Human immunodeficiency virus infection is associated with greater risk of pneumonia and readmission after cardiac surgery

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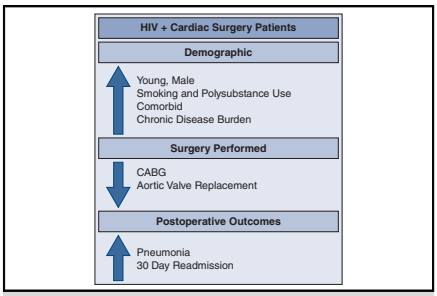
ABSTRACT

Objective: Human immunodeficiency virus infection (HIV+) is associated with a 2-fold increased risk of cardiovascular disease. Increasingly, patients who are HIV + are being evaluated to undergo cardiac surgery. Current risk-adjusted scoring systems, including the Society of Thoracic Surgeons Predicted Risk of Mortality score, fail to stratify HIV + risk. Unfortunately, there exists a paucity of cardiac surgery outcomes data in modern patients who are HIV+.

Methods: We conducted a retrospective review of PearlDiver, an all-payer claims administrative database. In total, 14,714,743 patients were captured between 2010 and 2020. Of these, 59,695 (0.4%) of patients had a history of HIV+, and 1759 (2.95%) of these patients underwent cardiac surgery. Patients who were HIV+ were younger, more often male, and had greater comorbidity, history of hypertension, chronic obstructive pulmonary disease, chronic liver disease, chronic kidney disease, chronic lung disease, and heart failure.

Results: Postoperatively, patients who were HIV + had significantly greater rates of pneumonia (relative risk, 1.70; $P = .0003$) and 30-day all-cause readmission (relative risk, 1.28, $P < .0001$). After linear regression analysis, these results remained significant. Data also show that a lesser proportion of patients with HIV + underwent coronary artery bypass grafting, aortic valve replacement, and any cardiac surgery compared with controls.

Conclusions: Patients who are HIV + undergoing cardiac surgery are at greater risk of pneumonia and readmission. Moreover, we discovered lower rates of cardiac surgery in patients who are HIV+, which may reflect limited access to surgery when indicated. Today's risk-adjusted scoring systems in cardiac surgery need to better account for the modern patient who is HIV+. (JTCVS Open 2024;18:145-55)



Summary for the HIV + cardiac surgery patient.

CENTRAL MESSAGE

Cardiac surgery outcomes in patients who are HIV + are poorly understood. Current risk-adjusted scoring systems fail to stratify the modern patient who is HIV+.

PERSPECTIVE

We present a retrospective review of patients who are HIV + undergoing cardiac surgery using PearlDiver, an all-payer claims database. Data show that patients who are HIV + experience greater rates of postoperative pneumonia and readmission after cardiac surgery. Less cardiac surgery performed in patients who are HIV + might also suggest differences in access to cardiac surgery care when indicated.

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The treatment of human immunodeficiency virus (HIV) is profoundly different today compared with the 1980s. Adherence to antiretroviral therapy (ART), with improvements in the diagnosis and management of HIV, has led patients who are HIV + toward living near-normal lifespans with a chronic disease. In fact, life expectancy following the diagnosis of HIV is 5 to 7 times longer for patients who are HIV + managed with ART.[1] With greater adherence to ART therapy, there has emerged a deeper appreciation for the effects of the virus and its treatment on the development of cardiovascular disease. Patients who are

Abbreviations and Acronyms

ART = antiretroviral therapy
AVR = aortic valve replacement
CABG = coronary artery bypass grafting
COPD = chronic obstructive pulmonary disease
ECI = Elixhauser Comorbidity Index
HAART = highly active antiretroviral therapy
HIV = human immunodeficiency virus
LOS = length of stay
NIS = National Inpatient Sample
RR = relative risk
STS = Society of Thoracic Surgeons

HIV + have a 2-fold excess risk of cardiovascular disease compared with patients who are HIV–.[2,3] ART medications are associated with dyslipidemia, reduced insulin sensitivity, and body fat lipodystrophy that additionally contributes to cardiovascular risk.[4] A recent *JAMA* study of HIV + patients in the MarketScan Commercial and Medicare databases found that patients who were HIV+ were at greater risk for the development of myocardial infarction, stroke, heart failure, peripheral vascular disease, atrial fibrillation, and any cardiovascular-related hospitalization.[5] With increased longevity, patients who are HIV + are now surviving long enough to require a full range of cardiac surgical procedures including coronary bypass, heart valve repair/replacement, and even heart transplantation.[2] However, an accurate assessment of HIV infection for cardiac surgery risk is still absent.

Multiple risk-adjusted scoring systems allow heart teams to prognosticate the risks of cardiac surgery, including the European System for Cardiac Operative Risk Evaluation and Society of Thoracic Surgeons (STS) Predicted Risk of Mortality score. Neither of these scoring systems identifies HIV infection as a perioperative risk factor. The category to which patients who are HIV + are most commonly listed is "immunocompromised." However, there remains a paucity of data regarding the outcomes of cardiac surgery in patients who are HIV+, especially the modern patient who is HIV+ and well managed on ART therapy, with negative viral loads.

METHODS

Data Collection, Study Population, and Design

We conducted a retrospective cohort study using the PearlDiver Database (PearlDiver Technologies). Institutional review board approval was waived, as the data were deidentified. PearlDiver is a subscription-based research suite that provides all-payer claims administrative data, including private insurance, Medicare, Medicaid, self-pay, and government insurance for inpatient settings. It offers longitudinal tracking based upon distinct patient identifiers. The medical data of almost 91 million US patients from 2010 to 2020 were available at the time of our study. Using Boolean operators and *International Classification of Diseases*, Ninth and Tenth Revision codes, a base population of patients with risk factors for heart disease was identified. Having a history of hospital admission for HIV was the criteria used to divide the study population into 2 groups. Within each group, patients who underwent heart surgery (index event) were identified and classified into type of cardiac surgery; coronary artery bypass grafting (CABG), aortic valve repair, mitral valve repair/replacement, and aortic repair/replacement. Baseline demographics and comorbidities were assessed. The Elixhauser Comorbidity Index (ECI) was captured by the database to reflect burden of chronic comorbidities. ECI, a risk-adjusted scoring scale developed in 1998, has been found to be more inclusive and statistically superior to other commonly used health care indices like the Charles Comorbidity Index.[6] Only patients with active records who remained enrolled with their insurance carrier over the follow-up period were included in study outcomes. Records were examined for the index event and up to 30 days thereafter. The database contains exclusively deidentified and retrospective data. Therefore, this study met the ethical criteria established by our organization's Exempt Determination Policy.

Study Variables

Independent variables. The principal independent variable in this study was having a history of HIV infection. This was defined as having a record designated with an HIV-related *International Classification of Diseases* code before the index event.

Outcome variables. Outcome measures included length of stay (LOS), pneumonia, stroke, heart failure, myocardial infarction, renal injury, and 30-day all-cause readmission. To compare outcomes, subsequent queries collected cumulative records for 30 days following the index event. LOS was defined as the average number of days that patients were hospitalized following the index event. Hospital readmission was defined as any subsequent hospital admission, for any cause, within 30 days of the index event. To avoid a biased estimation, only the first admission for the same complication was considered.

Statistical Analyses

Patient characteristics were represented as frequency (%) for categorical variables and mean with standard deviations for continuous variables. Pearson χ^2 and t tests were performed to compare the group baseline comorbidities and demographics. Relative risk (RR) with a 95% confidence interval was used to represent the strength of the association of HIV status with postoperative outcome using univariate analysis. We explored developing a multivariate regression analysis with 19 commonly used demographic and clinical variables. However, within the HIV + cohort, 18 of 19 (94%) of these variables were present. Therefore, our multivariate comparison options were limited. Because of this, we performed a simple linear regression analysis to examine the strength of the association of our independent variable, HIV status, with the studied clinical outcomes. The t value represents whether the predicted regression coefficient of having HIV is statistically different from zero. A greater t value indicates greater evidence against the null hypothesis, ie, that HIV status has stronger influence on predicting the postoperative outcome. All statistical analyses were 2-tailed. The data analyses were performed using R, version 4.1.0 (R Foundation for Statistical Computing).

RESULTS

Our search captured all hospital admissions from 2010-2020, including 14,714,743 patients from the PearlDiver Database. The HIV + cohort accounted for 0.4% (59,695) of all patients (Table 1). Patients who were HIV+ were younger, more often male, sicker (as measured by a greater ECI), more frequently smokers, polysubstance users, had obesity, and had greater rates of hypertension, chronic obstructive pulmonary disease (COPD), cerebrovascular disease, peripheral artery disease, chronic liver disease, chronic

TABLE 1. Population characteristics

Demographics	HIV-negative (n = 14,655,048)	%	HIV-positive (n = 59,695)	%	*P* value
Age, y, mean ± SD	64.32 ± 11.77		54.62 ± 11.19		<.0001
Male	7,408,206	50.00	38,607	65.00	<.0001
ECI, mean ± SD	4.6 ± 3.4		7.3 ± 3.8		<.00001
Current tobacco use	2,500,545	17.06	23,981	40.17	<.0001
Former tobacco use	3,588,722	24.49	18,930	31.71	<.0001
Any polysubstance use	1,034,395	7.06	20,997	35.17	<.0001
Insurance coverage	14,636,553	99.87	59,273	99.29	.005
HTN	8,831,554	60.26	41,591	69.67	<.0001
Obesity	2,106,580	14.37	11,483	19.24	<.0001
COPD	3,316,003	22.63	21,810	36.54	<.0001
Cerebrovascular disease	396,425	2.71	10,894	18.25	<.0001
PAD	2,332,990	15.92	10,226	17.13	<.0001
Chronic liver disease	1,062,888	7.25	17,207	28.82	<.0001
Diabetes mellitus	4,862,091	33.18	24,061	40.31	<.0001
CAD	11,941,355	81.48	47,191	79.05	<.0001
Chronic lung disease, severe	3,355,861	22.90	21,719	36.38	<.0001
Chronic kidney disease, stage III or greater	1,779,978	12.15	11,881	19.90	<.0001
Systolic heart failure, <50%	1,683,673	11.49	6753	11.31	.180
Any malignancy	1,615,827	11.03	7795	13.06	<.0001

HIV, Human immunodeficiency virus; *SD*, standard deviation; *ECI*, Elixhauser Comorbidity Index; *HTN*, hypertension; *COPD*, chronic obstructive pulmonary disease; *PAD*, peripheral artery disease; *CAD*, coronary artery disease.

lung disease, chronic kidney disease, and any malignancy. Most marked differences were seen in the rates of current tobacco use (40.17% vs 17.06%), polysubstance abuse (35.17% vs 7.06%), cerebrovascular disease (18.25% vs 2.71%), and chronic liver disease (28.82% vs 7.25%). No difference was observed in the rate of heart failure. Surprisingly, patients who were HIV + also had comparatively lower rates of baseline coronary artery disease in our cohort. HIV-specific variables including ART therapy, viral load, and CD4 count were not included in the database. Next, we assessed these data for demographic differences in patients who were HIV + undergoing cardiac surgery (Table 2). We found that patients who were HIV + undergoing cardiac surgery were younger, with more comorbidities, more often male, with a history of smoking or polysubstance use, less often insured, and had greater rates of hypertension, COPD, chronic liver disease, chronic lung disease, and chronic kidney disease. Heart failure was also more commonly present in patients who were HIV + undergoing cardiac surgery. No differences were observed in current tobacco use rates, morbid obesity, cerebrovascular disease, peripheral artery disease, diabetes mellitus, coronary artery disease, and malignancy. These data show lesser rates of surgical revascularization with CABG, aortic valve replacement (AVR), and total cardiac surgery in patients who were HIV+. No difference was demonstrated in the rates of mitral and aortic surgery in this cohort. However, when cardiac surgery was performed in patients who were HIV+, they more often underwent mitral valve repair/replacement, and less often underwent AVR (Table 3). Postoperative complications following cardiac surgery were then studied with univariate analysis (Table 4). We found greater rates of pneumonia (2.67% vs 1.54%; RR, 1.7; $P = .0003$) and 30-day readmission (15.69% vs 12.05%; RR, 1.28; $P \leq .0001$) in patients who were HIV + undergoing cardiac surgery. No differences were seen in the average hospital LOS (10 days), rates of stroke, postoperative heart failure, myocardial infarction, and renal injury. Following linear regression analysis, pneumonia (t value 3.244, $P = .001$) and readmission (t value 7.874, $P < .001$) remained the only significant differences between the cohorts. Univariate analyses were also performed to assess differences in postoperative outcomes of patients who were HIV + undergoing cardiac surgery based on the type of cardiac surgery performed. Table E1 shows that following surgical revascularization with CABG, patients who were HIV + experienced only proportionally greater rates of pneumonia. Following AVR, patients who were HIV + suffered greater rates of pneumonia, grater rates of readmission, and longer average hospital LOS than patients who were HIV– (Table E2). Following mitral valve repair/replacement, patients who were HIV + had increased risks of pneumonia and 30-day readmission (Table E3). No difference in postoperative outcome was demonstrated in patients

TABLE 2. Characteristics of cardiac surgery population

Demographics and comorbidities	HIV-negative (n = 541,306)	%	HIV-positive (n = 759)	%	*P* value
Age, y, mean ± SD	65 ± 10	N/A	56 ± 9	N/A	<.0001
Male	351,849	65	1292	72	.003
ECI, y, mean ± SD	6.57 ± 3.6	N/A	9.27 ± 4.1	N/A	<.0001
Current tobacco use	270,653	50	915	51	.388
Former tobacco use	205,696	38	413	23	<.0001
Any polysubstance use	37,891	7	359	20	<.0001
Insurance coverage	535,893	99	1741	97	<.0001
HTN	443,871	82	1544	86	.0014
Obesity	119,087	22	413	23	.8590
COPD	151,566	28	700	39	<.0001
Cerebrovascular disease	194,870	36	664	37	.4341
PAD	173,218	32	592	33	.2172
Chronic liver disease	48,718	9	556	31	<.0001
Diabetes mellitus	259,827	48	880	49	.5472
Coronary artery disease	465,523	86	1526	85	.4478
Chronic lung disease, severe	162,392	30	736	41	<.0001
Chronic kidney disease, stage III or greater	92,022	17	539	30	<.0001
Systolic heart failure, <50%	113,674	21	431	24	.0168
Any malignancy	59,544	11	251	14	.3119

HIV, Human immunodeficiency virus; *SD*, standard deviation; *N/A*, not available; *ECI*, Elixhauser Comorbidity Index; *HTN*, hypertension; *COPD*, chronic obstructive pulmonary disease; *PAD*, peripheral artery disease; *CAD*, coronary artery disease.

who were HIV + undergoing aortic surgery (Table E4). Patients taking highly active antiretroviral therapy (HAART) had lower rates of readmission (14.58 vs 18.10%). However, HAART therapy was not associated with differences in any other postoperative outcomes (Table E5).

DISCUSSION

The modern approach to managing heart disease in patients who are HIV+ is changing. As HIV has transitioned into a chronic disease, more patients who are HIV + are living longer and suffering from age-related pathology. Nearly 38 million people worldwide currently live with HIV, but the size and age of this community is growing.[7] At the time of the emergence of HIV in the early 1980s, the average patient age was 34 years.[8] Currently, more than half of the 1.4 million Americans living with HIV are >50 years. The Centers for Disease Control and Prevention estimates that this percentage will grow to more than 70% by 2030.[9] The RR of cardiovascular disease is 61% greater in the patient who is HIV+, as a result of viral pathology, ART therapy, and various clinical risk factors.[7] Unfortunately, current risk-adjusted calculators to assess the relative risk of HIV in cardiac surgery are inadequate.[7]

Our data show that cardiac surgery in patients who are HIV+ is performed on younger patients with more comorbidity, who experience greater rates of postoperative pneumonia and readmission (Figure 1). Although some prominent cardiac surgeons have advocated that patients who are HIV+ be considered for cardiac surgery without hesitation,[10,11] there exists a paucity of data to indicate the outcome. The majority of cardiac surgery outcomes data in patients who are HIV + remain limited to case reports and case series that demonstrate similar rates of perioperative morbidity as our data.[10,12,13] Our data also show high readmission rates (15.69%) for patients who are HIV+. Multiple large cohort studies have reported that patients who are HIV + uniquely experience average hospital readmission rates of nearly 20%.[14,15] Among patients living with HIV, HIV-related and bacterial infections are leading causes of hospital admission.[15] Risk factors for hospitalization in this cohort include low CD4 count, longer index hospital LOS, discharge against medical advice, lack of insurance coverage, multiple additional comorbidities, substance use, and housing instability, to name a few.[14,15] Postoperative pneumonia occurred in 2.67% of patients who were HIV + undergoing cardiac surgery in our study. Although bacterial infections are a leading cause of hospitalization in patients who are HIV+, other HIV-specific variables could not be studied using this administrative database, nor could their contribution to the reason for readmission in this cohort.

Filsoufi and colleagues[10] provided more granular data regarding HIV pathology in their retrospective review of 25 patients who were HIV + undergoing cardiac surgery.

TABLE 3. Frequency of heart surgery performed in patients who are HIV+

Type of cardiac surgery	HIV-negative			HIV-positive			*P* value	
	Number of patients	Total population (n = 14,655,048) Surgery/total population	Cardiac surgery (n = 541,306) Surgery/cardiac surgery	Number of patients	Total population (n = 59,695) Surgery/total population	Cardiac surgery (n = 1795) Surgery/cardiac surgery	Total	Cardiac surgery
CABG	324,718	2.22%	59.90%	1048	1.76%	59.60%	<.0001	.86
AVR	122,929	0.84%	22.70%	325	0.54%	18.47%	<.0001	<.00001
MVR	75,616	0.52%	13.90%	321	0.54%	18.20%	.47	<.00001
AOS	18,043	0.12%	3.30%	65	0.11%	3.69%	.35	.41
Total	541,306	3.60%	–	1759	2.90%	–	<.0001	–

HIV, Human immunodeficiency virus; *CABG*, coronary artery bypass graft surgery; *AVR*, aortic valve replacement; *MVR*, mitral valve repair/replacement; *AOS*, aortic surgery.

They reviewed all 4952 cardiac surgery cases between 1998 and 2004, at their New York academic center, and found just 25 patients (~0.5%) were HIV+. At that time just 52% were actively treated with ART therapy, and elective surgery comprised just 44% of cases. Our data show similar rates of preoperative heart failure (24% vs 28%) and high rates of preoperative comorbidity similar to their cohort.[10] Moreover, our data demonstrate that routine cardiac surgery with CABG and AVR was proportionately less often performed in patients who were HIV+. We predict that low rates of elective surgery, reported by Filsoufi and colleagues,[10] might similarly indicate differences to access to surgical treatment. Whether patients eligible for CABG or AVR were managed percutaneously with percutaneous coronary intervention or transcatheter aortic valve replacement, respectively, could not be determined, but this topic represents an avenue for further research.

Robich and his colleagues[11] from the Cleveland Clinic have published the only large, national database study of cardiac surgery outcomes in patients who are HIV + to date. Using the National Inpatient Sample between 1998 and 2009, the authors studied more than 5.6 million patients. The rate of HIV positivity was 0.17%. The HIV + cohort was disproportionately younger, with a large proportion (73 vs 19%) younger than the age of 55 years. Like our data, patients who were HIV + had greater preoperative rates of drug use (12% vs 0.7%), alcohol abuse (3.6% vs 1.9%), renal failure (16% vs 6.5%), and chronic lung disease (28% vs 21%) compared with controls. Preoperative smoking and clinical indices of comorbidity were not studied.[11] The proportion of patients who were HIV + undergoing cardiac surgery increased from 0.09 to 0.23% during their study time frame. Their data show that patients who were HIV+ were less likely to undergo CABG than patients who were uninfected. Patients who were HIV+, however, more often underwent valve replacement, partly due to a 6-fold greater rate of endocarditis in this group. We did not assess for endocarditis in our study. Given that our HIV + cohort was nearly 10 years younger than the HIV–cohort, our data may be capturing a different indication for aortic valve replacement than age-related aortic stenosis. Robich and colleagues[11] found greater rates of postoperative complications, stroke, blood transfusion, renal injury, and pneumonia occurred in patients who were HIV + undergoing cardiac surgery compared with patients who were controls. Surprisingly, after risk adjustment, postoperative renal injury and pneumonia were not statistically different. Readmission rates were not evaluated.

Our data are consistent with the findings of Robich and colleagues,[11] with few exceptions. Our more-modern data analysis of 2010-2020 shows the average age of patients

TABLE 4. Thirty-day post-heart surgery outcomes

Variable	Univariate								Linear regression	
	HIV-negative (n = 541,306)	%	HIV-positive (n = 1759)	%	RR	95% CI		*P* value	*t* value	Pr(>|t|)
Hospital LOS, mean ± SD	10 ± 10.6	–	10.5 ± 9	–	–	–	–	.2309	–	–
Pneumonia	8354	1.54	47	2.67	1.70	1.28	2.26	.0003	3.244	.00118
Stroke	3303	0.61	11	0.63	1.01	0.56	1.82	1.0000	–	–
Heart failure	30,587	5.65	108	6.14	1.07	0.89	1.28	.5145	–	–
Myocardial infarction	4547	0.84	16	0.90	1.06	0.65	1.73	.9000	0.919	.3580
Renal injury	31,843	5.88	111	6.31	1.05	0.88	1.26	.6006	0.333	.7390
30-d all-cause readmission	65,228	12.05	276	15.69	1.28	1.15	1.42	<.0001	7.874	<.00001

HIV, Human immunodeficiency virus; *RR*, relative risk; *CI*, confidence interval; *LOS*, length of stay; *SD*, standard deviation.

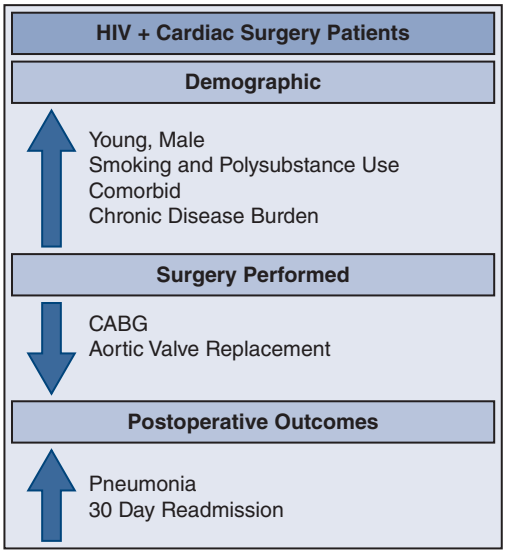

FIGURE 1. Cardiac surgery in HIV + patients is performed on younger, more comorbid patients who undergo lesser routine cardiac surgical procedures and experience greater rates of postoperative pneumonia and readmission. *HIV*, Human immunodeficiency virus; *CABG*, coronary artery bypass grafting.

who are HIV + undergoing cardiac surgery was 54 years, which is older than those patients in their report from the previous decade. We demonstrate high rates of polysubstance and tobacco use, with generally a more comorbid patient (as reflected by greater ECI scores) in the HIV + cohort. Our data demonstrate proportional differences in the rates of surgical revascularization and aortic valve replacement in patients who are HIV+. Supplemental data also suggest that patients who are HIV + experience a longer hospital LOS after aortic valve replacement, but their postoperative courses were only notable for greater rates of pneumonia and readmission, unlike other cardiac surgeries. Given the high rates of smoking and preoperative COPD in patients who are HIV+, it was not surprising to find greater rates of postoperative pneumonia in this cohort. However, our linear regression analysis suggests that HIV infection is independently associated with greater risks of pneumonia above that of their preoperative smoking alone. Patients who are HIV+ were also sicker preoperatively and may have had multiple needs for readmission apart from routine postoperative challenges. Without more clinical information, it difficult to determine whether the degree of immunosuppression contributed to this greater risk of perioperative pneumonia.

Large-volume databases are increasingly being used to track perioperative complications, costs, and resource use based on procedure type and patient risk factors.[16,17] These databases can be classified as either administrative (National Inpatient Sample [NIS], Centers for Medicare and Medicaid Services, and private analytics) or clinical (National Surgical Quality Improvement Program, National Cancer Database) databases.[16] Administrative databases comprise billing and claims data for clinical services. Clinical databases instead capture patient population data with relevant clinical information used for outcomes research. PearlDiver is a large, private analytics database containing data on more than 4 billion patients that is available for commercial purchase.[16,17] Data sources used to compile this database include commercial insurances sources (like Humana and UnitedHealthcare), government claims (Centers for Medicare and Medicaid Services), and other sources administrative sources (including the NIS).[17] Patients are deidentified, difficult to track longitudinally, do not include all insurance payers, include data-capture techniques that have changed over time, and include data independently adjudicated by the PearlDiver company itself.[17] Although the NIS, used by Robich and colleagues,[11] is the largest all-payer database of inpatient hospitalization, it too has its limitations. The NIS captures only predischarge information, making it difficult to distinguish comorbidities from complications, includes only complications during the index hospitalizations, and fails to capture many routine clinical parameters.[11,16] By contrast, the STS database provides the most homogenous practice pattern for cardiothoracic surgery performed in the United States. This clinical database captures more patients, is more complete, and provides more meaningful data analysis than other commonly used administrative databases.[18,19] Unfortunately, data capture by the STS database remains limited, particularly for the study of the evolving patient with HIV infection. Given the limitations of administrative data, we hope these results are hypothesis-generating and can promote the necessary changes need to study modern patients who are HIV + using robust, existing clinical databases.

Recently, the mechanical support and transplant community has appreciated improving clinical progress within the HIV community.[20,21] No longer an absolute contradiction to transplantation, patients who are HIV + are increasingly compliant with ART therapy and have low incidence of opportunistic infections.[21] Birk and colleagues[20] recently uncovered differences in data capture between the STS Adult Cardiac Surgery Database and the Interagency Registry for Mechanically Assisted Circulatory Support Database. Unlike the current STS Adult Cardiac Surgery Database, the Interagency Registry for Mechanically Assisted Circulatory Support registry differentiates patients who are HIV+ from other immunocompromised patients and also includes HIV-specific variables, including CD4 count and viral load. Using this registry, Birk and colleagues[20] reviewed the impact of HIV infection on outcomes of left ventricular assist device support. Similar to our results, their data demonstrate that patients who were HIV+ were more likely to abuse tobacco and other polysubstances than uninfected patients. Their cohort also had significantly greater rates of hepatitis, compared with high rates of chronic liver

disease in our review. After multifactorial matching, authors show that HIV infection no longer impacted postimplant survival, nor was associated with postoperative stroke, bleeding, and major infection.[20] It should be noted that all patients who were HIV + receiving ventricular assist devices in their study had nondetectable viral loads. Detectable HIV viral loads may therefore serve as a dividing line between surgical eligibility and exclusion. Given the aging HIV + patient population and their greater cardiovascular risks, the STS Database is poorly capturing an at-risk patient population that is currently better studied in its sister registry.

Our study highlights the need for greater inclusivity within the STS Database. HIV infection, similar to other chronic diseases like cirrhosis, syphilis, rheumatoid arthritis, systemic lupus erythematosus, for example, remain poorly accounted for when determining perioperative risk of heart surgery. The recently released STS Operative Risk Calculator Version 2.0.3 begins to include the risk of "liver disease" for patients with cirrhosis, similar to how patients with HIV may still be considered "immunocompromised." Birk and colleagues[20] have well demonstrated that the inclusion of HIV-specific variables including a history of diagnosis, CD4 count, and viral load are sufficient to study perioperative risk assessment in the surgical management of heart failure. Our authors propose that similar inclusion of these 3 HIV-specific variables would be sufficient to derive true surgical risk of HIV infection in adult cardiac surgery. By studying these HIV-specific variables along with our robust clinical STS data, like Birk and colleagues,[20] we may find that historically greater rates of perioperative mortality and major morbidity for patients with HIV are no longer relevant in modern, adult cardiac surgery.

As more patients who are HIV + are being evaluated for surgery, mitigating their perioperative risk becomes paramount. It is well appreciated that reducing viral load with ART is the best first step for reducing cardiovascular risk and subsequent mortality. The Food and Drug Administration has approved more than 30 antiretroviral medications, divided into 7 drug classes, to treat HIV (clinicalinfo.hiv.gov). Viral suppression should be continual, as interruptions in HAART therapy are associated with greater viral loads, reduced CD4 counts, increased opportunistic infection, and greater all-cause mortality.[22] Even with reduced viral load, HIV virus lives dormant in macrophages, promoting low-level, chronic activation of the innate immune system.[23] The recently published REPRIEVE (Randomized Trial to Prevent Vascular Events in HIV) trial found that aggressive statin therapy could reduce (4.81 vs 7/32 per 1000 person-years; hazard ratio, 0.65) major cardiovascular risk in patients who were HIV + that was well controlled with HAART therapy.[23] This trial targeted young patients with median age 50 years with limited comorbidities, placing them at low-to-moderate risk of cardiovascular disease. The trial was stopped early due to high efficacy. Researchers targeted this younger demographic because historically, existing cardiovascular risk models underestimate cardiovascular risk in HIV infection.[24] Patients who are HIV + demonstrate high prevalence of nonobstructive, noncalcified, vulnerable plaque in coronary arteries.[25] Implementing earlier monitoring, ART, statin therapy, and other aggressive risk modification might help delay the onset of heart disease and portend better outcomes. The New York State Department of Health AIDS Institute has developed perioperative care guidelines for caring for patients who are HIV + requiring surgery. Generally, clinical optimization, determining HIV clinical status if elective surgery is required, preventing interruption of HAART therapy, limiting drug–drug interaction with HAART medications, ensuring appropriate venous thromboembolism prophylaxis, and following established perioperative practice standards are all recommended.[26]

This study represents the most current review of cardiac surgery outcomes in patients who are HIV + to date, but there are limitations. We conducted a retrospective review of a heterogenic, administrative payor database. Although we started by analyzing 59,695 patients with HIV, only 1759 (2.94%) of these patients underwent cardiac surgery, significantly limiting the power of the study. Inherent as a claims-based dataset, only inpatient data were collected, primarily for insurance purposes. Patients who were HIV + undergoing heart surgery were significantly sicker preoperatively, with less insurance coverage, implying an additional sources of selection bias. We found a large number of clinical variables used to develop multivariate regression analyses were different for patients who were HIV+; therefore, our data analysis was limited to linear regression modeling. Like all administrative databases, PearlDiver has limited capacity to interrogate HIV-specific disease variables like CD4 count, viral load, timing and use of ART therapy, and AIDS-defining illnesses. HIV-specific factors are known to influence cardiovascular disease progression and perioperative outcomes.[4,10] Administrative databases have limited capacity to interrogate these variables. Given the limitations of these data, our conclusions cannot be interpreted as definitive, as more clinical information is necessary to derive true perioperative risks of HIV infection in cardiac surgery. Future studies using large clinical datasets are necessary to appropriately risk-stratify patients who are HIV + to assist determining perioperative risks and surgical eligibility. These authors propose that established clinical databases, like the STS Database, begin to include more granular information relative to the HIV + population, so that true clinical risk of HIV infection can be more accurately calculated using existing surgical risk scoring models. Understanding the cause for a lesser proportion of cardiac surgery in patients who are HIV+, and whether HIV alone limits a patient's access to surgical

care, cannot be directly evaluated. Intraoperative variables like cardiopulmonary bypass time, crossclamp time, and blood product use, known to influence postoperative outcomes, were also unable to be assessed using this administrative database.

CONCLUSIONS

We provide a modern assessment of the risk of HIV + infection for patients undergoing cardiac surgery. Data show that patients who are HIV + undergoing cardiac surgery are at greater risk for postoperative pneumonia and readmission. Patients who are HIV + proportionately undergo less cardiac surgery compared with patients who are uninfected. We acknowledge that the PearlDiver Database used in this study is administrative and lacks granular information of clinical HIV + variables, ART treatment, and subsequent AIDS-defining illnesses. Given the increasing utility of the STS Database, and similar large clinical databases, these authors propose that much can be learned of this growing patient population if more granular HIV data are collected.

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.

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Key Words: HIV, cardiac surgery, antiretroviral, STS PROM, European System for Cardiac Operative Risk Evaluation

TABLE E1. Thirty-day post-coronary artery bypass grafting

Variable	HIV-negative (n = 324,718)	%	HIV-positive (n = 1048)	%	RR	95% CI		*P* value
Hospital LOS, mean ± SD	8.1 ± 6.7	–	8 ± 5.44	–	–	–	–	.8327
Pneumonia	6039	1.86	30	2.86	1.54	1.08	2.19	.0225
Stroke	2130	0.66	2	0.19	0.29	0.07	1.16	.0944
Heart failure	19,196	5.91	71	6.77	1.15	0.92	1.44	.2639
Myocardial infarction	3475	1.07	12	1.14	1.07	0.61	1.88	.9324
Renal injury	23,193	7.14	79	7.54	1.06	0.85	1.31	.6625
30-d all-cause readmission	40,902	12.60	133	12.69	1.01	0.86	1.18	.9636

HIV, Human immunodeficiency virus; *RR*, relative risk; *CI*, confidence interval; *LOS*, length of stay; *SD*, standard deviation.

TABLE E2. Thirty-day post-aortic valve replacement

Variable	HIV-negative (n = 122,299)	%	HIV- positive (n = 325)	%	RR	95% CI		*P* value
Hospital LOS, mean ± SD	8.7 ± 7.65	–	10.5 ± 7.44	–	–	–	–	.0139
Pneumonia	2304	1.87	12	3.69	1.970	1.13	3.44	.0274
Stroke	1019	0.83	5	1.54	1.485	0.56	3.94	.6232
Heart failure	9889	8.04	29	8.92	1.109	0.78	1.57	.6316
Myocardial infarction	881	0.72	2	0.62	0.859	0.22	3.42	1.0000
Renal injury	9133	7.43	21	6.46	0.870	0.57	1.32	.5764
30-d all-cause readmission	19,818	16.12	87	26.77	1.660	1.39	1.99	<.00001

HIV, Human immunodeficiency virus; *RR*, relative risk; *CI*, confidence interval; *LOS*, length of stay; *SD*, standard deviation.

TABLE E3. Thirty-day post-mitral valve repair/replacement

Variable	HIV-negative (n = 76,616)	%	HIV-positive (n = 321)	%	RR	95% CI		*P* value
Hospital LOS, mean ± SD	10 ± 8.3	–	11 ± 8.8	–	–	–	–	.1476
Pneumonia	1495	1.98	15	4.67	2.364	1.44	3.88	.0011
Stroke	523	0.69	5	1.56	2.252	0.94	5.40	.1268
Heart failure	6622	8.76	22	6.85	0.783	0.52	1.17	.2689
Myocardial infarction	709	0.94	2	0.93	0.997	0.32	3.08	1.0000
Renal injury	4917	6.50	23	7.17	1.102	0.74	1.64	.7137
30-d all-cause readmission	14,601	19.31	95	29.60	1.533	1.29	1.82	<.00001

HIV, Human immunodeficiency virus; *RR*, relative risk; *CI*, confidence interval; *LOS*, length of stay; *SD*, standard deviation.

TABLE E4. Thirty-day post-aortic surgery

Variable	HIV-negative (n = 18,043)	%	HIV-positive (n = 65)	%	RR	95% CI		*P* value
Hospital LOS, mean ± SD	10.2 ± 9.6	–	10.5 ± 5.2	–	–	–		.8243
Pneumonia	399	2.21	0	0.00	–	–	–	.4300
Stroke	375	2.08	0	0.00	–	–	–	.4604
Heart failure	1266	7.02	3	4.62	0.66	0.22	1.99	.6075
Myocardial infarction	175	0.97	0	0.00	–	–	–	1.0000
Renal injury	1733	9.60	7	10.77	1.12	0.56	2.26	.9147
30-d all-cause readmission	3243	17.97	11	16.92	0.94	0.55	1.61	.9534

HIV, Human immunodeficiency virus; *RR*, relative risk; *CI*, confidence interval; *LOS*, length of stay; *SD*, standard deviation.

TABLE E5. HAART therapy and postoperative outcomes

Variable	HIV + cardiac surgery (n = 1759)							
	HAART− (n = 552)	%	HAART+ (n = 1207)	%	RR	95% CI		*P* value
Hospital LOS, mean ± SD	11, SD: 9	–	10, SD: 9	–	–	–	–	.14
History of percutaneous coronary intervention	23	4.16	66	5.47	0.78	0.49	1.24	.35
Pneumonia	13	2.35	34	2.81	0.86	0.46	1.66	.75
Stroke	1	0.18	10	0.83	0.22	0.03	1.75	.21
Heart failure	33	5.98	75	6.21	0.98	0.66	1.47	1
Myocardial infarction	4	0.72	12	0.99	0.89	0.55	1.45	.74
Renal injury	37	6.7	74	6.13	1.12	0.77	1.64	.62
30-d all-cause readmission	100	18.1	176	14.58	1.28	1.13	1.45	.0001

HIV, Human immunodeficiency virus; *HAART*, highly active antiretroviral therapy; *RR*, relative risk; *CI*, confidence interval; *LOS*, length of stay; *SD*, standard deviation.