Graduate thesis

NTNU
Norwegian University of Science and Technology
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Department of Circulation and Medical Imaging

Jiaji Li

# Concomitant treatment of atrial fibrillation for patients undergoing open cardiac surgery at St. Olavs university hospital 2010-2020

Graduate thesis in the Programme of Professional Study in Medicine
Supervisor: Alexander Wahba
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## Acknowledgements

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I would also like to thank my co-supervisor Associate Professor Øystein Pettersen for his practical guidance and insights, sharing his own experiences from a similar project he wrote in 2010. His help made the data collection much more comfortable.

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## Sammendrag på norsk


**Bakgrunn:** Atrieflimmer er den hyppigst forekommende hjertearytmien og er forbundet med økt risiko for slag, hjertesvikt og redusert livskvalitet. En effektiv behandling av atrieflimmer er kirurgisk ablasjon sammen med annen åpen hjertekirurgi. Dette har blitt utført ved St. Olavs siden 2003. Siden da er det kun gjort en studie på pasienter operert inntil 2010, som viste gode resultater ved gjenopprettelse av sinusrytme. Denne studien ser videre på effekten av operasjonen og i tillegg forekomsten av residiv, elektrokonvertering, kateterablasjon, slag og antikoagulantia i oppfølgingstiden.

**Metode:** Totalt ble 212 pasienter planlagt for kirurgisk ablasjon mellom 2010 og 2020 identifisert og inkludert i studien. Pasientene gjennomgikk koronarkirugi, aortakirurgi eller mitralkirurgi og 172 pasienter fikk i tillegg utført ablasjon i form av epikardiell lungeveneablasjon, bokslesjon eller en full Maze lesjon; mens 40 pasienter fikk kun okklusjon/fjerning av venstre aurikkel. For pasientene som ble kirurgisk abladert og i live ved gjennomføring av studien ble også et nytt EKG innhentet fra pasientenes fastleger eller tatt poliklinisk. All resterende pasientdata ble innhentet retrospektivt ved gjennomgang av elektronisk pasientjournal.

**Resultat:** Etter en median (IQR) oppfølgingstid på 66.7 (57.8) måneder var 130 pasienter i live og med tilgjengelig EKG. Blant disse hadde 98 (75.4%) sinusrytme ved oppfølging og 29 (22.3%) hadde avsluttet antikoagulasjonsbehandling. Av de 172 som ble abladert og oppfulgt fikk 78 (45.3%) residiv av atrietakykardi, 51 (29.7%) pasienter ble elektrokonvertert og 11 (6.4%) ble kateterabladert. Residiv av atrietakykardi viste en meget sterk sammenheng til rytme ved oppfølgingstidspunktet ($p < 0.001$). I tillegg kan det fra 2018 observeres at en økende andel av pasientene opereres med lungeveneisolasjon.
I oppfølgingsperioden ble det oppdaget 17 tromboemboliske slag. Ved sammenlikning med okklusjon av venstre aurikkel ble det ikke funnet en klar sammenheng.

**Konklusjon:** Studien viser at kirurgisk ablasjon av atrieflimmer ved St. Olavs er en god og effektiv operasjon for reetablering av sinusrytme. Resultatene viser en bedring i effekt sammenliknet med en tidligere studie og er sammenliknbare med andre nasjonale og internasjonale studier.

## Abstract in English

**Introduction:** Atrial fibrillation is the most common cardiac arrhythmia and is associated with an increased risk of stroke, heart failure and reduced quality of life. An effective treatment for atrial fibrillation is surgical ablation concomitant to open-heart surgery. This has been performed at St. Olavs university hospital since 2003. Since then, only one study has been performed on patients operated on until 2010, which showed good results in restoring sinus rhythm. This study looks further at the effect of the operation and in addition the incidence of recurrence, cardioversion, catheter ablation, stroke, and anticoagulation during the follow-up period.

**Material and method:** A total of 212 patients planned for surgical ablation between 2010 and 2020 were identified and included in the study. Patients underwent coronary surgery, aortic surgery or mitral surgery with 172 patients also receiving ablation in the form of epicardial pulmonary vein ablation, box lesion or a full Cox-Maze lesion; while 40 patients received only occlusion/removal of the left atrial appendage. For the patients who were surgically ablated and alive at follow-up, a new ECG was also obtained from the patients' GPs or taken at the outpatient clinic. All remaining patient data were obtained retrospectively through review of the patients’ hospital records.

**Results:** After a median (IQR) follow-up of 66.7 (57.8) months, 130 patients were alive and had an available ECG. Among these, 98 (75.4%) were in sinus rhythm at follow-up and 29 (22.3%) had discontinued anticoagulation therapy. Of the 172 who were ablated and followed up, 78 (45.3%) experienced recurrence of atrial tachyarrhythmia, 51 (29.7%) patients were cardioverted and 11 (6.4%) received catheter ablation. Recurrence of atrial tachycardia showed a very strong association with heart rhythm at the time of follow-up ($p < 0.001$). In addition, from 2018 it can be observed that an increasing proportion of patients are ablated with pulmonary vein isolation.
During the follow-up period, 17 thromboembolic strokes were observed. When compared with the occlusion of the left atrial appendage, no clear relationship could be established.

**Conclusion:** The study shows that surgical ablation of atrial fibrillation at St. Olavs is a good and effective treatment for re-establishing sinus rhythm. The results show an improvement in effect compared with a previous study and are comparable to similar national and international studies.

## 1. Introduction

Atrial fibrillation (AF) is one of the most common cardiovascular diseases and the most common cardiac arrythmia, affecting 2-4% of the general population. In Norway this prevalence is assumed to be 3.4% (1), which correlates with the international rates. AF increases the risks of several complications such as stroke up to fivefold (2) and all-cause mortality 3.5-fold. With an expected 2.3-fold increase in the prevalence of AF, due to an aging population and underdiagnosis of the disease, it is thus expected that AF may present an increasing challenge to our healthcare and society, as well as the overall quality of life itself. The currently known risk factors for developing AF are age, sex, race, hypertension, obesity, endurance exercise, obstructive sleep apnea (OSA), thyroid disease, and alcohol consumption. Among the aforementioned factors age is considered to be the most important (3).

The definition of AF is a supraventricular tachyarrhythmia with uncoordinated atrial electrical activation and consequently ineffective atrial contraction. On an electrocardiogram (ECG) this includes irregular R-R intervals, absence of repeating P-waves and irregular atrial activation. Clinically the diagnosis is set after an arrythmia lasting over 30 seconds or being present on an entire 12-lead ECG (4). AF can further be classified into four main subtypes:

- Paroxysmal: AF that terminates spontaneously or with intervention within 7 days.
- Persistent: AF that is continuously sustained over 7 days which includes episodes terminated with cardioversion over 7 days.
- Long-standing persistent: AF that is continuous over 12 months when decided to adopt a rhythm control strategy.
- Permanent: AF that is accepted by both patient and physician, and no further attempts to restore sinus rhythm will be undertaken.

Physiologically the causes and mechanisms of AF are not completely understood. However, as discovered by Haïssaguerre, AF is often initiated by rapidly firing ectopic beats from a focal source located around the pulmonary veins (PV) (5). Over time this will result in a remodelling of the atria, often a dilation and enlargement, forming multiple re-entry points. Due to the dysrhythmia caused by the AF contractile dysfunction and stasis will occur, increasing the risk of the formation of thromboembolism. This will again lead to the remodelling of the atria, especially the left atrium, which will further increase the risk of thromboembolism (6).

As of today, the best management and treatment of AF mainly consist of the integrated ABC pathway (7). This pathway consists of A – anticoagulation/avoid stroke, where the need for anticoagulant can be calculated using the $CHA_2DS_2$-VASc (at the same time considering the bleeding risks related to the use of anticoagulants); B – better symptom management which consists of rate or rhythm control using either medicine or more invasive techniques such as ablation and cardioversion; and C – cardiovascular and comorbidity optimization which aims to treat comorbidities and motivate for lifestyle changes. With regards to rhythm control and the conversion to sinus rhythm catheter ablation is generally used for patients with lone AF while surgical ablation is generally used when the patient is undergoing cardiac surgery for other indications (8).

Of the surgical ablation of AF, the Cox-Maze (9) procedure has long been considered the gold-standard. This procedure was developed by James Cox in the 1990's as the Cox-Maze I and initially involved cutting and sewing multiple re-entry points in both atria believed to perpetuate the AF, thus giving it the popular moniker "cut and sew". As of today, this procedure has been modified a number of times and exist in its current form as the Cox-Maze IV where the incisions have mostly been replaced with radiofrequency- or cryothermal ablation lines and can also be performed minimally invasive (10). However, the complete Maze procedure is still often considered complicated and time consuming, especially when performed concomitantly with other cardiac surgeries; and easier procedures have therefore been developed using components of the original Maze procedure (11). Many surgeons thus prefer only using ablation lines in the left atrium consisting of a epicardial pulmonary vein isolation (PVI) with a intracardial "box" lesion around the pulmonary veins, often in combination with an ablation line to the mitral valve annulus and sometimes an ablation line to the left atrial appendage (12). This is often considered being as effective as a biatrial approach (13).

Today surgical ablation of AF is regarded as an effective way to treat AF, being superior to no ablation in restoring sinus rhythm as demonstrated in an RCT from 2019 (14). The efficacy has been reported as up to 95% (15). With this high efficacy there has also been observed a reduction in stroke rates, which is also partly due to a surgical removal of the left atrial appendage as a part of a modified Maze procedure (16). Further it has also been hypothesized a possible reduction in anticoagulants after surgery, due to the unwanted increase in bleeding and intracranial haemorrhages (ICH) (17). However, there are currently no RCTs or larger studies examining the interruption of anticoagulation after surgical ablation (18). Therefore, long-term anticoagulation is still recommended for all patients still at risk of stroke, despite successful surgical ablation and the closure of the left atrial appendage (3).

At St Olavs university hospital surgical ablation has been performed since 2003 and is only performed concomitant to other open cardiac surgeries. This follows the 2020 ESC clinical practice guidelines for surgical treatment of AF and the 2017 EHRA expert consensus statement on surgical ablation. The most frequent concomitant cardiac surgery described in published literature is the mitral valve surgery, which is also the combination that has been studied most as one third of the mitral patient population have AF at surgical presentation (19). The surgical ablation is also practical as the left atrium is opened anyway during mitral valve surgery and can also be performed using minimal invasive thoracotomy (10). It is also common to perform surgical ablation concomitant to aortic valve- or CABG surgery with rates of pre-existing AF being 14% and 6%, respectively (19). Although AVR and CABG do not require an opening of the left atrium, it is still considered safe to perform surgical ablation in combination. The EHRA expert consensus statement therefore recommends concomitant surgical ablation with mitral valve surgery and aortic valve- or CABG-surgery for AF refractory or intolerant to class I and III antiarrhythmic medications (Class I Level B Non-randomized) (8), while the ESC guidelines states that concomitant AF ablation should be considered for patients undergoing cardiac surgery, balancing freedom from atrial arrhythmia and risk factors for recurrence (Class IIa Level A) (3). However, the surgical treatment of AF is not without complications, with the most known complication being the implantation of a permanent pacemaker (20).

Since the implementation of surgical ablation at St. Olavs university hospital there has been on average 20 of these surgeries each year. Until now only one study has been conducted on this treatment at St Olavs; a retrospective study with a prospective follow-up by Øystein Pettersen and Andreas Bachke (21). This study showed an increased success rate of treatment between 2003 and 2009, with postoperative AF decreasing from 75% to 36.8%. However as suggested in the study this may be due to a shorter follow-up of these patients. The study also suggests a decreased need for postoperative antiarrhythmic medication and anticoagulation that needs to be further examined. As this treatment is conducted at the same rate there is still need for further observation and studies, as well as comparing the results with previous, national, and international data.

**Study goals and objectives**

This study will examine how a variety of outcomes after surgery compares with national and international standards. The endpoints are as following:

**Primary endpoint:**

- Examine the freedom from AF and other atrial tachyarrhythmias (ATA) at time of follow-up.

**Secondary endpoints:**

- Compare the relationship between surgical procedure and freedom from ATA.
- Examine the importance of preoperative patient characteristics such as underlying condition and preoperative type of AF.
- Examine the use of anticoagulants and antiarrhythmic drugs during follow-up.
- Examine the need for cardioversion and/or catheter ablation during follow-up.
- Examine the implantation of a permanent pacemaker during follow-up.
- Examine the occurrence of thromboembolic stroke during follow-up.

# 2. Material and method

## Material

The study conducted is a retrospective analysis of concomitant surgical ablation of atrial fibrillation for patients who underwent cardiac surgery at St. Olav's hospital between 01.01.2010 and 31.12.2020. All relevant patients were identified through their registered procedure code in the NOMESCO Classification of Surgical Procedures (22) which was registered in the electronical operation planning tool OpPlan4. The search consisted of the following procedures: FPA96 (Other operation for supraventricular arrhythmia), FPB00 (Excision of ectopic heart focus), FPD00 (Maze procedure for atrial fibrillation), FPD96 (Other operation for atrial fibrillation), FFW96 (Other operation on atria) and FPW96 (Other operation for arrhythmia or disturbance of impulse propagation). With the list of all relevant patients, pre- and postoperative data were then retrieved from the patients' hospital records using the hospital record programme DocuLive. Furthermore, the patients' current ECGs and heart rhythms as well as their current medications were either requested from their general practitioners or taken at the hospital in a period between March and June of 2021.

## Surgical method

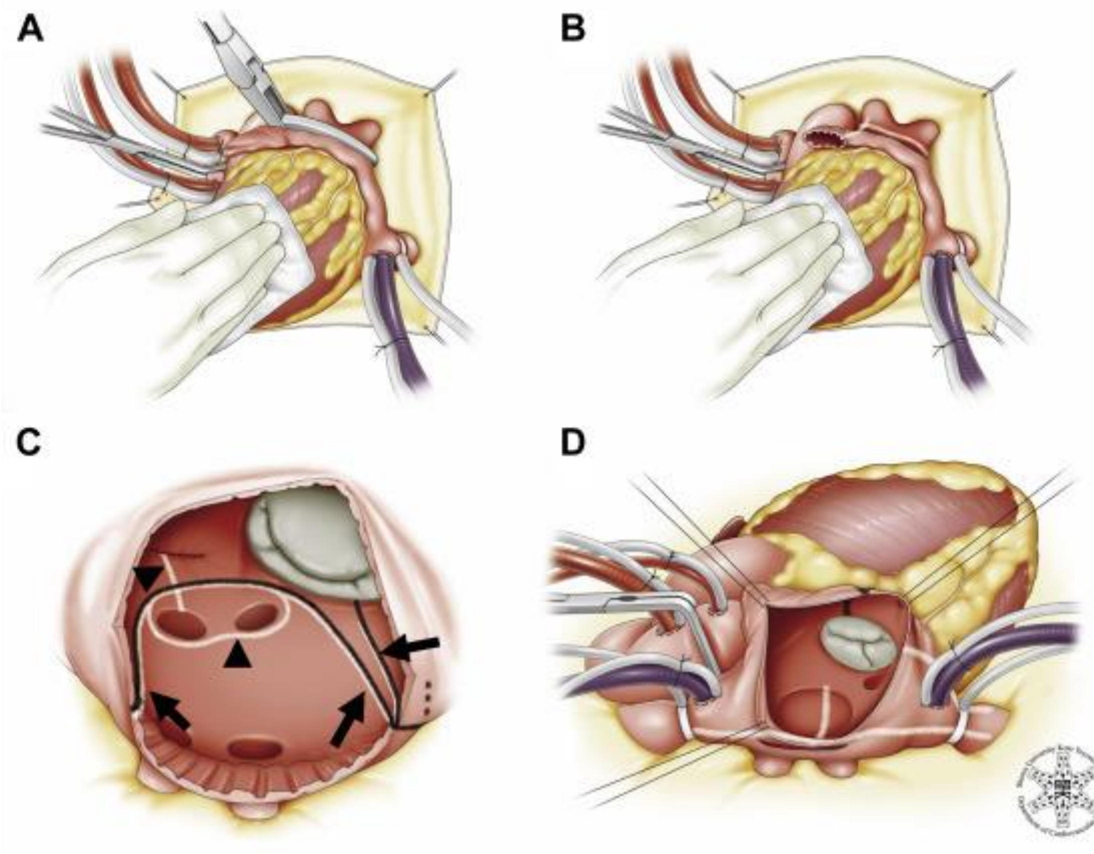
At St. Olav's hospital all surgical ablations are only performed concomitantly to other open cardiac surgeries using bipolar and/or monopolar radiofrequency to create the ablation lines, as opposed to the classical cut-and-sew approach. The ablation lines performed between 2010 and 2020 can broadly be classified into three main lesion sets. These include:

- Epicardial pulmonary vein isolation (PVI). This lesion set consists of an epicardial clamping of both sets of the pulmonary veins using bipolar radiofrequency. The benefit of this lesion set is that it does not require an opening of the left atrium and is sometimes performed concomitant to surgical procedures which do not require an opening of the left atrium such as CAGB or AVR. In figure 2.1 this is demonstrated in illustration A.
- Monoatrial box lesion. This procedure includes the lesion sets of the PVI. Unlike the epicardial PVI, the left atrium is also opened where monopolar isolation of the pulmonary veins is performed on both sides combined with connecting lines cranially

and caudally creating roof and floor lines, thus completing a “box lesion”. Additionally, connecting lines to the mitral valve isthmus and left atrial appendage (LAA) are also made. The LAA is often also removed/occluded either through stapling, or with surgical removal. Not all patients included received the full number of lesions. In figure 2.1 this is demonstrated in illustration C.

- Biatrial Cox-Maze IV. This procedure involves all the lesions from the box lesion set. Additionally, in the right atrium this includes an isolating line from the superior vena cava to the inferior vena cava, a free line in the right atrial wall and a connecting line to the tricuspid valve annulus. In figure 2.1 this is demonstrated in illustration D.

**Figure 2.1:** Illustration of the surgical procedure (23)




There were also several patients who did not go through with the surgical ablation and only had their LAA removed to reduce the risk of stroke and other thromboembolic events. In figure 2.1 this is demonstrated in illustration B. These patients were not ablated due to different factors such as large left atria, comorbidity, lack of interest or a change of mind.

## Variables

From the patients' medical records and from the data received from their general practitioners, we recorded the following variables: height (cm), weight (kg), primary surgical indication, atrial inclusion, lesion set, exclusion of LAA (yes/no), postoperative complications, perioperative antiarrhythmics, perioperative anticoagulation, preoperative type of AF, recurrence of AF during follow-up (yes/no), cardioversion during follow-up (yes/no), catheter ablation during follow-up (yes/no), permanent pacemaker during follow-up (yes/no), thromboembolic stroke during follow-up (yes/no), death during follow-up (yes/no), current heart rhythm and current anticoagulants.

## Statistical analysis

The data was collected and registered using Microsoft Office Excel 2016 and further analysis was conducted using Statistical Package for Social Sciences (SPSS, IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.) Correlation and effect sizes of statistical significance were compared using the Pearson's chi-squared test and Fisher's exact test. Significance was defined as p-value below 0.05.

# 3. Results

## 3.1 Pre- and perioperative patient characteristics

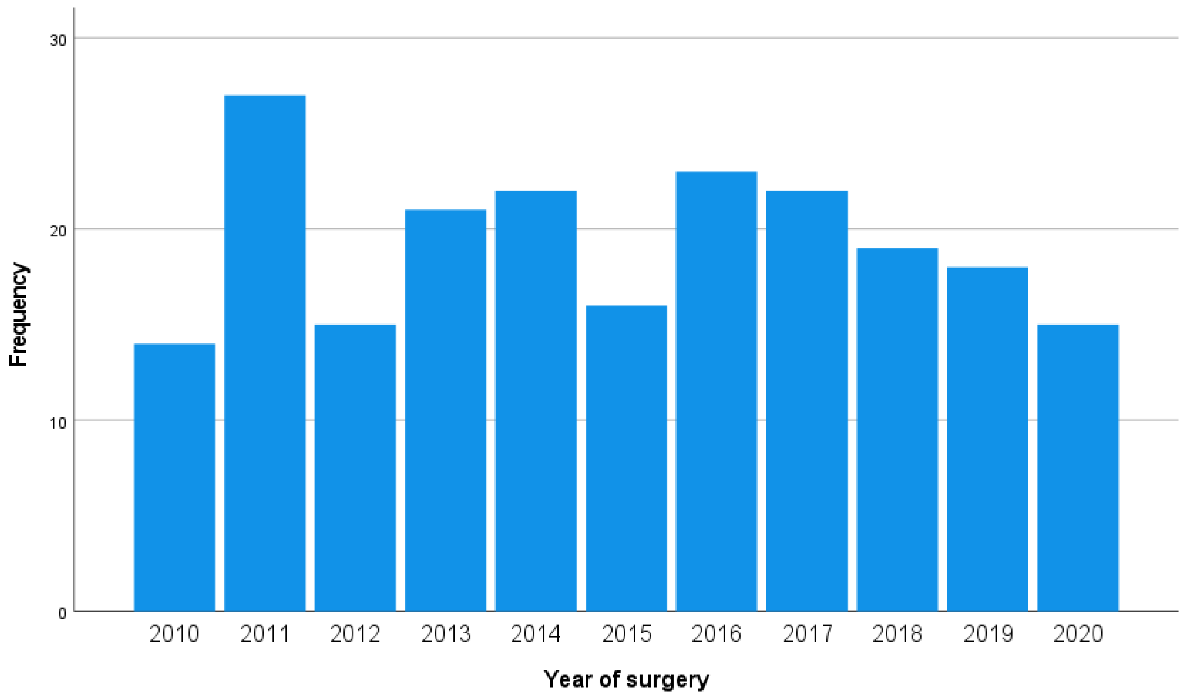
**Table 3.1:** Baseline- and perioperative patient characteristics

| Variable | | Percentage | Total (N = 212) |
|---|---|---|---|
| Age, median (min-max) | | 70 (42-83) | |
| BMI, mean (min-max) | | 27,27 (17.40-40.90) | |
| Sex | M | 78,8% | 167 |
| | F | 21,2% | 45 |
| Year of surgery | 2010 | 6,6% | 14 |
| | 2011 | 12,7% | 27 |
| | 2012 | 7,1% | 15 |
| | 2013 | 9,9% | 21 |
| | 2014 | 10,4% | 22 |
| | 2015 | 7,5% | 16 |
| | 2016 | 10,8% | 23 |
| | 2017 | 10,4% | 22 |
| | 2018 | 9,0% | 19 |
| | 2019 | 8,5% | 18 |
| | 2020 | 7,1% | 15 |
| Preoperative AF | Paroxysmal | 34,4% | 73 |
| | Persistent | 34,0% | 72 |
| | LSPAF | 20,8% | 44 |
| | Permanent | 10,8% | 23 |
| Surgical indication | CABG only | 38,7% | 82 |
| | Aortic valve surgery only | 25,0% | 53 |
| | Mitral valve surgery only | 18,9% | 40 |
| | Combined | 16,0% | 34 |
| | Tumour | 0,9% | 2 |
| | TVR | 0,5% | 1 |
| Ablation lines | Box | 66,5% | 141 |
| | Maze | 9,0% | 19 |
| | PVI | 5,7% | 12 |
| | LAA occlusion only | 18,9% | 40 |
| LAA occlusion | Yes | 76,9% | 163 |
| | No | 23,1% | 49 |
| Preoperative betablockers | Yes | 65,6% | 139 |
| | No | 34,4% | 73 |
| Preoperative anticoagulation | Warfarin | 44,8% | 95 |

| | | | |
|---|---|---|---|
| | Eliquis | 21,2% | 45 |
| | Xarelto | 10,4% | 22 |
| | Pradaxa | 3,3% | 7 |
| | Lixiana | 0,5% | 1 |
| | None | 19,8% | 42 |
| Preoperative cardioversion | Yes | 43,9% | 93 |
| | No | 56,1% | 119 |

From the data collection a total of 216 relevant patients were identified, 4 were excluded due to their surgical procedures which was primarily a right atrial only ablation intended for atrial flutter. These 212 patients include 172 patients who received surgical ablation, while 40 patients received occlusion of the LAA only. Table 1 describes the baseline and perioperative patient characteristics for the 212 patients. First, we see that 167, or almost 80% of the patients are male. The median age at the time of surgery is 70 years where with the youngest patient being 42 years and the oldest being 83 years.

**Figure 3.1.1:** Distribution of procedures per year




Furthermore, the distribution of these procedures from 2010 to 2020 is illustrated by figure 3.1.1, with an average of 19.27 procedures per year. At the time of surgery 34.4% of the patients had paroxysmal AF, 34% had persistent and 20.8% had LSPAF. Another 10.8% were

classified with permanent as these did not go through with the ablation due to various reasons and only received a removal/occlusion of the LAA. These patients also did not receive further treatment for their AF. The most prevalent concomitant surgical ablation was a standalone CABG operation at 38.7%, followed by a standalone aortic valve surgery at 25% and standalone mitral valve surgery at 18.9%. There were also 16% who underwent a combination of cardiac surgeries. Due to an unclear classification of the primary surgical indication these surgeries were classified as combined. In addition, 2 patients underwent tumour removal, and 1 patient received a standalone tricuspid valve repair. Preoperatively 65.6% of the patients received betablockers as means of rate control, while 80.2% of the patients received anticoagulation before surgery. Among these Warfarin was the most prevalent at 44.8% while the direct oral anticoagulants (DOACs) combined amounted to 35.4%. Also, 43.9% of the patients had received cardioversion at any time prior to the surgery.
The following figures compares several of the pre- and perioperative characteristics. Only patients receiving ablation are included. Total number of patients is 170.

**Figure 3.1.2:** Distribution of ablation lines per year.

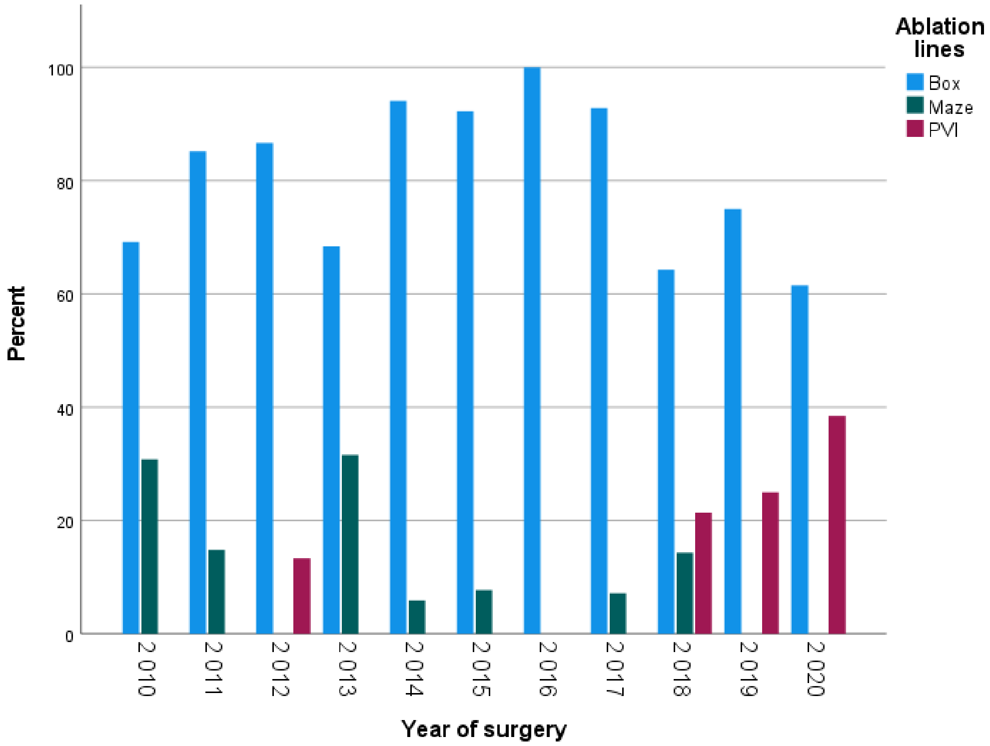



Figure 3.1.2 shows the distribution of ablation lines per year. The box lesion is the most frequently used lesion set every year, with the Maze procedure being at a low proportion. PVI usage has however seemingly increased during the recent years.

**Figure 3.1.3:** Preoperative AF compared to ablation lines

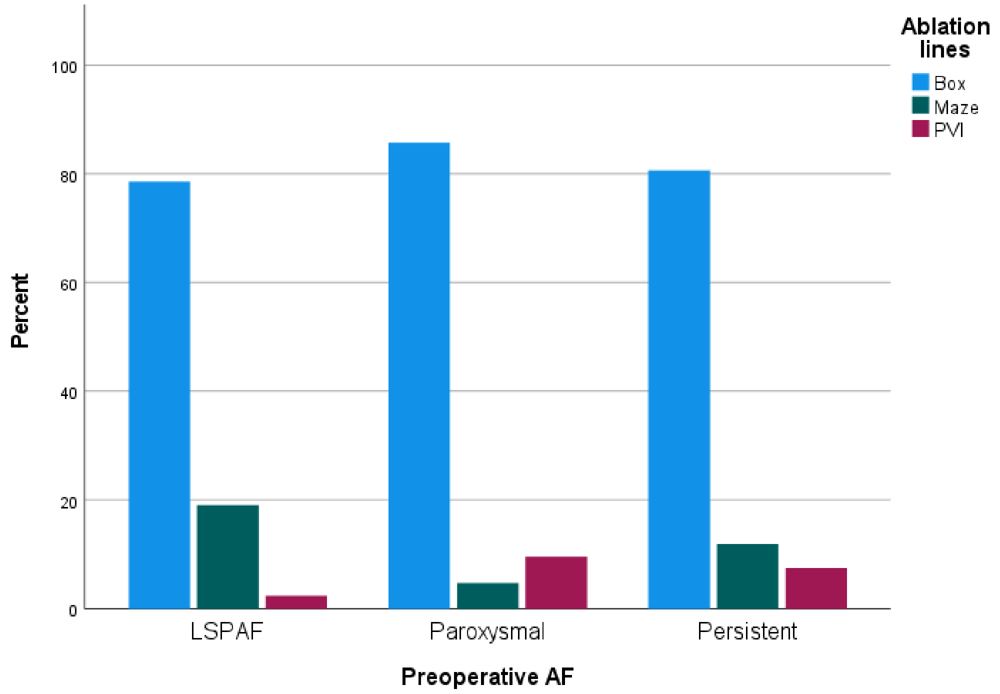



**Figure 3.1.4:** Preoperative AF compared to surgical indication

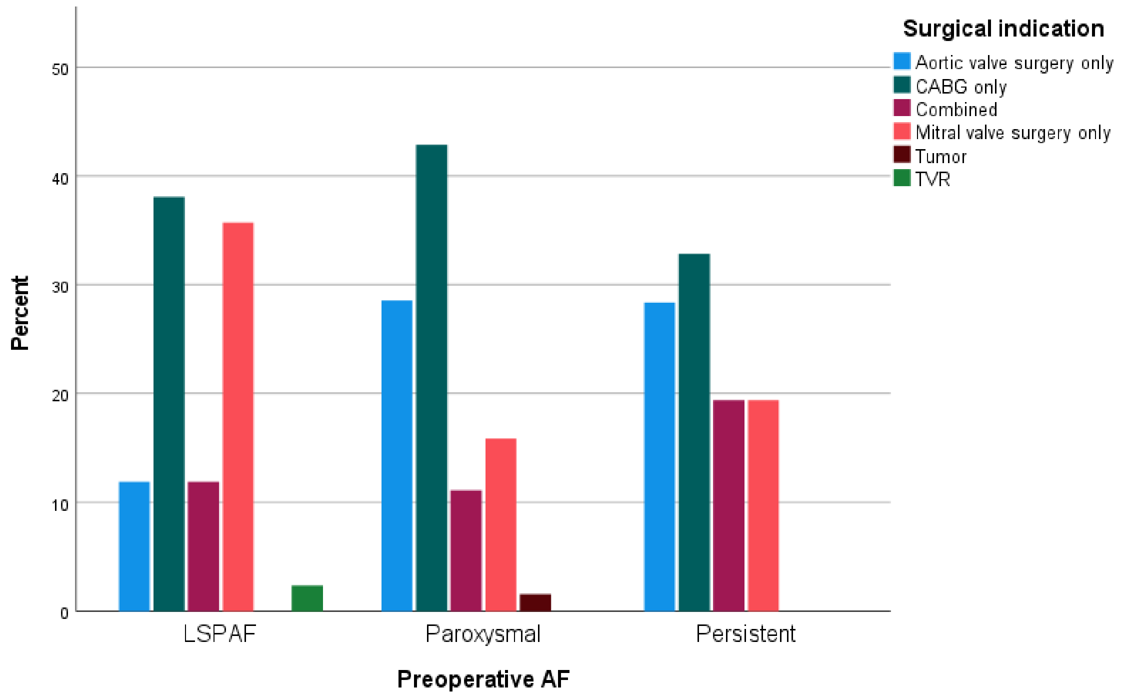



Figure 3.1.3 compares the preoperative AF with ablation lines received. We could not establish any significant association. (Maze vs. preop AF, $p = 0.067$) Figure 3.1.4 compares preoperative AF with surgical indication where patients with LSPAF receives significantly more mitral valve surgery than the other groups ($p = 0.019$) and significantly less aortic valve surgery ($p = 0.038$).

### 3.2 All patients alive at follow-up

**Table 3.2:** Patient characteristics of all patients at and during follow-up

| All patients | | Percentage | Total = 212 |
|---|---|---|---|
| Mortality during follow-up | Yes | 17,0% | 36 |
| | No | 83,0% | 176 |
| Stroke during follow-up | Yes | 8,0% | 17 |
| | No | 92,0% | 195 |
| **All patients alive at follow-up** | | **Percentage** | **Total = 176** |
| Anticoagulation at follow-up | Eliquis | 31,3% | 55 |
| | Warfarin | 29,5% | 52 |
| | Xarelto | 10,2% | 18 |
| | Pradaxa | 2,3% | 4 |
| | Lixiana | 1,1% | 2 |
| | None | 25,6% | 45 |
| Anticoagulation discontinued | Yes | 19,9% | 35 |
| | No | 80,1% | 141 |

Table 3.2 shows patient characteristics at and during follow-up. This consists of 212 patients where the mortality during follow-up is at 17%. In total 8% of all patients suffered a thromboembolic stroke during the follow-up. The next section shows all patients alive at follow-up. Of these 176 patients 74.4% received anticoagulation compared to 80.2% preoperatively. Eliquis was the most prevalent anticoagulant with a usage at 31.3% as opposed to Warfarin preoperatively.

**Figure 3.1:** Comparison of LAA occlusion and occurrence of ischemic stroke during follow-up

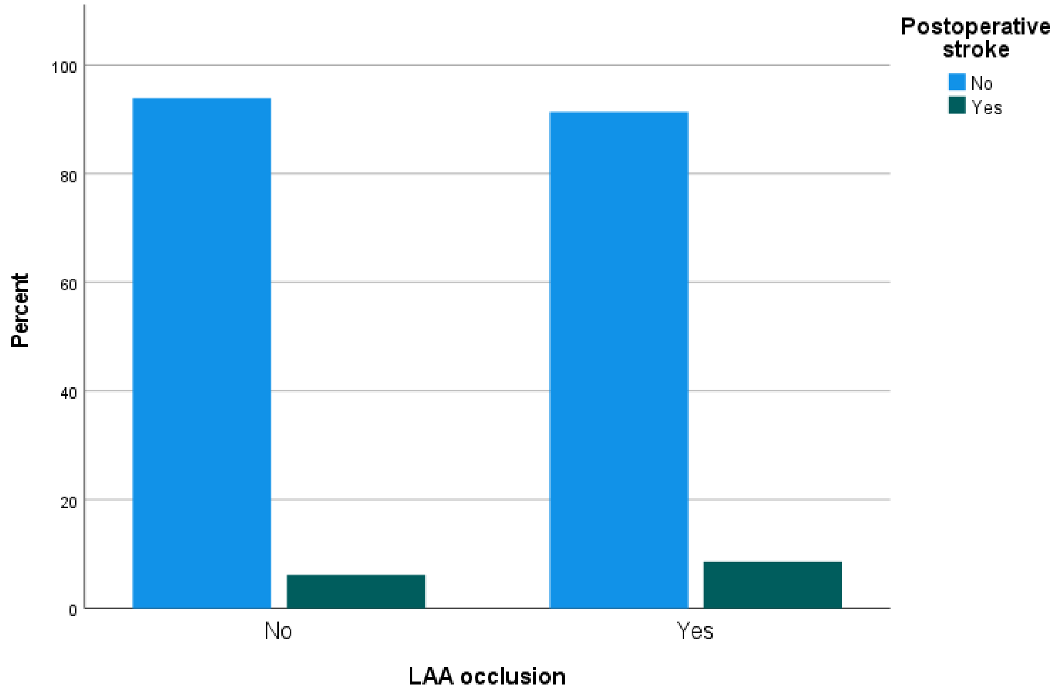



Figure 3.1 compares the incidence of thromboembolic stroke during follow-up with LAA occlusion. In total, from table 3.1, 76.9% of patients received LAA occlusion while 23.1% did not. We could, however, not establish any significant relation between LAA occlusion and stroke (p = 0.950).

### 3.3 ATA related events during follow-up

**Table 3.3:** Recurrence and treatment of ATA during follow-up

| Value | | Percentage | Total = 172 |
|---|---|---|---|
| Recurrence of ATA during follow-up | AF | 23,8% | 41 |
| | Atrial flutter | 21,5% | 37 |
| | No | 54,7% | 94 |
| Cardioversion during follow-up | Yes | 29,7% | 51 |
| | No | 70,3% | 121 |
| Catheter ablation during follow-up | AF | 6,4% | 11 |
| | Atrial flutter | 4,6% | 8 |
| | No | 89,0% | 153 |
| Pacemaker during follow-up | Yes | 8,7% | 15 |
| | No | 91,3% | 157 |

Table 3.3 describes AF and ablation related complications during follow-up. This includes only patients who underwent surgical ablation, including those not alive at follow-up. Of 172 patients, 45.3% experienced recurrence of ATA after surgery. This was defined as any ATA registered on ECG in the period after discharge. Among these 23.8% experienced AF while 21.5% experienced atrial flutter. Many of the patients experiencing ATA recurrence also received cardioversion during follow-up being at 29.7% of the surgically ablated patients, or 65.3% of patients with recurrence. A 19 patients also needed further catheter ablation for their ATA with 6.4% receiving for AF and 4.6% receiving for atrial flutter. There were also 15 patients who received a permanent pacemaker during the follow-up.
The following figures compares pre- and perioperative patient characteristics with ATA related complications during follow-up.

**Figure 3.3.1:** Preoperative AF compared to recurrence of AF during follow-up

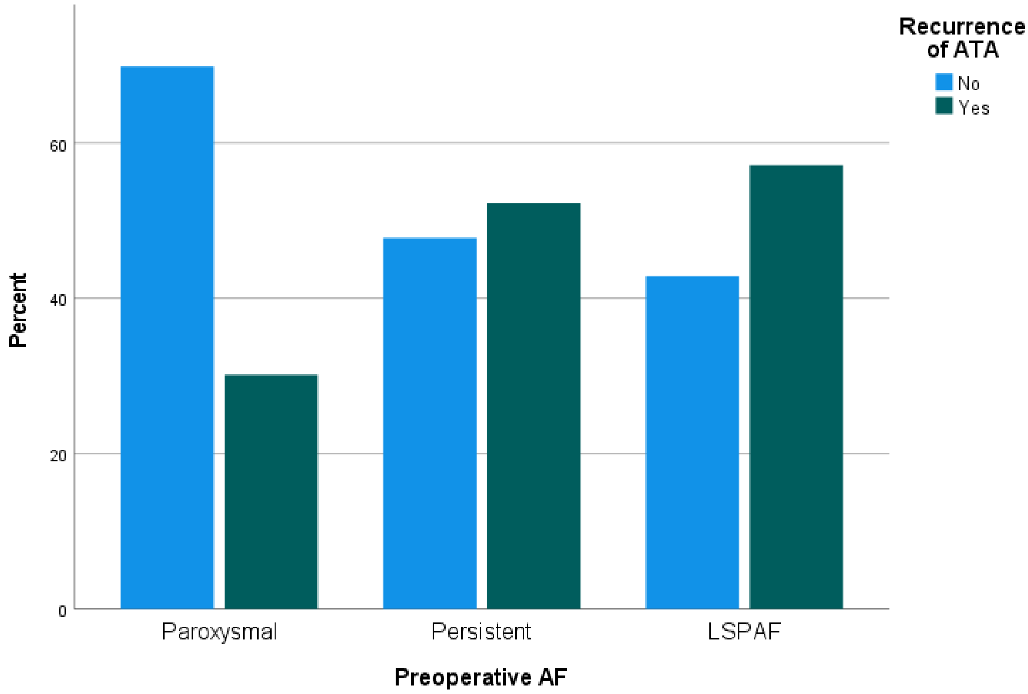


**Figure 3.3.2:** Ablation lines compared to recurrence of AF during follow-up

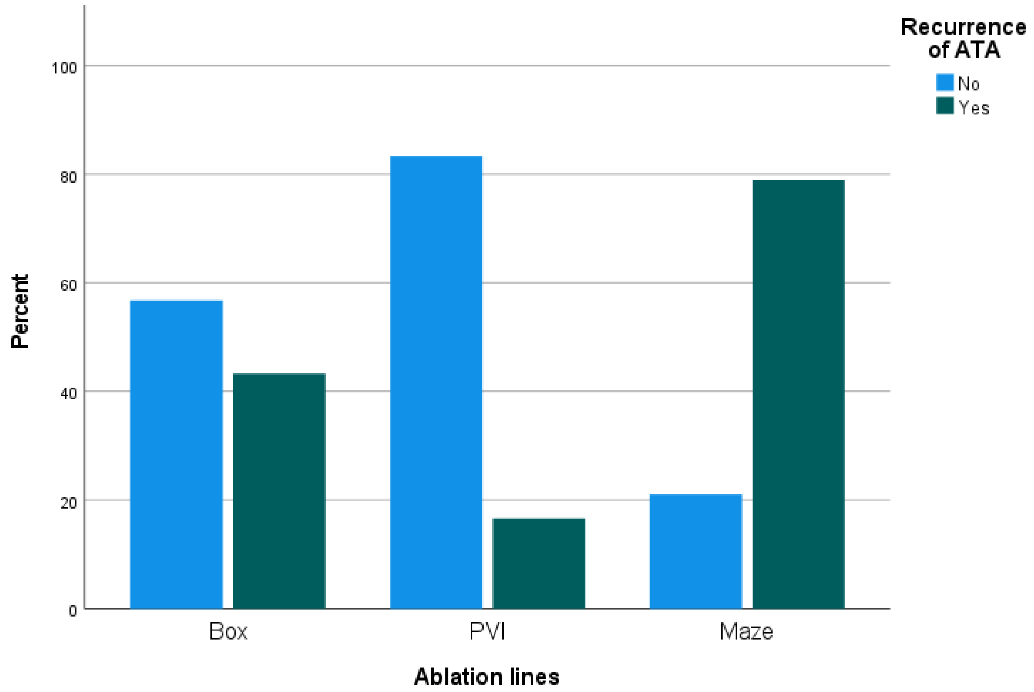
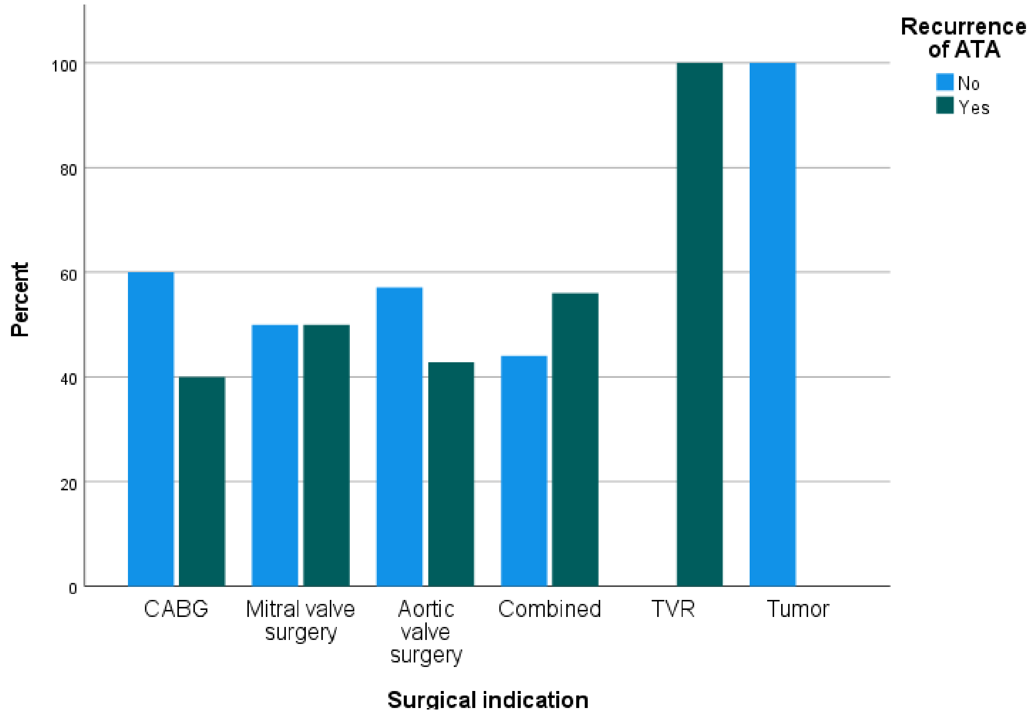



**Figure 3.3.3:** Surgical indication compared to recurrence of AF during follow-up



Figures 3.3.1-3 compares preoperative characteristics with recurrence of ATA during follow-up, which is defined here as recurrence of any ATA after hospital discharge. When comparing preoperative AF with recurrence of ATA a significant correlation p = 0.008 can be seen with less recurrence among patients with paroxysmal AF while more recurrence among patients with LSPAF. A similar correlation can be seen when comparing ablation lines with recurrence. Here a significant correlation p = 0.001 can be seen with increasing rates of recurrence with more complicated ablation lines. When comparing surgical indication however there could not be established a significant correlation p = 0.507.

**Figure 3.3.4:** Need for cardioversion during follow-up compared to preoperative AF

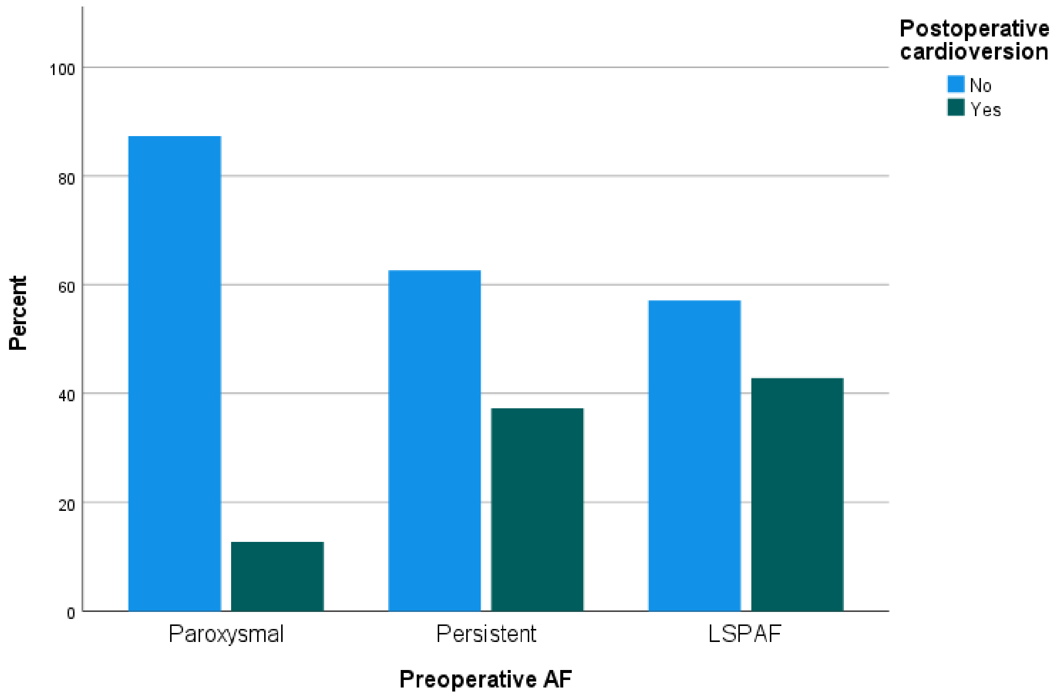


**Figure 3.3.5:** Need for cardioversion during follow-up compared to ablation lines

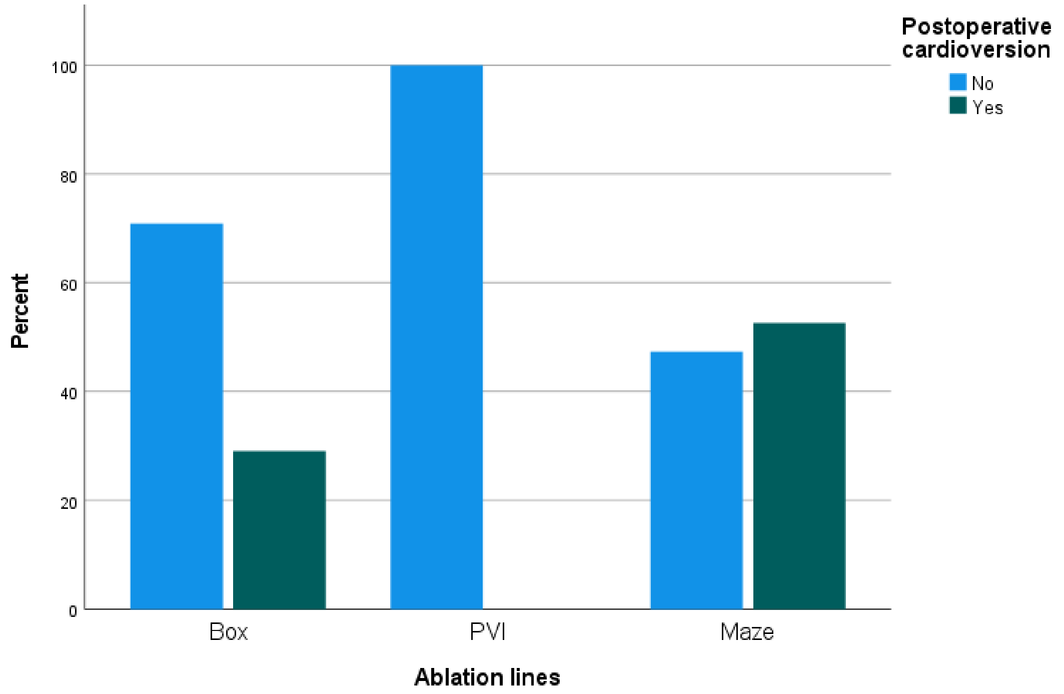



**Figure 3.3.6:** Need for cardioversion during follow-up compared to surgical indication

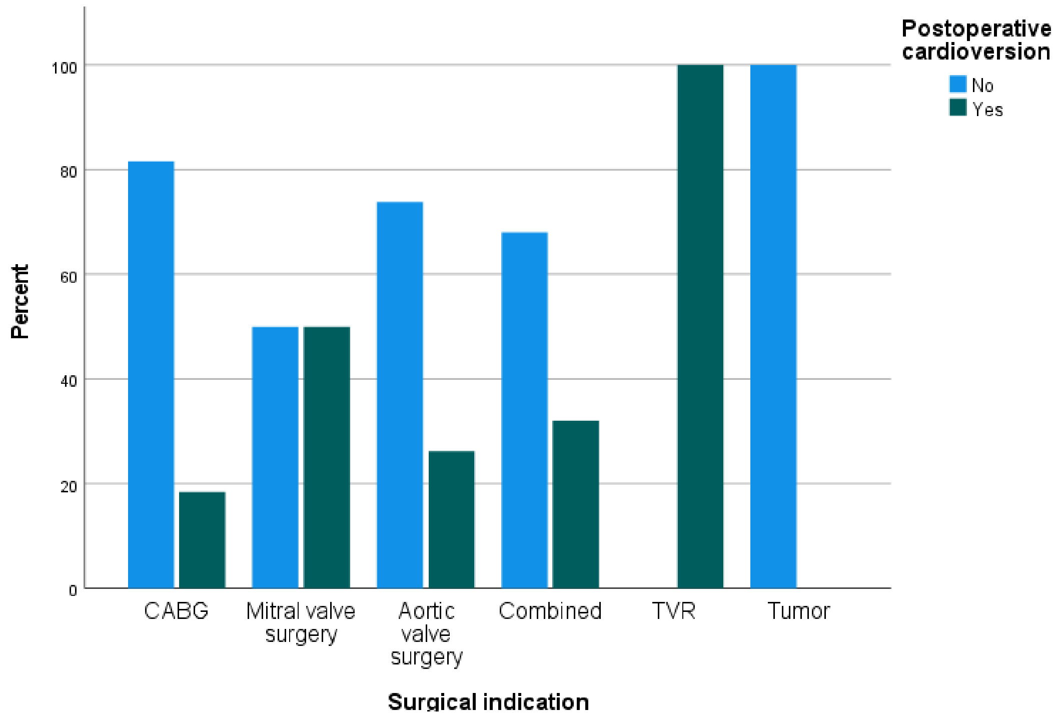


Figure 3.3.4-6 compares various pre- and perioperative variables with the need for cardioversion during follow-up. There was a significant statistical association p = 0.001 between preoperative AF and cardioversion with LSPAF requiring the most. Also, a strong association p = 0.005 could be established between ablation lines and cardioversion with patients undergoing the Maze procedure requiring the most. A similar association p = 0.008 could also be seen when comparing surgical indication with mitral valve surgery requiring the most.

**Figure 3.3.7:** Preoperative AF compared to need for catheter ablation during follow-up

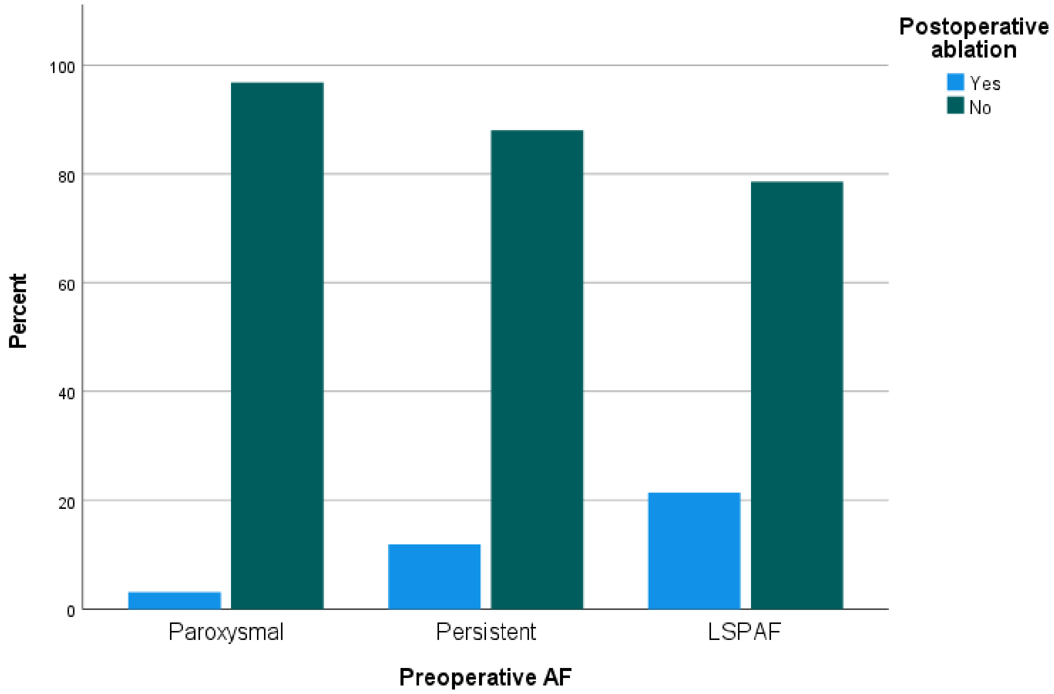


**Figure 3.3.8:** Ablation lines compared to need for catheter ablation during follow-up

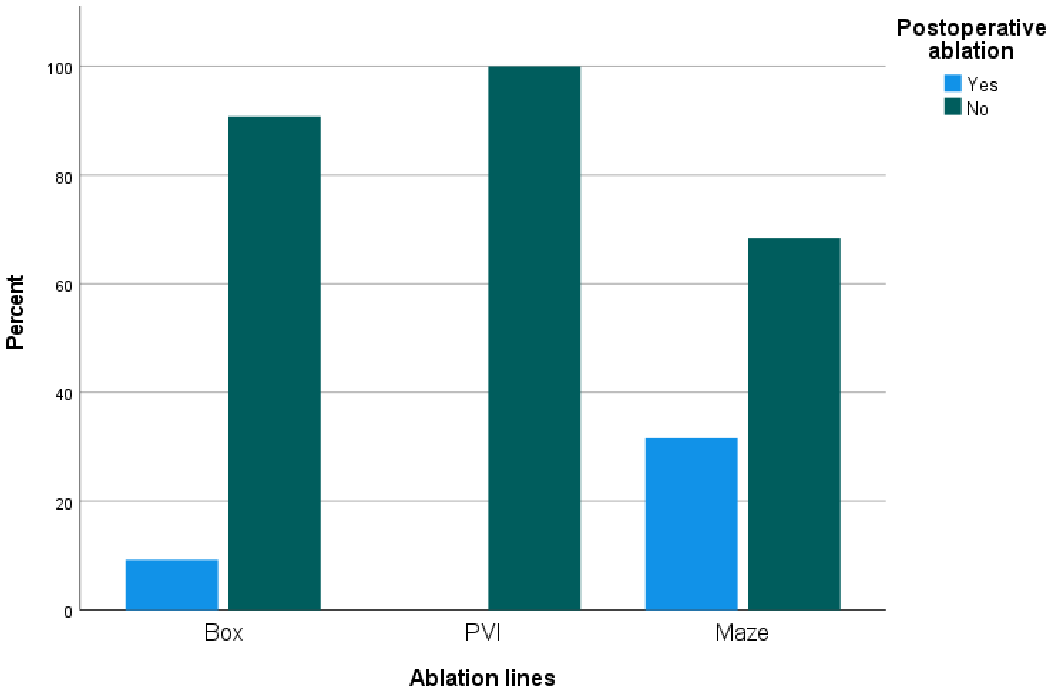



**Figure 3.3.9:** Surgical indication compared to need for catheter ablation during follow-up

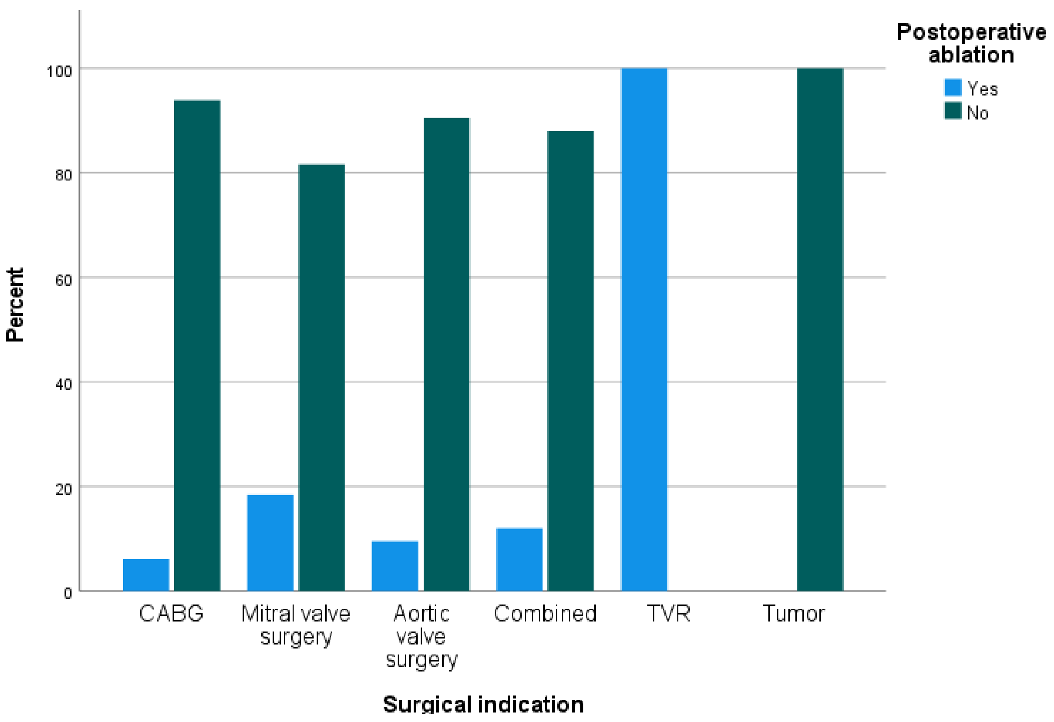


Figure 3.3.7-9 shows a comparison between pre- and perioperative characteristics with need for catheter ablation during follow-up. Like the need for cardioversion these comparisons show a significant association between both preoperative AF p = 0.011 and ablation lines p = 0.015. However, there is no significant association p = 0.098 between surgical indication and need for catheter ablation.

**Figure 3.3.10:** Need for permanent pacemaker during follow-up compared to ablation

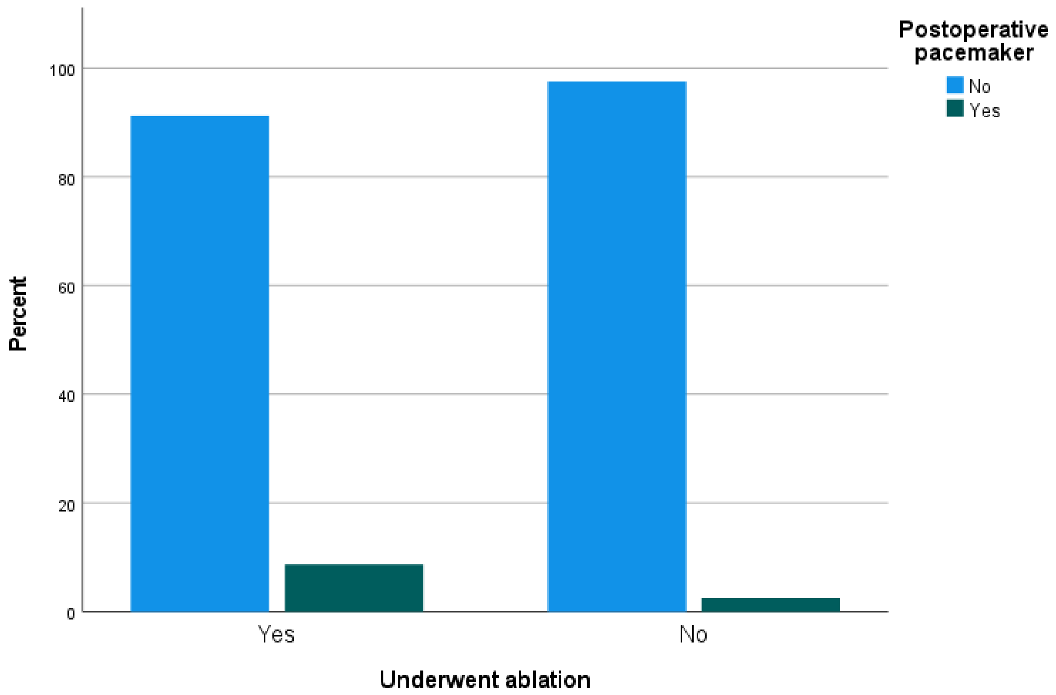



Figure 3.3.10 compares the implantation of permanent pacemaker between those who did and did not receive surgical ablation. Among the 172 who did receive surgical ablation 15 received a permanent pacemaker, while among the 40 who only received LAA occlusion 1 received a permanent pacemaker. There could however not be established any significant association between the two groups p = 0.317.

### 3.4 Heart rhythm at follow-up

**Table 3.4:** Heart rhythm of patients with ECG at follow up numbers must be corrected

| Variable | | Percentage | Total = 130 |
|---|---|---|---|
| Time of follow-up in months, median (min-max) | | | 66.72 (3.45 – 134.31) |
| Rhythm at follow-up | ATA | 24,6% | 32 |
| | Free of ATA | 75,4% | 98 |
| Atrial flutter at follow-up | | 6,3% | 8 |
| Anticoagulation discontinued | | 22,3% | 29 |

Table 3.4 describes the rhythm of patients followed up with ECG. There were 144 eligible patients where the ECGs of 14 patients were not acquirable. Reasons for this included country of residence, health or not wanting to participate. The median follow-up time was 66.72 months with the shortest time being 3.45 months and the longest being 134.31 months. Of the 130 patients 75.4% of the patients were free from ATA while 24,6% were in ATA, with 6.3% being in atrial flutter. Furthermore 22.3% of the patients followed-up discontinued their use of anticoagulation.

**Figure 3.4.1:** Freedom from ATA compared to year of surgery

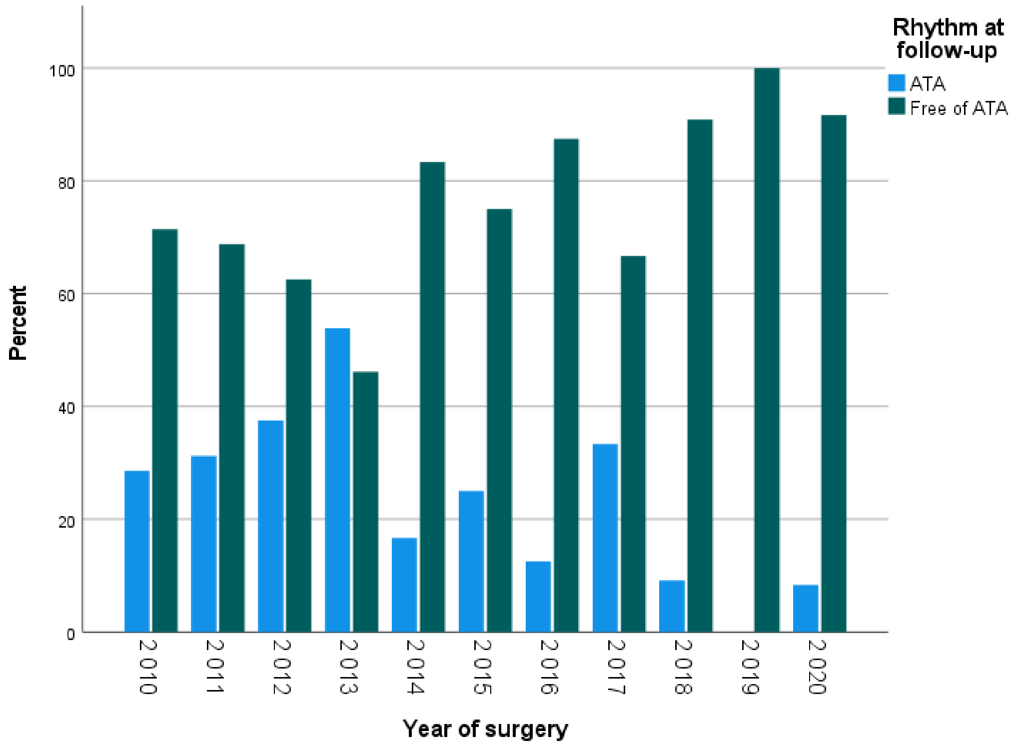


**Figure 3.4.2:** Freedom from ATA compared to preoperative AF

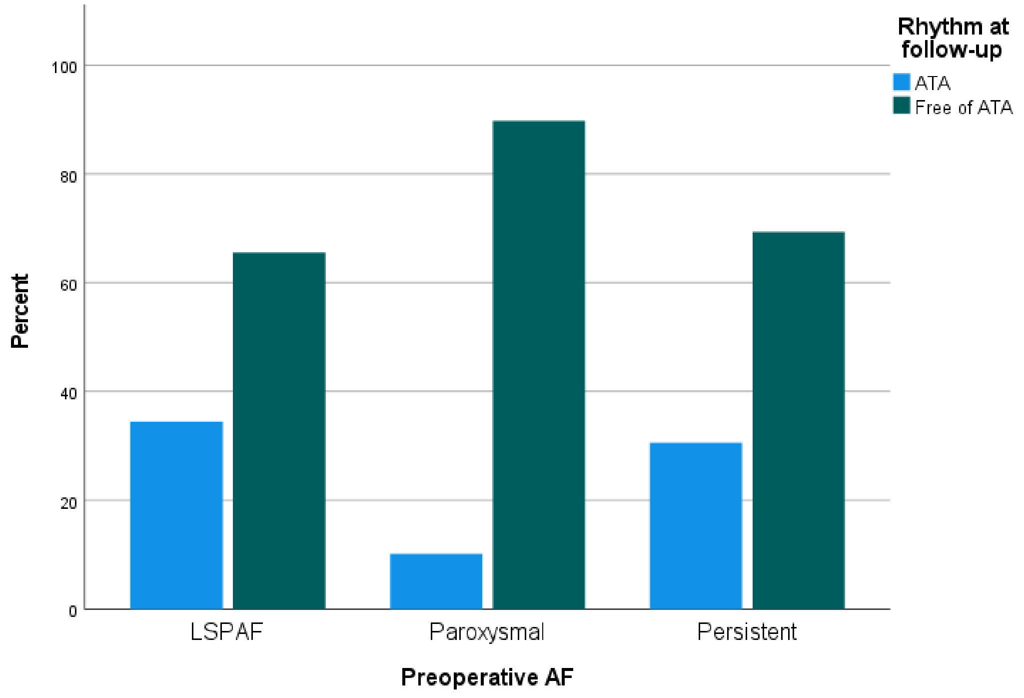



**Figure 3.4.3:** Freedom from ATA compared to surgical indication

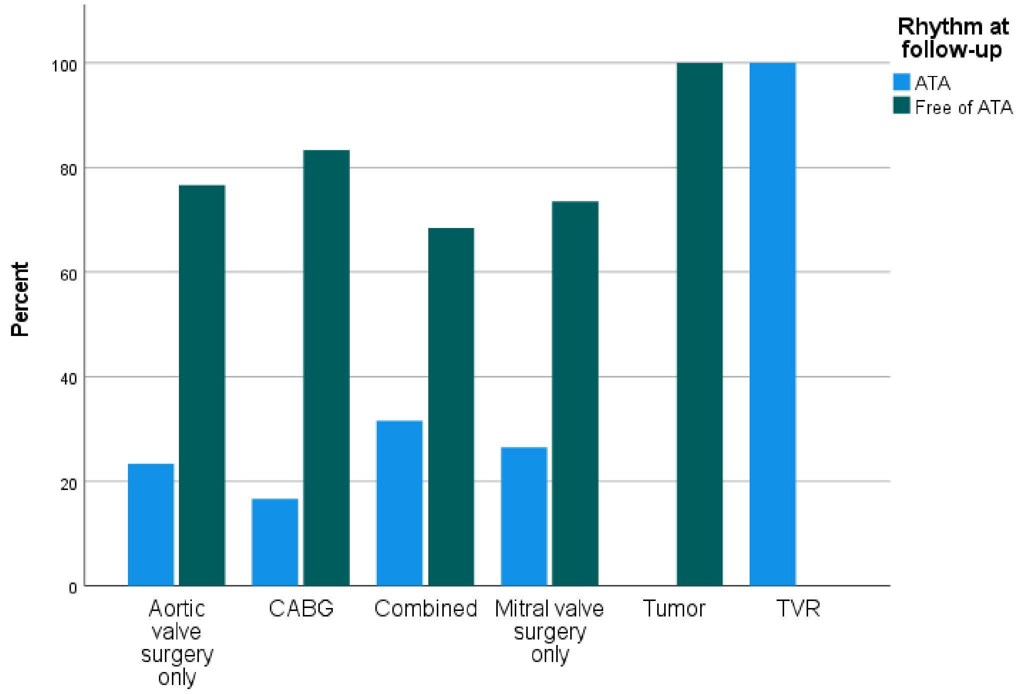


**Figure 3.4.4:** Freedom from ATA compared to ablation lines

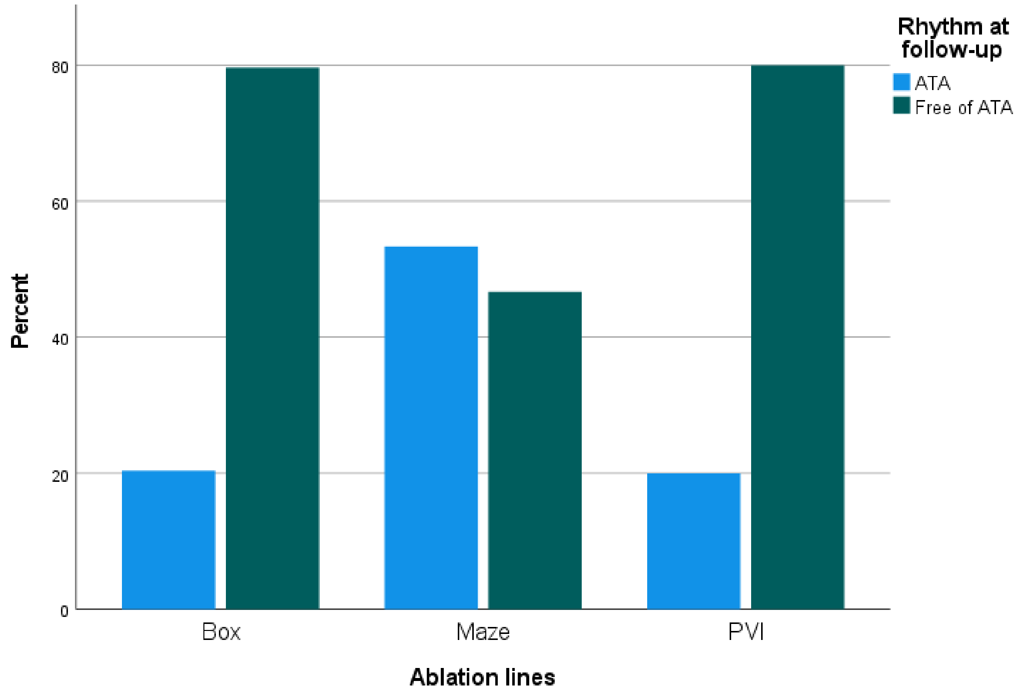



**Figure 3.4.5:** Recurrence of ATA during follow-up compared to rhythm at follow-up

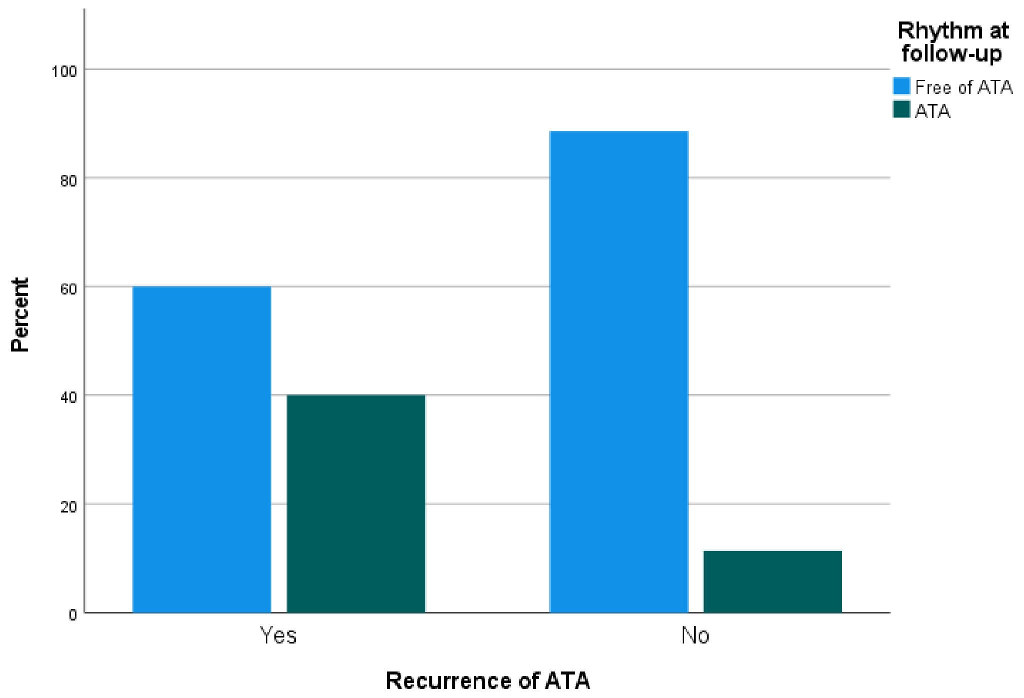
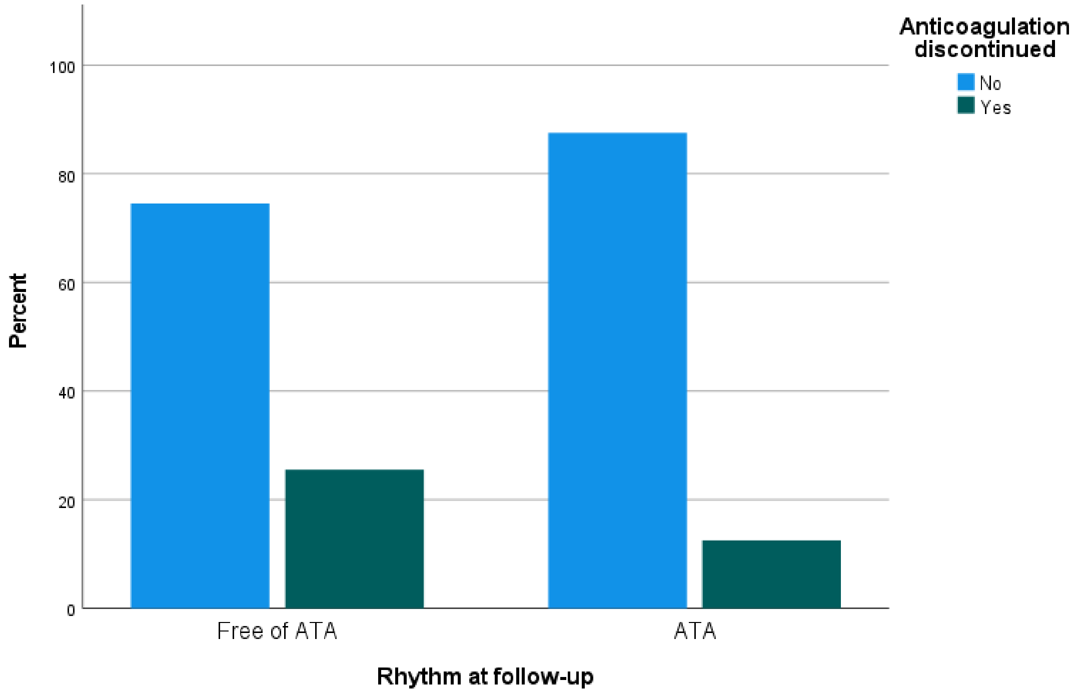


**Figure 3.4.6:** Discontinuation of anticoagulation compared to rhythm at follow-up




Figures 3.4.1-6 compares pre- and postoperative patient data with heart rhythm at follow up. When comparing year of surgery with rhythm at follow-up there seems to be a trend with less ATA with increasing year. There also seems to be a significant correlation p = 0.03 between preoperative ATA and rhythm at follow-up with less ATA at among those with paroxysmal AF. When comparing surgical indications however, there seems to be no significant correlation p = 0.369. Ablation lines also seems to have a significant correlation with rhythm at follow-up with a higher degree of ATA among those who underwent the Maze procedure. The strongest significant correlation is found between recurrence of ATA and rhythm at follow-up p < 0.000 with ATA at follow-up being far more present among those with recurrences during follow-up. Comparing rhythm at follow-up with the discontinuation of anticoagulation there seems to be a slightly higher amount of discontinuation among those who were free of ATA than those who were still in ATA. This difference is however not significant p = 0.148.

## 4. Discussion

This study demonstrates that concomitant ablation of atrial fibrillation with open cardiac surgery is an effective way to treat AF. At time of follow-up 98 (75%) of the patients were free from atrial tachyarrhythmia. Compared to a similar study conducted by Øystein Pettersen and Andreas Bachke (21) in 2010 on patients operated at St. Olavs university hospital in a period between 2003 and 2009 our study showed a higher degree of freedom from ATA compared to 54.8% suggesting improved treatment. These results also show a higher degree of freedom from ATA when compared to the Norwegian arm of the CURE-AF study (24) published by Andersen et al. with freedom from AF at 66% and is comparable with similar international 5-year result demonstrated at 78% (25) and 71% (26). However, these studies were more extensive as heart rhythm was recorded using 24-hours Holter monitors, and patients were followed-up more regularly.

When comparing pre- and perioperative patient characteristics we can see that the use of PVI has increased in recent years, although the box lesions are still dominant. This can be due to a non-inferior effect to the other ablation lines as shown earlier and due to its less invasive nature, not requiring an opening of the left atria. It also seems like it is more used among milder types of AF, while the Maze procedure seems to be used more often among those with LSPAF. However, we could not demonstrate any significant association. The LSPAF also has a significantly higher surgical indication of mitral valve surgery than the other AF groups. This has also been shown in other studies (24).

One of the endpoints of this study was to examine the effect of LAA occlusion on the incidence of thromboembolic stroke during follow-up. It has been hypothesized that it decreases the incidence of thromboembolic stroke and is recently demonstrated Whitlock et al. (27). When examining the effect of LAA occlusion on the occurrence of thromboembolic stroke during follow-up on our patients we could not find any great nor significant differences between those who received occlusion and those who didn’t. These results can be due to a low number of strokes during follow-up at 17 (8%) and unequal sample sizes with those receiving occlusion heavily outweighing those who didn’t; 76.9% vs 23.1%.

Examining the occurrence of ATA during follow-up, we see that this occurred in 78 (45.3%) of the patients. These results are comparable with other studies where ATA recurrence was found to be 36% during follow-up (26). Furthermore, a 37 out of the 78 (47.4%) who experienced ATA recurrence experienced atrial flutter. This has also been observed in other studies (28). However, the exact mechanism remains unknown. Of the patients who experienced recurrence of ATA, 51 of 78 (65.4%) also required cardioversion to convert back to sinus rhythm, while 19 of 78 (24.4%) patients required at least one catheter ablation during follow-up with 11 being for AF and 8 being for atrial flutter. The implementation of a permanent pacemaker was also an endpoint of this study, as this has been proposed as a common complication in a systematic review (20). In figure 3.3.10 we saw that a higher proportion of the surgically ablated required permanent pacemaker compared to those who only received LAA occlusion. This was however not significant and could be due to the great difference in group population (172 vs. 40) and the small total number of pacemaker implantations at 16.

The primary endpoint of this study was to examine the freedom from ATA at follow-up. After a median follow-up of 66.72 months (5.56 years), however with a large variance, 75.4% of the patients were free from any ATA. When examining the factors that might have affected the end-result, we found that patients with paroxysmal AF had a higher degree of freedom from AF. This can be explained as paroxysmal AF being the least severe of the three AF types described. Also there seemed to be a higher proportion of those who underwent the Maze procedure who were still in ATA at follow-up. In fact, in our study, there were significantly more patients who underwent the Maze procedure that experienced recurrence of AF, cardioversion and need for catheter ablation. This conflicts with the findings of Øystein Pettersen and Andreas Backhe in 2010 (21) which found that a higher proportion of patients operated with the Maze procedure were free from AF. There might be several reasons behind this. Since 2010 the classifications for AF have been modified to include LSPAF and to a higher degree move away from the the definition permanent AF (29). In our study there seemed to be more patients with persistent and LSPAF who received the Maze procedure. The fact that more of those receiving the Maze procedure had a more severe AF might imply that their rhythm at follow-up is just as dependent of their preoperative AF as their ablation lines. Also, both of our studies included relatively few patients undergoing the Maze procedure (19 vs. 15) as compared to the more dominant Box lines which may also have affected the result. The most significant factor, however, in determining freedom from ATA at follow-up was the recurrence of ATA with a p-value $< 0.000$. At follow-up it can also be noted that a far smaller proportion of the patients had atrial flutter at 8 of 130 patients (6.3%) as opposed to 37 of 172 patients (21.5%) suggesting the atrial flutter could be only temporary.

**Limitations**

This study was conducted as a retrospective analysis with a prospective follow-up, meaning patients were selected after the surgery was conducted. As a result of this we were not able to select patients preoperatively based on certain characteristics leading to many different comorbidities, preoperative AF and surgical indications; and also, not allowing us to have control groups and randomization. This also gave rise to the difference in population sizes between the ablation lines. Due to the nature of this study the postoperative time of follow-up also differed between the patients.

As most of the pre- and postoperative data was gathered through the patients' hospital records the information was therefore dependent on the author. This was especially evident when classifying preoperative AF, where the AF was often not classified; and surgical indication, where a primary indication was often not listed.

Unlike many larger studies our patients' heart rhythms were followed up through their hospital records and a single 12-lead ECG often taken by their general practitioners at follow-up. As a result, the follow-up may have been unequal as many of the patients were admitted to the hospital yearly, while some patients were not admitted to the hospital at all after their ablation. The ECG at follow-up only gives a snapshot of the patients' heart rhythms and is often unable to detect intermittent episodes of AF which is not uncommon in paroxysmal AF. This might have given us an overestimation of the freedom from ATA than other studies. The quality of the ECGs also differed between GP offices.

Possible improvements to this study could be to control patients at predefined time intervals such as 3 months, 6 months, 1 year and annually. Instead of using single 12-lead ECGs the heart rhythm could be controlled using 24-hours ECGs, Holter monitors or implantable cardiac monitors such as Reveal™. This would to a higher degree uncover intermittent episodes of AF and would therefore be more accurate. However, such modification would be much more costly and time-consuming, and would not suit a student thesis.

## 5. Conclusion

This study has examined the relationship between preoperative factors, postoperative factors, and hearth rhythm at follow-up. With the data of the 216 patients that underwent concomitant surgical ablation of AF with open cardiac surgery at St. Olavs between 2010 and 2020, an average of 19 patients have been operated per year, a frequency that remains unchanged. The main findings from this study have been a high degree of re-establishment of sinus rhythm at 75% at follow-up. Compared to earlier results this shows an improvement, and the results can be compared with larger national and international studies.

Of the secondary endpoints it was observed a shift towards the use of PVI in the recent years as opposed to the more invasive and complicated Box- and Maze ablations as the PVI seems to be non-inferior. This is of course linked to the higher degree of freedom from ATA among patients with paroxysmal AF. The study also investigated the relationship between LAA occlusion and stroke-prevention but were unable to find any. It could also not be established any significant relationship between ablation and the implantation of a permanent pacemaker. These inconclusive results were most likely due to the generally low numbers of stroke and pacemaker implantation. It could however be established a strong relation between recurrence of AF and heart rhythm at follow-up.

In conclusion this study demonstrates that the concomitant surgical ablation of AF with open cardiac surgery at St. Olavs is still safe and effective. Hopefully this trend will continue, yielding even better results in the years to come.

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# Appendix

## Appendix 3.1.3.1: Comparison between LSPAF and other preoperative AFs, and MVR and other surgical indications

### Surgical indication * Preoperative AF Crosstabulation

Count

| | | Preoperative AF | | |
|---|---|---|---|---|
| | | Other | LSPAF | Total |
| Surgical ind | Other | $107_a$ | $27_b$ | 134 |
| | Mitral valve surgery | $23_a$ | $15_b$ | 38 |
| Total | | 130 | 42 | 172 |

Each subscript letter denotes a subset of Preoperative AF categories whose column proportions do not differ significantly from each other at the ,05 level.

### Chi-Square Tests

| | Value | df | Asymptotic Significance (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) | Point Probability |
|---|---|---|---|---|---|---|
| Pearson Chi-Square | 5,990[a] | 1 | ,014 | ,019 | ,015 | |
| Continuity Correction[b] | 4,989 | 1 | ,026 | | | |
| Likelihood Ratio | 5,572 | 1 | ,018 | ,031 | ,015 | |
| Fisher's Exact Test | | | | ,019 | ,015 | |
| Linear-by-Linear Association | 5,955[c] | 1 | ,015 | ,019 | ,015 | ,010 |
| N of Valid Cases | 172 | | | | | |

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 9,28.

b. Computed only for a 2x2 table

c. The standardized statistic is 2,440.

**Appendix 3.1.3.2: Comparison between LSPAF and other preoperative AFs, and AVR and other surgical indications**

**Surgical indication * Preoperative AF Crosstabulation**

Count

| | | Preoperative AF | | |
|---|---|---|---|---|
| | | Other | LSPAF | Total |
| Surgical indication | Other | 93a | 37b | 130 |
| | Aortic valve surgery | 37a | 5b | 42 |
| Total | | 130 | 42 | 172 |

Each subscript letter denotes a subset of Preoperative AF categories whose column proportions do not differ significantly from each other at the ,05 level.

**Chi-Square Tests**

| | Value | df | Asymptotic Significance (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) | Point Probability |
|---|---|---|---|---|---|---|
| Pearson Chi-Square | 4,715[a] | 1 | ,030 | ,038 | ,021 | |
| Continuity Correction[b] | 3,861 | 1 | ,049 | | | |
| Likelihood Ratio | 5,265 | 1 | ,022 | ,038 | ,021 | |
| Fisher's Exact Test | | | | ,038 | ,021 | |
| Linear-by-Linear Association | 4,688[c] | 1 | ,030 | ,038 | ,021 | ,015 |
| N of Valid Cases | 172 | | | | | |

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 10,26.

b. Computed only for a 2x2 table

c. The standardized statistic is -2,165.

**Appendix 3.1.4: Comparison between Maze and other surgical indications, and preoperative AF**

**Lines * Preoperative AF Crosstabulation**

Count

| | | Preoperative AF | | | Total |
|---|---|---|---|---|---|
| | | Paroxysmal | Persistent | LSPAF | |
| Lines | Maze | $3_a$ | $8_a$ | $8_a$ | 19 |
| | Other | $60_a$ | $59_a$ | $34_a$ | 153 |
| Total | | 63 | 67 | 42 | 172 |

Each subscript letter denotes a subset of Preoperative AF categories whose column proportions do not differ significantly from each other at the ,05 level.

**Chi-Square Tests**

| | Value | df | Asymptotic Significance (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) | Point Probability |
|---|---|---|---|---|---|---|
| Pearson Chi-Square | 5,323[a] | 2 | ,070 | ,068 | | |
| Likelihood Ratio | 5,504 | 2 | ,064 | ,085 | | |
| Fisher-Freeman-Halton Exact Test | 5,339 | | | ,067 | | |
| Linear-by-Linear Association | 5,292[b] | 1 | ,021 | ,027 | ,016 | ,009 |
| N of Valid Cases | 172 | | | | | |

a. 1 cells (16,7%) have expected count less than 5. The minimum expected count is 4,64.

b. The standardized statistic is -2,300.

## Appendix 3.1: Comparison of LAA occlusion and occurrence of ischemic stroke during follow-up

**LAA occlusion * Postoperative stroke Crosstabulation**

Count

| | | Postoperative stroke | | |
|---|---|---|---|---|
| | | No | Yes | Total |
| LAA occlusion | No | 35 | 2 | 37 |
| | Yes | 133 | 8 | 141 |
| Total | | 168 | 10 | 178 |

**Chi-Square Tests**

| | Value | df | Asymptotic Significance (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) |
|---|---|---|---|---|---|
| Pearson Chi-Square | ,004[a] | 1 | ,950 | 1,000 | ,655 |
| Continuity Correction[b] | ,000 | 1 | 1,000 | | |
| Likelihood Ratio | ,004 | 1 | ,949 | 1,000 | ,655 |
| Fisher's Exact Test | | | | 1,000 | ,655 |
| N of Valid Cases | 178 | | | | |

a. 1 cells (25,0%) have expected count less than 5. The minimum expected count is 2,08.

b. Computed only for a 2x2 table

## Appendix 3.3.1: Preoperative AF compared to recurrence of AF during follow-up

### Preoperative AF * Recurrence of ATA Crosstabulation

Count

| | | Recurrence of ATA | | |
|---|---|---|---|---|
| | | Yes | No | Total |
| Preoperative AF | Paroxysmal | 19 | 44 | 63 |
| | Persistent | 35 | 32 | 67 |
| | LSPAF | 24 | 18 | 42 |
| Total | | 78 | 94 | 172 |

### Chi-Square Tests

| | Value | df | Asymptotic Significance (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) | Point Probability |
|---|---|---|---|---|---|---|
| Pearson Chi-Square | 9,506[a] | 2 | ,009 | ,008 | | |
| Likelihood Ratio | 9,703 | 2 | ,008 | ,008 | | |
| Fisher-Freeman-Halton Exact Test | 9,562 | | | ,008 | | |
| Linear-by-Linear Association | 8,260[b] | 1 | ,004 | ,004 | ,003 | ,001 |
| N of Valid Cases | 172 | | | | | |

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 19,05.

b. The standardized statistic is -2,874.

## Appendix 3.3.2: Ablation lines compared to recurrence of AF during follow-up

**Ablation lines * Recurrence of ATA Crosstabulation**

Count

| | | Recurrence of ATA | | |
|---|---|---|---|---|
| | | Yes | No | Total |
| Ablation lines | Box | 61 | 80 | 141 |
| | PVI | 2 | 10 | 12 |
| | Maze | 15 | 4 | 19 |
| Total | | 78 | 94 | 172 |

**Chi-Square Tests**

| | Value | df | Asymptotic Significance (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) | Point Probability |
|---|---|---|---|---|---|---|
| Pearson Chi-Square | 12,885[a] | 2 | ,002 | ,001 | | |
| Likelihood Ratio | 13,682 | 2 | ,001 | ,002 | | |
| Fisher-Freeman-Halton Exact Test | 12,824 | | | ,001 | | |
| Linear-by-Linear Association | 4,749[b] | 1 | ,029 | ,035 | ,020 | ,009 |
| N of Valid Cases | 172 | | | | | |

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 5,44.

b. The standardized statistic is -2,179.

## Appendix 3.3.3: Surgical indication compared to recurrence of AF during follow-up

### Surgical indication * Recurrence of ATA Crosstabulation

Count

| | | Recurrence of ATA | | |
|---|---|---|---|---|
| | | Yes | No | Total |
| Surgical indication | CABG | 26 | 39 | 65 |
| | Mitral valve surgery | 19 | 19 | 38 |
| | Aortic valve surgery | 18 | 24 | 42 |
| | Combined | 14 | 11 | 25 |
| | TVR | 1 | 0 | 1 |
| | Tumor | 0 | 1 | 1 |
| Total | | 78 | 94 | 172 |

### Chi-Square Tests

| | Value | df | Asymptotic Significance (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) | Point Probability |
|---|---|---|---|---|---|---|
| Pearson Chi-Square | 4,367[a] | 5 | ,498 | ,512 | | |
| Likelihood Ratio | 5,121 | 5 | ,401 | ,515 | | |
| Fisher-Freeman-Halton Exact Test | 4,245 | | | ,507 | | |
| Linear-by-Linear Association | 1,023[b] | 1 | ,312 | ,318 | ,173 | ,032 |
| N of Valid Cases | 172 | | | | | |

a. 4 cells (33,3%) have expected count less than 5. The minimum expected count is ,45.

b. The standardized statistic is -1,012.

### Appendix 3.3.4: Need for cardioversion during follow-up compared to preoperative AF

**Postoperative cardioversion * Preoperative AF Crosstabulation**

Count

| | | Preoperative AF | | | Total |
|---|---|---|---|---|---|
| | | Paroxysmal | Persistent | LSPAF | |
| Postoperative cardioversion | Yes | 8 | 25 | 18 | 51 |
| | No | 55 | 42 | 24 | 121 |
| Total | | 63 | 67 | 42 | 172 |

**Chi-Square Tests**

| | Value | df | Asymptotic Significance (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) | Point Probability |
|---|---|---|---|---|---|---|
| Pearson Chi-Square | 14,077[a] | 2 | ,001 | ,001 | | |
| Likelihood Ratio | 15,268 | 2 | ,000 | ,001 | | |
| Fisher-Freeman-Halton Exact Test | 14,949 | | | ,001 | | |
| Linear-by-Linear Association | 12,251[b] | 1 | ,000 | ,000 | ,000 | ,000 |
| N of Valid Cases | 172 | | | | | |

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 12,45.

b. The standardized statistic is -3,500.

## Appendix 3.3.5: Need for cardioversion during follow-up compared to ablation lines

**Postoperative cardioversion * Ablation lines Crosstabulation**

Count

| | | Ablation lines | | | Total |
|---|---|---|---|---|---|
| | | Box | PVI | Maze | |
| Postoperative cardioversion | Yes | 41 | 0 | 10 | 51 |
| | No | 100 | 12 | 9 | 121 |
| Total | | 141 | 12 | 19 | 172 |

**Chi-Square Tests**

| | Value | df | Asymptotic Significance (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) | Point Probability |
|---|---|---|---|---|---|---|
| Pearson Chi-Square | 9,890[a] | 2 | ,007 | ,006 | | |
| Likelihood Ratio | 12,820 | 2 | ,002 | ,002 | | |
| Fisher-Freeman-Halton Exact Test | 10,259 | | | ,005 | | |
| Linear-by-Linear Association | 1,737[b] | 1 | ,188 | ,203 | ,119 | ,042 |
| N of Valid Cases | 172 | | | | | |

a. 1 cells (16,7%) have expected count less than 5. The minimum expected count is 3,56.

b. The standardized statistic is -1,318.

## Appendix 3.3.6: Need for cardioversion during follow-up compared to surgical indication

### Surgical indication * Postoperative cardioversion Crosstabulation

Count

| | | Postoperative cardioversion | | |
|---|---|---|---|---|
| | | Yes | No | Total |
| Surgical indication | CABG | 12 | 53 | 65 |
| | Mitral valve surgery | 19 | 19 | 38 |
| | Aortic valve surgery | 11 | 31 | 42 |
| | Combined | 8 | 17 | 25 |
| | TVR | 1 | 0 | 1 |
| | Tumor | 0 | 1 | 1 |
| Total | | 51 | 121 | 172 |

### Chi-Square Tests

| | Value | df | Asymptotic Significance (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) | Point Probability |
|---|---|---|---|---|---|---|
| Pearson Chi-Square | 14,546[a] | 5 | ,012 | ,006 | | |
| Likelihood Ratio | 14,603 | 5 | ,012 | ,009 | | |
| Fisher-Freeman-Halton Exact Test | 13,947 | | | ,008 | | |
| Linear-by-Linear Association | 1,327[b] | 1 | ,249 | ,276 | ,141 | ,030 |
| N of Valid Cases | 172 | | | | | |

a. 4 cells (33,3%) have expected count less than 5. The minimum expected count is ,30.

b. The standardized statistic is -1,152.

## Appendix 3.3.7: Preoperative AF compared to need for catheter ablation during follow-up

**Preoperative AF * Postoperative ablation Crosstabulation**

Count

| | | Postoperative ablation | | |
|---|---|---|---|---|
| | | Yes | No | Total |
| Preoperative AF | Paroxysmal | 2 | 61 | 63 |
| | Persistent | 8 | 59 | 67 |
| | LSPAF | 9 | 33 | 42 |
| Total | | 19 | 153 | 172 |

**Chi-Square Tests**

| | Value | df | Asymptotic Significance (2-sided) | Exact Sig. (2-sided) |
|---|---|---|---|---|
| Pearson Chi-Square | 8,635[a] | 2 | ,013 | ,013 |
| Likelihood Ratio | 9,147 | 2 | ,010 | ,013 |
| Fisher-Freeman-Halton Exact Test | 8,705 | | | ,011 |
| N of Valid Cases | 172 | | | |

a. 1 cells (16,7%) have expected count less than 5. The minimum expected count is 4,64.

## Appendix 3.3.8: Ablation lines compared to need for catheter ablation during follow-up

**Ablation lines * Postoperative ablation Crosstabulation**

Count

| | | Postoperative ablation | | |
|---|---|---|---|---|
| | | Yes | No | Total |
| Ablation lines | Box | 13 | 128 | 141 |
| | PVI | 0 | 12 | 12 |
| | Maze | 6 | 13 | 19 |
| Total | | 19 | 153 | 172 |

**Chi-Square Tests**

| | Value | df | Asymptotic Significance (2-sided) | Exact Sig. (2-sided) |
|---|---|---|---|---|
| Pearson Chi-Square | 10,121[a] | 2 | ,006 | ,009 |
| Likelihood Ratio | 9,095 | 2 | ,011 | ,007 |
| Fisher-Freeman-Halton Exact Test | 7,755 | | | ,015 |
| N of Valid Cases | 172 | | | |

a. 2 cells (33,3%) have expected count less than 5. The minimum expected count is 1,33.

**Appendix 3.3.9: Surgical indication compared to need for catheter ablation during follow-up**

**Surgical indication * Postoperative ablation Crosstabulation**

Count

| | | Postoperative ablation | | |
|---|---|---|---|---|
| | | Yes | No | Total |
| Surgical indication | CABG | 4 | 61 | 65 |
| | Mitral valve surgery | 7 | 31 | 38 |
| | Aortic valve surgery | 4 | 38 | 42 |
| | Combined | 3 | 22 | 25 |
| | TVR | 1 | 0 | 1 |
| | Tumor | 0 | 1 | 1 |
| Total | | 19 | 153 | 172 |

**Chi-Square Tests**

| | Value | df | Asymptotic Significance (2-sided) | Exact Sig. (2-sided) |
|---|---|---|---|---|
| Pearson Chi-Square | 11,986[a] | 5 | ,035 | ,074 |
| Likelihood Ratio | 8,412 | 5 | ,135 | ,122 |
| Fisher-Freeman-Halton Exact Test | 9,366 | | | ,098 |
| N of Valid Cases | 172 | | | |

a. 7 cells (58,3%) have expected count less than 5. The minimum expected count is ,11.

### Appendix 3.3.10: Need for permanent pacemaker during follow-up compared to ablation

**Postoperative pacemaker * Underwent ablation Crosstabulation**

Count

| | | Underwent ablation | | |
|---|---|---|---|---|
| | | Yes | No | Total |
| Postoperative pacemaker | Yes | 15 | 1 | 16 |
| | No | 157 | 39 | 196 |
| Total | | 172 | 40 | 212 |

**Chi-Square Tests**

| | Value | df | Asymptotic Significance (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) | Point Probability |
|---|---|---|---|---|---|---|
| Pearson Chi-Square | 1,800[a] | 1 | ,180 | ,212 | ,156 | |
| Continuity Correction[b] | 1,019 | 1 | ,313 | | | |
| Likelihood Ratio | 2,261 | 1 | ,133 | ,212 | ,156 | |
| Fisher's Exact Test | | | | ,317 | ,156 | |
| Linear-by-Linear Association | 1,791[c] | 1 | ,181 | ,212 | ,156 | ,125 |
| N of Valid Cases | 212 | | | | | |

a. 1 cells (25,0%) have expected count less than 5. The minimum expected count is 3,02.

b. Computed only for a 2x2 table

c. The standardized statistic is 1,338.

## Appendix 3.4.2: Freedom from ATA compared to preoperative AF

### Preoperative AF * Rhythm at follow-up Crosstabulation

Count

| | | Rhythm at follow-up | | |
|---|---|---|---|---|
| | | Free of ATA | ATA | Total |
| Preoperative AF | Paroxysmal | 43 | 6 | 49 |
| | Persistent | 34 | 15 | 49 |
| | LSPAF | 21 | 11 | 32 |
| Total | | 98 | 32 | 130 |

### Chi-Square Tests

| | Value | df | Asymptotic Significance (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) | Point Probability |
|---|---|---|---|---|---|---|
| Pearson Chi-Square | 6,633[a] | 2 | ,036 | ,037 | | |
| Likelihood Ratio | 7,116 | 2 | ,028 | ,032 | | |
| Fisher-Freeman-Halton Exact Test | 6,954 | | | ,030 | | |
| Linear-by-Linear Association | 5,726[b] | 1 | ,017 | ,019 | ,012 | ,006 |
| N of Valid Cases | 130 | | | | | |

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 7,88.

b. The standardized statistic is 2,393.

## Appendix 3.4.3: Freedom from ATA compared to surgical indication

### Surgical indication * Rhythm at follow-up Crosstabulation

Count

| | | Rhythm at follow-up | | |
|---|---|---|---|---|
| | | Free of ATA | ATA | Total |
| Surgical indication | CABG | 35 | 7 | 42 |
| | Mitral valve surgery | 26 | 9 | 35 |
| | Aortic valve surgery | 22 | 9 | 31 |
| | Combined | 14 | 6 | 20 |
| | TVR | 0 | 1 | 1 |
| | Tumor | 1 | 0 | 1 |
| Total | | 98 | 32 | 130 |

### Chi-Square Tests

| | Value | df | Asymptotic Significance (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) | Point Probability |
|---|---|---|---|---|---|---|
| Pearson Chi-Square | 5,480[a] | 5 | ,360 | ,372 | | |
| Likelihood Ratio | 5,562 | 5 | ,351 | ,390 | | |
| Fisher-Freeman-Halton Exact Test | 5,314 | | | ,369 | | |
| Linear-by-Linear Association | 2,108[b] | 1 | ,147 | ,154 | ,088 | ,025 |
| N of Valid Cases | 130 | | | | | |

a. 5 cells (41,7%) have expected count less than 5. The minimum expected count is ,25.

b. The standardized statistic is 1,452.

## Appendix 3.4.4: Freedom from ATA compared to ablation lines

### Ablation lines * Rhythm at follow-up Crosstabulation

Count

| | | Rhythm at follow-up | | |
|---|---|---|---|---|
| | | Free of ATA | ATA | Total |
| Ablation lines | Box | 84 | 21 | 105 |
| | PVI | 8 | 2 | 10 |
| | Maze | 6 | 9 | 15 |
| Total | | 98 | 32 | 130 |

### Chi-Square Tests

| | Value | df | Asymptotic Significance (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) | Point Probability |
|---|---|---|---|---|---|---|
| Pearson Chi-Square | 11,441[a] | 2 | ,003 | ,005 | | |
| Likelihood Ratio | 9,815 | 2 | ,007 | ,013 | | |
| Fisher-Freeman-Halton Exact Test | 9,901 | | | ,005 | | |
| Linear-by-Linear Association | 9,557[b] | 1 | ,002 | ,003 | ,003 | ,002 |
| N of Valid Cases | 130 | | | | | |

a. 2 cells (33,3%) have expected count less than 5. The minimum expected count is 2,46.

b. The standardized statistic is 3,091.

## Appendix 3.4.5: Recurrence of ATA during follow-up compared to rhythm at follow-up

**Recurrence of ATA * Rhythm at follow-up Crosstabulation**

Count

| | | Rhythm at follow-up | | |
|---|---|---|---|---|
| | | Free of ATA | ATA | Total |
| Recurrence of ATA | Yes | 36 | 24 | 60 |
| | No | 62 | 8 | 70 |
| Total | | 98 | 32 | 130 |

**Chi-Square Tests**

| | Value | df | Asymptotic Significance (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) | Point Probability |
|---|---|---|---|---|---|---|
| Pearson Chi-Square | 14,213[a] | 1 | ,000 | ,000 | ,000 | |
| Continuity Correction[b] | 12,715 | 1 | ,000 | | | |
| Likelihood Ratio | 14,583 | 1 | ,000 | ,000 | ,000 | |
| Fisher's Exact Test | | | | ,000 | ,000 | |
| Linear-by-Linear Association | 14,103[c] | 1 | ,000 | ,000 | ,000 | ,000 |
| N of Valid Cases | 130 | | | | | |

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 14,77.

b. Computed only for a 2x2 table

c. The standardized statistic is -3,755.

## Appendix 3.4.6: Discontinuation of anticoagulation compared to rhythm at follow-up

### Anticoagulation discontinued * Rhythm at follow-up Crosstabulation

Count

| | | Rhythm at follow-up | | |
|---|---|---|---|---|
| | | Free of ATA | ATA | Total |
| Anticoagulation discontinued | No | 73 | 28 | 101 |
| | Yes | 25 | 4 | 29 |
| Total | | 98 | 32 | 130 |

### Chi-Square Tests

| | Value | df | Asymptotic Significance (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) |
|---|---|---|---|---|---|
| Pearson Chi-Square | 2,356[a] | 1 | ,125 | ,148 | ,095 |
| Continuity Correction[b] | 1,665 | 1 | ,197 | | |
| Likelihood Ratio | 2,585 | 1 | ,108 | ,148 | ,095 |
| Fisher's Exact Test | | | | ,148 | ,095 |
| N of Valid Cases | 130 | | | | |

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 7,14.

b. Computed only for a 2x2 table

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