Comparison of nasal prongs and nasopharyngeal catheter for the delivery of oxygen in children with hypoxemia because of a lower respiratory tract infection

[Original Articles]
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Abstract

Objective: To determine the best method of oxygen delivery for children in developing countries who have hypoxemia caused by acute lower respiratory tract infection.

Methods: One hundred eighteen children between 7 days and 5 years of age with a lower respiratory tract infection and arterial hemoglobin oxygen saturation (SaO2) less than 90 percent were randomly selected to receive oxygen by nasopharyngeal (NP) catheter (n = 56) or nasal prongs (n = 62). A crossover study to determine
the flow rate necessary to achieve an SaO2 of 95 percent was performed in 60 children.

**Results:** One hundred twelve children could be oxygenated by the allocated method; in six oxygenation was poor with either method. The mean duration of therapy was 87.5 hours for the prongs and 94.9 hours for the NP catheter (not significant). The median oxygen consumption was 2142 L for prongs and 1692 L for the NP catheter (not significant). In the crossover study the prongs needed, on average, 26 percent higher oxygen flow rates than the NP catheter to obtain an SaO2 of 95 percent (p = 0.003). Complete nasal obstruction was observed in 24 of the children (44 percent) in the NP catheter group and in 8 (13 percent) in the prongs group (p less than 0.001). Eighteen children died, 11 with NP catheter and 7 with prongs (not significant).

Conclusions: Because nasal prongs are less prone to complications, and oxygenation in children is equally effective, they are a more appropriate method than the NP catheter for oxygen delivery to children in developing countries with acute lower respiratory tract infections. (J Pediatr 1995;127:378-83)

The case fatality rate for pneumonia is inversely related to the arterial hemoglobin oxygen saturation. [1] Because respiratory infections are one of the main causes of death in children in developing countries, [2,3] attention has focused on the provision of cheap and reliable methods of oxygenation in hospitals in developing countries. [4] Because oxygen is expensive, only methods using low flow rates should be used. Two systems are recommended by the World Health Organization [5,6]: nasal prongs and the nasopharyngeal catheter. Table II There has been debate, however, over which method of delivery is preferable. Advocates of the nasal prongs claim that they are safer [7]; advocates of the NP catheter contend that it is more effective in achieving adequate oxygenation. [8] This study was done to determine the safety and efficacy of the two methods of oxygen delivery to young African children.

**METHODS**

Patients. The study was performed in the pediatric ward of the Royal Victoria Hospital in Banjul, the only pediatric referral hospital in The Gambia. In the first year of the study, children with a provisional diagnosis of pneumonia or bronchiolitis were assessed by a trained field assistant. The SaO2, respiratory rate, and temperature were measured. During the second year of the study, all children admitted to the hospital were screened in this way. Children with pneumonia or bronchiolitis who were not enrolled in the study on the day of admission were screened the same way on subsequent days in case their condition deteriorated. Children between 7 days and 5 years of age, with an SaO2, measured by
pulse oximeter, less than 90 percent, were eligible for the study if hypoxemia was presumed to be caused by acute lower respiratory tract infection. Children who had cyanotic congenital heart disease or a central diminished response to hypoxemia (hypoventilation) or who had been in the study previously were excluded. A history, physical examination, and chest x-ray study were obtained. Children were randomly selected to receive oxygen by one of the two methods, nasal prongs or NP catheter, by means of a sequential sealed envelope technique with random numbers. For practical reasons, a maximum number of three children could be studied at any time.

Oxygen delivery. Oxygen was supplied from cylinders obtained locally. The flow was adjusted with a flow meter with a range from 0.2 to 4 L/min (Gottlieb Weinmann; Hamburg, Germany). It was humidified with a bubble-through humidifier (Weinmann), to which the delivery system was fixed. In the case of nasal prongs, the tube was fixed directly to the humidifier outlet. The tube ends in two thin barrels, which lead a short distance into the nose (Infant Oxygen Nasal Cannula 1601; Salter Labs, Arvin, Calif.). The prongs were fixed with adhesive tape to the cheeks of the child. In the case of the NP catheter, a connecting tube with hubs at both ends (oxygen connecting tube, Uno Plast A/S; Hundested, Denmark) was fixed to the humidifier and a nasogastric tube was connected tightly to the distant hub. In children who weighed less than 6 kg and required a flow rate less than 1 L/min, a 6F nasogastric tube was used; in all other instances an 8F nasogastric tube was used (Uno Plast A/S). The tube was introduced into the nose a distance equal to that between the lateral side of the ala nasi and the tragus of the ear; as a result, as shown previously, [8] the tip of the NP catheter lay in the nasopharynx. A Nellcor N200 pulse oximeter (Nellcor Inc.; Hayward, Calif.) was fixed to one extremity of the child by means of an N25 transducer. The oxygen flow was adjusted to obtain an SaO2 reading that was consistently just above 95 percent. Pulse oximeter readings were compared with each other for consistent readings. No blood gas analysis was available in The Gambia.

Crossover study. Sixty children were enrolled in a cross-over study. After random selection as described above, children were attached to the first delivery system and the oxygen flow was adjusted to give an SaO2 of exactly 95 percent. After a stable reading had been obtained, the children were left for at least half an hour to confirm stability. They were then changed over to the other delivery system and the flow was adjusted again to obtain a stable SaO2 of 95 percent. The children were left, when this second delivery method was used, for half an hour after a stable reading had been obtained again. The two flow rates were then compared.

Observations and nursing. The children were admitted to the eight-bed special care unit of the pediatric ward, where the patients were cared for 24 hours a day by six to eight specially selected and trained nurses. The children were monitored continuously by use of a pulse oximeter. The alarm limit of the pulse oximeter was set at 95 percent. Nurses were trained to use the oxygen delivery sets and the pulse oximeter, to identify and document episodes of hypoxemia, and to take appropriate action. Flow rates and SaO2 were documented every 2 hours. Nurses removed the delivery system at least twice daily, more often if there were signs of nasal obstruction.

Daily observations were made by the study physician, who documented the flow rate. The nurses' observation sheet was checked for reported episodes of hypoxemia, and the nursing time required during the previous 24 hours was noted. The acceptability of the system was assessed in
three ways: a subjective impression of whether the child was "fighting," whether the child had removed the delivery system, and whether the child had removed the oximeter sensor probe, as a measure of general unrest. If the child's condition was clinically stable, oxygenation was discontinued and the SaO2 in the room air was noted. The temperature of the air and of the water in the humidifier was measured. The NP catheter and prongs were removed, and the amount of mucus in the nose was documented by use of a semiquantitative system: no mucus, 0; little mucus, 1; a considerable amount of mucus but not blocking the nose, 2; and obstruction of at least one nostril by mucus, 3. The nose was examined for ulceration. The oxygen was removed when the child was able to maintain an SaO2 greater than 95 percent in room air for more than an hour.

At the end of oxygen therapy, the outcome and any complications were documented. The total amount of oxygen used was calculated, and the duration of therapy was noted. The cost of oxygen therapy was calculated on the basis that one cylinder of oxygen containing 6000 L cost $31.5 (without transport) in U.S. dollars.

Safety aspects. If children could not be oxygenated with the highest flow rate of 4 L/min, they were switched to the other method. If a serious condition arose that could have been related, at least in part, to the delivery method, the child also was switched to the alternative method. No assisted ventilation is available in The Gambia, so the treatment given represents the best medical care available. Verbal consent was obtained from the caretaker and documented by a field assistant who spoke the appropriate language. The study was approved by the Gambian Government/Medical Research Council and World Health Organization ethical committees.

Statistical analysis. Frequencies were compared with the chi-square test or Fisher Exact Test, as appropriate. Normally distributed continuous variables were compared between groups by the use of a Student t test; those which were not distributed normally were compared by the use of the Wilcoxon rank sum test. The flow rates in the crossover study were compared by means of a paired samples t test. The analysis was performed with the SAS for Windows (SAS Institute Inc., Cary, N.C.), SPSS for Windows (SPSS, Inc., Chicago, Ill.), and EpiInfo (Centers for Disease Control and Prevention, Atlanta, Ga.) software packages.

RESULTS

Patients. One hundred twenty-three patients with an SaO2 less than 90 percent were initially assessed. Five children were excluded--three with cyanotic congenital heart disease and two with central hypopnea and gasping. Thus 118 children were enrolled into the study. Sixty-four of the children (54 percent) were male. The median age of the study patients was 5 months, with a range from 10 days to 58 months. Ninety-six children had a diagnosis of pneumonia. Of these, 13 had measles as a previous or concurrent illness, 8 had congenital, noncyanotic heart disease, 3 had meningitis, 4 had blood film results positive for malaria, and 1 child had human immunodeficiency virus infection. Twenty children had bronchiolitis, one had malaria without any x-ray film evidence of pneumonia, and one child had bronchiolitis obliterans. The median SaO2 on admission was 81 percent (range, 20 percent to 89 percent).
Oxygen therapy. Sixty-two children received oxygen by nasal prongs, 56 by NP catheter. One hundred twelve children were oxygenated satisfactorily with the allocated method, and six could not be oxygenated with the maximum flow of 4L/min. These latter patients were switched to the alternate method but could not be oxygenated with that method, either. All six children subsequently were oxygenated successfully by 2 to 10 hours after admission.

The number of children receiving oxygen decreased as children died or had oxygen therapy discontinued because their condition had improved sufficiently for them to maintain an SaO2 greater than 95 percent in room air. Six children had oxygen therapy discontinued before they could achieve an SaO2 of 95 percent in room air. Three of the six had congenital heart disease and their SaO2 did not improve to 95 percent; the three others were removed prematurely, because the beds were needed for sicker children and the study children were considered clinically stable. The condition of these three children improved during the following days to an SaO2 greater than 95 percent. The Table I shows the number of patients receiving oxygen by the respective modes of delivery and the mean flow rates required for the first 7 days of therapy. No difference between the two methods of delivery was significant. On the first morning after admission, 6 children (5 percent, 3 with prongs and 3 with an NP catheter) required flow rates of more than 1 L/min. Of the children younger than 2 months of age, 9 (24 percent, 5 with prongs and 4 with catheter) required flow rates of more than 0.5 L/min.

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<th>Table I. Number of children receiving each of the two methods of oxygen delivery during the first week of oxygen therapy and the daily mean oxygen flow rates</th>
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<td>The mean duration (plus/minus SD) of therapy for children whose therapy was started with the use of prongs or an NP catheter was 87.5 (plus/minus 70.1) hours and 94.9 (plus/minus 77.7) hours, respectively. After removal from the analysis of the children who died, who had been changed to the other delivery system, or who had been removed from therapy prematurely, the mean duration of therapy was 84 plus/minus 53 hours for the children with prongs and 91 plus/minus 78 hours for the children with the NP catheter. The median amount of oxygen used for these children was 2142 L for the prongs and 1692 L for the NP catheter. None of these differences was statistically significant. The condition of three children deteriorated again several days after oxygen therapy had been discontinued and hypoxemia resulted. They were reconnected to oxygen therapy, but the second oxygen treatment was not included in the analysis.</td>
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Crossover study. Twenty-six of the children achieved an SaO2 of 95 percent or greater with the smallest possible flow rate of 0.2 L/min with both systems. There was a strong period effect; children always needed less oxygen with the second method of delivery. During period 1, the mean flow rate (plus/minus SD) for the prongs was 0.568 (plus/minus 0.435) L/min; for the NP catheter it was 0.422 (plus/minus 0.363) L/min. During period 2, the mean flow rate for the prongs was 0.434 (plus/minus 0.366) L/min and for the NP catheter it was 0.404 (plus/minus
0.409) L/min Figure 1. Overall, the mean flow rate for prongs was 1.26 times that for the NP catheter (p = 0.003, paired samples t test).

Patient acceptability. Eighteen of the children with prongs (31 percent) and 18 of the children with the NP catheter (34 percent) were classified as "fighting" on at least 1 of the first 7 days. The delivery system was removed on at least one occasion by 23 children with prongs (37 percent) and 18 children with the NP catheter (32 percent); the oximeter probe was removed by 11 with the prongs (18 percent) and 16 with the NP catheter (28 percent). None of the differences was statistically significant.

Episodes of hypoxemia. Episodes of hypoxemia (oxygen saturation less than 95 percent) were relatively common in both groups. During the first day of therapy, 34 children with prongs (58 percent) and 29 children with the NP catheter (54 percent) had at least one episode in which the SaO2 fell to less than 95 percent. Thirteen children in each group (22 percent and 24 percent, respectively) had an episode in which SaO2 decreased to less than 85 percent. These differences were not statistically significant.

Nasal obstruction. The degree of nasal obstruction appeared to be consistently higher with the NP catheter. During the first day of treatment, 3 children with prongs (5 percent) and 17 children with the NP catheter (31 percent) had total obstruction of at least one nostril (p less than 0.001). During the first 7 days of treatment, complete obstruction was present on at least one occasion in 8 children with prongs (13 percent) and in 24 children in the NP catheter group (44 percent) (p less than 0.001).

Complications. Among those treated with nasal prongs, one child acquired ulceration of the nose. During the treatment of another child, one arm of the delivery system broke behind the child's head on day 11, resulting in wasting of oxygen and the development of hypoxemia. The fault was detected by the activation of the alarm of the pulse oximeter, and the child survived.

In the NP catheter group, one child had acute gastric distention associated with deep position of the NP catheter, and died. This child was 9 months of age and weighed 4 kg; he had Down syndrome, congenital heart disease, and acute pneumonia. The flow rate was 1 L/min. Another child had an apneic episode associated with severe nasal congestion caused by mucus. This child was 2 weeks of age, weighed 2.2 kg, and had been admitted to the hospital with a diagnosis of
pneumonia. She had received oxygen at a flow rate of 0.4 L/min during the previous 12 hours; she was resuscitated but died later the same day.

Three children were transferred from therapy with the NP catheter to therapy with the prongs. Two had repeated episodes of hypoxemia associated with obstruction of the nose by mucus, and one had mediastinal and subcutaneous emphysema. This last child died later.

Deaths. Eighteen children died. Seven deaths occurred in the group with prongs and were believed to be caused by sepsis/pneumonia (4), measles (1), bronchiolitis obliterans (1), and marasmus (1). Eleven children died in the NP-catheter group. The probable causes of death were sepsis/pneumonia (4), measles (2), apnea (3), and congenital heart disease (2). Most of these deaths were believed to be related to the underlying disease. The children in whom the deaths possibly could be related to the method of oxygen delivery are mentioned above, listed under apnea.

Cost of treatment. Nasogastric tubes, which are used as the NP catheter, cost $0.20 each in U.S. funds. Nasal prongs cost between $2 and $5 each. One cylinder containing 6000 L costs $31.5 in The Gambia, without transport. Because of the skewed distribution of the data, the median amount of oxygen used differed considerably from the mean amount. Because the actual cost is better reflected by the mean, the cost of therapy per child was calculated by multiplying the mean amount of oxygen used (2824 L for prongs and 2996 L for the NP catheter, deaths not excluded) with the cost per liter. The average cost of oxygen treatment per child was $14.83 for the prongs and $15.73 for the NP catheter. The cost of the NP catheters or prongs and the transport of the cylinders should be added to these figures.

DISCUSSION

Both the NP catheter and the nasal prongs produce adequate oxygenation with relatively low oxygen flow rates in the majority of children with hypoxemia. We did not find any patient who could be oxygenated with one of the systems and not with the other. However, some patients needed several hours of therapy to reach an SaO2 of 95 percent. This might indicate intrapulmonary shunting, which decreased as a result of antibiotic or oxygen therapy. In most hospitals in developing countries, oxygen will be given without monitoring the oxygen saturation with a pulse oximeter. The small measured difference in the efficacy between nasal prongs and the NP catheter therefore is not likely to be important in practical terms. The World Health Organization recommendations [6] of 0.5 L/min for children less than 2 months of age and 1 L/min for older infants appear to be adequate for both methods in the older age group, because 95 percent of the children needed flow rates of less than 1 L/min when assessed after the first night of treatment. However, 24 percent of the children less than 2 months of age needed oxygen flow rates of more than 0.5 L/min to achieve an SaO2 of more than 95 percent.

The two deaths in the NP-catheter group, which might have been caused by a complication of the oxygen delivery system--apnea with obstruction of the nose by mucus, and gastric distention--occurred in a unit with better nursing standards than in many other hospitals in developing countries; a nurse was present at all times. Before being enrolled into the study, another child received oxygen in the admission room by NP catheter. On enrollment, a distended abdomen was
noted and the child had a respiratory arrest. The NP catheter was removed and found to have been positioned in the hypopharynx. The child was resuscitated successfully. These case histories indicate that a very high standard of nursing with close patient supervision and frequent suctioning of the nose is necessary for oxygen delivery with the NP catheter. In many hospitals in developing countries, this standard will not be achieved. Thus complications are likely to be more frequent with the NP catheter.

Production of mucus was the main problem in another small study, in which the authors discontinued oxygen delivery by nasopharyngeal catheter because of excessive mucus or nasal irritation in two of six children. [9] These children were returned to therapy using a head hood, a method that uses a high oxygen flow rate and is therefore expensive. The higher amount of mucus seen in the NP-catheter group is a subjective finding and, because the study could not be masked in that respect, subject to observer bias. The one death, in a child with nasal obstruction, and the very frequent obstruction in two children whose therapy was switched indicate, however, that obstruction of the nose by mucus is important. The higher frequency of total obstruction of at least the nostril in which the catheter was placed might be related to the position of the exit holes in a nasogastric tube, which was used for oxygen delivery: the end of the tube is closed and rounded, and there are two holes, 8 mm and 16 mm from the tip. These direct the oxygen flow to the side, against the mucous membrane, which may result in irritation of the nose with increased secretion of mucus. The prongs, in contrast, direct the flow into the middle of the nostril. The relatively high differences in the transcutaneous partial pressure of oxygen observed in the study of Shann et al., [8] which compared nasal and nasopharyngeal location of the catheter, may have resulted in part from the greater spillage of oxygen with a nasally positioned catheter that has lateral holes. This spillage is likely to be less with the direct jet from the nasal prongs. Tubes with an outlet at the end, which could be used as NP catheters, are available; suction catheters could be used, but the cost of these is similar to the cost of the prongs, and they need a separate supply structure. The risk of gastric distention might increase as well. Another possibility is the nasal position of a catheter. A nasogastric tube is inserted only a few centimeters into the nose. The risk of gastric distention would be less, but with lateral outlet holes the amount of mucus accumulated would be similar to that with the NP catheter. This position was not evaluated in this study. Most of our subjects had nasogastric feeding tubes in addition to the oxygen delivery system. We did not evaluate the effect that they might have had on oxygen delivery.

The biggest disadvantage of nasal prongs is the higher cost. They are not yet widely used, but with increasing demand the cost is likely to come down. However, their price probably will remain higher than that of nasogastric tubes. The prongs can be disinfected and sterilized and therefore used for several patients, but the break in one arm of the prongs on day 11 indicates a limited life span for the device.

We conclude that nasal prongs are as effective as an NP catheter in delivering oxygen to children with a hypoxemia, and they are safer to use. Cost permitting, they are a more appropriate means of oxygen delivery to children with hypoxemia and acute lower respiratory tract infection in hospitals in developing countries.

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