Is It Time to Head Home for the Night? Home Sleep Testing in Young Children

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The gold standard for the diagnosis of obstructive sleep apnea (OSA) in children is in-laboratory polysomnography (PSG), and the American Academy of Pediatrics recommends that polysomnography be performed in children with snoring and symptoms or signs of OSA (1). The field's focus on this tool for evaluating OSA (as well as evaluating other sleep disorders) reflects the ability of PSG to comprehensively collect physiological data on respiration, sleep, heart rate, and leg movements in controlled settings where issues of sensor loss can be readily addressed. However, there are key limitations to use and interpretation of such data from single-night laboratory assessments. These include the cost and burden of testing and representativeness of data collected in the laboratory compared with what is typically experienced at home. When ordering an attended in-laboratory PSG, the response from caregivers is rarely enthusiasm. Instead, parents are concerned about the ability of the child to sleep in a strange place, the logistics of finding childcare for other children who cannot accompany the patient, and out-of-pocket expenses related to testing. In the era of coronavirus disease (COVID-19), concerns about bringing children into a sleep laboratory environment now include not just comfort but also safety. Although first-night effects and night-to-night variability in OSA severity estimates are well-recognized limitations to single-night in-laboratory PSG (2, 3), additional concerns are the early termination of studies by technicians working fixed shifts (that end before the child awakens), losing data for the last REM period when OSA may be most severe.

Although home-based sleep apnea testing is widely used in adults to diagnose OSA, its use in children has been much more limited, reflecting concerns about the safety and feasibility of collecting multiple respiratory signals in this population. In this issue of *AnnalsATS*, Vézina and colleagues (pp. 1238–1246) present data on use of home sleep cardiorespiratory monitoring in a large sample ($n = 562$) of very young children using a novel pilot sleep scoring algorithm (4). Notably, with technicians setting equipment up and activating the study in the children's homes and providing families with audio and video equipment to self-monitor potential safety issues (tangled and/or misplaced sensors), 91% of studies were deemed acceptable and no safety issues were reported. Importantly, the average duration of sleep monitored was 573 minutes, a period likely to provide representative sleep data for young children, and substantially longer than total sleep time reported from attended PSGs (5, 6). Although these data support the feasibility of home sleep studies in young children, there are important questions regarding the extent to which this protocol can generalize to other samples (older children, diverse households), is broadly acceptable to families, or can be simplified such that caregivers can be trained to set up equipment.

The primary objective of their study was to provide normative data in a historically understudied population—a worthwhile endeavor that provides data critical to age-specific PSG interpretation. The data reported in this sample on distributions of such parameters as the obstructive and central apnea index, oxygen desaturation index, apnea–hypopnea index, and average oxygen saturation levels are needed for understanding the variation of these parameters in a community sample of children. Notably, the frequency of central apneas exceeded that of obstructive apneas, supporting the relatively high frequency of central events in young children. The mean oxygen desaturation index exceeded 5 (a level generally considered abnormal) and no association was seen between objective parameters and elevated scores on the Pediatric Sleep Questionnaire subscore, underscoring the discordance between objective and caregiver-reported information. Further research testing the ability of statistically defined thresholds for sleep-disordered breathing (SDB) metrics—and their association with subjective reports—to predict clinical morbidity is needed to further inform the utility of sleep studies for clinical decision-making.

A unique aspect of the study by Vézina was the use of a scoring algorithm for

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classifying sleep state from heart rate and movement data in infants. Such data are readily available not only from cardiorespiratory monitors but also from many wearable health devices used in older children and adults, which similarly use those types of data for noninvasively estimating sleep state. Nonburdensome collection of data for estimating sleep state in real-world settings, including over multiple nights, holds tremendous promise for elucidating the role of sleep in health, including how sleep changes with interventions. Further research that defines the role of non–electroencephalogram-defined sleep states in characterizing sleep physiology across the population—including children—could inform a myriad of clinical and research applications, including elucidating longitudinal changes in sleep and sleep disorders with growth and development. Whether such data are best extracted with manual, expert-directed approaches, as done by Vézina and colleagues (4), or can be done more efficiently and objectively using artificial intelligence is a central question as the sleep field adopts advanced technologies.

As the pediatric sleep medicine field also evaluates newer measurement approaches, it is useful to remember the often-quoted refrain "Children are not small adults" when considering multiple aspects of sleep and polysomnography in young children and the implications for adapting home sleep testing in this population. Unattended portable monitoring is recommended for use in adults with a high pretest probability of OSA when performed in conjunction with a comprehensive evaluation by a medical provider (7, 8). In addition to addressing safety concerns about sleeping with sensors attached, and the need for parental oversight/involvement, we need to consider the indications for testing, accuracy of testing, and approach to sensor placement, all of which distinguish pediatric home-based sleep testing from standard adult protocols. The data presented by Vézina and colleagues suggest we can, and perhaps should, view these considerations not as barriers but as opportunities to innovate to study children where they and their parents are most comfortable. Innovations in technology demonstrated by Vézina and colleagues and many others (9) should do much to assuage concerns about safety and feasibility. Although further research is needed to validate these approaches in children, even the gold standard attended PSG–derived apnea–hypopnea index has limitations in terms of assigning severity and predicting long-term consequences.

Finally, as in many areas of health care, disparities in diagnosis, access to care, and treatment outcomes in children with SDB are a significant public health problem (10). SDB is more common in Black children than white children (11), and Black children are less likely to have spontaneous resolution of SDB (12). Higher poverty rates and percentage of children living in single-female–headed households are associated with higher apnea–hypopnea indices (13). What role does the reliance on in-lab PSG play in long-term health disparities related to SDB? In a study of more than 200 children referred from primary care physicians for evaluation of SDB, of whom 87% had public insurance, half of them were lost to follow-up (14). Among those referred for polysomnography, more than three-quarters were lost to follow-up. These parents are voting with their feet—the barriers to bringing their children to a sleep laboratory for an attended PSG are too high for most of them to overcome. In a separate study, it took twice as long for children with public insurance to be treated with adenotonsillectomy following PSG than their peers with private insurance (15). Delay in treatment is likely to have long-term consequences. Treatment of sleep disorders in young children improves outcomes (16), but complete response is the exception rather than the rule (17, 18), suggesting there are critical windows of exposure that have lifelong consequences. Race and poverty adversely affect response to treatment (16, 19). We owe it to children and their families to leverage technology to make it easier to be diagnosed and receive treatment for SDB and other sleep disorders.

Because of the complexities of successfully studying sleep in young children, is it time to challenge ourselves that the default approach of laboratory-based attended sleep studies provides the best care? We have seen an unprecedented rate of change in healthcare delivery in 2020 and a groundswell of support to address health disparities. Using that momentum, as well as advances in technology, to improve comfort and access to care for children with sleep disorders is the right thing to do. ■

Author disclosures are available with the text of this article at www.atsjournals.org.

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Riding a New Wave: Computational Fluid Dynamics Brings Clinical Trials for Tracheomalacia within Reach

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Although tracheomalacia is a widely recognized cause of respiratory morbidity, diagnosis of the condition remains difficult, and prevalence is likely underestimated because of limitations in noninvasive testing (1). Flexible bronchoscopy has long been the gold standard diagnostic test, but because of its invasive nature and because it requires a careful anesthetic approach (i.e., balancing depth of anesthesia that maximizes patient safety and comfort while allowing spontaneous, unobstructed breathing), it has typically been employed for select patients with moderate to severe symptoms to establish initial diagnosis and less so for subsequent evaluation of disease. Importantly, visual assessment of tracheal collapse via flexible bronchoscopy is subject to significant intra- and interrater variability, even at a qualitative level (2). Confounding these limitations, there is a lack of clarity regarding the "normal" degree of tracheal collapse that is present in healthy infants during inspiration and expiration as well as a lack of data that objectively characterize age-dependent variations.

A noninvasive diagnostic modality that can reliably and quantitatively assess tracheal collapse has long been elusive, with earlier methods, including airway fluoroscopy, contrast tracheobronchography, and computed tomography, falling short in one or more of these parameters. Recently, Hysinger and colleagues validated ultrashort echo time magnetic resonance imaging (UTE MRI) as a means to noninvasively assess tracheomalacia in neonates without sedation or ionizing radiation, thereby offering an unprecedented opportunity to objectively characterize tracheal dynamics as well as assess changes over time and in response to potential therapies (3). In an editorial accompanying the Hysinger and colleagues manuscript, we noted our optimism with this technology, but we also lamented that UTE MRI "fails to measure the magnitude of force required to produce that collapse," which is necessary to objectively assess tracheal compliance and determine whether the airway collapse is due to inherent defect in the trachea or excessive forces imposed on it by obstruction in the small airways (4). Though this has yet to be accomplished, an exciting new approach adds a functional component to this structural assessment.

In this issue of *AnnalsATS*, Gunatilaka and colleagues (pp. 1247–1256) demonstrate the utility of UTE MRI to quantify tracheal resistance in infants with tracheomalacia (5). Using computational fluid dynamics (CFD), the authors extracted clinically relevant physiological data from this noninvasive imaging modality, allowing calculation of work of breathing attributed to the defect. This three-dimensional

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