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Reduced incidence of atrial fibrillation after cardiac surgery by continuous wireless monitoring of oxygen saturation on the normal ward and resultant oxygen therapy for hypoxia

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Abstract

Objective: Monitoring of cardiac surgical patients after transfer from the intensive care unit to the normal ward is incomplete. Undetected hypoxia, however, is known to be a risk factor for occurrence of atrial fibrillation. We have utilized Auricall® for continuous wireless monitoring of oxygen saturation and heart rate until discharge. The object of the study was to analyze if oxygen therapy as a result of Auricall® alerts of hypoxia can decrease the incidence of postoperative atrial fibrillation. **Methods:** Auricall® is a wireless portable pulse oximeter. An alert is generated depending on preset threshold values (heart rate, oxygen saturation). Over a period of 6 months, 119 patients were monitored with the Auricall® following coronary artery bypass graft and/or valve surgery. Oxygen therapy was started subsequent to an oxygen saturation below 90%. These patients were compared with a cohort of 238 patients from the time period before availability of Auricall®. The patient characteristics were comparable in both groups. In a retrospective study, the incidence of atrial fibrillation was measured in both groups. **Results:** The postoperative AF was observed in 22/119 patients (18%) in group I and in 66/238 patients (28%) in group II. This difference between the two groups approached significance ($p = 0.056$). In the subgroup of patients with coronary artery bypass graft with our without simultaneous valve surgery ($n = 312$), Auricall® monitoring resulted in a significantly reduced incidence of atrial fibrillation (14% vs 26%, $p = 0.016$). **Conclusions:** Continuous monitoring of oxygen saturation on the normal ward and subsequent oxygen therapy for hypoxia can reduce the incidence of atrial fibrillation in a subgroup of patients after cardiac surgery. Prospective randomized trials are warranted to confirm these data.

Keywords: Auricall; Atrial fibrillation; Oxygen therapy; Wireless monitoring; Cardiac surgery

1. Introduction

The optimal treatment of the hypoxemia after cardiac surgery in the ward reduces the postoperative atrial fibrillation. With the Auricall Monitoring System, you can optimize the treatment, because the Auricall Monitoring System is a reliable tool for continuous monitoring of the oxygen saturation in the ward. Atrial fibrillation (AF), as the most common arrhythmia after cardiac surgery (incidence, 20—45%) [1—7] and is associated with increased morbidity, mortality, prolonged hospital stay, and increased costs [8,9]. Advanced age, hypoxemia and valvular heart operations are the risk factors for this arrhythmia [10,11]. It usually has an onset within 3—4 days postoperatively, and leads to tachycardia, heart failure, and increased cerebrovascular emboli as well as increased hospital stay and cost [12,13]. The incidence of AF after cardiac surgery is influenced by various factors such as type of cardiac surgery, age of the patient and preoperative treatment or withholding of beta-blockers [1,3,4,7,13—16]. Age has been repeatedly shown to be the major risk factor for atrial fibrillation after cardiac surgery [1,3,14]. The persistently high incidence of this complication over the past decades despite progress in surgical techniques and anesthesia can be explained by the increasing age of patients. Among the different types of cardiac operations, the combination of coronary artery bypass grafting (CABG) and valve procedures has the highest incidence reaching 62% [4]. Auricall® is continuous monitoring of oxygen saturation and allows immediate therapy. The assumption that the incidence of postoperative atrial fibrillation in the patient group that was monitored with the Auricall® system is lower than in the unmonitored control group was confirmed in this study. The reduction in the incidence of postoperative AF achieved varied depending on the type of operation. With the exception of one of the six subgroups, the use of Auricall® was associated with a reduced incidence of AF in all groups. In all the incidence of AF was reduced by 10%.

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2. Materials and methods

2.1. Auricall® pulsoxymetry

Since October 2005 all patients have been monitored with Auricall® postoperatively in the hospital's normal heart and vascular surgery ward. Auricall® is a monitoring system manufactured by Cardiosafe International AG. The central component of the system is a pulsoxymeter that measures the oxygen saturation in the blood and the pulse at the patient's ear lobe. The doctor equips the patient with one or more miniaturized sensors after the transfer from ICU to the general floor. The Auricall sensors are hardly noticed by the patient, either during the day or when asleep. Monitoring is assured wherever there is mobile network coverage; in the cafeteria, when walking in the park, during physiotherapy or in the course of activities outside the clinic. If there is no coverage, data are recorded, saved and sent as soon as the connection is re-established. As soon as a sensor registers a pathological event, data transfer is started; as an alarm if immediate response is called for, as a warning message otherwise. The MD can specify the patient profile and the corresponding triggering patterns. Data transfer takes place via mobile phone technology and a secure Internet link. When an alarm is triggered, the corresponding data will appear instantaneously on a PC. At the same time a pager and/or SMS message is sent to the treating doctor and to the nurse. In this way the patient will receive help within the shortest possible time. The patient receives oxygen therapy with 4 l oxygen until the SaO_2 is normal. Threshold values can be set individually. Intelligent algorithms ensure that artifacts are effectively filtered out and false alarms prevented. The MD receives an electronic documentation from the Auricall Monitoring System describing the incident of the atrial fibrillation, and can form a comprehensive picture of the situation as a basis for therapy definition. We detected the atrial fibrillation also with the elective daily ECG and from the documentation from the Auricall Monitoring System. The episodes of the hypoxemia were not followed by the atrial fibrillation. The system described the incident of the atrial fibrillation. After the appearance of atrial fibrillation, the patients have continuous oxygen therapy until they leave the hospital. The technical problems of the device were: defect in the miniaturized sensors of the earlobe or patients forgetting the device and leaving the room.

We had the approval of the ethics committee of the University Hospital Zurich. We did not inform the patients because the study was retrospective. The manufacture has no financial interest of this study.

The main included factors in this study were, that the patients were in sinus rhythm preoperative and we selected the patients in two groups for age, sex and operation type. There were 357 patients in total. A total of 119/357 patients were monitored with Auricall Monitoring System in 6 months. The main excluding factor was that the patients had atrial fibrillation preoperatively. Patients with preoperative documented chronic or paroxysmal AF or who were taking antiarrhythmic medications (e.g., amiodarone, sotalol) were excluded.

2.2. Patient characteristics

Between December 1984 and April 2006, 357 patients were included in the study of all the other patients at the University Hospital Zurich. We matched the patients for age, sex, operation type and preoperative sinus rhythm. A total of 119/357 (33%) patients were monitored postoperatively with the Auricall® pulsoxymeter on the normal ward between October 2005 and April 2006 (group I). The comparison group consisted of 238/357 (67%) patients who were treated before the introduction of Auricall®. Their operation dates were between December 1984 and September 2005 where only about 7% of patients were operated on before 1999 (group II). In order to ensure the best possible comparison between the two groups we selected patients with similar characteristics for the 238 people that made up the comparison group. In this the highest priority was given to the operation type, followed by the patient's sex and age.

2.3. Statistical analyses

Statistical analysis was performed using SPSS, Version 10.1 (SPSS Inc, Chicago, IL). Age data are presented as mean (±SD) and compared between groups by using the Mann—Whitney *U* test. The associations of all risk factors, operative data with postoperative AF and differences in incidences between the groups were analyzed using Pearson's chi-square test. All p values less than 0.05 were considered significant.

3. Results

3.1. Patient characteristics

The patient characteristics are demonstrated in Table 1.

3.2. Incidence of atrial fibrillation

The postoperative AF was observed in 22/119 patients (18%) in group I and in 66/238 patients (28%) in group II. This difference between the two groups approached significance ($p = 0.056$). The only significant point was the subgroup of patients with coronary artery bypass graft with or without simultaneous valve surgery ($n = 312$), Auricall® monitoring resulted in a significantly reduced incidence of atrial fibrillation (14% vs 26%, $p = 0.016$). The highest incidence of AF occurred on the second postoperative day. This applied

Table 1
Patient characteristics

	Group I $n = 119/357$ (33%)	Group II $n = 238/357$ (67%)
Time of observation	October 2005—April 2006	56/210 (27%)
Female	30/119 (25%)	60/238 (25%)
Male	89/119 (75%)	178/238 (75%)
Mean SD ± age (years)	65.0 ± 10.1	62.7 ± 10.1
Range	39.2—86.2	32—86.4
OPCAB procedure	80/119 (67%)	160/238 (67%)
Valve replacement	15/19 (15%)	30/238 (13%)

NS, not significant; age (years, mean ± SD) range.

Table 2
The risk factors and rates of atrial fibrillation in group I (n = 119) and group II (n = 238)

		Group I		Group II	
		AF/n (%)	p value	AF/n	p value
Sex	Male	12/89 (13%)	NS	48/178 (27%)	NS
	Female	10/30 (33%)		18/60 (30%)	
Hypertension	HT (+)	16/86 (19%)	NS	46/148 (31%)	NS
	HT (−)	6/33 (18%)		20/90 (22%)	
Nicotine	N (+)	5/65 (64%)	0.001	33/119 (28)	NS
	N (−)	17/55 (31%)		33/119 (28%)	
Obesity	O (+)	5/39 (13%)	NS	33/100 (33%)	NS
	O (−)	17/80 (21%)		33/138 (24%)	
Hypercholesterinemia	HC (+)	14/92 (15%)	NS	37/153 (24%)	NS
	HC (−)	8/27(30%)		29/85 (34%)	
Diabetes mellitus	DM (+)	4/32 (13%)	NS	12/48 (25%)	NS
	DM (−)	18/87(21%)		54/190 (28%)	
Family history	FH (+)	7/31 (23%)	NS	27/86 (31%)	NS
	FH (−)	15/88 (17%)		39/152 (26%)	

NS, not significant; age (years, mean ± SD) range.

for patients in group I as well as for group II. The first occurrence of AF was 24—48 h postoperatively in 21/66 (32%) patients in the group II and in 1/22 (5%) patients in group I. The relationship between the preoperative risk factors and occurrence of postoperative AF in group I and group II outlined in Table 2. When considering sex as a risk factor, there was not significant difference between the male (13%) and female (33%) in group I. The significant difference was not observed in group II. When considering hypertension as a risk factor, there was not significant difference between hypertensive and non-hypertensive patients in both groups. Moreover, we determined that the rate of AF was significantly higher in patient with nicotine history only in group I (p = 0.001). The baseline operative data and rates of atrial fibrillation are listed in Table 3. The incidence of post-operative AF after valve surgery was not significant in both groups. But there was a statistically significant difference between two groups when considering the incidence of AF after on-pump and off-pump myocardial revascularization. The relationship between preoperative main disease and occurrence of postoperative AF in group I and group II were summarized in Table 4. When considering valve disease, there was a significant difference between valve stenosis/insufficiency and non-valve stenosis/insufficiency in group II.

Table 3
The baseline operative data and rates of atrial fibrillation in group I (n = 119) and group II (n = 238)

		Patients (n)	AF (n)	AF (%)	p value
Surgical data					
CABG off-pump	Group I	80	10	13	0.051
	Group II	160	37	23	
CABG on-pump	Group I	11	1	9	NS
	Group II	22	4	18	
Valvular surgery only	Group I	15	7	47	NS
	Group II	30	11	37	
CABG, combined with valve surgery	Group I	13	4	31	NS
	Group II	26	14	54	

CABG, coronary artery bypass grafting; NS, not significant.

3.3. Oxygen saturation and therapy

If you look at group I that was monitored with Auricall®, the average number of hypoxemic events in patients both with and without postoperative AF was 4.6. Even the media with 2 was the same in both groups. What is noticeable is that with 35/97 patients (36%) with constantly recurring sinus rhythm, not a single hypoxemic phase was recorded. In 2/22 patients (9%) with postoperative AF not a single hypoxemic phase was recorded either. This difference is significant (chi-square test: p = 0.014). If you compare patients with constantly recurring sinus rhythm statistically with patients with AF, you will note a significant difference in the number of hypoxemic phases. The chi-square test gives a p value of 0.038.

Table 4
The main disease and rates of atrial fibrillation in group I (n = 119) and group II (n = 238)

		Group I		Group II	
		AF/n (%)	p value	AF/n (%)	p value
Coronary artery disease	(+)	15/105 (14%)	0.001	56/210 (27%)	NS
	(−)	7/14 (50%)		10/28 (36%)	
Valve stenosis	(+)	7/23 (30%)	NS	22/44 (50%)	<0.001
	(−)	15/96 (16%)		44/194 (23%)	
Valve insufficiency	(+)	6/18 (33%)	NS	22/54 (41%)	0.02
	(−)	16/101 (16%)		44/184 (24%)	
Acute myocardial infarction	(+)	0/7 (0%)	NS	1/7 (14%)	NS
	(−)	22/112 (20%)		65/231 (28%)	

NS, not significant; age (years, mean ± SD) range.

4. Discussion

We believe that the continuous monitoring of oxygen saturation and the optimal therapy of the hypoxemia after cardiac surgery lowered the incidence of AF. The incidence of AF in the group monitored with Auricall® was 10% lower in all than in the unmonitored patient group on the normal ward. The postoperative AF was observed in 18% of patients in group I and in 28% of patients in group II. There was an approached significant difference between the two groups when considering the incidence of postoperative AF ($p = 0.056$). The only significant point was that with the subgroup of patients with coronary artery bypass graft with or without simultaneous valve surgery ($n = 312$), Auricall® monitoring resulted in a significantly reduced incidence of atrial fibrillation (14% vs 26%, $p = 0.016$). For this patient group it follows consequently that the optimized oxygen treatment can reduce the incidence of AF after heart surgery. In the other subgroups no significant differences could be detected between patients who were monitored postoperatively and those who were not. The incidence of postoperative AF in the monitored patient cohort in the Zurich University Hospital was 25% in total and when differentiating between the individual types of operation, between 15% (off-pump CABG) and 46% (combined CABG and valve operations). Thus the incidence determined was within the range of values known from earlier studies. An American study in 1997 [17] relating to a very comparable cohort showed an incidence of 30%. It also describes a significantly increased incidence in operations on aortic and mitral valves and with combined CABG and valve operations. The incidence of AF that we detected with just CABG operations (19%) can be seen alongside literature values of 10% [18], 16% [19], and 18% [8]. The question of whether the use of a heart-lung machine represents a risk factor for postoperative AF is answered inconsistently in studies. While some studies indicate a higher incidence after operations with extracorporeal circulation [8,21], others detect a higher incidence after off-pump operations [17,18]. In our study the incidence of AF in off-pump operations was 5% higher than with operations using the heart-lung machine (20% compared with 15%). The incidence of AF associated with older people that we detected was also described in the literature [9—11]. We did not analyze the extracorporeal circulation or aortic clamping time. The connection between oxygen treatment and the occurrence of postoperative AF has already been investigated by Bäcklund et al. in a study published in 1998 [20]. For this, patients who had undergone a thoracotomy (without heart surgery) were given (35%) oxygenated air either up to the first or up to the third day after the operation. No significant difference in the incidence of AF could be detected. But the cohort studied by Bäcklund et al. only included 24 patients. In our study we approached significant difference in the incidence of postoperative AF in patients with optimized oxygen treatment. We noted a significant reduction in the incidence of AF in patients after CABG operations with and without the heart-lung machine and in patients with CABG operations with and without valve operations. Only the results from the patient group with valve operations did not agree with our hypothesis. With this type of operation we noted an increased frequency of AF in the group monitored with Auricall®. The incidence of AF was generally very high in this group at 47% or 37%. With all the other subgroups and with the whole cohort of patients investigated we were able to show, as expected, a reduced incidence of AF in patients who were treated from October 2005 and who thus used the Auricall® pulsoxymeter. A study by Mooe et al. in 1996 [11] investigated the connection between sleep associated respiratory disturbances and the occurrence of AF after bypass surgery. It is based on the assumption that hypoxemic phases can trigger arrhythmia because of sympathetic activation and hemodynamic stress [11]. In this study postoperative AF was detected in 26% of patients. With patients who had CABG operations in our study the frequency of postoperative AF was 19%. Mooe et al. divided their patient cohort into two groups using the desaturation index (ODI) and the apnea hypopnea index (AHI). AF was diagnosed in 32% of patients with AHI > 5 and in 18% of patients with AHI < 5 ($p = 0.11$). In patients with ODI > 5 the incidence was 39%, in those with ODI<5 18% ($p = 0.02$). The study by Mooe et al. also showed a significantly longer stay in hospital and, just as in our study, a significantly higher average age in patients with postoperative AF than with patients without AF. A study by Gami et al. [21] published in 2004 investigated the association of AF and obstructive sleep apnea regardless of operations undergone. One group of patients with AF was compared with a group of patients with other cardiac diagnoses to investigate the prevalence of obstructive sleep apnea. In the group of patients with AF significantly more patients with obstructive sleep apnea were noted than in the comparison group (49% vs 32%). Thus almost half of patients with AF suffered with obstructive sleep apnea syndrome. The study [22] explains the increased risk of nicotine with AF. We determined that the rate of AF was significantly higher in patient with nicotine history only in the group monitored with Auricall® ($p = 0.001$). The study [21] explains the increased risk of AF with obstructive sleep apnea syndrome because of a hypoxia-related chain reaction that led to arrhythmia via hypercapnia, reaction of chemoreceptors and an increased level of sympathicotonus. In addition the change in intrathoracal pressure that occurs when breathing against obstructions in the upper respiratory passages was described as the cause. This change leads, of course, to changes in the capacities of the heart chambers that may trigger disturbances in rhythm as a result of the expansion-dependent ion channels being activated. In a study by Gami et al. [10] the following risk factors for the occurrence of AF were mentioned: age, male, hypertonia, coronary heart disease, heart failure, smoking, diabetes mellitus, high BMI and obstructive sleep apnea syndrome. In our study, arterial hypertonia, adiposity and advanced age (significant) related to the whole cohort were also accompanied by an increased incidence of AF. Nicotine consumption and diabetes mellitus were, on the other hand, associated with a reduced incidence of postoperative AF. Patients with hypercholesterinemia in the cohort investigated by us were affected significantly less often by postoperative AF than patients with normal cholesterol readings. Also interesting is the fact that in the group with Auricall® monitoring and optimized oxygen treatment, AF was diagnosed significantly less often in patients with the nicotine risk factor than in those without this risk factor.

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