40 Application of Noninvasive Ventilation in the Obstetrical Patient

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40.1 Introduction

It is found that 9.1% of obstetric ICU admissions are due to pulmonary complications with the most common reasons being secondary to respiratory failure from asthma, pneumonia, cystic fibrosis, pulmonary edema, pulmonary embolism, acute respiratory distress syndrome (ARDS), and amniotic fluid embolism (Table 40.1) [1]. Acute respiratory failure (ARF) in pregnancy occurs in less than 0.1% [2] of pregnant patients, but is considered one of the most common indications for obstetric admissions into the intensive care units and cause for maternal and fetal mortality to be as high as 14% and 11% respectively [3, 4]. These are risks that are predisposed in these patients due to the anatomic and physiologic changes in the respiratory system that can affect overall management. Respiratory failure in pregnancy may be due to pregnancy-specific disease or exacerbation of previously existing respiratory disease.

In the pregnant patient, it is well described that intubation failure is eight times more common [5] with an incidence of fatal failed intubation to be 13 times higher when compared to the non-parturient [6, 7]. As a result, noninvasive modalities such as noninvasive positive pressure ventilation (NIPPV) and high-flow nasal canula (HFNC) can be considered to avoid the potential complications of endotracheal intubation and

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Table 40.1 Most common causes of respiratory failure in pregnancy

Asthma
Pulmonary infections
Pulmonary edema
Thromboembolic disease
Amniotic fluid embolism
ARDS
Restrictive lung disease
Aspiration

associated sedation protocols given that for its use will require the patient to be able to protect her airway, clear secretions, and co-operate.

The purpose of this review is to explore the literature and describe the utilization of NIV in the obstetrical patient.

40.2 Physiological and Anatomical Changes in Pregnancy

The phenomenon of pregnancy imposes many changes in the cardiorespiratory system that is needed to meet the increased demands induced by the gravid uterus. To meet the hormonal and metabolic requirements for both the mother and the fetus during gestational advancement, anatomical adaptations (in the upper airway, chest wall, diaphragm) and alterations in respiratory function (lung volumes, ventilation and gas exchange relationships) need to take place. In the critical care setting, understanding these physiologic adjustments will allow to discern between "normal physiologic dyspnea" in a pregnant patient from other more pathological entities.

40.2.1 Upper Respiratory Tract Changes

In the upper respiratory system, during pregnancy some of the histological changes in the mucosa that occur include hyperemia, glandular hyperactivity, increased phagocytic activity, and increased mucopolysaccharide content which was demonstrated by Toppozada et al. in 1982 [8]. These are changes that can be associated with edema and friability which often may cause nasal congestion and epistaxis also known as gestational rhinitis that occurs in the last few weeks of pregnancy and resolve after delivery [9]. This process is found to occur in 20–30% of pregnant patients [10, 11] and is theorized to be from the result of increasing levels of estrogen [12] and placental growth hormone. It is an entity that is clinically defined as "nasal congestion" lasting over 6 weeks during pregnancy without any evidence of respiratory tract infection or allergic cause. Increases in mucosal edema of the upper airway can lead to other consequences. Sleep-disordered breathing and snoring [13] can potentially contribute to maternal-fetal complications such as hypertension and preeclampsia through the reduced levels of inhaled nitric oxide (NO). Physiologically, as reviewed by Lungberg et al. [14], NO is primarily produced in the maxillary sinuses, and the nasal congestion and/or obstruction can lead to mouth breathing, resulting in decreased concentrations of the potent mediator of pulmonary vascular tone.

Increase in neck circumference [15] and decreases in the oropharyngeal junction size, leading to increases in mallampati scores [16], are adjustments that should also be understood. Factors that can potentially contribute to these modifications are described by White et al, where reduced volumes, particularly functional residual capacity (FRC), and fat infiltration of the upper airway can affect airway collapsibility [17]. During the course of pregnancy, it is found that patients can gain an average of 25–35 pounds, however similar to White and colleagues, Iczi et al. [15] also theorize that a decrease in airway patency is not related to the patient's body mass index but to the changes in FRC or changes in the upper airway interstitial fluid dynamics or edema. Overall, as a result of these upper airway changes from upper airway congestion and obstruction, this can contribute to difficulties in airway management which may lead to complicated nasogastric tube insertions and a higher risk of failed endotracheal intubations in pregnant patients.

40.2.2 Respiratory Function Changes

In pregnancy, the major effect occurs mostly in lung volumes while spirometry remains relatively unchanged. The forced expiratory volume (FEV1) was extensively studied in the pregnant population in the 1970s and 1980s, as it is a helpful measurement for evaluating patients with obstructive lung diseases, and was found to be unchanged [18]. In addition, the peak expiratory flow rate, a function of the large airway caliber, and forced expiratory flow at 50% and 25% (FEF 25–50) of vital capacity, which is representative of the small airway caliber, were also found to be unchanged demonstrated by the findings of Baldwin et al. [19] and Gazioglu et al. [20]. This coincides with the findings of Cugell et al. [21] and Ihrmann et al. [22], where the overall airway mechanics and respiratory muscle strength were found to be unchanged during pregnancy. As a result, spirometry is relatively stable during pregnancy and its interpretation for patients with obstructive diseases with asthma or COPD is unchanged during pregnancy. Therefore, an abnormal spirometry is likely to be from an underlying respiratory disease and not a sequela of pregnancy.

Total lung capacity is found to be unchanged or minimally decreased. As seen in Table 40.2, the function residual capacity (FRC), the addition of the expiratory reserve volume (ERV) and reserve volume (RV), is found to decrease by 20%, due to the mechanical adaptation of diaphragm elevation which consequently decreases the expiratory reserve volume and residual volume [23]. On the other hand, the inspiratory capacity which comprises of the inspiratory reserve volume (IRV) and tidal volume (TV) increases by 5–10% [24].

Table 40.2 Normal respiratory physiologic changes

Increase	Decrease	No change
IC	FRV (20–30%)	VC
TV (30–50%)	RV (7–22%)	RR
RR	FRC (10–25%)	Peak flow
MV (20–50%)	TLC	FEV1

40.3 Utilization of NIV in Pregnancy During Acute Respiratory Failure

Noninvasive positive pressure ventilation (NIPPV) is referred to ventilation that is delivered without the need for invasive endotracheal intubation, where positive pressure is able to reduce the patient's work of breathing and also improving gas exchange. HFNC is an alternative which also delivers high concentrations of humidified oxygen at a flow rate up to 60L/min with an added benefit of also generating a low positive end expiratory pressure (PEEP = 2–5 cmH_2O) subsequently improving gas exchange and decreasing work of breathing without increasing the risk of barotrauma. Treatment goals during respiratory failure in the pregnant patient are similar to those outside of pregnancy. These goals aim to maintain adequate ventilation and to provide hemodynamic and nutritional support to assist in determining the best timing for delivery, with fetal monitoring, when the mother is in respiratory distress or impending respiratory failure. In the review of the literature, the use of NIPPV and HFNC in pregnant patients with respiratory failure has only been demonstrated in case reports and case series summarized in Table 40.3. These reports convey favorable use of NIPPV and HFNC in a number of clinical scenarios ranging from obstructive lung disease like asthma, neuromusculoskeletal disorders, and in the perioperative/intraoperative setting. NIPPV has also been described to be beneficial for sleep disorders not only in the general population but also during pregnancy [25–27].

Ventilatory failure associated with neuromuscular diseases and severe kyphoscoliosis [28–30] were of the first cases described to utilize NIPPV in the pregnant patient. Kahler et al. [30] described the use of nasal BiPAP starting in the 20th week of gestation which was adapted throughout the pregnancy. This resulted in an improvement in exercise tolerance, fatigue, and nocturnal oxygen desaturations which lead to a successful cesarean section under combined spinal-epidural anesthesia with ongoing

Table 40.3 Summary of noninvasive ventilation use in pregnancy

Author	Year	Design	Modality	Patients (*n*)	Etiology of respiratory failure	Demonstrates benefit of use
Kahler [30]	2002	Case report	NIPPV	1	Ventilatory failure, severe kyphoscoliosis	Yes
Bach [31]	2003	Case series	NIPPV	4	Ventilatory failure, neuromuscular (severe poliomyelitis)	Yes
Diaz-Lobato [32]	2005	Case series	NIPPV	2	Ventilatory failure, neuromuscular (mitochondrial myopathy)	Yes
Reddy [28]	2005	Case report	NIPPV	1	Ventilatory failure, severe kyphoscoliosis	Yes
Terajima [38]	2006	Case report	NIPPV	1	Noncardiogenic pulmonary edema	Yes
Al-Ansari [45]	2007	Case series	NIPPV	4	ARDS, acute chest syndrome	Yes
Perbet [36]	2008	Case report	NIPPV	1	Noncardiogenic associated with tocolytic agents	Yes
Banga [47]	2009	Case report	NIPPV	1	ARDS, community-acquired pneumonia	Yes
Bassani [46]	2009	Case report	NIPPV	1	ARDS/ATRA syndrome	Yes
Yuan [33]	2009	Case report	NIPPV	1	Ventilatory failure, neuromuscular (mitochondrial myopathy)	Yes
Guterres [52]	2010	Case report	NIPPV	1	Ventilatory failure, neuromuscular (high neuraxial blockade)	Yes
Djibre [50]	2010	Case report	NIPPV	1	ARDS, H1N1	Yes
Erdogan [53]	2010	Case report	NIPPV	1	Noncardiogenic pulmonary edema, severe preeclampsia	Yes
Frassanito [48]	2011	Case report	NIPPV	1	ARDS, sepsis	Yes
Rojas-Suarez [39]	2011	Case report	NIPPV	1	Noncardiogenic pulmonary edema, severe preeclampsia	Yes
Duan [34]	2012	Case report	NIPPV	1	Aspiration pneumonia	Yes
Dalar [42]	2013	Case report	NIPPV	1	Community-acquired pneumonia	Yes
Draisci [54]	2013	Case series	NIPPV	2	Ventilatory failure, obstructive lung disease	Yes
Fujita [35]	2014	Case report	NIPPV	1	Noncardiogenic pulmonary edema	Yes
Polin [51]	2015	Case report	NIPPV	1	Intraoperative support for neuraxial blockade	Yes
Jallian [37]	2015	Case report	NIPPV	1	Noncardiogenic pulmonary edema, severe preeclampsia	Yes
Shoji [43]	2017	Case report	HFNC	1	Hypoxic RF due to dermatomyositis related interstitial pneumonia	Yes
Plotnikow [44]	2018	Case report	HFNC	1	Hypoxic RF	Yes

NIPPV. Bach et al. [31] in 2003 reported four cases of continuous NIPPV in three females with poliomyelitis developing chronic respiratory failure and another developing ventilator insufficiency due to severe kyphoscoliosis. In all of these cases, NIPPV was utilized to successfully permit the natural completion of pregnancy. In terms of other neuromuscular diseases, Diaz-Lobato et al. [32] and Yuan et al. [33] echo the successful use of NIPPV involving patients in their third trimester suffering from chronic respiratory insufficiency due to mitochondrial myopathies.

The utilization of NIPPV for hypoxemic respiratory failure has not been proven and at best controversial. Nonetheless, its successful utilization has been described in the parturient developing hypoxemic respiratory failure, where causes can range from pneumonia [34] to pulmonary edema [35] associated with tocolytic therapy [36] and severe preeclampsia [37–39]. Asthma is a common chronic condition associated with complications during pregnancy. Its prevalence among pregnant females is increasing which subsequently increases perinatal risks which include pre-eclampsia, preterm birth, low birth weight, spontaneous abortion, and perinatal mortality [40]. Severe attacks from asthma are usually seen at 21–24 weeks, but can occur at any stage of pregnancy. NIPPV and its use in an asthma exacerbation leading to hypoxic respiratory failure is a provocative modality, however has been proven to be beneficial in chronic obstructive pulmonary disease where hypercapnic respiratory failure is the main pathophysiology [41]. Dalar et al. [42] reported a case of a 28-year-old female in her 16th week of pregnancy with community-acquired pneumonia who presented during an asthma attack, which led to hypoxic respiratory failure who was successfully treated using NIPPV by significantly decreasing her oxygen requirements within 48 h along with her respiratory and cardiac rates. High flow nasal cannula (HFNC) is another modality that can be considered in the setting of acute hypoxic respiratory failure, however there is an absence of compelling evidence regarding its use in the obstetrical population. Only two case reports describe its successful utilization for respiratory management in rapidly progressive interstitial pneumonia complicated by dermatomyositis [43] and acute hypoxic respiratory failure due to sepsis [44].

NIPPV application in ARDS has also been described to be efficacious as in the case depicted by Al-Ansari et al. [45], which involved four pregnant patients with sickle cell disease who presented with acute chest syndrome and ARDS, and successful treatment with NIPPV was achieved while avoiding endotracheal intubation. Cases of ARDS related to all-trans-retinoic acid syndrome [46], community-acquired pneumonia, sepsis and influenza (H1N1) have also been found in the literature. Banga et al. [47] described a case of a primigravida female with ARDS due to community-acquired severe pneumonia in whom with NIPPV, lead to the improvement in arterial oxygenation, reduction in respiratory rate, and of importance gradual disappearance of fetal distress. In another case by Frassanito et al. [48], a 32-year-old woman who developed ARDS requiring urgent cesarean section under epidural anesthesia, in the setting of membrane rupture of one of the twins, required intermittent NIPPV during the postoperative period, which helped to restore physiological gas-exchange and prevent common complications associated in invasive mechanical ventilation. In terms of H1N1-related ARDS, mortality rate can reach as high as 60% for those who require mechanical ventilation, which as discussed in the pregnant population may possibly be higher. In 2012, a prospective multi-centered study found that the early application of NIPPV, with the aim to avoid invasive ventilation during the H1N1 pandemics, was associated with an overall success rate of 48% of the patients with elevated SAPS II score, acute respiratory failure and pulmonary infiltrates and a 75% success rate in patients not needing immediate intubation for a life-threatening condition [49]. This success is further depicted by Djibre et al. [50] in a case of a 28-year-old pregnant female with ARDS from the H1N1 virus, where through intermittent NIPPV the patient was suc-

cessfully treated without the means of mechanical ventilation. This brings out the point of a possible role for NIPPV in reducing this morbidity by decreasing the number of required intubations, in not only the pregnant patient, but patients with isolated respiratory failure and ARDS from H1N1.

In addition to salvage respiratory therapies, other descriptions of NIPPV in pregnancy have also been noted in the perioperative setting, particularly in combination with spinal anesthesia for parturients with respiratory failure requiring emergency cesarean delivery [51–53]. Sedation and NIPPV has also been a topic of interest for many years. In the 1960s, Duan et al. [34] described a case of successfully applying NIPPV with dexmetomidine (a selective alpha-2 receptor agonist) in a 16-year-old primigravida woman who developed acute hypoxemic respiratory failure and allowed for the achievement of sufficient oxygenation along with anxiety reduction, providing good outcomes for both the child and the patient.

40.4 Conclusion

NIV constitutes multiple modalities that lack adequate extensive evidence in the parturient patient. Despite this, there is a potential role for use as evidenced by multiple case reports and series. NIV should not be applied routinely in pregnancy but may be considered on case by case basis. As in the setting for NIPPV, there are theoretical concerns for aspiration risk and obtaining a proper fit for oxygenation. Although further studies are needed, NIV modalities have similar indications and contraindications in the pregnant patient as the general population. It must be noted that NIV will not be appropriate if the need of prolonged ventilation is expected and/or in the setting of other organ failure and should only be utilized when the patient is alert, protecting her airway and where the need for assisted ventilation will be brief. As a result, criteria required for its use should include that the patient possesses an adequate respiratory drive, toleration of the face interface, hemodynamically stability, an ability to protect her airway, low aspiration risks, and lastly an experienced team with the use of NIPPV in a proper monitored setting (Table 40.4).

Table 40.4 Summary of learning points

• Respiratory distress is a common cause of morbidity during gestation
• Many pulmonary diseases are common indications for obstetric admissions into the intensive care units and cause for maternal and fetal mortality
• Understanding the physiologic and anatomical changes during pregnancy will allow to differentiate between “normal physiologic dyspnea” from other more pathological entities
• Although controversial, NIPPV has been shown to be safe and effective during pregnancy in case reports and series
• NIPPV may prevent invasive mechanical ventilation avoiding use of sedating medications
• Limited evidence for the utilization of HFNC in the obstetrical patient
• Although further studies are needed, NIV modalities have similar indications and contraindications in the pregnant patient as the general population

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