Noninvasive Options for Ventilatory Support of the Traumatic High Level Quadriplegic Patient*

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The ventilation of 25 ventilator-dependent traumatic quadriplegic patients was supported by noninvasive means of ventilatory assistance. Twenty-four of the 25 were initially managed by endotracheal intubation, and 23 of these went on to tracheostomy intermittent positive pressure ventilation before being converted to NVA. Seventeen of the 23 patients had their tracheostomies closed. This included three patients with no significant free time except with the use of glossopharyngeal breathing. Seven of the 25 patients who used NVA for at least one year with no significant free time have employed NVA for a mean of 7.4 ± 7.4 years (1 to 22 years). Mouth IPPV was the most common form of NVA used both during the daytime and overnight. The wrap ventilators, intermittent abdominal pressure ventilator, and GPB were also employed for long-term respiratory support. It was concluded that, in general, because of their youth, intact mental status and bulbar musculature, and absence of obstructive lung disease, patients with traumatic high level spinal cord injury are candidates to benefit from these techniques.

EPR = electrophrenic respiration; GPB = glossopharyngeal breathing; GPa = glossopharyngeal maximum single breath capacity; IAPV = intermittent abdominal pressure ventilator; NVA = noninvasive means of ventilatory assistance; SaO₂ = oxygen saturation

There is an increasing number of ventilator-dependent, high level quadriplegic patients discharged to the community. The options for ventilating these patients have been electrophrenic nerve stimulation for ventilation and or tracheostomy IPPV. Potential long-term complications of tracheostomy are numerous, and EPR is extremely expensive and has not been shown to be an effective long-term alternative for the majority of patients for which it has been tried. Tracheostomy and tracheostomy IPPV have been considered essential in the long-term management of every high level spinal cord injured patient. The tracheostomy is also usually maintained in patients employing EPR because of the tendency of these patients to experience upper airway collapse during sleep and because phrenic pacer failure and resulting apnea can occur suddenly and without warning. Morbidity and mortality is high with these techniques. Whitenek et al reported that 55 percent of 76 chronic ventilator-dependent spinal cord injured patients on tracheostomy IPPV or EPR had pulmonary problems yearly with an average length of hospital stay of 22 days per year. Survival percentages at one, three, five, seven, and nine years postinjury were 86, 70, 63, 59, and 63 percent, respectively indicating that about 40 percent of patients are deceased by five to nine years postinjury. Slaingard et al reported 37 percent mortality in three years for 26 traumatic spinal cord injured patients on tracheostomy IPPV including 20 patients with C1-3 quadriplegia. Two of these patients died by accidental disconnection. Carter et al reported 17 deaths in 35 respirator-dependent quadriplegic patients on tracheostomy ventilation or EPR in an average of 1.5 years postinjury or four years postpacemaker placement, respectively. He felt that sudden death which occurred in at least nine of the patients was associated with the presence of the tracheostomy itself. Common hazards include accidental disconnection, mucous plugging with acute airway obstruction, tracheomalacia, tracheal stenosis, hemorrhage, granuloma and crusting with difficult tube changes, and chronic Gram-negative colonization with purulent bronchitis.

There is increasing interest in the use of NVA as alternatives to tracheostomy IPPV for patients with chronic respiratory insufficiency. Noninvasive aids have been described, for the most part, in the long-term management of patients with muscular dystrophy and poliomyelitis. Until recently, the literature concerning these methods has been almost solely confined to the application of body ventilators which, although effective for a time, present many inconveniences and cannot be used by many patients. Although the intermittent abdominal pressure ventilator has been used successfully by some patients for over 30 years, it, like other body ventilators,
tends to become less effective with time as pulmonary volumes and compliance decrease with age or progressive disease.24-26 To our knowledge, the use of body ventilators has not until now been reported for total respiratory support of high level spinal cord injured patients.

Recently, respiratory support by noninvasive direct positive airway pressure methods such as IPPV via the mouth,23,26,27 nose,24,26-32 and strapless oral-nasal interfaces32-34 has been described. These techniques have been successful in providing total ventilatory support without a tracheostomy for over 100 patients with little or no vital capacity or time free of a ventilator for up to 40 years.30 Acute respiratory tract illnesses were often managed without intubation or bronchial suctioning by effective manually35 or mechanically assisted coughing.36,37,39,40 The use of noninvasive positive airway pressure supported ventilation has not yet been described in the management of traumatic high level spinal cord injury. Guidelines are presented for transition from tracheostomy IPPV to these and other NVAs.

**Patients and Methods**

Eighty ventilator-dependent quadriplegic patients including 64 male and 16 female patients with a mean age of 21.9 ± 5 years at the time of injury were admitted for management of ventilator dependence and pulmonary rehabilitation from 1985 to the present. Seventy-eight of these patients had been managed by intubation and 77 by tracheostomy at some time following their acute injuries. Four of the patients presented with late-onset respiratory insufficiency 2 to 29 years after injury (one case) or after their tracheostomies had been allowed to close (three cases).

The patients underwent the management protocol in Table 1. End-tidal Pco2 monitoring, and more recently, continuous noninvasive blood gas monitoring during sleep with end-tidal Pco2 and pulse oximetry have been useful in proceeding through the steps from 24-h tracheostomy IPPV with an inflated cuff to unassisted breathing or dependence on less invasive means of ventilatory support. End-tidal Pco2 has also been used in the follow-up yearly evaluations of each patient’s assisted ventilation since 1985.

**Management Stages for Patients Presenting on Tracheostomy IPPV**

1. The patients were medically stabilized and the use of supplemental oxygen therapy was discontinued or minimized. Aggressive manual,9 and for some, mechanical7,8-9 assisted coughing were used as alternatives to tracheal suctioning for some patients on tracheostomy IPPV as well as for those on NVA who had not undergone tracheostomy.

2. All of the patients were placed on portable volume, or when preferred by the patient, pressures ventilators. The cuffs were completely deflated for increasing periods hourly until cuff deflation could be tolerated throughout daytime hours. Partial cuff deflation was then used overnight. The delivered insufflation volumes were increased to maintain the same ventilator pressures as with the cuff inflated. When necessary, the patient’s tracheostomy tube diameter was changed to permit sufficient leakage for speech while maintaining adequate fit to permit effective assisted ventilation with delivered ventilator volumes generally 1 to 2 L. The set volume was titrated to maintain Pco2 levels between 35 and 40 mm Hg. Tracheal integrity, tracheostomy tube width, and volitional glottic and vocal cord movements determined the amount of the delivered air to enter the lungs and the amount to “leak” up through the vocal cords with each breath. This leakage was used for inspiratory cycle speech. Along with end-tidal Pco2, oximetry has been used more recently for sleep monitoring. Oxygen saturation was maintained above 85 percent with a mean of 98 percent or greater during sleep.

Speech was crescendo/decrecendo with the rhythm dependent on the cycling ventilator while on IPPV with a deflated tube cuff. A low speech volume indicated either inadequate insufflation volume, a tracheostomy tube that was too wide, or supraglottic obstruction, usually by granulation tissue. For these patients, optimal insufflation volumes for normal ventilation and more effective speech were obtained by cuff removal, by placing a narrower diameter tracheostomy tube, or by the surgical ablation of the granulation tissue when indicated. A one-way valve was placed at the expiratory valve for one patient, permitting him continuous speech.

3. Patients were advanced to the use of 24-h tracheostomy IPPV with a deflated cuff. The use of partial cuff deflation was discouraged because of the tendency of the nursing staff to gradually increase the amount of air in the cuff with time. Some patients were introduced to ventilatory support by an iron lung or chest shell with the tracheostomy tube open. Care was taken to maintain the

### Table 1 - Steps in the Pulmonary Rehabilitation of Tracheostomized Patients with High Spinal Cord Injury

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<th>Tracheostomy Tube</th>
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TIPPV, tracheostomy intermittent positive pressure ventilation; vent, ventilator; MIPPV, mouth intermittent positive pressure ventilation; GPB, glossopharyngeal breathing; PB, intermittent abdominal pressure ventilator (Pneumobelt); N, nasal; M, mouth; mask, oral-nasal interface; IPPV, intermittent positive pressure ventilation.
tracheostomy tube above the iron lung collar.

4. All patients were trained in the use of mouth IPPV for daytime ventilatory support with the tracheostomy tube plugged. Each patient learned to close off the nasopharynx with his soft palate to prevent nasal leakage. Temporarily pinching the nostrils helped the patient to understand why this was necessary. Patients who had their cuffs inflated for long periods of time initially maintained their vocal cords fully adducted during attempts at mouth IPPV. Each patient was unaware that he was obstructing flow. This was not infrequently mistaken for tracheal stenosis. Each patient successfully relearned the reflex vocal cord abduction that permitted effective mouth IPPV. This took from minutes to up to several weeks of daily attempts, but once mastered, the three times daily sessions of mouth IPPV were prolonged until it was tolerated throughout daytime hours.

Once daytime mouth IPPV was mastered, body ventilators could be used for nocturnal support with the tracheostomy tube plugged. Body ventilator use not only facilitated tracheostomy site closure by relieving the stoma of the positive expulsive pressure which occurs during positive pressure assisted ventilation, but early use of a body ventilator also facilitated training in mouth IPPV by alleviating fear of dyspnea during early trials.

Mouth IPPV normalized speech rhythm, provided normal daytime ventilation, and permitted "air stacking" for volitional sighing, shouting, and assisted coughing. The change to a fenestrated tracheostomy tube often improved the efficacy of mouth IPPV as well as the effectiveness of body ventilator use with the tracheostomy tube plugged and the cuff deflated. It also improved speech volume while on mouth IPPV or on free time whenever possible. The fenestration of the commercially available tubes, however, was at times malpositioned against the posterior tracheal wall where invagination of the tracheal mucosa into the fenestration rendered it ineffective and caused bleeding while exacerbating granulation formation. Proper positioning of the fenestration was accomplished by ordering a custom made fenestrated tube or changing to a smaller sized tube.

5. Patients were advanced to the use of cuffless tracheostomy tubes. The great majority of patients did not require a tracheostomy diameter change to maintain optimal ventilation and speech volume; however, ventilator volumes often needed to be as much as doubled to compensate the increased leakage.

Every patient had a trial of ventilatory support by the IAPV unless he had an abdominal or pelvic osteotomy or indwelling catheter. Several trials were often necessary to determine the optimal belt size and position, and the optimal buckle or VELCRO strap pressures before the IAPV could optimally augment ventilation. The patient also learned to coordinate his breathing to the IAPV. The IAPV effectively ventilated many patients with unmeasurable VC, but it was generally neither effective in the presence of significant back deformity or intrinsic lung disease nor when the patient was less than 30° from supine. The less the patient's free time, the greater the tendency to prefer use of the IAPV over that of mouth IPPV for daytime support. The IAPV provided better cosmesis and permitted the patient to have his mouth free.

6. Ventilator weaning was facilitated by mouth IPPV. The mouth piece was fixed adjacent to the patient's mouth and accessible to the patient by neck rotation. As the patient required fewer assisted breaths, he spontaneously decreased his use of mouth IPPV and thus weaned himself. This technique relieved the anxiety that most patients felt when disconnected from tracheostomy IPPV for periods of autonomous breathing.

Mouth IPPV was also used overnight with a Bennett lip seal. Secure dressings were sometimes necessary to minimize stomal leakage around the plugged tracheostomy tube.

The GPB was taught to all motivated patients. 12. 13. Although patients with VC's below 500 ml, no tracheostomy, intact oropharyngeal muscles, and no free time are the best candidates for learning GPB, some GPB is possible in the presence of a plugged tracheostomy tube with the cuff deflated or removed. The number of milliliters of air per gulp, gulps per breath, and breaths per minute or GPB minute ventilation were observed weekly to monitor patient progress with the technique.

7. When the efficacy of NVA had been established, the tracheostomy tube was usually replaced by a tracheostomy button before definitively allowing the tracheostomy site to close.

8. In general, patients were tried on a variety of methods of NVA and allowed to use the techniques that were effective and which they preferred. No strapless oral-nasal interfaces were constructed for these patients. 12. 13 None of the patients on overnight mouth IPPV required the use of nasal cotton pledges to prevent excessive nasal leakage. 12 As with patients with other conditions, these patients on NVA without a tracheostomy and with no significant free time used nasal IPPV or an IAPV when dental work was needed. 12

During an URI or uncomplicated pneumonia some patients temporarily used an iron lung or Porta-lung (Porta-lung, Inc. Boulder, CO). This assured effective ventilation while freeing the mouth for suctioning and clearing airway secretions. Other patients continued mouth IPPV with deeper and more frequent sighs to improve coughing function and for longer hours because of greater fatigue. Some patients used mouth IPPV simultaneously with a body ventilator during these episodes. Intubation was only necessary for the patient with pneumonia and significant ventilation/perfusion disturbance inadequately compensated by NVA and minimal supplemental oxygen therapy. Standard care including appropriate diagnostic studies, antibiotics, frequent chest physical therapy, postural drainage, and supportive care were also essential during these episodes.

**RESULTS**

All 80 patients including 74 who had arrived on 24-h tracheostomy IPPV with a tracheostomy tube cuff inflated up to 24-h a day, and the four who were intubated, were successfully placed on portable positive pressure volume adjusted, or in some cases, pressure adjusted ventilators. Two patients with late-onset respiratory failure were managed without intubation by nocturnal body ventilator support and were trained in mouth IPPV with portable positive pressure ventilators for daytime aid. The respiratory function of both has subsequently deteriorated and one now requires mouth IPPV throughout daytime hours and has less than 2 h of free time.

Of the 74 tracheostomy IPPV users, all 73 with intact oropharyngeal muscles were successfully converted to fenestrated tubes and used mouth IPPV with their tubes plugged for increasing periods of daytime ventilatory support. Seventy of the 74 patients were also successfully converted to up to 24-h tracheostomy IPPV with completely deflated cuffs with tubes of optimal diameter. All of these patients had effective speech during the ventilator inspiratory cycle. Three patients slept with partially inflated cuffs and did not have wider gauged tubes placed. Three of the four patients who maintained at least partial cuff inflation did so because of severe tracheomalacia due to prolonged cuff use. The fourth patient had significant head trauma with bulbar muscle involvement which
precluded cuff deflation or progression to NVA.

Of the 70 patients who had advanced to 24-h tracheostomy IPPV with completely deflated cuffs, nine were discharged with fully deflated tubes and 12 were advanced to and discharged with cuffless tubes. These patients ceased to use mouth IPPV after discharge. Seven other patients were discharged home on a regimen of overnight tracheostomy IPPV with a cuffless tube and daytime IAPV support or mouth IPPV (Table 2). Of the 42 remaining patients, 27 were weaned. The other 15 patients were supported by NVA at discharge.

Of these 15 initially tracheostomized patients supported entirely by NVA, three had late-onset respiratory failure and no longer had tracheostomies when they presented with respiratory failure. The other 12 patients had medical complications, at times life-threatening, related to their tracheostomies or simply wished to have their tracheostomies removed and continue on NVA. Four of these patients had tracheostomy sites closed despite supine VCs of 50, 430, 740 and 560 ml and no significant free time. All except two patients supported entirely by NVA had their tracheostomy sites closed despite requiring up to 24-h ventilatory support. These two patients had severe tracheal stenosis. A small gauge tube had to be left in place but was not used for assisted ventilation. There were an additional three patients whose respiratory failure was managed only by NVA and who were never tracheostomized for a total of 18 patients supported by NVA without tracheostomy.

Three of the 18 patients with particularly diminished sitting VCs went on to require only long-term daytime mouth IPPV and were able to sleep unaided (Table 2). These patients used 24-h mouth IPPV along with a Bennett lip seal overnight only during colds or periods of extreme fatigue. Two other patients were discharged on only overnight mouth IPPV. Each had numerous attempts at weaning resulting in dyspnea and repeated bouts of pneumonia. Seven patients were discharged on 24-h NVA. For overnight support, six of the seven patients used mouth IPPV and one used a Nu-Mo Suit. For daytime support, six patients used mouth IPPV and one used primarily an IAPV. Patient 3 who was supported by mouth IPPV 24-h a day for four years has been able to get by on overnight mouth IPPV alone for the last 14 years.

In addition, of the six patients who were managed from onset of definitive respiratory insufficiency without tracheostomy (including the three initially tracheostomized patients whose sites were allowed to close but who developed late-onset failure), three were supported by mouth IPPV which they required up to 24-h a day, and three by wrap ventilators for nocturnal aid (Table 2). One of these patients had been converted directly from IPPV via nasotracheal intubation to mouth IPPV.

The seven patients who used NVA for at least one year with no significant free time have done so for a mean of 7.4 ± 7.4 years (1 to 22 years). One patient on 24-h mouth IPPV with a VC of 460 ml and no free time was successfully supported by nasal IPPV for several nights but he preferred to continue with 24-h mouth IPPV.

In all, the 31 patients who regained independent respiration did so for a mean of 2.4 ± 2.2 years (one month to eight years, median 1.7 years) following onset of injury (Table 2). At least five of the weaned patients required and routinely used mouth IPPV during URIs to aid in ventilation and facilitate coughing. Two of these patients used mouth IPPV 24-h a day including overnight with a lip guard for URIs incurred over the last 18 and 31 years, respectively.

Transient oxygen desaturations to 85 percent or less were not uncommon for seconds to up to one minute for patients employing NVA. These periods were sometimes associated with early rapid eye movement sleep and were likely due to transient hypopharyngeal
obstruction or periods of excessive insufflation leakage. They did not appear to be clinically significant nor did they occur in all patients. End-tidal PCO₂ and mean SaO₂ remained normal throughout the night for each patient using these techniques.

Twenty of the 25 patients using NVA were discharged to private residences although this was after a wait of one to six years for ten of the patients. Five patients were discharged to chronic care facilities. The time necessary to convert from tracheostomy IPPV to NVA was from two weeks to three months; however, cuffless tracheostomy tubes or buttons were left in place for up to one year following conversion.

Comparison of patient mortality using NVA with those continuing tracheostomy IPPV was difficult. Thirty-one of the initial 80 patients were weaned (27 from tracheostomy IPPV, four from NVA). Seven patients combined the use of NVA and tracheostomy IPPV including one patient who died suddenly after three years of ventilatory support. An additional seven patients on NVA and three patients on tracheostomy IPPV required aid less than 12-h a day with only one of the latter patients dying for unknown reasons at age 64 after 12 years of overnight tracheostomy IPPV. For only seven patients was NVA the definitive method of 24-h long-term ventilatory support. These patients had a mean age at onset of injury of 25.1 ± 12.1 years. They used 24-h NVA for 12.4 ± 6.3 years. Two of these patients died. One patient died from septicemia associated with massive decubiti following eight years of NVA including seven years of dependence on mouth IPPV 24-h a day. The other patient died from seizure-induced apnea while on mouth IPPV after five years of NVA. The 25 patients who continued 24-h tracheostomy IPPV had a mean age of 30.2 ± 20 years at onset of injury. They used 24-h tracheostomy IPPV for a mean of 7.1 ± 5.1 years. Five of these patients are currently lost to follow-up. Ten of the remaining 20 patients died after 3.8 ± 2.8 years of ventilatory support. Their deaths were associated with pneumonia in four cases, cancer in two cases, accidental tracheostomy disconnection in two cases, aspiration from tracheal hemorrhage, ventilator malfunction, and unknown etiology in one case each.

The longest case of total dependence on NVA was that of a 17-year-old boy (patient 1) who fell from a horse in a school gymnasium on March 10, 1967, and sustained a fracture dislocation of C1,2 and complete C2 quadriplegia. He was immediately and permanently dependent on supported ventilation with no free time. On Sept 27, 1967, a phrenic pacemaker was placed but it was ineffective bilaterally. He remained in a local intensive care unit for ten months with multiple pulmonary infections. He was transferred for rehabilitation in February 1968 with a 16 mm diameter Rausch tracheostomy tube and cuff inflated with 12 ml. He had severe tracheiectomy with a cuff-to-trachea diameter ratio of 3:1. He continued to have frequent formation of purulent mucus plugs while on the Rausch tube which led to one respiratory arrest resulting in partial blindness and two near arrests. Because of these difficulties, he was very motivated for tracheostomy closure.

He began daytime mouth IPPV with a volume ventilator at a rate of 18 and pressure 20 cm H₂O on April 17, 1968. He also began to use an iron lung on July 3, 1968, at a rate of 18 and pressure −17 cm H₂O which gave him a delivered volume of 660 ml, minute volume of 11.8 L, and normal blood gas values. On July 10, 1968, he was placed on a portable pressure ventilator for daytime mouth IPPV. His functionless pacemaker was removed and the Rausch tube was replaced by a metal cuffless tube with the orifice plugged by a custom-made prosthesis during mouth IPPV and iron lung use. Even with the tube plugged, tracheal site leakage prevented more than five minutes of free time by combined GPB and use of accessory muscles. During April 1969, the tracheostomy site was allowed to close after another two episodes of pneumonia. Free time increased to greater than three hours with GPB, and he had a GPB maximum single breath capacity of 1,700 ml. The VC increased to 420 ml by accessory muscle use when sitting. He had trials on the chest shell and the IAPV, neither of which worked as well for him as mouth IPPV or the iron lung. He was discharged to a permanent residence where he was converted from the iron lung to a wrap ventilator overnight. He continues to use mouth IPPV during the daytime and the Pulmowrap overnight. He uses the IAPV only during dental procedures. He has had two episodes of pneumonia resulting from URIs over the last 21 years. Five other patients also mastered GPB sufficiently after tracheostomy site closure to use it for free time during the day and as a back-up in the event of ventilator failure overnight (Table 3).

**DISCUSSION**

Body ventilators and noninvasive direct airway pressure methods, including mouth IPPV and possibly nasal IPPV, can maintain adequate alveolar ventilation in high level quadriplegic patients. This includes the patient with little or no measurable VC and no free time. Contraindications for the use of these techniques have been described and include depressed mental status and severe weakness of oropharyngeal musculature.

Ongoing polysomnography studies in our laboratory indicate that during sleep, the patient can continue conditioned reflex activity to prevent excessive nasal leak when on mouth IPPV and oral leak when on nasal IPPV. Patients who are optimally ventilated from onset
Table 3—Vital Capacity and Maximum Glossoptaryngeal Breaths: Patients on Noninvasive Ventilatory Assistance One Month or More

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<td>450</td>
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<td>690</td>
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<td>22</td>
<td>250</td>
<td>5</td>
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<tr>
<td>23</td>
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<td>22</td>
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<td>&gt;16</td>
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</table>

*The vital capacities recorded were the maximum effort of four to six attempts and were recorded at some time at least two months after onset of ventilatory assistance.
†GPmaxSBC is the glossoptaryngeal maximum single breath capacity.
‡Free time is defined as the average period of time the patient can breathe autonomously before shortness of breath or fatigue necessitate return to ventilatory assistance. The noted free time was from patient assessments within two months of onset of ventilator dependency and the most recent assessment.
§No contact since the year indicated.
||Indicates free time by glossoptaryngeal breathing in a patient that otherwise has <15 min of free time.

of injury and whose chemotaxis centers have not been altered have a tendency to maintain normal sleep blood gas values whether their ventilation is supported by tracheostomy with cuffless tubes or by mouth IPPV or nasal IPPV. The ventilation of patients left to hyperventilate during the daytime or whose hypercarbia is worsened by chronic administration of supplemental oxygen is more difficult to correct by NVA, particularly during sleep. There appears to be involvement of central respiratory control mechanisms in the conditioned reflexes which prevent excessive leakage during sleep. Resort to an oral-nasal interface or the use of cotton pledgets intranasally with mouth IPPV is necessary for a few patients, but none of the patients in this study.

Conversion to NVA is simpler from IPPV via endotracheal intubation rather than from tracheostomy. Unfortunately, few patients are referred to respiratory rehabilitation units while still intubated. Patients with adequate motivation to keep their tracheostomy tubes plugged throughout daytime hours for mouth IPPV and to practice and improve their GPB skills were the most successful at converting to 24-h NVA.

In these patients with little or no expiratory muscle function, unassisted coughing is rarely effective. A much higher than normal incidence of pneumonia results from otherwise benign URIs. Manual assisted coughing requires skill and is effort-intensive. A mechanically forced exsufflation device$^{29-37,39-39}$ is very effective for bronchial toilet in patients with or without tracheostomy. This device provides an adjustable deep insufflation followed by an adjustable pressure drop of about 80 mm Hg in 2/100 s which is sustained for one to two s. This brings airway secretions up to and out of the mouth. This device is coveted by patients who have one in their possession, but it has not been manufactured for the last 25 years. We are currently studying the prototype of a new model.

In conclusion, long-term NVA for patients with traumatic high level quadriplegia can be a safe and effective alternative to tracheostomy IPPV or EPR. Tracheostomy site closure and the mastery of GPB can permit freedom from the fear of accidental tracheostomy disconnection while providing up to hours

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of free time. NVA, and in particular, use of the newly described noninvasive positive airway pressure methods, deserve further study in this patient population.

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