

Evidence-Based Approach to Change in Clinical Practice: Introduction of Expanded Nasal Continuous Positive Airway Pressure Use in an Intensive Care Nursery

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ABSTRACT. *Objective.* Recent studies provide evidence that nasal intermittent positive pressure ventilation (NIPPV) may stabilize the airway of extremely low birth weight infants after endotracheal extubation. The objective of this project was to introduce the use of NIPPV into a busy level 3 intensive care nursery.

Methods. This report describes the process of NIPPV introduction using a series of rapid-cycle improvement projects, as proposed by the Vermont Oxford Network.

Results. In the first cycle, 7 (88%) of 8 infants were successfully extubated with NIPPV after meeting criteria for reintubation on nasal continuous positive airway pressure alone. Proper positioning of the prongs in the nasopharynx was found to be an important determinant of success. In a second cycle, shorter 2.5-cm nasopharyngeal prongs were more effective than standard 4-cm prongs in 12 recently extubated infants as assessed by objective measurements and subjective nursing reports. A third cycle confirmed the acceptance of this technique in our unit and demonstrated an associated decrease in markers of chronic lung disease in extremely low birth weight infants during the 22 months after its introduction.

Conclusion. This experience supports the role for the rapid-cycle change model in achieving effective evidence-based medical practices in a neonatal intensive care setting. *Pediatrics* 2003;111:e542–e547. URL: <http://www.pediatrics.org/cgi/content/full/111/4/e542>; NCPAP, NIPPV, low birth weight, quality improvement, evidence-based medicine, collaborative quality improvement, NIC/Q 2000.

ABBREVIATIONS. NIPPV, nasal intermittent positive pressure ventilation; ELBW, extremely low birth weight; NCPAP, nasal continuous positive airway pressure; RDS, respiratory distress syndrome; Pco₂, partial pressure of carbon dioxide; IMV, intermittent mandatory ventilation; ICN, intensive care nursery; PDSA, plan-do-study-act; CI, confidence interval; NP, binasopharyngeal; RT, respiratory therapy.

KEY POINTS OF ARTICLE

- Recent studies provide evidence that nasal intermittent positive pressure ventilation (NIPPV) may stabilize the airway of extremely low birth weight (ELBW) infants after endotracheal extubation.

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- The introduction of NIPPV into a busy level 3 intensive care nursery was done using a series of rapid-cycle improvement projects
- In the first cycle, 7 (88%) of 8 infants were successfully extubated with NIPPV after meeting criteria for reintubation on nasal continuous positive airway pressure (NCPAP) alone

APPLYING LESSONS LEARNED TO PRACTICE

- Proper positioning of the prongs in the nasopharynx was found to be an important determinant of success.
- Shorter 2.5-cm nasopharyngeal prongs were more effective than standard 4-cm prongs in 12 recently extubated infants as assessed by objective measurements and subjective nursing reports.
- The acceptance of this technique demonstrated an associated decrease in markers of chronic lung disease in ELBW infants during the 22 months after its introduction.
- This experience supports the role for the rapid-cycle change model in achieving effective evidence-based medical practices in a neonatal intensive care setting.

Mechanical ventilation is an important management tool in the treatment of preterm infants with respiratory distress syndrome (RDS).¹ However, prolonged use of an endotracheal tube may cause upper airway damage, alter normal mucociliary flow, and lead to infection and aspiration, all of which increase the risk of chronic lung disease.^{2–6} Even after the acute phase of RDS, extubation failure in extremely preterm infants is common and may be attributable to alveolar atelectasis or poor respiratory drive and coordination.^{7–9} These infants may exhibit increased apnea, respiratory acidosis, and increased oxygen need, which lead to reintubation and subsequent continued ventilation with associated morbidity and costs.

The use of NCPAP was first reported 30 years ago as a way of providing airway support without intubation in selected infants.¹⁰ NCPAP delivers continuous positive airway pressure via 1 of 2 prong types: nasopharyngeal prongs inserted to the level of the nasopharynx or nasal prongs inserted into the nares only. Published studies, including randomized, controlled trials, have reported outcomes of extubation using NCPAP compared with supplemental oxygen by headbox.^{11–20} Although some studies show no

improvement,^{11–14} the majority, including a recent meta-analysis, show a reduction in adverse clinical events, lower “failure” rate of extubation, and decreased incidence of chronic lung disease.^{15–20} More favorable results have been seen with use of positive end-expiratory pressures ≥ 5 cm H₂O and with nasal compared with nasopharyngeal prongs.^{19,21,22} Although physiologic mechanisms of NCPAP are uncertain, it seems to improve functional residual capacity, prevent atelectasis, stabilize the chest wall and upper airway, and reduce the work of breathing.^{7,9,23–27}

Despite reports suggesting efficacy, NCPAP had not been used widely in the intensive care nursery (ICN) at Children’s Mercy Hospital because of experiences with infants who continued to have frequent apneic episodes requiring extensive nursing support and nasal prong readjustment. Recently, investigators have suggested use of NIPPV.^{28–35} With this new evidence, the authors sought to introduce NIPPV into this unit, using a standardized change method as part of the Vermont Oxford Network Collaborative.³⁶ This approach consisted of small cycles of change, each with stated goals and measurements, with careful observation of outcome, modification of approach, and feedback to clinicians. Each cycle is composed of a series of plan-do-study-act (PDSA) steps used to implement and test changes. For individual cycles, specific plans are developed (plan), the plans are conducted (do), the results are evaluated (study), and actions are taken on the basis of what has been learned (act). This article describes the change cycles performed and the resulting outcomes, demonstrating how this approach allowed for acceptance of a new practice in the ICN.

METHODS

Paired sample *t* test and χ^2 analyses were used, as appropriate, with α level set at 0.05 for a 2-sided hypothesis. Confidence intervals (CIs) are given for the difference in the paired measurements. Statistics were performed using SPSS software (SPSS Inc, Chicago, IL). This quality improvement project was reviewed by the University of Missouri-Kansas City Institutional Pediatric Review Board before submission for publication.

When NCPAP support is referred to, all infants who were evaluated in these cycles were supported by binasopharyngeal CPAP.

Cycle 1 (September 1999–November 1999)

Objective

The goal of this quality improvement cycle was to apply the evidence of improved respiratory support using NIPPV in a limited number of patients who were failing extubation.

Measurement

1. Number of infants requiring reintubation following the implementation of NIPPV.
2. Change in number of apneas (defined as no respiratory rate for >15 seconds as measured by the Solar 8000 monitor [GE Marquette, Milwaukee, WI]).
3. Change in partial pressure of carbon dioxide (Pco₂) level after the use of NIPPV.

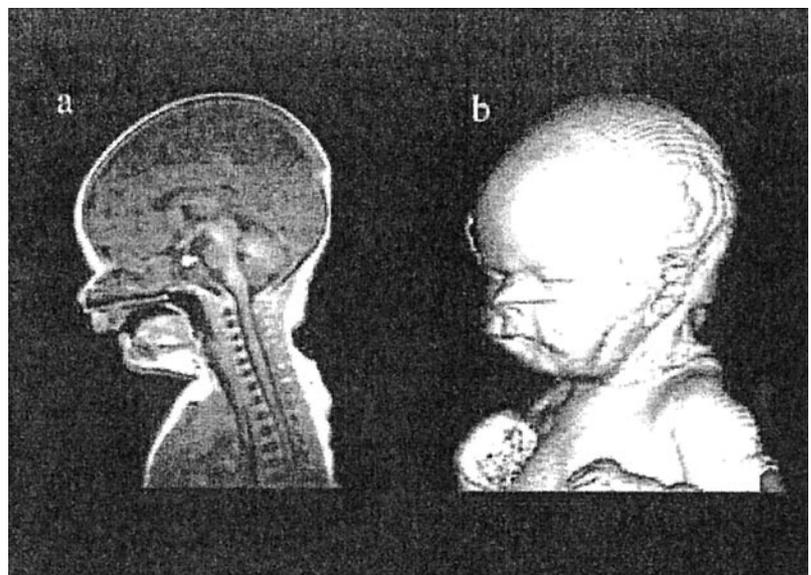
Plan

1. Add intermittent mandatory ventilation (IMV) to all recently extubated infants who had ≤ 1 kg birth weight, were treated by NCPAP with positive end-expiratory pressure 4 to 6 cm, but meet unit criteria for reintubation (>2 apnea/bradycardia spells/hour over 8–12 hours, frequent episodes of arterial oxygen desaturation <85%, rising Pco₂ trends on blood gas determinants, and/or >3 apnea episodes requiring bag/mask ventilation).
2. Record the number of apnea/bradycardia episodes and Pco₂ levels and pair for each patient before and after the change to NIPPV from NCPAP.
3. Use 3-dimensional reconstruction model to facilitate the understanding of appropriate nasal prong placement and nasopharyngeal length in relation to facial landmarks (Fig 1).

Do

1. During a 2-month period, IMV was added to all infants who exhibited evidence of imminent extubation failure, as defined above, and would have been reintubated if this intervention were not available for evaluation.
2. Drager Babylog 8000 ventilators (Drager Medical, Lawrenceville, GA) were used. Because the increase of airflow caused by infant respiratory effort is below the sensitivity of the Drager sensor, the ventilator rate was by IMV modality rather than synchronized to spontaneous ventilation.
3. The position of the 4-cm binasopharyngeal prongs (NP prongs) was reevaluated and secured at a length shorter than their entirety for placement in the nasopharynx. Prongs were taped to a stabilization device (NeoBar; Neotech Product, Inc, Chatsworth, CA).

Fig 1. Image generated using a biomedical imaging visualization tool demonstrating measurement of the length of the nasopharynx compared with distances on the 3-dimensional model of the infant’s head. The length of the nasopharynx consistently correlated to the distance from the tip of the infant’s nose to a point below the eye at the perpendicular to the middle of the eye.



Study

The characteristics of the 8 patients identified during this period were mean birth weight of 696 g (range: 450-1000 g), mean age of 9 days (range: 3-20), and mean days after extubation of 2.0 (range: 1-3). All infants had received intravenous caffeine before extubation and were receiving maintenance dosing. None of the infants had associated pathophysiologic findings (eg, new onset infection, volume overload) to explain respiratory insufficiency.

Seven (88%) of the 8 infants with respiratory failure on NCPAP were supported without endotracheal intubation after introduction of NIPPV. One infant required reintubation within 2 hours of extubation after a short trial of NIPPV (<30 minutes) as a result of severe apneic/bradycardic episodes. The other 7 infants had improved aeration on chest radiograph (Fig 2), improved P_{CO_2} levels on blood gas determinations (66 ± 16.8 TORR vs 50 ± 6.3 TORR, NCPAP and NIPPV, respectively; $P = .008$, 95% CI: 5.7-25.8), and significantly fewer apnea/bradycardia episodes (16 ± 10 events per day vs 4.7 ± 3.4 events per day, NCPAP and NIPPV, respec-

tively; $P = .006$, 95% CI 4.7-18.7). No change in feeding tolerance or feeding complications was identified with use of NIPPV.

When the prongs were inserted too far, problems were noted, including gastric distension, decreased aeration, and, for some, bradycardia. In extreme cases, laryngoscopic examination demonstrated the 4-cm prongs extending into the esophagus when inserted to their full length.

Improved air movement was heard through auscultation when prongs were adjusted to a length equal to the distance measured from the tip of the infant's nose to the point below the middle of the eye (Fig 1), then small adjustments could be made for best air movement and chest rise by clinical examination. For infants 500 to 1000 g body weight, the length of NP prong insertion was 2.0 to 2.5 cm.

Act

1. Disseminate information to all related staff concerning findings.

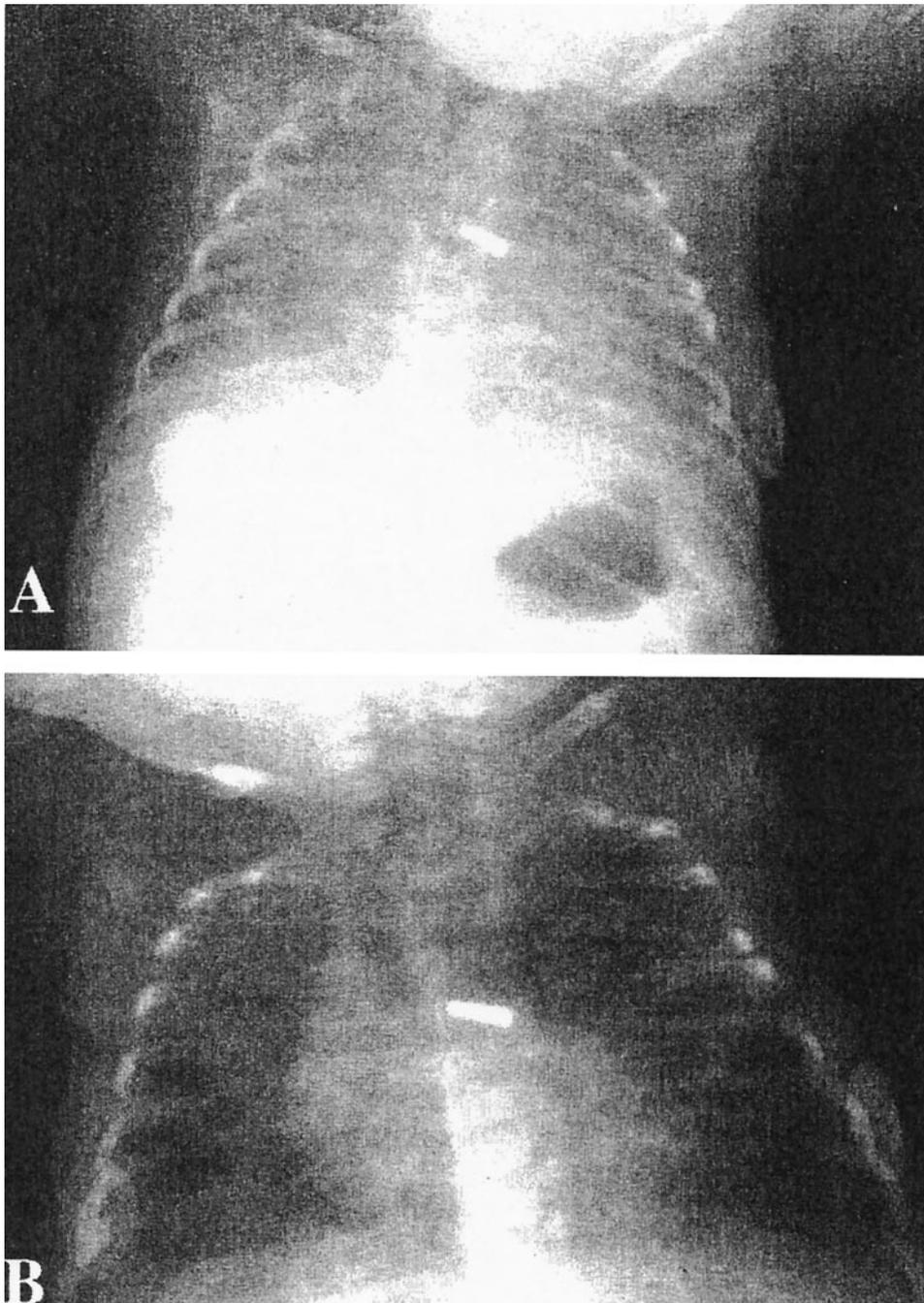


Fig 2. Chest radiographs before and after the addition of IMV to NCPAP in an infant with deteriorating respiratory status.

2. Generate new protocol concerning NIPPV use on infants when there is concern for extubation failure.
3. Continue to collect data concerning days of intubation and measures of chronic lung disease.
4. Continue education of all team members concerning correct insertion point of NP prongs.
5. Search for shorter NP prongs to be used in smaller infants, to decrease potential of error in NP prong placement.

Cycle 2 (December 2000–March 2001)

Objective

With the knowledge generated from the first cycle concerning optimal NP prong length, the goal of the second cycle was to trial 2.5-cm binasopharyngeal “premie” NP prongs (Neotech Product, Inc). These prongs were made specifically for small infants, based on findings from the first cycle.

Measurement

1. Subjective improvement of patient support with premie NP prongs.
2. Change in number of apnea/bradycardia episodes (as defined in cycle 1).
3. Change in P_{CO_2} level when patient changed from 4-cm “standard” NP prongs to premie NP prongs.

Plan

1. Change all infants who are supported by NIPPV and have increasing apnea episodes or rising P_{CO_2} levels from standard NP prongs to premie NP prongs.
2. Record the number of apnea/bradycardia episodes and P_{CO_2} levels and pair for each patient before and after the change in NP prong size.
3. Measure caregiver satisfaction of new premie NP prongs in comparison with standard NP prongs.

Do

1. During a 4-month period, prong size was changed on all infants who were supported by NIPPV and exhibiting increasing apnea episodes or rising P_{CO_2} levels.
2. Questionnaires were distributed to nursing and respiratory therapy (RT) personnel to assess comfort and satisfaction with the 2 types of NP prongs, using a 1 to 10 (best to worst) rating scale.

Study

Characteristics of the 12 patients identified during this period were mean birth weight of 750 g (range: 500-1200 g), gestational age at birth of 26 weeks (range: 23–30 weeks), and day of life of 24 days (range: 3–71 days). All patients were being supported on NIPPV and were receiving intravenous caffeine. None of the infants had associated pathophysiologic findings (new onset of infection, volume overload, etc) to explain respiratory insufficiency.

Four of the infants who were switched to the premie prongs had failed an attempt at extubation using the standard NP prongs and were again extubated using the premie prongs. Within 24 hours of the previous “failure,” all 4 infants were extubated and

maintained using the premie prongs. Fewer apneic episodes were noted in the remaining 8 patients with the use of the premie NP prongs (4.0 ± 2.4 apneic episodes vs 11.5 ± 8.9 apneic events per day, premie NP prongs and standard prongs, respectively; 95% CI: 0.6–9.4; $P = .03$). In addition, infants tended to have less abdominal distention with premie NP prongs.

Caregiver satisfaction was significantly higher for the premie NP prongs in the 5 areas assessed: irritation ($P < .001$), stability ($P = .001$), patency ($P = .007$), positioning ($P < .001$), and comfort level ($P = .001$; Fig 3). Twelve of the 40 caregivers surveyed independently made statements concerning improved air movement and breath sounds on auscultation when using the premie NP prongs compared with the standard NP prongs.

Act

1. Education of all team members.
2. Dissemination of information to all related staff concerning findings.
3. Routine use of premie NP prongs in all infants <1.5 kg.
4. Addition of premie (2.5-cm length) prongs to standard supplies of nursery.

Cycle 3 (July 2001)

Objective

The goal of this cycle was to assess the impact of these quality improvement cycles on unit practice and, as data were available, on infant pulmonary outcome.

Measurement

1. Frequency of NIPPV use.
2. Length of intubation.
3. Number of infants dismissed on oxygen before and during the 22-month period (September 1999–June 2001) of this quality improvement project.

Plan

1. Review charts of infants <1 kg birth weight for length of intubation, use of NCPAP alone, and use of NIPPV.
2. Assess rate of dismissal on oxygen for infants <1 kg before and with the onset of this project.

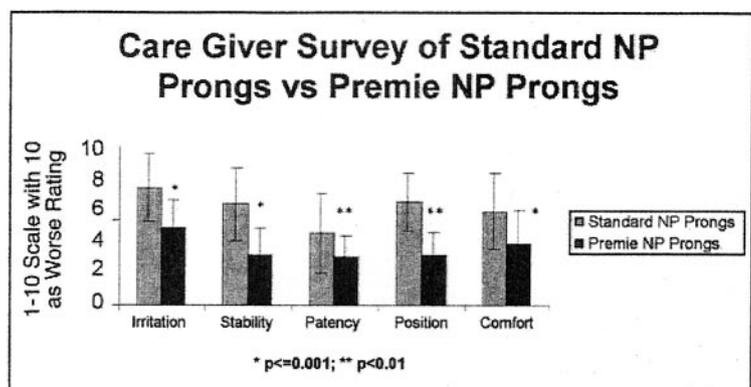
Do

1. Medical records were evaluated for 10 randomly selected infants who were <1 kg birth weight and admitted after the initiation of this project. Charts were selected by medical record number and were reviewed for use of NCPAP alone and use of NIPPV.
2. Days of intubation and dismissal on oxygen were compared between infants who were admitted after the onset of this project and those who were admitted during the 2 years before.

Study

In the year after the onset of these cycles, NIPPV was routinely used for ELBW infants after extubation if apnea or respiratory insufficiency was evident. NIPPV had been used in 9 (90%) of the 10 infants whose charts were randomly reviewed. The mean du-

Fig 3. Caregiver survey of standard NP prongs versus premie NP prongs.



ration of endotracheal intubation for infants <1 kg birth weight decreased after the onset of this project. Mean duration of intubation for 2 years before this project was 27 ± 20 days ($N = 50$), compared with 17 ± 17 ($N = 32$) in the following 22 months ($P = .02$). There was also a significant decline in the number of ELBW infants discharged on supplemental oxygen (75% and 47%, pre- and postperiods, respectively; $P = .01$).

DISCUSSION

Although randomized, controlled trials provide strong evidence for clinical practice, obstacles may remain for introduction of these practices to the clinical service. In some cases, published data may not be directly relevant to local culture and patient population or may not coincide with clinical experience, creating reluctance to introduce change.

At our center, the use of NCPAP in very low birth weight infants had previously been unsuccessful because of recurrent apnea and apparent increased nursing needs. Although there was strong evidence suggesting NIPPV addressed these issues, clinicians remained concerned on the basis of previous experiences.^{37,38} Because the existing literature gave strong evidence that this was a safe and useful intervention, the implementation of this new practice required the rigor of a closely monitored quality improvement trial rather than a repeated research project. Through this trial, NIPPV was introduced in a small number of patients to assess outcome and complications before its use was generalized in the ICN. In this way, the procedure was demonstrated on-site to be useful for support of high-risk infants after endotracheal extubation. During this trial, correct anatomic placement of the NP prongs was determined to relate to effectiveness of therapy. By use of a biomedical imaging visualization tool, important aspects of the newborn airway anatomy were clarified. Proper placement of NP prongs was in the nasopharynx, rather than deeper into the oropharynx, which would direct airflow toward the esophagus rather than the trachea.

The process of estimating and securing the NP prongs at optimal length was a skill set that took increased time, effort, and education to acquire. Experience with the first 8 patients suggested that risk for error in NP prong placement was great because of varied nursing and RT skill levels. This finding led directly to a second quality improvement cycle to assess a shorter length prong. Compared with standard 4-cm NP prongs, the 2.5-cm premie NP prongs were easier to position, less irritating to the nose, and more easily secured. Moreover, in a second sample of patients, 33% (4 of 12) failed extubation with the standard NP prongs but were successfully extubated using the shorter prongs.

After systematic, monitored application of published evidence regarding NIPPV, including introduction of new NP prongs, outcome data were shared with physicians, neonatal nurse practitioners, RTs, and staff nurses. The active involvement of these disciplines and periodic dissemination of knowledge throughout the process allowed for local modifications, and, as a result, the quality improvement process not only supported the published ran-

domized, controlled trials but also facilitated acceptance of the new techniques.

This "trial and learning" approach to improvement based on tests of change, with modification after periodic assessments, has been promoted by the Vermont Oxford Network using the terminology "rapid-cycle improvements."³⁶ An important feature of these cycles is that each individual cycle must address small aspects of a larger concept. Each cycle must be manageable, measurable, and able to be completed rapidly.³⁶ Without the initial sampling in the first 8 patients, the NP prong positioning problem may not have been identified and corrected and may have been the basis for subsequent rejection of the technique.³⁹

Lessons Learned Through This Quality Improvement Project

Evidence regarding NCPAP was adapted from published studies for application in an ICN with unique resources, personnel limitations, and knowledge base. The PDSA quality improvement process allowed for identification of potential complications and modification of procedures for best acceptance in that ICN. After adaptation, NIPPV use was found to facilitate successful extubation in ELBW infants. After initial implementation, NIPPV was associated with a decrease in markers of chronic lung disease. This experience supports the role of the PDSA change model in achieving effective evidence-based medical practice.⁴⁰

ACKNOWLEDGMENTS

This work represents the application of quality improvement methods and resources adopted as a result of participation in the Vermont Oxford Network NIC/Q 2000 Evidence-Based Quality Improvement Collaborative for Neonatology. The project was undertaken as a single-site project, based on local interest at Children's Mercy Hospital, not as part of the subgroup collaborative efforts in the area of respiratory care. The conclusions and opinions expressed are those of the authors and not necessarily those of the participants in the NIC/Q 2000 Collaborative or the Vermont Oxford Network.

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