Impact of Pulse Oximetry and Oxygen Therapy on Length of Stay in Bronchiolitis Hospitalizations

Alan R. Schroeder, MD; Andrea K. Marmor, MD; Robert H. Pantell, MD; Thomas B. Newman, MD, MPH

Background: Infants hospitalized with bronchiolitis are frequently monitored with a pulse oximeter. However, there is little consensus on an acceptable lower limit of oxygenation. No previous studies have examined how the use of pulse oximetry and supplemental oxygen therapy affects length of stay.

Objective: To determine the extent to which bronchiolitis hospitalizations are prolonged by a perceived need for supplemental oxygen based on pulse oximetry readings.

Design and Patients: Retrospective case series of subjects younger than 2 years who were hospitalized with bronchiolitis at an academic medical center. Two investigators independently reviewed the hospitalization records of 73 infants and determined at what point an infant met all discharge criteria except oxygenation. We then calculated the extent to which hospitalizations were prolonged by a perceived need for supplemental oxygen therapy based on pulse oximetry readings alone.

Results: Sixty-two infants met inclusion criteria. There was high interrater reliability in determining whether hospitalizations were prolonged ($\kappa=0.75$). In 16 (26%) of 62 patients (95% confidence interval, 15%-37%), the hospitalization was prolonged because of oxygenation concerns. Length of stay was prolonged an average of 1.6 days (range, 1.1-2.0 days) per hospitalization for these 16 patients, or 0.4 day (range, 0.2-0.6 day) per hospitalization for all 62 patients.

Conclusions: Hospitalizations of some infants with bronchiolitis are prolonged by a perceived need for supplemental oxygen therapy based on pulse oximetry readings. Further investigation into outcomes of different levels and durations of oxygen desaturation is needed and would have the potential to reduce practice variability and shorten the length of stay.

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In the United States, viral bronchiolitis causes more than 130,000 hospitalizations per year in children younger than 5 years, at a cost of almost $900 million annually. Considerable practice variation exists, and the length of stay (LOS) varies significantly across institutions. Several studies have examined the effects of bronchiolitis guidelines on use of health care resources and LOS, and have demonstrated that evidence-based guidelines can significantly improve cost-effectiveness.

There is little evidence, however, on the use of supplemental oxygen in infants hospitalized with bronchiolitis. Oxygen is generally administered in cases of cyanosis, moderate or severe respiratory distress, or hypoxemia as indicated by readings from pulse oximetry. Suggested guidelines in the recent pediatric literature for lower limits of acceptable oxygen saturation for bronchiolitis include 90%, 92%, and 94%. However, these guidelines fail to specify acceptable duration of desaturation. Furthermore, even healthy infants younger than 6 months have transient desaturations, at times to below 80%. Therefore, considerable uncertainty remains over when to apply, augment, or discontinue supplemental oxygen therapy. Because supplemental oxygen therapy is not...
The UCSF Committee on Human Research.

Before or after the hospitalization. The study was approved by hospitalization or if home oxygen use occurred immediately.

Chronic lung disease were excluded, as oxygen use in these patients is not representative of routine practice in healthy children.

Continuous pulse oximetry was obtained and supplemental oxygen therapy was used in 100% and 84% of patients, respectively. Patients who were not given supplemental oxygen had higher admission oxygen saturations (97% vs 91%; P = .002) and shorter LOS (1.3 vs 4.0 days; P = .01). Several of these patients were admitted for nonrespiratory reasons (e.g., fever, concern for apnea).

We collected data using a medical chart review protocol developed specifically for this study. Physicians’ daily progress notes and nursing flowcharts were analyzed to determine at what point widely accepted discharge criteria (e.g., feeding well, minimal to no respiratory distress, no outstanding social issues, and requirement of aerosol treatments no more frequently than every 4 hours) were met, except the criteria pertaining to oxygen saturation and supplemental oxygen use. We then estimated the number of days each hospitalization was prolonged, rounding to the nearest day (e.g., prolongations of <12 hours were considered not prolonged, and prolongations of 12-24 hours were considered prolonged for 1 day). This estimation was based on direct documentation (e.g., “patient to remain in hospital until saturations >90%”) or on documentation that the patient continued to receive supplemental oxygen therapy with no other stated reason for continued hospitalization. Two board-certified pediatricians (A.R.S. and A.K.M.) independently reviewed each medical chart. To assess interrater reliability, a κ statistic was calculated for whether or not the hospitalization was prolonged, and a weighted κ was calculated for the number of prolonged days. Cases of disagreement were resolved by consensus after reviewing the case again.

We computed descriptive statistics using Stata Version 7.0 (Stata Corp, College Station, Tex). We used 2-sample t tests to compare predictor variables in patients with vs those without prolonged stays and in patients who were given supplemental oxygen vs those who were not. With no previous estimates of patient characteristics that distinguish these groups, we were unable to make power calculations to detect significant differences between them. A P value of no greater than .05 was considered statistically significant. Sample size was based on a desired 85% confidence interval (CI) total width of 0.5 day and a predicted standard deviation of 1 day for the average number of days that the LOS was prolonged per patient.

We reviewed 73 medical charts and excluded 11 patients using the defined criteria. There was 90% agreement on whether the stay was prolonged (κ = 0.75) and 95% weighted agreement on the number of days prolonged (weighted κ = 0.78). Summary data for patient age, LOS, and oxygen saturation are presented in Table 1. Oxygen saturation cutoffs, as ordered by managing physicians, varied from 88% to 97% (92%). The number of times this cutoff changed during the hospitalization was recorded, as was the difference (if any) between the initial and final saturation cutoff.

**MEASUREMENTS AND VARIABLES**

We performed a retrospective medical chart review of infants hospitalized with viral bronchiolitis at the University of California–San Francisco (UCSF) from October 1, 2000, through September 30, 2002. The UCSF hospital is an academic medical center where the primary team to provide general pediatric inpatient care consists of a pediatric hospitalist, pediatric residents, and third- and fourth-year medical students. Patients younger than 2 years with a primary discharge diagnosis of bronchiolitis (International Classification of Diseases, Ninth Revision code 466.1) were identified through the medical records department. Patients with cyanotic congenital heart disease or chronic lung disease were excluded, as oxygen use in these patients is not representative of routine practice in healthy children. Patients were also excluded if death occurred during the hospitalization or if home oxygen use occurred immediately before or after the hospitalization. The study was approved by the UCSF Committee on Human Research.

<table>
<thead>
<tr>
<th>Table 1. Summary Data on Age, LOS, and Oxygen Saturation for Infants Hospitalized With Bronchiolitis</th>
<th>No. of Patients</th>
<th>Mean (SD)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mo</td>
<td>62</td>
<td>4.5 (4.8)</td>
<td>0-22</td>
</tr>
<tr>
<td>LOS, d</td>
<td>62</td>
<td>3.5 (3.1)</td>
<td>1-17</td>
</tr>
<tr>
<td>Admission oxygen saturation, %</td>
<td>60</td>
<td>92 (5.2)</td>
<td>79-100</td>
</tr>
<tr>
<td>Discharge oxygen saturation, %</td>
<td>59</td>
<td>96 (2.4)</td>
<td>89-100</td>
</tr>
<tr>
<td>Oxygen saturation cutoff as ordered by physician, %</td>
<td>90</td>
<td>93 (1.9)</td>
<td>88-97</td>
</tr>
<tr>
<td>No. of saturation cutoff changes per patient</td>
<td>62</td>
<td>0.64 (0.86)</td>
<td>0-3</td>
</tr>
</tbody>
</table>

Abbreviation: LOS, length of stay.

*Numbers of patients vary by category owing to multiple cutoffs per patient and missing data for some.

Subjects and Setting

We reviewed 73 medical charts and excluded 11 patients using the defined criteria. There was 90% agreement on whether the stay was prolonged (κ = 0.75) and 95% weighted agreement on the number of days prolonged (weighted κ = 0.78). Summary data for patient age, LOS, and oxygen saturation are presented in Table 1. Oxygen saturation cutoffs, as ordered by managing physicians, varied from 88% to 97%; most were in the range of 92% to 95% (“Keep saturations >92%”). The number of times this cutoff changed during the hospitalization was recorded, as was the difference (if any) between the initial and final saturation cutoff.

Statistical Methods

We computed descriptive statistics using Stata Version 7.0 (Stata Corp, College Station, Tex). We used 2-sample t tests to compare predictor variables in patients with vs those without prolonged stays and in patients who were given supplemental oxygen vs those who were not. With no previous estimates of patient characteristics that distinguish these groups, we were unable to make power calculations to detect significant differences between them. A P value of no greater than .05 was considered statistically significant. Sample size was based on a desired 85% confidence interval (CI) total width of 0.5 day and a predicted standard deviation of 1 day for the average number of days that the LOS was prolonged per patient.

We also collected data on the following variables: patient age and sex, LOS (rounded up or down to the nearest day on the basis of time of admission and discharge), supplemental oxygen use, oxygen saturation on admission and discharge, and the acceptable lower limit of oxygen saturation as ordered by the managing physician (eg, “Keep saturations >92%”). The number of times this cutoff changed during the hospitalization was recorded, as was the difference (if any) between the initial and final saturation cutoff.

**RESULTS**

We reviewed 73 medical charts and excluded 11 patients using the defined criteria. There was 90% agreement on whether the stay was prolonged (κ = 0.75) and 95% weighted agreement on the number of days prolonged (weighted κ = 0.78). Summary data for patient age, LOS, and oxygen saturation are presented in Table 1. Oxygen saturation cutoffs, as ordered by managing physicians, varied from 88% to 97%; most were in the range of 92% to 95% (Figure). Continuous pulse oximetry was obtained and supplemental oxygen therapy was used in 100% and 84% of patients, respectively. Patients who were not given supplemental oxygen had higher admission oxygen saturations (97% vs 91%; P = .002) and shorter LOS (1.3 vs 4.0 days; P = .01). Several of these patients were admitted for nonrespiratory reasons (eg, fever, concern for apnea).
Sixteen (26%) of 62 patients (95% CI, 15%-37%) were found to have a prolonged stay. The LOS was prolonged an average of 1.6 days (95% CI, 1.1-2.0 days) per hospitalization for these 16 patients, or 0.4 day (0.2-0.6 day) per hospitalization for all 62 patients.

Patients with a prolonged stay were younger and had lower admission and discharge oxygen saturations, lower average saturation cutoffs, and a higher number of saturation cutoff changes per patient, but none of these differences was statistically significant (Table 2). Although it is possible that infants may have been readmitted to outside hospitals, there were no readmissions to UCSF in either group.

<table>
<thead>
<tr>
<th>Prolonged Stay (n = 16)</th>
<th>Nonprolonged Stay (n = 46)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mo</td>
<td>3.5</td>
<td>4.9</td>
</tr>
<tr>
<td>Admission oxygen saturation, %</td>
<td>89.8</td>
<td>92.4</td>
</tr>
<tr>
<td>Discharge oxygen saturation, %</td>
<td>95.1</td>
<td>96.3</td>
</tr>
<tr>
<td>Saturation cutoff, %, as ordered by physician</td>
<td>92.6</td>
<td>93.4</td>
</tr>
<tr>
<td>No. of saturation cutoff changes per patient</td>
<td>0.88</td>
<td>0.48</td>
</tr>
<tr>
<td>Difference between first and last saturation cutoff, %</td>
<td>−1</td>
<td>−0.5</td>
</tr>
</tbody>
</table>

*Unless otherwise indicated, data are expressed as mean value for the group.

COMMENT

This study describes how pulse oximetry affected LOS in hospitalized infants with bronchiolitis at UCSF. Although multiple previous studies have examined resource utilization and LOS in bronchiolitis, none has specifically addressed the effect of pulse oximetry in actual practice. We found that about one quarter of bronchiolitis hospitalizations were prolonged because of a perceived need for oxygen based on pulse oximetry readings. In other words, had pulse oximetry not been used, these infants may have been discharged earlier. A recent study by Mallory et al16 attempted to link the 250% increase in bronchiolitis admissions during the past 2 decades to increasing pulse oximetry use. Using clinical vignettes, these authors demonstrated that a 2% difference in oxygen saturation measured by pulse oximetry has a significant impact on physicians’ decisions to hospitalize infants with bronchiolitis. Given the lack of understanding about the precise oxygen saturation needs of infants, it is unclear whether these increased admission rates and extended stays are beneficial or detrimental to the infants’ overall health.

Patients in the prolonged group demonstrated trends toward younger age, lower admission and discharge oxygen saturations, lower oxygen saturation cutoffs, and an increased number of oxygen saturation cutoff changes per hospitalization. As this study was the first of its kind, it was not powered to detect statistically significant differences between the prolonged and nonprolonged groups; however, these trends likely represent actual practice. Practitioners tend to be more cautious with younger patients, particularly those younger than 6 months who are at risk for sudden infant death syndrome. Patients with lower admission oxygen saturations are more likely to have continuing desaturations throughout the hospitalization. The increased number of saturation cutoff changes, the lower average cutoff, the greater decrease in the saturation cutoff between the first and last cutoffs, and the lower discharge saturations in the prolonged group may represent an acceptance of lower oxygen saturation as the hospitalization becomes prolonged.

Physicians at our institution accepted 93%, on average, as a lower limit of oxygen saturation. Previous studies have examined bronchiolitis practice guidelines that include 90% as an acceptable lower limit.13,14 These studies demonstrated that although oxygen use and LOS decreased from the preguideline to the postguideline eras, readmission rates did not change, indicating that a saturation of 90% may be a safe cutoff. However, there may be more subtle adverse effects of acute oxygen desaturation, such as neurologic or other end-organ insults, which were not measured in these studies, and the power to detect rare adverse outcomes was limited. Such outcomes admittedly are difficult to measure. However, given that oxygen saturation has emerged as “the fifth vital sign”17 and significantly impacts hospital admission and discharge, more investigation into the short- and long-term outcomes of various levels of saturation is clearly warranted to justify its use.

The costs accompanying bronchiolitis hospitalizations are substantial. In California, where the average LOS for respiratory syncytial virus bronchiolitis was 3.6 days in 2001, the cost per hospitalization was $13 400.1 In this study, we found that LOS was prolonged by 0.4 day per hospitalization because of oxygenation concerns, translating into a cost of approximately $1500 per hospitalization using the California 2001 estimates. The frequency of hospitalizations and the variability in interpretation of pulse oximetry suggest the need for development and implementation of a more standardized approach. Given the substantial costs of bronchiolitis hospitalizations, even a modest reduction in the frequency of prolonged stays has the potential to significantly reduce expenses for inpatient bronchiolitis care. Possible strategies to limit overreliance on pulse oximetry and LOS include (1) discontinuation of pulse oximetry use or transition to intermittent pulse oximetry during the convalescent stage of the illness; (2) strict orders to initiate or increase supplemental oxygen therapy only in cases of increasing respiratory distress or when other maneuvers such as stimulation, suctioning, or repositioning have failed to improve oxygenation; (3) establishing a hospital-wide consensus on an acceptable level and duration of desaturation; and (4) interventions to increase physician involvement in decisions to initiate and increase oxygen therapy, as these decisions are often made independently by nurses and respiratory therapists.

This study has several limitations. As is the case with most medical chart reviews, documentation is often poor and/or illegible. We relied on physicians’ progress...
notes to understand reasons for continued hospitalization, but these reasons are sometimes not included, may differ between physicians, and may not accurately represent clinical decision making. Because of these anticipated barriers, we had 2 investigators independently review each medical chart and we found high interrater reliability. Furthermore, in cases of ambiguity, we erred toward calling the hospitalization nonprolonged; thus, the true effect of pulse oximetry on LOS may have been underestimated. This investigation was limited to one institution and therefore may be limited in its external validity. However, average LOS in our institution (3.5 days) was similar to the reported LOS for respiratory syncytial virus bronchiolitis in all California hospitals in 2001 (3.6 days).3 Given the lack of consensus regarding acceptable oxygenation thresholds for bronchiolitis in the literature, it is likely that this phenomenon extends beyond our center. Finally, given the retrospective nature of the study, we had limited data on the duration of desaturations and on sleep/wake status during desaturations. Such information is an important aspect of pulse oximetry interpretation and should factor into management decisions.

This study did not intend to provide an answer to the question of what level of desaturation is acceptable. Instead, we have attempted to describe a controversial and extremely important management issue of a common disease in children, and in so doing we have contributed to an agenda for further research on evidence-based determinants for bronchiolitis hospitalizations.

Pulse oximetry is used variably in determining discharge and prolongs LOS in approximately one quarter of bronchiolitis hospitalizations of infants and young children. It is unclear whether the increased admission rates and extended hospitalizations that result from reliance on pulse oximetry are beneficial or detrimental to the infants’ overall health. Further evidence addressing outcomes of different levels and durations of oxygen desaturation would have the potential to reduce practice variability and shorten LOS.

Pulse oximetry is used extensively in bronchiolitis management. Although many pediatricians may be familiar with the concept of prolonged hospitalizations secondary to a reliance on pulse oximetry, this is the first study, to our knowledge, to document this occurrence in the pediatric literature.

Our data demonstrate a wide variability in the oxygen saturation cutoffs ordered by managing physicians, reflecting the fact that oxygen saturation guidelines for infants with bronchiolitis are inadequate. Our findings serve as justification and stimulus for further inquiry into appropriate oxygen saturations for infants with bronchiolitis and for consideration of strategies to limit overuse of pulse oximetry.

What This Study Adds

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CONCLUSIONS

Pulse oximetry is used variably in determining discharge and prolongs LOS in approximately one quarter of bronchiolitis hospitalizations of infants and young children. It is unclear whether the increased admission rates and extended hospitalizations that result from reliance on pulse oximetry are beneficial or detrimental to the infants’ overall health. Further evidence addressing outcomes of different levels and durations of oxygen desaturation would have the potential to reduce practice variability and shorten LOS.

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REFERENCES