Aus der Klinik für Herz-, Thorax-, und Gefäßchirurgie, des Städtischen Klinikums Braunschweig

Retrospektiver Vergleich der Inzidenz von postoperativ bestehendem Vorhofflimmern nach elektiver Koronararterien-Bypass-Operation mit MiECC gegenüber CECC

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Glossary

ACCT: aortic cross-clamp time
AF: atrial fibrillation
CABG: Coronary artery bypass grafting

CHD: Coronary heart disease
CPB: Cardiopulmonary bypass

CECC: Conventional extra corporeal circulation
ECC: Extra corporeal circulation
ECLS: Extra corporeal life support
ECMO: Extra corporeal membrane oxygenation
HLM: Heart lung machine
IMC: Intermediate care unit
ICU: Intensive care unit

mini HLM: Mini heart lung machine
MiECC: Minimal invasive extracorporeal circulation
MiECTiS: Minimal Invasive Extracorporeal Technologies International Society
OPCAB: Off-pump coronary artery bypass graft
PAOF: Postoperative atrial fibrillation.
RCTs: Randomized controlled trials
RBCS: Red blood cells
SR: Sinus rhythm

1.Introduction

1.1 Coronary artery bypass grafting

Coronary artery bypass grafting (CABG) is a surgical procedure performed to treat coronary heart disease (CHD). It utilizes autologous grafts to bypass narrowed or closed coronary arteries, thereby improving the blood flow to the myocardium.

CABG is one of the most commonly performed cardiac surgeries in the world. In 2019, the total number of heart surgeries performed in Germany reached 99,612. 44.2% of these were CABG procedures (44,093) (Beckmann et al., 2019).

1.2 Atrial fibrillation

Atrial fibrillation (AF) is a supraventricular arrhythmia characterized by rapid and irregular atrial activation with ineffective atrial contraction. In ECG, it is diagnosed by the absence of P-waves and irregular RR intervals.

AF can be categorized according to its cause; primary (idiopathic) or secondary, according to its frequency; paroxysmal, persistent, or permanent, or according to the symptoms; (symptomatic or asymptomatic (silent AF).

There are many causes for AF; some of the most common causes are hyperthyroidism, hypertension, valvular heart disease, CHD, and after cardiac surgery.

The risk of AF increases drastically with age. In the USA, approximately 2% of people younger than age 65 have AF compared to about 9% of people aged 65 years or older (January et al., 2014). In a study on 8 million patients in Germany, the prevalence of AF was estimated to be 2.2%, with an average age of 73,1 years (Wilke et al., 2013).

Ineffective atrial contraction in AF results in an increased risk of thrombus formation- These may embolize anywhere in the body, most notably to the brain, causing ischemic stroke.

Developing AF has deleterious effects not only on the patients but also on the whole health care system.

AF is associated with increased mortality (two-fold in women and 1.5-fold in men) (Andersson et al., 2013) and morbidity (Stewart et al., 2002).

Kim et al. (2011) estimated that the AF patient in the USA cost the health care system 8705$ more per year with an estimated total cost of 6.0$ billion.

1.2.1 Incidence of postoperative Atrial fibrillation (POAF)

All cardiac procedures are associated with an increased risk of postoperative atrial fibrillation. The incidence of POAF depends not only on the type of the procedure but also on the definition of postoperative atrial fibrillation, for which a universal definition is still lacking.

According to recommendations of the society of thoracic surgery, the definition of new-onset AF is the occurrence of POAF requiring treatment. This definition was used by some authors like EL-Chami et al., (2010) revealing an incidence of 18.5%.

The European society of cardiology guidelines defined POAF as an ECG-verified episode lasting longer than 30 seconds, whether symptomatic or not (Kirchhof et al., 2016) .

Other authors define it as an ECG-verified episode lasting at least 1 minute like Ahlsson et al., (2010) revealing logically a much higher incidence of 28.9%.

Because there are many different definitions of POAF, this may explain the considerable difference in the incidence rate of POAF after CABG, which varies between 20-40% (Willems et al., 1997; Guenancia et al., 2015; Tulla et al., 2015; Thorén et al., 2016; Aranki et al., 1996).

Melby et al., (2015) showed that there are two peaks for developing POAF, immediately postoperatively and at 48 hours.

Even much less research is available about the long-term incidence of AF after CABG and the related consequences.

The focus of our study lay on the incidence of postoperative atrial fibrillation persisting on hospital discharge and recorded on Holter monitoring at Rehab following elective CABG in patients with preoperative sinus rhythm and lacking a history of atrial arrhythmias. Further, we hypothesized that the type of extracorporeal circuit utilized during the procedure could influence the incidence.

1.2.2 Consequences of AF

Although some earlier evidence showed that POAF is a harmless self-limited condition (Kowey et al., 2001), there is increasing evidence to support the opposite.

Post-CABG-AF is linked to more prolonged Inpatient treatment and increased perioperative morbidity and early mortality (Maisel et al 2001; El-Chami et al., 2010).

El-Chami et al., (2010) showed that post-CABG-AF was associated with increased mortality over a mean follow up period of 6 years (96,3% were alive one year after surgery compared with 90.1%) and with more extended hospital stay (9.1 days vs. 5.4 days).

The difference in the mortality rate was still noticeable at ten years after surgery (70.2% vs. 55.2%) and after matching for the other comorbidities (El-Chami et al., 2010).

Tulla et al. (2015) showed an increase in total mortality (33.3% vs. 18.8%) as well as in cardiac mortality (15,2% vs. 4.3%) in patients with POAF at discharge vs. Sinus rhythm (SR) in a follow up for a mean of 8.5 years.

Phan K et al. (2015) proved similar results of increasing morbidity and short- (95.7 vs. 98% at one year) and long-term (65.5 vs. 75.3%) survival rates.

Another critical point is the economic impact and the extra cost of treatment of POAF. Aranki et al. (1996) showed that in 1996 in the USA, each patient who develops POAF costs 10,000 $ extra due to the more extended hospital stay and the necessary interventions.

1.3 Strategies to avoid POAF

The pathomechanism of POAF is multifactorial and still not entirely explained. It is believed that surgical manipulation, heart lung machine (HLM), and reperfusion injury lead to oxidative stress and the production of pro-inflammatory molecules associated with developing POAF.

In an attempt to reduce the incidence of postoperative atrial fibrillation, both surgical and non-surgical strategies were developed.

Non-surgical strategies involved perioperative prophylaxis against developing AF using medications. The most established regimes rely on Beta-blockers or Amiodarone.

Surgical strategies concentrated on avoiding the use of the HLM altogether, known as off-pump CABG (OPCAB), or improving the extracorporeal circuits, a development that paved the way to the emerging of the minimal invasive extracorporeal circuits.

1.3.1 On-pump vs. off-pump

To make the first CABG possible, the heart lung machine was developed to overtake the heart's pumping function and allow the surgeon to operate without cardiac motion and in a bloodless field.

The first heart lung machine was developed in 1953 by Dr. John Gibbon (Hill and Gibbon., 1982), but it was not until 1961 when Goetz (Goetz et al., 1961) performed the first CABG procedure.

Since then, the machine itself underwent various changes and developments. Those changes were always driven by the perioperative complications of the cardiopulmonary bypass (CPB).

In an effort to avoid these complications, off-pump CABG was developed. Off-pump CABG is performed on the beating heart using stabilizing devices to minimize cardiac motion in a small area of the heart while a surgeon works on it.

Since the development of the off-pump CABG in the 90s till to date, the results of many randomized controlled trials (RCTs) (Shroyer et al., 2009; Khan et al., 2004; Nathoe et al., 2003), meta-analyses (Hannan et al., 2007; Kuss et al., 2010) comparing the two techniques have been published. In general, both techniques proved to show excellent outcomes, though the off-pump approach failed to show general superiority.

In 2009, the results of the largest RCT to date comparing on-pump CABG to off-pump CABG, the ROOBY (Randomized On/Off Bypass) trial, were published, reporting the outcomes for 2203 patients (99% men) at 18 Veterans Affairs Medical Centers (Shroyer et al., 2009).

In short, the investigators failed to show an advantage of off-pump CABG compared with on-pump CABG in low risk patients. Instead, the use of the on-pump technique was associated with better 1-year composite outcomes and 1-year graft patency rates, with no difference in neuropsychological outcomes or resource utilization.

Unfortunately, this study did not include the incidence of POAF in both groups in the outcomes.

The GOPCABE trial (Diegeler et al., 2013) studied the benefit of off-pump CABG in elderly patients above 75 years old and showed no significant difference between the two techniques regarding death, stroke, myocardial infarction, repeat revascularization, or new renal-replacement therapy within 30 days and within 12 months after surgery. Unfortunately, the incidence of AF was not examined.

1.3.2 Conventional heart lung machine (Sorin Stockert SIII heart lung machine)

Although the off-pump method has established itself as a safe and effective operative technique. The on-Pump CABG is still the gold standard, with around 75% of all CABG performed in the USA using this technique (Bakaeen et al., 2014).

As we already discussed, the off-pump technique failed to show a complete superiority to the on-pump approach. The attitude changed from avoiding using the heart lung machine altogether to developing a newer machine that can deliver better results with fewer complications.

Figure 1: *Sorin Stockert SIII heart Lung Machine, reproduced with friendly permission from LivaNova PLC, Londo, UK, all rights reserved.*

Although the heart Lung machine has undergone many technical developments over the years, the core principles didn't change. For the duration of use of the HLM, it is responsible for the heart's transporting function and the lungs' gas exchange function.

The standard heart lung machine typically includes up to five pump assemblies and an oxygenator. The Pumps and the oxygenator are connected with tubes to the patient in a closed-circuit form. The patient's venous blood is collected and pumped to the oxygenator, which transforms this venous blood, rich in CO_2 and poor in O_2, through a semipermeable membrane to arterial blood rich in O_2 then pumps it back to the aorta through a cannula. Another pump is used to deliver cardioplegia, to arrest the heart so that the surgical field is motionless during the surgical procedure. Another Pump is connected to the drainage system and to a reservoir, it is used to suck blood from the surgical field and return it to the circuit.

Currently, there are two types of pumps available, roller and centrifugal. Both can provide semi-pulsatile or non-pulsatile blood flow. Centrifugal blood pumps' superior blood handling properties have led to their universal use in long-term extracorporeal circulation, such as ECMO (Extracorporeal membrane oxygenation). The scientific evidence for their use in routine cardiac surgery, however, is still debatable (Asante-Siaw et al., 2006). Most HLM today have roller pumps.

Another essential part of the HLM is the reservoir which acts as a collecting container that collects drained blood and acts as a volume buffer that can take or add blood to the circulation. There are two types of reservoirs, open and closed. Contrary to the closed system, in an open system, the blood has contact with the air. The patient's circulatory system in a closed system acts as a reservoir, and volume changes can only be controlled through medications (Vasodilators or Vasoconstrictors).

The arterialized blood passes through a filter to prevent the cell debris, fat cells, and air bubbles from returning to the patient's circulation.

Before starting the extracorporeal circulation, the reservoir and the tubes of the HLM need to be filled with a fluid (priming); this priming fluid is usually a crystalloid or colloidal fluid or a mix of both. In adults, the priming volume needed is about 1.5 Liters. Priming leads to hemodilution of the patient's blood.

1.3.3 Mini heart Lung machine

In an endeavor to avoid the complications related to the use of traditional heart lung machine and after the off-pump technique failed to show an absolute superiority to the use of heart lung machine (Shroyer et al., 2009; Khan et al., 2004; Nathoe et al., 2003; Hannan et al., 2007; Kuss et al., 2010) a miniaturized HLM was developed.

Before we dig into the differences between the standard HLM and the mini HLM, we must discuss the terminology. Several terms have been used to describe the mini HLM: miniaturized extracorporeal circulation (MECC), mini-extracorporeal circulation (mECC), minimized extracorporeal circulation, mini-cardiopulmonary bypass (mCPB, mini-CPB), minimally invasive cardiopulmonary bypass (MICPB), miniaturized cardiopulmonary bypass (MCPB), veno-arterial extracorporeal membrane oxygenation, minimized perfusion circuit, minimized extracorporeal life support system, minimized CPB.

The Minimal invasive Extracorporeal Technologies international society (MiECTiS) agreed to use the term minimal invasive extracorporeal circulation (MiECC). Because this terminology does not only describe the machine alone but the machine as a part of their global approach to rendering the procedure in general minimally invasive (Anastasiadis et al., 2016).

So, in this paper, we will use the abbreviation (MiECC) to describe the mini heart lung machine.

The main components of the MiECC are: a closed cardiopulmonary bypass (CPB) circuit; biologically inert blood contact surfaces; reduced priming volume; a centrifugal pump; a membrane oxygenator; a heat exchanger; a cardioplegia system; a venous bubble trap/venous air removing device and a shed blood management system.

When designing and developing the components of the MiECC, each piece was designed to avoid complications caused by this part in the standard heart lung machine.

For example, a closed CPB circuit minimizes blood contact with air in the different circuit parts in the extracorporeal circulation. This leads to less coagulation factor and platelet activation during CPB (El-Sabbagh et al., 2013).

The lack of a venous cardiotomy reservoir removes the foreign blood-air interface and avoids stasis in the reservoir. This leads to reducing clotting factors and inflammatory mediator activation.

Reinfusion of cardiotomy suction blood exposed to pericardial surfaces is associated with postoperative neurologic injury secondary to increased levels of hemolysis and fat in scavenged blood (Appelblad and Engström, 2002).

Traditionally the shed blood from the patient (cardiotomy suction blood) was returned unprocessed through the heart lung machine to the patient. (Intraoperative auto-transfusion) It has been proven that this blood is highly activated and might lead to thrombin generation, activation of coagulation and inflammatory pathways, as well as higher transfusion requirements (Aldea et al., 2002).

In the MiECC, a shed blood management system is used, in which the shed blood is collected separately in the reservoir of a cell saver and, if needed, can be transfused back to the patient after being processed. Processed blood is associated with decreased expression of markers for thrombin generation, platelet activation, inflammation, and reduced blood loss (Ranucci and Baryshnikova, 2009).

The biologically inert blood contact surfaces in the MiECC (tubes are coated end to end with heparin/ phosphorylcholine or poly(2-methoxyethyl acrylate)) leads to reduce protein adsorption and platelet activation. (Harling et al., 2011) Systematic reviews and meta-analysis showed many clinical benefits for bio-compatible coating, like reducing RBCS transfusion, atrial fibrillation, postoperative neurological and pulmonary functions, and reduced ICU-Stay (Ranucci et al., 2009; Mahmood et al., 2012; Landis et al., 2014; Mangoush et al., 2007).

The MiECC allows for lower prime volumes (500- 800 cc compared to 1500cc in standard HLM). A combination of reduced tubing area (due to the absence of venous reservoir) and reduced priming volume can minimize hemodilution. Hemodilution during CPB leads to reduced coagulation, fibrinolytic proteins, and fluid extravasation into the tissues. Finally, hemodilution has been implicated as a significant factor in organ dysfunction, short-term mortality, and long-term morbidity (Chatterjee et al., 2011). A centrifugal pump actively drains the right atrium to reduce platelet aggregation and cellular damage.

1.3.3.1 Types of MiECC

Not all MiECC are created equal; there is a wide variety of commercially available or customized CPB circuits with various components. The MiECC can be divided into four types:

Type I: extracorporeal life support (ECLS) circuit with the possibility to administrate cardioplegia and used mainly to perform CABG procedures.

Type II: A venous bubble trap/ venous air removing device was added to the system due to safety concerns regarding air entrapment/ airlock into the venous line. This air detection and removing possibility enabled aortic valve procedures.

Type III: A soft-bag/softshell reservoir was integrated into the system to enable blood volume management during valvular procedures.

Type IV: A second open circuit with a venous reservoir and cardiotomy suction was added as a standby component to enable the performance of complex surgeries that pertain to a high possibility of unexpected perfusion scenario.

Additional components that can be integrated into a MiECC system are: pulmonary artery vent, aortic root vent, pulmonary vein vent, soft bag/softshell reservoir, hardshell reservoir, regulated smart suction device, and arterial line filtration.

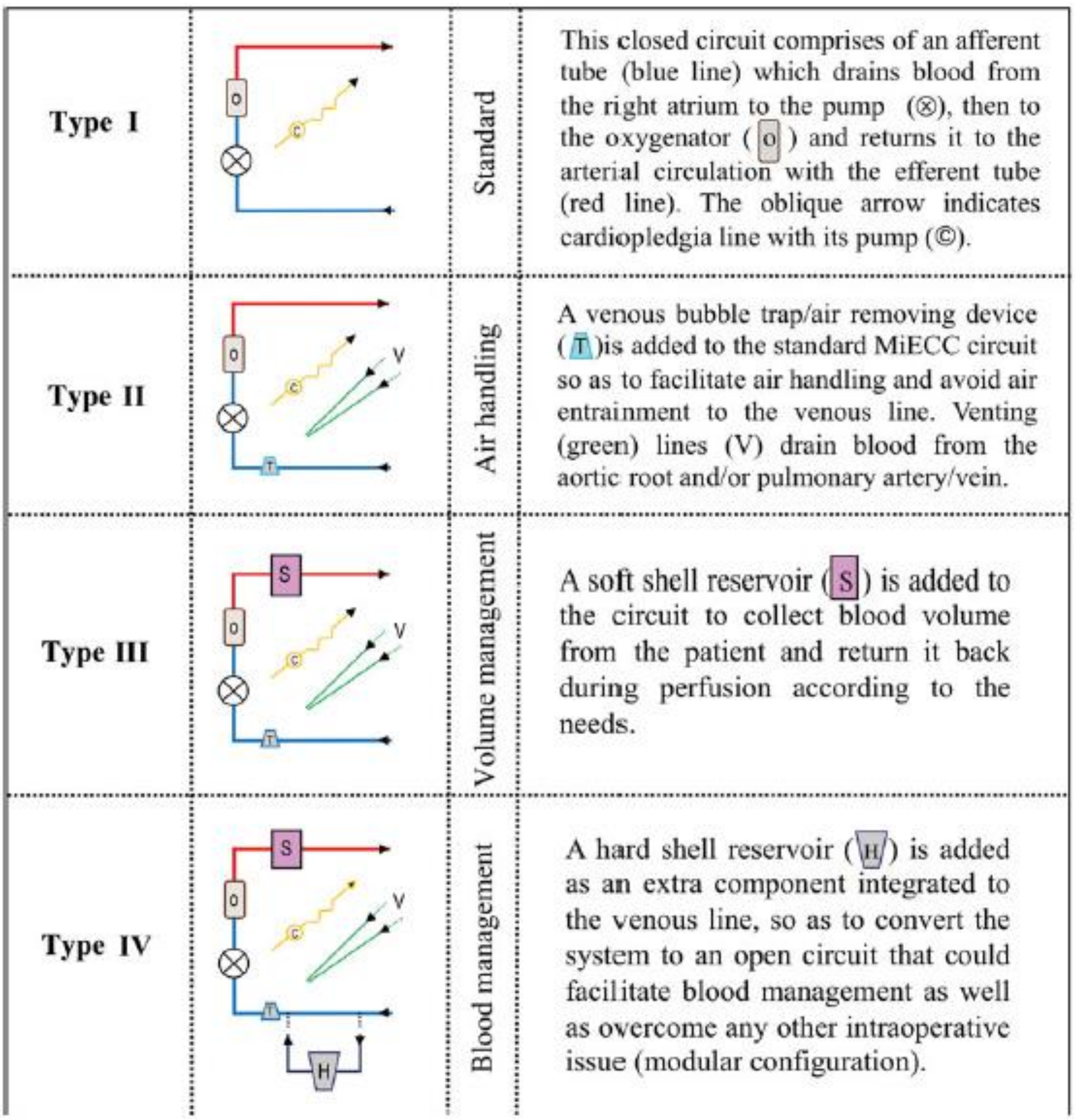

Figure 2: *classification of MiECC circuits.45 (X: pump; O: oxygenator; C: cardioplegia; T: bubble trap/air-removing device; V: vent (aortic/pulmonary); S: soft-bag/reservoir; H: hard-shell/reservoir) (Anastasiadis et al., 2016, with friendly permission from the Interactive European Journal of Cardiothoracic Surgery, published by Oxford University Press. All rights reserved.)*

The consensus meeting of the (MiECTiS) considers a system to be MiECC when it has at least a type II circuit (Anastasiadis et al., 2016).

Our center uses a type IV MiECC system: ROCSafe™ Hybrid Perfusion System (Terumo; Ann Arbor, MI).

Figure 3: *ROCSafe™ Hybrid Perfusion System reproduced with friendly permission from (Terumo cardiovascular; Ann Arbor, MI, USA), all rights reserved.*

2. Patients & Methods

2.1 Ethical aspects

This study protocol was reviewed and approved by the ethical committee of the Hannover medical school (Medizinische Hochschule Hannover Nr. 8485_BO_K_2019). Individual patient's consent was waivered because of the study's retrospective design and data collection from routine care.

3. Study design

We conducted a retrospective single-center study on all patients who underwent elective primary isolated coronary artery bypass grafting in our institution (Department of Thoracic and Cardiovascular Surgery, Städtisches Klinikum Braunschweig, Germany) from 2009 to 2014.

This period was chosen for several reasons:

First, during that period, a standardized protocol for prophylaxis and treatment against postoperative atrial fibrillation (POAF) was implemented in our department.

Second, our initial learning curve with MiECC and the diffusion of the technique with its principles to the whole team had been achieved, but we still did not have enough MiECC systems to cover 100% of our CABG patients; hence there were still enough patients undergoing elective CABG with a conventional extracorporeal circuit (CECC) to compare with.

The selection of the patients to either circuit was furthermore primarily dependent on availability.

3.1 Exclusion criteria

All patients who underwent urgent or emergency CABG surgeries were excluded. All patients who had a history of atrial fibrillation (intermittent or persistent) or other supraventricular arrhythmias were also excluded. There was no lower or upper age limit.

3.2 Procedural strategy

Surgery was performed through a median sternotomy. After heparinisation (with a target activated clotting time of 480s), cardiopulmonary bypass was established with an arterial cannula in the ascending aorta and a two-stage venous cannula introduced via the right atrium. Flow rates of 2.4 cardiac index (CI) X body surface area (BSA) were aspired. All circuits were primed solely with a crystalloid solution as retrograde autologous priming was employed in most patients (with this, approximately 500-600 ml of the priming solution was retrieved). Myocardial protection was achieved with intermittent warm-blood cardioplegia. Cardioplegia was given repeatedly every 20 minutes in the MiECC patients and Bretschneider cardioplegia (1000 ml initially and another 500 ml after 40-60 minutes of cross-clamping) in the conventional ECC patients. Cardiotomy suction was used in the conventional ECC, while a cell-saver was used in the MiECC. In case of significant bleeding after protamine reversal, a cell-saver was also employed in the conventional ECC patients. Venting was via the aortic root in both circuits, passing to the venous reservoir in the CECC and into the venous line before the bubble trap in the MiECC. At the end of cardiopulmonary bypass, the patient's blood was re-transfused from the circuit by antegrade washout in all patients. At the end of the operation, heparin was antagonized with protamine sulfate.

Anesthesiologists and perfusionists, as well as the anesthetic management, were the same for all patients. All surgeons involved utilized both types of circuits regularly and had achieved a sufficient learning curve with the MiECC. Postoperatively, all patients were transferred to the intensive care unit (ICU) and received standard monitoring and mechanical ventilation.

3.3 Monitoring

An electrocardiogram (ECG) was recorded on arrival to the ICU, on the first postoperative day, and at discharge. When any new arrhythmia was detected, an ECG was recorded. All patients stayed for at least 24 hours in our ICU then for at least 24 hours in our intermediate care unit (IMC). During their ICU stay and in the IMC, the patients had continuous monitoring of their ECG. Hence, all patients were continually monitored for at least 48-72 hours postoperatively. After this, in the ward, the pulse and blood pressure of the patients were measured at least three times daily. When any new arrhythmia was detected, an ECG was recorded as well.

3.4 Postoperative management of atrial fibrillation

Prophylaxis against atrial fibrillation included continuing the patient´s beta-blocker up to the morning of the operation, followed by metoprolol 50 mg twice daily up to discharge. Additionally, patients received Magnesium five mmol p.o. one day before surgery, 12.6 mmol/24hours intravenously via an infusion pump for the first 48 hours after surgery and five mmol p.o. daily up to the 5th postoperative day. Furthermore, Potassium was substituted to keep the serum potassium level above four mmol/l.

Table 1: *Perioperative Management of atrial fibrillation*

Perioperative management of atrial fibrillation	
Beta-Blocker	**Pre-Op:** If the Patient was on a β-blocker, it was continued up to the morning of the operation.
	Post-Op: metoprolol 50 mg twice daily up to discharge.
magnesium	**Pre-Op:** 5 mmol p.o. one day before surgery.
	Post-Op: 12.6 mmol/24hours intravenously via an infusion pump for the first 48 hours after surgery and five mmol p.o. daily up to the 5th postoperative day.
potassium	**Peri-Op:** substituted to keep the serum potassium level above four mmol/l.

3.5 Treatment of POAF

Our standard treatment for new-onset atrial fibrillation included raising the postoperative metoprolol dose as well as a single intravenous dose of 5-10 mg metoprolol or 150-300 mg of Amiodarone depending on the patient's condition (blood pressure, heart rate, ejection fraction, etc.) and the preference of the attending physician. If the atrial fibrillation persists for more than 24-48 hours, depending on the patient's condition, electric cardioversion was attempted before the patient was discharged from the hospital. Patients discharged with atrial fibrillation during the study period were maintained on Warfarin (in the absence of any contraindication) for at least three months.

3.6 Definition of atrial fibrillation persisting at discharge

Atrial fibrillation was defined according to the following electrocardiographic features in the ECG performed one day before discharge: irregular R-R intervals when atrioventricular conduction is present, absence of distinct and repeat P wave, and irregular atrial activity.

3.7 Postoperative discharge and monitoring of atrial fibrillation

The patients were usually discharged between the tenth and twelfth postoperative day in the absence of any complications.

In Germany, it is a general policy that all the patients who undergo coronary artery bypass grafting are discharged to a rehabilitation facility where they stay for another 3-4 weeks before they are discharged. Naturally, in all these facilities, there is further monitoring of their Rhythm. A standard ECG is recorded on the day of admission and another ECG before discharge in all patients. When any arrhythmias were detected, an ECG was recorded. Most of the patients also get a Holter monitoring at least once during their stay. Holter is a portable device that can record ECG for a more extended period. In the rehabilitation facilities, it is used to record 24-hour ECGs. In Patients where AF was detected on Holter monitoring, the Holter monitoring was repeated for another 24 hours before discharge.

3.8 Treatment of POAF in the rehabilitation facilities

In general, the management of POAF in the rehabilitation facilities was similar to ours.

In patients transferred to the rehabilitation facilities with AF, the medical therapy (Warfarin) was continued. In patients where a new-onset AF was detected, first medical therapy was used (Beta-blockers, Amiodarone). If AF persisted, electric cardioversion was attempted after excluding intracardiac thrombi by transesophageal echocardiography before the patient was discharged from the hospital. If the AF persisted, the patient was discharged on Warfarin, and an appointment at a cardiology outpatient clinic was recommended in three months to reevaluate the Rhythm and the indication of anticoagulation.

4. Study aim

This study aimed to identify predisposing factors for new-onset atrial fibrillation persisting on discharge and beyond and assess if the type of extracorporeal circuit utilized during the procedure may play a role in this setting.

5. Data collection and statistical evaluation

Patient data were retrospectively extracted from the department's database and medical records. The patients' discharge letters from the rehabilitation facilities are also stored in these records. Variables were defined according to the European System of Cardiac Operative Risk Evaluation (EuroSCORE I) (Nashef et al., 1999) in addition to intraoperative variables.

Following parameters were collected: age, gender, chronic pulmonary disease, extracardiac arteriopathy, neurological dysfunction, previous cardiac surgery, Creatinine > 200 µmol/ L, active endocarditis, critical preoperative state, unstable angina, left ventricle function, recent MI, pulmonary hypertension, extracorporeal circulation time (ECC), cross-clamping time and type of the HLM machine whether it was a conventional extracorporeal circuit (CECC) or MiECC.

The incidence of the AF was recorded at the following stages: AF recorded in discharge ECG, AF in the rehabilitation facility in a standard ECG at admission, AF in rehabilitation Facility recorded in a Holter ECG, AF recorded at the discharge from the rehabilitation facility.

All ECGs recorded at our hospital during a patient's stay are routinely evaluated by a cardiology consultant who writes a detailed report for each ECG. While collecting the data from the files, the ECG itself, as well as the report, were reviewed. If any obscurities or mismatches were noticed by the researcher collecting the data, the ECG was again examined by a cardiac surgery consultant from the research group to clear it.

The type of extracorporeal circulation used was kept blinded from the researcher collecting the data to avoid bias. Only after all data was collected the case number of each patient was used to match each patient to the type of extracorporeal circulation used.

Results are reported as mean ± standard deviation or percentages as appropriate. Unpaired Student's t-test compared continuous variables while the Chi-Square test and Fisher's exact test were used to compare discrete variables. Binary logistic regression using a forward stepwise selection method was carried out to test for independent predictors of atrial fibrillation. The model included all variables with a *p*-value of <0.2 on univariate analysis. The corresponding confidence interval was computed using the DeLong method. (Delong et al., 1988).

To compare the results between ECC groups, we applied a 1:2 nearest neighbor propensity score matching. A maximum caliper width of 0.2 times the standard deviation of the propensity score logit was used to match the groups. For all tests, a *p*-value of <0.05 was deemed statistically significant.

We performed a receiver operating characteristic (ROC) analysis and reported the area under the ROC curve for this model.

All analyses were performed with the SPSS (Version26) statistical software (IBM Corporation, Armonk, New York, USA) as well as the statistical programming environment R (version 3.6.0) using the R-packages MatchIt (version 3.0.2, Ho et al. 2011), table one (version 0.12.0), and pROC (version 1.15.3, Robin et al., 2011) for propensity score matching, the computation of the SMD and the ROC analysis, respectively.

6. Results

After scanning the patients' files, 770 were found with preoperatively documented sinus rhythm. After excluding seven patients, who died in-hospital, the rest 763 patients were included in our analysis. Out of the 763 patients with preoperative sinus rhythm, 731 (95.8%) were discharged from our department in sinus rhythm, and 32 patients (4,2%) were discharge with atrial fibrillation.

Table 2: *Demographic, preoperative and operative differences between patients discharged in SR or AF*

Variables	NOAF n= 32	SR n= 731	*p*=
Age (years)	71 ± 8	66 ± 9	<0.01
Male gender (n/%)	28 (88%)	570 (78%)	0.2
Body mass index (kg/m^{-2})	28 ± 4	28 ± 4	0.4
Weight (kg)	82 ± 13	84 ± 15	0.6
IDDM (n/%)	3 (9.4%)	86 (12%)	1.0

COPD (n/%)	4 (12.5%)	69 (9.4%)	0.5
Renal dysfunction (n/%)	0 (0%)	12 (1.6%)	1.0
Peripheral vascular disease (n/%)	4 (125%)	161 (22%)	0.2
Myocardial infarction <90days (n/%)	5 (16%)	110 (15%)	1.0
Unstable angina (n/%)	0 (0%)	22 (3.0%)	1.0
Pulmonary hypertension (n/%)	0 (0%)	17 (2.3%)	1.0
Neurological dysfunction (n/%)	0 (0%)	17 (2.3%)	1.0
Ejection fraction (n/%)			
LVEF 30-50%	7 (22%)	164 (22%)	0.9
LVEF <30%	1 (3.1%)	25 (3.4%)	1.0
NYHA class	2.9 ± 0.6	2.8 ± 0.4	0.3
Logistic Euro-SCORE I	3.9 ± 3.3%	3.3 ± 2.8%	0.3
ECC time (min)	98 ± 29	89 ± 26	0.078
Cross calmping time (min)	57 ± 18	57 ± 18	1.0
CECC (n/%)	13 (41%)	125 (17%)	0.001

AF: new-onset postoperative atrial fibrillation; SR: sinus rhythm; COPD: chronic obstructive pulmonary disease; IDDM: insulin-dependent diabetes mellitus; LVEF: left ventricular ejection fraction; ECC: extracorporeal circulation; CECC: conventional extracorporeal circuit. Renal dysfunction, pulmonary hypertension, and neurological dysfunction are defined in accordance with the EuroSCORE 1. Data presented as mean ± standard deviation unless otherwise mentioned.

Moreover, we compared the patients discharged in sinus rhythm (SR) (n= 731) and those discharged with new-onset atrial fibrillation (POAF) (n= 32) according to the variables mentioned in table 2. The results showed that those patients in the POAF group were significantly older (71 ± 8 vs. 66 ± 9 years; p= <0.01) and were more frequently operated by a conventional extracorporeal circuit (CECC), namely (41% vs. 17%; p=0.001).

All the 763 Patients who survived the in-hospital stay were discharged into a rehabilitation center. 685 Patients (90%) received a Holter monitoring (24 hours ECG) at least once in the rehabilitation facility (about 30 days after their surgery). In 10 Patients (1.5%) atrial fibrillation was still recorded. (Table 3). It is worthy of mention that all patients who were discharged from our department with atrial fibrillation had a Holter monitoring at least twice during their stay at Rehab

Table 3: *Demographic, preoperative, and operative differences between patients with AF or SR on Holter Monitor*

Variables	AF Holter n= 10	SR Holter n= 675	*p*=
Age (years)	74 ± 6	66 ± 9	<0.01
Male gender (n/%)	8 (80%)	529 (78%)	1.0
Body mass index (kg/m^{-2})	29 ± 4	28 ± 4	0.7
Weight (kg)	84 ± 10	83 ± 15	1.0
IDDM (n/%)	2 (20%)	75 (11%)	1.0
COPD (n/%)	2 (20%)	60 (8.9%)	0.2
Renal dysfunction (n/%)	0 (0%)	9 (1.3%)	1.0
Peripheral vascular disease (n/%)	2 (20%)	143 (21%)	1.0
Myocardial infarction <90days (n/%)	1 (10%)	106 (16%)	1.0
Unstable angina (n/%)	0 (0%)	21 (3.1%)	1.0
Pulmonary hypertension (n/%)	0 (0%)	17 (2.5%)	1.0
Neurological dysfunction (n/%)	0 (0%)	15 (2.2%)	1.0
Ejection fraction (n/%)			
LVEF 30-50%	2 (20%)	144 (21%)	1.0
LVEF <30%	0 (0%)	21 (3.1%)	1.0
NYHA class	2.9 ± 0.6	2.8 ± 0.4	0.3
Logistic Euro-SCORE I	4.4 ± 3.0	3.4 ± 2.8	0.3
ECC time (min)	96 ± 21	89 ± 26	0.5
Cross calmping time (min)	61 ± 14	56 ± 18	0.4
CECC (n/%)	5 (50%)	120 (18%)	0.02

AF: atrial fibrillation; SR: sinus rhythm; COPD: chronic obstructive pulmonary disease; IDDM: insulin-dependent diabetes mellitus; LVEF: left ventricular ejection fraction; ECC: extracorporeal circulation; CECC: conventional extracorporeal circuit. Renal dysfunction, pulmonary hypertension, and neurological dysfunction are defined in accordance with the EuroSCORE 1. Data presented as mean ± standard deviation unless otherwise mentioned.

Out of the 685 patients who received Holter monitoring 10 patients developed atrial fibrillation, 50% of them were operated with a CECC. In the other 675 patients who stayed in sinus rhythm only 120 patients (18%) were operated with CECC (p=0.02). Beside the type of extracorporeal circuit used age was another statistically significant predictor of AF beyond discharge.

In addition, 48 patients who went to rehabilitation despite not having Holter monitoring, had at least two electrocardiograms during their stay. Thus 723 Patients (95%) had excellent documentation of their rhythm during rehabilitation. Out of those 723 Patients, 12 Patients (1.7%) still had atrial fibrillation beyond the 30th postoperative day (table 4).

Table 4: *Demographic, preoperative, and operative differences between patients with AF or SR during Rehab*

Variables	AF Rehab n= 12	SR Rehab n= 723	*p*=
Age (years)	73 ± 6	66 ± 9	0.02
Male gender (n/%)	10 (83%)	568 (79%)	1.0
Body mass index (kg m^{-2})	29 ± 4	28 ± 4	0.7
Weight (kg)	82 ± 10	83 ± 15	0.8
IDDM (n/%)	2 (17%)	84 (12%)	0.6
COPD (n/%)	2 (17%)	69 (9.5%)	0.3
Renal dysfunction (n/%)	0 (0%)	11 (1.5%)	1.0
Peripheral vascular disease (n/%)	2 (17%)	155 (21%)	1.0
Myocardial infarction <90days (n/%)	1 (8.3%)	109 (15%)	1.0
Unstable angina (n/%)	0 (0%)	22 (3%)	1.0
Pulmonary hypertension (n/%)	0 (0%)	17 (2.4%)	1.0
Neurological dysfunction (n/%)	0 (0%)	16 (2.2%)	1.0
Ejection fraction (n/%)			
LVEF 30-50%	2 (17%)	161 (22%)	1.0
LVEF <30%	0 (0%)	23 (3.2%)	1.0
NYHA class	2.8 ± 4	2.8 ± 4	0.8
Logistic Euro-SCORE I	3.9 ± 2.9	3.4 ± 2.8	0.5
ECC time (min)	91 ± 23	90 ± 26	0.9
Cross clamping time (min)	58 ± 15	57 ± 18	0.8
CECC (n/%)	6 (50%)	129 (18%)	0.01

AF: atrial fibrillation; SR: sinus rhythm; COPD: chronic obstructive pulmonary disease; IDDM: insulin-dependent diabetes mellitus; LVEF: left ventricular ejection fraction; ECC: extracorporeal circulation; CECC: conventional extracorporeal circuit. Renal dysfunction, pulmonary hypertension, and neurological dysfunction are defined in accordance with the EuroSCORE 1. Data presented as mean ± standard deviation unless otherwise mentioned.

The comparisons in Tables 3 and 4 show that age and the type of extracorporeal circuit utilized during their coronary revascularization remain the only statistically significant differences between both groups (p=<0.01 and 0.02 respectively for age and p=0.02 and 0.01 respectively for CECC at discharge).

After this, we compared the patients according to the machine utilized. 625 patients (82%) were operated using MiECC and 138 patients (18%) were operated using CECC (Table 5). Comparing the two groups revealed that both groups showed statistically significant differences in both the incidence of AF on discharge from our hospital with 3% in the MiECC group and 9% in the CECC group (P <0.01) as well as on Holter monitor during their rehabilitation with 0.9% in the MiECC group and 4% in the CECC group (P=0.02). According to the mentioned variables in table 4, the two groups had similar characteristics and did not show any statistically significant differences except for the age and the bypass time.

The CECC group was older (68±9Vs. 66±9, P=0.01) and had a longer bypass time (94 ± 28 Vs. 89 ± 26, P=0.03). The difference was statistically significant.

Table 5: *Demographics, perioperative characteristics and operative differences between patients in the MiECC group Vs. CECC.*

Variables	All n = 763	MiECC n= 625	CECC n= 138	*p*=
Age(years)	67±9	66±9	68±9	0.01
Male gender (n/%)	598 (79%)	492 (79%)	106 (77%)	0.65
Body mass index (kg/m^{-2})	28 ± 4	28 ± 4	28 ± 4	0.59
IDDM (n/%)	89 (12%)	72 (12%)	17 (12%)	0.77
COPD (n/%)	73 (10%)	62 (10%)	11 (8%)	0.63
Renal dysfunction (n/%)	12 (2%)	11 (2%)	1 (0.7%)	0.70
Peripheral vascular disease(n/%)	165 (22%)	136 (22%)	29 (21%)	0.91
Myocardial infarction <90days (n/%)	115 (15%)	92 (15%)	23 (17%)	0.60
Unstable angina (n/%)	22 (3%)	20 (3%)	2 (1%)	0.40
Pulmonary hypertension (n/%)	17 (3%)	16 (3%)	1 (1%)	0.33
Neurological dysfunction (n/%)	17 (2%)	15 (2%)	2 (1%)	0.75
Ejection fraction (n/%) :				0.38
LVEF >50%	566 (74%)	462 (74%)	104 (75%)	
LVEF 30-50%	171 (23%)	144 (23%)	27 (20%)	
LVEF <30%	26 (3%)	19 (3%)	7 (5%)	
NYHA class (n/%):				0.80
I/II	124 (2%)	103 (17%)	21 (15%)	
III/IV	639 (97%)	522 (84%)	117 (85%)	
Logistic EuroSCORE I	3.4 ± 2.8	3.3 ± 2.7	3.7 ± 3.2	0.21
Type of ECC (n/%)				
MiECC	625 (82%)			
CECC	138 (18%)			
ECC time (min)	90 ± 26	89 ± 26	94 ± 28	0.03
AF at discharge (n/%)	32 (3%)	19 (3%)	13 (9%)	<0.01
AF Holter Rehab (n/%)	10 (0.9%)	5 (0.9%)	5 (4%)	0.02

MiECC: minimal invasive extracorporeal circuit; CECC: conventional extracorporeal circuit; COPD: chronic obstructive pulmonary disease; IDDM: insulin-dependent diabetes mellitus; LVEF: left ventricular ejection fraction; ECC: extracorporeal circulation; AF: atrial fibrillation; Renal dysfunction, pulmonary hypertension, and neurological dysfunction are defined in accordance with the EuroSCORE 1. Data presented as mean ± standard deviation unless otherwise mentioned.

Consequently, this comparison also emphasizes the big difference in the incidence of atrial fibrillation between the two groups. The incidence AF at discharge beiing three folds higher in the CECC group (9% versus 3%). while atrial fibrillation after discharge on Holter monitoring was four-fold higher among patients in whom a CECC was used (4% versus 0.9%).

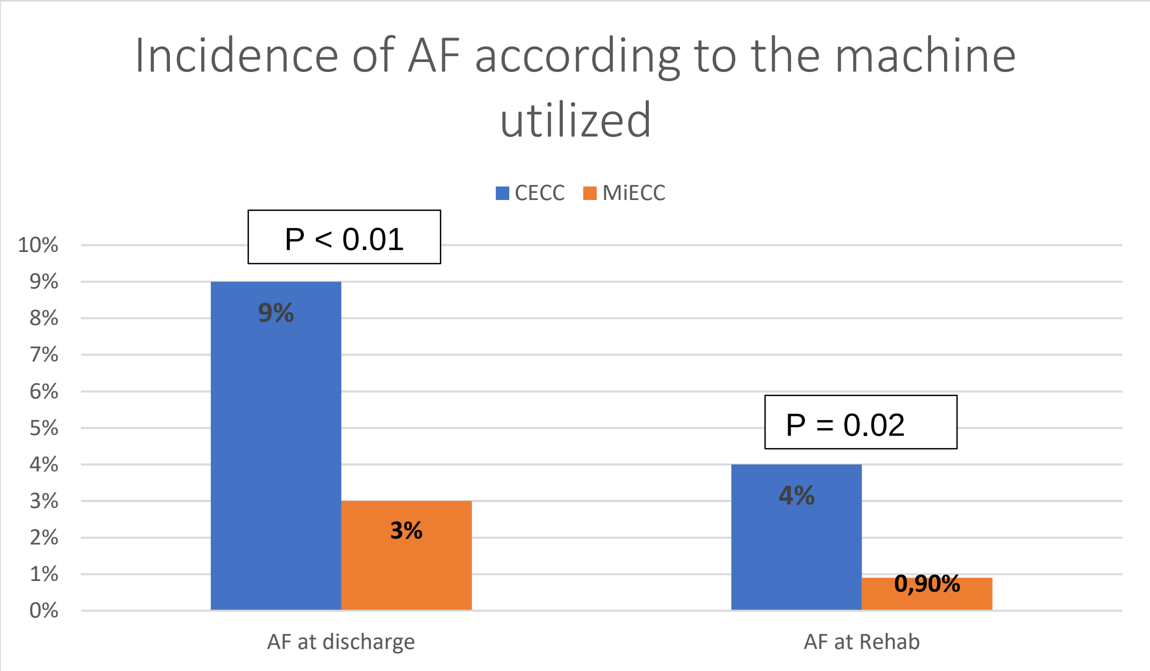

***Figure 4**: Incidence of AF at discharge vs. at rehab*

We then performed a further sub-analysis. We divided the patients according to the machine utilized and compared in each group the patients who developed POAF at discharge versus the patients who stayed in SR (table 6). In the MiECC group (625 patients) age (p= 0.03) was the only predictor of POAF. In the CECC group (138 patients) both age and ECC time (p=0.01 and 0.02 respectively) were predictors for POAF.

Table 6: *Demographic, preoperative and intraoperative differences between patients discharged in SR or AF according to the ECC utilized*

Variables	POAF(CECC) n=13	SR(CECC) n= 125	*p=*	POAF (MiECC) n= 19	SR (MiECC) n= 606	*p=*
Age (years)	74 ± 9	68 ± 9	0.01	69 ± 6	66 ± 10	0.03
Male gender (n/%)	10 (77%)	96 (77%)	1.0	18 (95%)	474 (78%)	0.9
Body mass index (kg/m^{-2})	28 ± 4	29 ± 4	0.4	28 ± 4	28 ± 4	0.7
Weight (kg)	81 ± 12	84 ± 15	0.6	83 ± 14	83 ± 15	0.8
IDDM (n/%)	1 (7.7%)	16 (13%)	1.0	2 (11%)	70 (12%)	1.0
COPD (n/%)	1 (7.7%)	10 (8.0%)	1.0	3 (16%)	59 (10%)	0.4
Renal dysfunction (n/%)	0 (0%)	1 (0.8%)	1.0	0 (0%)	11 (1.8%)	1.0
Peripheral vascular disease (n/%)	2 (15%)	27 (22%)	1.0	2 (11%)	134 (22%)	0.4
Myocardial infarction <90days (n/%)	1 (7.7%)	22 (18%)	0.7	4 (21%)	88 (15%)	0.5
Unstable angina (n/%)	0 (0%)	2 (1.6%)	1.0	0 (0%)	20 (3.3%)	1.0
Pulmonary hypertension (n/%)	0 (0%)	1 (0.8%)	1.0	0 (0%)	16 (2.6%)	1.0
Neurological dysfunction (n/%)	0 (0%)	2 (1.6%)	1.0	0 (0%)	15 (2.5%)	1.0
Ejection fraction (n/%) :						
LVEF 30-50%	1 (7.7%)	26 (21%)	0.5	6 (32%)	138 (23%)	0.4
LVEF <30%	1 (7.7%)	6 (4.8%)	0.5	0 (0%)	19 (3.1%)	1.0
NYHA class	2.9 ± 0.6	2.9 ± 0.4	0.7	2.9 ± 0.6	2.8 ± 0.4	0.5
Logistic Euro-SCORE I	4.8 ± 4.0%	3.5 ± 3.1%	0.2	3.2 ± 2.6	3.3 ± 2.7	0.9
ECC time (min)	111 ± 23	92 ± 27	0.02	89 ± 29	89 ± 26	1.0
Cross clamping time (min)	62 ± 22	59 ± 19	0.6	53 ± 14	56 ± 18	0.5

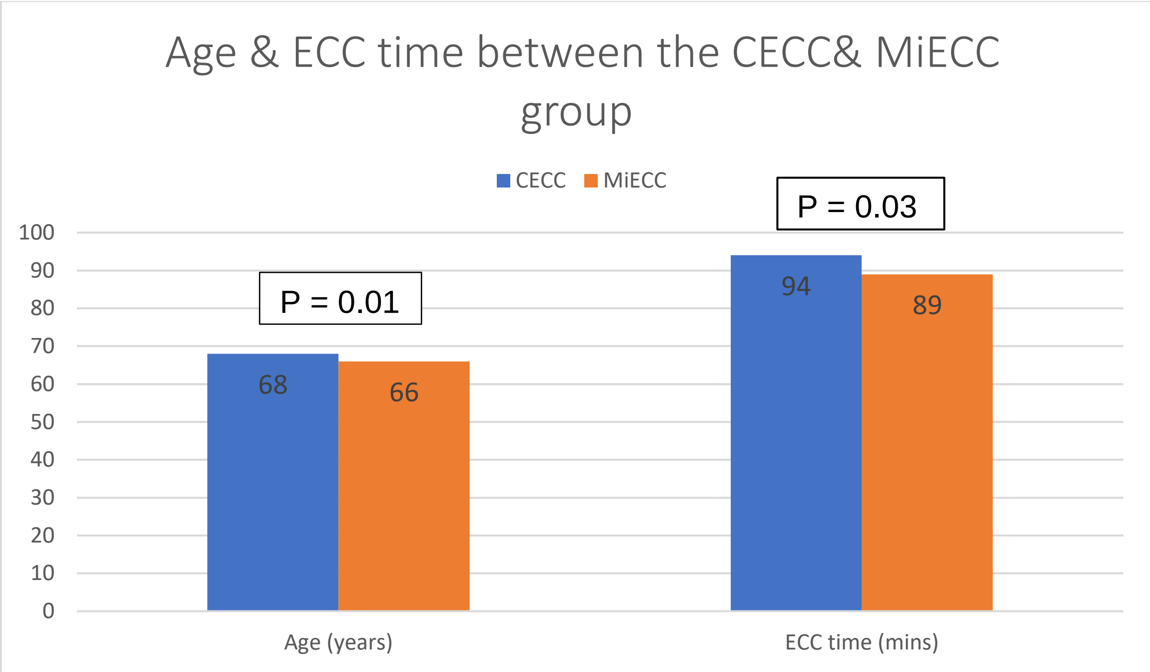

Figure 5: *Difference in Age & ECC time between the CECC& MiECC group*

We then performed a propensity score matching between the two groups (CECC vs. MiECC (Table 7)). We applied a 1:2 nearest neighbor propensity score matching. 239 Patients from the MiECC group were matched to 124 patients from the CECC group. A maximum caliper width of 0.2 times the standard deviation of the logit of the propensity score was used for matching the groups.

Table 7: Demographics, perioperative characteristics, and results propensity score matched patients

Variables	MiECC (PSM) n= 239	CECC (PSM) n= 124	SMD (standardized mean difference)	*p*=
Age (years)	67 ± 10	68 ± 9	0.11	0.31
Male gender (n/%)	190 (80%)	95 (77%)	0.07	0.59
Body mass index (kg m^{-2})	28 ± 4	29 ± 4	0.1	0.34
IDDM (n/%)	27 (11%)	14 (11%)	0	1.00
COPD (n/%)	16 (7%)	9 (7%)	0.02	0.83
Renal dysfunction (n/%)	5 (2.1%)	0 (0%)	0.21	0.17
Peripheral vascular disease (n/%)	51 (21%)	24 (19%)	0.05	0.68
Myocardial infarction <90days (n/%)	40 (17%)	22 (18%)	0.03	0.88
Unstable angina (n/%)	9 (4%)	2 (2%)	0.13	0.34
Pulmonary hypertension (n/%)	8 (3%)	1 (1%)	0.18	0.17
Neurological dysfunction (n/%)	5 (2%)	2 (2%)	0.04	1.00
Ejection fraction (n/%):			0.14	0.41
LVEF >50%	194 (81%)	94(76%)		
LVEF 30-50%	38 (16%)	24 (19%)		
LVEF <30%	7 (3%)	6 (5%)		
NYHA class:			0.06	0.66
I/II	44 (19%)	20 (16%)		
III/IV	194 (82%)	104 (84%)		
Logistic EuroSCORE I	3.5 ± 3.0	3.6 ± 3.1	0.04	0.73
ECC time (min)	94 ± 27	94 ± 27	0	0.99
Cross clamping time (min)	60 ± 18	60 ± 19	0.03	0.79
AF at discharge (n/%)	6 (2.5%)	12 (9.7%)	0.3	<0.01
AF Holter Rehab (n/%)	1 (0.4%)	5 (4%)	0.25	0.02

MiECC: minimal invasive extracorporeal circuit; CECC: conventional extracorporeal circuit; PSM: propensity score-matched; COPD: chronic obstructive pulmonary disease; IDDM: insulin-dependent diabetes mellitus; LVEF: left ventricular ejection fraction; ECC: extracorporeal circulation; AF: atrial fibrillation; Renal dysfunction, pulmonary hypertension, and neurological dysfunction are defined in accordance with the EuroSCORE 1. Data presented as mean ± standard deviation unless otherwise mentioned.

After matching the two groups the difference in the incidence of AF at discharge and on Holter monitoring remained statistically significant. The incidence of AF on discharge in the CECC group still was four times higher than in the MiECC group ((2.5% vs. 9.7%) (P<0.01)). On Holter monitoring the incidence of AF in the CECC was ten times higher than in the MiECC group ((0.4% vs. 4%) (P= 0.02)) (table 7).

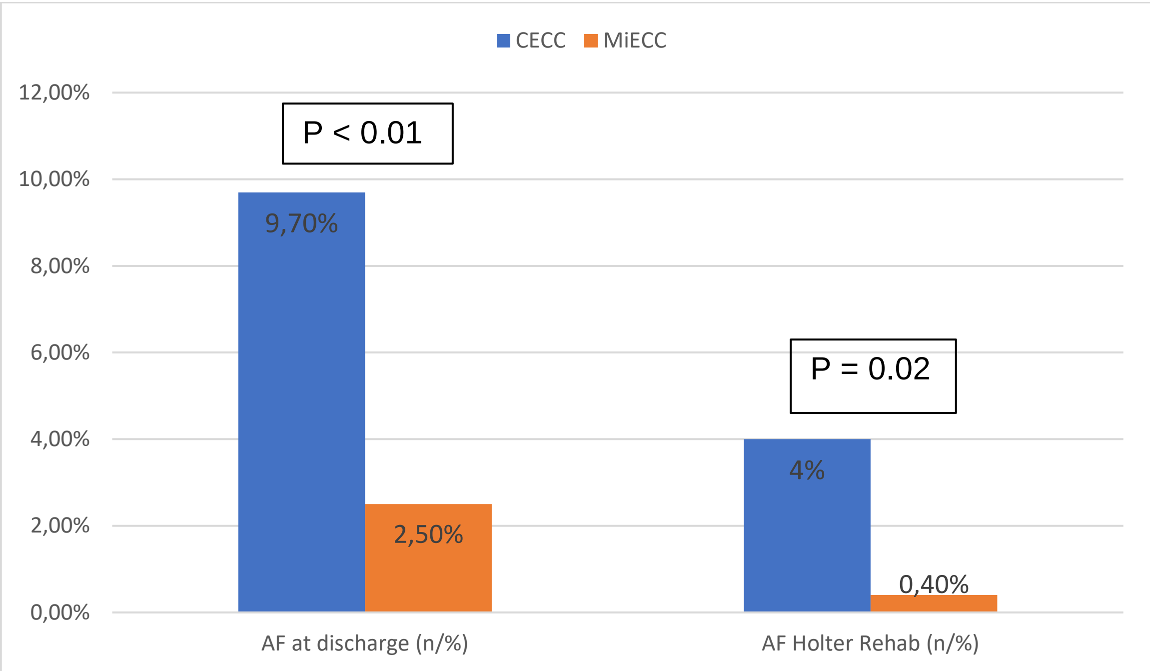

Figure 6: Incidence of AF at discharge and on Holter post-PSM

Finally, multivariate analysis for the predictors of AF persisting at discharge, on Holter monitoring, and at Rehab as a whole, all confirm age and the type of circuit utilized as independent risk factors (Table 8). Further, they confirm extracorporeal circulation time as an independent predictor of AF at discharge for the patients in whom a CECC was used. The discriminatory ability of the prediction model for predicting postoperative atrial fibrillation persisting at discharge was moderate, with an area under the curve (AUC) of 0.68 (95%CI, 0.57- 0.78) (Figure 7).

Table 8: *Independent predictors of AF persisting at discharge and in Rehab*

Variables	Odds ratio	95% Wald confidence limits	*p*-value
AF at discharge (ALL)			
Age	1.065	1.018 – 1.114	<0.01
ECC used	2.685	1.266 – 5.697	0.01
ECC time	1.011	0.998 – 1.024	0.09
AF Holter (ALL)			
Age	1.113	1.019 – 1.216	0.02
ECC used	3.846	1.073 – 13.785	0.04
AF Rehab (ALL)			
Age	1.090	1.009 – 1.178	0.03
ECC used	3.967	1.241 – 12.682	0.02
AF at discharge (CECC)			
Age	1.101	1.016 – 1.193	0.02
ECC time	1.023	1.002 – 1.044	0.03

AF: atrial fibrillation; ECC: extracorporeal circulation; CECC: conventional extracorporeal circulation, AF Rehab included the patients who only had standard ECG on Rehab.

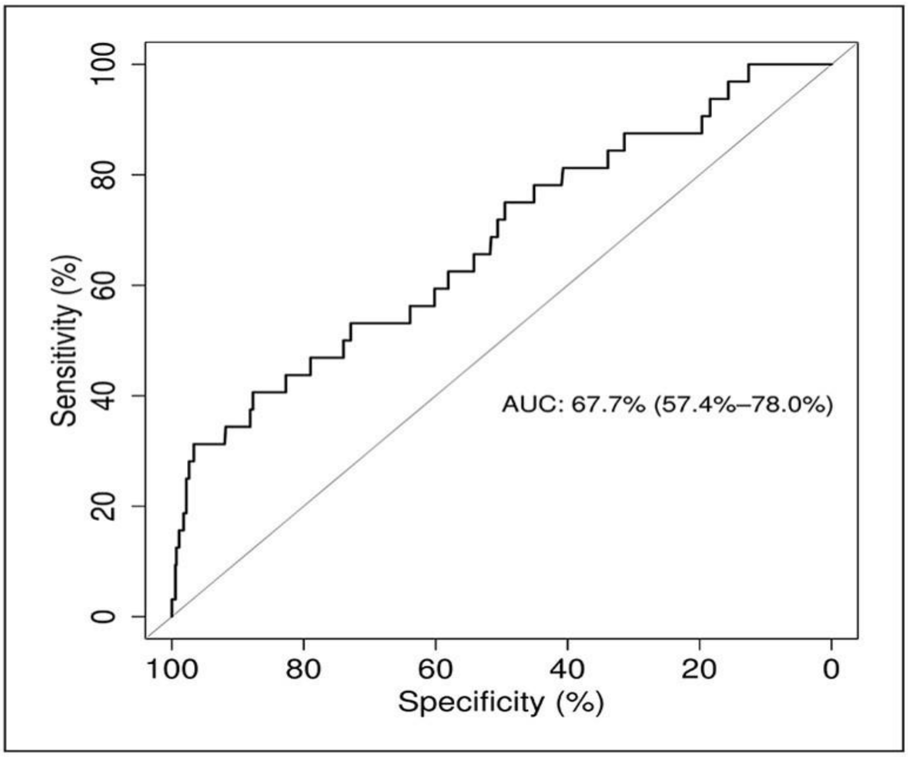

Figure 7: *ROC curve for postoperative atrial fibrillation persisting at discharge after elective coronary artery bypass grafting, based on preoperative and surgical data*

7. Discussion

Performing an open-heart surgery was a dream in the early twentieth century. This dream became a reality through the invention of the heart lung machine (HLM).

John Gibbon performed the first successful open-heart procedure on a human utilizing the heart lung machine in 1953 at Thomas Jefferson University Hospital in Philadelphia. The operation performed was a repair of an atrial septal defect (Cohn, 2003), but it was not until 1961 when Goetz et al. (1961) performed the first CABG procedure.

Since then, the heart lung machine has undergone many changes. These changes were driven by a high incidence of major postoperative complications. One of these complications is post operative atrial fibrillation (POAF), which is the focus of our study.

7.1 The detrimental effect of postoperative AF

All cardiac procedures are correlated with an increased risk of postoperative atrial fibrillation.

For a long time POAF (POAF) was considered to be a benign temporary condition (Levy and Kannel, 2004) Recent evidence however suggests that postoperative atrial fibrillation may be more 'malignant' than previously thought, associated with long-term mortality and morbidity. Newer studies could prove that developing AF has deleterious effects on the patients and the whole health care system.

Woldendorb et al. (2020) published a meta-analysis on the effect of postoperative atrial fibrillation after cardiac surgery on short- and long-term outcomes. This meta-analysis included 61 studies and 239,018 patients. POAF occurred in 25.5% of patients and was associated with significantly higher rates of early mortality and stroke along with longer intensive care and overall hospital length of stay. After a median of 6.6 years, mortality and stroke remained significantly higher for those with POAF.

Taha et al. (2021) published a nationwide retrospective study including all patients who underwent coronary artery bypass grafting without preoperative atrial fibrillation in Sweden from 2007 to 2015 were included (24,523 patients). The impact of new-onset postoperative atrial fibrillation after coronary artery bypass grafting and the benefit of early-initiated oral anticoagulation (OAC) were examined.

During follow-up (median 4.5 years, range 0–9 years), POAF was associated with increased risk of ischemic stroke, thromboembolism (ischemic stroke, transient ischemic attack, or peripheral arterial embolism), heart failure hospitalization, and recurrent atrial fibrillation, but not with all-cause mortality. Early initiation of OAC was not associated with a reduced risk of ischemic stroke or thromboembolism but with an increased risk for major bleeding. POAF occurred in 7368 patients (30.0%), and 1770 (24.0%) of them were prescribed OAC within 30 days after surgery. Although Oral anticoagulation is usually an effective treatment against atrial fibrillation, this could not be proven for POAF.

Pahwa et al. (2021) studied the impact of postoperative complications after CABG on long-term survival. He examined 26,221 operative survivors who underwent CABG, valve surgery, or combined CABG and valve surgery from 1993 to 2019. A total of 17 postoperative complications were analyzed. POAF was the second most common complication and did impact long-term survival.

Phan et al. (2015) performed a meta-analysis with reconstructed individual patient data using six databases from inception to August 2014. Relevant studies with long-term survival data presented for POAF versus No-POAF were identified. The pooled hazard ratio (HR) significantly favored higher survival in No-POAF over POAF (HR 1.28; 95% CI, 1.19-1.37; $P < 0.00001$). Analysis of aggregate data using Kaplan-Meier curve methods for POAF versus No-POAF groups (69,518 patients) determined survival rates at the 1-year (95.7 vs. 98%), 2-year (92.3 vs. 95.4%), 3-year (88.7 vs. 93.9%), 5-year (82.6 vs. 89.4%) and 10-year (65.5 vs. 75.3%) follow-up. Other complications, including 30-day mortality, strokes, respiratory failure, pneumonia, and hospitalization, were significantly higher in the POAF group.

As we can see in the studies mentioned above, developing POAF after CABG was related to increased morbidity and mortality. The difference was still noticeable even after ten years.

Developing POAF is also associated with increased therapy costs due to the related complications and the longer hospital stay. Aranki et al. (1996) examined prospectively all patients who undergone a CABG over 12 months. POAF was the most common postoperative complication. Patients who developed POAF had a longer hospital stay after surgery (15.3 +/- 28.6 days for patients with AF compared with 9.3 +/- 19.6 days for patients without AF). The adjusted length of hospital stay attributable to AF was 4.9 days, corresponding to in-hospital charges exceeding 10,000 dollars.

LaPar et al. (2014) examined the data of 49,264 patients who underwent cardiac surgery between 2001 and 2012; 19% of the patients had developed POAF. The POAF patients had a higher unadjusted incidence of mortality, morbidity, hospital readmission, longer intensive care unit (ICU) and postoperative length of stay, and higher hospital costs. After risk adjustment, POAF was associated with a twofold increase in the odds of mortality (adjusted odds ratio=2.04, $p<0.001$), greater hospital resource utilization, and increased costs; POAF was associated with 48 additional ICU hours ($p<0.001$), three additional hospital days ($p<0.001$), and $3,000 ($p<0.001$) and $9,000 ($p<0.001$) of increased ICU and total hospital-related costs, respectively.

Almassi et al. (2021) could reach similar results while comparing the 5-years clinical outcome and costs retrospectively between patients developing POAF and patients who did not. POAF patients had a longer postoperative length of stay (+3.9 days) and higher discharge costs (+$13,993) than no-POAF patients. Adjusted first-year post-CABG costs in the POAF group were $15,300 higher than the non-POAF group. Interestingly the 2- through 5-year costs were similar, though.

Despite the rise in the treatment costs for patients developing POAF and the increase in morbidity and mortality, the prophylaxis strategies are still not effective enough.

7.2 Prophylaxis against POAF

There are a wide variety of pharmacotherapeutic prophylactic strategies against post operative atrial fibrillation, however with mixed evidence of efficacy.

It is a common practice that all patients undergoing CABG get Magnesium and Potassium directly postoperative. In a meta-analysis (De Oliveira et al., 2012) Magnesium did not reduce the incidence of postoperative atrial fibrillation as well as the incidence of complications associated with the development of postoperative cardiac arrhythmias.

In a study by Lancaster et al. (2016), Potassium supplementation was not protective against POAF, while magnesium supplementation was even associated with increased POAF risk.

The administration of Beta-blockers has also showed mixed results. In the systematic review and meta-analysis done by Thein et al. (2018) the administration of Beta-blocker before elective cardiac surgery could significantly reduce the incidence of POAF but with no significant reduction in ischemic stroke, non-fatal myocardial infarction, overall mortality, or length of stay. An increased rate of bradycardic episodes was also observed.

Also, in high-risk groups like patients above 65 years old or with ejection fraction <40%, Piccini et al. (2013) could not prove efficacy for different pharmacotherapies like beta-blockers or calcium antagonists in reducing the incidence of POAF.

Medical prophylaxis could lead to adverse outcomes too. Johnson and Brophy (2016) could prove that the use of Amiodarone was associated with an increased risk of mortality.

In our center, Potassium was given to all patients to maintain a serum potassium level above 4 mmol/l. The Substitution started directly postoperatively. All patients undergoing CABG in our institution get 5 mmol Magnesium daily for the first 5 postoperative days regardless of their serum Magnesium level. All patients undergoing CABG were put on Beta blocker postoperatively unless there was a contraindication (bradycardia, etc.). Our prophylaxis strategy stayed the same over the years and did not change.

Despite the various medical prophylaxis strategies used routinely in clinical practice, all have not resulted in real breakthroughs. The incidence of POAF after CABG and mortality have not really declined in the last two decades.

Shen et al. (2011) could not find a trend for the incidence of POAF after cardiac surgery over the last 20 years in their institute. The incidence stayed around 30% (25%-36%) with no difference between patients operated in 1986 and in 2005.

A reason why prophylaxis might not be very effective is that the exact cause and mechanism of POAF is not yet precisely clear; It is thought to be complex and multifactorial. Including intrinsic factors (Age, male gender, atrial dilatation, etc.) as well as extrinsic factors (surgical manipulation (cannulation, arteriotomy, etc.), the use of HLM, etc.).

7.3 MiECC VS CECC

After the medical prophylaxis failed to show good efficacy over the years, this turned our sights to the Heart lung machine itself and which changes could be done to minimize the trauma inflicted by the machine on the patient.

Minimal invasive extracorporeal circuits (MiECC) were designed to minimize this trauma and cause less complications. Over more than two decades, studies have evolved to examine this hypothesis.

In a single center randomized control trial in 2006, Remadi et al. included 400 patients undergoing CABG with either MiECC or CECC. In the MiECC group, the inflammatory response as well as the intraoperative transfusion rate were significantly reduced.

In a prospective randomized single-center trial, Sakwa et al. (2009) showed that in 199 patients undergoing elective CABG between 2005 and 2006, the group in which a MiECC was used had less hemodilution, platelet consumption, chest tube output, and lower postoperative blood loss than CECC group.

A prospective randomized multicenter trial (El-Essawi et al., 2011) showed that among 500 patients who received a CABG and/or an aortic valve replacement, there was a statistically significant lower transfusion rate and volume for both packed red blood cells and fresh frozen plasma as well as a lower incidence of postoperative major adverse events. Further, the incidence of postoperative atrial fibrillation was significantly lower (16.3 vs. 24.2%; p=0.03) among the MiECC patients. In addition, the type of circuit employed was the only modifiable independent risk factor for sustaining postoperative atrial fibrillation (Odd ratio of 1.7).

Those findings were also confirmed in a systemic review of the literature and a meta-analysis of randomized controlled trials (2770 patients in total) done by Anastasiadas et al. (2013) to evaluate the Impact of MiECC compared to conventional extracorporeal circulation (CECC) on mortality and major adverse cardiovascular events in patients undergoing heart surgery. The use of MiECC was associated with a significant decrease in mortality, in the risk of postoperative myocardial infarction, and reduced rate of neurologic events. Additionally, MiECC was associated with reduced systemic inflammatory response, hemodilution, need for red blood cell transfusion, the incidence of low cardiac output syndrome, need for inotropic support, peak creatinine level, the occurrence of postoperative atrial fibrillation, duration of mechanical ventilation, and intensive care unit stay.

A meta-analysis of prospective randomized trials (41 randomized controlled trials enrolling 3744 patients) comparing MiECC to CECC published by Sun et al. (2015) confirmed a reduced incidence of POAF among the MiECC patients with an incidence of 19.2 vs. 27.6% (p= <0.001; RR of 0.76). Interestingly the forest plot showed that almost all studies showed a lower incidence of postoperative atrial fibrillation among the MiECC patients.

A comprehensive Bayesian framework network meta-analysis published by Kowalewski et al. (2016) showed that based on an analysis of 46 randomized controlled trials with 10,980 patients regarding the incidence of postoperative atrial fibrillation both off-pump coronary artery bypass grafting (OPCAB) and MiECC to similar extents significantly reduced the odds of postoperative atrial fibrillation in comparison to CECC with an OR of 0.66 and 0.62, respectively.

Despite of the above-mentioned studies the guidelines have given MiECC very restrictive recommendation. The 2017 European Association for Cardio-Thoracic Surgery (EACTS)/European Association of Cardiothoracic Anaesthesiology (EACTA) guidelines on patient blood management for adult cardiac surgery have given MiECC only a class IIa recommendation (Pagano et al., 2017).

The 2019 EACTS/EACTA/EBCP (European Board of Cardiovascular Perfusion) guidelines on cardiopulmonary bypass in adult cardiac surgery also gave MiECC a class IIa recommendation “ MiECC should be considered over standard conventional CPB systems to reduce blood loss and the need for transfusion ” (Wahba et al., 2019).

In a prospective observational study from our center (El-Essawi et al., 2017), MiECC was used for all cardiac procedures performed by a single surgeon in 2013, Excluding procedures done under circulatory arrest or with the potential need for it. Neither operative mortality nor device-related complications were encountered. In a subgroup analysis, we could show that among 64 patients who underwent elective, urgent, and emergent CABG and/or AVR, only 16% developed POAF but all of them were on sinus rhythm (demonstrated by Holter monitoring) during their postoperative stay at a rehabilitation facility. This finding gave us the idea for the current study. The question we tried to answer was if the type of heart lung machine had an influence on POAF persisting beyond hospital discharge.

7.4 Recurrence of POAF and long-term complications

Although there is a lot of data on the incidence of POAF, the data on the recurrence rate is way less. Only in the last few years more research have been available on this point.

Thoren et al. (2020) did an observational cohort study of 7145 in-hospital survivors after isolated CABG with preoperative SR and no history of AF. The median follow-up period was 9.8 years, and 31% of patients developed POAF. Patients with POAF had three times the incidence of long-term AF compared with both patients without POAF and matched controls in the general population (HR 3.03; 95% CI 2.66–3.49). Conversely, the non-POAF cohort showed no AF increase beyond the first postoperative year. POAF was further associated with ischemic stroke, heart failure, and mortality (overall, cardiac, and cerebrovascular). Patients with POAF had an increased incidence of AF compared with patients without POAF and matched, presumably healthy, controls. Moreover, regarding POAF patients, the increase in AF compared with controls persisted over time and was valid after more than ten years of follow-up.

Ayoub et al. (2018) did a retrospective study trying to detect the recurrence rate of POAF following cardiac surgery (CS) and non-cardiac surgery (NCS). He included all patients who developed POAF (112 patients (61 cardiac; 51 non-cardiac)). Mean follow-up was 943 days (range 32-2052 days), duration of follow-up was defined as the time between 30 days of hospital discharge (to distinguish between early and late recurrence). At discharge, a 30-day follow-up was scheduled in the cardiac electrophysiology to record an ECG. A Holter monitor was repeated at six months to rule out asymptomatic recurrences.

POAF occurred around the 2nd to 3rd postoperative day. Interestingly all patients were discharged in SR. AF recurrence rate within 30 days after hospital discharge was 10% in the CS group (0% in the NCS group). The mean follow-up duration was 943 days (range 32-2052 days). The median time to AF recurrence was 724 days. AF recurred in 12.5% of patients in both groups (9.4% in CS groups vs. 17.1% in the NCS group). This study proves that when patients develop POAF, even if they were discharged in SR, there is still an increased incidence of recurrence. In this study, three years after POAF, 1 in 6 patients developed recurrent AF.

El Chami et al. (2016) did an interesting study trying to detect the rate of recurrence of AF after newly diagnosed POAF in patients undergoing CABG. To reach a very high accuracy rate, the research group went the extra mileage and implanted a loop recorder subcutaneously in 23 patients who developed POAF after CABG. 14 out of the 23 included patients (60.9 %) experienced recurrent AF during a follow-up period of 25.35 ± 10.51 months. 39% of patients with POAF had a recurrence within three months after surgery and 47% within 12 months. It is worth noting that only 1 out of the 14 patients who had recurrent AF was symptomatic in this study, while the rest were diagnosed incidentally. In El Chami's study (El Chami et al., 2016), although asymptomatic, the POAF group had a fourfold risk of embolic events and a threefold risk of cardiac death.

Konstantino et al. (2016) reached similar results while analyzing the incidence of recurrence of AF in patients undergoing CABG. 27% of the patients developed POAF. POAF was a statistically significant predictor of late AF in the follow-up period of up to 8.5 years as well as the incidence of late stroke. Patients who developed POAF were significantly more likely to develop recurrent AF (30% vs. 7%, $P < 0.001$) and were more likely to have a cerebrovascular accident (CVA) during long-term follow-up (16% vs. 6%, $P = 0.087$).

Philip et al. (2014) retrospectively identified 5205 consecutive patients who underwent an elective CABG at his institute. 1490 patients developed POAF, but only 70 patients

(4.7%) still had AF at discharge. Those patients were excluded, and the patients who developed (transient) POAF were compared to patients with postoperative SR. The patients were followed up for up to 5 years. POAF group had a higher mortality rate in the multivariate analysis. Unfortunately, in this study, the authors did not include the recurrence rate of AF in the five years follow-up period. This confirms that POAF was associated with an increased occurrence of AF during follow-up. The results of this study strengthen the idea that the cause of POAF is a mix of intrinsic and extrinsic factors. The extrinsic factor (like using HLM) accelerates the process that leads to the development of AF in susceptible patients.

In none of the above-mentioned studies, the type of the extra corporeal circulation (ECC) was explicitly reported or compared. To our knowledge our study was the first study to examine the effect of the type of the ECC on the incidence of POAF persisting after discharge.

We could prove that the incidence of POAF on discharge was three times higher in the CECC group (9% Vs. 3%). This higher incidence of POAF was sill traceable during Rehab. Around 30 days post-op the CECC group still had four times higher incidence of POAF recorded using Holter monitoring (4% Cs. 0,9%).

7.5 POAF and cardiopulmonary Bypass time

The use of HLM represents a severe interaction with the physiology of the patient. The technical necessities of the HLM like; laminar flow, haemodilution, hypothermia, blood contact to air and foreign surface, mechanical cell trauma through sucking and pumping of the blood, and anticoagulation; All these factors can lead to a systematic inflammatory response (SIRS), which manifests clinically to different degrees in each patient.

It could be proven that there is a strong link between systemic inflammation and POAF (Boos et al., 2006). Patients developing POAF usually have higher inflammatory markers such as interleukin-6 and C-reactive protein (Boos et al., 2006). Furthermore, the first peak of developing POAF is usually within the first 72 hours after cardiac surgery, which correlates with peak CRP levels (Chung et al., 2001).

It could also be proven in many studies that there is a correlation between the duration of CBP (cardiopulmonary bypass time) and the incidence of POAF. Dave et al. (2018) did a prospective randomized control trial including 150 patients undergoing coronary artery bypass graft (CABG) surgery and valvular surgeries and could show that patients who had a CBP >100 min had a higher incidence of developing POAF (P < 0.001).

Hashemzadeh et al. (2013) showed in a prospective trial including 1254 patients in sinus rhythm undergoing heart surgery (80.3% had CABG as an isolated surgical procedure) that a longer CBP time was a statistically significant predictor of POAF (OR=0.984; P<0.001).

Mathew et al.(1996) did a prospective multicenter observational trial including a total of 2417 patients undergoing CABG with or without concurrent valvular surgery. He did a multivariate analysis trying to detect the independent predictors of POAF. Age and cross-clamp time were independent predictors of POAF with a 6% increase in the odds of developing POAF with each 15-minutes increase in cross-clamping time in patients undergoing CABG. Patients who developed POAF had a substantially longer cross-clamp time (105.3 vs. 61. minutes; P<0.01).

In our study, the ECC was a predictor for POAF persisting beyond discharge in the group operated by CECC but not in the MiECC group.

The results from the studies mentioned above and our study strengthen the hypothesis that the CECC has a more significant effect on disturbing homeostasis, causing POAF. While MiECC offer a better preservation of the patient’s homeostasis thereby allowing for longer exposure to the circuits without triggering a pathophysiology that may induce arrythmia.

7.6 Other predictors for POAF

The most important intrinsic factor for developing POAF is Age. Almost all studies done on the incidence of POAF confirmed that age is one of the main predictors of POAF; for every 10-year increase in patients' age, the odds of developing AF increase by 75% (Tran et al., 2015).

Bidar E. et al. (2014) did a randomized controlled trial including 148 without a history of atrial fibrillation undergoing aortic valve replacement or coronary artery bypass graft. The patients were randomized into two groups, a pacing group (75 patients) and a control group. The goal of the study was to determine the predictors of POAF in the early phase (postoperative days (PODs) 0-5) and the late phase (PODs 5-30) and total POAF (PODs 0-30) and the effect of atrial pacing on the incidence of POAF. All patients were treated with sotalol postoperatively, and rhythm was continuously monitored for 30 days. Postoperatively, the pacing was maintained for 72 hours and was discontinued during AF or sinus tachycardia and resumed after conversion to SR.

In this study, biatrial pacing could only reduce the risk of late POAF incidence in patients with aortic cross clamping time (ACCT) >50 minutes but did not affect early POAF. Sotalol didn't have any effect on the incidence of POAF in any phase.

In the multivariate analysis patients who had ACCT longer than 50 minutes had a higher incidence of late POAF (POD 6-30). Atrial pacing could only reduce the incidence of late POAF in patients who had ACCT longer than 50 minutes but not in the overall patient population. ACCT longer than 60 min was associated with a higher probability of developing total POAF. A high level of baseline C-reactive protein (CRP) combined with a history of myocardial infarction (MI) or with low body mass index (BMI) was associated with a higher probability of developing early POAF (P =0.03 and P = 0.022, respectively).

The fact that longer ACCT time had more effect on the late and total POAF than on the early POAF while higher CRP level had more effect on the early POAF might support the theory that the effect of the CECC as an extrinsic factor on the homeostasis of the patient, causing the generation of inflammatory responses and adaptations to oxidative stress (which takes time after the initial insult), in patients with the right intrinsic factors for AF, might prevent them from returning to SR and expose them to persistence or recurrence of AF.

Melby et al. (2015) did a time-related parametric risk factor analysis for POAF after heart surgery on 1583 patients. He could notice two peaks for developing POAF; Peak I immediately post OP and Peak II after 48 hours. During peak I, Age and longer cross-clamping time were predominant risk factors for POAF (RR, 1.3, P=0.001) but not in Peak II. In Peak II age, higher weight and Caucasian race were associated with higher incidence of POAF.

Therefore, it is not a surprise that in our study age was an independent risk factor for developing POAF at any stage and in both groups as it has been proven in almost every other study.

Maesen et al. (2012) summarized the interaction between intrinsic and extrinsic factors in a figure showing how both factors contribute to the patient reaching the 'AF threshold' or not. In this figure, the time course of two hypothetical patients is depicted. Both patients have no AF history at the time of surgery and undergo on-pump CABG at the same age. Patient 1, acute surgery-related factors enhance the AF susceptibility, but the 'AF threshold' is not reached, and sinus rhythm is maintained in the postoperative phase. Patient 2, the synergistic interaction of acute, surgery-induced factors and the pre-existence of a substrate for AF due to structural heart disease enhances AF susceptibility that the 'AF threshold' is exceeded. In this sense, the postoperative setting can be regarded as a 'stress test' for the propensity to arrhythmia.

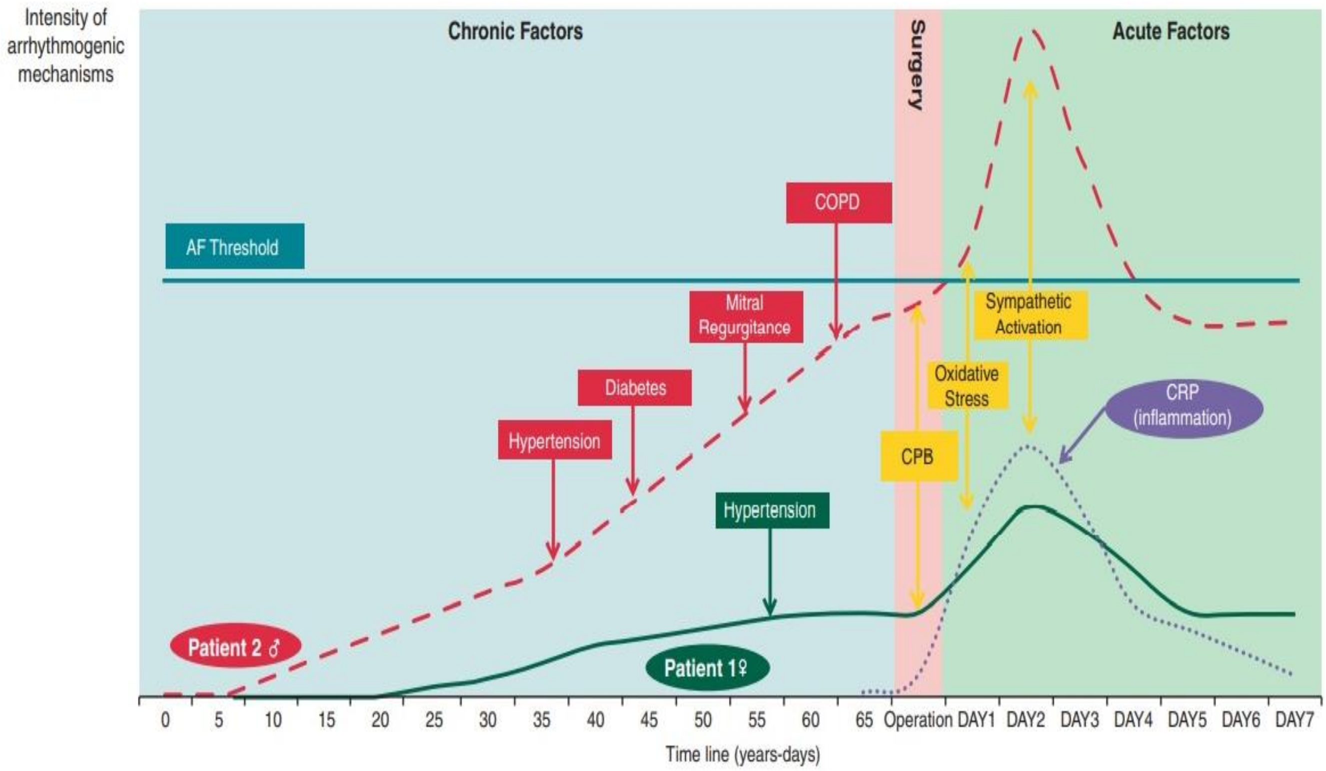

Figure 8: *Time course of intrinsic (chronic) and extrinsic (acute) factors of atrial fibrillation.*

Both chronic as well as acute factors related to the operation on day 0, are shown. When the intensity of pro-arrhythmic factors reaches a certain threshold, atrial fibrillation will occur. Patient 1 has no relevant cardiovascular history, only hypertension (green) at the age of 57. Patient 2 already developed hypertension (red) at a younger age, followed by diabetes (red), mitral regurgitation (red), and COPD (red) at an older age, respectively. Both patients have no history of AF and undergo on-pump coronary artery bypass grafting at the same age. However, patient 2 has developed an AF substrate by the time of operation due to above mentioned cardiovascular diseases. Acute, surgery-related factors occur in both patients: cardiopulmonary bypass (CPB, yellow), inflammation (CRP, purple), oxidative stress (yellow), and sympathetic activation (yellow). Patient 2 develops postoperative atrial fibrillation (exceeds the 'AF threshold'), while patient 1 remains in sinus rhythm. AF, atrial fibrillation; COPD, chronic obstructive pulmonary disease (Maesen et al. 2012), with friendly permission from EUROPACE. published by Oxford University Press).

It can be hypothesized from our results that the magnitude of extrinsic stress inflicted by operative factors including the extaracorporeal circuit may even push the patient to a point of no return, in which case the atrial fibrillation persists beyond discharge. A threshold that is less likely to be reached when a minimal invasive extracorporeal circuit is utilized during the procedure.

8. Summary

The current study shows that the age and type of circuit employed were indeed predictive for the incidence of POAF on discharge and beyond discharge during rehabilitation. Furthermore, all the patients discharged to Rehab received a Holter monitoring at least twice during their stay. So, we can assume a very high accuracy of our data. Further, we could demonstrate that the incidence of POAF on discharge and at rehabilitation was more than 3-fold higher among the patients who were operated on with a CECC. As age has been one of the most constantly reported predictors of POAF in the literature, this finding was to be expected.

To our knowledge, this is the first report showing that the type of ECC employed during CABG influenced the incidence of POAF beyond discharge. Another point of interest is that the bypass time, another frequently mentioned predictor of POAF in the literature (Greenberg et al., 2017), was not confirmed for POAF persisting beyond discharge in our cohort. This led to a further analysis depending on the type of circuit utilized. This analysis showed that cardiopulmonary bypass duration was a predictor for POAF on discharge for the patients in whom a CECC was employed but not for those patients in whom a MiECC was used. This finding supports the idea that MiECC provides better preservation of homeostasis, thereby allowing for more prolonged exposure of the patients to the circuits without triggering pathophysiology that may induce the arrhythmia.

More research is needed to understand the exact mechanism of MiECC causing less incidence of POAF at discharge and beyond. If it is due to milder inflammatory response, a milder ischemic-reperfusion injury, or other mechanisms, still needs to be proven.

Therefore, we assume that the tolerance to the extracorporeal circulatory support by a MiECC is longer, making them even more attractive for complex cardiac procedures that need longer cardiopulmonary bypass times. More research is needed to prove that.

Likewise, it would be interesting to see if we could reach similar results in patients who receive an aortic valve replacement, in whom the incidence of POAF is typically higher.

9. Limitations

The biggest limitation of this study is its retrospective nature. However, the variables of primary interest in this study, namely age, type of extracorporeal circuit used during the coronary artery bypass grafting, duration of cardiopulmonary bypass, atrial fibrillation on discharge, Holter monitoring, or electrocardiogram at Rehab are well-documented variables that are rarely misinterpreted or incorrectly documented. Furthermore, neither the patients nor the staff at the rehabilitation facility knew which extracorporeal system had been used, so that this could not have biased the results. Finally, the type of the extracorporeal system used in each patient kept blinded from the researcher collecting all other data to avoid any possible bias.

The fact that different types of cardioplegia were used in both groups is a weak point in this study. Still, it is a flaw of almost all retrospective studies in this field. At the same time, the largest randomized controlled trial (Ovrum et al., 2004) (1440 consecutive CABG patients) comparing blood cardioplegia to crystalloid cardioplegia has found no significant differences in the incidence of postoperative atrial fibrillation between both groups, not even in a subgroup analysis of high-risk patients.

10. Conclusion

This study confirms that the use of MiECC is correlated with lower incidence of postoperative atrial fibrillation. This benefit also persists beyond discharge and may thus have a positive effect on the outcomes of patients beyond the early postoperative period.

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Appendix

Curriculum Vitae

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Geburtsdatum/-ort	08.02.1991 in Giza, Ägypten
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Adresse	Spittastr. 2 10317 Berlin
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Schullaufbahn

1996 - 2001	Grundschule, Giza
2001 - 2004	Vorbereitungsschule, Giza
2004 - 2007	Sekundärschule, Mansoura

Studium

2007 - 2013	Medizinstudium an der Medizinischen Universität Mansoura, Examen im Januar 2014 mit 79% (sehr gut)
01.03.2014 –28.02.2015	Praktisches Jahr im Klinikum Braunschweig
01.03.2015	Ägyptische Approbation
01.07.2015	Berufserlaubnis in Thüringen
17.02.2016	Berufserlaubnis in Bayern
31.01.2018	Deutsche Approbation

Klinische und Praktische Erfahrungen

15/08/2011 - 13/09/2011	Famulatur in der Abteilung für Urologie im Krankenhaus der Hamburg Eppendorf Universität unter der Leitung von Prof. Dr. Fisch
01/07/2013 - 02/08/2013	Famulatur in der Abteilung für Sportorthopädie der Technischen Universität München unter der Leitung von Prof. Dr. Imhoff
03/08/2013 - 05/09/2013	Famulatur in der Abteilung für Hand- und Plastische Chirurgie der Freiburger Universitätsklinik unter der Leitung von Prof. Dr. Stark

08/09/2013 - 09/10/2013	Famulatur im Adipositas Zentrum des Charité Klinikums unter der Leitung von Prof. Dr. Ordemann
01/03/2014 – 30/04/2014	Famulatur in der Abteilung für Herz-, Thorax- und Gefäßchirurgie im Klinikum Braunschweig unter der Leitung von PD Dr. Harringer
01/05/2014 – 31/07/2014	Famulatur in der Abteilung für Unfallchirurgie und Orthopädie im Klinikum Braunschweig unter der Leitung von Prof. Dr. Gösling
01/08/2014 – 31/09/2014	Famulatur in der Abteilung für Allgemein und Viszeral Chirurgie im Klinikum Braunschweig unter der Leitung von Prof. Dr. Schumacher
01/10/2014 – 31/10/2014	Famulatur in der Abteilung für Mund-, Kiefer- und Plastische Gesichtschirurgie im Klinikum Braunschweig unter der Leitung von Prof. Dr. Hellner
01/11/2014 – 31/12/2014	Famulatur in der Abteilung für Plastische, Ästhetische und Handchirurgie im Klinikum Braunschweig unter der Leitung von Dr. med. Peters
01/01/2015 – 28/02/2015	Famulatur in der Abteilung für Neurochirurgie im Braunschweig Klinikum unter der Leitung von Prof. Dr. Sollman
09/11/2015- 30/03/2018	Assistenzarzt in der Abteilung für Gefäßchirurgie im Weiden Klinikum unter der Leitung von Dr. med. Müller
01/04/2018- 30/06/2022	Assistenzarzt in der Abteilung für Herz-, Thorax-, und Gefäßchirurgie am städtisches Klinikum Braunschweig unter der Leitung von PD Dr. Harringer
01/01/2020-31/12/2020	Interne Rotation in der Thoraxchirurgie
01/01/2021- 31/10/2021	Rotation auf der Herz-, Thorax-, und Gefäßchirurgie -Intensivstation im Rahmen des common Trunk
01/08/2022 - bis jetzt	Assistenzarzt in der Abteilung für Gefäßchirurgie – vaskuläre und endovaskuläre Chirurgie in der Vivantes Klinik Neukölln, Berlin unter Leitung von Dr. med. Kalender

<u>Kenntnisse</u>

Sprachen	Arabisch (Muttersprache) Englisch (sehr gut) Deutsch (B2 bestanden, Lesen und Hören C2 bestanden, Telc C1 Medizin Fachsprache Prüfung)
EDV	Microsoft Office, Adobe Photoshop, Microsoft Power Point, SAP Software, iMed-One, ePA

Aktivitäten

2012	Teilnahme am ,,Grundlagen der Klinischen Forschung" Kurs in experimentellen Forschungszentrum von Mansoura Universität.
17/11/2014 – 20/11/2014	Nahtkurs in der Abteilung für Allgemein Chirurgie im Klinikum Braunschweig unter Leitung von PD Dr. Möbius
23/03/2015	„Basic Life Support“ Kurs an den Helios Fachkliniken Hildburghausen
09/09/2016-11/09/2016	Interdisziplinären Grundkrus Doppler-/ Duplexsonographie der Hirnversorgenden Arterien, peripheren Arterien und Venen und abdominellen/ mediastinalen Gefäße am Regensburg Universitätsklinikum
29/09/2016-01/10/2016	Aufbau CW-Doppler- und Duplex Sonographie der peripheren Arterien und Venen am Regensburg Universitätsklinikum
12/10/2017	Basic surgical skills (Gefäßnaht), Uniklinik Münster
18/03/2018 & 19/03/2018	VATS-Kurs anatomische Resektionen an der Lunge. Uniklinik Tübingen
04/2018 & 08/2018	Grund- und Spezialkurse bei der Untersuchung mit Röntgenstrahlen
11/06/2021-18/06/2021	Einführungskurs Intensivmedizin Arnsberg
15/02/2022-20/02/2022	Notarztkurs-Hannover

Des Weiteren hatte ich im Zuge des Mansoura-Manchester Medical Programm mehrere medizinische Trainingseinheiten in den verschiedenen Abteilungen wie Urologie und Nephrologie, Innere Medizin, Pulmologie, Onkologie, Endokrinologie, Gastroenterologie, Pädiatrie und Notfallmedizin der Mansoura Universität.

Essays

2009	„Herzversagen, eine up-to-date Bewertung“ in der Kardiologie unter der Leitung von Prof. Gamal Faheem
2010	„Wie Fettleibigkeit sich auf die Leber auswirkt“ in der Hepatologie unter der Leitung von Prof. Nagy Abd ElHady

2011	„Schweres Asthma“ in der Pulmologie unter der Aufsicht von Prof. Magda Abd ElSalam
2012	„Der Zusammenhang zwischen Koffein und psychischen Erkrankungen“ in der Psychiatrie unter der Aufsicht von Prof. Wafaa ElBahe
2014	Belegung des Zweiten Platzes im Journal Club des Klinikum Braunschweig mit dem Vortrag„Bloodtransfusion –Can it be harmful?“
2019	Beginn meiner Doktorarbeit in der Herzchirurgie mit dem Thema „Retrospective comparison of the incidence of postoperative atrial fibrillation persisting beyond discharge after elective coronary artery bypass grafting with MiECC versus CECC“

Persönliche Fähigkeiten

- motiviert, zuverlässig und dynamisch
- kommunikativ und fähig im Team zu arbeiten
- aufgeschlossen und organisiert
- belastbar; Es fällt mir leicht neue Aufgaben schnell zu lernen
- Hobbys: Lesen, Psychologie, Formula 1 (im Fernsehen), Joggen, Fitnessstudio, Salsa Tanzen und Tennis.

Unterschrift

Ahmed Abdelhalim

Erklärung nach § Abs. 2 Nr. 7+8

Ich erkläre, dass ich die an der medizinischen Hochschule Hannover zur Promotion eingereichte Dissertation mit dem Titel „Retrospective comparison of the incidence of postoperative atrial fibrillation persisting beyond discharge after elective coronary artery bypass grafting with MiECC versus CECC “ in der Abteilung für Herz-, Thorax-, und Gefäßchirurgie des städtischen Klinikums Braunschweig unter Betreuung von Herrn PD. Dr. med. Wolfgang Harringer mit der Unterstützung durch Herrn PD Dr. med Aschraf El-Essawi ohne sonstige Hilfe erstellt und bei der Abfassung der Dissertation keine anderen als die dort aufgeführten Hilfsmittel benutzt habe. Die Gelegenheit zum vorliegenden Promotionsverfahren ist mir nicht kommerziell vermittelt worden. Insbesondere habe ich keine Organisation eingeschaltet, die gegen Entgelt Betreuerinnen und Betreuer für die Anfertigung von Dissertationen sucht oder die mir obliegenden Pflichten hinsichtlich der Prüfungsleistungen für mich ganz oder teilweise erledigt. Ich habe diese Dissertation bisher an keiner In- oder ausländischen Hochschule zur Promotion eingereicht. Weiterhin versichere ich, dass ich den beantragten Titel bisher noch nicht erworben habe.

23.03.2024 Abdelhalim

Datum Unterschrift