Contents lists available at ScienceDirect

Journal of Arrhythmia

journal homepage: www.elsevier.com/locate/joa

Original Article

Clinical benefits of deep sedation with a supraglottic airway while monitoring the bispectral index during catheter ablation of atrial fibrillation

Satoru Hida, M.D.[a,1], Masao Takemoto, M.D., Ph.D.[a,*], Akihiro Masumoto, M.D., Ph.D.[b,1],
Takahiro Mito, M.D., Ph.D.[a,1], Kazuhiro Nagaoka, M.D., Ph.D.[c,1], Hiroshi Kumeda, M.D.[b],
Yuki Kawano, M.D.[a], Ryota Aoki, M.D.[a], Honsa Kang, M.D.[a], Atsushi Tanaka, M.D., Ph.D.[a],
Atsutoshi Matsuo, M.D.[a], Kiyoshi Hironaga, M.D., Ph.D.[c], Teiji Okazaki, M.D., Ph.D.[a],
Kiyonobu Yoshitake, M.D.[a], Kei-ichiro Tayama, M.D., Ph.D.[a], Ken-ichi Kosuga, M.D., Ph.D.[a]

[a] Cardiovascular Center, Munakata Suikokai General Hospital, Fukutsu, Japan
[b] Cardiology, Fukuoka Kinen Hospital, Fukuoka, Japan
[c] Heart Center, Fukuoka City Hospital, Fukuoka, Japan

ARTICLE INFO

ABSTRACT

Background: Pulmonary vein antrum isolation (PVAI) under sedation has proven to be a useful strategy for catheter ablation of atrial fibrillation (AF).
Methods: To evaluate the clinical benefits of respiratory management using supraglottic airways (SGAs) under deep sedation while monitoring the bispectral (BIS) index during the PVAI and the durations from admission to the catheterization room to starting the radiofrequency energy delivery (Time α), and from starting the radiofrequency energy delivery to completion of the PVAI (Time β), X-ray time, frequency of dislocations of the three-dimensional maps (D3DM), procedure-related complications, and proportion of an AF-free rate 15 months after the PVAI (PAFFR) in patients who received deep sedation without SGAs (Group A: $n=48$) and those with SGAs (Group B: $n=51$) were evaluated.
Results: There were no significant differences in patient characteristics, Time α (77 ± 3 versus 78 ± 2 min; $p=0.816$), complications of cardiac tamponade (2% versus 2%; $p=0.966$), or PAFFR (81% versus 88%; $p=0.313$) between the two groups. However, the Time β (84 ± 4 versus 67 ± 3; $p=0.001$), X-ray time (53 ± 2 versus 34 ± 2; $p < 0.001$), and minor complications of nasal bleeding (25% versus 0%; $p=0.001$) were significantly shorter and lower in Group B than in Group A, in accordance with a reduction in the hypoxia (15% versus 0%; $p=0.007$) and D3DM (31% versus 8%; $p=0.003$).
Conclusions: These results may demonstrate the clinical benefits of deep sedation with SGAs while monitoring the BIS index without any hypoxia during PVAI in patients with AF.
© 2017 Japanese Heart Rhythm Society. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

Pulmonary vein (PV) antrum isolation (PVAI) has proven to be a useful strategy for radiofrequency catheter ablation (RFCA) of atrial fibrillation (AF) worldwide [1–3]. Many kinds of sedation or anesthesia during PVAI including simple minimal sedation, deep sedation, and general anesthesia, have generally been applied in

these procedures [4–8]. However, patient movements because of a procedure-related incidence of pain and/or hypoxia associated with sedation or anesthesia often occur during PVAI, and procedural delays during PVAI often unexpectedly occur. Moreover, patient movements can often and easily cause a dislocation of the three-dimensional (3D) map, which can also lead to procedural delays during the PVAI procedure, especially with the use of the EnSite™ system (St. Jude Medical, St. Paul, MN, USA), rather than the CARTO™ system (Biosense Webster Ltd., Tokyo, Japan), in real clinical practice. During anesthesia, supraglottic airways (SGAs) have been introduced over the last 10 years, and are widely used for the majority of general anesthetics because of their efficacy and safety [9]. Moreover, it has been reported that the bispectral index (BIS) could accurately detect deep levels of sedation [10]. Thus, in

this study, we evaluated the clinical benefit of respiratory management using SGAs under deep sedation while monitoring the BIS index with a BIS monitoring system (A-3100C™, NIHON KODEN, Tokyo, Japan) during RFCA of AF using the EnSite NavX/Velocity™ Cardiac Mapping System (St. Jude Medical, St. Paul, MN, USA).

2. Material and methods

2.1. Baseline clinical characteristics of the patient groups (Table 1)

This study was approved by the institutional review committee and ethics review board of our hospitals. From January 2014 to September 2015, 99 consecutive patients (69 males and 30 females, with a mean age of 63 ± 2 years) with non-valvular paroxysmal or persistent AF underwent an initial session of RFCA using the EnSite NavX/Velocity™ Cardiac Mapping System (St. Jude Medical, St. Paul, MN, USA) at our hospitals. AF was classified according to the HRS/EHRA/ECAS 2012 Consensus Statement on Catheter and Surgical Ablation of AF [11]. Patients with long lasting AF, hemodialysis, RFCA using CARTO™ (Biosense Webster Ltd., Tokyo, Japan), and/or a re-session of RFCA for AF, were excluded from this study. All included patients had their history recorded, and underwent a physical examination, laboratory analysis, chest radiogram, 12-lead electrocardiogram, and echocardiography (SONOS 2500, Hewlett-Packard, San Diego, CA, USA) within at least one month before admission. CHADS$_2$ score [12], chamber size, and volume of the left atrium (LA) by echocardiography, and anatomy and size of the PVs and LA by computed tomography (Aquilion 64 and Aquilion ONE TSX-301A, TOSHIBA, Tokyo, Japan), were also evaluated prior to the RFCA.

2.2. Procedure for RFCA of AF (Fig. 1)

All patients were effectively anticoagulated for at least one month before the procedure. The procedures were performed following transesophageal echocardiography, to rule out any LA thrombi. All patients gave their informed consent. RFCA was performed as described previously [1,3,4,]. In brief, deep sedation

without (Group A) or with SGAs (i-gel™, Intersurgical Ltd., Wokingham, Berkshire, UK) (Group B) was performed for the RFCA of AF under an intravenous administration of propofol and dexmedetomidine. The initial i-gel™ (Intersurgical Ltd., Wokingham, Berkshire, UK) size chosen was based on the manufacturer's recommendations with respect to patient body weight [13]. A temperature probe (SensiTherm™, St. Jude Medical, St. Paul, MN, USA) for monitoring the esophageal temperature was inserted through a nostril in those patients without an SGA or a side hole of the SGA with an SGA under deep sedation, and placed between the level of the left superior and inferior pulmonary veins in both groups. Femoral arterial access was routinely acquired for continuous blood pressure and heart rate monitoring. A 100 unit per kilogram administration of heparin was administered following the transseptal puncture, and heparinized saline was additionally infused to maintain the activated clotting time at 300–350 s. After an open irrigated 3.5-mm-tip ablation catheter (FlexAbility™, St. Jude Medical, St. Paul, MN, USA) and circular mapping catheter (Optima™, St. Jude Medical, St. Paul, MN, USA) were positioned in the LA after a double transseptal puncture, the LA was reconstructed by an EnSite™ system (St. Jude Medical, St. Paul, MN, USA). Then, a circumferential PVAI was performed under electroanatomic guidance with a 3D mapping system. The generator was set to a maximal temperature of 45 °C, maximum power of 35 W, and irrigation rate of 13 ml per minute. When ablating the posterior wall in front of the esophagus, a maximum power of 20–25 W was used to avoid esophageal damage from the high energy supplied, and when the temperature exceeded 39 °C, the energy supply was discontinued. Each application of radiofrequency energy was delivered for about 30–90 s while dragging, with the goal of a $\geq 70\%$ decrease in the electrogram amplitude at the local site [14]. The completion of the PVAI procedure was defined as the achievement of bidirectional conduction block between the LA and PVs under the administration of isoproterenol and adenosine. In patients with persistent AF, when AF persisted after the PVAI, internal electrical conversion was performed in order to recover sinus rhythm. If firing from the superior vena cava (SVC) was induced under an intravenous administration of isoproterenol after recovering sinus rhythm, an SVC isolation was additionally performed. Further, if common atrial flutter was previously

Table 1
Patient characteristics.

	Group A	Group B	*p* Value
Number of patients	48	51	
Male	32 (67%)	37 (73%)	0.530
Age (years)	61 ± 2	64 ± 2	0.341
Body surface area (m^2)	1.65 ± 0.03	1.62 ± 0.02	0.459
Body mass index (kg/m^2)	21.4 ± 0.6	22.8 ± 0.6	0.066
CHADS$_2$ score	1.3 ± 0.1	1.7 ± 0.2	0.081
LVEF (%)	62 ± 1	62 ± 1	0.796
Volume of LA and PVs			
LA diameter by echocardiography (mm)	38 ± 1	37 ± 1	0.625
LA volume index by echocardiography (ml/m^2)	32 ± 2	32 ± 1	0.829
Number of PVs	4.1 ± 0.1	4.0 ± 0.1	0.536
Type of atrial fibrillation			
Paroxysmal	39 (81%)	42 (82%)	0.888
Persistent	9 (19%)	9 (18%)	0.888
Type of ablation procedures			
PVAI alone	42 (88%)	44 (86%)	0.858
PVAI+SVCI	4 (8%)	2 (4%)	0.368
PVAI+CTI	2 (4%)	5 (10%)	0.264

LVEF=left ventricular ejection fraction, LA=left atrium, CT=computed tomography, PVs=pulmonary veins, PVAI=pulmonary vein antrum isolation, SVCI=superior vena cava isolation, CTI=cavo tricuspid isthmus ablation.
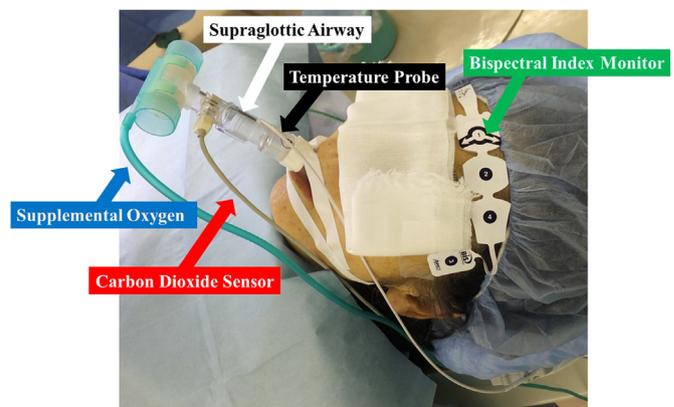

Fig. 1. In a patient with a supraglottic airway (SGA) (white arrow), in who deep sedation was monitored by a bispectral index monitor (green arrow) pasted on the front of the forehead, radiofrequency catheter ablation of atrial fibrillation was performed under an intravenous administration of propofol and dexmedetomidine. Supplemental oxygen (blue arrow) was routinely used with a flow rate of 5–10 l per minute via an SGA with spontaneous breathing to maintain the peripheral oxygen saturation at more than 95%. The exhaling carbon dioxide sensor (red arrow) was attached to the SGA. A temperature probe to monitor the esophageal temperature (black arrow) was inserted through the nostril of the patient through a side hole of the SGA.
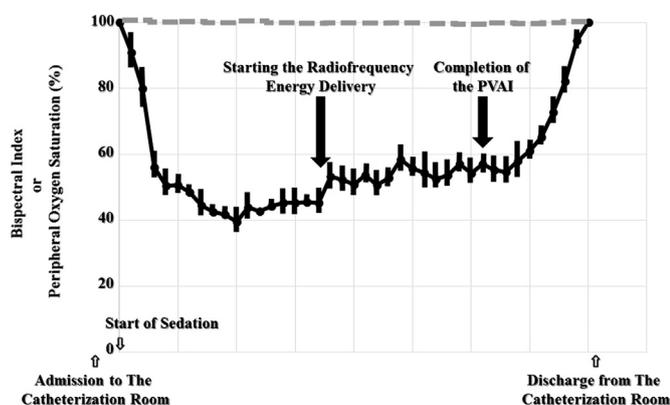
Fig. 2. Monitoring the bispectral index (full line) and peripheral oxygen saturation (dotted line) under deep sedation using a supraglottic airway (Group A) during radiofrequency catheter ablation (RFCA) of atrial fibrillation using EnSite™ (St. Jude Medical, St. Paul, MN, USA). RFCA could be steadily performed by monitoring the BIS index without any hypoxia. PVAI=pulmonary vein antrum isolation.

documented or induced by programmed stimulation after the PVAI, an additional cavo-tricuspid isthmus (CTI) line ablation was performed. There was no potential for confounding data between the centers and operators, because the procedures for the RFCA of AF were performed by electrophysiologists who were trained in advanced RFCA, and the cases were assisted by four-to-five staff members who were well-trained in catheterization laboratory practices at our three hospitals.

2.3. Respiratory management during the PVAI

Respiratory management during the RFCA was performed under an intravenous administration of propofol (bolus dose of 1 mg/kg and maintenance dose of 2 g/kg to 5 g/kg per hour) and dexmedetomidin (bolus dose of 1 μg/kg and maintenance dose of 0.2 μg/kg to 0.7 μg/kg per hour). In all patients, it was attempted to maintain the BIS index level between 40 and 60 [10] using a bispectral index monitor pasted on the front of the forehead (Fig. 2). If necessary, an intravenous bolus administration of pentazocine (15–30 mg) was used when patient movements resulting from an incidence of pain during the RFCA occurred. If pentazocine was not effective enough, or the BIS level was over 60, an intravenous bolus administration of propofol at a dose of 1 mg/kg was added. The peripheral oxygen saturation was monitored continuously, and supplemental oxygen was routinely used with a flow rate of 5–10 l per minute via a mask in the patients in Group A, or via an SGA in Group B with spontaneous breathing to maintain the peripheral oxygen saturation at more than 95%. When the peripheral oxygen saturation fell to less than 95%, even though supplemental oxygen with a flow rate of 10 l per minute via a mask or SGA during the procedures was used, an oropharyngeal airway was inserted into the mouth. To monitor the exhaling carbon dioxide concentration, a CO_2 Sensor (TG-980P ™, NIHON KODEN, Tokyo, Japan) was attached to the SGA during the procedure. If it was still not adequate, mechanical respiratory support with non-invasive positive pressure ventilation (NIPPV) or endotracheal intubation was used. Hypotension was defined as a systolic blood pressure of 90 mmHg or less. If the hypotension did not improve with an intravenous administration of supplementary fluids, an intravenous administration of dopamine (maintenance dose of 5 μg/kg/min) was used.

2.4. Evaluation of the procedure time and frequency of dislocations of the 3D maps

The X-ray time; the duration (in minutes) from admission to the catheterization room to starting the radiofrequency energy delivery, defined as Time α; and the duration from starting the radiofrequency energy delivery to the completion of the PVAI, defined as Time β, were evaluated. The X-ray dose could not be evaluated, because there were five new and old X-ray machines, single- or bi-plane, used in our three hospitals. Therefore, the X-ray dose could not be compared, due to the high X-ray dose with the old machines and the low dose with the new ones. Further, the frequency of the dislocations of the 3D maps, defined as a case in which the ablation procedure had to be delayed more than at least one minute associated with a more than 5 mm shift of the catheter position or ablation tags, was also evaluated.

2.5. Complications associated with the procedures and adverse events associated with insertion of SGAs

Persistent and/or transient complications associated with the procedures, including any new PV stenosis, phrenic nerve palsy, cerebrovascular accidents, death, cardiac tamponade, pericardial effusions, vascular complications, and any bleeding, during or within the 48 h after the procedures, were evaluated. Adverse events associated with the insertion of the SGA, including laryngeal spasms, transient nerve damage, hematomas, or vagal responses, were also evaluated.

2.6. Patient care and follow-up

Following the procedure, anticoagulation therapy was continued for at least three months after the RFCA in all patients. All patients underwent monthly follow-ups for at least six months after the RFCA. The anti-arrhythmic agents were withdrawn in all patients three months after the RFCA. The proportion of AF-free rates were evaluated during the 15-month follow-up period. Documented episodes of AF of > 30 s after the three-month blanking period were identified as recurrences of AF. If AF recurred after the three-month blanking period, the anti-arrhythmic agent(s) were re-administered.

2.7. Statistical analysis

Numerical results are expressed in the text as the mean $\pm$ standard deviation. Paired data were compared by Student's t-tests. The comparison of the proportion of AF-free patients between in Groups A and B was performed using the Kaplan–Meier survival analysis with a log-rank test. All analyses were performed with SAS version 9.2 software (SAS Institute, Cary, NC, USA). A p-value of < 0.05 was considered to indicate statistical significance.

3. Results

3.1. Patient characteristics (Table 1)

There were 48 and 51 patients in Groups A and B, respectively. There was no statistical difference in the sex (67% versus 73% of male; $p=0.530$); age (61 ± 2 versus 64 ± 2 years; $p=0.341$); body surface area (1.65 ± 0.03 versus 1.62 ± 0.02 m^2; $p=0.459$); left ventricular ejection fraction (62 ± 1 versus $62 \pm 1\%$; $p=0.796$); LA diameter (38 ± 1 versus 37 ± 1 mm; $p=0.625$); LA volume index by echocardiography (32 ± 2 versus 32 ± 1 ml/m^2; $p=0.829$); number of PVs (4.1 ± 0.1 versus 4.0 ± 0.1; $p=0.536$); type of AF

Table 2
Hypoxia, hypotension, procedure time, dislocation of the 3D maps, and complications associated with the procedures.

	Group A	Group B	p Value
Hypoxia			
Hypoxia under deep sedation	7 (15%)	0 (0%)	0.007
Respiratory support with an oropharyngeal airway	7 (15%)	1 (2%)	0.025
Mechanical respiratory support	2 (4%)	0 (0%)	0.159
Non-invasive positive pressure ventilations	1 (2%)	0 (0%)	0.322
Endotracheal intubation	1 (2%)	0 (0%)	0.322
Hypotension			
Hypotension under deep sedation	13 (27%)	11 (22%)	0.528
Catecholamine use for hypotension	0 (0%)	1 (2%)	0.322
Procedure time and dislocation of the 3D maps			
Time α (min)	77 ± 3	78 ± 2	0.816
Time β (min)	84 ± 4	67 ± 3	0.001
X-ray time (min)	53 ± 2	34 ± 2	<0.001
Dislocation of the 3D maps	15 (31%)	4 (8%)	0.003
Complications associated with the procedures			
Cardiac tamponade	1 (2%)	1 (2%)	0.966
Nasal bleeding	12 (25%)	0 (0%)	<0.001
Other complications associated with the procedures	0 (0%)	0 (0%)	NA
Adverse events with insertion of oropharyngeal airways	1 (2%)	NA	NA
Adverse events with insertion of SGAs	NA	0 (0%)	NA

Time α=duration from admission to the catheterization room to starting the radiofrequency energy delivery, Time β=duration from starting the radiofrequency energy delivery to completion of the pulmonary vein antrum isolation, NA=not applicable. SGAs= supraglottic airways.

Table 3
Procedure time and dislocation of the 3D maps.

Dislocation of the 3D maps	Yes ($n=19$)	No ($n=80$)	p Value
Time α (min)	78 ± 3	78 ± 2	0.881
Time β (min)	88 ± 7	71 ± 3	0.047
X-ray time (min)	48 ± 2	41 ± 2	0.013

Time α=duration from admission to the catheterization room to starting the radiofrequency energy delivery, Time β=duration from starting the radiofrequency energy delivery to completion of the pulmonary vein antrum isolation.

(81% versus 82% of paroxysmal AF; $p=0.888$ and 19% versus 18% of persistent AF; $p=0.888$); or type of RFCA procedures (88% versus 86% of PVAI alone; $p=0.858$, 8% versus 4% of PVAI+SVCI; $p=0.368$, and 2% versus 5% of PVAI+CTI; $p=0.264$) observed between the two groups. The body mass index (BMI) (21.4 ± 0.6 versus 22.8 ± 0.6 kg/m^2; $p=0.066$) and CHADS$_2$ score (1.3 ± 0.1 versus 1.7 ± 0.2; $p=0.081$) tended to be higher and larger in Group B, but ultimately there was no statistically significant difference between the two groups.

3.2. Deep sedation, respiratory management, hypotension, and the BIS index (Table 2 and Fig. 2)

The insertion success rate of the SGA, i-gel™ (Intersurgical Ltd., Wokingham, Berkshire, UK), in Group B was 98% (50 of 51), and only one patient had an airway leak with the SGA. In that patient, a mask was used instead of an SGA for respiratory management. The proportion of respiratory support with an oropharyngeal airway because of hypoxia in Group A was significantly larger than that in Group B (15% versus 0%; $p=0.007$). Because respiratory support with an oropharyngeal airway was not effective in two of seven patients in Group A, mechanical
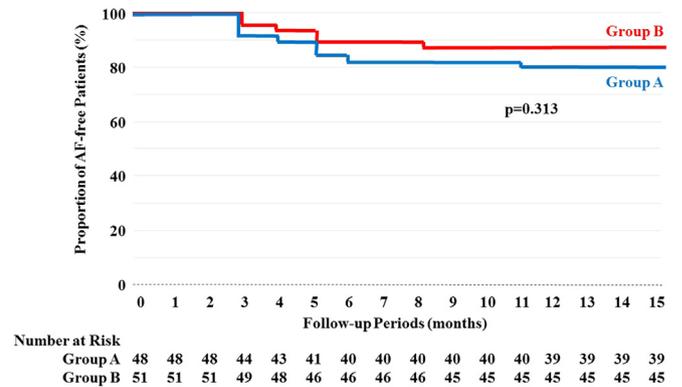

Fig. 3. Atrial fibrillation-free Kaplan–Meier curves after the blanking period between the two groups. This analysis, completed with a log-rank test, revealed that there were no statistically significant differences in the proportion of the AF-free rates ($p=0.313$) between the groups with deep sedation with supraglottic airways (SGAs) (red line) (88%, 45 of 51) and those without SGAs (blue line) (81%, 39 of 48) during the latter three months of the 15-month follow-up period, as the initial three-month blanking period was excluded from consideration.

respiratory support with NIPPV (one of seven) or endotracheal intubation (one of seven) was needed instead. All patients in Group B were controlled between a BIS index level of about 40–60 [10] without any hypoxia (Fig. 2). The prevalence of hypotension was similar between the two groups (27% versus 22%; $p=0.528$). The exhaling carbon dioxide concentration was within normal range in all patients during the procedure (data not shown). The hypotension in all those patients, except for one, steadily improved with an intravenous administration of supplementary fluids. However, one patient in Group B needed an intravenous administration of dopamine. There were no statistical differences in the total doses of propofol, dexmedetomidin, and pentazocine during the procedure between the two groups (data not shown). The BMI in the patients that needed oropharyngeal airways or mechanical respiratory support during the PVAI statistically was significantly larger than that in those who did not (22.1 ± 1.1 versus 25.3 ± 1.1 kg/m^2; $p=0.019$).

3.3. Procedure time (Table 2)

There were no significant differences in the Time α (77 ± 3 versus 78 ± 2 min; $p=0.816$) between the two groups. However, both the Time β (84 ± 4 versus 67 ± 3 min; $p=0.001$) and X-ray time (53 ± 2 versus 34 ± 2 min; $p<0.001$), probably associated with the X-ray dose, were significantly shorter in Group B than Group A, in accordance with a reduction in the frequency of dislocations of the 3D maps (31% versus 8%; $p=0.003$). The dislocations of the 3D maps were thought to be caused by patient movements resulting from incidences of pain and difficulty in obtaining patient cooperation associated with deep sedation, contributing to the discontinuation of the RFCA procedures.

3.4. Hypoxia, dislocations of the 3D maps, and the procedure time (Table 3)

There were 19 and 80 out of 99 patients with or without dislocations of the 3D maps during the PVAI, respectively. There were no significant differences in the Time α (78 ± 3 versus 78 ± 2 min; $p=0.881$) between those with or without dislocations of the 3D maps. However, both the Time β (88 ± 7 versus 71 ± 3 min; $p=0.047$) and X-ray time (48 ± 2 versus 41 ± 2 min; $p=0.013$) were significantly shorter without dislocations of the 3D maps during the PVAI than with it.

3.5. Complications associated with the procedures (Table 2)

There were no significant differences in the complications involving cardiac tamponade (2% versus 2%; $p=0.966$) between the two groups. However, minor complications involving nasal bleeding were significantly fewer in number in Group B than Group A (25% versus 0%; $p < 0.001$). No other complications associated with the procedures were observed in either group (both 0%, respectively). Further, in Group B, there were no adverse events associated with the insertion of the SGAs, including laryngeal spasms, transient nerve damage, hematomas, and vagal responses. On the other hand, in Group A, there was one adverse event of oral minor bleeding associated with the insertion of the oropharyngeal airway.

3.6. Proportion of AF-free rates (Fig. 3)

The Kaplan–Meier survival analysis with a log-rank test revealed that there were no statistically significant differences in the proportion of AF-free rates ($p=0.313$) between Group B (88%, 45 of 51) and Group A (81%, 39 of 48) during the latter three months of the 15-month follow-up period, as the initial three-month blanking period was excluded (Fig. 3).

4. Discussion

4.1. The new findings and important points of this manuscript

The duration of the procedure and X-ray times, which probably contributed to a reduced X-ray dose, could be significantly shortened in patients with deep sedation using SGAs while monitoring the BIS index in accordance with a reduction in the frequency of dislocations of the 3D mapping.
Minor complications associated with nasal bleeding could be more significantly decreased in patients with SGAs than in those without.
However, there were no statistically significant differences in the proportion of AF-free rates between the two groups during the latter three months of the 15-month follow-up period.
The BMI in the patients that needed respiratory support was significantly greater than that in those who did not, indicating that deep sedation using SGAs during the PVAI may be more recommended and effective in obese patients.
Our study demonstrated that RFCA could be steadily performed under deep sedation using SGAs while monitoring the BIS index, and rendered the procedure safer and more comfortable for those patients undergoing long procedures.

4.2. Efficacy of respiratory management using SGAs during the PVAI (Table 2)

It has been reported that endotracheal intubation is not necessary in patients with deep sedation for RFCA of AF [6]. However, that report did not clearly demonstrate the level of deep sedation according to a known scoring system, such as the Ramsey Sedation Score [15], Richmond Agitation–Sedation Scale [16], or BIS index. In our study, all patients were controlled between a Ramsey Sedation Score level of 4–5 [15], a Richmond Agitation–Sedation Scale of -4 to -5 [16], and a BIS index of 40–60. There were seven, one, and one patient(s) who required respiratory support with an oropharyngeal airway, NIPPV, or endotracheal intubation, respectively, in the patients with deep sedation without SGAs (Group A), probably due to deep sedation and/or obesity-induced hypoxia. These findings may indicate that our sedation might have been a deeper sedation than that in the trial [6]. There

was only one patient in which an oropharyngeal airway was used in the patients with deep sedation with SGAs (Group B), because of airway leaks of the SGA. The SGA, i-gel™ (Intersurgical Ltd., Wokingham, Berkshire, UK), features a non-inflatable cuff and the possibility to introduce an esophageal catheter. Its successful use during anesthesia has been proven in some randomized control trials [17,18]. Thus, the present study could reveal that deep sedation while monitoring the BIS index with SGAs during the PVAI significantly maintained a stable respiratory condition without any depression of the oxygen saturation. One of the probable mechanism(s) of deep sedation-induced hypoxia is obesity-associated glossoptosis contributing to obstructive apnea and hypopnea. It has been reported that sleep apnea syndrome (SAS) is complicated by other diseases including AF, heart failure, hypertension, diabetes mellitus, obesity, all of which are risk factors for AF [19]. Although the interactions between AF and SAS were not evaluated in this study, sedation-induced hypoxia might be associated with obesity and obstructive apnea. Actually, the BMI of the patients that needed oropharyngeal airways or mechanical respiratory support was significantly larger than that in those that did not (22.1 ± 1.1 versus 25.3 ± 1.1 kg/m^2; $p=0.019$), and there were no adverse events observed during the insertion of the SGAs, indicating that deep sedation with SGAs during PVAI may be recommended and effective, especially in obese patients.

4.3. Hypoxia, dislocations of the 3D maps, and the procedure time (Tables 2 and 3)

Once hypoxia and/or dislocations of the 3D maps occur, it takes time until the peripheral oxygen saturation and/or 3D maps normalize. Thus, it may be important to know how to reduce the hypoxia and dislocations of the 3D maps during the PVAI, in order to steadily and successfully perform the RFCA, shorten the procedure time, and render the procedure safer and more comfortable for the patients. In this study, the frequency of dislocations of the 3D maps due to patient movements resulting from incidences of pain and/or difficulties in obtaining patient cooperation associated with deep sedation in Group A, were interestingly and significantly larger than that in Group B (31% versus 8%; $p=0.003$), in spite of both groups undergoing the same level of deep sedation. Hence, it has been reported that hypoxia increases pain sensitivity [20], and that this may be one of the underlying mechanism(s) for the higher frequency of dislocations of the 3D maps associated with the incidence of pain in Group A than in Group B. Owing to a reduction in the frequency of dislocations of the 3D maps, the RFCA procedure for AF might be possible to perform steadily, and this could render the procedure safer and more comfortable for patients undergoing long procedures. As a result, both the Time β (84 ± 4 versus 67 ± 3 min; $p=0.001$) and X-ray time (53 ± 2 versus 34 ± 2 min; $p < 0.001$) could be significantly shortened.

4.4. Complications associated with the procedures (Table 2)

Neither major complications associated with the procedures other than cardiac tamponade, nor adverse events associated with the insertion of the SGAs, were observed in either group. However, although perceived to be a minor complication, nasal bleeding was significantly more frequent in occurrence in Group A than Group B (25% versus 0%; $p < 0.001$). Because the activated clotting time was maintained at 300–350 s during the PVAI, it was comparably easy for bleeding to occur in that situation. Hence, a temperature probe to monitor the esophageal temperature (Fig. 1) was inserted through the side hole of the SGA when an SGA was used (Group B), and therefore the nasal and/or intraoral bleeding could be significantly reduced.

4.5. Proportion of an AF-free rate (Fig. 3)

The identified proportion of an AF-free rate revealed that there were no statistically significant differences in the proportion of the AF-free rate ($p = 0.313$) between in Group B (88%, 45 of 51) and in Group A (81%, 39 of 48). The collection of supporting data from a longer follow-up period for these patients may be needed in order to determine the effects of deep sedation in those AF patients in which an SGA was used during the PVAI on the proportion of an AF-free rate.

5. Limitations of the study

This study was not a randomized clinical trial. Although our study was a multi-center trial, it was limited by a relatively short follow-up period (15 months), and a relatively small number of involved patients. Because of the short follow-up period, our study still could not demonstrate the long-term clinical benefits. Whether our results can safely be extrapolated to the inclusion of a larger number of patients, and a longer follow-up period for these patients, should be determined in further studies. Recent advancement in new technologies including the cryoballoon- [2] and hot balloon [21]-based ablation systems has facilitated a stable lesion creation of PVs. However, currently they can be used only in limited facilities in some countries, including Japan. When they become commercially available all over the world, they may improve current respiratory support systems and help lead to the development of new ones, as well as alternative anesthesia methods.

6. Conclusions

These results may demonstrate the clinical benefits, efficacy, feasibility, and safety of deep sedation with SGAs while monitoring the BIS index without any hypoxia during the PVAI in patients with AF.

Conflict of interest

All authors declare no conflicts of interest related to this study.

References

[1] Haissaguerre M, Jais P, Shah DC, et al. Spontaneous initiation of atrial fibrillation by ectopic beats originating in the pulmonary veins. N Engl J Med 1998;339:659–66.

[2] Luik A, Radzewitz A, Kieser M, et al. Cryoballoon versus open irrigated radiofrequency ablation in patients with paroxysmal atrial fibrillation: the prospective, randomized, controlled, noninferiority FreezeAF study. Circulation 2015;132:1311–9.

[3] Takahashi A, Iesaka Y, Takahashi Y, et al. Electrical connections between pulmonary veins: implication for ostial ablation of pulmonary veins in patients with paroxysmal atrial fibrillation. Circulation 2002;105:2998–3003.

[4] Ichihara N, Miyazaki S, Taniguchi H, et al. Simple minimal sedation for catheter ablation of atrial fibrillation. Circ J 2015;79:346–50.

[5] Lu F, Lin J, Benditt DG. Conscious sedation and anesthesia in the cardiac electrophysiology laboratory. J Cardiovasc Electrophysiol 2013;24:237–45.

[6] Kottkamp H, Hindricks G, Eitel C, et al. Deep sedation for catheter ablation of atrial fibrillation: a prospective study in 650 consecutive patients. J Cardiovasc Electrophysiol 2011;22:1339–43.

[7] Salukhe TV, Willems S, Drewitz I, et al. Propofol sedation administered by cardiologists without assisted ventilation for long cardiac interventions: an assessment of 1000 consecutive patients undergoing atrial fibrillation ablation. Europace 2012;14:325–30.

[8] Wutzler A, Rolf S, Huemer M, et al. Safety aspects of deep sedation during catheter ablation of atrial fibrillation. Pacing Clin Electrophysiol 2012;35:38–43.

[9] Bamgbade OA, Macnab WR, Khalaf WM. Evaluation of the i-gel airway in 300 patients. Eur J Anaesthesiol 2008;25(10):865–6.

[10] Wang ZH, Chen H, Yang YL, et al. Bispectral index can reliably detect deep sedation in mechanically ventilated patients: a prospective multicenter validation study. Anesth Analg; 2016. Epub 2016 Dec 22.

[11] Calkins H, Kuck KH, Cappato R, et al. h/EHRA/ECAS expert consensus statement on catheter and surgical ablation of atrial fibrillation: recommendations for patient selection, procedural techniques, patient management and follow-up, definitions, endpoints, and research trial design: a report of the Heart Rhythm Society (HRS) Task Force on Catheter and Surgical Ablation of Atrial Fibrillation. Developed in partnership with the European Heart Rhythm Association (EHRA), a registered branch of the European Society of Cardiology (ESC) and the European Cardiac Arrhythmia Society (ECAS); and in collaboration with the American College of Cardiology (ACC), American Heart Association (AHA), the Asia Pacific Heart Rhythm Society (APHRS), and the Society of Thoracic Surgeons (STS). Endorsed by the governing bodies of the American College of Cardiology Foundation, the American Heart Association, the European Cardiac Arrhythmia Society, the European Heart Rhythm Association, the Society of Thoracic Surgeons, the Asia Pacific Heart Rhythm Society, and the Heart Rhythm Society. Heart Rhythm; 2012;9:632–96.e21; 2012.

[12] Gage BF, Waterman AD, Shannon W, et al. Validation of clinical classification schemes for predicting stroke: results from the National Registry of Atrial Fibrillation. J Am Med Assoc 2001;285:2864–70.

[13] Theiler L, Gutzmann M, Kleine-Brueggeney M, et al. i-gel supraglottic airway in clinical practice: a prospective observational multicentre study. Br J Anaesth 2012;109:990–5.

[14] Kumagai K, Sakamoto T, Nakamura K, et al. Pre-procedural prediction of termination of persistent atrial fibrillation by catheter ablation as an indicator of reverse remodeling of the left atrium. Circ J 2013;77:1416–23.

[15] American College of Critical Care Medicine of the Society of Critical Care Medicine, American Society of Health-System Pharmacists, American College of Chest Physicians. Clinical practice guidelines for the sustained use of sedatives and analgesics in the critically ill adult. Am J Health Syst Pharm 2002;59:150–78.

[16] Riessen R. Comparison of the RAMSAY score and the Richmond Agitation Sedation Score for the measurement of sedation depth. Crit Care 2012;16:326.

[17] Richardson PB, Krishnan S, Janakiraman C, et al. Extubation after anaesthesia: a randomised comparison of three techniques. Acta Clin Croat 2012;51:529–36.

[18] Theiler LG, Kleine-Brueggeney M, Kaiser D, et al. Crossover comparison of the laryngeal mask supreme and the i-gel in simulated difficult airway scenario in anesthetized patients. Anesthesiology 2009;111:55–62.

[19] Miller JD, Aronis KN, Chrispin J, et al. Obesity, exercise, obstructive sleep apnea, and modifiable atherosclerotic cardiovascular disease risk factors in atrial fibrillation. J Am Coll Cardiol 2015;66:2899–906.

[20] Ristoiu V, Shibasaki K, Uchida K, et al. Hypoxia-induced sensitization of transient receptor potential vanilloid 1 involves activation of hypoxia-inducible factor-1 alpha and PKC. Pain 2011;152:936–45.

[21] Yamaguchi Y, Sohara H, Takeda H, et al. Long-term results of radiofrequency hot balloon ablation in patients with paroxysmal atrial fibrillation: safety and rhythm outcomes. J Cardiovasc Electrophysiol 2015;26:1298–306.