BTS Guideline for diagnosing and monitoring paediatric sleep disordered breathing

Online Appendix 7 Question 7 Evidence Review and Protocol

Q7 For children with suspected sleep disordered breathing, does pulse oximetry or cardiorespiratory sleep study (CRSS) monitoring over more than one night improve the accuracy of diagnosing sleep disordered breathing?

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Question Evidence Review

Q7 For children with suspected sleep disordered breathing, does pulse oximetry or cardiorespiratory sleep study (CRSS) monitoring over more than one night improve the accuracy of diagnosing sleep disordered breathing?

Background

There is some debate as to whether sleep studies over multiple nights confer any benefit in the diagnosis of sleep disordered breathing (SDB). Hence, this review aims to investigate if pulse oximetry or cardiorespiratory sleep study (CRSS) monitoring over more than one night improves the accuracy of diagnosing SDB in children.

Outcomes

Diagnostic accuracy of pulse oximetry, or cardiorespiratory sleep study (CRSS) monitoring for one night, or over more than one night

Evidence Review

The literature search identified 12 papers and seven were deemed relevant to the review. Only one study reported on the diagnostic accuracy of CRSS over more than one night to diagnose SDB in children[1], but no studies reported on the diagnostic accuracy of pulse oximetry over more than one night. Instead, five papers reported on multiple nights of home pulse oximetry and the impact of night-to-night variation within the sleep study groups[2-6]. A final study compared night-to-night variation in CRSS respiratory parameters.[7]

Pulse oximetry

Two studies compared the use of the McGill oximetry score (MOS), acquired over consecutive nights, as a predictor of OSA in children.[2,3] Pavone et al directly compared the accuracy of night one versus night two oximetry measurements to diagnose obstructive sleep apnoea (OSA) in children and an agreement between both nights was found in 143 out of 148 subjects (Spearman's correlation coefficient = 0.90 [0.81, 0.99]).[2] A summary of the results is shown in Table 7a.

Table 7a: Night-to-night variability in pulse oximetry diagnoses of obstructive sleep apnoea in children[2]

		Abnormal oximetry			Inconclusive oximetry			
Subjects	**(No.)**	**Night 1**	**Night 2**	**Total**	**Night 1**	**Night 2**	**Total**	**Agreement**
All	(148)	32	31	34	116	117	114	143/148 (97%)
<4 years old	(68)	20	19	22	48	49	46	63/68 (93%)
≥4 years old	(80)	12	12	12	68	68	68	80/80 (100%)

Pavone et al also reported the night-to-night variation in assessing the severity of OSA using the MOS and a summary of the data is shown in Table 7b.[2]

Table 7b: Night-to-night variability in McGill Oximetry Scores (MOS)[2]

Subjects	**(No.)**	**Agreement**	**Comment**
All	(148)	133/148 (90%)	Spearman's correlation coefficient = 0.91 [0.84, 0.98]
<4 years old	(68)	55/68 (81%)	MOS changed 1 level in 9 subjects and 2 levels in 4 subjects
≥4 years old	(80)	78/80 (98%)	MOS increased from level 3 to level 4 in 2 subjects on night 2

Galway et al similarly investigated variation in MOS scores from data acquired over three consecutive nights of home pulse oximetry recordings in differing groups of participants (Group 1 – otherwise healthy children

with tonsillar ± adenoidal hypertrophy, Group 2 – children with Down syndrome and Group 3 – children with comorbidities other than Down syndrome).[3] A summary of the Night 1 versus Night 2 results and Night 1 versus Night 3 results is shown in Table 7c.

Table 7c: Night-to-night variability in McGill Oximetry Scores (MOS) in three differing subject groups[3]

Group	Agreement	MOS changes on Night 2 or Night 3
	Night 1 versus Night 2	
All*	146/236 (62%)	1 level in 68 subjects, 2 levels in 15 subjects and 3 levels in 7 subjects
Group1†	99/152 (65%)	1 level in 40 subjects, 2 levels in 10 subjects and 3 levels in 3 subjects
Group 2‡	16/27 (59%)	1 level in 9 subjects, 2 levels in 2 subjects and 3 levels in 0 subjects
Group 3§	27/53 (51%)	1 level in 23 subjects, 2 levels in 3 subjects and 3 levels in 0 subjects
	Night 1 versus Night 3	
All*	133/223 (60%)	1 level in 64 subjects, 2 levels in 16 subjects and 3 levels in 10 subjects
Group1†	83/142 (59%)	1 level in 47 subjects, 2 levels in 9 subjects and 3 levels in 3 subjects
Group 2‡	16/26 (62%)	1 level in 7 subjects, 2 levels in 3 subjects and 3 levels in 0 subjects
Group 3§	31/51 (61%)	1 level in 16 subjects, 2 levels in 4 subjects and 3 levels in 0 subjects

* Including Group 1†, Group 2‡, Group 3§ and 8 additional children not assigned to another group due to lack of clinical information

† Group 1 – otherwise healthy children with tonsillar ± adenoidal hypertrophy

‡ Group 2 – children with Down syndrome

§ Group 3 – children with comorbidities other than Down syndrome (achondroplasia (n = 10), arthrogryposis (1), cerebral palsy (2), CHARGE syndrome (1), cleft palate (1) complex neuro-disability (5), cri du chat syndrome (1), Crouzon syndrome (3), macroglossia (1), mitochondrial disorder (4), obesity (5), partial trisomy 9 (1), Pfeiffer syndrome (1), Pierre-Robin sequence (12), Prader-Willi syndrome (18), Rubenstein-Taybi syndrome (4), spina bifida (5), subglottic stenosis (1), Turners syndrome (4) and 22q deletion (1))

Four pulse oximetry studies also compared oximetry metrics between differing nights of oximetry recordings[2,4-6] All results are summarised in Table 7d and shown in supplementary tables 7d-1[2], 7d-2[4], 7d-3[5] and 7d-4[6].

Three studies showed good correlation between night one and night two pulse oximetry metrics in children suspected of SDB.[2,5,6] Although Burke et al showed variation in the oximetry traces acquired over three consecutive nights of oximetry recording, this study group comprised children with and without comorbidities. However, it should also be noted that Burke et al used a different definition to define abnormal oximetry where only desaturations lasting >10 seconds were regarded as abnormal.[4] Children with comorbidities were either excluded[2,6], or not reported[5] in the other three studies.

Comorbidities

Galway et al showed that the mean night-to-night agreement in pulse oximetry MOS scores, acquired over three consecutive nights, was 64% ± 5% for otherwise healthy children with tonsillar ± adenoidal hypertrophy (Group 1, n = 152), 58% ± 4% for children with Down syndrome (Group 2, n = 27) and 54% ± 6% for children with comorbidities other than Down syndrome (mean ± SD for Night 1 versus Night 2, Night 2 versus Night 3 and Night 1 versus Night 3, Night 1 versus Night 2 and Night 1 versus Night 3 data shown in Table 7c).[3] Burke et al also investigated the interpretation of home overnight oximetry recorded over three consecutive nights with the study group including children suspected of OSA with and without comorbidities. Comorbidities included craniofacial abnormalities, central nervous system disorder, Down syndrome and neuromuscular disorder[4] and some of the participants in the Galway et al study[3] were also included in the Burke et al study[4], but different observations were reported. Galway et al only reported MOS levels[3] whereas Burke et al reported oximetry recordings as normal or abnormal, with normal defined as basal SpO_2 ≥94%, <2% of total time with SpO_2<90% and adjusted index (defined as >4% drop in SpO_2 for >10s) <5[4]. A summary of the results is

reported in Table 7e, which shows night-to-night variation in normal oximetry recordings across all diagnostic groups.

Table 7d: Summary of comparisons of differing nights of home/hospital oximetry recordings

Study	Description / Results
Pavone 2013[2]	Two consecutive nights of monitoring Good correlation in mean SpO_2, lowest SpO_2, % of time SpO_2 <90% and falls in saturation ≥4% per hour between night one and night two (r = 0.74, 0.80, 0.91 and 0.95 respectively) (Table 7d-1)
Burke 2016[4]	Three nights of monitoring Some night-to-night variability in mean SpO_2, 'adjusted index' >4% (>4% SpO_2 drop for >10 s per hour) and % of time SpO_2 <90% (Table 7d-2)
Hoppenbrouwer 2018[5]	Two nights of monitoring No significant differences in any of the measured oximetry metrics (signal quality, mean SpO_2, lowest SpO_2, t100-95, t95-90, t90, $ODI_{3,2}$ and $ODI_{3,10}$) (Table 7d-3)
Kirk 2003[6]	Two nights of home monitoring and one night of inpatient monitoring Similar agreement in oxygen desaturation indices between night one and night two (Table 7d-4)

Table 7e: Pulse oximetry recording night-to-night variation in children with and without comorbidities suspected of obstructive sleep apnoea[4]

		Patients with normal oximetry (%)		
Clinical diagnosis	**Patients**	**Night 1**	**Night 2**	**Night 3**
No comorbidities	70	55 (79%)	41 (59%)	38 (54%)
CNS	14	4 (29%)	4 (29%)	3 (21%)
NMD	20	13 (65%)	7 (35%)	10 (50%)
Craniofacial abnormalities	15	6 (40%)	4 (27%)	8 (53%)
Down syndrome	13	6 (46%)	3 (23%)	5 (38%)
Total	**132**	**84**	**59**	**64**

CNS – central nervous system disorder; NMD – neuromuscular disorder

Intra-class correlation analysis of the basal SpO_2, <2% of total time with SpO_2<90% and adjusted index <5 also revealed lower intra-class correlation coefficients for all metrics in the Down syndrome subgroup (Table 7f). The study concluded that there was night-to-night variation in home oximetry readings in children suspected of SDB with, or without comorbidities, but the issue was more marked in children with Down syndrome. However, it should be noted that this is based on very small study size of 13 children with Down syndrome.[4]

Table 7f: Intra-class correlation coefficients over three nights home oximetry monitoring[4]

Diagnosis	Intra-class correlation coefficient [95% CIs]		
	Basal SpO_2	**Time SpO_2 <90%**	**'Adjusted index'**
Suspected OSA only	0.72 [0.62, 0.81]	0.63 [0.51, 0.73]	0.90 [0.85,0.93]
Pooled all non-Down syndrome diagnoses*	0.74 [0.67, 0.80]	0.65 [0.15, 0.78]	0.88 [0.84, 0.91]
Down syndrome	0.48 [0.15, 0.77]	0.48 [0.15, 0.78]	0.54 [0.20, 0.81]

*Suspected OSA only, central nervous system disorder, neuromuscular disorder and structural craniofacial abnormalities

CRSS

Scalzitti et al compared the diagnostic accuracy of inpatient CRSS (one night) and home CRSS (two nights) to diagnose OSA in children. The study was very small (45 participants enrolled, 16 completing two nights of home CRSS) and OSA was defined as an apnoea-hypopnea index (AHI) ≥1. The prevalence of OSA was not reported, but a summary of the results is shown in Table 7g.[1]

Table 7g: Sensitivity and specificity of CRSS to diagnose OSA in children[1]

Age	Home CRSS (night one)		Home CRSS (night two)	
	Sensitivity	**Specificity**	**Sensitivity**	**Specificity**
All	0.70	0.43	0.70	0.83
<6 years old	0.75	0.50	0.70	0.63
≥6 years old	0.57	0.33	0.83	0.80

However, although the Scalzitti et al study suggests an improvement in diagnostic accuracy on night two, this may be due to a tolerance of the equipment and less motion artefact.[1]

A second CRSS study also compared respiratory parameter output (AHI, OAI, hypopnea index (HI), mixed apnoea index (MAI), central apnoea index (CAI), oxygen desaturation index (ODI) and mean SpO_2) from two consecutive nights of home CRSS monitoring in obese children using a type 3 sleep monitor. Although no significant differences were found between the individual night one and night two parameter measurements, 15/30 participants (50%) where found to have a change in the presence or severity of OSA as defined by AHI. A summary of the results is shown in Table 7h.[7]

Table 7h: Comparison of measured OSA severity over two consecutive nights of CRSS monitoring[7]

	Second night			
First night	**Normal AHI** (AHI <2)	**Mild OSA** (2 ≤ AHI <5)	**Moderate OSA** (5 ≤ AHI <10)	**Severe OSA** (AHI ≥10)
Normal AHI	6	4	-	-
Mild OSA	3	4	3	-
Moderate OSA	1	3	2	-
Severe OSA	-	-	1	3

However, it should be noted that out of 86 participants who were enrolled onto the study, only 30 achieved the inclusion criteria of two consecutive nights of at least 3.75 hours of sleep data acquisition with a signal quality >90%.

Evidence Statement

This review had limited supporting evidence.

Between-night pulse oximetry metric variations appear to be limited in children without comorbidities (**Ungraded**)

There is not enough evidence to comment on night-to-night variability in pulse oximetry metrics in children with comorbidities, or cardiorespiratory sleep study metrics in children with, or without comorbidities

Recommendation

- A single night of pulse oximetry monitoring ideally consisting of six hours of continuous sleep duration can be considered adequate for identifying sleep disordered breathing in children without comorbidities (**Conditional** – by consensus)

Good Practice Points

- ✓ A single night of cardiorespiratory sleep study (CRSS) monitoring should also be considered adequate for diagnosing sleep disordered breathing in children without comorbidities
- ✓ If it is anticipated that a child will poorly tolerate a pulse oximetry probe, consider providing a pulse oximeter for more than one night to acquire at least one night of technically adequate data. Alongside the sleep log data, information on how typical the period of sleep was for the child should also be collected
- ✓ If pulse oximetry or CRSS is being considered for diagnosing sleep disordered breathing in children with comorbidities more than one night of monitoring should be considered, particularly if a parent/carer reports that an initial period of monitoring is not representative of the child's sleep
- ✓ If a CRSS is normal but symptoms are ongoing, a repeat cardiorespiratory sleep study should be performed

Research Recommendation

- Further research is needed on night-to-night variability in oximetry parameters for children with comorbidities using modern oximeter technology, in particular in children with Down Syndrome where pulse oximetry is increasingly used as a screening tool for obstructive sleep apnoea syndrome
- Further research is needed into determining the diagnostic effect of cardiorespiratory sleep study (CRSS) monitoring over more than one-night to diagnose obstructive sleep apnoea (OSA) in children with and without comorbidities

Supplementary data tables

Table 7d-1: Comparison of oximetry metrics over two nights of pulse oximetry recording[2]

	Mean ± SD		
Oximetry metric	**Night 1**	**Night 2**	**r**
Mean SpO_2	97.7 ± 1.1	97.8 ± 1.0	0.74
Lowest SpO_2	87.7 ± 11.4	88.3 ± 10.2	0.80
% time SpO_2 <90%	0.5 ± 2.0	0.5 ± 1.7	0.91
Falls in saturation by at least 4%	3.5 ± 6.4	3.8 ± 7.3	0.95

r – Pearson correlation coefficient

Table 7d-2: Comparison of night two versus night three and night one versus night three home pulse oximetry measurements[4]

	Mean difference [95% CIs*]	
Oximetry measurement	**Night 1 – Night 3**	**Night 2 – Night 3**
Mean SpO_2	0.28 [-3.20, 3.70]	0.15 [-2.70, 3.00]
t90	1.07 [-19.8, 17.7]	0.53 [-13.4, 12.3]
ODI_4	0.17 [-9.60, 9.30]	0.63 [-9.40, 8.10]

Bland-Altman 95% limits of agreement

CI – confidence interval; ODI_4 – oxygen desaturation 'adjusted index' (average number of >4% drop in SpO_2 for >10 s); SpO_2 – oxygen desaturation; t90 - time SpO_2 <90% (% of time recorded)

Table 7d-3: Comparison of night two versus night three and night one versus night three home pulse oximetry measurements[5]

Oximetry measurement	**Difference Night 1 – Night 2** (mean ± SE)	***p***
Signal quality	-5.3 ± 4.2	0.63
Mean SpO_2	-0.3 ± 0.4	1.00
Lowest SpO_2	-4.0 ± 1.7	0.01
t100-95	-4.7 ± 3.3	0.47
t95-90	-0.01 ± 1.7	1.00
t90	2.7 ± 1.5	0.23
$ODI_{3,2}$	0.5 ± 0.4	0.79
$ODI_{3,10}$	0.3 ± 0.2	0.32

$ODI_{3,2}$ – oxygen desaturations ≥3% for >2 s; $ODI_{3,10}$ – oxygen desaturations ≥3% for >10 s; SE – standard error; t100-95 - time SpO_2 <100% and >95% (% of time recorded); t95-90 - time SpO_2 <95% and >90% (% of time recorded); t90 - time SpO_2 <90% (% of time recorded)

Table 7d-4: Comparison between night one and night two of home pulse oximetry monitoring and one night of inpatient pulse oximetry using the same device[6]

Comparison	Mean difference [95% CI]
Night 1 – Night 2	0.32 [-8.00, 8.64]

Bland-Altman 95% limits of agreement

CI – confidence interval

References

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3. Galway NC, Maxwell B, Shields M, O'Donoghue D. Use of oximetry to screen for paediatric obstructive sleep apnoea: is one night enough and is 6 hours too much? *Archives of Disease in Childhood.* 2021;106:58-61.
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6. Kirk VG, Bohn SG, Flemons WW, Remmers JE. Comparison of home oximetry monitoring with laboratory polysomnography in children. *Chest.* 2003;124:1702-1708.
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Question Protocol

Field	Content
Review Question	For children with suspected sleep disordered breathing, does pulse oximetry or cardiorespiratory sleep study (CRSS) monitoring over more than one night improve the accuracy of diagnosing obstructive sleep apnoea (OSA)?
Type of review question	Diagnostic accuracy
Objective of the review	There is a difference of opinion as to whether sleep studies over multiple nights confer any benefit in the diagnosis of OSA. This review aims to: • Determine whether the accuracy of predicting OSA is affected by undertaking more than one night of monitoring as opposed to a single night when using either pulse oximetry or cardiorespiratory sleep studies • Identify practical difficulties in undertaking more that a single night of monitoring which might have implications on introducing this into clinical practice • Determine whether children with co-morbidities have more variability in oximetry parameters and AHI as determined by CRSS compared to typically developing children
Eligibility criteria – population / disease / condition / issue / domain	Children (<17 years) with suspected sleep disordered breathing
Eligibility criteria – index test(s)	Pulse oximetry for 1 night of monitoring Pulse oximetry for >1 night of monitoring CRSS for 1 night of monitoring CRSS for >1 night of monitoring
Eligibility criteria – gold standard	Polysomnography
Outcomes and prioritisation	Diagnostic accuracy
Eligibility criteria – study design	Meta-analyses Randomised controlled trials – oximetry versus cardiorespiratory sleep studies Prospective Cohort Studies Retrospective Case Note Reviews

Other inclusion /exclusion criteria	Non-English language excluded unless full English translation Conference abstracts, Cochrane reviews, systematic reviews, reviews Cochrane reviews and systematic reviews can be referenced in the text, but **DO NOT** use in a meta-analysis
Proposed sensitivity / subgroup analysis, or meta-regression	Typically developing children <2 years Typically developing children 2-16 years Children with co-morbidities <2 years Children with co-morbidities 2-16 years
Selection process – duplicate screening / selection / analysis	Agreement should be reached between Guideline members who are working on the question. If no agreement can be reached, a decision should be made by the Guideline co-chairs. If there is still no decision, the matter should be brought to the Guideline group and a decision will be made by consensus
Data management (software)	RevMan5 — Meta-analysis data input. Evidence review/considered judgement. Storing Guideline text, tables, figures, etc. MetaDTA — Data meta-analyses Gradepro — Quality of evidence assessment / Recommendations
Information sources – databases and dates	MEDLINE, Embase, PubMED, Central Register of Controlled Trials and Cochrane Database of Systematic Reviews No date restrictions
Methods for assessing bias at outcome / study level	RevMan5 diagnostic accuracy full review template (based on QUADAS2) (follow instructions in '*BTS Guideline Process Handbook - Diagnostic Accuracy*')
Methods for quantitative analysis – combining studies and exploring (in)consistency	If 3 or more relevant studies: RevMan5 for forest plots, summary ROC plot MetaDTA to combine studies (pooled specificity, sensitivity, likelihood ratios, diagnostic odds ratio and confidence intervals) and calculate RevMan parameters for summary ROC plot (follow instructions in '*BTS Guideline Process Handbook - Diagnostic Accuracy*')
Meta-bias assessment – publication bias, selective reporting bias	GRADEpro — Diagnostic accuracy quality of evidence assessment for each index test (follow instructions in '*BTS Guideline Process Handbook - Diagnostic Accuracy*')

Rationale / context – what is known	The body of literature is small and conflicting as to whether multiple nights of monitoring confers additional diagnostic capability over a single night. Most of the literature refers to oximetry studies. The practicalities of undertaking multiple nights of CRSS monitoring in an NHS environment needs consideration.