

Upper Airway Obstruction in Neonates: Does Sleep Exacerbate Symptoms?

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Objective: Describe the factors that exacerbate upper airway obstructions (UAOs) in neonates.

Study Design: Retrospective chart review.

Setting: Pediatric tertiary care hospital.

Subjects and Methods: All neonates hospitalized between 1/1/2010 and 12/31/2014 diagnosed with either: 1) laryngomalacia, 2) Pierre Robin sequence, or 3) vocal cord paralysis were included in this study. Patient charts were reviewed to determine factors that exacerbated symptoms of airway obstruction. The independent variable was patient diagnosis, and the outcome measure was exacerbating factors.

Results: In patients with laryngomalacia ($n = 31$), 41.9% worsened with agitation, 38.7% worsened with feeding, 16.1% worsened with positioning, 0.0% worsened during sleep, and 25.8% had no aggravating factors. In Pierre-Robin patients ($n = 31$), 48.4% worsened with agitation, 16.1% worsened with feeding, 61.3% worsened with positional changes, 0.0% worsened during sleep, and 12.9% had no aggravating factors. In vocal cord paralysis patients ($n = 25$), 72.0% worsened with agitation, 8.0% worsened with feeding, 20.0% worsened with positional changes, 4.0% worsened during sleep, and 24.0% had no aggravating factors.

Conclusion: Airway obstruction was not reliably exacerbated during sleep for any of the diagnoses studied in this review. Our findings show that agitation exacerbates airway obstruction in most patients with vocal cord paralysis, and positioning exacerbates airway obstruction in the majority of patients with PRS. Aggravating factors in laryngomalacia are variable. These findings question the utility of polysomnography as a diagnostic tool for hospitalized neonates with these conditions.

Key Words: Upper airway obstruction, neonates, laryngomalacia, vocal cord paralysis, Pierre-Robin sequence.

Level of Evidence: 4.

INTRODUCTION

Upper airway obstruction is a common and potentially devastating problem in neonates. Children born with congenital craniofacial, pharyngeal, or laryngeal abnormalities are at an increased risk for severe upper airway obstruction (UAO). Severe UAO can be caused by

a variety of disease processes, including Pierre Robin Sequence (PRS), laryngomalacia, and vocal cord (VC) paralysis. Diagnosing and treating any UAO associated with these conditions is a central goal of management.

While polysomnography (PSG) is the gold standard diagnostic tool for obstructive sleep apnea in older children,¹ it has become increasingly common to use PSG to determine the extent of other forms of UAO, despite the fact that PSG has not been validated in neonates.² PSG directly monitors and quantifies respiratory events and their consequences during sleep, including hypoxia, hypercapnia, arousals, and awakenings. The concept of using PSG to diagnose UAO is based on the notion that patients have greater structural narrowing of the upper airway during sleep due to decreased neuromuscular tone. The further narrowing of the airway during sleep is an important factor in the pathogenesis of obstructive sleep apnea, justifying the use of PSG for diagnosing UAOs.

However, to our knowledge, no studies have explicitly investigated whether sleep or other specific factors aggravate UAO in neonates. Because using PSG for diagnosing UAO rests on the notion that UAO worsens during sleep, it is important to determine whether sleep actually contributes to UAO in neonates. If sleep does not contribute to or cause UAO in neonates, it is possible that unnecessary PSGs are being performed on many

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neonates with suspected UAO. Furthermore, if clinicians are using PSG to make clinical decisions, the frequency of UAOs in neonates may be underestimated.

The goal of this retrospective review was to determine which factors aggravate obstruction in three common causes of neonatal UAO. We hypothesized that sleep would not be an aggravating factor for laryngomalacia, PRS, or VC paralysis.

MATERIALS AND METHODS

Data was obtained from an internal database of all patients hospitalized in the neonatal intensive care unit (NICU) at Children's-Minnesota, Minneapolis campus, where this study was performed. Institutional Review Board approval was obtained for this study.

Inclusion criteria were all patients born between 1/1/2010 and 12/31/2014 at >35 weeks gestational age with Pierre Robin sequence (PRS), laryngomalacia, or vocal cord (VC) paralysis requiring hospitalization in the NICU. Exclusion criteria included more than one of the study diagnoses, admission after the first four weeks of life, absence of signs or symptoms of upper airway obstructions, or immediate intubation that ultimately required permanent ventilation.

After patients were identified in the database, each chart was reviewed to confirm the diagnosis. Information gathered directly from patient medical records included the presence of desaturation events, the presence of symptoms of airway obstructions, diagnosis, comorbid diseases, the factors that aggravate the airway obstruction, as well as blood gas results. Arterial, venous, and capillary pCO₂ were recorded for each patient when available. If multiple labs were drawn, the pCO₂ that was collected closest to the documented otolaryngology consultation was used. Patients with an arterial pCO₂ > 48 mmHg, capillary pCO₂ > 45 mmHg, or venous pCO₂ > 52 mmHg were considered CO₂ retaining.

Patients in the institution's level four NICU were on continuous pulse oximetry, and desaturation events were recorded in nursing notes throughout the length of the hospitalization. Nurses were assigned to patients either 1:1 or 2:1. The nursing notes contained descriptions of desaturations or obstructive events and routinely described what precipitated these events. In cases where no precipitating factors were listed, patients were classified as having no aggravating factors. Symptoms of airway obstruction included stridor, retractions, increased work of breathing, and apnea, which were also recorded in nursing notes. Aggravating factors included agitation, feeding, positioning, and sleeping. Information gathered from the database included sex, gestational age, birth weight, and length of stay.

RESULTS

There were 87 patients passed both inclusion and exclusion criteria and were included in the study. Thirty-one patients were diagnosed with laryngomalacia, 31 patients were diagnosed with PRS/micrognathia, and 25 patients were diagnosed with VC paralysis. Of the patients with VC paralysis, 4 patients had bilateral paralysis, 19 patients had unilateral paralysis, and 1 patient was unspecified. Overall, there were 47 males and 40 females. The average gestational age was 39.0 (SD = 1.5) weeks. The average birth weight was 3348 (SD = 728.5) grams. The average hospital length of stay was 36.3 (SD = 41.2) days.

TABLE I.
Clinical Manifestations of Upper Airway Obstruction by Diagnosis.

Diagnosis	Total No.	Desaturations Only		Obstructive Symptoms Only		Both	
		No.	Percent	No.	Percent	No.	Percent
Laryngomalacia	31	1	3.2%	13	41.9%	17	54.8%
PRS	31	3	9.7%	5	16.1%	23	74.2%
VC Paralysis	25	0	0.0%	5	20.0%	20	80.0%
Total		4	4.6%	23	26.4%	60	70.0%

PRS = Pierre Robin Sequence; VC = vocal chord.

Overall, the clinical manifestations of upper airway obstruction (Table I) were as follows: 4 (4.6%) patients had oxygen desaturations alone, 23 (26.4%) patients had obstructive symptoms only, and 60 (69.0%) patients demonstrated both oxygen desaturations and obstructive symptoms. For patients with laryngomalacia (n = 31), 1 (3.2%) patient had oxygen desaturations alone, 13 (41.9%) patients had obstructive symptoms only, and 17 (54.8%) patients demonstrated both oxygen desaturations and obstructive symptoms. In patients with PRS/micrognathia (n = 31), 3 (9.7%) patients had oxygen desaturations alone, 5 (16.1%) patients had obstructive symptoms only, and 23 (74.2%) patients demonstrated both oxygen desaturations and obstructive symptoms. For patients with VCP (n = 25), 0 (0.0%) patients had oxygen desaturations alone, 5 (20.0%) patients demonstrated obstructive symptoms only, and 20 (80.0%) patients demonstrated both oxygen desaturations and obstructive symptoms.

For factors exacerbating airway obstruction, we found that 46 (52.9%) patients worsened with agitation, 19 (21.8%) patients worsened with feeding, 29 (33.3%) patients worsened with positional changes, 1 (1.1%) patient worsened with sleep, and 18 (20.7%) patients had no aggravating factors (Table II). In patients with laryngomalacia (n = 31), 13 (41.9%) worsened with agitation, 12 (38.7%) worsened with feeding, 5 (16.1%) worsened with positional changes, 0 (0.0%) worsened during sleep, and 8 (25.8%) had no recognized aggravating factors. In PRS/micrognathia patients (n = 31), 15 (48.4%) worsened with agitation, 5 (16.1%) worsened with feeding, 19 (61.3%) worsened with positional changes, 0 (0.0%) worsened during sleep, and 4 (12.9%) had no recognized aggravating factors. In VCP patients (n = 25), 18 (72.0%) worsened with agitation, 2 (8.0%) worsened with feeding, 5 (20.0%) worsened with positional changes, 1 (4.0%) worsened during sleep, and 6 (24.0%) had no aggravating factors.

Blood gas values were obtained in 65 of the 87 patients included in the study, including 22 (71.0%) patients with laryngomalacia, 27 (87.1%) patients with PRS/micrognathia, and 16 (64.0%) patients with VC paralysis. A pCO₂ value greater than the upper limit of the reference range on either arterial, capillary, or venous blood gas was defined as an elevated pCO₂. Overall, 19 (29.2%) patients who had blood gas laboratories drawn had elevated pCO₂ values, including 4 (18.2%) patients with laryngomalacia, 12 (44.4%) patients with PRS/micrognathia, and 3 (18.8%) patients with VC paralysis.

TABLE II.
Aggravating Factors of Upper Airway Obstruction by Diagnosis.

Diagnosis	Total No.	Agitation		Feeding		Positional		Sleep		None	
		No.	%	No.	%	No.	%	No.	%	No.	%
Laryngomalacia	31	13	41.9%	12	38.7%	5	16.1%	0	0.0%	8	25.8%
PRS	31	15	48.4%	5	16.1%	19	61.3%	0	0.0%	4	12.9%
VC Paralysis	25	18	72.0%	2	8.0%	5	20.0%	1	4.0%	6	24.0%
Total		46	52.9%	19	21.8%	29	33.3%	1	1.2%	18	20.7%

PRS = Pierre Robin Sequence; VC = vocal chord.

DISCUSSION

The purpose of this study was to describe the factors that aggravate UAO in patients with PRS, laryngomalacia, and VC paralysis. Our findings show that patients with laryngomalacia often worsened with agitation and feeding, and occasionally with positioning. This is consistent with a recent review article, which found that stridor in laryngomalacia typically worsens with feeding, crying, supine positioning, and agitation.³ For patients with VC paralysis, our study shows that the majority of patients worsen with agitation. This again is consistent with previous literature, which describe activity or exertion worsening stridor in patients with VC paralysis.⁴ Our findings that positioning exacerbated UAO in patients with PRS were again supported by the literature, where prone positioning has long been used as first-line management and has been shown to successfully treat over half of all patients with PRS.⁵ Almost one out of three (29.2%) patients in our study who had blood gasses drawn showed evidence of respiratory acidosis. Patients with PRS/micrognathia were more likely to have an elevated pCO₂ (44.4%) compared to laryngomalacia (18.2%) or VC paralysis (18.8%). While not all patients had UAOs severe enough to cause a blood gas disturbance, the presence of this cohort confirms the clinical relevance of the UAOs.

Notably, sleep was not found to exacerbate UAO for any of the diagnoses studied in this chart review. While this paper does not analyze PSG data directly, our findings imply that PSG is not the gold standard diagnostic study in this population. Neonates spend most of their time sleeping. If PSG is to be the gold standard for diagnosing neonates with UAO, sleep should be the state in which the obstruction is at its worse. This study found the opposite. Our findings suggest that neonates with the three conditions studied are less obstructed when sleeping, and more obstructed with feeding, agitation, or positioning.

Furthermore, the impact of PSG on patient outcomes in neonates with UAO is relatively understudied. A recent review article summarized the available evidence regarding the role of PSG in the evaluation of PRS and found that there is minimal evidence available to support or refute the use of PSG at this time.² The review found that most studies were retrospective in nature and did not provide detailed reports about how the PSG studies were conducted. In the few studies that did provide details about the use of PSG, both the methods used and the scoring of the study varied greatly. Our study suggests that supine positioning aggravates UAO

in the majority of patients with PRS. For this reason, it is critical that future research studies report positioning of patients during PSG testing, as positioning will likely impact the results of the test. Along these same lines, clinical evaluations of patients with PRS should be performed with the patient supine, as this position will more likely bring out any UAO that is not apparent when the patient is prone.

A recent case report also demonstrates the limitations of PSG as a diagnostic tool for UAOs. Khirani et al. describe a patient who developed stridor and dyspnea 13 months after being successfully decannulated from a tracheotomy for bilateral vocal fold palsy.⁶ Interestingly, the patient had normal nocturnal gas exchange on PSG, despite having increased daytime work of breathing that did not improve on CPAP. This case study suggests that certain UAOs may be missed on PSG. For example, fixed obstructions are likely to be at their best during sleep, when respiratory demand is lowest. This case report, in conjunction with our study results, highlights an important limitation of PSG as a diagnostic tool for UAOs: patients with these conditions may have clinically relevant UAOs that would not be diagnosed with PSG. Although our study does not directly assess the utility of PSG in this population, a prospective study to address this clinical question would be an important area of future research.

Strengths of this study include a relatively long timeframe encompassed by our chart review, enabling more patients to be included in our study. This is also the first study to our knowledge explicitly investigating aggravating factors in neonates with UAO.

Our study has limitations inherent to retrospective reviews based on a database. Although each chart was reviewed to confirm diagnosis, it is possible there were additional patients not correctly entered into the database and therefore missed in our initial database screen. The reliance on nursing notes is another limitation, as there is potential for inconsistent charting and subjective interpretation. However, the intensive care unit (ICU) nurses at the study institution are assigned to patients either 1:1 or 2:1, and have experience caring for patients with the study diagnoses. A further limitation is that the study population is relatively narrow. Patients in our study had disease significant enough to require admission to the NICU, but not so severe as to require immediate intubation with long-term ventilation. Thus, the findings of our study have limited generalizability to other populations. Finally, our study does not directly assess PSG data. Any conclusions therefore

about the use of PSG based on this study are only inferential and require further research to support.

CONCLUSION

UAOs were not reliably exacerbated during sleep for any of the diagnoses studied in this review. Our findings show that agitation exacerbates airway obstructions in most patients with VC paralysis, while positioning exacerbates airway obstruction in most patients with PRS. Aggravating factors for laryngomalacia are variable. Sleep was not found to be an aggravating factor for any of the conditions studied, calling into question the utility of PSG as a diagnostic tool for hospitalized neonates with these diagnoses.

BIBLIOGRAPHY

1. Section on Pediatric Pulmonology, Subcommittee on Obstructive Sleep Apnea Syndrome Clinical Practice Guideline: Diagnosis and Management of Childhood. *Pediatrics* 2002;109(4):1158.
2. Reddy VS. Evaluation of upper airway obstruction in infants with Pierre Robin sequence and the role of polysomnography—Review of current evidence. *Paediatr Respir Rev* 2016;17:80–87.
3. Landry AM, Thompson DM. Laryngomalacia: disease presentation, spectrum, and management. *Int J Pediatr* 2012;2012:1–6.
4. Lyons M, Vlastarakos P V, Nikolopoulos TP. Congenital and acquired developmental problems of the upper airway in newborns and infants. *Early Hum Dev* 2012;88(12):951–955.
5. Evans KN, Sie KC, Hopper RA, Glass RP, Hing AV, Cunningham ML. Robin sequence: from diagnosis to development of an effective management plan. *Pediatrics* 2011;127(5):936–948.
6. Khirani S, Pierrot S, Leboulanger N, et al. Work of breathing as a tool to diagnose severe fixed upper airway obstruction. *Pediatr Pulmonol* 2014; 49(3):e35–39.