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Atrial Fibrillation After Robotic Cardiac Surgery

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Abstract

Atrial fibrillation is one of the commonest complications after cardiac surgery and it is associated with considerable morbidity and increase in mortality. Recently, robotic approach to many heart operations has become feasible and reproducible. We here investigate and review the incidence of atrial fibrillation after robotic cardiac surgery. We found that its incidence is overall low and less than in conventional heart surgery.

Introduction

Atrial fibrillation (AF) is a common and important event after cardiac surgery. It is associated with increased morbidity and mortality in the short and long term after surgery. Morbidity includes perioperative stroke, myocardial infarction, renal failure, infections and use of inotropic medications.[1,2] AF increases hospital length of stay as well as resource utilization and total costs. Although many efforts are aimed at decreasing its occurrence, AF continues to be very common, achieving a prevalence of approximately one third of patients in general.[3]

Many pre operative patient characteristics have been identified as risk factors for post operative development of this arrhythmia such as: advanced age, history of AF, chronic obstructive pulmonary disease (COPD) and valve surgery.[3] On the other hand some preventive measures seem to be effective in avoiding this complication in the post operative period: use of beta-blockers, ACE inhibitors, and amiodarone.[4] Post operative AF (POAF) usually occurs in the first 5 days after surgery and is generally self-limiting. The initial treatment is mainly pharmacological (up to 76%) with electrical cardioversion and overdrive pacing being performed in 3.7% and 2.1% respectively.[3]

Patients who stay more than 48h in AF should be anticoagulated to avoid thrombo-embolic complications.[4] In the real world, 70% of patients who suffer POAF need some form of anticoagulation.[3]

The combination of the potential hazardous complications secondary to AF, its impact on costs and its high frequency led investigators to pursue a variety of measures to prevent it. As mentioned before, prophylactic pharmacological treatment is a popular one, but still faces many limitations. Particular surgical measures therefore also gained attention. Bicaval cannulation seems to be a risk factor for repeated AF after the first post op episode. In the realm of Coronary Artery Bypass Surgery (CABG), an off pump approach was found to be a protective factor in a large meta-analysis[5] reducing its incidence almost to half compared to an on pump approach. Off pump coronary artery bypass grafting may be therefore be used as part of an anti AF strategy.[4]

The pathophysiology of post operative atrial fibrillation (POAF) is multifactorial and complex. Systemic and local inflammation, post operative pericarditis, atrial incisions and reperfusion injury may all play a role in this condition. Left atrium characteristics of each patient such as left atrial size and presence of degenerative changes and fibrosis may also influence this outcome. The interaction of patient`s pre operative anatomy and underlying disease, surgery performed, and post operative response gives rise to a truly complex system, difficult to predict.

Robotic cardiac surgery has emerged as an effective and attractive minimally invasive option for many heart procedures. In brief, the currently available robotic system (da Vinci, Surgical Intuitive, California) comprises three elements. First, a slave unit which has three arms and a camera that physically gets in contact with the patients. Then the master console in which the surgeon controls the slave unit through a set of joysticks or "masters" and footpedals. And third a video tower in which all personal in the room is able to see the same images as the surgeon.[6]

Less invasive approaches, such as robotic surgery, can potentially diminish POAF by limiting the inflammatory response secondary to reduced overall trauma. The aim of this review is to evaluate the incidence of POAF after robotic cardiac surgery and compare,

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Table 1: POAF in robotic mitral valve surgery

Paper	Reference number	Pathology	Concomitant AF ablation?	Number of patients	New onset AF (%)
Murphy, 2007	11	All pathologies	No	201	35 (17.4%)
Bhamidipati, 2010	12	All pathologies	No	43	12 (27.9%)
Suri, 2011	10	All pathologies	No	100	20 (20%)
Nifong, 2012	14	All pathologies	Yes, 86 (15,9%)	540	143 (26.5%)
Mihaljevic, 2013	9	Posterior leaflet only	No	334	56 (16.7%)
Ramsy 2013	13	All pathologies	No	300	47 (15.6%)
Total	-	Mixed	Mixed. Afib ablation: 86 (5,6%)	1518	313 (20.6%)

whenever possible, to conventional surgery.

Methods

We conducted a review of the literature in PubMed searching for the following terms: [atrial fibrillation] and [robotic mitral valve repair] or [robotic coronary revascularization] or [robotic myxoma excision] or [robotic atrial septal defect closure]. Articles that presented atrial fibrillation as a post operative complication were selected for evaluation. When the same institution reported different follow up of patients, only the most recent one was considered. References from articles were also searched for if they seemed appropriate. Only articles in English were considered.

Robotic Mitral Valve Surgery

Mitral valve repair (MVR) for degenerative disease is the most common heart operation performed with robotic assistance in the US and in the world. The robotic approach to the mitral valve is through a small right thoracotomy (3-4cm) in the fourth intercostal space just anterior to the anterior axillary line (working port and camera) with additional portholes in the third and fifth intercostal spaces for the robot arms and one port in the forth space in the mid clavicular line for the atrial retractor. Cardiopulmonary bypass (CPB) is installed through the femoral vessels. Clamping of the aorta can be performed either through a transthoracic clamp (Chitwood clamp) or with the use of an intra-aortic balloon occlusion device (Edwards Inc). Cardiac arrest is induced by infusion of cardioplegia through this balloon catheter or in cases of transthoracic clamping through a catheter placed directly into the ascending aorta. After the heart is arrested, the left atrium is opened in the Sondergaard groove and the mitral valve can be visualized. Both resection and neochordae techniques can be performed depending on underlying pathology. Annuloplasty with a malleable ring usually is included in the repair operation. Closure of the atrium is also done with the robot and, after dearing, the aorta is unclamped, the patient is weaned from cardiopulmonary bypass and the functionality of the valve is checked in the transesophageal echocardiogram (TEE).

The prevalence of AF after conventional mitral valve surgery classically ranges from 37% to 49%.[7-8] Several series on robotic MVR are found in the literature but we included in our evaluation only those which reported AF as a post operative complication.[9-14] For our analysis, if two series from the same institution included repeated patients, we only considered the most recent one (Table 1). POAF in these series varies from 15.6% to 27.9%. The mean in this set of studies was 20.6%. In these series there is some heterogeneity in terms of disease treated: one study included only posterior prolapse disease.[9] Another one study included cryo ablation in 16% of their operations.[14] If one compares this to conventional mitral valve surgery, there seems to be a reduction of POAF with robotic approach. There might be some selection bias in terms of less advanced disease and less sick patients being treated with robotic approach.

There are few direct comparisons between robotic and sternotomy approaches for MVR. Suri et al.[15] in the Mayo Clinic performed a propensity score matched comparison between robotic MVR and full sternotomy MVR for degenerative disease. Ninety five pairs could be matched. The authors found no difference in temporary POAF between the groups (Full sternotomy: 23%, robotic: 20%, P=0.60). No difference in permanent AF was found either (none in both groups). On the other hand, Mihaljevic et al[16] in a large study of 759 patients submitted to MVR for posterior leaflet prolapse through four different approaches (Full sternotomy, partial sternotomy, right mini-anterolateral thoracotomy, robotic approach) found, using propensity-score matching, that the robotic approach offered the lowest incidence of POAF. Pairs were matched between the robotic approach and each of the other ones. Between full sternotomy and robotic approach 106 pairs were matched, and there was no difference in POAF (30% versus 26%, P:0.5). Between partial sternotomy and robotic approach 223 pairs were matched and the robotic group had less POAF (35% versus 22%, P:0.002). Between the anterolateral thoracotomy and robotic approach 113 pairs were matched and no difference was found in POAF (26% versus 19%, P: 0.3).

When comparing resection and neochordae techniques through the robotic approach the Cleveland Clinic group found no differences in POAF incidence in matched pairs (16% versus 25%, P: 0.2). There were also no differences in POAF incidence when comparing patients who needed multiple intraoperative repair attempts and those with a successful initial repair (30% versus 20%, P: 0.2).[9]

Overall, direct comparisons between robotic and conventional approaches show either similarity or a decrease in POAF in robotic patients. When comparing current large series of robotic MVR and historical series of conventional MVR, a robotic approach may be beneficial in preventing POAF.

Robotic Totally Endoscopic Coronary Artery By Pass Surgery

Totally endoscopic coronary artery bypass (TECAB) surgery has become an acceptable option for selected patients who need surgical myocardial revascularization. Either used as a stand alone procedure or as part of a hybrid approach (that is, combined with percutaneous artery intervention) TECAB has been performed with or without use of CPB, in single and multivessel disease and with revascularization of up to four coronaries.

The general conduct of operation is described in detail elsewhere [17,18] but could be summarized as follows. The patient is intubated with a double lumen tube to allow single right lung ventilation. The robotic arms are docked to the patient's left chest. With the left lung down, the camera port is inserted in the fifth intercostal space at the

Table 2: POAF in robotic mitral valve surgery

Paper	Reference number	Number of patients	New onset AF (%)
Srivastava 2010	24	241	25 (10.3%)
Dhawan 2012	23	106	17 (16%)
Srivastava 2012	22	164	13 (7.9%)
Weighted mean		511	55 (10.7%)

Table 3: POAF in Arrested heart TECABG

Paper	Reference number	Number of patients	New onset AF (%)
Argenziano 2006	26	98	1 (1.2%)
Bonatti 2013	25	500	73 (15%)
Weighted mean		598	74 (12,3%)

level of the anterior axillary line. The right and left arms are inserted in the third and seventh intercostal spaces, 2-3 cm anterior to the camera port. CO2 is inflated in the chest to allow space for work. Internal mammary artery (IMA) harvesting is performed with low power cautery. After the IMA is ready and canulation in the femoral vessels is complete, CPB is initiated. The pericardium is opened and the coronary targets are definied. The endo-balloon is advanced to the ascending aorta and inflated. Cold blood antegrade cardioplegia is given through the tip of the intra-aortic balloon. After cardiac arrest is achieved the coronary arteries are exposed in the epicardium and incised. The artery is opened with robotic knife and Potts scissors. Anastomosis is performed with running suture of 7-0 Pronova. The endoballoon is deflated and heart re-starts to beat. The patency of the graft is tested with transit time ultrasound probes. The patient is weaned from cardiopulmonary bypass and decannulated. One chest tube is left in the left pleura and the ports are closed.

Alternatively the TECAB can be performed on the beating heart. Port placement and internal mammary artery harvesting are carried out in the same fashion as in the arrested heart version of the procedure. After opening of the pericardium an endostabilizer is inserted through a left subcostal port. After heparinization, the target vessel is occluded using silastic bands and opened using a robotic lancet. The anastomotic technique is the same as described above. An intraluminal shunt may be inserted.

The prevalence of POAF after conventional CABG is well established reported in the range of 28.5% to 31%[2,19] and it contributes to an increased risk of stroke, renal failure, gastrointestinal complications and longer length of stay. Off pump CABG may decrease incidence of POAF by almost 50%[5] and has been advocated as a strategy to avoid this complication.

On the realm of TECAB, Weidinger et al studied the predictors of POAF. Although they found in univariate analysis that hypertension, increased age, body weight, body mass index, EuroSCORE, hybrid approach and off pump TECAB time were associated to POAF, multivariate regression analysis showed only age and body weight to be significant.[20] Another study showed that POAF in TECAB increases length of stay by one day in univariate analysis but had no impact in multivariable analysis.[21]

Tables 2-4 summarize the main articles that report on POAF after TECAB, divided by use or not of CPB and use of left minithoracotomy for the anastomosis (robotic minimally invasive direct coronary artery bypass graft). By looking at those numbers one can note two facts: first there is a wide variation on the incidence of POAF from 1.2% to 20.7%, second all series report incidences bellow the usual range in conventional CABG. The wide variance could be explained by a combination of different patient populations and different approaches (use of CPB, use of mini thoracotomy). The persistent lower incidence of POAF if compared to conventional CABG could be explained by better patient selection (lower severity patients for TECAB), less manipulation of right atrium (cannulation through the femoral vessels in TECAB opposed to right atrium in conventional CABG), less overall manipulation of the heart, and reduced chest trauma in TECAB (leading to less inflammatory response).

Table 4: POAF in Robotic MIDCABG

Paper	Reference number	Number of patients	New onset AF (%)
Srivastava 2006	29	150	14 (9.3%)
Caynak 2009	27	196	16 (8.3%)
Halkos 2013	28	300	62 (20.7%)
Weighted mean		646	92 (14.2%)

Robotic Atrial Septal Defect Closure

Atrial septal defect (septum secundum, ASD) closure was one of the first operations to be performed with robotic assistance.[30] The overall approach, access and conduct of operation are similar to MVR, with the difference of the need to go around and occluding both venae cavae and opening of the right atrium instead of the left atrium. The right atrium is opened robotically, a basket sucker is placed through the defect into the left atrium, and the defect is closed either using direct suture or patch repair. 4/0 Goretex is the usual suture material for defect and atrial closure.

Atrial fibrillation and atrial flutter are common arrhythmias to be found in patients with ASD who are undergoing surgery. Eight percent to 32.5%[31,32,33] of patients have pre op AF and the older the patient population, the higher the prevalence.[33] It is believed that ASD closure does not affect the natural history of Afib in patients operated after 40 years of age[34,35] although it can improve clinical status and prevent right heart failure.[34] The incidence of new onset AF after conventional ASD repair in adults is reported in the range of 6.5% to 11.3%[32, 34] and it seems to be higher in older patients. POAF increases LOS in the ICU in these patients.[32] Thoracoscopic closure of ASD has reported POAF in the range of 9% [36]. Today it is recognized that patients undergoing surgical ASD repair who present with preoperative AF should undergo a concomitant ablation.

Totally endoscopic ASD closure with or without robotic assistance is feasible, safe and efficient[37] according to a recent meta-analysis. Incidence of POAF in robotically assisted closure of ASD in different series are depicted in table 5. Mean overall incidence found was 2.9%. This is lower than most reports in conventional ASD closure. The mean age in the population submitted to robotic ASD closure in our review (42.2 years old) is similar to most conventional ASD closure reports.

Robotic Myxoma Resection

Primary cardiac tumors are a rare entity and myxoma is the most common of all benign tumors.[43] The preferred location is the left

Table 5: POAF in robotic ASD closure

Paper	Reference number	Number of patients	Mean age (years)	New onset AF (%)
Torraca 2001	40	6	42	0 (0%)
Argenziano 2003	41	17	47	2 (11.7%)
Ak 2007	39	24	45.5	1 (4.1%)
Gao 2008	38	45	38	0 (0%)
Watanabe 2010	42	9	46	0 (0%)
Weighted mean		101	42.2	3 (2.9%)

atrium. Most series of conventional surgical resection of myxomas do not report on atrial fibrillation as a complication. Centofanti et al[44] in their study of myxoma resection on 83 patients found an incidence of atrial arrhythmias in 37% postoperatively. Schilling et al[45] more recently reports on 29 conventional isolated left atrium myxoma removals with an incidence of POAF of 17%.

The surgical approach to robotic myxoma resection is very similar to robotic mitral valve repair or ASD closure. The left and/or right atrium are incised and the tumor is resected robotically with or without a segment of interatrial septum. If an atrial septal defect is created it is closed primarily or using a patch.

Primary benign cardiac tumor resections were one of the first operations attempted with robotic assistance. The series are small and not all of them report AF as a complication. Table 6 summarizes the main series. The only direct comparison between conventional and robotic approaches comes from Schilling and coworkers.[45] In the 16 robotic cases there was no POAF. In the 29 open cases there were 5 cases (17%) but this difference, did not reach statistical significance (p=0.14).

Consistency of genotype frequencies with the Hardy-Weinberg equilibrium (HWE) was tested using a chi-squared goodness-of-fit test on a contingency table of observed versus expected genotype frequencies in cases and controls. Post-hoc evaluations, where necessary, were made by means of the Bonferroni correction. A two-sided p value <0.05 was considered significant for all tests.

Table 6: POAF in robotic excision of atrial mixoma

Paper	Reference number	Number of patients	Mean age (years)	New onset AF
Murphy 2005	47	3	0 (0%)	0 (0%)
Gao 2010	46	19	2 (10.5%)	2 (11.7%)
Schilling 2012	45	16	0 (0%)	1 (4.1%)
Weighted mean		38	2 (5.2%)	0 (0%)

Conclusions:

Atrial fibrillation after robotic cardiac surgery appears to be low, probably lower than in conventional cardiac surgery. Further investigation, preferably in a randomized trial environment, is necessary to further clarify this finding.

References:

1. Shantsila E, Watson T, Lip GY. Curr Med Res Opin. Atrial fibrillation post-cardiac surgery: changing perspectives. 2006 Aug;22(8):1437-41.
2. Mariscalco G, Klersy C, Zanobini M, Banach M, Ferrarese S, Borsani P, Cantore C, Biglioli P, Sala A. Atrial fibrillation after isolated coronary surgery affects late survival. Circulation. 2008 Oct 14;118(16):1612-8.
3. Mathew JP, Fontes ML, Tudor IC, Ramsay J, Duke P, Mazer CD, Barash PG, Hsu PH, Mangano DT; Investigators of the Ischemia Research and Education Foundation; Multicenter Study of Perioperative Ischemia Research Group. A multicenter risk index for atrial fibrillation after cardiac surgery. JAMA. 2004 Apr 14;291(14):1720-9.
4. Dunning J, Treasure T, Versteegh M, Nashef SA. Guidelines on the prevention and management of de novo atrial fibrillation after cardiac and thoracic surgery. Eur J Cardiothorac Surg 2006; 30: 852–872.
5. Cheng DC, Bainbridge D, Martin JE, Novick RJ; Evidence-Based Perioperative Clinical Outcomes Research Group. Does off-pump coronary artery bypass reduce mortality, morbidity, and resource utilization when compared with conventional coronary artery bypass? A meta-analysis of randomized trials. Anesthesiology. 2005 Jan;102(1):188-203.
6. DiMaio S, Hanuschik M, Kreaden U. The da Vinci Surgical System. In: Rosen J, Hannaford B, Satava RM, eds. Surgical Robots: System Applications and Visions. 1st Ed., New York, Springer. 2011; 199-217
7. Dunning J, Treasure T, Versteegh M, Nashef SA. Guidelines on the prevention and management of de novo atrial fibrillation after cardiac and thoracic surgery. Eur J Cardiothorac Surg 2006; 30: 852–872.
8. Asher CR, Miller DP, Grimm RA, Cosgrove DM, Chung MK III. Analysis of risk factors for development of atrial fibrillation early after cardiac valvular surgery. Am J Cardiol 1998; 82:892–895.
9. Mihaljevic T, Pattakos G, Gillinov AM, Bajwa G, Planinc M, Williams SJ, Blackstone EH. Robotic posterior mitral leaflet repair: neochordal versus resectional techniques. Ann Thorac Surg. 2013 Mar;95(3):787-94.
10. Suri RM, Burkhart HM, Rehfeldt KH, Enriquez-Sarano M, Daly RC, Williamson EE, Li Z, Schaff HV. Robotic mitral valve repair for all categories of leaflet prolapse: improving patient appeal and advancing standard of care. Mayo Clin Proc. 2011 Sep;86(9):838-44.
11. Murphy D, Smith JM, Siwek L, Langford DA, Robinson JR, Reynolds B, Seshadri-Kreaden U, Engel AM. Multicenter mitral valve study: a lateral approach using the da vinci surgical system. Innovations (Phila). 2007 Mar;2(2):56-61.
12. Bhamidipati CM, Mehta GS, Sarwar MF, Sooppan R, Dilip KA, Lutz CJ. Robot-assisted mitral valve repair: a single institution review. Innovations (Phila). 2010 Jul-Aug;5(4):295-9.
13. Ramzy D, Trento A, Cheng W, De Robertis MA, Mirocha J, Ruzza A, Kass RM. Three hundred robotic-assisted mitral valve repairs: The Cedars-Sinai experience. J Thorac Cardiovasc Surg. 2013, S0022-5223(13)01131-8.
14. Nifong LW, Rodriguez E, Chitwood WR Jr. 540 consecutive robotic mitral valve repairs including concomitant atrial fibrillation cryoablation. Ann Thorac Surg. 2012 Jul;94(1):38-42; discussion 43.
15. Suri RM, Burkhart HM, Daly RC, Dearani JA, Park SJ, Sundt TM 3rd, Li Z, Enriquez-Sarano M, Schaff HV. Robotic mitral valve repair for all prolapse subsets using techniques identical to open valvuloplasty: establishing the benchmark against which percutaneous interventions should be judged. J Thorac Cardiovasc Surg. 2011 Nov;142(5):970-9.
16. Mihaljevic T, Jarrett CM, Gillinov AM, Williams SJ, DeVilliers PA, Stewart WJ, Svensson LG, Sabik JF 3rd, Blackstone EH. Robotic repair of posterior mitral valve prolapse versus conventional approaches: potential realized. J Thorac Cardiovasc Surg. 2011 Jan;141(1):72-80
17. Canale LS, Mick S, Mihaljevic T, Nair R , Bonatti J. Robotically assisted totally endoscopic coronary artery bypass surgery. J Thorac Dis 2013;5(S6):S641-S649.
18. Ann Cardiothorac Surg. 2013 Jul;2(4):408-18. Systematic review of robotic-assisted, totally endoscopic coronary artery bypass grafting. Seco M, Edelman JJ, Yan TD, Wilson MK, Bannon PG, Vallely MP.
19. Usefulness of postoperative atrial fibrillation as an independent predictor for worse early and late outcomes after isolated coronary artery bypass grafting (multicenter Australian study of 19,497 patients). Saxena A, Dinh DT, Smith JA, Shardey GC, Reid CM, Newcomb AE. Am J Cardiol. 2012 Jan 15;109(2):219-25.
20. Weidinger F, Schachner T, Bonaros N, Hofauer B, Lehr EJ, Vesely M, Zimrin D, Bonatti J. Predictors and consequences of postoperative atrial fibrillation following robotic totally endoscopic coronary bypass surgery. Eur J Cardiothorac Surg. 2013 May 23. [Epub ahead of print]
21. Lee JD, Bonaros N, Hong PT, Kofler M, Srivastava M, Herr DL, Lehr EJ, Bonatti J. Factors influencing hospital length of stay after robotic totally endoscopic coronary artery bypass grafting. Ann Thorac Surg. 2013 Mar;95(3):813-8. Epub 2013 Jan 24.
22. Srivastava S, Barrera R, Quismundo S.One hundred sixty-four consecutive beating heart totally endoscopic coronary artery bypass cases without intraoperative conversion. Ann Thorac Surg. 2012 Nov;94(5):1463-8

23. Dhawan R, Roberts JD, Wroblewski K, Katz JA, Raman J, Chaney MA. Multivessel beating heart robotic myocardial revascularization increases morbidity and mortality. J Thorac Cardiovasc Surg. 2012 May;143(5):1056-61.
24. Srivastava S, Gadasalli S, Agusala M, Kolluru R, Barrera R, Quismundo S, Kreaden U, Jeevanandam V. Beating heart totally endoscopic coronary artery bypass. Ann Thorac Surg. 2010 Jun;89(6):1873-9; discussion 1879-80.
25. Bonaros N, Schachner T, Lehr E, Kofler M, Wiedemann D, Hong P, Wehman B, Zimrin D, Vesely MK, Friedrich G, Bonatti J. Five hundred cases of robotic totally endoscopic coronary artery bypass grafting: predictors of success and safety. Ann Thorac Surg. 2013 Mar;95(3):803-12. Epub 2013 Jan 10.
26. Argenziano M, Katz M, Bonatti J, Srivastava S, Murphy D, Poirier R, Loulmet D, Siwek L, Kreaden U, Ligon D; TECAB Trial Investigators. Results of the prospective multicenter trial of robotically assisted totally endoscopic coronary artery bypass grafting. Ann Thorac Surg. 2006 May;81(5):1666-74.
27. Caynak B, Sagbas E, Onan B, Onan IS, Sanisoglu I, Akpinar B. Robotically enhanced coronary artery bypass grafting: the feasibility and clinical outcome of 196 procedures. Int J Med Robot. 2009 Jun;5(2):170-7.
28. Halkos ME, Walker PF, Vassiliades TA, Douglas JS, Devireddy C, Guyton RA, Finn AV, Rab ST, Puskas JD, Liberman HA. Clinical and Angiographic Results After Hybrid Coronary Revascularization. Ann Thorac Surg. 2013 Oct 17. pii: S0003-4975(13)01911-5.. [Epub ahead of print]
29. Srivastava S, Gadasalli S, Agusala M, Kolluru R, Naidu J, Shroff M, Barrera R, Quismundo S, Srivastava V. Use of bilateral internal thoracic arteries in CABG through lateral thoracotomy with robotic assistance in 150 patients. Ann Thorac Surg. 2006 Mar;81(3):800-6;
30. Argenziano M, Williams MR. Robotic atrial septal defect repair and endoscopic treatment of atrial fibrillation. Semin Thorac Cardiovasc Surg. 2003 Apr;15(2):130-40.
31. Gatzoulis MA, Freeman MA, Siu SC, Webb GD, Harris L. Atrial arrhythmia after surgical closure of atrial septal defects in adults. N Engl J Med. 1999 Mar 18;340(11):839-46.
32. Hörer J, Eicken A, Müller S, Schreiber C, Cleuziou J, Prodan Z, Holper K, Lange R. Risk factors for prolonged intensive care treatment following atrial septal defect closure in adults. Int J Cardiol. 2008 Mar 28;125(1):57-61. Epub 2007 Apr 25.
33. Ghosh S, Chatterjee S, Black E, Firmin RK. Surgical closure of atrial septal defects in adults: effect of age at operation on outcome. Heart. 2002 Nov;88(5):485-7.
34. Jemielity M, Dyszkiewicz W, Paluszkiewicz L, Perek B, Buczkowski P, Ponizyński A. Do patients over 40 years of age benefit from surgical closure of atrial septal defects? Heart. 2001 Mar;85(3):300-3.
35. Berger F, Vogel M, Kramer A, Alexi-Meskishvili V, Weng Y, Lange PE, Hetzer R. Incidence of atrial flutter/fibrillation in adults with atrial septal defect before and after surgery. Ann Thorac Surg. 1999 Jul;68(1):75-8.
36. Casselman FP, Dom H, De Bruyne B, Vermeulen Y, Vanermen H. Thoracoscopic ASD closure is a reliable supplement for percutaneous treatment. Heart. 2005 Jun;91(6):791-4.
37. Yao DK, Chen H, Ma LL, Ma ZS, Wang LX. Totally endoscopic atrial septal repair with or without robotic assistance: a systematic review and meta-analysis of case series. Heart Lung Circ. 2013 Jun;22(6):433-40. Epub 2013 Jan 26.
38. Gao C, Yang M, Wang G, Wang J. Totally robotic resection of myxoma and atrial septal defect repair. Interact Cardiovasc Thorac Surg. 2008 Dec;7(6):947-50. Epub 2008 Sep 16.
39. Ak K, Aybek T, Wimmer-Greinecker G, Ozaslan F, Bakhtiary F, Moritz A, Dogan S. Evolution of surgical techniques for atrial septal defect repair in adults: a 10-year single-institution experience. J Thorac Cardiovasc Surg. 2007 ep;134(3):757-64.
40. Torracca L, Ismeno G, Alfieri O. Totally endoscopic computer-enhanced atrial septal defect closure in six patients. Ann Thorac Surg. 2001 Oct;72(4):1354-7.
41. Argenziano M, Oz MC, Kohmoto T, Morgan J, Dimitui J, Mongero L, Beck J, Smith CR.Totally endoscopic atrial septal defect repair with robotic assistance. Circulation. 2003 Sep 9;108 Suppl 1:II191-4.
42. Watanabe G. Successful intracardiac robotic surgery: initial results from Japan. Innovations (Phila). 2010 Jan;5(1):48-50.
43. Blondeau P. Primary cardiac tumors--French studies of 533 cases. Thorac Cardiovasc Surg. 1990 Aug;38 Suppl 2:192-5.
44. Centofanti P, Di Rosa E, Deorsola L, Dato GM, Patanè F, La Torre M, Barbato L, Verzini A, Fortunato G, di Summa M. Primary cardiac tumors: early and late results of surgical treatment in 91 patients. Ann Thorac Surg. 1999 Oct;68(4):1236-41.
45. Schilling J, Engel AM, Hassan M, Smith JM. Robotic excision of atrial myxoma. J Card Surg. 2012 Jul;27(4):423-6. Epub 2012 May 29.
46. Gao C, Yang M, Wang G, Wang J, Xiao C, Wu Y, Li J. Excision of atrial myxoma using robotic technology. J Thorac Cardiovasc Surg. 2010 May;139(5):1282-5.
47. Murphy DA, Miller JS, Langford DA. Robot-assisted endoscopic excision of left atrial myxomas. J Thorac Cardiovasc Surg. 2005 Aug;130(2):596-7.