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Association between Glycemic Control and Adverse Outcomes in Atrial Fibrillation: Evidence from a Large Real-world Cohort

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Abstract

Objectives: Diabetes mellitus is a common comorbidity in patients with atrial fibrillation (AF), but the impact of glycemic control on clinical outcomes in this population remains incompletely characterized. This study aimed to compare clinical outcomes between AF patients with poorly controlled versus well-controlled diabetes mellitus.

Materials and Methods: We performed a retrospective cohort study using the TriNetX Research Network, a global federated health research platform providing access to electronic medical records across 128 healthcare organizations. Adult patients (18-90 years) with type 2 diabetes mellitus and AF were stratified based on HbA1c levels: poorly controlled diabetes (HbA1c ≥7.0%) and well-controlled diabetes (HbA1c ≤6.9%). After propensity score matching for baseline demographics and comorbidities, cohorts of 332,060 patients each were analyzed. The primary outcome was all-cause mortality. Secondary outcomes included cardiogenic shock, heart failure, ventricular tachycardia, acute kidney injury (AKI), cerebrovascular disease, chronic kidney disease (CKD), coronary artery disease (CAD), and hypertension. Outcomes were analyzed using risk analysis and Kaplan-Meier survival analysis with hazard ratios (HRs) and 95% confidence intervals (CIs) over a five-year follow-up period.

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Results: In this propensity-matched cohort study, patients with poorly controlled diabetes demonstrated significantly higher all-cause mortality compared to those with well-controlled diabetes (26.3% vs. 25.6%; HR: 1.070, 95% CI: 1.060-1.080; p<0.001). Poor glycemic control was associated with increased risk of heart failure (23.1% vs. 22.8%; HR: 1.071, 95% CI: 1.056-1.086; p<0.001), AKI (19.8% vs. 18.3%; HR: 1.132, 95% CI: 1.117-1.148; p<0.001), and CKD (19.4% vs. 17.8%; HR: 1.161, 95% CI: 1.145-1.178; p<0.001). Poorly controlled patients also had higher rates of CAD (18.3% vs. 17.9%; HR: 1.079, 95% CI: 1.062-1.096; p<0.001). Conversely, well-controlled diabetes was associated with reduced cardiogenic shock (2.2% vs. 2.3%; HR: 0.995, 95% CI: 0.963-1.028; p=0.771) and ventricular tachycardia (5.1% vs. 4.8%; HR: 0.977, 95% CI: 0.956-1.000; p=0.048).

Conclusion: Among patients with diabetes mellitus and AF, poor glycemic control is associated with significantly increased mortality and higher rates of cardiovascular and renal complications. These findings emphasize the importance of optimal glycemic control in diabetic patients with AF to improve clinical outcomes and reduce adverse events.

Keywords: Atrial fibrillation, diabetes mellitus, glycemic control, hemoglobin A1c, mortality, heart failure, acute kidney injury

Introduction

Atrial fibrillation (AF) is the most common sustained cardiac arrhythmia, affecting over 33 million people worldwide and representing a significant public health burden[1]. The prevalence of AF continues to increase with aging populations and rising cardiovascular comorbidities[2]. Among these comorbidities, diabetes mellitus stands out as one of the most prevalent and clinically significant, affecting approximately 20-25% of patients with AF[3]. The relationship between diabetes mellitus and AF is complex and bidirectional. Diabetes increases the risk of developing AF by approximately 40%, while patients with established AF have a higher prevalence of diabetes compared to the general population[4]. This association is mediated through multiple pathophysiological mechanisms, including structural cardiac remodeling, autonomic dysfunction, inflammation, and metabolic disturbances that create a substrate for arrhythmogenesis[5].

The coexistence of diabetes and AF creates a particularly high-risk clinical scenario. Both conditions independently increase the risk of stroke, heart failure, and cardiovascular mortality, and their combination appears to have synergistic effects on adverse outcomes[6]. Furthermore, diabetes complicates the management of AF by increasing bleeding risk with anticoagulation and potentially affecting the efficacy of rate and rhythm control strategies[7].

While the importance of glycemic control in diabetic patients is well-established, the specific impact of HbA1c levels on clinical outcomes in patients with concomitant AF remains incompletely characterized. Most studies have focused on the general diabetic population or specific cardiovascular subgroups, but comprehensive data examining outcomes across the spectrum of glycemic control in AF patients are limited[8].

Understanding the relationship between glycemic control and outcomes in AF patients has important clinical implications. Poor glycemic control may exacerbate the pathophysiological mechanisms underlying AF complications, including endothelial dysfunction, increased thrombogenicity, accelerated atherosclerosis, and worsening heart failure[9]. Conversely, tight glycemic control might reduce these risks but could also introduce hypoglycemic episodes that may trigger arrhythmias[10].

Recent guidelines emphasize individualized approaches to diabetes management, particularly in patients with multiple comorbidities[11]. However, specific

recommendations for glycemic targets in patients with AF are lacking, largely due to insufficient evidence from large-scale studies. This knowledge gap is particularly relevant given the expanding population of patients with both conditions and the need for evidence-based management strategies.

Therefore, we conducted this large-scale, propensity-matched study using a federated health research network to comprehensively evaluate the association between glycemic control and clinical outcomes in patients with diabetes mellitus and AF. We hypothesized that poor glycemic control would be associated with increased mortality and higher rates of cardiovascular complications in this high-risk population.

Materials and Methods

Data Source

This study utilized data from the TriNetX Research Network, a global federated health research platform providing access to electronic medical records (diagnoses, procedures, medications, laboratory values) across large healthcare organizations (HCOs). For this analysis, we used data from 128 HCOs within the Global Collaborative Network, representing a diverse array of healthcare settings across multiple geographic regions. The platform allows for real-time queries and robust analysis of de-identified patient data while maintaining privacy and security.

Study Population

We identified adult patients (aged 18-90 years) with both type 2 diabetes mellitus (ICD-10 code E11) and AF (ICD-10 codes I48.91, I48.0, I48.1, I48.2, I48.19, I48.21, I48.20, I48.11). From this population, we created two cohorts based on glycemic control: (1) poorly controlled diabetes defined by HbA1c ≥7.0% (TNX: 9037 or UMLS: LNC:4548-4), and (2) well-controlled diabetes defined by HbA1c ≤6.9% using the same laboratory codes.

The index date was defined as the first date when patients met all inclusion criteria (diabetes, AF, and qualifying HbA1c level). Both cohorts were followed for up to five years (1,825 days) after the index date, with a time window starting 1 day after the index event.

Our cohort included patients with all types of AF (paroxysmal, persistent, chronic, permanent, longstanding persistent, and unspecified) to provide a comprehensive real-world representation of AF patients with diabetes. This inclusive approach reflects actual clinical practice where AF subtype may vary over time or may be incompletely characterized across different healthcare settings.

All patients meeting initial inclusion criteria were followed for the entire observation period using an intention-to-treat approach. No patients were excluded during follow-up based on receiving interventions such as cardioversion, ablation, or antiarrhythmic drugs, as these treatments represent standard AF management and excluding patients receiving them would compromise generalizability.

Outcomes

The primary outcome was all-cause mortality within the follow-up period. Secondary outcomes included cardiogenic shock (ICD-10 code R57.0), heart failure (ICD-10 codes I50.x), ventricular tachycardia (ICD-10 codes I47.2, I47.20), acute kidney injury (ICD-10 codes N17, N17.9), cerebrovascular disease (ICD-10 codes I60-I69), chronic kidney disease (ICD-10 code N18) and coronary artery disease (ICD-10 codes I25.1, I25.10)

For each outcome, we excluded patients who had experienced the specific outcome before the index date to ensure we were capturing incident events during the follow-up period.

Propensity Score Matching

To minimize confounding by indication and create comparable cohorts, we employed propensity score matching. Propensity scores were calculated based on baseline demographics including age, sex, race, and ethnicity; and clinical comorbidities including acute kidney failure and chronic kidney disease, metabolic disorders, and hypertensive diseases.

Patients in the poorly controlled and well-controlled diabetes groups were matched 1:1 using nearest-neighbor matching. Balance between the matched cohorts was assessed using standardized mean differences, with values <0.1 considered indicative of good balance.

Statistical Analysis

Baseline characteristics were compared between the matched groups using standardized mean differences and p-values. For the primary and secondary outcomes, we employed risk analysis calculating the risk (proportion of patients experiencing the outcome) in each cohort, risk difference, risk ratio, and odds ratio with 95% confidence intervals (CIs). Kaplan-Meier survival analysis was performed to generate survival curves and estimate the probability of each outcome over time. Log-rank tests were used to compare survival distributions between cohorts, with hazard ratios (HRs) and 95% CIs calculated using Cox proportional hazards models.

All analyses were conducted using the TriNetX platform's built-in analytics tools. A two-sided p-value <0.05 was considered statistically significant.

Ethical Considerations

This study utilized de-identified data from the TriNetX Research Network, which complies with all relevant data protection regulations. As the study used only de-identified data, it was determined to be exempt from Institutional Review Board approval according to 45 CFR 46.104(d)(4). The study was conducted in accordance with the Declaration of Helsinki and the STROBE guidelines for reporting observational studies.

Results

Study Population and Baseline Characteristics

Before propensity score matching, we identified 339,206 patients with AF and poorly controlled diabetes (Cohort 1) and 594,706 patients with AF and well-controlled diabetes (Cohort 2). After propensity score matching, 332,060 patients remained in each cohort.

The baseline characteristics of the matched cohorts are presented in Table 1. The matched groups were well-balanced in terms of demographics and comorbidities, with standardized mean differences <0.02 for most variables,

Table 1. Baseline characteristics of propensity-matched cohorts

Characteristic	Poorly controlled diabetes (n=332,060)	Well-controlled diabetes (n=332,060)	p-value	Standardized difference
Demographics				
Age (years), mean ± SD	76.0±11.2	76.0±11.4	0.827	0.001
Age at index (years), mean ± SD	70.7±11.5	70.7±11.6	0.802	0.001
Female, n (%)	125,680 (37.8%)	124,166 (37.4%)	<0.001	0.009
Male, n (%)	191,498 (57.7%)	192,613 (58.0%)	0.006	0.007
Race, n (%)				
White	222,478 (67.0%)	224,534 (67.6%)	<0.001	0.013
Black or African American	42,099 (12.7%)	41,129 (12.4%)	<0.001	0.009
Asian	16,541 (5.0%)	16,224 (4.9%)	0.072	0.004
Ethnicity, n (%)				
Not Hispanic or Latino	232,619 (70.1%)	233,653 (70.4%)	0.006	0.007
Hispanic or Latino	18,573 (5.6%)	18,266 (5.5%)	0.100	0.004
Comorbidities, n (%)				
Acute kidney failure and CKD	135,537 (40.8%)	136,696 (41.2%)	0.004	0.007
Metabolic disorders	253,817 (76.4%)	254,735 (76.7%)	0.008	0.007
Hypertensive diseases	267,234 (80.5%)	267,677 (80.6%)	0.170	0.003

SD: Standard deviation, CKD: Chronic kidney disease

indicating excellent balance. The mean age was 76.0±11.2 years in the poorly controlled group and 76.0±11.4 years in the well-controlled group. Female representation was similar between groups (37.8% vs. 37.4%). The prevalence of key comorbidities was comparable, including acute kidney failure and chronic kidney disease (40.8% vs. 41.2%), metabolic disorders (76.4% vs. 76.7%), and hypertensive diseases (80.5% vs. 80.6%).

Primary Outcome: All-cause Mortality

The primary outcome of all-cause mortality occurred in 86,693 patients (26.3%) in the poorly controlled diabetes group compared to 84,273 patients (25.6%) in the well-controlled diabetes group (risk ratio 1.029, 95% CI: 1.021-1.038; p<0.001) (Table 2). The Kaplan-Meier survival analysis demonstrated significantly lower survival probability in the poorly controlled diabetes group compared to the well-controlled group (60.54% vs. 62.55% at the end of the 5-year follow-up period; HR: 1.070, 95% CI: 1.060-1.080; p<0.001) (Figure 1).

Secondary Outcomes

Poor glycemic control was associated with significantly higher incidence of several major cardiovascular and renal outcomes. Heart failure occurred in 41,363 patients (23.1%) in the poorly controlled group versus 40,607 patients (22.8%) in the well-controlled group (HR: 1.071, 95% CI: 1.056-1.086; p<0.001) (Figure 2A).

Acute kidney injury affected 43,545 patients (19.8%) in the poorly controlled group compared to 40,903 patients (18.3%) in the well-controlled group (HR: 1.132, 95% CI: 1.117-1.148; p<0.001) (Figure 2B). Similarly, chronic kidney disease developed in 40,034 patients (19.4%) in the poorly controlled group versus 36,702 patients (17.8%) in the well-controlled group (HR: 1.161, 95% CI: 1.145-1.178; p<0.001).

Coronary artery disease occurred in 30,371 patients (18.3%) in the poorly controlled group compared to 31,004 patients (17.9%) in the well-controlled group (HR: 1.079, 95% CI: 1.062-1.096; p<0.001). Cerebrovascular disease affected 29,497 patients (12.4%) in the poorly controlled group versus 28,790 patients (12.3%) in the well-controlled group (HR: 1.056, 95% CI: 1.039-1.073; p<0.001).

Conversely, some outcomes showed lower rates in the poorly controlled group. Cardiogenic shock occurred in 7,020 patients (2.2%) in the poorly controlled group versus 7,295 patients (2.3%) in the well-controlled group (HR: 0.995, 95% CI: 0.963-1.028; p=0.771). Ventricular tachycardia affected 14,638 patients (4.8%) in the poorly controlled group compared to 15,381 patients (5.1%) in the well-controlled group (HR: 0.977, 95% CI: 0.956-1.000; p=0.048).

Table 2. Risk ratios and hazard ratios of primary and secondary outcomes

Outcome	Poorly controlled diabetes (n=332,060)	Well-controlled diabetes (n=332,060)	Risk ratio (95% CI)	Hazard ratio (95% CI)	p-value
Primary outcome					
All-cause mortality	86,693 (26.3%)	84,273 (25.6%)	1.029 (1.021-1.038)	1.070 (1.060-1.080)	<0.001
Secondary outcomes					
Heart failure	41,363 (23.1%)	40,607 (22.8%)	1.013 (1.001-1.025)	1.071 (1.056-1.086)	<0.001
Acute kidney injury	43,545 (19.8%)	40,903 (18.3%)	1.078 (1.065-1.091)	1.132 (1.117-1.148)	<0.001
Chronic kidney disease	40,034 (19.4%)	36,702 (17.8%)	1.087 (1.073-1.101)	1.161 (1.145-1.178)	<0.001
Coronary artery disease	30,371 (18.3%)	31,004 (17.9%)	1.017 (1.003-1.032)	1.079 (1.062-1.096)	<0.001
Cerebrovascular disease	29,497 (12.4%)	28,790 (12.3%)	1.011 (0.996-1.027)	1.056 (1.039-1.073)	<0.001
Cardiogenic shock	7.020 (2.2%)	7,295 (2.3%)	0.957 (0.925-0.989)	0.995 (0.963-1.028)	0.771
Ventricular tachycardia	14,638 (4.8%)	15,381 (5.1%)	0.938 (0.918-0.959)	0.977 (0.956-1.000)	0.048

CI: Confidence interval

Discussion

In this large propensity-matched cohort study of over 664,000 patients with diabetes mellitus and AF, we found that poor glycemic control was associated with significantly higher all-cause mortality and increased risk of major cardiovascular and renal complications. These findings provide important real-world evidence regarding the impact of glycemic control on clinical outcomes in this high-risk population.

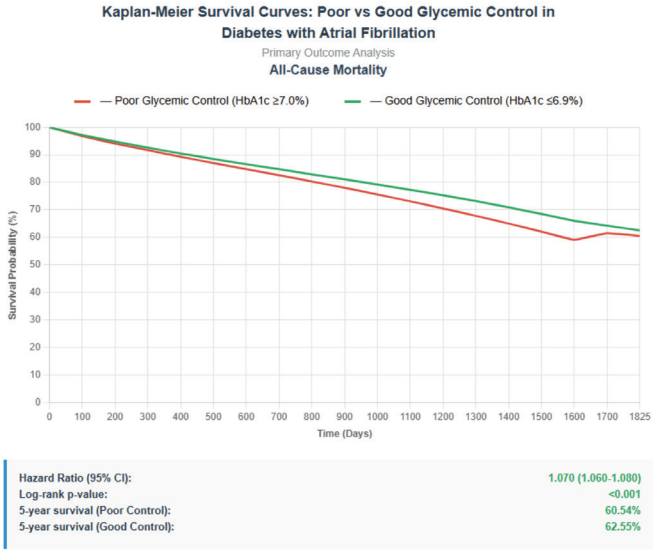

Figure 1. Kaplan-Meier survival curves for all-cause mortality
This figure shows survival probability over time (days) for patients with poorly controlled diabetes (orange line) versus well-controlled diabetes (green line). The poorly controlled diabetes group demonstrates lower survival probability throughout the follow-up period
CI: Confidence interval

Our findings of increased mortality with poor glycemic control align with previous studies in diabetic populations, but extend these observations specifically to patients with concomitant AF[12]. The 7% relative increase in mortality risk associated with poor glycemic control, while modest, represents a clinically significant difference given the large absolute number of patients affected and the already elevated baseline risk in this population.

The increased risk of heart failure associated with poor glycemic control is particularly noteworthy given the bidirectional relationship between diabetes and heart failure[13]. Poor glycemic control contributes to myocardial dysfunction through multiple mechanisms, including advanced glycation end products, oxidative stress, microvascular dysfunction, and metabolic alterations[14]. In patients with AF, these effects may be amplified by the hemodynamic consequences of irregular heart rhythm and the potential for tachycardia-induced cardiomyopathy.

The strong association between poor glycemic control and both acute and chronic kidney disease represents another critical finding with important clinical implications.

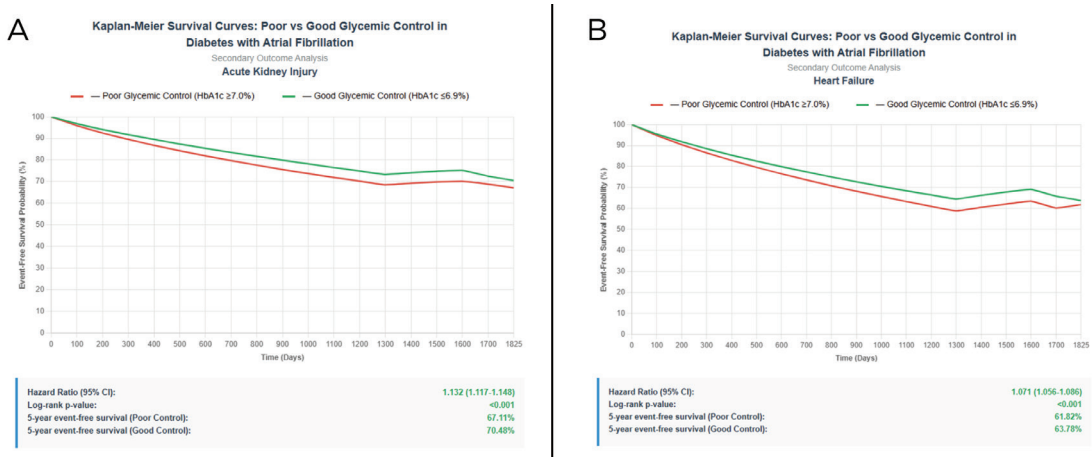

Figure 2 A, B. Kaplan-Meier curves for key secondary outcomes
A) Heart failure: event-free probability for heart failure over time, with the poorly controlled diabetes group showing higher event rates. B) Acute kidney injury: event-free probability for acute kidney injury over time, demonstrating increased risk in the poorly controlled diabetes group
CI: Confidence interval

Diabetic nephropathy is a well-recognized complication of diabetes, but our results suggest that the risk may be particularly pronounced in patients with concomitant AF[15]. This finding is concerning given that chronic kidney disease further increases cardiovascular risk and complicates anticoagulation management in AF patients.

The increased risk of coronary artery disease and cerebrovascular disease with poor glycemic control underscores the systemic vascular effects of hyperglycemia[16]. These findings are consistent with the established role of diabetes as a major risk factor for atherosclerotic cardiovascular disease, but highlight the particular vulnerability of patients with both diabetes and AF.

Interestingly, we observed lower rates of certain outcomes in the poorly controlled diabetes group, including cardiogenic shock, ventricular tachycardia, and pulmonary embolism. These seemingly paradoxical findings may reflect several factors, including differences in healthcare utilization patterns, competing risks, or differential coding practices between patient groups. The lower rate of ventricular tachycardia in poorly controlled patients might reflect the predominance of atrial arrhythmias in this population or differences in monitoring intensity.

The mechanisms underlying the adverse effects of poor glycemic control in AF patients are likely multifactorial. Hyperglycemia promotes endothelial dysfunction, increases oxidative stress, enhances inflammation, and accelerates atherosclerosis[17]. In the context of AF these effects may be particularly detrimental due to the increased thrombotic risk, irregular hemodynamics, and potential for rapid ventricular rates that characterize this arrhythmia.

Our study has several important clinical implications. First, it emphasizes the critical importance of achieving and maintaining optimal glycemic control in diabetic patients with AF. The current findings support more aggressive diabetes management in this population, potentially including earlier initiation of combination therapy and more frequent monitoring.

Second, our results suggest that patients with both diabetes and AF represent a particularly high-risk group that may benefit from enhanced surveillance and preventive interventions. This might include more frequent cardiovascular risk assessments, earlier implementation of cardioprotective medications, and closer monitoring for complications such as heart failure and kidney disease.

Third, the findings highlight the need for integrated care approaches that address both conditions simultaneously. This may involve collaboration between cardiologists, endocrinologists, and primary care providers to optimize management of both diabetes and AF[18].

The influence of rate control strategies on outcomes in AF is well established, with landmark trials such as RACE and AFFIRM demonstrating the impact of rate versus rhythm control on mortality and morbidity. Our study did not specifically account for rate control medications or adequacy of ventricular rate control, as these variables involve complex confounding by indication and require granular clinical data not consistently available in large electronic health record databases. It is possible that differences in rate control between our cohorts could have influenced outcomes. However, our primary focus was on the association between glycemic control and outcomes, independent of specific medication effects. Future prospective studies should investigate the interaction between glycemic control, rate control strategies, and clinical outcomes in AF patients with diabetes[18-20].

Study Limitations

Several limitations of our study should be acknowledged. As an observational study, residual confounding cannot be excluded despite robust propensity matching. The use of a single HbA1c measurement to define glycemic control may not capture the full complexity of glucose management over time. A limitation of our propensity matching approach is that specific stroke and bleeding history were not included as discrete matching variables, though broad comorbidity categories and outcome-specific exclusion criteria were applied. The TriNetX database

structure did not permit calculation of composite clinical risk scores such as CHA2DS2-VASc and HAS-BLED, which would have provided additional risk stratification. However, key components of these scores, including age, sex, hypertension, and kidney disease, were included in our propensity matching. Our study included all AF subtypes rather than stratifying by AF pattern (paroxysmal, persistent, permanent), which enhances generalizability but precludes subtype-specific analyses. The relationship between glycemic control and outcomes may potentially vary by AF type, which warrants investigation in future studies. Additionally, specific diabetes medications and their potential cardioprotective effects could not be fully characterized in our analysis.

Despite these limitations, our study has important strengths, including the large sample size, diverse patient population, comprehensive assessment of outcomes, and robust propensity matching. The consistency of our findings across multiple outcome measures and their biological plausibility strengthen the validity of our conclusions.

Conclusion

In this large propensity-matched cohort study of patients with diabetes mellitus and AF, poor glycemic control was associated with significantly higher all-cause mortality and increased risk of cardiovascular and renal complications. These findings emphasize the critical importance of optimal glycemic control in diabetic patients with AF and support the need for integrated management approaches that address both conditions.

Our results provide real-world evidence supporting intensive diabetes management in patients with concomitant AF. The increased risks associated with poor glycemic control highlight the need for individualized treatment strategies that balance glycemic targets with other cardiovascular risk factors.

Future research should focus on identifying optimal glycemic targets for patients with both diabetes and AF, evaluating the effectiveness of specific diabetes medications in this population, and developing integrated care models that optimize outcomes for both conditions. Prospective randomized trials examining glycemic management strategies specifically in AF patients would provide higher-quality evidence to inform clinical practice guidelines.

Ethics

Ethics Committee Approval: This study utilized de-identified data from the TriNetX Research Network and was determined to be exempt from Institutional Review Board approval according to 45 CFR 46.104(d)(4).

Informed Consent: This study used anonymized data from the TriNetX Research Network.

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Footnotes

Authorship Contributions

Surgical and Medical Practices: Essien E, Agyekum A, Carboo A, Amoako G, Owusu-Achiaw J, Concept: Essien E, Agyekum A, Carboo A, Amoako G, Design: Essien E, Agyekum A, Carboo A, Amoako G, Owusu-Achiaw J, Data Collection and/or Processing: Essien E, Agyekum A, Carboo A, Amoako G, Analysis and/or Interpretation: Essien E, Agyekum A, Carboo A, Literature Search: Essien E, Agyekum A, Writing: Essien E, Amoako G, Owusu-Achiaw J.

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