Noninvasive Ventilation in Cardiac Procedures: Key Technical and Practical Implications

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Abbreviations

AMI	Acute myocardial infarction
AS	Aortic stenosis
CPAP	Continuous positive airway pressure
EPAP	Expiratory positive airway pressure
FiO_2	Inspiratory oxygen fraction
ICU	Intensive care unit
IPAP	Inspiratory positive airway pressure

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MR	Mitral regurgitation
NIV	Noninvasive ventilation
$PaCO_2$	Arterial partial pressure of CO_2
PCI	Percutaneous coronary intervention
PEEP	Positive end-expiratory pressure
PSV	Pressure support ventilation
SaO_2	Arterial oxygen saturation
TAVI	Transcatheter aortic valve implantation
TEE	Transesophageal echocardiography

70.1 Introduction

Noninvasive ventilation (NIV) is broadly used in patients with both chronic and acute respiratory failure, both inside and outside the intensive care unit (ICU). Moreover, NIV may be applied to allow safe sedation in several clinical contexts and increasingly is used to treat or even prevent postoperative pulmonary complications after major surgery. Today, NIV is also increasingly used during nonsurgical cardiac procedures in which there is an actual risk of respiratory distress or failure, such as percutaneous coronary interventions (PCI) performed in patients with pulmonary edema secondary to acute myocardial infarction (AMI), as well as percutaneous valve procedures, which mostly involve high-risk patients who often need sedation. Finally, the use of NIV to aid less-invasive diagnostic cardiac procedures such as transesophageal echocardiography (TEE) has been reported.

Although some concerns regarding the use of NIV in these procedures may exist, a team well trained in managing NIV often may carry them out safely, even in highly compromised patients. The following sections describe the use of NIV in the cardiac catheterization laboratory, during percutaneous cardiac valve procedures, to aid TEE examination, and during electrophysiological procedures, focusing on both technical and clinical aspects.

70.2 Cardiac Catheterization Laboratory

Procedures performed in the cardiac catheterization laboratory include coronary angiography, PCI, percutaneous closure of septal defects, and transcatheter cardiac valve stents [1]. Coronary angiography and PCI are usually performed without sedation and/or ventilatory support. Accordingly, these procedures do not need anesthesia care, except when respiratory distress or hemodynamic instability coexist, due to AMI, pulmonary edema, or heart failure.

Yamamoto and colleagues [2] successfully used NIV in 261 patients with pulmonary edema (secondary or not to AMI) undergoing coronary angiography and PCI. In this retrospective, single-center study, patients received continuous positive airways pressure (CPAP) via a full or total face mask using a BiPAP Vision machine

(Respironics, Murrysville, PA, USA) as first-line treatment. The initial positive end-expiratory pressure (PEEP) was 4–10 cmH_2O and was subsequently adjusted to improve patient comfort. Inspiratory oxygen fraction (FiO_2) was set to achieve an arterial oxygen saturation (SaO_2) > 95 %. If the patient complained of dyspnea at 30 min after initiation of CPAP treatment, NIV with a bi-level positive airway pressure (BiPAP) modality was started. NIV effectively improved oxygenation and lowered the tracheal intubation rate in patients with cardiogenic pulmonary edema of all etiologies, including AMI.

Whereas percutaneous closure of septal defects is usually performed under general anesthesia with tracheal intubation, transcatheter cardiac valve procedures can be also performed in awake patients with sedation and the aid of NIV [3, 4], as discussed in the following section.

70.3 Percutaneous Cardiac Valve Procedures

Surgery is the standard of care for valve diseases such as aortic stenosis (AS) or mitral regurgitation (MR). However, percutaneous procedures represent an alternative in patients for whom the risk of surgery is considered too high, due to older age, poor general health status, or severe comorbidities. In particular, about 30 % of patients with AS belongs to this "inoperable"/high-risk subset [3]. In these patients, transcatheter aortic valve implantation (TAVI) allows minimization of surgical stress (by avoiding sternotomy and cardiopulmonary bypass, and decreasing the duration of intervention). Moreover, TAVI can usually be performed under local anesthesia, thus avoiding the potential risks of general anesthesia, tracheal intubation, and mechanical ventilation [4]. However, the supine position, which is necessary during the procedure (usually lasting at least 1.5 h), is often poorly tolerated by orthopneic patients, especially when respiratory diseases coexist. Accordingly, sedation is generally required, with possible further worsening of respiratory function and gas exchanges.

Guarracino and colleagues reported the use of NIV during TAVI in five patients with orthopnea and severe chronic pulmonary disease (pulmonary fibrosis in four patients and silicosis in one patient) [4], as well as in patients undergoing transfemoral [5] or transaxillary [3] TAVI who needed intraprocedural TEE, which may contribute to respiratory impairment. The five patients with severe pulmonary comorbidities underwent CoreValve (Medtronic, CV Luxembourg) implantation and received pressure support ventilation (PSV) by a Vision NIV ventilator (Respironics Inc., Murrysville, PA, USA) connected to an adult oronasal mask (VIP 75™ 7500 Series V masks™, Hans Rudolph, Inc., Kansas City, MO, USA). PSV was initially set at 8–12 cmH_2O, with a PEEP of 4–6 cmH_2O and a FiO_2 of 0.35–0.5, and was subsequently adjusted to maintain a SaO_2 >92 % and an arterial partial pressure of CO_2 ($PaCO_2$) <50 mmHg. All patients were adequately sedated to be comfortable during the entire procedure. No complications occurred.

Theoretically, even percutaneous mitral repair (mitral clip) could be performed in awake patients with the aid of NIV [6], which may also allow safe intraprocedural TEE (see below). However, to the authors' knowledge, there are no literature reports in this regard.

70.4 TEE

TEE has been used for many years both as a diagnostic tool, mostly in patients with severe cardiac diseases (e.g., atrial fibrillation, prosthetic valve dysfunction, and infective endocarditis), and as a monitoring adjunct for percutaneous cardiac procedures, including TAVI and, more recently, mitral clip, which are usually performed in high-risk patients [3–5, 7]. Because TEE often causes temporary arterial blood gas worsen during and after examination, respiratory failure and/or severe cardiac arrhythmias may occur in frail patients undergoing diagnostic or intraprocedural TEE [5]. For example, orthopneic patients may develop respiratory failure due to the supine position, in addition to the presence of the probe [6]. Moreover, because TEE is a relatively invasive procedure, possibly causing pain, dangerous reflexes, and emotional distress, sedation is often required to perform the exam. However, sedation itself, besides the examination-related stress, may cause cardiorespiratory failure, while general anesthesia may result in significant complications, primarily respiratory, and is generally poorly tolerated by high-risk cardiac patients [5, 6, 8].

The use of NIV to aid TEE examination in severely ill, high risk patients has been suggested in recent years [3, 5, 8]. Indeed, under these circumstances, NIV could both improve patient tolerance to the examination and allow safe sedation.

Guarracino et al. [3, 5] reported the use of NIV via a modified face mask to support TEE examination in severe, orthopneic cardiac patients undergoing transcatheter aortic valve implantation or valvuloplasty. The TEE probe was passed through a vertical hole obtained on the anterior part of an adult oronasal NIV mask (VIP 75 7500 Series V masks) by a surgical cutter. No air leakage was observed. PSV, with an inspiratory positive airway pressure (IPAP) of 8–12 cmH_2O, a PEEP of 4–6 cmH_2O, and a FiO_2 of 0.35–0.5 was used. NIV was administered for the entire procedure and for the following 2 hours, and appeared to be effective in allowing orthopneic patients to lie in the supine position and in preventing respiratory failure due to sedation.

More recently, Pisano et al. [8] performed TEE during NIV through a helmet in a poorly cooperative ICU patient, with multiple severe comorbidities, who developed cardiorespiratory failure following high-risk replacement of a malfunctioning mitral mechanical prosthesis. No change of ventilator settings or modality (PSV) was necessary. Tidal volumes, respiratory rate, arterial blood gases, and hemodynamic parameters remained unchanged during and after the procedure. Moreover, NIV allowed adequate sedation, thus avoiding general anesthesia and tracheal intubation.

However, a technical issue limits the possibility of performing TEE through a helmet. In fact, the airtight ports for catheters or probes available on helmets are not large enough to allow insertion and movements of the TEE probe. Pisano and colleagues used the larger airtight port that is located on the Castar R Next helmet

Fig. 70.1 TEE examination through a non-invasive ventilation helmet in a sedated patient. Part of a tracheostomy foam dressing is used as an airtight sleeve (*arrow*). Reproduced from Pisano et al. [8]

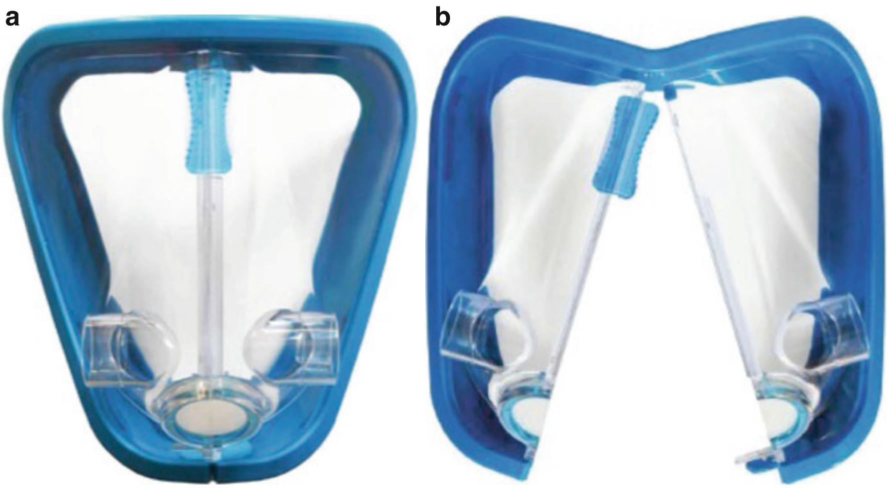

Fig. 70.2 The Janus full face mask. (**a**). Closed. (**b**). Opened. Courtesy of Biomedical (Florence, Italy)

(StarMed, Mirandola, Italy), after removing the inner airtight sleeve. The resulting gross air leakage was avoided by using part of a tracheostomy foam dressing (Pharmaplast, Alexandria, Egypt), rolled up around the portion of the probe that crossed the helmet, as an airtight sleeve (Fig. 70.1). The availability on NIV helmets of a multipurpose airtight port, allowing insertion and adequate movements of the TEE probe, may be desirable if further research will confirm safety and effectiveness of this, as well as other endoscopic procedures, through NIV helmets.

Conversely, oronasal masks provided with an airtight port for endoscopy, which also allows TEE examination, are already available on the market. In particular, an openable full face mask exists (Janus, Biomedical, Florence, Italy) (Fig. 70.2), which can be applied to the patient even after the TEE probe has been positioned, allowing NIV to start, if necessary (unexpected respiratory distress or need of sedation) without stopping the exam [6].

70.5 Electrophysiological Procedures

Patients undergoing electrophysiological mapping, which is a catheter-based procedure for ventricular arrhythmias, or catheter ablation for atrial fibrillation are required to lie motionless on the table for several hours, and repeated stimuli from ablation are sometimes painful. For these reasons, patients usually need deep sedation or general anesthesia.

Sbrana et al. [9] described a case series of patients who underwent catheter ablation for atrial fibrillation. In these patients, NIV and deep sedation were started after trans-septal puncture. NIV was performed through a latex-free total face mask (Respironic®, Murrysville, PA, USA) (Fig. 70.3) connected to a Garbin ventilator (Linde Inc., Herrsching, Germany) in spontaneous/temporized mode, applying incorporated algorithms to improve patient-ventilator synchrony by adjusting to changing breathing patterns and dynamic leaks. During the procedure, in addition to routine monitoring, serial arterial blood gas analyses and invasive arterial pressure monitoring were performed. IPAP, expiratory positive airway pressure (EPAP), and respiratory rate were modified according to the clinical response, including patient tolerance, to obtain an exhaled tidal volume of 6–8 ml/kg; the FiO_2 requirement to maintain SaO_2 above 92 % was ≤ 0.4.

In this group of patients, no respiratory complications, problems due to gastric distention, issues related to the ventilation interface (mask), NIV discomfort, or significant hemodynamic effects due to positive pressure ventilation were reported. Furthermore, these patients maintained (although with respiratory parameters in the physiological range) better arterial blood gases and acid–base balance compared

Fig. 70.3 A patient ventilated through the Respironic® latex-free total face mask during catheter ablation for atrial fibrillation

with a deep sedation group without NIV [10]. Finally, a continuous monitoring of tidal volume, air leak, and actual minute ventilation during the entire procedure contributed to patient safety.

Key Major Recommendations

- NIV should be considered in patients with pulmonary edema (including patients with acute myocardial infarction) undergoing coronary angiography and PCI.
- NIV may have an additional role in the anesthetic management of percutaneous cardiac valve procedures (TAVI and mitral clip) and electrophysiological procedures.
- The use of NIV to aid TEE examination in severely ill, high-risk patients could both improve patient tolerance to the examination and allow safe sedation.
- Skilled personnel, adequate monitoring, and appropriate ventilatory interfaces allow the safe use of NIV during most cardiac procedures, minimizing complications in frail or high-risk patients.

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