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Catheter-related complications and mortality of atrial fibrillation ablation following introduction of contact force-sensing technology

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ABSTRACT

Objectives Contact force-sensing catheters allow real-time catheter-tissue contact force monitoring during atrial fibrillation. These catheters were rapidly adopted into clinical practice following market introduction in 2014, but concerns have been raised regarding collateral damage such as esophageal injury. We sought to examine whether the introduction of force-sensing catheters was associated with a change in short-term and intermediate-term acute care use, complications and mortality following atrial fibrillation ablation.

Design Retrospective cohort analysis. We used inverse probability treatment weight matching to account for the differences in baseline characteristics between groups.

Setting We examined patients included in the OptumLabs Data Warehouse who underwent ablation for atrial fibrillation before (2011–2013) and after (2015–2017) the market introduction of contact force-sensing catheters.

Main outcome measures We examined 30-day and 90-day rates of all-cause acute care use, including hospitalizations and emergency department visits, as well as death and hospitalization for catheter-related complications, including atrioesophageal fistula, pericarditis, cardiac tamponade/perforation and stroke/transient ischemic attack.

Results Our sample included 3470 and 5772 patients who underwent atrial fibrillation (AF) ablation before and after market introduction of contact force-sensing catheters, respectively. Complication rates were low and did not differ between the two periods (p>0.10 for each outcome). The 30-day and 90-day mortality was 0.1% and 0.3%, respectively after market introduction and unchanged from prior to 2014. The 90-day rates of all-cause acute care use decreased, from 27.0% in 2011–2013 to 23.9% in 2015–2017 (p<0.001).

Conclusions AF ablation-related catheter complications and mortality are low and there has been no significant change following the introduction of force-sensing catheters.

Key messages

What is already known about this subject?

- Previous studies examining complications following atrial fibrillation (AF) ablation are limited in their application to contemporary practice.
- Force-sensing catheter technology was rapidly and widely adopted for AF ablation procedures, however there are limited data on complications related to the use of these catheters.
- Force-sensing catheters produce more extensive ablation lesions that could predispose to complications related to cardiac perforation and collateral damage to the esophagus.

What are the new findings?

- We performed a retrospective cohort analysis using OptumLabs Data Warehouse to compare rates of adverse outcomes among patients undergoing ablation before (n=3470) and after (n=5772) the market introduction of contact force-sensing catheters.
- Complication rates were low and did not differ between the two periods (p>0.10 for each outcome).
- The 30-day and 90-day mortality was 0.1% and 0.3%, respectively and did not change after introduction of force sensing technology.
- The 90-day rates of all-cause acute care use decreased from 27.0% to 23.9% after introduction of force sensing technology (p<0.001).

How might these results affect future research or surgical practice?

- The introduction of contact-force catheter technology was not associated with increasing rates of 30-day or 90-day mortality, or serious peri-procedural complications such as atrial perforation.
- The real-world use of these catheters does not appear to be associated with increased rates of hospitalization or emergency visits.

INTRODUCTION

The incidence of short-term and intermediate-term safety outcomes following catheter ablation of atrial fibrillation (AF) requires continual reappraisal. Not only has the AF ablation technique evolved from segmental pulmonary vein ablation to wide area circumferential isolation with possible

substrate modification, but there have also been significant advances in mapping and ablation catheter technology to improve procedural safety and effectiveness. Previous studies examining complications following AF ablation are limited in their application to contemporary practice because they preceded the introduction of currently used catheters capable of force-sensing and increased power delivery to the posterior left atrial wall.[1–5] Furthermore, there are limited data on specific procedure-related complications that occur in the short-term and intermediate-term such as pericarditis and atrioesophageal fistula (AEF) in a contemporary cohort.[6]

The most significant recent advance in catheter technology has been the ability to measure contact force. Contact force-sensing catheters were introduced to the US market in early 2014 and have been rapidly and widely adopted. Contact force-sensing catheters are not dependent on tactile sensation and allow titration of contact force resulting in more consistent transmural ablation lesions.[7–9] While this is generally desirable for procedural success, the deeper ablation lesions could predispose to procedural complications, especially those related to cardiac perforation and collateral damage to adjacent structures. A recent analysis of the Food and Drug Administration's Manufacturer and User Facility Device Experience database suggested that use of contact force-sensing catheters may be associated with increased risk for AEF formation.[10]

To evaluate these concerns and provide contemporary safety data, we examined real-world outcomes following AF ablation using data from a large, national contemporary population of commercially insured patients and Medicare Advantage beneficiaries. Specifically, we examined whether the introduction of force-sensing catheters was associated with an increase in short-term and intermediate-term acute care use (hospitalization and emergency department (ED) visits), death, and complications, particularly those related to cardiac perforation including AEF.

METHODS

Data source

We conducted a retrospective cohort analysis using OptumLabs Data Warehouse, a large US database with de-identified administrative claims data for individuals enrolled in private and Medicare Advantage health plans.[11] All ages, ethnicities, and racial groups are represented in the database spanning all 50 states. Medical claims include information on physician, hospital, and outpatient prescription services.[12]

Study population

The study population included adult patients (≥18 years) with AF who underwent AF ablation between January 1, 2011 and September 30, 2017. The patients were identified using International Classification of Diseases (ICD)-9 and ICD-10 diagnostic codes for AF, combined with Current Procedural Terminology (CPT) procedural codes for AF ablation. If a patient received multiple ablations, the date of the first ablation was defined as the index date. All patients were required to have continuous medical enrollment for at least 12 months prior to the index procedure and 90 days post the index procedure or death. The Mayo Clinic Institutional Review Board exempted this study from review because the study used pre-existing, deidentified data.

Because contact force-sensing technology was introduced in 2014, we excluded patients who underwent AF ablation during this time. Essentially, we used this as a wash-out period, recognizing that while there was widespread adoption, time was needed for cardiac electrophysiology labs to use already purchased catheters and replace existing stock, exchanging contact force-sensing catheters for traditional catheters.

Covariates

Independent variables of interest at baseline were demographics: age, gender, and race (white, black, Hispanic, Asian, or unknown), region (Midwest, Northeast, South, or West) and baseline clinical characteristics: anemia, vascular disease, chronic obstructive pulmonary disease, obesity, hypertension, diabetes, renal disease, congestive heart failure, history of cardioversion, or stroke. These factors included all components of the HAS-BLED (a bleeding risk score) and CHA_2DS_2-VASc (a stroke risk score) scores. We also included baseline prescriptions for amiodarone. Comorbidities were captured by ICD-9 and ICD-10 codes in any position on claims in the 12 months prior to the index ablation procedure. Use of amiodarone in the 90 days prior to index ablation date was determined based on pharmacy claims.

Primary and secondary outcomes

Our primary outcome was all-cause acute care use, including the immediate peri-procedural period (index hospitalization for ablation), as well as subsequent ED visits and hospitalizations, within 30 days and 90 days of AF ablation. Secondary outcomes were all-cause mortality and ablation-specific complications within 30 days and 90 days of ablation. Ablation-specific complications encountered during the index hospitalization included cardiac perforation resulting in tamponade or need for urgent intervention, pericarditis, stroke or transient ischemic attack (TIA), and AEF (see online supplemental appendix table 1 for pertinent ICD-9, ICD-10, and CPT codes). Catheter-related complications were identified using primary and secondary discharge diagnosis codes (see online supplemental appendix table 2 for pertinent ICD-9, ICD-10, and CPT codes). The codes and algorithms used herein have been commonly used and validated in many previous studies.[13 14]

Mortality was identified based on the Social Security Death Master File and patient discharge status.

Since AEF is difficult to assess with a single diagnosis code, we used a hierarchical method incorporating

multiple codes as outlined in online supplemental appendix table 3. In brief, AEF was assessed as either definite or probable based on diagnosis codes occurring within 90 days of ablation. Definite AEF was defined as: (1) a diagnosis code for AEF *or* esophageal injury associated with death; or (2) an esophageal intervention associated with a diagnosis of either AEF, esophageal injury, mediastinal infection, air embolism, or hematemesis. Probable AEF was defined when: (1) patients underwent an esophageal intervention *and* had other possible signs of AEF including stroke, multi-organ failure, infection/sepsis, altered mental status, fever chest pain, or dysphagia; or (2) codes for mediastinal infection, air embolism, or hematemesis were associated with death; or (3) codes for both stroke *and* infection/sepsis were associated with death.

In order to reflect the known clinical difficulty in establishing a diagnosis of AEF, we performed a sensitivity analysis in which AEF was defined as *any two* of the diagnosis codes occurring within 90 days of ablation: mediastinal infection, air embolism, hematemesis, stroke/TIA, multi-organ failure, infection/sepsis, altered mental status, fever, chest pain, or dysphagia.

Statistical analyses

To examine the association of the contact force-sensing technology introduced in 2014 on the risk of several outcomes, we created a balanced cohort (before 2011–2013 vs after 2015–2017). We used inverse probability of treatment weighting (IPTW) to balance covariates between the two time periods. The underlying propensity model included the demographics, comorbidities, and baseline medication use shown in table 1. We evaluated the balance among the two time periods by comparing standardized mean differences of baseline covariates. A baseline characteristic was considered balanced if the standardized mean difference was <10%. We used a logistic regression to compare treatments in the weighted population. All analyses were conducted using SAS software V.9.4 and Stata V.15.1.

Table 1 Patient characteristics before and after IPTW.

	Before IPTW			After IPTW		
	2011–2013 (N=3470)	2015–2017 (N=5772)	Std. Diff. (%)	2011–2013 (N=3470)	2015–2017 (N=5772)	Std. Diff. (%)
Age, mean	61	64.2	31.60	62.83	62.9	0.90
Gender						
Female	28.60%	33.90%	11.30	31.60%	31.80%	0.50
Male	71.40%	66.10%	11.30	68.40%	68.20%	0.50
Race						
White	82.20%	82.30%	4.00	82.40%	82.30%	0.20
Black	8.80%	7.70%	4.30	8.10%	8.10%	0.00
Hispanic	4.30%	5.10%	3.70	4.80%	4.80%	0.40
Asian	1.70%	1.60%	1.00	1.60%	1.60%	0.10
Unknown	3.00%	3.30%	2.10	3.20%	3.20%	0.10
Baseline characteristics						
Amiodarone use	9.00%	12.00%	12.60	11.00%	11.00%	0.80
Anemia	21.00%	19.00%	4.40	20.00%	20.00%	0.20
Vascular disease	24.00%	27.00%	5.90	26.00%	26.00%	0.20
COPD	6.00%	5.00%	3.00	6.00%	6.00%	0.10
Obesity	31.00%	43.00%	23.80	38.00%	38.00%	0.30
Hypertension	78.00%	81.00%	7.40	80.00%	80.00%	0.30
Diabetes	19.00%	23.00%	10.40	22.00%	21.00%	0.90
Renal disease	7.00%	12.00%	16.20	10.00%	10.00%	0.80
CHF	24.00%	28.00%	8.60	27.00%	27.00%	0.90
Cardioversion	41.00%	43.00%	3.90	42.00%	42.00%	0.20
Stroke	7.00%	3.00%	18.90	5.00%	5.00%	0.30
HAS-BLED, mean*	1.7	1.9	14.40	1.8	1.9	2.70
CHA_2DS_2-VASc, mean*	2.4	2.7	23.10	2.6	2.6	4.70

*Not included in IPTW.
CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; IPTW, inverse probability of treatment weighting.

Table 2 Clinical events before (2011-2013) and after (2015-2017) introduction of force-sensing catheters.

	Before (2011–2013) n=3470 (%)	After (2015–2017) n=5772 (%)	P value
30-day events			
AEF	0.0	0.01	–
Definite	0.0	0.01	–
Probable	0.0	0.01	–
Sensitivity	1.1	0.9	0.247
Death	0.2	0.1	0.309
Tamponade or intervention	0.2	0.3	0.321
Pericarditis	1.4	1.5	0.735
Stroke/TIA	0.1	0.1	0.630
Hospitalization or ED visit	18.1	16.8	0.134
90-day events			
AEF	0.04	0.09	0.379
Definite	0.04	0.04	0.942
Probable	0.04	0.07	0.580
Sensitivity	2.2	1.6	0.039
Death	0.5	0.3	0.226
Tamponade or intervention	0.4	0.5	0.494
Pericarditis	1.7	1.8	0.675
Stroke/TIA	0.2	0.2	0.960
Hospitalization or ED visit	27.0	23.9	0.001

AEF, atrioesophageal fistula; ED, emergency department; TIA, transient ischemic attack.

RESULTS

Patient characteristics

Table 1 shows the baseline characteristics of patients undergoing AF ablation before and after introduction of contact force-sensing catheters, including 3470 patients who underwent ablation between 2011 and 2013 and 5722 patients who underwent ablation between 2015 and 2017. Patients undergoing ablation after 2014 were older, more obese, more likely females and with lower history of stroke. As demonstrated in the right panel of table 1, the groups were well-balanced following inverse probability weight matching, with all standardized mean differences <1%. There was no significant difference in age, gender, race, or comorbidities. The majority of patients included in our sample were men and white, and most had a history of hypertension. The mean CHA_2DS_2-VASc score was 2.6 in both groups between 2011–2013 and 2015–2017, respectively. The mean HAS-BLED score was 1.8 and 1.9, respectively.

Outcomes

The overall adjusted rates of short-term and intermediate-term all-cause emergency visits and hospitalizations are reported in table 2. There was a statistically significant reduction in the 90-day rates of all-cause acute care use, including ED visits and hospitalizations, in the years following market introduction of the contact-sensing catheters, from 27.0% to 23.9% (p<0.001). Prior to the introduction of contact force-sensing catheters, 18.1% of patients had at least one hospitalization or emergency visit within 30 days of undergoing AF ablation, compared with 16.8% in the years following the introduction of contact force-sensing catheters (p=0.134).

Adjusted rates of short-term and intermediate-term risk of mortality and procedural complications are also reported in table 2. We found no difference in the secondary outcomes of mortality and procedural complications before and after the market introduction of contact force-sensing catheters. The 30-day and 90-day mortality rates were not significantly changed after market introduction of force-sensing catheters (0.2% and 0.5% before vs 0.1% and 0.3% after, respectively; p values >0.10). Specifically, there was no difference in 30-day and 90-day risk of AEF (0.0% and 0.04% before vs 0.01% and 0.09% after; p>0.10), tamponade or intervention (0.2% and 0.4% before vs 0.3% and 0.5% after; p>0.3) and stroke (0.1% and 0.2% before vs 0.1% and 0.2% after; p>0.6).

DISCUSSION

We examined short-term and intermediate-term safety outcomes of patients undergoing AF ablation following the introduction and widespread adoption of contact-force sensing catheters in 2014, compared with outcomes observed among patients for whom previously available standard catheters were used. The main findings of analysis include: (1) the introduction of contact-force catheter technology did not appear to be associated with increasing rates of death and serious peri-procedural complications, including short-term and intermediate-term adverse events; (2) specifically, the introduction of contact-force catheter technology did not appear to be associated with increased risk of AEF or cardiac perforation; (3) the introduction of contact-force catheter technology did not appear to be associated with increased rates of hospitalization or emergency visits and may have been associated with a reduction in overall healthcare utilization at 90 days.

This study compares real-world, modern-era outcomes in a large, national adjusted cohort. Contrary to previous unadjusted reports, we found that AF ablation as practiced in the modern era following introduction of force-sensing catheters does not carry an increased risk of AEF or cardiac perforation. Our study suggests that the use of contact force-sensing catheters carries a small, approximately 0.1%, risk of AEF as well as low rate of mortality and morbidity due to serious adverse events related to stroke, cardiac perforation, hospitalizations, and emergency room visits. While this study did not examine the effectiveness of AF ablation following the introduction of force-sensing catheters, the low rates of adverse outcomes of AF ablation as practiced in the real world is highly encouraging and consistent with recent reports examining short-term events.[6] A recent analysis of AF ablation

trends using the Nationwide Readmissions Database from 2010 to 2015 reported a 30-day inpatient mortality rate of 0.46%, which is higher than our study despite not capturing out-of-hospital deaths, readmissions across different states, or long-term complications that can occur after 30 days (eg, AEF). It is worth noting that the Nationwide Readmissions Database contains only AF ablations performed among hospitalized patients, which likely represents a higher risk patient population given that the majority of contemporary AF ablation procedures are performed in the ambulatory setting. Another recent analysis of demonstrated that both contact force and non-contact force ablation catheters have similarly low incidence of AEF, however this analysis was derived only from ablation device manufacturer's complaint database.[15] Thus, in comparison to other studies, our analysis has the advantage of being both contemporaneous and representative of broad populations of patients undergoing AF ablation in routine practice.

AEF is one of the most morbid and lethal complications of catheter ablation of AF. While initially thought to be exceedingly rare, the incidence of AEF is now being revised and is thought to be higher than originally expected, with current estimates ranging from 0.02% to 0.11%.[16–20] Given the increase in AF ablation procedures in recent years, AEF continues to be among the most feared complications. However, the actual incidence of AEF has likely been underestimated due to the difficulty in establishing the diagnosis and its association with the AF ablation procedure. Patients with AEF usually present 2–4 weeks following the index ablation procedure with variable symptoms of fever, sepsis, hematemesis, or stroke.[16 21] Given the acuity and non-specificity of the symptoms, the patient may not be referred back to the institution where the index ablation is performed, and an association with the AF ablation procedure may be overlooked. Thus, the diagnosis of AEF may be missed and/or under-reported in single-center studies. Furthermore, given the temporal delay in the formation and clinical presentation of AEF, studies that examine acute or short-term peri-procedural complications are likely to miss or under-report this complication. Our study examined multiple algorithms as sensitivity analyses and did not find an increase in AEF over time.

Previous reports examining the period between 2000 and 2010 have demonstrated similarly low rates of serious complications with AF ablation, but these studies generally examined acute peri-procedural complications and did not examine potential adverse outcomes that may occur in the intermediate term following AF ablation, such as AEF or late-presenting tamponade. These studies also preceded the use of contact force-sensing technology and thus are not representative of modern practice. More recent studies examining AF ablation from single tertiary referral centers probably underestimated the true incidence of procedure-related death, AEF and other major complications, both because these centers tend to be more specialized and perform a larger number of procedures, but also because the centers tend to have greater experience, having used the novel technologies for a longer period of time. Our study is the first claims-based examination of AF ablation in the modern era to focus on intermediate-term complications and mortality, thereby capturing all hospitalizations regardless of institution or geography.

Limitations

There are several limitations that should be considered. First, using claims-based data, we are unable to identify the exact catheters used for ablation, as this information is not available. Therefore, our finding of no increasing rates of mortality and complications following the introduction of contact-force ablation catheters does not lead to a firm conclusion of no increased risks associated with this technology because it might have been confounded by other factors such as the increasing adoption of cryoballoon catheters in recent years. Given the rapid adoption of contact force-sensing catheters, it is reasonable to assume that these catheters were increasingly used after the 12-month blanking period following their introduction in 2014. Nevertheless, this limitation emphasizes the importance of integrating the Unique Device Identifier into claims,[22] which would enable future studies to explicitly compare outcomes among patients for whom different catheters are used. Second, while we found no trends of increased risk of safety outcomes after the introduction of contact-force catheters, we cannot rule out residual confounding despite propensity risk adjustment. In addition, we emphasize that the ascertainment of outcomes and covariates in this study relied on administrative data/claims which are subject to misclassification. No manual chart review to validate individual codes was feasible given the de-identified nature of the database. However, there would be no systematic ascertainment differences between the two treatment groups, and any potential misclassification should be non-differential and should not influence estimated treatment effects. In addition, the diagnosis and procedure codes used in this study have demonstrated good performance in validation studies with positive predictive values around 90%.[14 23–29]

CONCLUSIONS

The introduction of contact-force catheter technology in the modern era was not associated with increasing rates of 30-day or 90-day mortality, or serious peri-procedural complications, including short-term and intermediate-term serious adverse events and, importantly, AEFs. Furthermore, real-world use of these catheters does not appear to be associated with increased rates of hospitalization or emergency visits. Continued efforts are needed to monitor contemporary use of novel technologies to ensure that patients are achieving higher-quality care outcomes.

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Supplemental Appendix

Appendix table 1

Category	Code Type	Code	Description
Pericarditis (which includes all diagnoses of pericarditis that were not intervened upon)	ICD9-DX	420.0	Acute Pericarditis in diseases classified elsewhere
	ICD10-DX	I30.0	Acute nonspecific idiopathic pericarditis
	ICD9-DX	420.90	Acute pericarditis, unspecified
	ICD9-DX	420.91	Acute idiopathic pericarditis
	ICD9-DX	420.99	Other acute pericarditis
	ICD9-DX	423.0	Hemopericardium
	ICD9-DX	423.1	Adhesive pericarditis
	ICD9-DX	423.2	Constrictive pericarditis
	ICD9-DX	423.8	Other specified diseases of pericardium
	ICD9-DX	423.9	Unspecified disease of the pericardium
	ICD10-DX	I30.0	Acute nonspecific idiopathic pericarditis
	ICD10-DX	I30.1	Infective pericarditis
	ICD10-DX	I30.8	Other forms of acute pericarditis
	ICD10-DX	I30.9	Acute pericarditis, unspecified
	ICD10-DX	I31.2	Hemopericardium, not elsewhere specified
	ICD10-DX	I31.3	Pericardial effusion (noninflammatory)
	ICD10-DX	I31.8	Other specified diseases of the pericardium
	ICD10-DX	I31.9	Disease of the pericardium, unspecified
Tamponade or intervention	ICD-9 DX	423.9	Cardiac Tamponade
	ICD-10 DX	I31.4	Cardiac Tamponade
	ICD-9 PX	37.0	Pericardiocentesis
	ICD-10 PX	0W9C30Z	Drainage of Mediastinum with Drainage Device, Percutaneous Approach
	ICD-10 PX	0W9C3ZZ	Drainage of Mediastinum, Percutaneous Approach

ICD-10 PX	0W9D30Z	Drainage of Pericardial Cavity with Drainage Device, Percutaneous Approach
ICD-10 PX	0W9D3ZX	Drainage of Pericardial Cavity, Percutaneous Approach, Diagnostic
ICD-10 PX	0W9D3ZZ	Drainage of Pericardial Cavity, Percutaneous Approach
ICD-10 PX	0W9D40Z	Drainage of Pericardial Cavity with Drainage Device, Percutaneous Endoscopic Approach
ICD-10 PX	0W9D4ZX	Drainage of Pericardial Cavity, Percutaneous Endoscopic Approach, Diagnostic
ICD-10 PX	0W9D4ZZ	Drainage of Pericardial Cavity, Percutaneous Endoscopic Approach
CPT	33010	Pericardiocentesis; initial
CPT	33011	Pericardiocentesis; subsequent
CPT	G9408	Patients with cardiac tamponade and/or pericardiocentesis occurring within 30 days
CPT	G9409	Patients without cardiac tamponade and/or pericardiocentesis occurring within 30 days
ICD-9 PX	37.10	Incision of Heart, Not Otherwise Specified
ICD-10 PX	02N60ZZ	Release Right Atrium, Open Approach
ICD-10 PX	02N63ZZ	Release Right Atrium, Percutaneous Approach
ICD-10 PX	02N64ZZ	Release Right Atrium, Percutaneous Endoscopic Approach
ICD-10 PX	02N70ZZ	Release Left Atrium, Open Approach
ICD-10 PX	02N73ZZ	Release Left Atrium, Percutaneous Approach
ICD-10 PX	02N74ZZ	Release Left Atrium, Percutaneous Endoscopic Approach
ICD-9 PX	37.11	Cardiotomy
ICD-10 PX	02C60ZZ	Extirpation of Matter from Right Atrium, Open Approach
ICD-10 PX	02C63ZZ	Extirpation of Matter from Right Atrium, Percutaneous Approach
ICD-10 PX	02C64ZZ	Extirpation of Matter from Right Atrium, Percutaneous Endoscopic Approach
ICD-10 PX	02C70ZZ	Extirpation of Matter from Left Atrium, Open Approach

ICD-10 PX	02C73ZZ	Extirpation of Matter from Left Atrium, Percutaneous Approach
ICD-10 PX	02C74ZZ	Extirpation of Matter from Left Atrium, Percutaneous Endoscopic Approach
ICD-10 PX	02PA0YZ	Removal of Other Device from Heart, Open Approach
ICD-10 PX	02PA4YZ	Removal of Other Device from Heart, Percutaneous Endoscopic Approach
ICD-10 PX	02WA0YZ	Revision of Other Device in Heart, Open Approach
ICD-10 PX	02WA3YZ	Revision of Other Device in Heart, Percutaneous Approach
ICD-10 PX	02WA4YZ	Revision of Other Device in Heart, Percutaneous Endoscopic Approach
CPT	33310	Cardiotomy, exploratory
CPT	33315	Cardiotomy, exploratory with cardiopulmonary bypass
ICD-9 PX	37.12	Pericardiotomy
ICD-10 PX	02CN0ZZ	Extirpation of Matter from Pericardium, Open Approach
ICD-10 PX	02CN3ZZ	Extirpation of Matter from Pericardium, Percutaneous Approach
ICD-10 PX	02CN4ZZ	Extirpation of Matter from Pericardium, Percutaneous Endoscopic Approach
ICD-10 PX	02NN0ZZ	Release Pericardium, Open Approach
ICD-10 PX	02NN3ZZ	Release Pericardium, Percutaneous Approach
ICD-10 PX	02NN4ZZ	Release Pericardium, Percutaneous Endoscopic Approach
ICD-10 PX	0W9D00Z	Drainage of Pericardial Cavity with Drainage Device, Open Approach
ICD-10 PX	0W9D0ZX	Drainage of Pericardial Cavity, Open Approach, Diagnostic
ICD-10 PX	0W9D0ZZ	Drainage of Pericardial Cavity, Open Approach
ICD-10 PX	0WCD0ZZ	Extirpation of Matter from Pericardial Cavity, Open Approach
ICD-10 PX	0WCD3ZZ	Extirpation of Matter from Pericardial Cavity, Percutaneous Approach

ICD-10 PX	0WCD4ZZ	Extirpation of Matter from Pericardial Cavity, Percutaneous Endoscopic Approach
ICD-9 PX	37.24	Biopsy of Pericardium
ICD-10 PX	02BN0ZX	Excision of Pericardium, Open Approach, Diagnostic
ICD-10 PX	02BN3ZX	Excision of Pericardium, Percutaneous Approach, Diagnostic
ICD-10 PX	02BN4ZX	Excision of Pericardium, Percutaneous Endoscopic Approach, Diagnostic
ICD-9 PX	37.31	Pericardiectomy
ICD-10 PX	02BN0ZZ	Excision of Pericardium, Open Approach
ICD-10 PX	02BN3ZZ	Excision of Pericardium, Percutaneous Approach
ICD-10 PX	02BN4ZZ	Excision of Pericardium, Percutaneous Endoscopic Approach
ICD-10 PX	02TN0ZZ	Resection of Pericardium, Open Approach
ICD-10 PX	02TN3ZZ	Resection of Pericardium, Percutaneous Approach
ICD-10 PX	02TN4ZZ	Resection of Pericardium, Percutaneous Endoscopic Approach
ICD-9 PX	37.49	Other Repair of Heath and Pericardium
ICD-10 PX	02163Z7	Bypass Right Atrium to Left Atrium, Percutaneous Approach
ICD-10 PX	02H60YZ	Insertion of Other Device into Right Atrium, Open Approach
ICD-10 PX	02H63YZ	Insertion of Other Device into Right Atrium, Percutaneous Approach
ICD-10 PX	02H64YZ	Insertion of Other Device into Right Atrium, Percutaneous Endoscopic Approach
ICD-10 PX	02H70YZ	Insertion of Other Device into Left Atrium, Open Approach
ICD-10 PX	02H73YZ	Insertion of Other Device into Left Atrium, Percutaneous Approach
ICD-10 PX	02H74YZ	Insertion of Other Device into Left Atrium, Percutaneous Endoscopic Approach

ICD-10 PX	02HA0YZ	Insertion of Other Device into Heart, Open Approach
ICD-10 PX	02HA3YZ	Insertion of Other Device into Heart, Percutaneous Approach
ICD-10 PX	02HA4YZ	Insertion of Other Device into Heart, Percutaneous Endoscopic Approach
ICD-10 PX	02HK0YZ	Insertion of Other Device into Right Ventricle, Open Approach
ICD-10 PX	02HK3YZ	Insertion of Other Device into Right Ventricle, Percutaneous Approach
ICD-10 PX	02HK4YZ	Insertion of Other Device into Right Ventricle, Percutaneous Endoscopic Approach
ICD-10 PX	02HL0YZ	Insertion of Other Device into Left Ventricle, Open Approach
ICD-10 PX	02HL3YZ	Insertion of Other Device into Left Ventricle, Percutaneous Approach
ICD-10 PX	02HL4YZ	Insertion of Other Device into Left Ventricle, Percutaneous Endoscopic Approach
ICD-10 PX	02HN0YZ	Insertion of Other Device into Pericardium, Open Approach
ICD-10 PX	02HN3YZ	Insertion of Other Device into Pericardium, Percutaneous Approach
ICD-10 PX	02HN4YZ	Insertion of Other Device into Pericardium, Percutaneous Endoscopic Approach
ICD-10 PX	02QA0ZZ	Repair Heart, Open Approach
ICD-10 PX	02QA3ZZ	Repair Heart, Percutaneous Approach
ICD-10 PX	02QA4ZZ	Repair Heart, Percutaneous Endoscopic Approach
ICD-10 PX	02QN0ZZ	Repair Pericardium, Open Approach
ICD-10 PX	02QN3ZZ	Repair Pericardium, Percutaneous Approach
ICD-10 PX	02QN4ZZ	Repair Pericardium, Percutaneous Endoscopic Approach
ICD-9 PX	37.91	Open Chest Cardiac Massage
ICD-10 PX	02QA0ZZ	Repair Heart, Open Approach

CPT	33015	Tube pericardiostomy
CPT	33300	Repair of cardiac wound, without bypass
CPT	33305	Repair of cardiac wound with cardiopulmonary bypass
ICD-9 PX	37.93	Injection of Therapeutic Substance into Pericardium
ICD-10 PX	3E080GC	Introduction of Other Therapeutic Substance into Heart, Open Approach
ICD-10 PX	3E083GC	Introduction of Other Therapeutic Substance into Heart, Percutaneous Approach

*****Stroke/TIA codes are contained in Appendix Table 2

Appendix table 2.

Logic Code	Description	Code Type	Codes	Description	Additional Logic
A1	Atrioesophageal fistula	ICD-9 DX	530.89	Other specified disorders of esophagus	
		ICD-10 DX	K22.8	Other specified diseases of esophagus	
A2	Esophageal Injury/ Esophageal hematoma	ICD-9 DX	862.22	Injury to esophagus without menton of open wound in cavity	
		ICD-9 DX	998.6	Persistent postoperative fistula	
		ICD-9 DX	530.4	Perforation of esophagus	
		ICD-9 PX	42.84	Repair of esophageal fistula, not elsewhere classified	
		ICD-10 DX	S27.81xx	Injury of esophagus (thoracic part)	
		ICD-10 DX	T81.83XA	Persistent postprocedural fistula, initial encounter	
		ICD-10 DX	K22.3	Perforation of esophagus	
		ICD-10 DX	J95.04	Tracheo-esophageal fistula following tracheostomy	
B	Esophageal Surgery/ Resection	ICD-9 PX	42.4	Excision of esophagus	
		ICD-9 PX	42.41	Partial esophagectomy	
		ICD-9 PX	42.42	Total esophagectomy	
		ICD-9 PX	42.84	Repair of esophageal fistula, not elsewhere classified	
		ICD-9 PX	42.82	Suture of laceration of esophagus	
		ICD-9 PX	43.9	Total gastrectomy	
		ICD-9 PX	43.5	Partial gastrectomy with anastomosis to esophagus	
		ICD-10 PX	0DB50ZZ	Excision of Esophagus, Open Approach	
		ICD-10 PX	0DB53ZZ	Excision of Esophagus, Percutaneous Approach	

		ICD-10 PX	0DB57ZZ	Excision of Esophagus, Via Natural or Artificial Opening
		ICD-10 PX	0DT50ZZ	Resection of Esophagus, Open Approach
		ICD-10 PX	0DT54ZZ	Resection of Esophagus, Percutaneous Endoscopic Approach
		ICD-10 PX	0DT57ZZ	Resection of Esophagus, Via Natural or Artificial Opening
		ICD-10 PX	0DT58ZZ	Resection of Esophagus, Endo
		ICD-10 PX	0DB40ZZ	Excision of Esophagogastric Junction, Open Approach
		ICD-10 PX	0DB43ZZ	Excision of Esophagogastric Junction, Percutaneous Approach
		ICD-10 PX	0DB44ZZ	Excision of Esophagogastric Junction, Perc Endo Approach
		ICD-10 PX	0DB47ZZ	Excision of Esophagogastric Junction, Via Opening
		ICD-10 PX	0DT40ZZ	Resection of Esophagogastric Junction, Open Approach
		ICD-10 PX	0DT44ZZ	Resection of Esophagogastric Junction, Perc Endo Approach
		ICD-10 PX	0DT47ZZ	Resection of Esophagogastric Junction, Via Opening
		ICD-10 PX	0DT48ZZ	Resection of Esophagogastric Junction, Endo
		ICD-10 PX	0DQ50ZZ	Repair Esophagus, Open Approach
C	Esophageal stenting	ICD-9 PX	42.81	Insertion of permanent tube into esophagus
		ICD-10 PX	0DH50DZ	Insertion of Intraluminal Device into Esophag, Open Approach
		ICD-10 PX	0DH50UZ	Insertion of Feeding Device into Esophagus, Open Approach
		ICD-10 PX	0DH53DZ	Insertion of Intraluminal Device into Esophag, Perc Approach

		ICD-10 PX	0DH53UZ	Insertion of Feeding Device into Esophagus, Perc Approach
		ICD-10 PX	0DH54DZ	Insertion of Intralum Dev into Esophag, Perc Endo Approach
		ICD-10 PX	0DH54UZ	Insertion of Feeding Device into Esophag, Perc Endo Approach
		ICD-10 PX	0DH57DZ	Insertion of Intraluminal Device into Esophagus, Via Opening
		ICD-10 PX	0DH57UZ	Insertion of Feeding Device into Esophagus, Via Opening
		ICD-10 PX	0DH58DZ	Insertion of Intraluminal Device into Esophagus, Endo
		ICD-10 PX	0DH58UZ	Insertion of Feeding Device into Esophagus, Endo
		CPT	43212	Esophagoscopy, flexible, transoral; with placement of endoscopic stent (includes pre- and post-dilation and guide wire passage, when performed)
		CPT	43266	Esophagogastroduodenoscopy, flexible, transoral; with placement of endoscopic stent (includes pre- and post-dilation and guide wire passage, when performed)
D	Mediastinal infection	ICD-9 DX	519.2	Mediastinitis
		ICD-9 DX	519.3	Other diseases of mediastinum, not elsewhere classified
		ICD-10 DX	J98.51	Mediastinitis
		ICD-10 DX	J98.59	Other diseases of mediastinum, not elsewhere classified
E	Air Embolism (pulmonary/cardiac)	ICD-9 DX	999.1	Air embolism as a complication of medical care, not elsewhere classified
		ICD-9 DX	909.3	Late effect of complications of surgical and medical care

		ICD-10 DX	T80.0XXA	Air embolism following infusion, transfusion and therapeutic injection, initial encounter	
		ICD-10 DX	T80.0XXD	Air embolism following infusion, transfusion and therapeutic injection, subsequent encounter	
		ICD-10 DX	T80.0XXS	Air embolism following infusion, transfusion and therapeutic injection, sequela	
F	Hematemesis	ICD-10 DX	K92.0	Hematemesis	
G	Stroke/TIA	ICD-9 DX	430	Subarachnoid hemorrhage	EXCLUSION: If any of the qualifying claims have: 800 <= DX Code <= 804.9, 850 <= DX Code <= 854.1 in any DX position OR DX V57xx as the principal DX Code, then EXCLUDE.
		ICD-9 DX	431	Intracerebral hemorrhage	
		ICD-9 DX	433.01	Occlusion and stenosis of basilar artery with cerebral infarction	
		ICD-9 DX	433.10	Occlusion and stenosis of carotid artery without mention of cerebral infarction	
		ICD-9 DX	433.11	Occlusion and stenosis of carotid artery with cerebral infarction	
		ICD-9 DX	433.21	Occlusion and stenosis of vertebral artery with cerebral infarction	
		ICD-9 DX	433.31	Occlusion and stenosis of multiple and bilateral precerebral arteries with cerebral infarction	
		ICD-9 DX	433.81	Occlusion and stenosis of other specified precerebral artery with cerebral infarction	
		ICD-9 DX	433.91	Occlusion and stenosis of unspecified precerebral artery with cerebral infarction	
		ICD-9 DX	434.00	Cerebral thrombosis without mention of cerebral infarction	
		ICD-9 DX	434.01	Cerebral thrombosis with cerebral infarction	
		ICD-9 DX	434.10	Cerebral embolism without mention of cerebral infarction	
		ICD-9 DX	434.11	Cerebral embolism with cerebral infarction	

ICD-9 DX	434.90	Cerebral artery occlusion, unspecified without mention of cerebral infarction	
ICD-9 DX	434.91	Cerebral artery occlusion, unspecified with cerebral infarction	
ICD-9 DX	435.0	Basilar artery syndrome	
ICD-9 DX	435.1	Vertebral artery syndrome	
ICD-9 DX	435.3	Vertebrobasilar artery syndrome	
ICD-9 DX	435.8	Other specified transient cerebral ischemias	
ICD-9 DX	435.9	Unspecified transient cerebral ischemia	
ICD-9 DX	436	Acute, but ill-defined, cerebrovascular disease	
ICD-9 DX	997.02	Iatrogenic cerebrovascular infarction or hemorrhage	
ICD-10 DX	G45.0	Vertebro-basilar artery syndrome	EXCLUSION: If any of the qualifying claims have any of the following codes in any DX position then EXCLUDE: S01.90XA, S02.0XXA, S02.0XXB, S02.10XA, S02.10XB, S02.101A, S02.101B, S02.102A, S02.102B, S02.109A,
ICD-10 DX	G45.1	Carotid artery syndrome (hemispheric)	
ICD-10 DX	G45.2	Multiple and bilateral precerebral artery syndromes	
ICD-10 DX	G45.8	Other transient cerebral ischemic attacks and related syndromes	
ICD-10 DX	G45.9	Transient cerebral ischemic attack, unspecified	
ICD-10 DX	G46.0	Middle cerebral artery syndrome	
ICD-10 DX	G46.1	Anterior cerebral artery syndrome	
ICD-10 DX	G46.2	Posterior cerebral artery syndrome	
ICD-10 DX	G46.3	Brain stem stroke syndrome	
ICD-10 DX	G46.4	Cerebellar stroke syndrome	
ICD-10 DX	G46.5	Pure motor lacunar syndrome	
ICD-10 DX	G46.6	Pure sensory lacunar syndrome	
ICD-10 DX	G46.7	Other lacunar syndromes	
ICD-10 DX	G46.8	Other vascular syndromes of brain in cerebrovascular diseases	

ICD-10 DX	G97.31	Intraoperative hemorrhage and hematoma of a nervous system organ or structure complicating a nervous system procedure	S02.109B, S02.11GA, S02.11GB, S02.11HA, S02.11HB, S02.110A, S02.111A, S02.112A, S02.113A, S02.110B, S02.111B, S02.112B, S02.113B, S02.118A, S02.118B, S02.119A, S02.119B, S02.19XA, S02.19XB, S02.2XXA, S02.2XXB, S02.3XXA, S02.30XA, S02.3XXB, S02.30XB, S02.31XA, S02.31XB, S02.32XA, S02.32XB, S02.40AA,
ICD-10 DX	G97.32	Intraoperative hemorrhage and hematoma of a nervous system organ or structure complicating other procedure	
ICD-10 DX	I60.00	Nontraumatic subarachnoid hemorrhage from unspecified carotid siphon and bifurcation	
ICD-10 DX	I60.01	Nontraumatic subarachnoid hemorrhage from right carotid siphon and bifurcation	
ICD-10 DX	I60.02	Nontraumatic subarachnoid hemorrhage from left carotid siphon and bifurcation	
ICD-10 DX	I60.10	Nontraumatic subarachnoid hemorrhage from unspecified middle cerebral artery	
ICD-10 DX	I60.11	Nontraumatic subarachnoid hemorrhage from right middle cerebral artery	
ICD-10 DX	I60.12	Nontraumatic subarachnoid hemorrhage from left middle cerebral artery	
ICD-10 DX	I60.2	Nontraumatic subarachnoid hemorrhage from anterior communicating artery	
ICD-10 DX	I60.30	Nontraumatic subarachnoid hemorrhage from unspecified posterior communicating artery	
ICD-10 DX	I60.31	Nontraumatic subarachnoid hemorrhage from right posterior communicating artery	
ICD-10 DX	I60.32	Nontraumatic subarachnoid hemorrhage from left posterior communicating artery	
ICD-10 DX	I60.4	Nontraumatic subarachnoid hemorrhage from basilar artery	
ICD-10 DX	I60.50	Nontraumatic subarachnoid hemorrhage from unspecified vertebral artery	

ICD-10 DX	I60.51	Nontraumatic subarachnoid hemorrhage from right vertebral artery	S02.40AB, S02.40BA,
ICD-10 DX	I60.52	Nontraumatic subarachnoid hemorrhage from left vertebral artery	S02.40BB, S02.40CA,
ICD-10 DX	I60.6	Nontraumatic subarachnoid hemorrhage from other intracranial arteries	S02.40CB, S02.40DA,
ICD-10 DX	I60.7	Nontraumatic subarachnoid hemorrhage from unspecified intracranial artery	S02.40DB, S02.40EA,
ICD-10 DX	I60.8	Other nontraumatic subarachnoid hemorrhage	S02.40EB, S02.40FA,
ICD-10 DX	I60.9	Nontraumatic subarachnoid hemorrhage, unspecified	S02.40FB, S02.400A,
ICD-10 DX	I61.0	Nontraumatic intracerebral hemorrhage in hemisphere, subcortical	S02.400B, S02.401A,
ICD-10 DX	I61.1	Nontraumatic intracerebral hemorrhage in hemisphere, cortical	S02.401B, S02.402A,
ICD-10 DX	I61.2	Nontraumatic intracerebral hemorrhage in hemisphere, unspecified	S02.402B, S02.411A,
ICD-10 DX	I61.3	Nontraumatic intracerebral hemorrhage in brain stem	S02.411B, S02.412A,
ICD-10 DX	I61.4	Nontraumatic intracerebral hemorrhage in cerebellum	S02.412B, S02.413A,
ICD-10 DX	I61.5	Nontraumatic intracerebral hemorrhage, intraventricular	S02.413B, S02.42XA,
ICD-10 DX	I61.6	Nontraumatic intracerebral hemorrhage, multiple localized	S02.42XB, S02.600A,
ICD-10 DX	I61.8	Other nontraumatic intracerebral hemorrhage	S02.600B, S02.601A,
ICD-10 DX	I61.9	Nontraumatic intracerebral hemorrhage, unspecified	S02.601B, S02.602A,
ICD-10 DX	I63.00	Cerebral infarction due to thrombosis of unspecified precerebral artery	

ICD-10 DX	I63.011	Cerebral infarction due to thrombosis of right vertebral artery	S02.602B, S02.609A,
ICD-10 DX	I63.012	Cerebral infarction due to thrombosis of left vertebral artery	S02.609B, S02.61XA,
ICD-10 DX	I63.013	Cerebral infarction due to thrombosis of bilateral vertebral arteries	S02.610A, S02.610B,
ICD-10 DX	I63.019	Cerebral infarction due to thrombosis of unspecified vertebral artery	S02.611A, S02.611B,
ICD-10 DX	I63.02	Cerebral infarction due to thrombosis of basilar artery	S02.612A, S02.612B,
ICD-10 DX	I63.031	Cerebral infarction due to thrombosis of right carotid artery	S02.62XA, S02.620A,
ICD-10 DX	I63.032	Cerebral infarction due to thrombosis of left carotid artery	S02.62XB, S02.620B,
ICD-10 DX	I63.039	Cerebral infarction due to thrombosis of unspecified carotid artery	S02.621A, S02.621B,
ICD-10 DX	I63.09	Cerebral infarction due to thrombosis of other precerebral artery	S02.622A, S02.622B,
ICD-10 DX	I63.10	Cerebral infarction due to embolism of unspecified precerebral artery	S02.63XA, S02.630A,
ICD-10 DX	I63.111	Cerebral infarction due to embolism of right vertebral artery	S02.63XB, S02.630B,
ICD-10 DX	I63.112	Cerebral infarction due to embolism of left vertebral artery	S02.631A, S02.631B,
ICD-10 DX	I63.119	Cerebral infarction due to embolism of unspecified vertebral artery	S02.632A, S02.632B,
ICD-10 DX	I63.12	Cerebral infarction due to embolism of basilar artery	S02.64XA, S02.640A,
ICD-10 DX	I63.131	Cerebral infarction due to embolism of right carotid artery	S02.64XB, S02.640B,

ICD-10 DX	I63.132	Cerebral infarction due to embolism of left carotid artery	S02.641A, S02.641B,
ICD-10 DX	I63.139	Cerebral infarction due to embolism of unspecified carotid artery	S02.642A, S02.642B,
ICD-10 DX	I63.19	Cerebral infarction due to embolism of other precerebral artery	S02.65XA, S02.650A,
ICD-10 DX	I63.20	Cerebral infarction due to unspecified occlusion or stenosis of unspecified precerebral arteries	S02.65XB, S02.650B,
ICD-10 DX	I63.211	Cerebral infarction due to unspecified occlusion or stenosis of right vertebral artery	S02.651A, S02.651B,
ICD-10 DX	I63.212	Cerebral infarction due to unspecified occlusion or stenosis of left vertebral artery	S02.652A, S02.652B,
ICD-10 DX	I63.213	Cerebral infarction due to unspecified occlusion or stenosis of bilateral vertebral arteries	S02.66XA, S02.66XB,
ICD-10 DX	I63.219	Cerebral infarction due to unspecified occlusion or stenosis of unspecified vertebral artery	S02.67XA, S02.670A,
ICD-10 DX	I63.22	Cerebral infarction due to unspecified occlusion or stenosis of basilar artery	S02.670B, S02.671A,
ICD-10 DX	I63.231	Cerebral infarction due to unspecified occlusion or stenosis of right carotid arteries	S02.671B, S02.672A,
ICD-10 DX	I63.232	Cerebral infarction due to unspecified occlusion or stenosis of left carotid arteries	S02.672B, S02.69XA,
ICD-10 DX	I63.233	Cerebral infarction due to unspecified occlusion or stenosis of bilateral carotid arteries	S02.61XB, S02.62XA,
ICD-10 DX	I63.239	Cerebral infarction due to unspecified occlusion or stenosis of unspecified carotid artery	S02.63XA, S02.64XA,
ICD-10 DX	I63.29	Cerebral infarction due to unspecified occlusion or stenosis of other precerebral arteries	S02.65XA, S02.66XA,
ICD-10 DX	I63.30	Cerebral infarction due to thrombosis of unspecified cerebral artery	S02.67XB, S02.69XB,

ICD-10 DX	I63.311	Cerebral infarction due to thrombosis of right middle cerebral artery	S02.8XXA, S02.80XA,
ICD-10 DX	I63.312	Cerebral infarction due to thrombosis of left middle cerebral artery	S02.8XXB, S02.80XB,
ICD-10 DX	I63.313	Cerebral infarction due to thrombosis of bilateral middle cerebral arteries	S02.81XA, S02.81XB,
ICD-10 DX	I63.319	Cerebral infarction due to thrombosis of unspecified middle cerebral artery	S02.82XA, S02.82XB,
ICD-10 DX	I63.321	Cerebral infarction due to thrombosis of right anterior cerebral artery	S02.91XA, S02.91XB,
ICD-10 DX	I63.322	Cerebral infarction due to thrombosis of left anterior cerebral artery	S02.92XA, S02.92XB,
ICD-10 DX	I63.323	Cerebral infarction due to thrombosis of bilateral anterior cerebral arteries	S06.0X0A, S06.0X1A,
ICD-10 DX	I63.329	Cerebral infarction due to thrombosis of unspecified anterior cerebral artery	S06.0X2A, S06.0X3A,
ICD-10 DX	I63.331	Cerebral infarction due to thrombosis of right posterior cerebral artery	S06.0X4A, S06.0X5A,
ICD-10 DX	I63.332	Cerebral infarction due to thrombosis of left posterior cerebral artery	S06.0X6A, S06.0X7A,
ICD-10 DX	I63.333	Cerebral infarction due to thrombosis of bilateral posterior cerebral arteries	S06.0X8A, S06.0X9A,
ICD-10 DX	I63.339	Cerebral infarction due to thrombosis of unspecified posterior cerebral artery	S06.1X0A, S06.1X1A,
ICD-10 DX	I63.341	Cerebral infarction due to thrombosis of right cerebellar artery	S06.1X2A, S06.1X3A,
ICD-10 DX	I63.342	Cerebral infarction due to thrombosis of left cerebellar artery	S06.1X4A, S06.1X5A,
ICD-10 DX	I63.343	Cerebral infarction due to thrombosis of bilateral cerebellar arteries	S06.1X6A, S06.1X7A,

ICD-10 DX	I63.349	Cerebral infarction due to thrombosis of unspecified cerebellar artery	S06.1X8A, S06.1X9A,
ICD-10 DX	I63.39	Cerebral infarction due to thrombosis of other cerebral artery	S06.2X0A, S06.2X1A,
ICD-10 DX	I63.40	Cerebral infarction due to embolism of unspecified cerebral artery	S06.2X2A, S06.2X3A,
ICD-10 DX	I63.411	Cerebral infarction due to embolism of right middle cerebral artery	S06.2X4A, S06.2X5A,
ICD-10 DX	I63.412	Cerebral infarction due to embolism of left middle cerebral artery	S06.2X6A, S06.2X7A,
ICD-10 DX	I63.413	Cerebral infarction due to embolism of bilateral middle cerebral arteries	S06.2X8A, S06.2X9A,
ICD-10 DX	I63.419	Cerebral infarction due to embolism of unspecified middle cerebral artery	S06.2X0B, S06.2X1B,
ICD-10 DX	I63.421	Cerebral infarction due to embolism of right anterior cerebral artery	S06.2X2B, S06.2X3B,
ICD-10 DX	I63.422	Cerebral infarction due to embolism of left anterior cerebral artery	S06.2X4B, S06.2X5B,
ICD-10 DX	I63.423	Cerebral infarction due to embolism of bilateral anterior cerebral arteries	S06.2X6B, S06.2X7B,
ICD-10 DX	I63.429	Cerebral infarction due to embolism of unspecified anterior cerebral artery	S06.2X8B, S06.2X9B,
ICD-10 DX	I63.431	Cerebral infarction due to embolism of right posterior cerebral artery	S06.300A, S06.301A,
ICD-10 DX	I63.432	Cerebral infarction due to embolism of left posterior cerebral artery	S06.302A, S06.303A,
ICD-10 DX	I63.433	Cerebral infarction due to embolism of bilateral posterior cerebral arteries	S06.304A, S06.305A,
ICD-10 DX	I63.439	Cerebral infarction due to embolism of unspecified posterior cerebral artery	S06.306A, S06.307A,

ICD-10 DX	I63.441	Cerebral infarction due to embolism of right cerebellar artery	S06.308A, S06.309A,
ICD-10 DX	I63.442	Cerebral infarction due to embolism of left cerebellar artery	S06.310A, S06.311A,
ICD-10 DX	I63.443	Cerebral infarction due to embolism of bilateral cerebellar arteries	S06.312A, S06.313A,
ICD-10 DX	I63.449	Cerebral infarction due to embolism of unspecified cerebellar artery	S06.314A, S06.315A,
ICD-10 DX	I63.49	Cerebral infarction due to embolism of other cerebral artery	S06.316A, S06.317A,
ICD-10 DX	I63.50	Cerebral infarction due to unspecified occlusion or stenosis of unspecified cerebral artery	S06.318A, S06.319A,
ICD-10 DX	I63.511	Cerebral infarction due to unspecified occlusion or stenosis of right middle cerebral artery	S06.320A, S06.321A,
ICD-10 DX	I63.512	Cerebral infarction due to unspecified occlusion or stenosis of left middle cerebral artery	S06.322A, S06.323A,
ICD-10 DX	I63.513	Cerebral infarction due to unspecified occlusion or stenosis of bilateral middle cerebral arteries	S06.324A, S06.325A,
ICD-10 DX	I63.519	Cerebral infarction due to unspecified occlusion or stenosis of unspecified middle cerebral artery	S06.326A, S06.327A,
ICD-10 DX	I63.521	Cerebral infarction due to unspecified occlusion or stenosis of right anterior cerebral artery	S06.328A, S06.329A,
ICD-10 DX	I63.522	Cerebral infarction due to unspecified occlusion or stenosis of left anterior cerebral artery	S06.330A, S06.331A,
ICD-10 DX	I63.523	Cerebral infarction due to unspecified occlusion or stenosis of bilateral anterior cerebral arteries	S06.332A, S06.333A,
ICD-10 DX	I63.529	Cerebral infarction due to unspecified occlusion or stenosis of unspecified anterior cerebral artery	S06.334A, S06.335A,
ICD-10 DX	I63.531	Cerebral infarction due to unspecified occlusion or stenosis of right posterior cerebral artery	S06.336A, S06.337A,

ICD-10 DX	I63.532	Cerebral infarction due to unspecified occlusion or stenosis of left posterior cerebral artery	S06.338A, S06.339A,
ICD-10 DX	I63.533	Cerebral infarction due to unspecified occlusion or stenosis of bilateral posterior cerebral arteries	S06.340A, S06.341A,
ICD-10 DX	I63.539	Cerebral infarction due to unspecified occlusion or stenosis of unspecified posterior cerebral artery	S06.342A, S06.343A, S06.344A,
ICD-10 DX	I63.541	Cerebral infarction due to unspecified occlusion or stenosis of right cerebellar artery	S06.345A, S06.346A,
ICD-10 DX	I63.542	Cerebral infarction due to unspecified occlusion or stenosis of left cerebellar artery	S06.347A, S06.348A,
ICD-10 DX	I63.543	Cerebral infarction due to unspecified occlusion or stenosis of bilateral cerebellar arteries	S06.349A, S06.350A,
ICD-10 DX	I63.549	Cerebral infarction due to unspecified occlusion or stenosis of unspecified cerebellar artery	S06.351A, S06.352A,
ICD-10 DX	I63.59	Cerebral infarction due to unspecified occlusion or stenosis of other cerebral artery	S06.353A, S06.354A,
ICD-10 DX	I63.6	Cerebral infarction due to cerebral venous thrombosis, nonpyogenic	S06.355A, S06.356A,
ICD-10 DX	I63.89	Other cerebral infarction	S06.357A,
ICD-10 DX	I63.9	Cerebral infarction, unspecified	S06.358A,
ICD-10 DX	I66.01	Occlusion and stenosis of right middle cerebral artery	S06.359A, S06.360A,
ICD-10 DX	I66.02	Occlusion and stenosis of left middle cerebral artery	S06.361A, S06.362A,
ICD-10 DX	I66.03	Occlusion and stenosis of bilateral middle cerebral arteries	S06.363A, S06.364A,
ICD-10 DX	I66.09	Occlusion and stenosis of unspecified middle cerebral artery	S06.365A, S06.366A,
ICD-10 DX	I66.11	Occlusion and stenosis of right anterior cerebral artery	S06.367A, S06.368A,

ICD-10 DX	I66.12	Occlusion and stenosis of left anterior cerebral artery	S06.369A, S06.370A,
ICD-10 DX	I66.13	Occlusion and stenosis of bilateral anterior cerebral arteries	S06.371A, S06.372A,
ICD-10 DX	I66.19	Occlusion and stenosis of unspecified anterior cerebral artery	S06.373A, S06.374A,
ICD-10 DX	I66.21	Occlusion and stenosis of right posterior cerebral artery	S06.375A, S06.376A,
ICD-10 DX	I66.22	Occlusion and stenosis of left posterior cerebral artery	S06.377A, S06.378A,
ICD-10 DX	I66.23	Occlusion and stenosis of bilateral posterior cerebral arteries	S06.379A, S06.380A,
ICD-10 DX	I66.29	Occlusion and stenosis of unspecified posterior cerebral artery	S06.381A, S06.382A,
ICD-10 DX	I66.3	Occlusion and stenosis of cerebellar arteries	S06.383A,
ICD-10 DX	I66.8	Occlusion and stenosis of other cerebral arteries	S06.384A,
ICD-10 DX	I66.9	Occlusion and stenosis of unspecified cerebral artery	S06.385A, S06.386A,
ICD-10 DX	I67.841	Reversible cerebrovascular vasoconstriction syndrome	S06.387A, S06.388A,
ICD-10 DX	I67.848	Other cerebrovascular vasospasm and vasoconstriction	S06.389A, S06.4X0A,
ICD-10 DX	I67.89	Other cerebrovascular disease	S06.4X1A, S06.4X2A,
ICD-10 DX	I97.810	Intraoperative cerebrovascular infarction during cardiac surgery	S06.4X3A, S06.4X4A,
ICD-10 DX	I97.811	Intraoperative cerebrovascular infarction during other surgery	S06.4X5A, S06.4X6A,
ICD-10 DX	I97.820	Postprocedural cerebrovascular infarction following cardiac surgery	S06.4X7A, S06.4X8A,
ICD-10 DX	I97.821	Postprocedural cerebrovascular infarction following other surgery	S06.4X9A,

	S06.5X0A, S06.5X1A, S06.5X2A, S06.5X3A, S06.5X4A, S06.5X5A, S06.5X6A, S06.5X7A, S06.5X8A, S06.5X9A, S06.6X0A, S06.6X1A, S06.6X2A, S06.6X3A, S06.6X4A, S06.6X5A, S06.6X6A, S06.6X7A, S06.6X8A, S06.6X9A, S06.810A, S06.811A, S06.812A, S06.813A, S06.814A, S06.815A, S06.816A, S06.817A, S06.818A, S06.819A, S06.820A,

	S06.821A, S06.822A, S06.823A, S06.824A, S06.825A, S06.826A, S06.827A, S06.828A, S06.829A, S06.890A, S06.891A, S06.892A, S06.893A, S06.894A, S06.895A, S06.896A, S06.897A, S06.898A, S06.899A, S06.9X0A, S06.9X1A, S06.9X2A, S06.9X3A, S06.9X4A, S06.9X5A, S06.9X6A, S06.9X7A, S06.9X8A, S06.9X9A, OR Z51.89 as the principal DX

					Code then EXCLUDE.
H	Multi-organ failure	ICD-9 DX	995.94	Systemic inflammatory response syndrome due to noninfectious process with acute organ dysfunction	
		ICD-10 DX	R65.1x	Systemic inflammatory response syndrome (SIRS) of non-infectious origin	
I	Infection/sepsis (including septic shock)	ICD-9 DX	038.xx	Septicemia	
		ICD-9 DX	472.1	Chronic Pharyngitis	
		ICD-9 DX	785.50	Unspecified Shock	
		ICD-9 DX	785.52	Septic shock	
		ICD-9 DX	790.7	Bacteremia	
		ICD-9 DX	421.0	Acute and subacute bacterial endocarditis	
		ICD-9 DX	421.9	Acute endocarditis, unspecified	
		ICD-9 DX	424.9x	Endocarditis, valve unspecified	
		ICD-9 DX	995.91	Sepsis	
		ICD-9 DX	995.92	Severe sepsis	
		ICD-9 DX	998.5	Other complications of procedures, NEC; postoperative infection	
		ICD-9 DX	998.59	Other postoperative infection	
		ICD-9 DX	999.3x	Complications of medical care, not elsewhere classified; other infection	
		ICD-10 DX	A40.x	Streptococcal sepsis	
		ICD-10 DX	R65.2x	Severe sepsis	
		ICD-10 DX	R78.81	Bacteremia	
		ICD-10 DX	I33.0	Acute and subacute infective endocarditis	
		ICD-10 DX	I33.9	Acute and subacute endocarditis, unspecified	
		ICD-10 DX	I38	Endocarditis, valve unspecified	
		ICD-10 DX	A41.xx	Other sepsis	

		ICD-10 DX	T81.4xxx	Infection following a procedure
		ICD-10 DX	K68.11	Postprocedural retroperitoneal abscess
		ICD-10 DX	T81.12xx	Postprocedural septic shock
J	Altered mental status	ICD-10 DX	R41.82	Altered mental status, unspecified
		ICD-10 DX	R41.0	Disorientation unspecified
		ICD-10 DX	R40.0	Somnolence
		ICD-10 DX	R40.1	Stupor
		ICD-10 DX	R40.2	Coma
		ICD-10 DX	R40.4	Transient alteration of awareness
K	Fever	ICD-9 DX	780.60	Fever, unspecified
		ICD-9 DX	780.61	Fever presenting with conditions classified elsewhere
		ICD-9 DX	780.62	Postprocedural fever
		ICD-10 DX	R50.81	Fever presenting with conditions classified elsewhere
		ICD-10 DX	R50.82	Postprocedural fever
L	Chest pain	ICD-10 DX	R07.9	Chest pain, unspecified
		ICD-10 DX	R07.89	Other chest pain
M	Dysphagia	ICD-10 DX	R13.1	Dysphagia
		ICD-10 DX	R13.19	Other dysphagia
		ICD-10 DX	R13.10	Dysphagia unspecified
		ICD-10 DX	R13.14	Dysphagia pharyngoesophageal phase
		ICD-10 DX	K21.0	GERD with Esophogitis

Appendix Table 3.

Definition	Code Logic
Definite AEF	(A1 or A2) AND Death or (B or C) AND (A1 or A2 or D or E or F)
Highly Probable AEF	(B or C) AND (G or H or I or J or K or L or M) or (D or E or F) AND Death or (G and I) AND Death
Sensitivity Analysis	(A1 or A2 or D or E or F or G or H or I or J or K or L or M) Any 2 of the above