Original Investigation

Effect of Oxygen Desaturations on Subsequent Medical Visits in Infants Discharged From the Emergency Department With Bronchiolitis

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Editorial

Author Audio Interview at jamapediatrics.com

IMPORTANCE Reliance on pulse oximetry has been associated with increased hospitalizations, prolonged hospital stay, and escalation of care.

OBJECTIVE To examine whether there is a difference in the proportion of unscheduled medical visits within 72 hours of emergency department discharge in infants with bronchiolitis who have oxygen desaturations to lower than 90% for at least 1 minute during home oximetry monitoring vs those without desaturations.

DESIGN, SETTING, AND PARTICIPANTS Prospective cohort study conducted from February 6, 2008, to April 30, 2013, at a tertiary care pediatric emergency department in Toronto, Ontario, Canada, among 118 otherwise healthy infants aged 6 weeks to 12 months discharged home from the emergency department with a diagnosis of acute bronchiolitis.

MAIN OUTCOMES AND MEASURES The primary outcome was unscheduled medical visits for bronchiolitis, including a visit to any health care professional due to concerns about respiratory symptoms, within 72 hours of discharge in infants with and without desaturations. Secondary outcomes included examination of the severity and duration of the desaturations, delayed hospitalizations within 72 hours of discharge, and the effect of activity on desaturations.

RESULTS A total of 118 infants were included (mean [SD] age, 4.5 [2.1] months; 69 male [58%]). During a mean (SD) monitoring period of 19 hours 57 minutes (10 hours 37 minutes), 75 of 118 infants (64%) had at least 1 desaturation event (median continuous duration, 3 minutes 22 seconds; interquartile range, 1 minute 54 seconds to 8 minutes 50 seconds). Among the 118 infants, 59 (50%) had at least 3 desaturations, 12 (10%) had desaturation for more than 10% of the monitored time, and 51 (43%) had desaturations lasting 3 or more minutes continuously. Of the 75 infants who had desaturations, 59 (79%) had desaturation to 80% or less for at least 1 minute and 29 (39%) had desaturation to 70% or less for at least 1 minute. Of the 75 infants with desaturations, 18 (24%) had an unscheduled visit for bronchiolitis as compared with 11 of the 43 infants without desaturation (26%) (difference, −1.6%; 95% CI, −0.15 to ∞; $P = .66$). One of the 75 infants with desaturations (1%) and 2 of the 43 infants without desaturations (5%) were hospitalized within 72 hours (difference, −3.3%; 95% CI, −0.04 to 0.10; $P = .27$). Among the 62 infants with desaturations who had diary information, 48 (77%) experienced them during sleep or while feeding.

CONCLUSIONS AND RELEVANCE The majority of infants with mild bronchiolitis experienced recurrent or sustained desaturations after discharge home. Children with and without desaturations had comparable rates of return for care, with no difference in unscheduled return medical visits and delayed hospitalizations.

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Bronchiolitis is the most common lower respiratory tract infection among infants, characterized by wheeze and respiratory distress.[1] To date, the benefit of pharmacotherapy in the treatment of bronchiolitis has not been demonstrated, and adequate hydration and oxygenation constitute important disposition criteria for this disease.[2-8] Following the introduction of routine oximetry in the 1980s, the hospitalization rate for bronchiolitis rose from 12.9 per 1000 to 31.2 per 1000.[9] Experts feel that this increase in hospital admissions may have happened owing to a high reliance on oximetry.[10-12] Currently, bronchiolitis represents the leading cause of infant hospitalizations in the United States, at an estimated annual cost of $1.73 billion.[13]

The recent American Academy of Pediatrics bronchiolitis guideline suggests that physicians may choose not to administer supplemental oxygen to children with oxygen saturations of 90% and greater.[8] However, the criteria for using oxygen therapy vary widely,[5,8,14] without evidence that oxygen saturations predict disease progression.[11] Indeed, pulse oximetry in bronchiolitis is sometimes used as a proxy for illness severity[8] despite poor correlation between these parameters.[15] This focus on and credence given to oximetry may in part relate to lack of evidence on the natural history of desaturations in bronchiolitis, which are often transient, self-resolving, and frequently not accompanied by increased respiratory distress.

Transient desaturations occur in young healthy infants,[16] especially during sleep,[17] and may also occur in infants with mild bronchiolitis at home. Although it is known that many infants with bronchiolitis remain in the hospital owing to desaturations when other clinical discharge criteria are met,[18] no study to our knowledge has investigated desaturations in bronchiolitis after discharge home from the emergency department (ED) and their effect on use of health care resources. Desaturations occurring in infants with mild bronchiolitis in an ED often result in hospitalizations or prolonged hospital stay.[11] Information on the frequency, severity, and effect of desaturations in infants with mild bronchiolitis will help to shed light on the natural course of bronchiolitis and may provide a better perspective on the clinical significance of these events.

The primary objective of this study of infants with acute bronchiolitis was to determine whether there is a difference in the proportion of unscheduled medical visits within 72 hours of ED discharge in infants with desaturations to less than 90% for at least 1 minute during home oximetry monitoring vs those without desaturations. Secondary objectives were to describe the duration and frequency of the desaturations and to examine the association between desaturations and both all-cause medical visits within 72 hours and delayed hospitalizations.

Key Points

Question: Is there a difference in unscheduled medical visits within 72 hours of emergency department discharge in infants with bronchiolitis with vs without desaturations during home oximetry monitoring?

Findings: In this cohort study of 118 infants, 64% of infants had at least 1 desaturation event. Unscheduled medical visits occurred in 24% of infants with desaturations vs 26% without desaturations, a nonsignificant difference.

Meaning: The majority of infants with mild bronchiolitis experience desaturations after discharge home. Desaturations do not predict the need for additional medical visits.

Methods

Study Design and Population

This was a prospective cohort study comparing outcomes of infants discharged home with acute bronchiolitis from a tertiary care pediatric ED between February 6, 2008, and April 30, 2013. We included previously healthy infants aged 6 weeks to 12 months diagnosed as having bronchiolitis, defined as the first episode of respiratory distress with coryza, cough, wheezing or crackles, and tachypnea or chest retractions.[8] Children with cardiopulmonary, neuromuscular, immunologic, hematologic, or airway anomalies, prematurity with 36 weeks' gestation or less, or known chronic hypoxia were excluded, as were those needing inpatient care and those with poor command of the English language. Written informed consent was obtained from all participating families. The Hospital for Sick Children Research Ethics Board approved the study.

Study Procedure

Infants diagnosed as having acute bronchiolitis about to be discharged home from the ED, without the need for supplemental oxygen, were screened for eligibility and approached for enrollment by 2 trained research nurses on duty between noon and midnight 6 days per week. They maintained a log of all potentially eligible children. A structured data collection form was used to document presenting demographic and clinical parameters. Six portable oxygen saturation monitors (Radical-7; Masimo Corp) were used for home monitoring.

Prior to discharge home, the study nurses applied the saturation probe to a foot of the participating infants and secured its position with a self-adherent wrap and sock to minimize the possibility of displacement. Parents were asked to keep the monitor connected to an electrical outlet whenever possible to avoid battery drain and instructed to avoid submerging the infant's foot in water. Because the standard of home care in children with bronchiolitis does not include oximetry, the study monitor threshold alarms and the display of saturation values were turned off. We did use an alarm for probe dislodgment and instructed caretakers in how to reapply the probe. The caretakers were also asked to fill out a brief diary, with information regarding the time of sleeping, feeding, or sitting in a car seat.

Follow-up

The study monitors and diaries were collected from patients' homes by a courier service and delivered to our hospital's department of respiratory therapy for data analysis. Using standard interviewing techniques, the study nurses, blinded to the oximetry results, conducted telephone follow-up of all participants 72 hours after discharge to identify unscheduled medical visits for bronchiolitis and delayed hospitalizations.

Definitions

Desaturations were defined as at least 1 documented desaturation to less than 90% lasting 1 minute or more. Major desaturations were defined as the following: recurrent, ie, consisting of at least 3 desaturations to less than 90% for at least 1 minute; prolonged, ie, saturations of less than 90% for 10% or more of the monitored time; or sustained, ie, saturations of less than 90% lasting 3 or more minutes continuously. Unscheduled medical visit was defined as a visit to any health care professional due to concern about respiratory symptoms. To further evaluate differences in oxygen saturations between the 2 cohorts, a cumulative hypoxemia score was calculated based on the following previously published formula[19] with minor modification to fit our data capture method: [(percentage of recording time with oxygen saturation of 80% to 89%) × 2.5] + [(percentage of recording time with oxygen saturation of 79% or less) × 4].

Outcome Measures

The oxygen saturation data were downloaded and analyzed from the study monitors using specialized software (PROFOX Oximetry Software; PROFOX Associates, Inc). This software was customized by PROFOX Associates, Inc to capture the key data points for desaturation events as defined in this study. This provided accurate and consistent analysis of the downloaded data and generated a comprehensive report for each patient. The PROFOX software technology also allowed for the analysis of only valid sampling, excluding any artifacts or poor signal. This software eliminates artifacts and distinguishes poor tracings from true desaturations. The PROFOX technology has been used clinically around the world and was also used in several research studies.[20] The respiratory therapist was blinded to the infants' outcome and the software independently determined whether there was a desaturation event, ie, oxygen saturation less than 90% for at least 1 minute. The comprehensive report also included the number of desaturation events, duration of desaturation, mean oxygen saturation, and percentage of time spent with saturations between 80% and 89% as well as less than 80%.

In keeping with the aforementioned definitions, participants were divided into those with desaturations and those without as well as those with major desaturations and those without. The primary outcome measure was an unscheduled medical visit for bronchiolitis within 72 hours of discharge in infants with and without desaturations.[12,21] The secondary outcomes were the following: (1) to describe the duration and frequency of desaturations; (2) to examine the association between desaturations and all-cause medical visits within 72 hours, delayed hospitalizations, and infant activity such as sleeping and feeding; and (3) to determine the association between major desaturations and unscheduled medical visits. We also investigated the association between desaturation and plausible predictors thereof such as age, duration of respiratory distress, previous visits for bronchiolitis, history of atopy, estimated feeding less than 50% of the usual amount, presenting ED oxygen saturation, Respiratory Disease Assessment Instrument severity level at discharge from the ED, and the use of inhaled epinephrine in the ED. The Respiratory Disease Assessment Instrument (range of possible scores, 0-17) is used in bronchiolitis studies to quantify the degree of respiratory abnormality by using severity of chest retractions and wheezing.[22] Exploratory outcomes included a determination of the cumulative hypoxemia score[19] and mean oxygen saturation in infants with desaturations and those without.

Sample Size

The sample size was estimated to provide 80% power for a targeted 20% difference in the primary outcome between the groups. Based on previous literature, we have estimated the overall proportion of bronchiolitis revisits at 20%.[23] Assuming revisit rates of 30% and 10% in infants with vs without desaturation, respectively, and further estimating that 30% of infants with bronchiolitis have desaturation during sleep,[19] we estimated a sample size requirement of approximately 123 analyzable patients, with 41 experiencing desaturations and 82 not.

Statistical Analysis

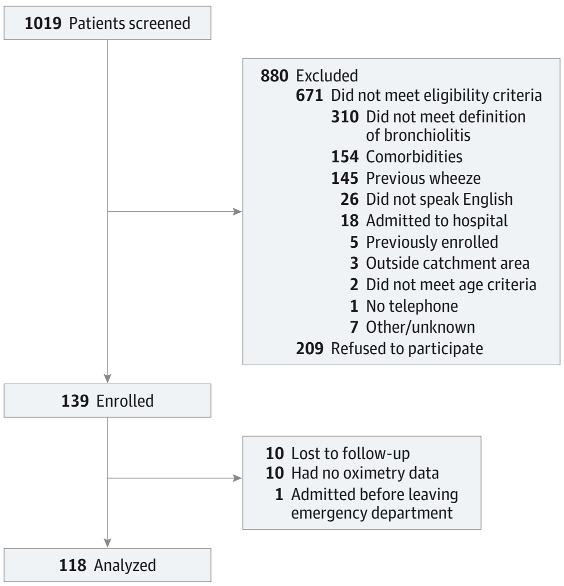
A statistician blinded to the study hypothesis carried out the analysis using SAS version 9.3 statistical software (SAS Institute, Inc). Because the primary hypothesis was 1-sided (ie, do infants with desaturation experience more revisits than those without desaturation?), the difference in the primary outcome between the groups was compared using the 1-sided unadjusted Fisher exact test. All other analyses were 2-tailed. The Fisher exact test was also used to detect the difference in all-cause medical visits and hospitalizations in the 2 groups as well as for the calculation of the difference in the unscheduled medical visits in infants with and without major desaturations. The relevant 95% confidence intervals were determined. Univariate analysis was used to identify patient characteristics to be included in the multiple logistic regression, which determined whether there was a significant independent association between unscheduled visits for bronchiolitis as a dependent variable and the aforementioned plausible predictors thereof. Clinically significant, uncorrelated variables with univariate $P < .20$ were included in the final model. To select the final model, $\alpha = .05$ was used for statistical significance.

Results

During the study period, 1019 patients were screened, 348 met enrollment criteria, and 139 were enrolled in the study (**Figure**). A total of 825 patients presented outside the study hours and 65 were missed. Most refusals occurred because of a lack of interest in research; some parents felt home monitoring would incur too much inconvenience. The mean (SD) age of the included children was comparable with that of those who were missed and those who refused participation (4.5 [2.1], 5.8 [3.5], and 6.0 [3.5] months, respectively). Of the 139 patients who agreed to participate, 118 had both successful follow-up and oximetry records and 103 participants had diary data.

Among the 118 infants included in the analysis (69 male [58%]), the infants with and without desaturations had comparable characteristics, with the exception of more prior medical visits in the group with desaturations (**Table 1**). However, this difference was not significant when adjusted for multiple comparisons.[24] Overall, the mean (SD) monitoring period was 19 hours 57 minutes (10 hours 37 minutes). The mean duration of monitoring was 21.0 hours (95% CI, 18.9-23.2) in children with desaturations and 18.1 hours (95% CI, 14.3-22.0) in those without desaturations (*P* = .18).

Figure. Enrollment of Patients Into the Study



Primary Outcome

Of the 118 infants, 29 (25%) had unscheduled medical visits for bronchiolitis within 72 hours of the index ED visit: 15 returned to their primary care physician, 11 visited an ED, and 3 both saw their primary care physician and visited an ED. Ten of the 29 returning infants (34%) received additional medication: 4 received albuterol, 1 received inhaled corticosteroids, 2 received oral corticosteroids, 2 received antibiotics, and 1 received inhaled epinephrine. Among the 118 infants, 75 (64%) had at least 1 desaturation to less than 90% lasting 1 minute or longer and 43 (36%) had no desaturations. Of the 75 infants with desaturations, 59 (79%) spent more than 1 minute with oxygen saturations of 80% or less and 29 (39%) spent more than 1 minute with oxygen saturations of 70% or less. The median continuous desaturation lasted 3 minutes 22 seconds (interquartile range [IQR], 1 minute 54 seconds to 8 minutes 50 seconds) and the median percentage of monitored time spent with oxygen saturations below 90% was 3.6% (IQR, 1.2%-8.2%).

There were 18 infants with unscheduled medical visits for bronchiolitis symptoms among the 75 infants with desatura-

Table 1. Demographic and Clinical Characteristics of the Participating Infants[a]

Characteristic	Desaturation (n = 75)	No Desaturation (n = 43)	Difference (95% CI)
Age, mean (SD), mo	4.6 (2.3)	4.4 (2.1)	0.2 (−0.66 to 1.02)
Male, No. (%)	41 (55)	28 (65)	−10 (−0.29 to 0.08)
Temperature ≥38°C within 48 h, No. (%)	44 (59)	28 (65)	−6 (−0.25 to 0.12)
History of atopy, No. (%)	57 (77)	33 (77)	0 (−0.16 to 0.16)
Family history of atopy, No. (%)	36 (48)	26 (60)	−12 (−0.31 to 0.06)
Duration of respiratory distress, mean (SD), h	49 (33)	49 (77)	0 (−20.5 to 20.3)
Previous medical visit, No. (%)	52 (70)	21 (49)	21 (0.02 to 0.39)
Feeding <50% of usual amount, No. (%)	34 (46)	13 (30)	16 (−0.34 to 0.02)
Therapy within 48 h of arrival, No. (%)			
Inhaled albuterol	22 (29)	8 (19)	10 (−0.26 to 0.05)
Oral corticosteroids	9 (12)	5 (12)	0 (−0.12 to 0.12)
Inhaled corticosteroids	8 (11)	4 (9)	2 (−0.13 to 0.09)
Any ED treatments, No. (%)	41 (55)	19 (45)	10 (−0.28 to 0.09)
Inhaled albuterol	32 (43)	16 (38)	5 (−0.23 to 0.14)
Oral corticosteroids	16 (21)	10 (24)	−3 (−0.13 to 0.18)
Inhaled epinephrine	9 (12)	2 (5)	7 (−0.17 to 0.03)
At discharge, mean (SD)			
Respiratory rate, breaths/min	42 (10)	44 (10)	−2 (−5.1 to 2.5)
Heart rate, beats/min	146 (17)	144 (14)	2 (−3.4 to 8.7)
Oxygen saturation, %	97.9 (1.9)	98.2 (1.4)	−0.3 (−0.99 to 0.32)
RDAI score at ED discharge, mean (SD)	3.8 (2.3)	3.8 (2.8)	0 (−0.99 to 0.92)
Discharged with albuterol, No. (%)	23 (31)	14 (33)	−2 (−0.16 to 0.19)
Duration of ED visit, mean (SD), h	3.6 (1.9)	3.5 (2)	0.1 (−0.60 to 0.85)
Mean home oxygen saturation, mean (SD), %	95.9 (2.1)	97.9 (1.3)	2.0 (−2.81 to −0.98)

Abbreviations: ED, emergency department; RDAI, Respiratory Disease Assessment Instrument.

[a] Statistical significance was set at $P < .0025$ to adjust for multiple testing.[24]

Table 2. Outcomes of Infants With and Without Desaturation

Outcome	Desaturation (n = 75)	No Desaturation (n = 43)	Difference (95% CI)[a]
Primary			
Unscheduled medical visits, No. (%)	18 (24)	11 (26)	−1.6 (−0.15 to ∞)
Secondary			
All-cause medical visits, No. (%)	24 (32)	16 (37)	−5.2 (−0.13 to 0.23)
Hospitalizations, No. (%)	1 (1)	2 (5)	−3.3 (−0.04 to 0.10)
Exploratory			
Cumulative hypoxemic score, median (IQR)	10.7 (2.7 to 22.6)	0.5 (0.25 to 0.75)	10.2 (6.6 to 13.8)

Abbreviation: IQR, interquartile range.

[a] Differences are expressed as difference in percentages where appropriate and as difference in medians for values not expressed as percentages.

tions (24%) vs 11 returning infants among the 43 without desaturations (26%) (difference, −1.6%; 95% CI, −0.15 to ∞; *P* = .66) (**Table 2**).

Secondary Outcomes

All-cause medical visits within 72 hours of enrollment were made by 24 of the 75 infants with desaturations (32%) vs 16 of the 43 infants without desaturations (37%) (difference, −5.2%; 95% CI, −0.13 to 0.23; *P* = .56). One of the 75 infants with desaturations (1%) and 2 of the 43 without desaturations (5%) were hospitalized within 72 hours (difference, −3.3%; 95% CI, −0.04 to 0.10; *P* = .27) (Table 2).

Among the 118 participating infants, 62 (53%) experienced major desaturations at home; 59 infants (50%) had recurrent desaturations, 12 (10%) had prolonged desaturations, and 51 (43%) had sustained desaturations. Unscheduled medical visits for bronchiolitis symptoms were made by 15 of the 62 infants with major desaturations (24%) as compared with 14 of the 56 infants without major desaturations (25%) (difference, −0.8%; 95% CI, −0.15 to 0.16; *P* = .92). The median cumulative hypoxemic score was 10.7 (IQR, 2.7 to 22.6) in infants with desaturations and 0.5 (IQR, 0.25 to 0.75) in those without desaturations (difference, 10.2; 95% CI, 6.6 to 13.8; *P* < .001). An increase in the cumulative hypoxemic score was not associated with increased unscheduled medical visits (relative risk = 1; *P* = .40).

Based on the univariate analysis, the following variables were included in the multivariate regression: family history of atopy, previous medical visit, feeding less than 50% of the usual amount, and the use of inhaled epinephrine in the ED. The multivariable regression analysis showed the previous medical visits to be independently associated with desaturation (odds ratio = 2.2; 95% CI, 1.0-5.0; *P* = .04). Of the 75 infants with desaturations, 62 (83%) had diary information. Of these 62 infants, 48 (77%) experienced desaturations during sleep or while feeding.

Discussion

Our study shows that the majority of infants with mild bronchiolitis experienced recurrent or sustained desaturations after discharge home. Children with and without desaturations had comparable rates of return for care, with no difference in unscheduled return medical visits and delayed hospitalizations within 72 hours. These findings challenge the concept that infants with desaturations were sicker and suggest that pulse oximetry is not an effective tool to predict morbidity leading to escalated return for care.

Bronchiolitis occurs in young infants who are subject to numerous age-related physiological factors that make this population hypoxia prone. Episodic hypoxia with saturation nadirs as low as 84% to 86% have been previously documented in healthy young infants.[16,25] Sleeping state, feeding, sitting in a car seat, and air travel augment the probability of desaturations,[17,26-28] and the first 2 factors also proved to be true in this study.

Oxygen saturation is routinely used for assessment of bronchiolitis,[29] often with an expectation that an oximetry reading represents a key indicator of a child's health[30] and identifies children at risk for deterioration.[31] However, to date there is no information about how desaturations, which occur without a change in respiratory status yet are severe and long enough to trigger monitor alarms, affect outcomes. Typically, oximeter alarms are preset at saturation thresholds in the vicinity of 90%. If the saturation reading reaches below this threshold, the intensity of monitoring is frequently escalated and supplemental oxygen therapy begun. To accommodate practice variation in oximetry interpretation[32-35] and given the lack of evidence as to the optimal saturation threshold on which to act, the latest American Academy of Pediatrics guideline includes an option not to initiate oxygen therapy in infants with saturation of 90% or greater.[8] Perceived need for supplemental oxygen in bronchiolitis is reported as the sole reason for hospitalization, prolongation of hospital stay, delay in discharge from observation units, and use of oxygen after discharge home.[11,18,36-38] The results of this study suggest that infants with bronchiolitis who are deemed suitable for discharge home from a respiratory and hydration point of view should not undergo further oximetry measurements. This opinion has been expressed in a recent editorial on the frequency of oximetry monitoring in bronchiolitis that points out that well-hydrated infants with bronchiolitis and saturations of 90% or greater should go home and not be monitored further.[39] A recent multisite randomized trial of continuous vs intermittent oximetry concluded that intermittent monitoring can be routinely considered in stable inpatients with bronchiolitis, owing to lack of associated escalation of care, diagnostic testing, or respiratory interventions.[40] One advantage of spot checking is that this approach is less likely to detect transient desaturations of questionable significance. The results of our study underscore the conclusion of the aforementioned trial that the desaturations missed by intermittent oximetry monitoring are likely clinically unimportant in the context of satisfactory clinical status. Of note, many of our participants with desaturations would have undergone significant medical interventions if they had been in a hospital monitoring setting.

Our definition of a desaturation event may be perceived as arbitrary because it was based on expert opinion and observed practice of interpreting oximetry results for escalation of care. Nevertheless, we have also demonstrated a lack of association between the hypoxemic index in our population and both unscheduled return medical visits and delayed hospitalizations, which strengthens the study result. Another limitation of our study is the lack of information on outcomes beyond 72 hours. It is therefore possible that some children required return for care after this time. However, most escalation of bronchiolitis management happens within the initial few days following ED discharge.[21] Although we cannot generalize our study results to the inpatient population, many stable infants with mild to moderate bronchiolitis are observed and monitored in the ED setting prior to discharge. Such infants with self-resolving desaturations should not be subjected to unnecessary medical interventions.[39] The results of this study also do not apply to infants with chronic desaturations due to chronic respiratory conditions. The effect of brief hypoxia on the developing brain is not well characterized and is well beyond the scope of this study. While chronic hypoxia in infants and low sleep saturation in school-aged children have been linked to suboptimal academic performance,[41] there is no evidence that transient desaturations during acute bronchiolitis are associated with adverse outcomes.

Conclusions

The majority of infants with mild bronchiolitis experienced recurrent or sustained desaturations after discharge home. Children with and without desaturations had comparable rates of return for care, with no difference in unscheduled return medical visits and delayed hospitalizations. Pulse oximetry is not an effective tool to predict subsequent return for care.

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Study concept and design: Principi, Coates, Parkin, Schuh.
Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Principi, Coates, Schuh.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: Stephens.
Obtained funding: Principi, Schuh.
Administrative, technical, or material support: Principi, DaSilva, Schuh.
Study supervision: Principi, Schuh.

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