Inferior Vena Cava Compression as a Novel Maneuver to Detect Patent Foramen Ovale: A Transesophageal Echocardiographic Study

Eiji Yamashita, MD, Tomoyuki Murata, MD, Eri Goto, MD, Takeshi Fujiwara, MD, Takehito Sasaki, MD, Kentaro Minami, MD, Kohki Nakamura, MD, PhD, Koji Kumagai, MD, PhD, Shigeto Naito, MD, PhD, Kazuomi Kario, MD, PhD, FESC, FACC, FAHA, and Shigeru Oshima, MD, PhD, *Maebashi and Shimotsuke, Japan*

Background: The Valsalva maneuver, the most sensitive test for patent foramen ovale (PFO) detection, is difficult during transesophageal echocardiography (TEE), especially after sedation. The aim of this study was to compare PFO detection effectiveness between inferior vena cava (IVC) compression and the Valsalva maneuver.

Methods: A total of 293 patients with paroxysmal atrial fibrillation undergoing TEE before initial atrial fibrillation ablation were prospectively enrolled. Agitated saline was injected in 290 patients under three conditions: Valsalva maneuver under conscious sedation, at rest, and IVC compression under deep sedation. Three patients with newly diagnosed atrial septal defects on TEE were excluded. The IVC compression maneuver consisted of manual compression 5 cm to the right of the epigastric region and depressed the abdominal wall by 5 cm for 30 sec and compression release immediately before right atrial opacification with microbubbles by agitated intravenous saline.

Results: The overall PFO detection rate was better with IVC compression (57 PFOs [19.7%]) than at rest (15 patients [5.2%]) ($P < .0001$) or with the Valsalva maneuver (37 patients [12.8%]) ($P = .024$). There were no significant differences in PFO detection between IVC compression and the Valsalva maneuver (IVC compression, 43 patients [22.5%]; Valsalva maneuver, 35 patients [18.3%]; $P = .31$), even in patients who could perform the Valsalva maneuver effectively ($n = 191$).

Conclusions: IVC compression is feasible and effective for detecting PFO and is not inferior to the Valsalva maneuver. In particular, IVC compression could be an alternative diagnostic method for PFO using TEE when the Valsalva maneuver cannot be performed under deep sedation. (J Am Soc Echocardiogr 2016;■:■-■.)

Keywords: Patent foramen ovale, Inferior vena cava compression maneuver, Valsalva maneuver, Transesophageal echocardiography, Sensitivity and specificity

Patent foramen ovale (PFO) is associated with a variety of disorders, including cryptogenic stroke, migraine, platypnea-orthodeoxia syndrome, and decompression illness.[1] Moreover, PFO is associated with a substantially increased risk for embolic stroke, even in patients with endocardial leads as implantable cardioverter-defibrillators or pacemakers.[2] Recently, as-treated analysis of the Randomized Evaluation of Recurrent Stroke Comparing PFO Closure to Established Current Standard of Care Treatment trial showed that PFO closure by a transcatheter occluder is superior to conservative treatment.[3] Therefore, transesophageal echocardiography (TEE) plays a more important role in the evaluation of PFO because of its improved imaging of cardiac structures and easier identification of PFO with the use of intravenous agitated saline contrast compared with transthoracic echocardiography (TTE).[4] Although an adequate Valsalva maneuver is crucial for diagnosing PFO, sedation status and/or the presence of a transesophageal echocardiographic probe inside the esophagus and laryngopharynx often decreases patient effort during this maneuver.[5] Thus, a more feasible and reproducible maneuver to detect PFO, irrespective of sedation status and/or the presence of a probe, is needed. As a feasible provocation test, inferior vena cava (IVC) compression maneuver, which involves manual compression of the abdomen to produce partial IVC collapse and increased IVC flow upon release, has been developed. Accordingly, we aimed to compare the effectiveness of IVC compression and the Valsalva maneuver to diagnose PFO in a rigorous manner.

From the Department of Cardiology, Gunma Prefectural Cardiovascular Center, Maebashi, Japan (E.Y., T.M., E.G., T.S., K.M., K.N., K. K., S.N., S.O.); and the Division of Cardiovascular Medicine, Department of Medicine, Jichi Medical University School of Medicine, Shimotsuke, Japan (T.F., K. K.).

Reprint requests: Eiji Yamashita, MD, Department of Cardiology, Gunma Prefectural Cardiovascular Center, 3-12 Kameizumi, Maebashi 371-0004, Japan (E-mail: *yamashita-e@cvc.pref.gunma.jp*).

0894-7317/$36.00

http://dx.doi.org/10.1016/j.echo.2016.11.011

Abbreviations

AF = Atrial fibrillation

BMI = Body mass index

IAS = Interatrial septum

IVC = Inferior vena cava

LA = Left atrial

PFO = Patent foramen ovale

RA = Right atrial

TEE = Transesophageal echocardiography

TTE = Transthoracic echocardiography

METHODS

Patient Population

Between May 2014 and June 2015, we prospectively enrolled 293 patients with paroxysmal atrial fibrillation (AF) who underwent TEE before left atrial (LA) catheter ablation at the Gunma Prefectural Cardiovascular Center. Exclusion criteria were AF rhythm at the time of TEE, known atrial septal defects, moderate or severe valvular heart disease, prior cardiac surgery or repeated AF ablation, and inability to perform the Valsalva maneuver because of cognitive or coordination impairment. The present study was approved by the ethical committee of our hospital. All patients provided written consent for the study.

Before TEE, all patients were instructed to perform the Valsalva maneuver. The examiner placed a hand on the patient's abdomen to check for abdominal muscular contraction and confirmed the efficacy of the Valsalva maneuver in all patients. Complete TEE using a 5-MHz multiplane probe (iE33 with an X7-2t probe; Koninklijke Philips, Amsterdam, the Netherlands) was performed. Following oropharyngeal anesthesia, 1% propofol was used for conscious sedation, in an intravenous bolus of 0.2 to 0.4 mg/kg (10–30 mg) before and during TEE. Blood pressure, pulse oximetry, and the electrocardiogram were monitored. A search for other cardiac sources of emboli (assessment of the aorta and LA appendage) was systematically undertaken. Images of the interatrial septum (IAS) were obtained from the best imaging plane for septal membrane visualization, typically 50° to 75°. At that time, atrial septal defects were newly documented in three patients, who were subsequently excluded from the present study. The Valsalva maneuver was then attempted in the remaining 290 patients (mean age, 65 ± 10 years; 189 men) during TEE, with simultaneous abdominal strain assessment. In case the Valsalva maneuver was ineffective, coughing and conventional abdominal compression (Figure 1B) were used to complement the examination.[5] At least two saline contrast injections were administered during TEE, and additional contrast injections were administered with images obtained from other transesophageal echocardiographic planes if the site of microbubble passage in the septum was not clear. Contrast injections consisted of 1 mL air and 9 mL saline agitated by a three-way stopcock with two connected syringes, one of which was filled with saline; the injections were administered intravenously from an antecubital vein. Contrast was injected during the strain phase of the Valsalva maneuver, and normal respiration resumed as the first bubbles appeared in the right atrium. The Valsalva maneuver was considered effective if we could observe the leftward deviation of the atrial septum following the maneuver.[4,6] PFO was judged as present when microbubbles were seen in the left chambers within three heartbeats, after full opacification of the right chambers. Quantification of LA opacification was regarded as grade I (mild; three to 10 microbubbles), grade II (moderate; 11–30 microbubbles), or grade III (severe; >30 microbubbles).[7] Following the Valsalva maneuver, additional intravenous propofol (0.5–1.0 mg/kg, 30–80 mg) was administered to relieve patient discomfort. A level of deep sedation was targeted in this study according to the statement on the use of non-anesthesiologist-administered propofol sedation.[8] Subsequently, contrast was injected

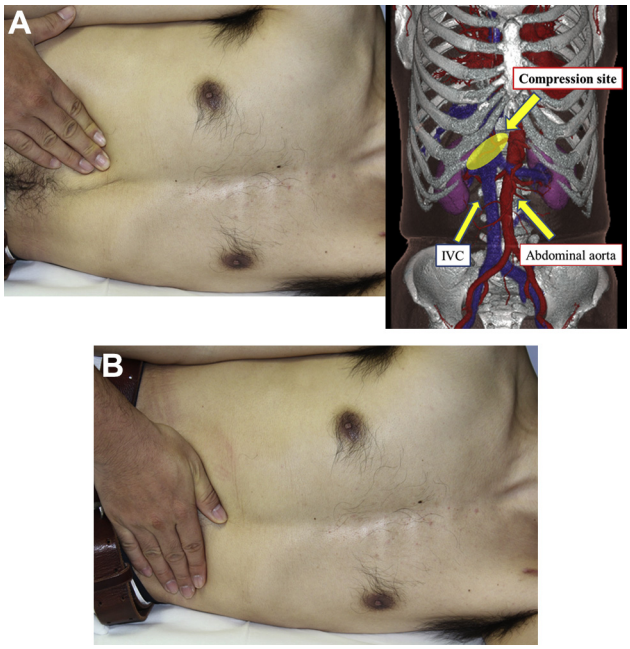

Figure 1 Compression sites of the IVC compression maneuver **(A)** and conventional abdominal compression **(B)**. Schematic representation of the IVC compression site by three-dimensional computed tomographic imaging is also shown in the right panel of **(A)**.

at least twice at rest and under IVC compression. The IVC compression maneuver was performed as follows (Figures 1 and 2): We firmly performed manual compression 5 cm to the right of the epigastric region and depressed the abdominal wall of the patients by 5 cm for 30 sec (Figure 1A). IVC flow was interrupted during the compression, which resulted in decreased venous return and LA pressure. IVC compression was released immediately before right atrial (RA) opacification with microbubbles by agitated intravenous saline. The augmented IVC stream increased RA pressure and the RA-LA pressure gradient, which provoked right-to-left shunting in patients with PFOs. Figure 2A shows the concept of the IVC compression maneuver, and Figure 2B and Video 1 (available at www.onlinejase.com) shows a representative case. Before the actual maneuver, we performed a pretest using color Doppler imaging to confirm that the compression effectively indirectly interrupted the IVC flow (Figure 2C and Video 2 available at www.onlinejase.com). Color Doppler flow (Nyquist limit, 30–40 cm/sec) from the IVC was assessed following release of the compression for 5 sec, as a trial. In 260 patients (89.7%), increased IVC flow to the right atrium by color Doppler imaging could be observed by initial compression. We could obtain increased IVC flow by adjusting compression more firmly in the remaining 30 patients. Effectiveness of IVC compression was evaluated by leftward atrial septal motion as with the Valsalva maneuver. A right-to-left shunt was diagnosed as described previously. Moreover, to assess the change in preload as a result of IVC compression, pulse Doppler transmitral early diastolic (E) velocity during IVC compression was also measured from a midesophageal long-axis view in the first 21 patients after the study protocol.

Demographic Data Collection

Clinical data, including age, sex, body surface area, body mass index (BMI), brachial blood pressure, heart rate, documented diagnosis of