions were also diagnosed with arrhythmias as a secondary cause. The principal cause of arrhythmias was atrial fibrillation/flutter (82.4%); thus, it may be argued that this secondary cause of readmission could have been the main reason for the development of heart

TABLE 2. Competing risk regression models for readmission after heart valve surgery in the United Kingdom

Covariate	SHR (95% CI)	P value
Age	1.01 (1.01-1.01)	<.001
Sex		
Male		
Female	1.00 (0.98-1.03)	.35
Body mass index	1.00 (1.00-1.00)	.84
Operative urgency		
Elective		
Urgent	1.10 (1.07-1.14)	<.001
Emergency	1.24 (1.12-1.36)	<.001
Salvage	1.13 (0.85-1.36)	.40
CCS angina grade		
0		
1	1.03 (0.99-1.08)	.14
2	1.04 (1.00-1.08)	.016
3	1.06 (1.00-1.12)	.034
4	1.20 (1.08-1.33)	<.001
NYHA status		
1		
2	1.05 (0.99-1.10)	.066
3	1.08 (1.04-1.14)	<.001
4	1.05 (0.99-1.12)	.14
Diabetes		
Nondiabetic		
Diet control	1.04 (0.97-1.12)	.29
Medication	1.06 (1.02-1.11)	.008
Insulin use	1.08 (0.99-1.17)	.052
Left ventricular function		
Good (>50%)		
Moderate (31%-49%)	0.97 (0.94-1.01)	.10
Poor (21%-30%)	0.89 (0.82-0.96)	.003
Very poor (≤20%)	0.99 (0.83-1.19)	.92
Peripheral vascular disease	0.95 (0.89-1.02)	.16
Hypertension	1.06 (1.03-1.09)	<.001
Preoperative neurologic dysfunction	1.00 (0.94-1.07)	.96
History of pulmonary disease	1.07 (1.03-1.11)	<.001
Smoking		
Nonsmoker		
Ex-smoker	0.98 (0.95-1.01)	.13
Current smoker	0.96 (0.91-1.01)	.10
Interval between MI and surgery		
No previous MI		
MI < 6 h	0.52 (0.15-1.81)	.30
MI 6-24 h	1.14 (0.71-1.82)	.58
MI 1-30 d	0.86 (0.76-0.98)	.019
MI 31-90 d	1.00 (0.80-1.25)	.99
MI > 90 d	0.97 (0.90-1.04)	.39
Preoperative dialysis	0.98 (0.89-1.07)	.61
Preoperative cardiogenic shock	1.00 (0.88-1.14)	.99
Postoperative dialysis/hemofiltration	1.41 (1.15-1.74)	

(Continued)

TABLE 2. Continued

Covariate	SHR (95% CI)	P value
Postoperative neurologic dysfunction		
TIA	1.07 (0.93-1.24)	.32
Stroke	1.02 (0.90-1.16)	.72
Deep sternal wound infection (in hospital)	1.00 (0.79-1.27)	1.00
CPB time	1.00 (1.00-1.00)	.14
Cross-clamp time	1.00 (1.00-1.00)	.16
Number of valves repaired/replaced		
1		
2	0.83 (0.66-1.05)	.46
3	0.92 (0.72-1.16)	.55
4	0.92 (0.72-1.12)	.75
Surgical incision		
Median sternotomy		
Hemi-sternotomy	1.15 (1.08-1.22)	<.001
Mini thoracotomy	1.15 (1.08-1.23)	<.001
Other	1.07 (0.86-1.33)	.54
Return to operating theater	0.98 (0.92-1.05)	.55

SHR, Subdistribution hazard ratio; *CI,* confidence interval; *CCS,* Canadian Cardiovascular Society; *NYHA,* New York Heart Association; *MI,* myocardial infarction; *TIA,* transient ischemic attack; *CPB,* cardiopulmonary bypass.

failure. Atrial fibrillation can occur in up to 40% of patients following heart surgery, and many individuals who are discharged may remain in atrial fibrillation/flutter or may have a recurrence after being converted to normal sinus rhythm before discharge.[21]

The rapid expansion of transcatheter aortic valve intervention (TAVI) has provided an alternative to treatment for aortic valve disease. Several clinical trials, including NOTION 2, PARTNER 3, and Evolute low-risk trials, have included hospitalization as the endpoint of the trials.[22-24] This likely is related to the idea that an invasive technique (ie, surgery) would lead to a higher rate of readmission. However, the rate of rehospitalization for heart failure/valve-related causes was similar between TAVI and surgical aortic valve replacement in the lower-risk cohort in the NOTION 2 trial (12-month valve-related rehospitalization, 3.7% vs 4.9%; $P = .6$) and Partner 3 trial (5-year valve-related rehospitalization, 13.7% vs 17.4%; $P > .05$). Results from these trials demonstrate a burden of readmission regardless of technique.

The Getting It Right First Time (GIRFT) program, a national program to improve the treatment and care of patients, first raised the issue of readmissions in both cardiac and thoracic surgery in the United Kingdom.[25] The rates of readmission (to any hospital) within 30 days following discharge ranged from 12.5% to 17.9%. Thus, if all units improved to match the average (15.1%) or current best quartile (14.1%), potential savings of £515,000 and £935,000 (excluding costs for investigations and

procedures), respectively, could have been realized. Following this report, emergency readmission within 30 days of discharge after a cardiac surgical procedure has become an outcome measure and is being monitored/audited by NHS England. However, like many other recommendations, the COVID-19 pandemic disrupted the plans for cardiothoracic units to address these quality metrics.

In the United Kingdom, the standard follow-up appointment with the surgical team after cardiac surgery is at 6 weeks after hospital discharge. However, it is not unusual for these appointments to be postponed by up to 3 months because of staffing and resource shortages. Our findings suggest that this standard practice may need to be reconsidered, given readmission rates of 12.9% by 30 days and 24.3% by 90 days postdischarge. It can be argued that some of these readmissions might have been preventable had patients been seen earlier, perhaps between 2 and 4 weeks after discharge. Furthermore, pressure on bed availability in the NHS also leads to discharging patients sooner, and it is likely that such complications as fluid overload, infections in the early stages, mild pleural and pericardial effusions, and arrhythmias like atrial fibrillation may be missed. Once discharged, patients typically turn to their general practitioners for assistance or advice, a service that has faced significant stress over the last decade, exacerbated by the COVID-19 pandemic. Unlike in many European countries, in the United Kingdom most convalescence units have long since closed. As a result, patients often arrive at emergency services too late, and issues that could have been addressed earlier result in hospital admission.

Our study has several limitations. We did not consider various factors, such as ethnicity, socioeconomic status, or variables like frailty and preoperative liver disease. Although a primary diagnosis is used for coding, patients may be admitted with multiple concurrent diagnoses; for example, heart failure, pleural effusion, and pericardial effusion as a result of arrhythmias. Additionally, patients who sought care in primary or secondary settings but were not admitted (eg, those discharged by emergency department physicians) were not included in the study, potentially omitting a significant number of patients with minor conditions. However, that group did not contribute to readmissions, which was the primary focus of our research.

We also did not consider the availability of local postoperative care services, such as wound clinics or ambulatory rapid access clinics, which may influence readmission rates. The HES dataset is primarily administrative in nature and is not designed for clinical or research purposes; its main role is to support hospital reimbursement for services provided. Nonetheless, use of the HES dataset in research has become increasingly prevalent owing to its ability to track individuals across all NHS hospitals over an extended period.

CONCLUSIONS

In the first 12 months following heart valve surgery, nearly 1 in 2 patients required at least 1 hospital readmission in the UK. Of these, one-half were cardiovascular or procedure-related readmissions. This trend places considerable strain on an already overstretched healthcare system. The costs associated with hospital readmissions are substantial, and investing in strategies that reduce readmissions, such as enhanced postoperative care and closer out-of-hospital monitoring, could lead to improved patient outcomes and contribute to a more sustainable healthcare model.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, the authors used ChatGPT to identify grammatical mistakes. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Data Availability

The data used in this study are available in NHS England's Secure Data Environment (SDE) service for England, but as restrictions apply they are not publicly available (https://digital.nhs.uk/services/secure-data-environment-service). The CVD-COVID-UK/COVID-IMPACT program, led by the BHF Data Science Centre (https://bhfdatasciencecentre.org/), received approval to access data in NHS England's SDE service for England from the Independent Group Advising on the Release of Data (IGARD) (https://digital.nhs.uk/about-nhs-digital/corporate-information-and-documents/independent-group-advising-on-the-release-of-data) via an application made in the Data Access Request Service (DARS) online system (DARS-NIC-381078-Y9C5K). The CVD-COVID-UK/COVID-IMPACT Approvals & Oversight Board (https://bhfdatasciencecentre.org/areas/cvd-covid-uk-covid-impact/) subsequently approved this project to access the data within NHS England's SDE service for England.

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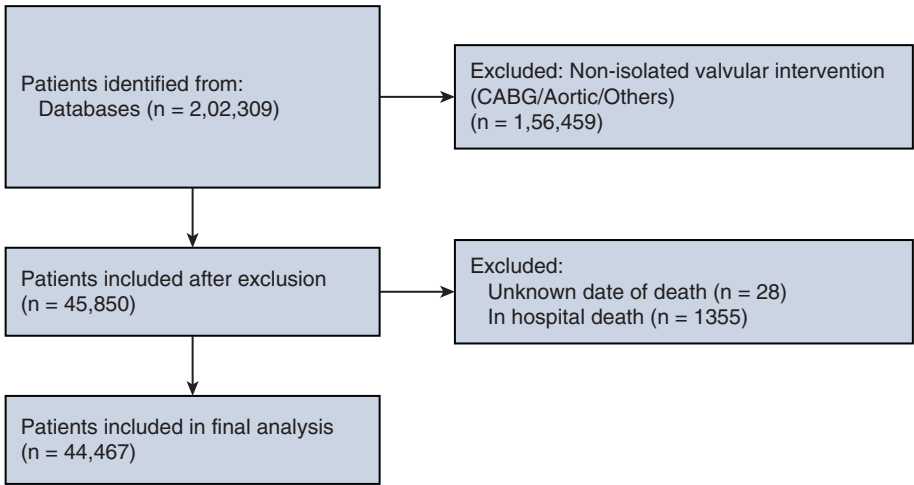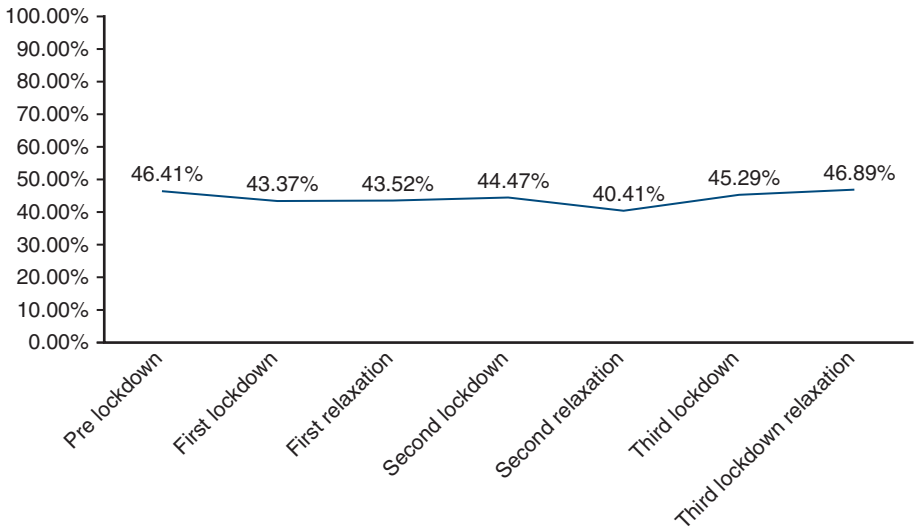
FIGURE E1. Patient flow diagram for the study.

FIGURE E2. Readmission rate during several phases of the COVID-19 pandemic lockdown in the United Kingdom.
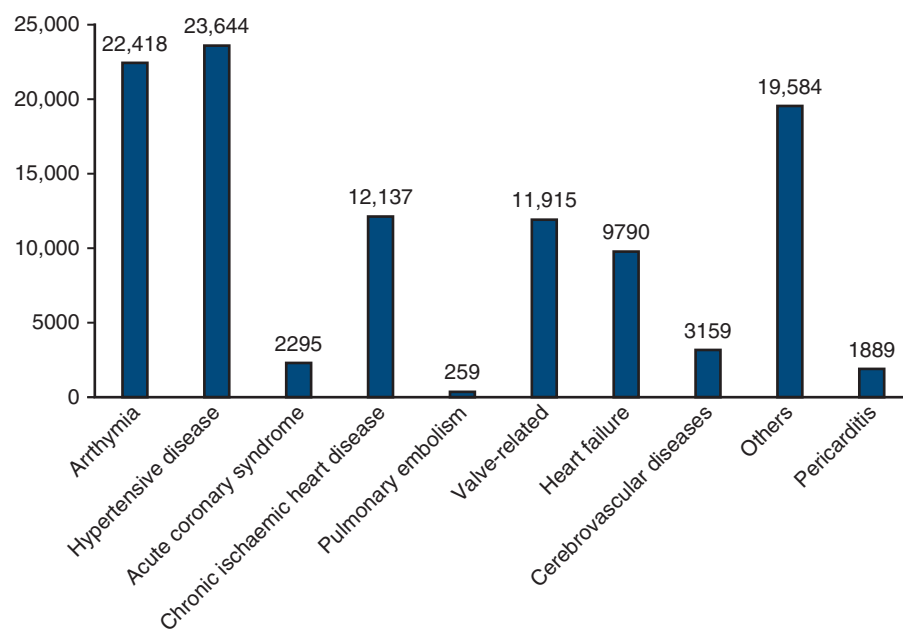
FIGURE E3. Cardiovascular-related secondary diagnoses.

TABLE E1. ICD-10 codes for cardiovascular-related and surgical valve procedure–related primary diagnoses

ICD-10 code	Disease	Cardiovascular/ noncardiovascular	Subclassification	Total number
I10-I15: Hypertensive disease				
I10	Essential (primary) hypertension	Cardiovascular	Hypertensive disease	95
I11	Hypertensive heart disease	Cardiovascular	Hypertensive disease	0
I12	Hypertensive renal disease	Cardiovascular	Hypertensive disease	1
I13	Hypertensive heart and renal disease	Cardiovascular	Hypertensive disease	8
I15	Secondary hypertension	Cardiovascular	Hypertensive disease	0
I20-I25: Ischemic heart disease				
I20	Angina pectoris	Cardiovascular	Ischemic heart disease	93
I21	Acute myocardial infarction	Cardiovascular	Ischemic heart disease	122
I22	Subsequent myocardial infarction	Cardiovascular	Ischemic heart disease	2
I23	Certain current complications following acute myocardial infarction	Cardiovascular	Ischemic heart disease	1
I24	Other acute ischemic heart diseases	Cardiovascular	Ischemic heart disease	95
I25	Chronic ischemic heart disease	Cardiovascular	Others	120
I26-I28: Pulmonary heart disease and diseases of pulmonary circulation				
I26	Pulmonary embolism	Cardiovascular	Pulmonary embolism	133
I27	Other pulmonary heart diseases	Cardiovascular	Others	31
I28	Other diseases of pulmonary vessels	Cardiovascular	Others	0
I30-I52: Other forms of heart disease				
I30	Acute pericarditis	Cardiovascular	Pericarditis	37
I31	Other diseases of pericardium	Cardiovascular	Pericarditis	633
I32	Pericarditis in diseases classified elsewhere	Cardiovascular	Pericarditis	0
I33	Acute and subacute endocarditis	Cardiovascular	Valve-related disorders	1020
I34	Nonrheumatic mitral valve disorders	Cardiovascular	Valve-related disorders	214
I35	Nonrheumatic aortic valve disorders	Cardiovascular	Valve-related disorders	231
I36	Nonrheumatic tricuspid valve disorders	Cardiovascular	Valve-related disorders	12
I37	Pulmonary valve disorders	Cardiovascular	Valve-related disorders	0
I38	Endocarditis, valve unspecified	Cardiovascular	Valve-related disorders	85
I39	Endocarditis and heart valve disorders in diseases classified elsewhere	Cardiovascular	Valve-related disorders	2
I40	Acute myocarditis	Cardiovascular	Others	2
I41	Myocarditis in diseases classified elsewhere	Cardiovascular	Others	0
I42	Cardiomyopathy	Cardiovascular	Others	22
I43	Cardiomyopathy in diseases classified elsewhere	Cardiovascular	Others	1
I44	Atrioventricular and left bundle-branch block	Cardiovascular	Arrhythmia	264
I45	Other conduction disorders	Cardiovascular	Arrhythmia	33
I46	Cardiac arrest	Cardiovascular	Others	35
I47	Paroxysmal tachycardia	Cardiovascular	Arrhythmia	267
I48	Atrial fibrillation and flutter	Cardiovascular	Arrhythmia	3187
I49	Other cardiac arrhythmias	Cardiovascular	Arrhythmia	119
I50	Heart failure	Cardiovascular	Heart failure	1654
I51	Complications and ill-defined descriptions of heart disease	Cardiovascular	Others	93
I52	Other heart disorders in diseases classified elsewhere	Cardiovascular	Others	0
I60-I69: Cerebrovascular diseases				
I60	Subarachnoid hemorrhage	Cardiovascular	Cerebrovascular diseases	17
I61	Intracerebral hemorrhage	Cardiovascular	Cerebrovascular diseases	69
I62	Other nontraumatic intracranial hemorrhage	Cardiovascular	Cerebrovascular diseases	41
I63	Cerebral infarction	Cardiovascular	Cerebrovascular diseases	432
I64	Stroke, not specified as hemorrhage or infarction	Cardiovascular	Cerebrovascular diseases	25
I65	Occlusion and stenosis of precerebral arteries, not resulting in cerebral infarction	Cardiovascular	Cerebrovascular diseases	37

(Continued)

TABLE E1. Continued

ICD-10 code	Disease	Cardiovascular/ noncardiovascular	Subclassification	Total number
I66	Occlusion and stenosis of cerebral arteries, not resulting in cerebral infarction	Cardiovascular	Cerebrovascular diseases	0
I67	Other cerebrovascular diseases	Cardiovascular	Cerebrovascular diseases	16
I68	Cerebrovascular disorders in diseases classified elsewhere	Cardiovascular	Cerebrovascular diseases	0
I69	Sequelae of cerebrovascular disease	Cardiovascular	Cerebrovascular diseases	0
I95-99: Other and unspecified disorders of the circulatory system				
I95	Hypotension	Cardiovascular	Others	255
I970	Postcardiotomy syndrome	Cardiovascular	Others	18
I971	Heart failure following cardiac surgery or due to presence of cardiac prosthesis	Cardiovascular	Heart failure	7
Surgical valve, procedure-related cause				
D50	Iron deficiency anemia	Noncardiovascular	Anemia	901
D649	Anemia, unspecified	Noncardiovascular	Anemia	573
E870	Hyperosmolality and hypernatremia	Noncardiovascular	Abnormal lab results	2
E871	Hypo-osmolality and hyponatremia	Noncardiovascular	Abnormal lab results	126
E875	Hyperkalemia	Noncardiovascular	Abnormal lab results	76
E876	Hypokalemia	Noncardiovascular	Abnormal lab results	36
J90-94: Other diseases of pleura				
J90X	Pleural effusion, not elsewhere classified	Noncardiovascular	Pleural effusion	1049
J91	Pleural effusion in conditions classified elsewhere	Noncardiovascular	Pleural effusion	6
J93	Pneumothorax	Noncardiovascular	Others	26
(R00-R09) Symptoms and signs involving the circulatory and respiratory systems				
R07.2	Precordial pain	Noncardiovascular	Pain (noncardiac)	231
R07.3	Anterior chest wall pain NOS	Noncardiovascular	Pain (noncardiac)	674
R07.4	Chest pain, unspecified	Noncardiovascular	Pain (noncardiac)	977
T81: Complications of procedures, not elsewhere classified				
T810	Hemorrhage and hematoma complicating a procedure, not elsewhere classified	Noncardiovascular	Major bleeding	184
T813	Disruption of operation wound, not elsewhere classified	Noncardiovascular	Wound	117
T814	Infection following a procedure, not elsewhere classified	Noncardiovascular	Wound	631
J12	Viral pneumonia, not elsewhere classified	Noncardiovascular	Respiratory tract infection	13
J13	Pneumonia due to *Streptococcus pneumoniae*	Noncardiovascular	Respiratory tract infection	6
J14	Pneumonia due to *Haemophilus influenzae*	Noncardiovascular	Respiratory tract infection	3
J15	Bacterial pneumonia, not elsewhere classified	Noncardiovascular	Respiratory tract infection	18
J16	Pneumonia due to other infectious organisms, not elsewhere classified	Noncardiovascular	Respiratory tract infection	0
J17	Pneumonia in diseases classified elsewhere	Noncardiovascular	Respiratory tract infection	0
J18	Pneumonia, organism unspecified	Noncardiovascular	Respiratory tract infection	1038
J22X	Unspecified acute lower respiratory infection	Noncardiovascular	Respiratory tract infection	429
J440	Chronic obstructive pulmonary disease with acute lower respiratory infection	Noncardiovascular	Respiratory tract infection	136
R42	Dizziness and giddiness	Noncardiovascular	Dizziness/syncope	295
R060	Chest pain, unspecified	Noncardiovascular	Chest pain (non-ACS)	493
R00	Abnormalities of heartbeat	Noncardiovascular	Arrhythmias	323
R071	Chest pain on breathing	Noncardiovascular	Chest pain (non-ACS)	21
R072	Precordial pain	Noncardiovascular	Chest pain (non-ACS)	231
R073	Other chest pain, anterior chest wall pain NOS	Noncardiovascular	Chest pain (non-ACS)	674
R074	Chest pain, unspecified	Noncardiovascular	Chest pain (non-ACS)	977
R55	Syncope and collapse	Noncardiovascular	Dizziness/syncope	392
R060	Shortness of breath	Noncardiovascular	Heart failure	493

ICD-10, International Classification of Diseases, 10th Revision; *NOS*, not otherwise specified; *ACS*, acute coronary syndrome.

TABLE E2. ICD-10 codes for the cardiovascular-related and procedure-related secondary diagnoses

ICD-10 code	Disease	Cardiovascular/ noncardiovascular	Subclassification	Total number
I10-I15: Hypertensive disease				
I10	Essential (primary) hypertension	Cardiovascular	Hypertensive disease	23,443
I11	Hypertensive heart disease	Cardiovascular	Hypertensive disease	22
I12	Hypertensive renal disease	Cardiovascular	Hypertensive disease	122
I13	Hypertensive heart and renal disease	Cardiovascular	Hypertensive disease	30
I15	Secondary hypertension	Cardiovascular	Hypertensive disease	27
I20-I25: Ischemic heart disease				
I20	Angina pectoris	Cardiovascular	Ischemic heart disease	1884
I21	Acute myocardial infarction	Cardiovascular	Ischemic heart disease	178
I22	Subsequent myocardial infarction	Cardiovascular	Ischemic heart disease	3
I23	Certain current complications following acute myocardial infarction	Cardiovascular	Ischemic heart disease	5
I24	Other acute ischemic heart diseases	Cardiovascular	Ischemic heart disease	255
I25	Chronic ischemic heart disease	Cardiovascular	Others	12,137
I26-I28: Pulmonary heart disease and diseases of pulmonary circulation				
I26	Pulmonary embolism	Cardiovascular	Pulmonary embolism	259
I27	Other pulmonary heart diseases	Cardiovascular	Others	1452
I28	Other diseases of pulmonary vessels	Cardiovascular	Others	18
I30-I52: Other forms of heart disease				
I30	Acute pericarditis	Cardiovascular	Pericarditis	38
I31	Other diseases of pericardium	Cardiovascular	Pericarditis	1851
I32	Pericarditis in diseases classified elsewhere	Cardiovascular	Pericarditis	0
I33	Acute and subacute endocarditis	Cardiovascular	Valve-related disorders	1210
I34	Nonrheumatic mitral valve disorders	Cardiovascular	Valve-related disorders	3196
I35	Nonrheumatic aortic valve disorders	Cardiovascular	Valve-related disorders	6504
I36	Nonrheumatic tricuspid valve disorders	Cardiovascular	Valve-related disorders	360
I37	Pulmonary valve disorders	Cardiovascular	Valve-related disorders	354
I38	Endocarditis, valve unspecified	Cardiovascular	Valve-related disorders	235
I39	Endocarditis and heart valve disorders in diseases classified elsewhere	Cardiovascular	Valve-related disorders	56
I40	Acute myocarditis	Cardiovascular	Others	1
I41	Myocarditis in diseases classified elsewhere	Cardiovascular	Others	0
I42	Cardiomyopathy	Cardiovascular	Others	601
I43	Cardiomyopathy in diseases classified elsewhere	Cardiovascular	Others	16
I44	Atrioventricular and left bundle-branch block	Cardiovascular	Arrhythmia	3419
I45	Other conduction disorders	Cardiovascular	Arrhythmia	1285
I46	Cardiac arrest	Cardiovascular	Others	209
I47	Paroxysmal tachycardia	Cardiovascular	Arrhythmia	684
I48	Atrial fibrillation and flutter	Cardiovascular	Arrhythmia	16,519
I49	Other cardiac arrhythmias	Cardiovascular	Arrhythmia	511
I50	Heart failure	Cardiovascular	Heart failure	9766
I51	Complications and ill-defined descriptions of heart disease	Cardiovascular	Others	5560
I52	Other heart disorders in diseases classified elsewhere	Cardiovascular	Others	0
I60-I69: Cerebrovascular diseases				
I60	Subarachnoid hemorrhage	Cardiovascular	Cerebrovascular diseases	36
I61	Intracerebral hemorrhage	Cardiovascular	Cerebrovascular diseases	75
I62	Other nontraumatic intracranial hemorrhage	Cardiovascular	Cerebrovascular diseases	69
I63	Cerebral infarction	Cardiovascular	Cerebrovascular diseases	523
I64	Stroke, not specified as hemorrhage or infarction	Cardiovascular	Cerebrovascular diseases	35
I65	Occlusion and stenosis of precerebral arteries, not resulting in cerebral infarction	Cardiovascular	Cerebrovascular diseases	283

(Continued)

TABLE E2. Continued

ICD-10 code	Disease	Cardiovascular/ noncardiovascular	Subclassification	Total number
I66	Occlusion and stenosis of cerebral arteries, not resulting in cerebral infarction	Cardiovascular	Cerebrovascular diseases	27
I67	Other cerebrovascular diseases	Cardiovascular	Cerebrovascular diseases	1480
I68	Cerebrovascular disorders in diseases classified elsewhere	Cardiovascular	Cerebrovascular diseases	12
I69	Sequelae of cerebrovascular disease	Cardiovascular	Cerebrovascular diseases	619
I95-99: Other and unspecified disorders of the circulatory system				
I95	Hypotension	Cardiovascular	Others	2010
I970	Postcardiotomy syndrome	Cardiovascular	Others	17
I971	Heart failure following cardiac surgery or due to presence of cardiac prosthesis	Cardiovascular	Heart failure	24
Surgical valve, procedure-related cause				
D50	Iron deficiency anemia	Noncardiovascular	Anemia	2146
D649	Anemia, unspecified	Noncardiovascular	Anemia	3299
E870	Hyperosmolality and hypernatremia	Noncardiovascular	Abnormal lab results	131
E871	Hypo-osmolality and hyponatremia	Noncardiovascular	Abnormal lab results	1061
E875	Hyperkalemia	Noncardiovascular	Abnormal lab results	471
E876	Hypokalemia	Noncardiovascular	Abnormal lab results	819
J90-94: Other diseases of pleura				
J90X	Pleural effusion, not elsewhere classified	Noncardiovascular	Pleural effusion	5382
J91	Pleural effusion in conditions classified elsewhere	Noncardiovascular	Pleural effusion	46
J93	Pneumothorax	Noncardiovascular	Others	161
(R00-R09) Symptoms and signs involving the circulatory and respiratory systems				
R07.2	Precordial pain	Noncardiovascular	Pain (noncardiac)	153
R07.3	Anterior chest wall pain NOS	Noncardiovascular	Pain (noncardiac)	298
R07.4	Chest pain, unspecified	Noncardiovascular	Pain (noncardiac)	564
T81, Complications of procedures, not elsewhere classified				
T810	Hemorrhage and hematoma complicating a procedure, not elsewhere classified	Noncardiovascular	Major bleeding	325
T813	Disruption of operation wound, not elsewhere classified	Noncardiovascular	Wound	258
T814	Infection following a procedure, not elsewhere classified	Noncardiovascular	Wound	556
J12	Viral pneumonia, not elsewhere classified	Noncardiovascular	Respiratory tract infection	172
J13	Pneumonia due to *Streptococcus pneumoniae*	Noncardiovascular	Respiratory tract infection	10
J14	Pneumonia due to *Haemophilus influenzae*	Noncardiovascular	Respiratory tract infection	2
J15	Bacterial pneumonia, not elsewhere classified	Noncardiovascular	Respiratory tract infection	55
J16	Pneumonia due to other infectious organisms, not elsewhere classified	Noncardiovascular	Respiratory tract infection	0
J17	Pneumonia in diseases classified elsewhere	Noncardiovascular	Respiratory tract infection	3
J18	Pneumonia, organism unspecified	Noncardiovascular	Respiratory tract infection	2382
J22X	Unspecified acute lower respiratory infection	Noncardiovascular	Respiratory tract infection	761
J440	Chronic obstructive pulmonary disease with acute lower respiratory infection	Noncardiovascular	Respiratory tract infection	774
R42	Dizziness and giddiness	Noncardiovascular	Dizziness/syncope	542
R060	Chest pain, unspecified	Noncardiovascular	Chest pain (non-ACS)	948
R00	Abnormalities of heartbeat	Noncardiovascular	Arrhythmias	1001
R071	Chest pain on breathing	Noncardiovascular	Chest pain (non-ACS)	19
R072	Precordial pain	Noncardiovascular	Chest pain (non-ACS)	153
R073	Other chest pain, anterior chest wall pain NOS	Noncardiovascular	Chest pain (non-ACS)	298
R074	Chest pain, unspecified	Noncardiovascular	Chest pain (non-ACS)	564
R55	Syncope and collapse	Noncardiovascular	Dizziness/syncope	517
R060	Shortness of breath	Noncardiovascular	Heart failure	948

ICD-10, International Classification of Diseases, 10th Revision; *NOS*, not otherwise specified; *ACS*, acute coronary syndrome.

TABLE E3. Twenty most common primary readmissions causes (noncardiovascular- or surgical valve procedure–related causes)

ICD-10 code	Disease	Total number
N185	End-stage renal disease	806
R060	Shortness of breath	498
H269	Unspecified conjunctivitis	436
R69X	Symptoms, signs, and abnormal clinical and laboratory findings, not elsewhere classified	425
R798	Abnormal findings on examination of other specified body fluids	349
N179	Chronic kidney disease, unspecified	347
K573	Diverticular disease of the colon	324
R42X	Dizziness and giddiness	296
H251	Senile nuclear cataract	264
K635	Polyp of colon	262
C61X	Malignant neoplasm of prostate	204
c900	Multiple myeloma	201
M169	Coxarthrosis, unspecified [arthrosis of hip]	199
C679	Malignant neoplasm of bladder	183
A099	Gastroenteritis and colitis of unspecified origin	168
L031	Cellulitis of other parts of limb (axilla, hip, shoulder)	155
K409	Unilateral or unspecified inguinal hernia, without obstruction or gangrene	154
R33X	Retention of urine	148
M798	Other specified soft tissue disorders	142
M179	Gonarthrosis, unspecified	134

ICD-10, International Classification of Diseases, 10th Revision.

TABLE E4. Preoperative characteristics in patients with and without readmission at 12 mo after heart valve surgery in the United Kingdom

Characteristic	Overall (N = 44,467)	No readmission (N = 24,844)	Readmission (N = 19,623)	P value
Age, y, median (IQR)	69.26 (59.62-75.89)	68.45 (59.01-75.18)	70.34 (60.48-76.73)	<.001
Male sex, n (%)	27,213 (61)	15,310 (62)	11,903 (61)	.037
Body mass index, median (IQR)	27.34 (24.24-31.20)	27.34 (24.23-31.02)	27.45 (24.26-31.46)	<.001
Operative urgency, n (%)				<.001
Elective	32,824 (74)	18,714 (75)	14,110 (72)	
Urgent	10,679 (24)	5642 (23)	5037 (26)	
Emergency	848 (1.9)	423 (1.70)	425 (2.2)	
Salvage	96 (0.2)	51 (0.2)	45 (0.2)	
CCS angina grade, n (%)				<.001
0	28,891 (65)	16,343 (66)	12,548 (64)	
1	4679 (11)	2534 (10)	2145 (11)	
2	7378 (17)	4054 (16)	3324 (17)	
3	2620 (5.9)	1421 (5.8)	1199 (6.2)	
4	541 (1.2)	275 (1.1)	266 (1.4)	
NYHA status, n (%)				<.001
1	4779 (11)	2925 (12)	1854 (9.6)	
2	15,997 (37)	9310 (38)	6687 (34)	
3	19,039 (43)	10,167 (42)	8872 (46)	
4	4002 (9.1)	2031 (8.3)	1971 (10)	
Diabetes management, n (%)				<.001
Nondiabetic	37,531 (85)	21,373 (87)	16,158 (83)	
Diet control	1231 (2.8)	643 (2.6)	588 (3)	
Medication	4138 (9.4)	2098 (8.5)	2040 (10)	
Insulin use	1168 (2.7)	504 (2.0)	664 (3.4)	
Left ventricular function, n (%)				<.001
Good (>50%)	34,353 (78)	19,399 (79)	14,954 (77)	
Moderate (31%-49%)	7848 (18)	4179 (17)	3669 (19)	
Poor (21%-30%)	1417 (3.2)	774 (3.2)	643 (3.3)	
Very poor (≤20%)	248 (0.6)	149 (0.6)	99 (0.5)	
Peripheral vascular disease, n (%)	1860 (4.2)	856 (3.5)	1004 (5.2)	<.001
Hypertension, n (%)	25,232 (57)	13,605 (55)	11,627 (60)	<.001
Preoperative neurologic dysfunction, n (%)	1507 (3.4)	727 (3.0)	780 (4.0)	<.001
History of pulmonary disease, n (%)	5586 (13)	2734 (11)	2852 (15)	<.001
Smoking, n (%)				<.001
Nonsmoker	22,435 (51)	12,911 (53)	9524 (49)	
Ex-smoker	17,851 (41)	9684 (39)	8167 (42)	
Current smoker	3598 (8.2)	1922 (7.8)	1676 (8.7)	
Interval between MI and surgery, n (%)				<.001
No previous MI	41,171 (95)	23,144 (95)	18,027 (94)	
<6 h	10 (<0.1)	6 (<0.1)	4 (<0.1)	
6-24 h	21 (<0.1)	11 (<0.1)	10 (<0.1)	
1-30 d	503 (1.2)	274 (1.1)	229 (1.2)	
31-90 d	125 (0.3)	56 (0.2)	69 (0.4)	
>90 d	1609 (3.7)	788 (3.2)	821 (4.3)	
Preoperative dialysis, n (%)	205 (0.5)	98 (0.4)	107 (0.6)	<.001
Preoperative cardiogenic shock, n (%)	507 (1.1)	254 (1.0)	253 (1.3)	.009

CCS, Canadian Cardiovascular Society; *IQR*, interquartile range; *NYHA*, New York Heart Association; *MI*, myocardial infarction.

TABLE E5. Intraoperative and postoperative outcomes in patients who underwent heart valve surgery before and after the COVID-19 pandemic in the United Kingdom.

Characteristic	Overall (N = 44,467)	Before pandemic (N = 33,250)	After pandemic (N = 11,217)	P value
CPB time, min, median (IQR)	96 (76,124)	95 (75,122)	100 (80, 128)	<.001
Cross-clamp time, min, median (IQR)	71 (56,92)	70 (55, 91)	74 (59, 96)	<.001
Number of valves repaired/replaced, n (%)				.31
1	36,713 (89%)	26,852 (89%)	9861 (88%)	
2	4197 (10%)	3015 (10.0%)	1182 (11%)	
3	453 (1.1%)	332 (1.1%)	121 (1.1%)	
4	5 (<0.1%)	4 (<0.1%)	1 (<0.1%)	
Surgical incision, n (%)				.15
Median sternotomy	24,936 (88%)	15,548 (88%)	9388 (88%)	
Hemi-sternotomy	1863 (6.3%)	1130 (6.4%)	733 (6.8%)	
Mini thoracotomy	1487 (5.2%)	926 (5.2%)	561 (5.2%)	
Other	135 (0.5%)	94 (0.5%)	41 (0.4%)	
Return to operating theater, n (%)	1831 (4.3%)	1369 (4.3%)	462 (4.3%)	.94
Neurologic events, n (%)				<.001
TIA	327 (0.8%)	269 (0.9%)	58 (0.5%)	
CVA	431 (1.0%)	284 (0.9%)	147 (1.4%)	
Postoperative dialysis, n (%)	823 (1.9%)	601 (1.9%)	222 (2.0%)	.33
Deep sternal wound infection, n (%)	138 (0.4%)	101 (0.4%)	37 (0.4%)	.93

CPB, Cardiopulmonary bypass; *IQR*, interquartile range; *TIA*, transient ischemic attack; *CVA*, cerebrovascular accident.

TABLE E6. Readmission rates during phases of the COVID-19 pandemic lockdown in the United Kingdom

Lockdown phase	Dates	Patients who underwent heart valve surgery	12-mo readmissions	Readmission rate, %
Pre-lockdown	1 January 2013 to 22 March 2020	30,772	14,280	46.41
First lockdown	23 March 2020 to 23 June 2020	694	301	43.37
First relaxation	24 June 2020 to 5 November 2020	2098	913	43.52
Second lockdown	5 November 2020 to 2 December 2020	380	169	44.47
Second relaxation	3 December 2020 to 5 January 2021	344	139	40.41
Third lockdown	6 January 2021 to 7 March 2021	446	202	45.29
Third lockdown relaxation	8 March 2021 to 21 June 2021	1623	761	46.89