

Surgical left atrial appendage closure: Success rate and its relationship with cerebrovascular accident

Received: 08 June 2021
Accepted: 11 Aug. 2021

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Keywords

Atrial Fibrillation; Surgical Left Atrial Appendage Closure; Cerebrovascular Accident; Mitral Valve Prosthesis; Completely Closed; Partially Closed

Abstract

Background: Several surgical procedures such as excision or exclusion are recommended for the closure of the left atrial appendage (LAA). This study was conducted with the aim to evaluate the success rate of different surgical techniques for LAA closure, their respective complications, and the rate of post-surgical cerebrovascular accident (CVA).

Methods: This retrospective study included 150 consecutive patients who underwent LAA closure most commonly after mitral valve surgery within 3 to 6 months after surgery. An expert echocardiographic

fellow collected the data on patients' surgical LAA closure methods and history of CVA, types of prosthetic valves, mortality, and bleeding.

Results: The failure rate for complete LAA closure was 36.7% (55 patients) in our study. The greatest success rate of complete LAA closure was seen in purse-string method (75.5%), followed by resection method (71.4%), while the lowest success rate ($\approx 33.3\%$) was observed in ligation method. A significant relationship was observed between clots on the surface of metallic valve and postoperative CVA ($P = 0.001$; likelihood ratio: 32).

How to cite this article: Peighambari MM, Moradkarami F, Sadeghpour A, Baharestani B, Alizadeh-Ghavidel A, Ghadrdoost B, et al. Surgical left atrial appendage closure: Success rate and its relationship with cerebrovascular accident. Curr J Neurol 2021; 20(4): 235-40.

In multivariate analysis, there was also no statistically significant relationship between partial LAA closure and the incidence of post-surgical CVA ($P > 0.050$).

Conclusion: We observed the highest success rate of complete LAA closure in purse-string method followed by resection method. Interestingly, our results showed that despite the higher rate of residual LAA clot in cases of partial LAA closure, the occurrence of post-surgical CVA was mostly related to the presence of clots on the surface of metallic mitral prostheses rather than the presence of partial LAA closure.

Introduction

Atrial fibrillation (AF) is the most common type of cardiac arrhythmia and is a major cause of morbidity and mortality.^{1,2} AF is associated with an increased risk of stroke and leads to more severe stroke cases than the other causes of ischemic attack.^{3,4} The left atrial appendage (LAA), as the cardiogenic source of clot embolism in patients with AF, is now of great interest to researchers because available evidence indicates that up to 90% of left atrial (LA) clots in non-valvular AF originate from the LAA.⁵ Generally, there are 2 methods available for reducing the complications of AF incidence, pharmaceutical (i.e., anticoagulants or substitutes) and non-pharmacological (removal or closure of the LAA from the atrial blood flow cycle).⁶

For the first time, in 1949, Madden resected the LAA to prevent recurrent arterial embolism in patients with AF and rheumatic mitral valve stenosis.⁷ Since then, several studies have reported lower stroke risks after LAA closure, especially in patients with AF.^{5,8} Thus, to prevent stroke in the future, percutaneous and surgical LAA closure has been accorded special attention in patients undergoing open-heart surgery.^{5,9,10} In this regard, several surgical procedures are recommended for LAA closure, including excision (LAA removal with scissors or amputating stapling devices) and exclusion (LAA closure with running sutures, external ligation, or the purse-string method) by stapling.

In some cases, for such reasons as the inadequate intensity of mechanical closure or the continuous movement of the myocardium, the closure of the LAA may prove incomplete, or the LAA might reopen in some instances, all of which are considered incomplete LAA closure.¹¹ In these situations, a continuous Doppler flow is maintained between the LA and its adjacent appendage. The presence of even a small residual stump after excision could increase the risk of thrombosis formation, which is a potential source

for embolization.¹² The remaining stump is also regarded as the unsuccessful closure of the appendage, even if it is free of thrombosis or its flow and velocity are low.¹³ In about half of the cases with incomplete LAA closure (41%), LAA thrombi are likely identified. In some studies, an incomplete LAA closure rate of up to about 60% has been reported. Among various LAA closure methods, the reported success rate of surgical LAA excision is about 73%, and it has been recognized as the most effective method.⁹ Some investigations have reported approximate incomplete LAA closure rates of 60% with suture exclusion and 58% with stapler exclusion and in the partially closed LAA, thrombus formation is observed in 46% and 67% of cases with suture and stapler exclusion, respectively.^{10,11} It is, therefore, not reasonable to discontinue anticoagulants in patients with incomplete LAA closure.

Notwithstanding the availability of simple surgical methods for LAA closure, there is still insufficient assurance regarding efficacy and reliability. What further compounds the situation is the current paucity of evidence for the success rate of LAA closure via different surgical techniques.¹¹ Accordingly, in the present study, we sought to evaluate the success rate of different surgical procedures for LAA closure and their respective complications, together with the rate of post-surgical cerebrovascular accident (CVA).

Materials and Methods

The current retrospective study was conducted on 150 individuals who underwent LAA closure (most of them underwent mitral valve surgery) followed by transesophageal echocardiography (TEE) within 3 to 6 months after surgery between 2017 and 2018. The requested data were gathered retrospectively from the patients' files on a checklist. The information collected included the patients' demographic characteristics, LAA velocity before and after surgery, LAA closure/removal surgical methods (including resection, purse string, ligation, and sutures), and heart rhythms before and after surgery, LA area, left ventricular ejection fraction, history of transient ischemic attack or CVA before and after surgery, LA clots, and LAA smoke/clots before and after surgery. In our center, the main methods of LAA closure are purse-string ligation, suture ligation, and surgical resection. In the present study, stapling for LAA closure was not used due to unavailability and high cost. The surgical LAA closure methods drawn upon in this investigation

are illustrated schematically in figure 1. Although there are no discrete criteria for incomplete LAA closure, many investigators have relied upon patent LAAs, persistent flow into the LAA after its surgical exclusion as detected in TEE, and the presence of residual stumps.¹³ Results of incomplete LAA closure was also included. In the patients with valvular surgery, the type of the valve (mechanical or bioprosthetic) and clots on it were recorded. Additionally, post-surgical complications, including mortality and bleeding, were incorporated in the data analysis.

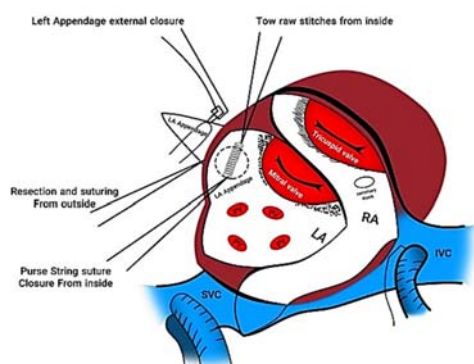


Figure 1. Schematic picture of surgical LAA closure method

Statistical analyses were performed in SPSS (version 18, SPSS Inc., Chicago, IL, USA). Data were expressed as mean values $\pm$ standard deviation for interval variables and count (%) for categorical variables. All variables were tested in terms of normal distribution using Kolmogorov-Smirnov test. Categorical values were compared using chi-square test or Fisher's exact test. Comparisons between the sub-groups were performed using Mann Whitney U test for categorical variables and Kruskal-Wallis or ANOVA for quantitative variables. P values < 0.05 were considered statistically significant.

Results

Patients' characteristics: The present study was performed on 150 cases, comprised of 40 (26.7%) men and 110 women at a mean age of 55 years (range: 19–79 years). Prior to surgery, 53 (36.0%) patients had sinus rhythm, which decreased to 48 (32.0%) after surgery. The mean values of left ventricular systolic function, body surface area, and body mass index (BMI) were roughly equal in different applied LAA closure approaches.

Left atrial appendage closure method and the

related success rate: LAA closure was performed in 74 (49.3%), 53 (35.3%), 14 (9.3%), and 9 (6.0%) cases, respectively, through purse-string, suture, resection, and ligation methods. In total, 63% of the LAAs (95 patients) were completely closed according to postoperative TEE. LAA was partially closed in 55 patients, only for 23 of whom LAA velocity was recorded. However, there was no significant difference in the mean value of velocities in the same individuals (Table 1).

Table 1. Demographic and clinical characteristics of the entire study population

Variable	Mean $\pm$ SD or n (%)
Age (year)	55.35 $\pm$ 10.53
BSA (cm ²)	27.11 $\pm$ 19.19
Sex (female/male)	110 (73.3)/40 (26.7)
BMI (kg/m ²)	26.66 $\pm$ 4.61
INR	1.81 $\pm$ 1.25
LVEF (%)	39.83 $\pm$ 10.51
Left atrial area (cm ²)	1.63 $\pm$ 0.79
LAA velocity before surgery (cm/s)	27.11 $\pm$ 19.19
LAA velocity after surgery (cm/s)	29.52 $\pm$ 13.75

SD: Standard deviation; BSA: Body surface area; BMI: Body mass index; INR: International normalized ratio; LVEF: Left ventricular ejection fraction; LAA: Left atrial appendage

The frequency of LAA closure via different methods is presented in table 2. The greatest success rate of complete LAA closure in our center was seen in purse-string method (75.5%) followed by resection method (71.4%), while the lowest success rate ($\approx 33.3\%$) for complete LAA closure was observed in ligation method, which resulted in a 66.65% rate of partial LAA closure. There was a significant relationship between surgical type of LAA closure and success and failure of complete LAA closure ($P = 0.030$).

Table 2. Frequency of left atrial appendage closure

Type of LAA closure	n (%)
Purse-String	74 (49.3)
Suturing	53 (35.3)
Ligation	9 (6.0)
Resection	14 (9.3)

LAA: Left atrial appendage

Left atrial appendage closure and related complications: The rate of clot on the surface of the prosthetic valve was higher in cases with partial LAA closure ($P = 0.008$). A higher rate of recent stroke was also seen in this patient population ($P = 0.400$) (Table 3).

Table 3. The relationship between some variables and complete vs. atrial closure of left atrial appendage

	Completely closed [n (%)]	Partially closed [n (%)]	P
LAA clot	0 (0)	6 (10.9)	0.001
LAA smoke	0 (0)	10 (18.2)	< 0.001
Valve clot	8 (8.4)	13 (24.1)	0.008
Recent stroke	6 (6.3)	9 (16.4)	0.040
Type of LAA closure			
Purse-string	42 (44.2)	32 (58.2)	0.030
Suture	40 (42.1)	13 (23.6)	
Ligate	3 (3.2)	6 (10.9)	
Resection	10 (10.5)	4 (7.3)	

LAA: Left atrial appendage

Moreover, 20 (13.3%) patients had a history of stroke before surgery, and 15 (10.0%) reported postoperative stroke. Whereas among the 55 (36.7%) patients with partially closed LAAs, 9 (16.3%) cases exhibited no presentation of CVA, 6 (6.3%) out of the 95 (63.3%) patients with complete LAA closure experienced a stroke, which is a statistically significant difference ($P = 0.047$). Postoperative bleeding and mortality were seen in 6% and 2% of the patients, respectively. The lowest rate of bleeding ($P = 0.530$) and death ($P = 0.520$) was reported in ligation method, albeit it was not significant. The occurrence of stroke and postoperative AF rhythm were not different in various methods of LAA closure ($P = 0.100$, $P = 0.720$, respectively). Complications of post-surgical LAA closure are presented in table 4.

Before surgery, LAA clots and smoke patterns were detected in 39 (26%) and 86 (57.3%) cases, respectively. Furthermore, the rate of clot formation ($P < 0.001$) and smoke patterns ($P = 0.001$) in LAA after partial surgical closure was 6 (4.0%) and 10 (6.7%), respectively, which is much lower than the reported rate in other studies. LAA clots were seen in 7.5% and 2.7% of the patients who underwent LAA closure via the suture method and the purse-string method, respectively. This rate was 0% in other methods of LAA closure. LAA smoke patterns were reported in 9.4% and 6.8% of the cases of partial LAA closure via the suture and purse-string methods, respectively. Nonetheless, no smoke pattern was reported in ligation and resection cases.

Clots on the valve surface were observed in 21 (14.0%) of the patients who underwent

simultaneous LAA closure and mitral valve prosthesis implantation. Moreover, recent stroke was seen in 12 (73.3%) of these patients. As seen in table 5, a significant relationship was observed between clots on the valvular surface and the occurrence of postoperative CVA ($P = 0.001$; likelihood ratio: 32). None of the 6 patients with LAA clots reported a stroke. In other words, none of the 15 cases of post-surgical stroke were attributable to LAA clots. Furthermore, only 2 out of the 10 (20.0%) patients with LAA smoke patterns reported that they had experienced a post-surgical stroke, which was 13.3% of all the cases presenting with stroke. It is of note that 1 out of the 2 mentioned cases had simultaneous clots on their metallic valve. In the patients affected by post-surgical stroke, there was a slightly higher rate of AF rhythm; however, the incidence of stroke did not significantly correlate with the patients' underlying rhythm (sinus rhythm vs. AF), the presence or absence of clots or smoke patterns in LAA, or the mean left ventricular systolic function. Mild, moderate, and severe LA enlargement was seen in 44.7%, 35.3%, and 16.0% of the patients, respectively. Among patients presenting with stroke, 6.7% had a normal-size LA, 60.0% had mild LA enlargement, 26.1% had moderate LA enlargement, and 6.7% had severe LA enlargement. Consequently, the size of the LA did not correlate with the incidence of stroke after open left-heart surgery. The highest rate of post-surgical stroke was observed in patients who underwent LAA resection (28.6%). Table 5 depicts the association between recent stroke and echocardiographic parameters.

Table 4. Postoperative complications in different types of left atrial appendage closure

	Purse-string [n (%)]	Suturing [n (%)]	Ligation [n (%)]	Resection [n (%)]	P
Bleeding	3 (4.1)	5 (9.4)	0 (0)	1 (7.1)	0.530
Stroke	5 (6.8)	5 (9.4)	1 (11.1)	4 (28.6)	0.100
Atrial fibrillation rhythm	49 (66.2)	35 (66.0)	7 (77.8)	11 (78.6)	0.720
Death	1 (1.4)	1 (1.9)	0 (0)	1 (7.1)	0.520

Table 5. Association between recent stroke and echocardiographic parameters

	Recent stroke (Yes) [n (%)]	Recent stroke (No) [n (%)]	P
LAA in TEE (completely closed)	6 (40.0)	89 (65.9)	0.040
Partially closed	9 (60.0)	46 (34.1)	
LAA clots	0 (0)	6 (4.4)	0.520
LAA smoke	2 (13.3)	8 (5.9)	0.260
AF rhythm	8 (53.3)	94 (69.6)	0.190
Prosthetic valve clots	11 (73.3)	10 (7.5)	< 0.001
Atrium size (cm ²)	1.33 ± 0.72	1.67 ± 0.80	0.100
Ejection fraction (%)	39.0 ± 12.42	39.92 ± 10.33	0.780

LAA: Left atrial appendage; TEE: Transesophageal echocardiography; AF: Atrial fibrillation

Discussion

The main finding of our investigation was that despite the high rate of incomplete LAA closure, the rate of stroke was not related to smoke patterns or even clots in a partially closed LAA. Moreover, the occurrence of stroke was more frequently associated with clots on the patients' valve surface than with the presence of LAA clots or smoke patterns, or even residual stumps. Furthermore, the incidence of stroke was not related to patients' background heart rhythm and LA size. Therefore, clots on the surface of cardiac valves appear to be the strongest risk factor for the occurrence of stroke following surgical LAA closure and the absence of LAA clots in patients with CVA may be due to the formation of microthrombosis or embolization after clot formation or the presence of small clots that the current TEE resolution scales cannot visualize. Thus, in cases of incomplete LAA closure following surgical LAA closure in conjunction with the maze surgery or mitral valve surgery, the incompleteness of LAA closure may be less daunting than the presence of prosthetic valve clots regarding post-surgical stroke. In this setting, appropriate anticoagulation therapy is of greater significance than the patency or closure of LAA.¹⁴

Complete surgical LAA closure is a highly operator-dependent and challenging method. In our investigation, the rate of incomplete LAA closure was 37%, which is approximately similar to the previously reported rate of 35% in the literature.^{11,14,15} Katz et al. reported a 36% rate of incomplete LAA closure in their cohort study.¹⁵ In the Left Atrial Appendage Occlusion Study (LAAOS), postoperative TEE elucidated a 34% rate of incomplete LAA closure in individuals who underwent either stapling or suture ligation.¹⁶ Likewise, the highest rate of incomplete LAA closure (33.3%) was seen in ligation method in our survey. The explanation might be the application of shallow suture bites recommended to avoid closure of the adjacent circumflex coronary artery or failure to extend running sutures to the distal

edge of LAA orifice.¹³

The highest success rate in our study was seen in complete LAA resection and suture ligation methods. Suture exclusion through epicardial or endocardial ligation, surgical exclusion or resection, and stapler are the currently used surgical LAA closure methods.¹⁷ Thus, the LAA resection method is suitable since no LAA would be left behind. LAA closure using staplers has been implemented in Europe and the US with excellent outcomes,¹⁸ but it is highly costly and is associated with side effects. The high success rate in our center for LAA closure without the use of staplers implies that the closure of the LAA can be accomplished through far more straightforward methods without incurring high costs and causing complications such as bleeding.

In the current study, the reported rates of clots and smoke in partially closed LAAs were much lower than those reported in other investigations. This might be related to the size of the partially closed LAA orifices or residual stumps. It is worth noting that the majority of our patients underwent surgery due to severe mitral stenosis; hence, our lower rate of clots and smoke patterns in partially closed LAAs may have been the consequence of increased atrial blood flow after the reestablishment of the mitral inflow of severe stenotic mitral valves. This explanation needs confirmation through further investigations.

Conclusion

Our results indicate that the greatest success rate of complete LAA closure was seen in purse-string method followed by resection method. Indeed, the occurrence of post-surgical CVA is related to the presence of clots on the surface of metallic mitral prostheses rather than the presence of partial LAA closure. Undeniably, the purse-string method is the choice method for surgical LAA closure due to its surgeon-friendly nature and high success rate of complete closure. However, further studies are required in this regard.

Limitations: One of the limitations of retrospective studies is that the study population cannot be recalled to undergo a semi-invasive procedure like TEE without evident indications. This is one of the inherent and ethical constraints of retrospective studies that can undermine the assumption of the success rate of LAA closure.

Conflict of Interests

The authors declare no conflict of interest in this

study.

Acknowledgments

We would like to thank all counselors and all personnel of Rajaie Cardiovascular, Medical, and Research Center for their cooperation.

This study was approved by the Ethics Committee of Rajaie Cardiovascular, Medical, and Research Center, Tehran, Iran.

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