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ORIGINAL RESEARCH

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Incidence and Causes of 30-day Readmissions after Surgical Versus Percutaneous Secundum Atrial Septal Defect Closure: A United States Nationwide Analysis

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ABSTRACT

Background: The preferred approach for secundum atrial septal defect (ASD) closure has evolved from surgical repair to the current standard of practice being percutaneous closure. Although studies have highlighted a reduction in procedural complications with the percutaneous method, there is a paucity of data on readmissions after ASD closure. We evaluated the incidence and reasons for 30-day hospital readmissions in patients undergoing secundum ASD repair via surgical versus percutaneous approach.

Methods: Data for hospitalizations for surgical or percutaneous closure of secundum ASD, during the years 2013–2014, were obtained from the Nationwide Readmissions Database (NRD). Hospitalization characteristics and relevant comorbidities were identified using the corresponding International Classification of Diseases, Ninth Edition, Clinical Modification [ICD-CM 9] codes. Propensity score matching was conducted to evaluate the 30-day rates and causes of readmission following surgical repair compared with percutaneous closure.

Results: Of 4,616 hospital stays for adult patients undergoing ASD closure (3,004 percutaneous and 1,612 surgical), 163 were readmitted within 30 days from their index hospitalization. The unadjusted incidence of readmission was higher in the surgical group (5.2% vs. 2.7%, OR = 1.99, 95% CI 1.08–3.69, $p = 0.028$). Atrial fibrillation/flutter and post-pericardiotomy syndrome were the most common reasons for readmission after percutaneous and surgical closures, respectively. Patients who underwent surgical ASD repair had a higher median length of stay (8.8 vs. 5.2 days, $p < 0.001$) and cost of index hospitalization ($169,513 vs. $105,189, $p < 0.001$).

Conclusions: Percutaneous ASD closure is associated with lower rates of 30-day readmissions, mean length of hospital stay, and hospital charges as compared with surgical closure.

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KEYWORDS Atrial septal defect (ASD); readmission rates; surgical ASD repair; percutaneous ASD-device closure

Introduction

Atrial septal defects (ASD) account for 10–17% of all congenital heart diseases,[1] with the secundum subtype representing 75% of all ASDs.[2] Based on the indications for ASD closure as outlined in society guidelines,[3,4] roughly 38–64% of patients with an ASD, eventually require closure.[5,6] This may be due for revision since the criteria for secundum ASD closure were established when only surgical closure was available, with the need for general anesthesia, thoracotomy, and cardio-pulmonary bypass. The ease of percutaneous device closure, which can be performed as an outpatient procedure with only local anesthesia, could expand the indication to smaller ASDs without enlargement of heart chambers.[7] Although surgical closure was considered the standard treatment option for multiple decades, percutaneous device closure is now the preferred therapeutic approach.[8–10] National utilization of ASD closure has substantially increased over time (from 1.08 per 100,000 population in 1988 to 2.59 per 100,000 population in 2005; an increase of 139%),[5] primarily driven by an uptrend in the use of percutaneous ASD-occluding devices. Despite the increased frequency in ASD closures, estimated

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mortality rates have remained low at ~1% for either technique.[5] A recent meta-analysis of 26 observational studies demonstrated that compared with surgical closure, percutaneous secundum ASD closure was associated with lower all-cause mortality, major and minor complications, and length of hospital stay; residual shunting was more common with percutaneous closure but the need for reintervention was similar in both groups.[11] The Centers for Medicare and Medicaid Services of the United States consider the 30-day readmission rate as a major criterion to measure the quality of care provided by hospitals for various medical conditions and procedures.[12] However, there is a paucity of data on readmissions in secundum ASD patients who underwent surgical versus percutaneous closure. The aim of this study was to evaluate the incidence and reasons of 30-day readmissions following surgical versus percutaneous secundum ASD closure.

Materials and methods

Data source

Data were obtained from the Nationwide Readmissions Database (NRD) years 2013 and 2014. The NRD was developed by the Agency for Healthcare Research and Quality for the Healthcare Cost and Utilization Project, and represents an all-payer database. NRD includes ~50% of overall hospitalizations in the United States, and is thus the largest national database that surveys readmission patterns. The NRD includes hospitalization records of discharges from American hospitals, excluding rehabilitation and long-term acute care facilities. Discharge weights are provided to assess national estimates. The NRD has verified hospitalization linkage numbers that could be utilized to track same patient hospitalizations across hospitals within a state. However, the linkage numbers do not track the same patient from one year into another.

Study population

The NRD database was used to identify hospitalizations with a primary or secondary diagnosis of secundum ASD (International Classification of Diseases, Ninth Edition, Clinical Modification [ICD-CM 9] code 745.5) without a prior diagnosis of endocardial cushion defect (ICD-CM codes 745.6x) who underwent surgical repair (ICD-9 procedure codes 35.51, 35.61, 35.71, and 39.61) or percutaneous closure (ICD-9 CM code 35.52) during years 2013 and. 2014[5] To increase the sample size, on screening, records of all patients with a history of secundum ASD were included even if the primary reason for the index hospitalization was not related to that diagnosis. Hospitalization records were then excluded if: (1) patient age was <18 years; (2) no surgical or percutaneous closure was performed during the index hospitalization; (3) the patient died during the index hospitalization; (4) the discharge month was December since 30-day readmission data would be lacking; (5) the discharge disposition was unknown or the patient left against medical advice (Figure 1).

Patient and hospital characteristics

Patient characteristics included baseline demographics. Age, sex, race/ethnicity, median household income by zipcode, and primary expected payer were identified. Hospital-related descriptors such as number of beds (small, medium, and large), location (urban vs. rural), and teaching status were also extrapolated. The severity of disease was measured using the All Patient Refined-Diagnosis Related Group (APR-DRG) methodology, which was developed by 3M™ corporation to allow analysis of outcomes across large cohorts for a given diagnostic group.[13] The APR-DRG scores are calculated from discharge billing codes and are based on primary and secondary discharge diagnosis, age, and preexisting medical conditions.[14] In addition to other scores, APR-DRG ranks the risk of mortality and disease severity as low, medium, high, and extreme.

Outcome measure

The primary outcome for this study was 30-day all-cause unplanned hospital readmissions. Thirty-day readmission was defined as any inpatient admission (i.e. all cause) that occurred within 30 days of discharge. If a patient had >1 readmission within the 30-day period, only the earliest readmission was included. Transfer to another hospital was not considered a readmission. The reasons for readmission were determined using primary diagnosis categories and the corresponding HCUP Clinical Classification Software; secondary diagnosis categories were not used to avoid double counting of readmissions. The secondary outcomes included median length of stay (LOS) and median incurred hospital charges.

Statistical analysis

For descriptive purposes, means and 95% confidence intervals (CI) were used for expression of continuous variables while frequencies were used for categorical variables. The weighted discharge variable supplied by NRD was used for estimation of the weighted incidence of all variables of interest with 95% CI. To ensure accuracy of the weighted estimates, the NRD hospital strata and clustering variables were utilized in the calculation of the weighted estimates. We used complex samples logistic regression model provided by SPSS to adjust for the different hospital clusters, and National Inpatient Sample strata. Those are two variables supplied by the National Inpatient Sample database for accurate calculation of both weighted estimates and effect sizes. The primary outcome of interest is 30-day readmission following surgical ASD closure compared with percutaneous closure. Two adjustment methods were used to evaluate the odds ratio; the first method was done using a propensity score matching model, where 2:1 nearest neighbor with a caliper of 0.01 and allowing for replacement method was used to construct two similar cohorts after adjusting for various covariables such as age, day of admission, status of admission (elective vs. non-elective), sex, hospital characteristics (bed-size and teaching status). In the second method, the odds ratio was adjusted for

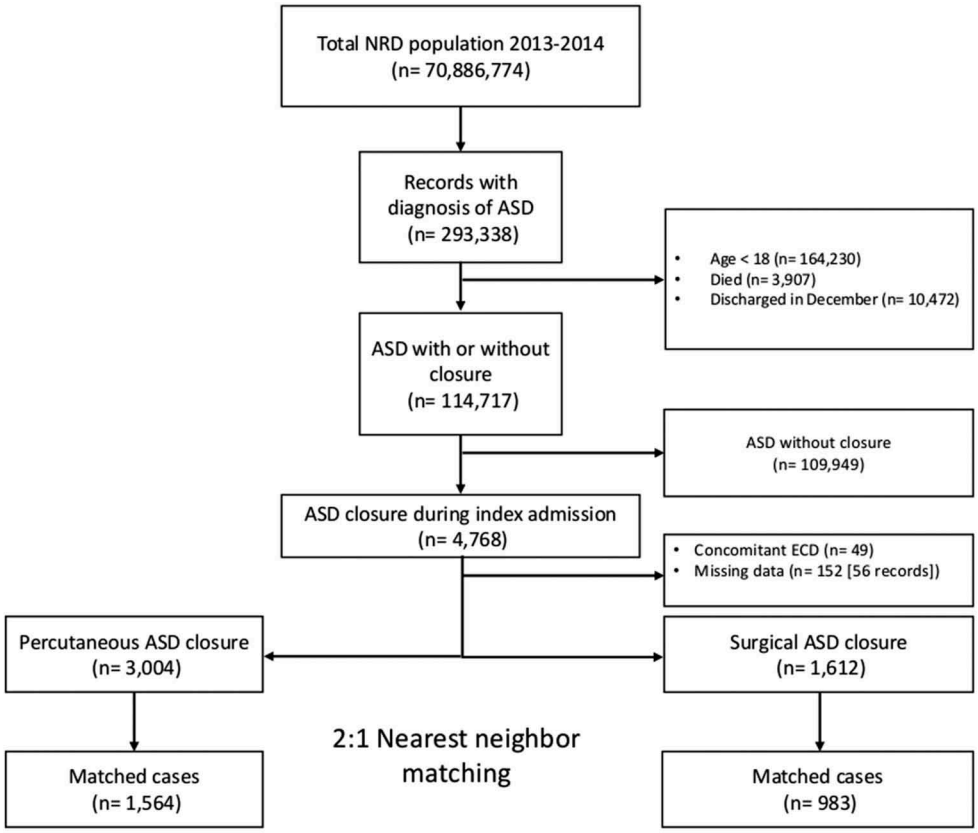

Figure 1. Flow diagram of study participants. Summary of how the systematic search was conducted and patients were enrolled in the study after propensity score matching. NRD, Nationwide Readmission Database; ASD, atrial septal defect; ECD, endocardial cushion defect.

comorbidities and variables including age, sex, APR-DRG, hospital teaching status, location, and bed size. Secondary outcomes were the length of hospital stay and hospital charges during the index hospitalization. All statistical analyses were conducted with assumption of $p < 0.05$ for statistical significance and a confidence interval (CI) of 95%. All analyses were conducted using IBM SPSS Statistics software (version 23.0; IBM Corporation, Armonk, NY, USA).

Results

Population characteristics

Among the 293,338 weighted hospitalizations with a primary diagnosis of secundum ASD in the NRD database years 2013 and 2014, 114,717 adults met the inclusion criteria. Of these, a total of 4,616 underwent ASD closure (3,004 underwent percutaneous closure and 1,612 underwent surgical closure) and were included in the final analysis (Figure 1). Only 0.8% had a concomitant procedure code of coronary artery bypass surgery and 0.8% had a co-procedure code of open valve repair/replacement in the surgical ASD closure group; since the incidence of concomitant surgery was very low and would not statistically skew the analysis, these patients were not excluded. Table 1 represents the baseline and hospital-related characteristics in both the unmatched and propensity-matched cohorts. A total of 1,564 surgical closure hospitalizations were matched to 983 percutaneous closure hospitalizations in a 2:1 fashion. The standardized mean difference was <0.1 for all the covariables included in the model after propensity score matching. The total incidence of atrial fibrillation/flutter was 0.33% (95% 0.07–0.6%) in the percutaneous closure arm as compared with 0.31% (95% 0.06–0.6%) in the surgical closure arm ($p = 0.90$).

Incidence of 30-day readmissions in both the unadjusted and adjusted cohorts

A total of 163 re-hospitalizations (3.5%) occurred within 30 days after their index ASD closure hospitalization; the incidence of 30-day readmission was higher in the surgical group (83 hospitalizations; 5.2%, 95% CI 3.4–7.8%) compared with the percutaneous group (80 hospitalizations; 2.7%, 95% CI 0.6–1.8%) in the unadjusted cohort (OR = 1.99, 95% CI 1.08–3.69, $p = 0.028$). This was also confirmed by both the propensity score matching with 6.3% in the surgical groups versus 1.9% in the percutaneous group (OR = 3.43, 95% CI 1.64–7.19, $p = 0.001$) and the multivariable logistic regression models (Table 2).

Reasons, length of stay, and hospital charges of 30-day readmissions

The most frequent reasons for readmission in those who underwent ASD closure were cardiac causes for both surgical and percutaneous closure (56% vs. 35% of all readmissions in each

Table 1. Baseline clinical characteristics in both the unmatched and propensity matched cohorts.

	Unmatched		Propensity score matched	
Variable	Surgical closure % (95% CI)	Percutaneous closure % (95% CI)	Surgical closure % (95% CI)	Percutaneous closure % (95% CI)
Hospitalization, n	3,004	1,612	1,564	983
Age, yr	50.4 (48.7–52.1)	55.2 (53.9–56.5)	53.4 (51.1–55.6)	52.8 (51.2–54.3)
Female	55.3 (51.0–59.5)	56.6 (53.7–59.5)	56.9 (51.8–62.0)	55.6 (51.3–59.9)
Weekend admission	4.3 (3.0–6.1)	10.4 (8.5–12.7)	6.3 (4.4–9.0)	8.4 (6.3–11.2)
Discharge quarter				
January–March	24.7 (21.7–28.0)	28.3 (25.5–31.2)	26.1 (21.9–30.8)	24.7 (21.5–28.2)
April–June	26.2 (23.0–29.7)	25.6 (23–28.4)	26.7 (22.4–31.4)	25.1 (21.4–29.3)
July–September	31.5 (27.9–35.5)	26.9 (23.9–30.2)	30.9 (26.1–36.2)	30.0 (26.1–34.3)
October–December	17.5 (14.7–20.8)	19.2 (16.5–22.2)	16.3 (13.0–20.2)	20.2 (16.4–24.6)
Elective admission	75.8 (71.4–79.7)	48.5 (42.2–54.9)	66.9 (60.9–72.4)	65.4 (60.0–70.4)
insurance				
Medicare	26.7 (22.4–31.5)	35.1 (31.6–38.7)	31.9 (26.6–37.7)	30.2 (26.3–34.5)
Medicaid	14.2 (11.6–17.3)	11.6 (9.7–13.8)	11.2 (8.6–14.5)	13.5 (10.7–16.9)
Private insurance	50.8 (46.2–55.5)	46.4 (41.6–51.3)	49.7 (43.9–55.4)	47.9 (43.1–52.8)
Self-pay	3.2 (2.1–5.0)	2.4 (1.5–3.8)	2.3 (1.2–4.3)	2.7 (1.6–4.5)
No charge	0.5 (0.2–1.3)	0.6 (0.3–1.4%)	0.8 (0.3–2.2)	48.9 (21.8–76.6)
Other	4.5 (3.1–6.4)	3.8 (2.2–6.5)	4.1 (2.6–6.4)	5.1 (2.9–8.8)
Median household income				
1st quartile	23.9 (20.2–28.0)	23.4 (19.4–27.9)	24.8 (20.3–29.9)	24.5 (20.6–28.9)
2nd quartile	25.8 (22.5–29.4)	25 (21.5–28.8)	24.8 (20.9–29.2)	68.6 (22.3–30.7)
3rd quartile	25.9 (22.2–30.0)	22.2(19.4–25.2)	23.3 (18.7–28.6)	23.7 (20.2–27.6)
4th quartile	24.4 (20.2–29.2)	29.5 (23.8–35.9)	27.1 (21.8–33.2)	25.5 (21.1–30.5)
Calendar year				
2013	52.3 (47.2–57.3)	57.1 (48.5–65.3)	55.2 (49.7–60.6)	53.5 (46.2–60.6)
2014	47.7 (42.7–52.8)	42.9 (34.7–51.5)	44.8 (39.4–50.3)	46.5 (39.4–53.8)
Hospital characteristics				
Hospital bed size				
Small	4.9 (3.9–6.1)	8.4 (6.0–11.7)	7.7 (6.2–9.6)	5.6 (4.2–7.4)
Medium	16.8 (13.7–20.5)	16.9 (13.3–21.3)	19.4 (15.3–24.3)	19.2 (15.3–23.9)
Large	78.3 (74.5–81.7)	74.7 (69.0–79.6)	72.9 (68.0–77.3)	75.2 (70.1–79.6)
Hospital location				
Large metropolitan area	65.0 (59.1–70.5)	69.2 (61.3–76.1)	68.5 (63.1–73.5)	66.8 (58.6–74.1)
Small metropolitan area	34.1 (28.7–40.0)	30.2 (23.4–38.1)	30.4 (25.5–35.8)	32.7 (25.4–40.9)
Micropolitan area	0.9 (0.8–1.0)	0.6 (0.2–1.8)	1.1 (1.0–1.2)	0.5 (0.4–0.6)
Teaching status				
Metropolitan non-teaching	12.2 (9.8–15.1)	19.8 (16.0–24.3)	15.2 (12.2–18.8)	16.1 (13.0–19.8)
Metropolitan teaching	86.9 (84.0–89.3)	79.6 (75.0–83.6)	83.7 (80.1–86.8)	83.4 (79.7–86.5)
Non-metropolitan	0.9 (0.8–1.0)	0.6 (0.2–1.8)	1.1 (1.0–1.2)	0.5 (0.4–0.6)
All Patient Refined DRG: Severity of illness subclass				
Minor loss of function	43.0 (38.0–48.2)	34.3 (29.6–39.4)	38.6 (32.8–44.8)	40.6 (35.9–45.6)
Moderate loss of function	15.7 (13.1–18.6)	37.8 (34.5–41.2)	23.9 (20.1–28.3)	25.9 (22.1–30.0)
Major loss of function	31.9 (27.3–36.9)	21.4 (17.4–26.1)	27.3 (22.1–33.2)	26.8 (21.4–33.1)
Extreme loss of function	9.4 (7.1–12.4)	6.5 (4.9–8.4)	10.1 (7.3–14.0)	6.7 (4.9–9.0)
Length of stay (days)	8.8 (8.0–9.7)	5.2 (4.5–6.0)	8.32 (7.45–9.19)	5.91 (5.00–6.82)
Hospital charges for index admission	169,512 (150,981–188,043)	105,189 (92,870–117,509)	166,997 (144,105–189,889)	114,955 (100,179–129,732)

Notes. CI, confidence interval; n, number; yr, year; DRG, diagnosis related group.

group respectively, $p = 0.01$) (Figure 2). Among the cardiac causes (Figure 3), atrial fibrillation/flutter was the most frequent cause of readmission after percutaneous ASD closure (12.5% of all readmissions in the percutaneous group). Of all-cause readmissions, the incidence of atrial fibrillation/flutter readmissions were 12.5% (95% CI 2.5–21.2%) and 6.0% (1.2–13.3%) after percutaneous and surgical closure, respectively ($p = 0.15$). Post-surgical cardiac complications including post-pericardiotomy syndrome were the most frequent cardiac cause of readmission in the surgical group constituting 19.9% (95% CI 13.3–25.3%) of all readmissions in the surgical group. Congestive heart failure was the second most common cause of readmission in both the surgical and percutaneous groups constituting 16.9% (95% CI 9.6–22.9%) of all readmissions in the surgical group versus 9.8%

Table 2. Odds ratio of 30-day readmission following surgical versus percutaneous ASD closure by 4 multivariable logistic regression models.

Multivariable logistic regression model	Odds ratio	95% Confidence interval	*p*-value	Adjusted variables
Model 1	2.388	1.288–4.428	0.01	Age and sex
Model 2	2.181	1.196–3.975	0.01	Age, sex, and APR-DRG score
Model 3	2.226	1.171–4.232	0.02	Age, sex, APR-DRG score, hospital teaching status, hospital location, and hospital bed size
Model 4	2.227	1.170–4.239	0.02	Age, sex, APR-DRG score, hospital teaching status, hospital location, hospital bed size, and year of admission

Note. APR-DRG, all patients refined diagnosis related groups.

(95% CI 2.5–16.3%) in the percutaneous group ($p = 0.20$). The other causes of 30-day readmissions are illustrated in Figure 2. The mean length of stay during the index admission was higher in the surgical ASD closure group compared with percutaneous closure (8.8 ± 0.4 days, vs. 5.2 ± 0.38 days, $p < 0.001$). In addition, surgical closure had higher mean hospital charges at index hospitalization (169,513 ± 9,428 dollars, vs. 105,189 ± 6,267 dollars, $p < 0.001$).

Discussion

In this large, observational, non-randomized analysis of a real-world cohort of hospitalized patients with secundum ASD who underwent surgical or percutaneous ASD closure, 3.5% of rehospitalizations occurred within 30-days. The incidence of readmissions was higher in the surgical group as compared with the percutaneous group (5.2% vs. 2.7%, $p = 0.028$). Among hospitalizations with a secundum ASD closure, the most frequent reason for readmission was a cardiac-related cause. Within the realm of cardiac causes, atrial fibrillation/flutter was the most common reason for readmission in the percutaneous closure group and post-cardiac disturbances including post-pericardiotomy syndrome was the leading cause of readmission in the surgical group.

The increased utilization of percutaneous ASD-occluding devices has resulted in a dramatic increase in the number of ASDs that have undergone closure over time, with a marked shift in repair type having occurred since 2001.[5,15] With a decrease in potential adverse consequences of percutaneous intervention (i.e. need for thoracotomy, cardiopulmonary bypass, length of hospital-stay, and cost), it is expected that the use of a percutaneous approach to treat congenital heart disease will increase. Although the increased utilization of percutaneous ASD devices over surgical closure had previously been justified by their favorable safety, efficacy, morbidity, and mortality;[11,16–18] the significantly lower rates of readmissions observed in this study further justify the preference of percutaneous ASD closure over surgical repair on top of the not yet fully exploited potential of simplification of percutaneous ASD closure.[7] Higher readmission rates have downstream implications for patients' well-being as well as from a standpoint of CMS (Centers for Medicare and Medicaid Services) reimbursements. Hospital readmissions not only impose an additional financial burden on the patient, they are also associated with

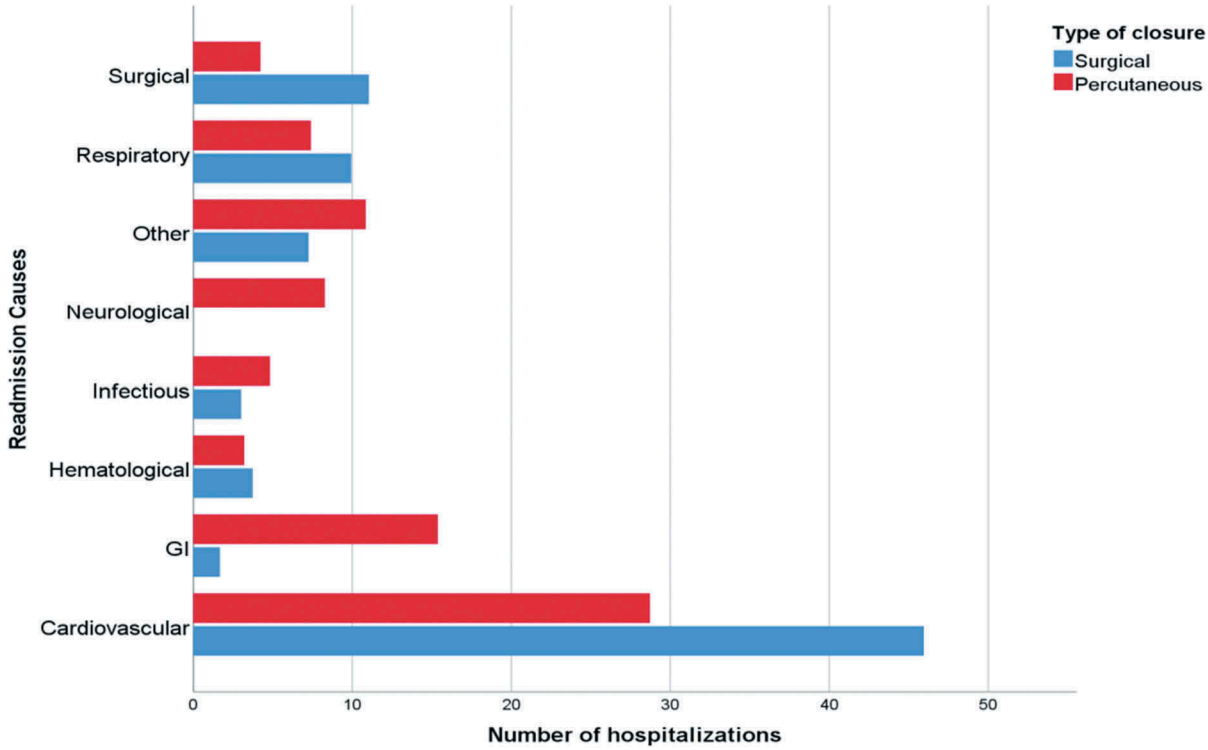

Figure 2. Systematic causes of hospital readmissions stratified by type of ASD closure. GI, gastrointestinal.

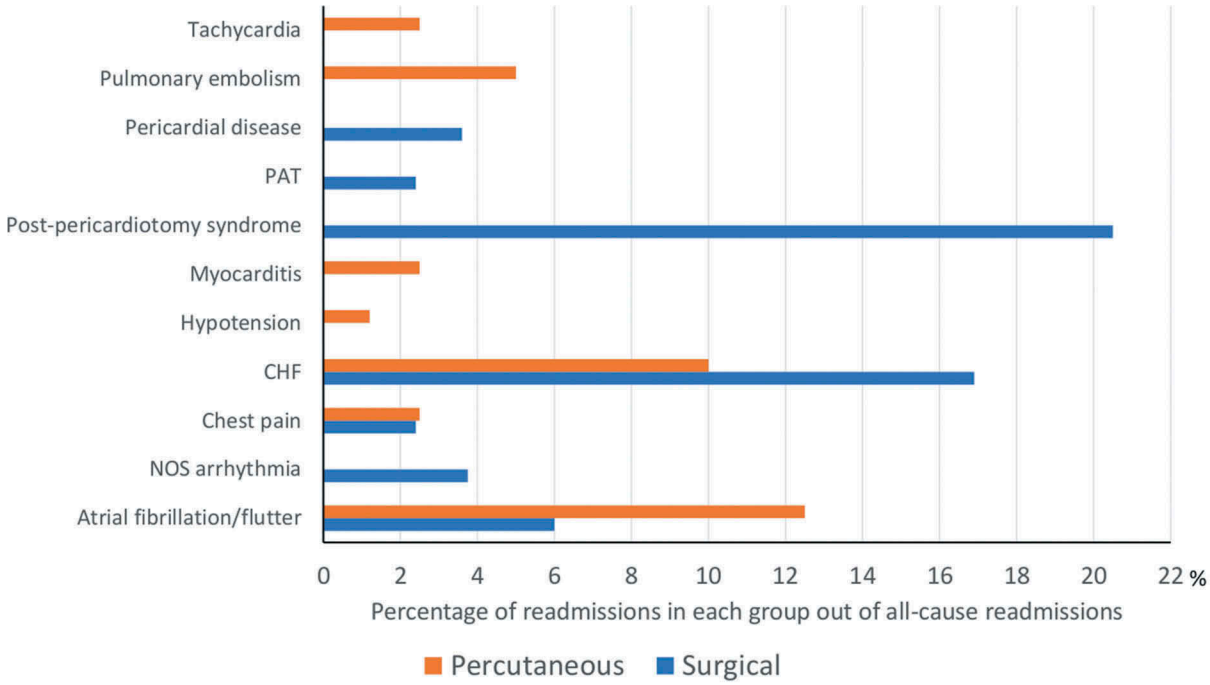

Figure 3. Percent of all cardiac readmissions stratified by type of ASD closure. PAT, paroxysmal atrial tachycardia; CHF, congestive heart failure; NOS, not otherwise specified.

delays in recovery back to baseline functional status and persistent functional deficits in the elderly.[19] Furthermore, with development of programs such as the CMS Readmissions Reduction Program, hospitals with higher rates of readmissions are financially penalized by the CMS.[20]

Apart from readmission rates, the benefits of percutaneous as compared to surgical closure also pertains to the index hospitalization. Significant differences in peri-procedural or perioperative complication rates, favoring the percutaneous approach, have been previously highlighted in the literature.[10] Such reductions in complications often translate into significant decreases in hospitalization charges and length of stay during the index hospitalization, as demonstrated in this study.

Singh et al. [15] reported that the majority of percutaneous ASD closures in the United States (70.5%) are currently performed in low volume centers that perform <10 procedures/year. The authors demonstrated that procedures performed at higher volume hospitals (>14 procedures/year) were associated with reduced complications, length of stay, and hospitalization cost when compared to the lower volume centers (<13 procedures/year). The latest American College of Cardiology (ACC)/American Heart Association (AHA)/Society for Cardiovascular Angiography and Interventions (SCAI) guidelines recommend that cardiac catheterization laboratories maintain a proficiency in percutaneous ASD closure by performing a minimum of 10 procedures per year, a requirement suggestion that was based on expert consensus rather than previous data.[21] Although this study found that the rate of readmissions is relatively low with percutaneous ASD closure, it is possible that performance of this procedure in low volume centers played a role in readmission outcomes. Based on this study's analysis, although it is difficult to clearly delineate low versus high volume centers, hospitals in small metropolitan areas (30.2%) and non-teaching hospitals (19.8%), potentially low volume centers compared to their teaching and large metropolitan high-volume counterparts, had higher rates of readmission.

In this study, atrial fibrillation/flutter was the most common cardiac cause of hospital readmission following percutaneous ASD closure. Of all-cause readmissions, the rate of atrial fibrillation/flutter readmissions represented a larger part with percutaneous closure as compared with post-surgical ASD closure (12.5% vs. 6.0% of all-cause readmissions, $p < 0.001$); however, there was no significant difference in the total incidence of atrial fibrillation/flutter readmissions between percutaneous and surgical closure (0.33% vs. 0.31% respective; $p = 0.90$). It should be noted that this does not represent the true incidence of atrial fibrillation/flutter post ASD closure as there may be patients with occult atrial fibrillation/flutter, those whose atrial arrhythmias were detected in an outpatient clinic without requiring readmission, or patients whose arrhythmias were not captured because of database coding errors. The low observed frequency of atrial arrhythmias in each arm (<1% in both cohorts) was contrary to the popular belief that there exists a higher propensity of atrial fibrillation/flutter post percutaneous closure as compared with surgical closure. Post-procedural atrial fibrillation in these instances is often attributed to irritation of the atrial septum which can be equally arrhythmogenic after percutaneous device closure as with surgical patch closure. Additionally, ASD and patent foramen ovale (PFO)-occluding devices are known to transiently irritate the atrial septum post-implant with less long-term sequela in terms of atrial arrhythmias; randomized clinical trials have demonstrated that most device-associated atrial fibrillation/flutter incidences occur early (<30 days) after implant, consisting of

a single paroxysmal episode that resolves spontaneously or with cardioversion.[22–25] The incidence of stroke from device-associated atrial arrhythmias was low in the PFO closure studies (~0.2% of patients randomized to a device in the cryptogenic stroke trials).[26] Only a small fraction of post-device closure atrial arrhythmias (3.8%) are reported to progress to permanent atrial fibrillation.[27] Hence, with longer follow up, the incidence of atrial fibrillation-related readmissions would likely diminish substantially.

Post-pericardiotomy syndrome was the most common cause of hospital readmissions following surgical ASD closure. This syndrome which is often propagated by an amplified immune response, occurs 1–6 weeks after a cardiac surgery requiring pericardial incision. Fever, pleuritic chest pain, new or worsening pleural or pericardial effusion, or pericardial friction rub are some of the most common clinical findings associated with this condition.[28] The incidence of this syndrome has been reported in 10–50% of cardiac surgeries.[29,30] The 30-day follow-up period for hospital readmissions coincides directly with the period when patients undergoing surgical ASD closure are at high risk for developing this syndrome due to a surge in the immune response. The second most common cause of readmissions (in both surgical and percutaneous groups) was heart failure. Among other indications, ASD closure is recommended in patients with right ventricle volume overload due to shunt physiology or underlying pulmonary artery hypertension. Such patients are at high risk for heart failure exacerbations and hence, a large proportion of readmissions seen in this study may be attributed to this etiology.

The implications of the findings from this study are mainly two-fold. First, given the near equivalence of effective closure and the lower complication rates, percutaneous ASD closure should be considered the preferred approach in patients deemed suitable by a multidisciplinary cardiovascular team. Additionally, given the most common readmissions being due to atrial fibrillation/flutter, patients should be followed closely to allow early detection of an atrial arrhythmia which may be managed on an outpatient basis rather than being readmitted and causing a burden on patients' well-being as well as finances.

Study limitations

Although this study included a large number of hospitalizations from real-world data, there are several limitations. This is an observational, nonrandomized analysis where risk of unmeasured confounding could not be completely eliminated, even after conducting thorough propensity score matching. Moreover, the data from NRD inherently lacks certain details such as medications and information regarding interim follow-up between index hospitalization discharge and readmission, both of which may impact the reported outcomes. By virtue of being an administrative database, data from NRD is subject to limitations such as coding errors or other biases. This also includes the database's inability to identify the reasons why surgical approach was chosen over percutaneous closure; potential reasons for this include a large defect and lack of a supportive septal rim for a potential ASD device. Inability to track readmissions across different states or across calendar years also precluded accurate readmission reporting and thus, likely resulted in an overall underestimation. Given the restraints of administrative data, hospital readmissions for atrial fibrillation/flutter could not be distinguished in terms of patients with pre-existing chronic atrial fibrillation/flutter versus those with new onset atrial fibrillation/flutter post-ASD-closure. Lastly, there are no ICD-9 codes that are specific to PFO—hence, it may be plausible that some cases which were labeled as secundum ASD in both arms (surgical and percutaneous closure), were in fact PFOs. Finally, this study does not examine the long-term sequela of septal occluder devices versus surgical ASD closure. One observational analysis of nearly 14,000 atrial septal device implants worldwide reported a 1 in 500 incidence of implants resulting in surgical extraction, predominately due to severe, persistent chest pain, attributed to allergy-induced excessive scar tissue formation in 50% of cases; erosion was the culprit of 5% of the devices that were explanted.[31]

Conclusion

Percutaneous ASD closure is associated with lower rates of 30-day readmissions, mean length of hospital stay, and incurred hospital charges as compared with surgical closure. Cardiac causes were the most common reasons for readmission in both the surgical and percutaneous closure groups, with atrial fibrillation/flutter being the predominant culprit in percutaneous ASD closure, while post-pericardiotomy syndrome was the predominant reason for readmission following surgical repair.

Clinical perspectives

What's known?

As compared with surgical repairs, percutaneous ASD closures are associated with lower all-cause mortality, major and minor complications, and length of hospital stay.

What's new?

Thirty-day readmission rates after percutaneous ASD closure are significantly lower than rates of readmission after surgical ASD closure. In hospital charges and length of stay during the index hospitalization remain significantly lower following percutaneous ASD closure as compared with surgical repair. Atrial fibrillation/flutter is the most common reason for readmission after percutaneous closure whereas readmission due to post-pericardiotomy syndrome was commonly seen after surgical ASD closure.

What's next?

Future studies should evaluate the specific predictors for readmission after ASD closure. Additionally, targeting these predictors to see improvement in readmission rates would be of future clinical benefit. Evaluation is warranted to distinguish between readmission rates after percutaneous closure done at high volume centers as compared to low volume centers.

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Disclosure statement

Dr Meier has received speaker fees from Abbott. Dr Meier served as a primary investigator of the PC and PRIMA trials. Dr Tobis was a consultant for St. Jude Medical and W.L. Gore, served as a co-investigator of the RESPECT trial, and on the steering committee of the PREMIUM trial. All other authors have no conflicts of interest or financial disclosures pertaining to this manuscript.

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