High Frequency Jet Ventilation During Ablation of Supraventricular and Ventricular Arrhythmias: Efficacy, Patient Tolerance and Safety

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ABSTRACT. High-frequency jet ventilation (HFJV) is used to decrease respiratory motion during atrial fibrillation ablations; however, the patient safety and efficacy of HFJV has not been evaluated during routine electrophysiology (EP) studies with radiofrequency ablation. This is a retrospective chart review of consecutive patients who underwent EP studies and ablations for supraventricular and ventricular arrhythmias while using HFJV. Any EP studies performed using HFJV where ablation was attempted were included for analysis; EP studies where no ablation was performed were not included. Patients underwent induction of general anesthesia with endotracheal intubation using intermittent positive pressure ventilation with sevoflurane in the EP laboratory prior to vascular access. HFJV was then provided by a commercial system with initial settings: ventilation rate at 100 cycles/min and driving pressure at 20–25 psi. Total intravenous anesthesia was then provided with dexmedetomidine and propofol as well as fentanyl and rocuronium titrated to bispectral index (Bis) score <60. The overall mean age of patients (n=72) was 55±18 years (range=18–84 years). The mean creatinine (mg/dl) was 1.0±0.3, the mean ejection was 0.58±0.08, and mean post-EP study length of stay was 1.4±0.9 days (range 1–5 days). There were no intraprocedural or major complications. There was a 6.9% rate of minor complications (n=5). There was a 97.2% overall ablation success rate (70 of 72 ablations). Ablations were successful in all subjects except for one left atrial flutter and one right atrial tachycardia. Only one of 72 (1.4%) procedures required discontinuation of general anesthesia and HFJV to induce arrhythmia (right ventricular outflow tract ventricular tachycardia). No patient experienced procedural awareness and the mean Bis score was 40±5.3. This report provides further evidence the routine use of jet ventilation in the electrophysiology laboratory is safe, well tolerated, and efficacious, with ablation success rates similar to traditional sedation/ventilation techniques with a variety of arrhythmias.

KEYWORDS. electrophysiology, high-frequency jet ventilation, intermittent positive pressure ventilation, postoperative pulmonary complication.
Introduction
The safety and efficacy of high-frequency jet ventilation (HFJV) during routine electrophysiology (EP) studies and, more specifically, ablations has not been extensively studied. This is a retrospective chart review of consecutive patients who underwent EP studies and radiofrequency ablation while using total intravenous anesthesia and HFJV. HFJV is used to decrease atrial motion and increase intracardiac catheter stability during atrial fibrillation ablations, avoid barotrauma, and maintain better circulatory hemodynamics than traditional conscious sedation and general anesthesia with endotracheal intubation.

Methods

Patient population
Seventy-two consecutive patients who underwent EP studies and radiofrequency ablation at the Good Samaritan Hospital Invasive Cardiac Electrophysiology Laboratory starting with its inception were included for analysis. This retrospective study was approved by the hospital ethics committee. Any EP studies performed using HFJV where ablation was attempted were included for analysis; EP studies where ablation was not attempted or performed without HFJV were excluded. The Good Samaritan Hospital is a 215-bed, not-for-profit, non-academic, community hospital where open heart surgery is carried out. All patients had routine laboratory analysis and chest radiographs performed preoperatively.

Anesthetic protocol
Patients underwent induction of general anesthesia and endotracheal intubation using intermittent positive pressure ventilation (IPPV) with sevoflurane in the EP laboratory prior to vascular access. IPPV was continued during sheath/catheter insertion and preablation period. Blood pressure support was provided if necessary with phenylephrine. Prior to intracardiac mapping and ablation, HFJV was instituted using a double-lumen orotracheal catheter (Laser Jet catheter, ACUTRONIC Medical Systems AG) as shown in Figure 1. HFJV consists of artificial ventilation by high-velocity insufflation of gas through a narrow nozzle into the open airway. Figure 2 depicts the major differences between conventional IPPV and HFJV.

HFJV was provided by a commercial system (Monsoon Universal Jet Ventilator, ACUTRONIC Medical Systems AG) with initial settings: ventilation rate

![Luer-Lock connection with lumen for CO2 and airway pressure measurement](image)

**Figure 1:** Double lumen orotracheal catheter used for high-frequency jet ventilation. (With permission from ACUTRONIC Medical Systems AG, CH-8816 Hirzel, Switzerland.)

![Rounded tip, in order to avoid lesions of tracheal mucosa](image)

**Figure 2:** Major differences between conventional IPPV and HFJV.
at 100 cycles/minute, FIO₂=0.6, humidity 40–100% (adjusted for peak inspiratory pressure, mucus plugging, or condensation), driving pressure of 20–25 psi. The peak pressure was set at 24 cmH₂O, peak inspiratory pressure at 28 cmH₂O, and inspiratory time set to 30% of the cycle (I/E=30%). Total intravenous anesthesia, which is mandatory as inhaled anesthetics cannot be used with HFJV,1,6 was provided using dexmedetomidine and propofol. Fentanyl and rocuronium were titrated to a bispectral index (Bis) score of less than 60 (bis Monitor Model A2000, Aspect Medical Systems, Inc., Natick, MA). At the end of the procedure, the patient was weaned off general anesthesia and extubated in the EP laboratory.

**EP study protocol**

Standard femoral vascular access was achieved using a sterile, modified Seldinger technique. Deflectable recording catheters were placed under fluoroscopic guidance in the right atrium, His bundle position, right ventricle, and coronary sinus. All transseptal punctures and slow atrioventricular node (AVN) pathway modifications were performed under radial intracardiac echocardiographic guidance (9 MHz Ultrasound, Boston Scientific Corporation, Natick, MA). Three-dimensional mapping was performed for all ablations (CARTO, Biosense-Webster, Diamond Bar, CA). Ablation was performed using the power control setting, with power titrated on the basis of the local biophysics (T<60°C). Open irrigated tip ablation catheters were used for left atrial ablations; otherwise, standard (non-irrigated) ablation catheters were used (Navi-Star, Biosense-Webster). After the procedure, patients were observed in the hospital (mean 1.4 days) prior to discharge. Ablation attempts (for atrial tachycardia (AT), atrioventricular node re-entrant tachycardia (AVNRT), orthodromic reciprocating tachycardia (ORT), and right ventricular outflow tract (RVOT) tachycardia) were considered successful if there was absence of tachycardia for 30 min after the final ablation despite pacing and/or isoproterenol infusion. In the case of accessory pathway (AP) without inducible ORT, ablation was considered successful if there was no AP conduction 30 min after final ablation. An atrial flutter ablation was considered successful if no evidence of tachycardia and/or bidirectional cavotricuspid isthmus block was documented 30 min after ablation. Atrial fibrillation ablation via wide pulmonary venous antrum isolation (PVAI) was considered successful if antral lesion was completed and entrance/exit block was demonstrated as described previously.7 Patients undergoing PVAI were placed on intravenous and/or low molecular weight heparins until the international normalized ratio was ≥2. Patients had postoperative day 1 posterior-anterior and lateral chest radiographs (read by radiologists) if clinically indicated. Follow-up visits were conducted with electrophysiologists within 4–6 weeks of the procedure.

**Data analysis**

Major and minor complications were defined based upon prior reports of anesthesia and EP procedure-related complications.3,6–10 Major complications were defined as death, cardiac arrest, AV block requiring pacemaker, cardiac perforation, cardiac valve injury, coronary venous dissection, hemothorax, pneumothorax, transient ischemic attack, stroke, myocardial infarction, pericardial tamponade, severe respiratory failure, and acute respiratory distress syndrome. Minor complications included
intraprocedural drug reaction, peripheral embolus, phlebitis, peripheral nerve injury, atelectasis, pulmonary edema, fever, or pleural effusion. All complications that occurred during the hospitalization were included for analysis. Data are reported as mean ± standard deviation (SD). Statistical comparisons were performed using a binary logistic regression model (SPSS V. 16, IBM Corp., New York, NY) using backward (stepwise) multivariate analysis and the Hosmer–Lemeshow test of goodness-of-fit for the model. The model estimation was terminated at the iteration when model parameter estimates (–2 log likelihood) changed by less than 0.001. A p-value ≤ 0.05 was considered statistically significant.

Results

Demographics and procedural outcomes

A total of 72 patients were included for analysis. Data were available for 100% of patients, with the exception of complete (i.e. every 15 min) Bis scores were unavailable for 9.7% of patients. Table 1 depicts the demographics and procedural outcomes for patients in this study. The overall mean age was 55.4 ± 17.9 years, mean creatinine was 1.0 ± 0.3, and mean ejection fraction was 0.58 ± 0.08. Forty-two of 72 patients (58.3%) were female. The majority (33.3%) of ablations were for AVNRT, followed by atrial flutter (27.8%). (See Table 1 for remaining ablation frequencies.) The overall length of stay was 1.4 ± 0.9 days. Contrast was used in 4 of 72 (5.6%) cases to evaluate for coronary sinus diverticuli (n=2 accessory pathways) or assess difficult coronary sinus access (n=2 AVNRT). No patient experienced procedural awareness and the mean Bis score was 40 ± 5.3.

In-hospital complications

There were no major complications as defined previously. Minor complications were seen in 5 of 72 procedures (6.9%). Table 2 describes the complications and treatment required. All patients were weaned from general anesthesia and extubated prior to leaving the EP laboratory. No patient required reintubation. Two of 5 (40%) complications occurred in women. The average age of patients with complications was 68.6 ± 10.9 years. The average age of patients who did not have complications was 54.4 ± 17.9 years.

Table 1: Demographics and procedural outcomes for patients undergoing ablation using high-frequency jet ventilation

<table>
<thead>
<tr>
<th>Complication</th>
<th>No. of patients (%)</th>
<th>AVNRT</th>
<th>Atrial flutter</th>
<th>AT</th>
<th>RVOT VT</th>
<th>PVAI</th>
<th>AP</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients (%)</td>
<td>72 (100)</td>
<td>24 (33.3)</td>
<td>20 (27.8)</td>
<td>7 (9.7)</td>
<td>4 (5.6)</td>
<td>7 (9.7)</td>
<td>10 (13.9)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>55.4 ± 17.9</td>
<td>53.4 ± 20.8</td>
<td>64.6 ± 12.8</td>
<td>49.9 ± 19.4</td>
<td>39.3 ± 7.9</td>
<td>65.3 ± 4.7</td>
<td>44.9 ± 15.3</td>
</tr>
<tr>
<td>Female sex (%)</td>
<td>58.3</td>
<td>79.2</td>
<td>20</td>
<td>71.4</td>
<td>50</td>
<td>71.4</td>
<td>70</td>
</tr>
<tr>
<td>Fluoroscopy time (min)</td>
<td>34.5 ± 17.3</td>
<td>26.8 ± 14.1</td>
<td>40.7 ± 20.1</td>
<td>30.1 ± 17.6</td>
<td>38 ± 9.8</td>
<td>34.6 ± 15.3</td>
<td>42.2 ± 16.5</td>
</tr>
<tr>
<td>Success rate (%)</td>
<td>97.2</td>
<td>100</td>
<td>95</td>
<td>85.7</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Major complication rate (%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Minor complication rate (%)</td>
<td>6.9 (5 of 72)</td>
<td>4.2 (1 of 24)</td>
<td>15 (3 of 20)</td>
<td>0 (0 of 7)</td>
<td>0 (0 of 4)</td>
<td>14.3 (1 of 7)</td>
<td>0 (0 of 10)</td>
</tr>
<tr>
<td>Creatinine (mg/dl)</td>
<td>1.0 ± 0.3</td>
<td>0.94 ± 0.2</td>
<td>1.1 ± 0.3</td>
<td>1.0 ± 0.6</td>
<td>1.0 ± 0.1</td>
<td>1.1 ± 0.3</td>
<td>0.9 ± 0.2</td>
</tr>
<tr>
<td>Ejection fraction</td>
<td>0.58 ± 0.08</td>
<td>0.61 ± 0.06</td>
<td>0.54 ± 0.12</td>
<td>0.62 ± 0.06</td>
<td>0.54 ± 0.03</td>
<td>0.55 ± 0.06</td>
<td>0.61 ± 0.02</td>
</tr>
<tr>
<td>Length of stay (days)</td>
<td>1.4 ± 0.9</td>
<td>1.0 ± 0.2</td>
<td>1.6 ± 1.1</td>
<td>1.3 ± 0.8</td>
<td>1.3 ± 0.8</td>
<td>2.7 ± 1.4</td>
<td>1.0 ± 0.0</td>
</tr>
<tr>
<td>Contrast (cc)</td>
<td>0.9 ± 4.4</td>
<td>1.5 ± 6.2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3 ± 6.7</td>
</tr>
</tbody>
</table>

AVNRT: atrioventricular nodal re-entrant tachycardia; AT: atrial tachycardia; RVOT VT: right ventricular outflow tract tachycardia; PVAI: pulmonary venous antrum isolation; AP: accessory pathway.

Table 2: Complications and treatment required

<table>
<thead>
<tr>
<th>Complication</th>
<th>Procedure</th>
<th>Diagnosis</th>
<th>Treatment required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fever of unknown origin</td>
<td>Atrial flutter (non-CTI-dependent right atrial flutter)</td>
<td>T&gt;38.6°C</td>
<td>None</td>
</tr>
<tr>
<td>Mild pulmonary vascular</td>
<td>Typical AVNRT</td>
<td>Hypoxia, CXR</td>
<td>Diuretics</td>
</tr>
<tr>
<td>congestion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LLL subsegmental atelectasis</td>
<td>Pulmonary venous antrum isolation</td>
<td>Hypoxia, CXR</td>
<td>Incentive spirometry</td>
</tr>
<tr>
<td>Mild pericarditis</td>
<td>Atrial flutter (CW CTI-dependent atrial flutter)</td>
<td>Chest Pain</td>
<td>NSAID</td>
</tr>
<tr>
<td>RML subsegmental atelectasis</td>
<td>Atrial flutter (CCW CTI-dependent atrial flutter)</td>
<td>Hypoxia, CXR</td>
<td>Incentive spirometry</td>
</tr>
</tbody>
</table>

Possible factors influencing rates of complication

Multivariate analysis was used to assess the influence of various factors on complication rates (Table 3). The binary logistic regression model using backward (stepwise) analysis starts with the possible covariates (age, ejection fraction, gender, creatinine, fluoroscopy time, contrast, success, ablation type, length of stay) and at each step (iteration) removes the least significant covariate until the model estimates demonstrate no improvement. None of the covariates demonstrated a statistically significant influence on complication rates. The order of decreasing significance of covariates for complications was: age > length of stay > ejection fraction > fluoroscopy time > contrast > ablation type > creatinine > success > GENDER. Overall, increased age and length of stay demonstrated a non-significant trend toward increased rates of complication.

Discussion

These data suggest that routine use of jet ventilation in the EP laboratory is safe, well tolerated, and efficacious. Ablation success rates are similar to traditional sedation/ventilation techniques in a variety of arrhythmias. Prior reports indicate a 2–6% rate of major and minor complications during EP studies with ablation using traditional sedation/ventilation methods, whereas this report indicates a 6.9% rate of minor complications; the complication rate in this study becomes 0% if we do not consider complications excluded in those reports (e.g., atelectasis, fever, vascular congestion, pericarditis). We chose to include these complications in order to specifically examine any postoperative pulmonary complications (PPCs) that may be related to HFJV. Rates of major and minor complications for HFJV have ranged from 1.7% to 7.5% in prior reports. There is substantial evidence that HFJV is as safe as IPPV.

Closer examination of the results in our experience reveal that minor complications (e.g., atelectasis, fever, vascular congestion) may simply be reflective of common PPCs seen after general anesthesia. Atelectasis can be seen on CT scan in up to 90% of patients who are anesthetized, and PPCs have been found to occur in 9.6% of patients. Furthermore, 40% of the minor complications in our study were related to atelectasis. Atelectasis is caused by three basic mechanisms: compression (decreased transmural pressure distending the alveolus), absorption (less gas enters the alveolus than removed by uptake by blood), and loss-of-surfactant atelectasis (reduced surfactant action increases alveolar surface tension promoting collapse). HFJV provides lower airway pressure but higher end-expiratory (intrathoracic) pressure. However, HFJV has been found to enhance alveolar recruitment in dependent lung areas, improve gas exchange, and provide better arterial oxygenation in adult patients with acute lung injury. In this manner, HFJV serves to counteract compressive atelectasis. Thus, if one were to implicate HFJV as a contributor to postoperative atelectasis, then HFJV would have to influence absorption or loss-of-surfactant atelectasis; the authors are unaware of any data that support these hypotheses.

It is also important to note that no patient experienced procedural awareness during their procedure. Awareness with recall after surgery in the United States is infrequent (0.13–1.0% incidence) but may be associated with post-traumatic stress disorder in nearly 50% of patients who experience procedural awareness. Adequate anesthesia is recognized by a Bis score of 40–60, and the patients in this cohort demonstrated an overall mean Bis score of 40±5.3, with no patient’s mean Bis score greater than 53.8.

Lastly, the utility of HFJV in ablation performance improvement has been demonstrated during percutaneous ablation of atrial fibrillation, and this report adds to the body of knowledge about the use of HFJV during ablation of other supraventricular and ventricular arrhythmias.

Table 3: Results of multivariate analysis to assess the influence of various factors on complication rates

<table>
<thead>
<tr>
<th></th>
<th>No complication</th>
<th>Complication</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>54.4 ± 17.9</td>
<td>68.6 ± 10.9</td>
<td>0.107</td>
</tr>
<tr>
<td>Length of stay (days)</td>
<td>1.33 ± 0.8</td>
<td>2.2 ± 1.6</td>
<td>0.185</td>
</tr>
<tr>
<td>Ejection fraction</td>
<td>0.59 ± 0.08</td>
<td>0.53 ± 0.10</td>
<td>0.185</td>
</tr>
<tr>
<td>Fluoroscopy time (min)</td>
<td>34.3 ± 17.3</td>
<td>35.9 ± 19.1</td>
<td>0.263</td>
</tr>
<tr>
<td>Contrast (cc)</td>
<td>0.89 ± 4.5</td>
<td>1.4 ± 3.1</td>
<td>0.254</td>
</tr>
<tr>
<td>Ablation type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accessory pathway</td>
<td>10 of 10</td>
<td>0 of 10</td>
<td>1</td>
</tr>
<tr>
<td>Atrial tachycardia</td>
<td>7 of 7</td>
<td>0 of 7</td>
<td>1</td>
</tr>
<tr>
<td>AVNRT</td>
<td>23 of 24</td>
<td>1 of 24</td>
<td>0.999</td>
</tr>
<tr>
<td>Atrial flutter</td>
<td>17 of 20</td>
<td>3 of 20</td>
<td>0.999</td>
</tr>
<tr>
<td>PVAI</td>
<td>6 of 7</td>
<td>1 of 7</td>
<td>0.999</td>
</tr>
<tr>
<td>VT</td>
<td>4 of 4</td>
<td>0 of 4</td>
<td>0.911</td>
</tr>
<tr>
<td>Creatinine (mg/dl)</td>
<td>1.0 ± 0.3</td>
<td>1.0 ± 0.3</td>
<td>0.955</td>
</tr>
<tr>
<td>Successful (%)*</td>
<td>65 of 70 (92.9)</td>
<td>5 of 70 (7.1)</td>
<td>1</td>
</tr>
<tr>
<td>% Female†</td>
<td>40 of 42 (95.2)</td>
<td>2 of 42 (4.8)</td>
<td>0.985</td>
</tr>
</tbody>
</table>

AVNRT: atrioventricular nodal reentrant tachycardia; PVAI: pulmonary venous antrum isolation; VT: ventricular tachycardia.

*No complication in unsuccessful ablations (n=2).

†Forty-two of 72 patients (58.3%) were female.
Mechanism of high-frequency jet ventilation

HFJV uses tidal volumes (V\(_T\)) that are often smaller than anatomical plus equipment dead space (V\(_D\)) and thus the traditional alveolar ventilation (V\(_A\)) formula \([V_A = f \times (V_T - V_D)]\) does not apply.\(^{20}\) During HFJV, the driving pressure (as opposed to respiratory frequency) is most influential for CO\(_2\) elimination.\(^{20}\) Several mechanisms of gas (and hence oxygen) transport are present during HFJV:

- **Laminar flow (Convective Dispersion due to Asymmetric Velocity Profiles):** HFJV produces a spike of gas moving down the central lumen of the airway while gas traveling in the margins of the airway is exiting the lungs.\(^{25,20}\)
- **Taylor-type dispersion ("Augmented Diffusion"):** Enhanced molecular diffusion as a result of interacting velocity profiles in smaller airways causes a radial gas mixing effect.\(^{25,20}\)
- **Turbulent convective mixing:** Turbulent convective exchange caused by the jet in the trachea and convective streaming (e.g. gas particles in the airways do not return to their starting positions at the end of a flow cycle) in the airways combines with molecular diffusion to produce augmented O\(_2\) and CO\(_2\) transport.\(^{26}\)
- **Pendelluft (or collateral) Ventilation:** Regional variation in airway resistance and compliance causes gas flow between alveoli; high-frequency breathing exaggerates this regional gas recirculation causing smaller gas volumes to effectively reach more respiratory units than conventional IPPV.\(^{25,20}\)
- **Direct Alveolar Ventilation:** Even with a small tidal volume is inspired, the fresh gas may reach alveoli closer to the mouth but not those at a greater distance in the bronchial tree.\(^{25}\)
- **Cardiogenic Mixing:** Increased air circulation from mechanical agitation of lung units in proximity to the heart.\(^{20}\)

Advantages and disadvantages of high-frequency jet ventilation

Advantages of HFJV include:

- improved electrode catheter endocardial contact and stability,\(^1,2\)
- improved stability of left atrial,\(^1\) thoracic,\(^{27}\) and mediastinal structures;\(^{28}\)
- very effective transport of CO\(_2\); hypoxia secondary to CO\(_2\) retention on IPPV often will improve on HFJV;\(^29\)
- less or no interference between spontaneous and controlled ventilation;\(^6\)
- supports bronchopulmonary clearance;\(^6\)
- lower airway pressure though higher end-expiratory (intrathoracic) pressure;\(^6,20\)
- better view of the operative field (during pulmonary procedures);\(^6,3\)
- HFJV maintains better hemodynamics that IPPV during shock, adult respiratory distress syndrome\(^4\) and ischemia.\(^5\)

The disadvantages of HFJV and means to limit these effects are shown in **Table 4**. The most severe instances of barotrauma have been related to airway outflow tract obstruction during jet ventilation (most often laryngospasms).\(^8\) Indeed, HFJV must be monitored extremely closely in patients with chronic obstructive pulmonary disease as the positive end expiratory effect of this ventilation (and risk of barotrauma) may be increased because of increased static respiratory compliance and elevated bronchial resistance.\(^6\) There is evidence that barotrauma is more related to changes of lung parenchymal structure rather than the type of mechanical ventilation used.\(^{14}\) Necrotizing tracheobronchitis, one of the most severe complications of HFJV, can be prevented by adequate humidification of the HFJV circuit.\(^{32}\)

**Table 4:** Disadvantages/risks of high-frequency jet ventilation (HFJV) and approaches to mitigate these issues

<table>
<thead>
<tr>
<th>Disadvantages</th>
<th>Mitigation of these issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>No airtight sealing of airway to decrease secretions(^6)</td>
<td>Place HFJV orotracheal catheter through cuffed endotracheal tube (only use with HFJV system with automatic pressure cutoff feature)</td>
</tr>
<tr>
<td>Cannot use inhaled anesthesia(^6)</td>
<td>Cause continuous gas flow outward through the larynx(^3)</td>
</tr>
<tr>
<td>Experience with conventional ventilation (intermittent positive pressure ventilation) does not help to understand HFJV(^6)</td>
<td>Total intravenous sedation.</td>
</tr>
<tr>
<td>Difficult measurement of resulting ventilator parameters and efficiency of gas exchange(^6)</td>
<td>Develop HFJV program in coordination with experienced centers and personnel</td>
</tr>
<tr>
<td>Barotrauma (e.g. volutrauma, pneumothorax, mediastinal emphysema)(^6,8,30)</td>
<td>Routine arterial blood gases and pulse oximetry</td>
</tr>
<tr>
<td>Mucosal damage, especially necrotizing tracheobronchitis(^8,29,32)</td>
<td>Unrecognized outflow obstruction can be avoided by close monitoring and pressure measurement(^{31})</td>
</tr>
<tr>
<td>Hypercapnia(^5) especially in the obese patient(^23)</td>
<td>Humidification during HFJV</td>
</tr>
<tr>
<td></td>
<td>Transcutaneous capnography during HFJV can decrease danger of hypoventilation.(^5)</td>
</tr>
<tr>
<td></td>
<td>CO(_2) monitor attached to bronchoscopy port of ventilatory circuit</td>
</tr>
</tbody>
</table>
Limitations of this study

This report has a limited sample size, and, in fact, may be biased toward higher complication rates because it included the first 72 consecutive patients undergoing EP study and ablation using HFJV by a single operator (JLW) since inception of the program. Although the Good Samaritan Hospital is the only hospital in the county and the authors are the only providers of EP services at this hospital, this is not a “closed system,” and underestimation of complications/readmissions is possible. HFJV requires anesthesiology support, which may add complexity and cost to EP procedures. Indeed, less than 20% of EP programs in the United States exclusively use anesthesia professionals for procedural sedation.34 There are data to suggest that patients undergoing invasive EP procedures may require deep conscious sedation that often is converted to general anesthesia;35 thus, the use of general anesthesia (including HFJV) during EP procedures may enhance patient safety.36

Conclusion

Our data contribute to the body of knowledge concerning the use of HFJV during EP studies with intracardiac ablation. There were no major complications and we found overall rates of minor complications similar to existing data on HFJV in other surgical procedures. Multivariate analysis revealed that none of the covariates analyzed demonstrated a statistically significant influence on complication rates, although increased age and length of stay demonstrated a non-significant trend toward increased rates of minor complications. These data provide a “real-world” examination of the efficacy, patient safety, and tolerance of HFJV during ablation of supraventricular and ventricular arrhythmias.

References


