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Predictors of Complications Related to Cardiac Ablation for Atrial Arrhythmias

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Summary

The heterogeneity of the patient population and the lack of uniform approaches to periprocedural management highlight the importance of investigating the predictors of catheter ablation (CA) related complications in patients with atrial arrhythmias.

Aim of the study: to identify risk factors for procedure-related (PR) and procedural sedation and analgesia (PSA)-related complications in patients with atrial arrhythmias.

Materials and Methods. A single-center retrospective cohort observational study analyzed 2,340 electronic medical records (EMRs) from the I. I. Mechnikov NWSMU database from 2015 to 2022. A total of 1,793 EMRs were included in the study. All the patients underwent radiofrequency CA for atrial arrhythmia under procedural sedation and analgesia. The risk factors for PR- and PSA-related complications were identified using single-factor regression analysis and multivariate logistic regression with Jamovi 2.3.21 and IBM SPSS Statistics 26 software.

Results. The PR and PSA-related complication rates were 3.29% and 0.73%, respectively. Hemopericardium/cardiac tamponade with an incidence of 1.45% and cerebral stroke/TIA documented in 1.17% of cases predominated among the PR complications. PSA-related complications included postoperative nausea and vomiting syndrome (0.22 %) and respiratory depression (requiring mechanical ventilation in 0.06% and non-invasive ventilation in 0.45%). Of all PR complications, 30.5% were documented in patients aged 70–74 years. BMI > 30.0 kg/m² (adjusted OR, 1.963; 95% CI, 1.09–3.36; p=0.023), age > 69 years (adjusted OR, 3.081; 95% CI, 1.764–5.383; P<0.001), pain severity on the numerical rating scale (NRS) > 3 points (adjusted OR, 4.317; 95% CI, 2.390–7.800; P<0.001), and previous CA procedure in the patient's history (adjusted OR, 10.276; 95% CI, 4.006–26.354; P<0.001) were found to be risk factors for the development of PR complications, whereas BMI > 35 kg/m² (adjusted OR, 4.955; 95% CI, 1.485-16.535; P=0.009) and duration of CA procedure > 142 min (adjusted OR, 11.070; 95% CI, 2.440-50.228; P=0.002) were found to be risk factors of PSA complications.

Conclusion. The following independent predictors of CA-related complications were identified: patient-related factors such as BMI > 30.0 kg/m² and age > 69 years, as well as procedure-related factors such as duration of CA > 142 min, history of CA, and pain intensity > 3 NRS points.

Keywords: procedural complications; catheter ablation; risk factors; atrial arrhythmias; procedural sedation and analgesia

Conflict of interest. The authors declare no conflict of interest.

Introduction

According to projections for the period 2030–2034, the global incidence of atrial fibrillation (AF) in men will be 16.08 million, with 1.01 million disease-related deaths, while the global incidence in women will be 16.85 million, with 1.49 million deaths [1]. Atrial fibrillation (AF) is a progressive and multifactorial arrhythmia often associated with the most common cardiovascular diseases. These conditions share traditional cardiovascular risk factors such as hypertension, high body mass index (BMI), alcohol consumption, smoking, and a high sodium diet [1]. Catheter ablation (CA) procedures for atrial fibrillation are becoming increasingly common. Because CA alters the pathogenetic mechanism underlying the onset and persistence of AF, early intervention can limit disease progression and improve clinical outcomes [2].

Over the past decade, technological advances in CA for AF have aimed to shorten the ablation procedure and improve its safety [3]. Complications such as cardiac tamponade, stroke, pulmonary vein stenosis, vascular access-related sequelae (e. g., bleeding, hematoma, femoral pseudoaneurysm), and pneumothorax occur rapidly and can be fatal [4].

Identifying patients at high risk for complications and considering predictors of their development in preprocedural planning remains a priority [5]. Increasing age is independently and significantly associated with the total number of complications [5]; however, low complication rates and favorable outcomes after CA have been reported even in patients with AF aged ⩾80 years [6]. Data on the relationship between complications and patient sex have been equivocal, but the study by R. Yadav et al. demonstrated the absence of sex differences in the safety and efficacy of ablation [7]. Studies in recent years did not show any association between BMI and complications of CA for AF [8,9], but procedure time and radiation exposure were increased in obese patients [10].

During the complex and prolonged procedure of CA for AF, patients often experience excruciating pain when the ablation reaches the autonomic nerve distribution area or the esophageal region [11]. Sedation and analgesia are necessary to reduce pain and maintain catheter stability. General anesthesia increases patient comfort during the procedure and ensures safety of transseptal puncture and accuracy of catheter manipulation [12]. However, general anesthesia is associated with increased total procedure time and potential complications such as aspiration, anaphylaxis, and trauma associated with tracheal intubation.

A study of 300 patients comparing the use of procedural sedation and analgesia (PSA) [13] with general anesthesia in patients with atrial fibrillation showed no significant difference in complication rates between the groups. A higher American Society of Anesthesiologists (ASA) anesthesia risk was found with general anesthesia (45% vs. 75%, $P<0.01$), and procedure time was shorter in patients with PSA (110 vs. 139 min, $P<0.001$) [14]. Although general anesthesia is the standard in some centers, CA procedures can also be performed under PSA using propofol as the only anesthetic and fentanyl for analgesia [12].

Between 2010 and 2019, the number of CAs for AF performed under general anesthesia (36.1–40.5%; $P=0.02$) and in deep sedation (22.7–27.5%; $P<0.01$) increased, while the frequency of PSA with a Richmond Agitation-Sedation Scale (RASS) score of –1 to –2 decreased to 9.2%. Nevertheless, in 2019, 32.0% of CA for AF were performed with PSA [15].

Multivariate analysis showed that each five-year increase in age, female sex, and ASA > III were associated with a 7.0% ($P<0.0001$), 9.0% ($P=0.032$), and 200.0% ($P<0.0001$) increase in the incidence of PSA with RASS –1/–2 scores, respectively [4]. A 2019 meta-analysis including 9 observational studies of CA for AF compared general anesthesia and PSA. General anesthesia/deep sedation was associated with a reduced risk of AF recurrence (OR: 0.79, 95% CI 0.56 to 1.13, $P=0.20$) and complications (OR: 0.95, 95% CI 0.64 to 1.42, $P=0.82$), although the differences were not statistically significant [16]. According to Y. Yokokawa et al., who compared the efficacy, safety, clinical outcomes and costs of CA for AF performed with PSA and general anesthesia, the prevalence of procedural complications (PC) was similar in the two groups (4% vs. 4%, $P=0.89$). General anesthesia was associated with a small (~7%) increase in total cost due to longer observation time in the recovery room [17]. Patient demographics, comorbidities, and differences between centers and anesthesia techniques used were predictors of complications. There is an urgent need to identify modifiable risk factors for complications of CA of atrial arrhythmias under PSA.

The aim of this study was to determine risk factors for the development of PC and PSA complications in patients undergoing CA of atrial arrhythmias under PSA.

Materials and Methods

A single-center retrospective cohort observational study was approved by the Local Ethical Committee (LEC) of the I. I. Mechnikov Northwestern State Medical University (I. I. Mechnikov NWSMU), protocol No. 6 of the LEC meeting dated 14.06.2023. We conducted consecutive screening of 2340 electronic medical records (EMR) from the database of I.I. Mechnikov NWSMU for the period from 03.03.2015 to 14.07.2022.

Inclusion and exclusion criteria are shown in the study scheme (Fig. 1).

CA for AF and antiarrhythmic therapy were performed according to the 2014 and 2019 updates of the American College of Cardiology/American Heart Association/Heart Rhythm Society (AHA/ACC/HRS) guidelines. [18,19]. Radiofrequency CA was routinely performed in the radiosurgical operating room using PSA while monitoring RASS scores (–1 to –3). PSA was induced by intravenous fractional bolus injection of diazepam, propofol, and fentanyl (Table 1). Monitoring during surgery was performed with a four-lead body surface electrocardiogram and intracardiac electrograms (CARTO® 3 device, Biosense Webster, Johnson & Johnson MedTech, USA), measurement of HR, SpO_2, and NIBP (GE B 30, General Electric Company, USA).

To avoid hypoxemia, oxygen therapy was administered, starting in most cases with a flow rate of 2 L/min (or 1 L/min in patients with chronic obstructive pulmonary disease) through a nasal cannula. The flow rate was increased when SpO_2 decreased. The ablation index was considered during CA. In patients with RASS –1 to –2, pain was assessed by verbal contact during CA using the NRS.

The following data were collected in the study: sex, weight, height, age, ASA score [20], Charlson Comorbidity Index (CCI) score [21], CHA_2DS_2-VASc risk score (Congestive heart failure, Hypertension, Age ⩾75 years, Diabetes mellitus, Prior Stroke or TIA or Thromboembolism) [22] and HAS-BLED (Hypertension, Abnormal renal-liver function, Stroke,

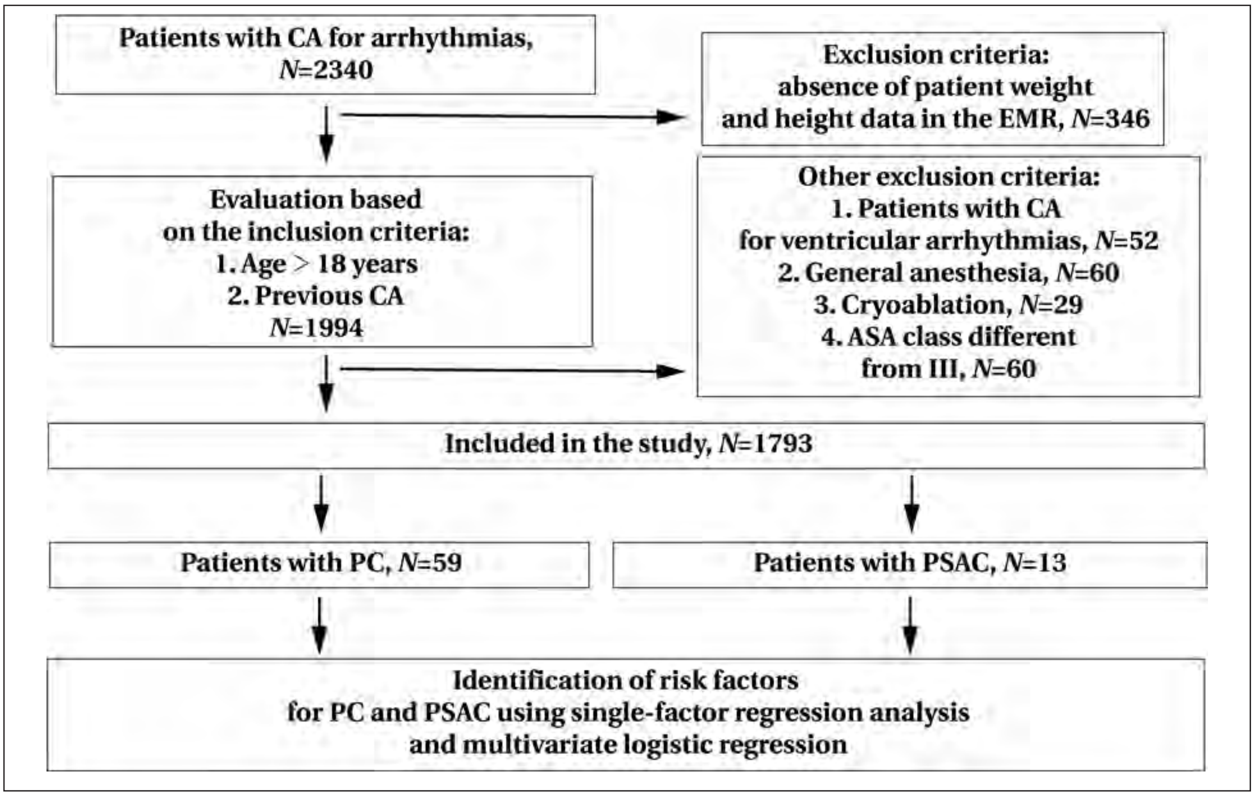

Fig. 1. Study design.
Note. PC, procedural complications; PSAC, «procedural» sedation and analgesia complications.

Bleeding history or predisposition, Labile international normalized ratio, Elderly (65 years), Drugs or alcohol concomitantly) [23], medications, need for surgery, previous procedures, need for electrical cardioversion, duration of procedure, anesthesia, level of sedation according to RASS [24], doses of hypnotics and analgesics, frequency and pattern of PC, complications of PSA including pain score using the Numerical Rating Scale (NRS) [25], length of hospital stay.

Statistical analysis was performed using Jamovi 2.3.21 and IBM SPSS Statistics 26 software packages. Data were reported as mean and standard deviation *(M±SD)* or median and interquartile range of *Me (Q1; Q3)*, depending on the distribution. Qualitative variables were reported as absolute numbers *(N)* and percentages (%). Normality of the distribution of quantitative variables was determined by the Shapiro–Wilk test. In the comparative analysis of 2 independent groups, the Mann-Whitney test was used. The influence of parameters on target binary variables was evaluated using Pearson's χ^2 test. The Bonferroni correction was used for multiple comparisons. For multivariate analysis, we selected factors that showed a significant effect on the outcome. From these factors, independent predictors were selected by binary logistic regression (by sequential elimination using the Wald statistic), and adjusted odds ratios *(ORs)* were calculated. Cutoff points for quantitative parameters were determined by ROC curve analysis. Binary logistic regression was used to determine ORs and adjusted ORs *(AORs)*. Differences were considered significant when $P<0.05$. Risk factors for the development of PC and PSA complications were identified using single-factor regression analysis and multivariate logistic regression.

Results and Discussion

The EMR data of 1793 patients with CA for atrial arrhythmias under PSA were included in the study. The study design is shown in Fig. 1.

Patient characteristics and interventions performed are shown in Table 1.

In our study, a low incidence of PC (3.29%) and 0.05% in-hospital mortality was observed, which is in agreement with the data of Y. Yokoyama, et al. (complication rate 3.4% and in-hospital mortality 0.04%) [5]. All complications were detected during the intraoperative or early postoperative period. In a meta-analysis by Jafry et al, the authors also found no significant difference in complication rates between groups of patients discharged on the day of surgery or later [26]. They showed that vascular/hemorrhagic complications such as hemopericardium/tamponade (1.45%) and neurological complications such as acute cerebrovascular accident/transient ischemic attack (1.17%) were the most common PC, which is in line with results from other centers [27]. In our study, no atrioe-

Table 1. Patient and intervention characteristics.

Parameters	Values (N=1793)
Age, years *(M±SD)*	58.7±12.4
Age groups, years, *N* (%)	
under 60	829 (46.2)
60–64	307 (17.1)
65–69	340 (19.0)
70–74	211 (11.8)
75–79	78 (4.4)
80–84	23 (1.3)
85 and older	5 (0.3)
Female sex, *N* (%)	905 (50.5)
Weight, kg *(Me (Q1; Q3))*	78.0 (69.0; 90.0)
Height, cm *(Me (Q1; Q3))*	170.0 (164.0; 177.0)
BMI, kg/m² *(Me (Q1; Q3))*	26.4 (23.7; 29.9)
BMI, kg/m², WHO classification, *N* (%)	
18.5–25.0 normal	639 (35.6)
25.0–30.0 overweight	692 (38.6)
30.0–35.0 obesity I	308 (17.2)
35.0–40.0 obesity II	104 (5.8)
>40,0 morbid obesity	35 (2.0)
16–18.5 weight deficit	15 (0.8)
Comorbidities, *N* (%)	
Hypertension	320 (17.8)
CHD	132 (7.3)
NYHA class I heart failure	6 (0.3)
NYHA class II heart failure	16 (0.9)
NYHA class III heart failure	1 (0.1)
History of ACVA	15 (0.8)
Diabetes mellitus	62 (3.5)
Score, points *(Me (Q1; Q3))*	
CCI	2 (1; 3)
CHA_2DS_2-VASc	1 (0; 1)
HAS-BLED	0 (0; 1)
The use of medications, *N* (%)	
Amiodarone	217 (12.1)
β-blockers (bisoprolol)	1793 (100)
Procedures	
RF pulmonary vein isolation, *N* (%)	1552 (86.6)
RFA of the cavo-tricuspid isthmus, *N* (%)	61 (3.4)
RF AV node modification, *N* (%)	132 (7.4)
RFA of arrhythmogenic substrate for atrial extrasystoles, *N* (%)	43 (2.4)
Duration of procedure, min *(Me (Q1; Q3))*	120.0 (70.0; 155.0)
Electrical cardioversion during procedure, *N* (%)	593 (33.1)
History of CA, *N* (%)	32 (1.8)
Average length of hospital stay, days *(Me (Q1; Q3))*	5 (3; 7)
PSA characteristics	
Frequency of RASS –1 to –2 sedation, *N* (%)	1188 (66.3)
Dose of propofol, mg/kg *(Me (Q1; Q3))*	1.613 (1.295; 2.439)
Dose of diazepam, mg/kg *(Me (Q1; Q3))*, *N*=66	0.131 (0.120; 0.166)
Dose of fentanyl, µg/kg *(Me (Q1; Q3))*	1.724 (1.351; 3.333)
Frequency of NRS >3, *N* (%)	182 (15.3%)
Frequency of RASS – 2 to – 3 sedation, *N* (%)	605 (33.7)
Dose of propofol, mg/kg *(Me (Q1; Q3))*	2.439 (2.151; 2.857)
Dose of diazepam, mg/kg *(Me (Q1; Q3))*, *N*=39	0.143 (0.125; 0.165)
Dose of fentanyl, µg/kg *(Me (Q1; Q3))*	2.3353 (1.961; 2.857)

Note. Samples of patients who differed in level of sedation according to the RASS scale and accordingly had different doses of hypnotics and analgesics are shown. For Tables 1, 3–6: CHD, coronary heart disease; ACVA, acute cerebrovascular accident; NYHA, New York Heart Association; CCI, Charlson Comorbidity Index; CHA2DS2-VASc, Congestive heart failure (Hypertension, Age ⩾75 years, Diabetes mellitus, Prior Stroke or TIA or Thromboembolism); HAS-BLED — Hypertension, Abnormal renal-liver function, Stroke, Bleeding history or predisposition, Labile international normalized ratio, Elderly (65 years), Drugs or alcohol concomitantly; RF, radiofrequency; RFA, radiofrequency ablation; AV, atrioventricular.

sophageal fistula formation or phrenic nerve injury was found. Complicated PSA occurred in 0.73% of cases, which was significantly lower than in the study by Y. Yokokawa et al. (4.0%) [17] and R. Garcia et al. (2.9%) [15]. PSA complications were represented by postoperative nausea and vomiting (PONV) syndrome in 4 (0.22%) patients, respiratory depression related to anesthetic effects requiring ventilatory support in 1 (0.06%) patient, and NIVL in 8 (0.45%) patients. Periprocedural complications are shown in Table 2.

We found that patients with PC were significantly older than those without (Table 3), which is consistent with the literature [4].

In the 70–74 year age group, PC was detected in 30.5% (18/59) of patients, while 11.1% (193/1734) of patients did not have PC, P<0.001 (Table 3). Patients aged 70–74 years were 3.5 times more likely to develop PC (OR: 3.51; 95% CI: 1.97; 6.22, P<0.001). In contrast to the study by Y. Y. Liu et al., in our study, AF patients aged ⩾80 years did not differ in the number of PC identified [6].

R. Yadav et al. showed no effect of sex on safety and efficacy of ablation [7]. In our study, women had significantly more PC detected, P=0.030. Similar data were obtained by D. D. Spragg et al. [28] and M. L. Campbell et al. [29] who showed that the incidence of PC was significantly higher in women. Ac-

Table 2. Periprocedural complications in the studied patients (N=1793).

Complication	Frequency, *N* (%)
Procedural	
Hemopericardium/tamponade	26 (1.45)
Acute myocardial infarction	1 (0.06)
AV block	3 (0.17)
Conduction blocks and arrhythmias	1 (0.06)
Hemothorax	2 (0.12)
ACVA/TIA	21 (1.17)
Hematoma in the vascular access area	6 (0.33)
Intraoperative blood loss requiring blood transfusion	5 (0.28)
Total	59 (3.29)
Frequency of complications during previous CA	7 (0.39)
Procedural sedation and analgesia related	
PONV	4 (0.22)
Need for non-invasive lung ventilation after the procedure	8 (0.45)
Need for lung ventilation after the procedure	1 (0.06)
Total	13 (0.73)

Note. TIA, transient ischemic attack; AV, atrioventricular; PONV, postoperative nausea and vomiting.

cording to M. L. Campbell et al., neurological complications such as stroke/TIA were found in 0.51% of women and 0.39% of men, and intraprocedural mortality was 0.25% in women and 0.19% in men [29].

According to the data of a research team, there was no relationship between BMI and PC in relation to CA for AF [9]. Similar data were obtained by R. Providência et al., but two patients with high BMI had atrio-esophageal fistula and one patient with morbid obesity developed acute left ventricular failure during ablation [8]. In the work of S. D'Souza et al., obesity was associated with an increased risk of vascular/hemorrhagic complications [30]. Analysis of our data showed that morbid obesity was associated with the development of PC, $P<0.001$.

In our study, coronary heart disease (CHD) was found in 16.9% of patients with PC and 7% without PC ($P=0.004$, Table 3), which is consistent with the data of G. Steinbeck et al. (18.6% of patients with PC) [31].

Significant differences in CHA_2DS_2-VASc ($P=0.029$) and HAS-BLED ($P<0.001$) scores were observed between patients with and without PC (Table 3). CHA_2DS_2-VAS score ⩾1 was observed in the group with PC, similar to the study by E. Yang et al. [32]. As shown by K. Senoo et al., the HAS-BLED score was significantly associated with the risk of bleeding (any clinically significant bleeding: OR: 1.85; 95% CI: 1.43–2.40, $P<0.001$; major bleeding: OR: 2.40; 95% CI: 1.28–4.52; $P=0.007$) [33]. In our study, a HAS-BLED score ⩾1 point was associated with a 2.3-fold increased risk of developing PC (OR: 2.364; 95% CI; 1.404–3.981, $P=0.001$).

A history of previous ablation significantly increased the incidence of PC, $P<0.001$ (Table 3), similar findings were reported by Szegedi et al [34].

Procedural complications were found to increase the length of hospital stay by >7 days (Table 3), in contrast to the data obtained by A. Gupta et al [35].

The level of peri- and post-interventional pain experienced is considered a determinant of patient satisfaction with the ablation procedure [36]. In PO, a pain score of >3 points was recorded more frequently in patients with PSA with a RASS level of –1 to –2, $P<0.001$, and the fentanyl dose was higher in the PC group, $P=0.001$. The studied parameters in patients with and without PC are shown in Table 3.

Longer procedure times were associated with a higher incidence of PSAC ($P<0.001$) (Table 3).

B. Cronin et al. showed that minimal to moderate sedation during cryoablation is effective in most patients with AF, whereas deep sedation or general anesthesia is mandatory for RFA with 3D electroanatomic mapping, as the success of the procedure depends on minimal patient movement [37, 38]. Sedation is a continuum with a wide range of levels of consciousness, and the transition to deeper levels can be rapid and not always predictable [39].

In our study of 1793 patients, respiratory depression requiring ventilatory support occurred in 1 (0.06%) patient (RASS sedation level –2 to –3; propofol dose 2.439 (2.151; 2.857) mg/kg and fentanyl dose 2.3353 (1. 961; 2.857) μg/kg), and NIVL was performed in 8 (0.45%) patients (of whom 5 had RASS sedation level –1 to –2; propofol dose 1.613 (1.295; 2.439) mg/kg and fentanyl dose 1.724 (1.351; 3.333) μg/kg) (Tables 1, 2).

In a study of drug-related complications in a cohort of 3211 patients with AF undergoing deep sedation during CA [40], one patient (0.03%) required ventilatory support and 47 (1.5%) required NIVL. The mean doses of propofol, midazolam, and fentanyl were 33.7±16.7 mg, 3.0±11.1 mg, and 0.16±2.2 mg, respectively. Norepinephrine was administered to 396 of 3211 patients (12.3%) for hypotension (mean arterial pressure <60 mmHg). No hypotensive patients requiring vasopressor support were observed in our study.

In our study, 4 (80.0%) of 5 patients with PSA complications and a RASS score of >3 points received fentanyl 7.0 μg/kg at a sedation level corresponding to a RASS score of –1 to –2 points (Table 4). According to the literature, the use of higher doses of opioids is associated with a higher risk of adverse effects, morbidity, longer recovery time, and higher costs [41]. The length of hospital stay was not significantly different between the study groups (Table 4).

Multivariate analysis by J. Plášek et al. showed that older age was an independent predictor of major vascular complications in men [42]. The multivariate analysis showed that age >69 years was a predictor of PC, increasing their risk 3.08-fold (Table 5), in contrast to the study by A. Numminen et al. which found that age and weight were not significant predictors of PC [43].

Age ⩾65 years ($P=0.0231$), female sex ($P=0.0438$), hypertension ($P=0.0488$), CHA_2DS_2-VASc score ⩾2 ($P=0.0156$) and previous CA for AF in the study by N. Szegedi et al. were associated with the development of complications in a single factor analysis [34]. Previous CA for AF does not rule out the possibility of posterior wall thinning, atrial septal changes, and adhesions in the vascular access area, which may explain the technical difficulties in performing CA [44, 45]. Furthermore, repeated CA procedures increase the risk of developing pulmonary vein stenosis [46]. Multivariate analysis by N. Szegedi et al. showed that the only independent predictor of AF was a history of previous AF ablation (AOR: 3.18; 95% CI 1.99–5.08; $P<0.0001$) [34]. In multivariate analysis, we found similar results: previous CA increased the odds of PC by 10.2-fold compared to patients without previous CA (Table 5).

According to the US National Registry 2005–2013, obesity was an independent predictor of PC (AOR: 1.39; 95% CI: 1.20–1.62) and was asso-

Table 3. Comparison of patients with atrial arrhythmias with or without procedural complications of CA.

Parameter	Values in patients		*P*-value
	without PC, *N*=1734	with PC, *N*=59	
Age, years *(M±SD, Me (Q1; Q3))*	58.5±12.4	64.6±10.6	<0.001
	60.5 (52.0; 67.0)	68.0 (59.0; 73.0)	
Age groups, years (*N* (%))			
Under 60	814 (46.9)	15 (25.4)	0.001
60–64	297 (17.1)	10 (16.9)	0.968
65–69	329 (19.0)	11 (18.6)	0.924
70–74	193 (11.1)	18 (30.5)	<0.001
75–79	75 (4.3)	3 (5.1)	0.767
80–84	22 (1.3)	1 (1.7)	0.791
85 and older	4 (0.2)	1 (1.7)	—
Female sex, *N* (%)	867 (50.0)	38 (64.4)	0.030
Weight, kg *(Me (Q1; Q3))*	78.0 (69.0; 89.0)	83.0 (71.0; 97.5)	0.029
Height, cm *(Me (Q1; Q3))*	170.0 (164.0; 177.5)	167.0 (161.5; 177.5)	0.047
BMI, kg/m² *(Me (Q1; Q3))*	26.3 (23.7; 29.7)	28.7 (25.2; 33.0)	0.002
BMI, kg/m², WHO classification, *N* (%)			
18.5–25.0 normal	626 (36.1)	13 (22.0)	0.026
25.0–30.0 overweight	670 (38.6)	22 (37.3)	0.840
30.0–35.0 obesity I	297 (17.1)	11 (18.6)	0.764
35.0–40.0 obesity II	101 (5.8)	3 (5.1)	0.821
>40.0 morbid obesity	25 (1.4)	10 (16.9)	<0.001
16–18.5 weight deficit	15 (0.9)	0 (0.0)	0.464
Comorbidities, *N* (%)			
Hypertension	306 (17.6)	14 (23.7)	0.229
CHD	122 (7.0)	10 (16.9)	0.004
NYHA class I heart failure	5 (0.3)	1 (1.7)	0.072
NYHA class II heart failure	16 (0.9)	0 (0.0)	0.494
NYHA class III heart failure	1 (0.1)	0 (0.0)	0.808
History of ACVA	15 (0.9)	0 (0.0)	0.494
Diabetes mellitus	62 (3.6)	0 (0.0)	0.138
Score, points, *Me (Q1; Q3)*			
CCI	2 (1; 3)	2 (2; 3)	0.144
CHA_2DS_2-VASc	1 (0; 1)	1 (0; 2)	0.029
HAS-BLED	0 (0; 1)	1 (0; 1)	<0.001
Medications, *N* (%)			
Amiodarone	214 (12.3)	3 (5.1)	0.093
β-blockers (bisoprolol)	1734 (100)	59 (100)	—
Procedures			
RF pulmonary vein isolation, *N* (%)	1503 (86.7)	54 (91.5)	0.283
RFA of the cavo-tricuspid isthmus, *N* (%)	60 (3.5)	1 (1.7)	0.456
RF AV node modification, *N* (%)	129 (7.4)	3 (5.1)	0.505
RFA of arrhythmogenic substrate for atrial extrasystoles, *N* (%)	42 (2.4)	1 (1.7)	0.729
Duration of procedure, minutes *(Me (Q1; Q3))*	115.0 (70.0; 155.0)	130.0 (102.5; 165.0)	0.016
Electrical cardioversion during procedure, *N* (%)	572 (33.0)	21 (35.6)	0.676
History of CA, *N* (%)	25 (1.4)	7 (11.9)	<0.001
Average length of hospital stay, days *(Me (Q1; Q3))*	4 (3; 7)	8 (4.5; 11)	<0.001
PSA characteristics			
Frequency of RASS – 1 to – 2 sedation, *N* (%)	1151 (66.4%)	37 (62.7%)	0.558
Dose of propofol, mg/kg (Me (Q1; Q3))	1.613 (1.282; 2.439)	1.961 (1.389; 2.469)	0.475
Dose of diazepam, mg/kg (Me (Q1; Q3)), *N*=66	*N*=60	*N*=6	0.166
	0.133 (0.121; 0.165)	0.068 (0.058; 0.159)	
Dose of fentanyl, μg/kg *(Me (Q1; Q3))*	1.695 (1.333; 3.333)	2.678 (1.786; 3.659)	0.001
Frequency of NRS >3, *N* (%)	162 (14.1%)	20 (54.1%)	<0.001
Frequency of RASS –2 to –3 sedation, *N* (%)	582 (33.6%)	22 (37.3%)	0.552
Dose of propofol, mg/kg *(Me (Q1; Q3))*	2.469 (2.151; 2.857)	2.381 (2.026; 2.730)	0.376
Dose of diazepam, mg/kg *(Me (Q1; Q3))*, *N*=39	*N*=36	*N*=3	0.091
	0.138 (0.125; 0.162)	0.192(0.168; 0.248)	
Dose of fentanyl, μg/kg *(Me (Q1; Q3))*	2.353 (1.961; 2.837)	2.395(1.971; 2.828)	0.687

ciated with longer hospital stay (1.36; 1.23;1.49) and higher costs (1.16; 1.12;1.19) [30]. D. J. Friedman et al. showed that obesity (AOR: 1.35; 95% CI: 1.09–1.68; *P*=0.005) was associated with an increased risk of cardiac perforation [47]. In our study, BMI >30.0 kg/m² increased the odds of developing PC 1.9-fold compared to patients with BMI <30.0 kg/m² (Table 5).

Pain with a NRS intensity score >3 increased the odds of developing PC 4.3-fold compared to patients with a NRS score <3 (Table 5). Assessment of intraprocedural nociception in patients with

Table 4. Comparison of groups of patients with and without PSA complications.

Parameter	Values in patients		*P*-value
	without PSAC, *N*=1780	with PSAC, *N*=13	
Age, years *(M±SD, Me (Q1; Q3))*	58.7±12.4 61.0 (52.0; 68.0)	61.7±12.1 64.0 (53.0; 69.0)	0.591
Age groups, years (*N* (%))			
Under 60	823 (46.2)	6 (46.2)	1.000
60–64	306 (17.2)	1 (7.7)	0.365
65–69	337 (18.9)	3 (23.1)	0.700
70–74	210 (11.8)	1 (7.7)	0.648
75–79	77 (4.3)	1 (7.7)	0.548
80–84	23 (1.3)	0 (0.0)	0.679
85 and older	4 (0.2)	1 (7.7)	—
Female sex, *N* (%)	898 (50.4)	7 (53.8)	0.807
Weight, kg *(Me (Q1; Q3))*	78.0 (69.0; 90.0)	85.0 (80.0; 100.0)	0.062
Height, cm *(Me (Q1; Q3))*	170.0 (164.0; 177.0)	174.0 (160.0; 182.0)	0.699
BMI, kg/m² *(Me (Q1; Q3))*	26.4 (23.7; 29.8)	25.8 (24.8; 37.2)	0.216
BMI, kg/m², WHO classification, *N* (%)			
18.5–25.0 normal	635 (35.7)	4 (30.8)	0.713
25.0–30.0 overweight	689 (38.7)	3 (23.1)	0.250
30.0–35.0 obesity I	306 (17.2)	2 (15.4)	0.864
35.0–40.0 obesity II	102 (5.7)	2 (15.4)	0.135
>40.0 morbid obesity	33 (1.9)	2 (15.4)	<0.001
16–18.5 weight deficit	15 (0.8)	0 (0.0)	0.746
Comorbidities, *N* (%)			
Hypertension	315 (17.7)	5 (38.5)	0.051
CHD	130 (7.3)	2 (15.4)	0.265
NYHA class I heart failure	6 (0.3)	0 (0.0)	0.843
NYHA class II heart failure	16 (0.9)	0 (0.0)	0.731
NYHA class III heart failure	1 (0.1)	0 (0.0)	0.909
History of ACVA	15 (0.8)	0 (0.0)	0.746
Diabetes mellitus	62 (3.5)	0 (0.0)	0.492
Scores, points *(Me (Q1; Q3))*			
CCI	2 (1; 3)	2 (2; 3)	0.089
CHA_2DS_2-VASc	1 (0; 1)	1 (0; 1)	0.637
HAS-BLED	0 (0; 1)	0 (0; 1)	0.694
Medications, *N* (%)			
Amiodarone	217 (12.2)	0 (0.0)	0.179
β-blockers (bisoprolol)	1780 (100)	13 (100)	—
Procedures			
RF pulmonary vein isolation, *N* (%)	1549 (87.0)	8 (61.5)	0.007
RFA of the cavo-tricuspid isthmus, *N* (%)	59 (3.3)	2 (15.4)	0.016
RF AV node modification, *N* (%)	129 (7.2)	3 (23.1)	0.028
RFA of arrhythmogenic substrate for atrial extrasystoles, *N* (%)	43 (2.4)	0 (0.0)	0.571
Duration of procedure, minutes *(Me (Q1; Q3))*	120.0 (70.0; 155.0)	170.0 (145.0; 260.0)	<0.001
Electrical cardioversion during procedure, *N* (%)	586 (32.9)	7 (53.8)	0.110
History of CA, *N* (%)	30 (1.7)	2 (15.4)	—
Average length of hospital stay, days *(Me (Q1; Q3))*	5 (3; 7)	4 (3; 10)	0.811
PSA characteristics			
Frequency of RASS –1 to –2 sedation, *N* (%)	1183 (66.5)	5 (38.5)	0.033
Dose of propofol, mg/kg *(Me (Q1; Q3))*	1.613 (1.290; 2.439)	1.695 (1.429; 2.000)	0.821
Dose of diazepam, mg/kg *(Me (Q1; Q3))*, *N*=66	*N*=65 0.130 (0.120; 0.164)	*N*=1 0.286	—
Dose of fentanyl, μg/kg *(Me (Q1; Q3))*	1.724 (1.351; 3.333)	7.000 (4.237; 7.500)	0.001
*Frequency of NRS >3, *N* (%)	178 (15.0)	4 (80.0)	<0.001
Frequency of RASS –2 to –3 sedation, *N* (%)	597 (33.5)	8 (61.5)	0.033
Dose of propofol, mg/kg *(Me (Q1; Q3))*	2.469 (2.151; 2.857)	2.300 (2.000; 2.417)	0.183
Dose of diazepam, mg/kg *(Me (Q1; Q3))*, *N*=39	*N*=38 0.143 (0.125; 0.163)	*N*=1 0.303	—
Dose of fentanyl, μg/kg *(Me (Q1; Q3))*	2.353 (1.961; 2.817)	3.201 (2.663; 3.551)	0.021

Note. * — for patients with RASS sedation level from –1 to –2.

arrhythmias is challenging. The main limitation for nociception monitoring with registration of autonomic variability parameters in such patients is cardiac arrhythmia, and nociception monitoring based on registration of electrophysiological parameters (EEG, EMG) demonstrates the possibility of assessing the response to a nociceptive stimulus only under general anesthesia. Near-infrared functional spectroscopy has shown promising results for the objective measurement of intraoperative nociception in CA patients under general anesthesia, with cortical meas-

Table 5. Risk factors for the procedural complications of CA in patients with atrial arrhythmias.

Predictors	Frequency in patients, *N* (%)		Crude OR (95% CI)		Adjusted OR (95% CI)	
	with PC, *N*=59	without PC, *N*=1734	Value	*P*-value	Value	*P*-value
Age > 69 years	23 (39.0)	294 (17.0)	3.129 (1.827; 5.359)	<0.001	3.081 (1.764–5.383)	<0.001
BMI > 30 kg/m²	24 (40.7)	423 (24.4)	2.125 (1.250; 3.614)	0.005	1.919 (1.094; 3.363)	0.023
CHA_2DS_2-VASc > 1 points	19 (32.2)	335 (19.3)	1.984 (1.134; 3.469)	0.016	—	—
Duration of procedure > 117 minutes	38 (64.4)	864 (49.8)	1.822 (1.061; 3.130)	0.030	—	—
NRS > 3 points	20 (33.9)	203 (11.7)	4.976 (2.835; 8.736)	<0.001	4.317 (2.390; 7.800)	<0.001
Fentanyl dose > 2.37 μg/kg	36 (61.0)	692 (39.9)	2.357 (1.385; 4.012)	0.002	—	—
History of CA	7 (11.9)	25 (1.4)	9.202 (3.808; 22.238)	<0.001	10.276 (4.006–26.354)	<0.001
History of CHD	10 (16.9)	122 (7.03)	2.697 (1.333; 5.455)	0.006	—	—

Table 6. Risk factors for PSA complications in patients with CA for atrial arrhythmias.

Predictors	Frequency in patients, *N* (%)		Crude odds ratio (COR)		Adjusted odds ratio (AOR)	
	with PC, *N*=13	without PC, *N*=1780	COR (95% CI)	*P*-value	AOR (95% CI)	*P*-value
BMI > 35 kg/m²	4 (30.8)	135 (7.6)	5.416 (1.646–17.816)	0.005	4.955 (1.485–16.535)	0.009
Duration of procedure > 142 min	11 (84.6)	576 (32.4)	11.497 (2.540–52.037)	0.002	11.070 (2.440–50.228)	0.002

urements potentially more accurate than current assessment methods [48].

A. Vevecka et al. demonstrated in a multivariate analysis that obstructive sleep apnea was the only independent predictor of NILV [49]. S. D'Souza et al. found that obesity was associated with a 2.6-fold increased risk of respiratory complications (AOR: 1.39; 95% CI: 1.20–1.62) [30]. In a study by L. Foerschner et al., BMI > 30.1 kg/m² was a predictor of the need for NILV/ILV (AOR: 1.6, *P*=0.03) [40]. In our study, BMI > 35 kg/m² increased the odds of PSA complications by 4.95-fold, while procedure duration >142 min increased the odds by 11.0-fold compared to lower values of these parameters (Table 6).

Conclusion

Independent predictors of CA complications were patient-related factors such as BMI > 30.0 kg/m², age > 69 years and CA procedure-related factors such as duration of CA > 142 min, previous history of CA, and presence of pain with intensity > 3 points on the NRS.

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