Noninvasive Ventilatory Support: The Detail Lies in the Interface

Over the last decade, the use of noninvasive ventilatory support has expanded considerably[1] for both children[2] and adults.[3] The options are extensive, ranging from high-flow humidified nasal oxygen[4] to noninvasive ventilation (NIV) using techniques such as negative-pressure ventilation,[5] neurally adjusted ventilatory assist,[6] and multiple modes of ventilation.[7] The indications are ever expanding and now include patients with terminal disease,[8-10] chronic and acute respiratory disease[11] (or both), following cardiac surgery,[12] hemodynamic instability, muscular weakness, and central hypoventilation. The settings of use have expanded from ICUs to include emergency care,[4,13] transport systems,[14] ward care, home care, and many variations of care delivery, the one consistent theme being that patients should be able to protect their airways from aspiration or obstruction.

The benefits derived from NIV appear to be substantial over a range of age groups and multiple patient groups in many diverse settings. The benefits have included improved survival,[15] a reduction in the adverse events related to endotracheal intubation, reductions in ICU and hospital stay, and significantly reduced costs to health-care systems and to patients,[16] and in some parts of the world, this technology has provided access to ventilatory support that was simply not available before.[17] In settings such as status asthmaticus, there is a suggestion that some modes of NIV relieve symptoms but may also reduce airway reactivity.[18] However, there remains a paucity of randomized, controlled studies to fully evaluate the impact of NIV, particularly in children.[19]

Throughout this expansion, one of the most challenging aspects of practical care has been the interface between the patient and the ventilator, between the ventilator circuit and the patient's airway, and between the patient's respiratory efforts and the ventilator. In many settings, one of the strongest motivations for use of noninvasive ventilatory support is limitation of adverse events associated with invasive ventilation (with endotracheal and/or tracheostomy tubes), yet adverse events are common for patients receiving NIV, with damage to skin and facial structures being particularly frequent events,[20] whereas many other patients suffer discomfort related to the mask/interface.

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A wide range of interfaces (full face mask, oronasal mask, nasal mask) have been introduced to adapt to a variety of situations. More recently, nasal cannulae and helmets[21,22] have been added to the armamentarium. In some children, use of a nasopharyngeal tube has been an effective route of NIV.[23] Some of the challenges related to interfaces include: discomfort (particularly in patients who are struggling to breathe); development of pressure damage to the skin and underlying structures; inappropriate humidification; ventilatory dead space; and problems with the triggering and pressure delivery from the ventilator system, particularly when leaks are present (which may be exacerbated by the presence of nasogastric tubes). The selection of the particular interface may be further complicated by the attached ventilator tubing systems, since the drag and weight of the system may exert significant pressure on areas of the face.

These challenges are exacerbated by the fact that many of the patients who require noninvasive ventilatory support may have facial structures that differ from the norm,[24] creating challenges for the selection of the optimal interface. In a pediatric population, the challenges may be even more striking because children come in a wide range of sizes and facial shapes and have skin that (particularly in neonates and preterm infants) may be exceptionally fragile and liable to injury; also, children may find it difficult to tolerate sensations that adult patients may find acceptable. Some clinicians have used the helmet approach, where there is actually no contact of the interface with the face, and there is a significant body of evidence suggesting that many children find the helmet acceptable.[21,22,25,26] However, this interface is not available in the United States.

In this issue of the Journal, Visscher et al[27] have started to address many aspects of this interface using innovative technologies on a relatively large group of subjects (most pediatric and with a high proportion of craniofacial abnormalities). They used high definition color photography

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(with selection of red pixels) to identify early pressure damage to the skin. Only 28% of subjects had no visible skin compromise. In this process, they have highlighted the availability of techniques that can be used to identify early skin damage,[28] regardless of skin pigmentation. They also measured skin hydration in relation to the NIV interface, of particular interest because the surfaces of NIV masks are often occlusive in nature, resulting in increased skin moisture with possible changes in susceptibility to injury from pressure or friction.[29] They were able to examine some of the effects of different materials between the face and the mask, showing that cloth materials were associated with less skin hydration and erythema.

In addition, Visscher et al[27] used an innovative 3-dimensional imaging process to evaluate the fit between the face and the mask. This particular technique was challenging and in some ways produced an artificial situation because it was not possible to consider how the face and the mask might mold together, and it assumed that pressure or indentation had the same effects throughout the face. It is likely that the pressure effects will most affect skin and subcutaneous tissue that is caught between the mask and underlying bone. The particular damage that results will probably depend on the qualities of the skin, the patient's hemodynamic status, and the actual pressures produced. However, Visscher et al[27] have highlighted the need for masks that fit the individual patient appropriately. This echoes the call from other authors[23,24,30-32] for the utilization of interfaces that are fitted to individual patients. However, this intervention depends heavily on the experience and expertise of the therapists involved. That becomes challenging as NIV moves from highly specialized pediatric ICUs to less well-equipped areas.

There is clearly a need for intensive research focused on the ideal interface: how to provide a mass-produced commercially available interface that is comfortable; adaptable to a wide range of facial shapes and structures; lined with material that prevents overhydration of the skin; and can be fitted (together with the ventilator circuit) in such a way that it does not leak, increase dead space, or compromise patient-ventilator synchrony. The techniques that the authors have introduced may well open doors to new developments.

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