Sleep Medicine Disruptors: Change Agents

Virtual Paediatric Level 1 Polysomnography – A new model of care in Paediatric OSA

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Obstructive sleep apnoea (OSA) is a medical condition heralded by snoring which leads to partial or complete upper airway collapse during sleep. It affects about up to 5% of children (1) and is most commonly caused by adenotonsillar hypertrophy. It may also be influenced by many other contributors such as obesity, allergic rhinitis and structural abnormalities of the face, neck and jaw. In childhood, left untreated, the condition can potentially cause deficits in attention and concentration, growth delay, high blood pressure and other cardiovascular complications (2)(3-5).

Diagnosis of OSA in children is difficult on history and examination alone. Establishing an objective diagnosis depends on overnight evaluation and quantification of respiratory parameters during sleep. The current gold standard diagnostic test remains in-laboratory attended polysomnography(PSG) (6) - also known as a Level 1 PSG. It is a multichannel test complete with video, audio, and attendance by a trained sleep scientist. Whilst Level 1 PSG's remain the paediatric gold standard in 2021, this test is far from perfect. Level 1 PSG's are time-intensive, expensive, and mostly tertiary based which means they remain a limited service (7). Hospital waiting lists for this test are long and worldwide have worsened during the COVID-19 pandemic. For example, in our institution at the Royal Children's Hospital (RCH) Melbourne, the waiting time has more than doubled in the last year, currently standing at 10 months from the time a paediatric sleep specialist orders the test. Patients in rural and remote areas are further disadvantaged in accessing this service. The result is that diagnosis and subsequent treatment of OSA in children is often delayed. This bears a significant health burden to the child - with both immediate and long-term impacts (8).

In Australia like many countries around the world, there are further barriers to care of children with OSA such as long waiting times for the initial sleep specialist consultation and relatively few Paediatricians trained in analysis and reporting of sleep studies in tertiary centres. Most Paediatric centres run services focused on the gold standard Level 1 PSG. In our service at the RCH we also facilitate level 2 PSG's, which are limited channel unattended studies performed in the home. Although this approach is mainstream in adult sleep medicine (9), and these studies are

feasible and convenient for children and families (10, 11), there are recognised diagnostic limitations in children which potentially lead to under-estimation of the degree of obstruction (10).

More specifically, these issues are secondary to the absence of a camera, audio, a surrogate measure of carbon dioxide and attendance by a sleep scientist to ensure electrode and sensor signals are adequate. Safety issues associated with unattended studies in children have also been raised. The American Academy of Sleep Medicine (AASM) does not recommend level 2 PSG's in children (12).

A further problem arises when it comes to funding these services in the Australian healthcare system. Outpatient consultations and the studies themselves are funded in separate ways. Whilst outpatient consultations are funded through a federally administered system of public healthcare for patients, the sleep studies are covered by state government administered funding for hospitals.

Putting this all together: the inherent delays of clinic wait times, PSG waiting times, access issues, limitations on current home PSG options and complexity with respect to funding streams amounts to sub-optimal care for children with OSA. The current system is inefficient and potentially impacts clinical efficacy. We believe that a new model of care is needed, and we think we've "cracked the case".

A recent audit of our level 2 home PSG service provided evidence that patients and families prefer to have sleep studies performed at home and sleep in their own bed (unpublished data). There is also mounting evidence from around the world during the COVID-19 pandemic that the convenience of telehealth consultations improves efficiency and satisfaction in already busy family life (13). Hence our team has developed a virtual health solution that uses telehealth consultations with paediatric sleep specialists, and virtual home sleep studies that have equivalent quality to the gold standard level 1 PSG.

Our optimised and novel home PSG equipment comes packed in a "suitcase" ready to travel. The suitcase itself contains equipment capable of level 2 PSG acquisition, with the addition of a transcutaneous CO₂ monitor, camera and audio channels to bring it up to a level 1 PSG capability. There is a laptop with 4G SIM card and software that allow access to the hospital's VPN and servers. The hard-shell suitcase ensures protection during transportation to and from the Patient's home.

Our sleep nurse travels to the patient's home to set the study up under our Hospital in the Home (HITH) service. There are established safety and security procedures which include risk assessment, a modern vehicle fleet, and multiple monitoring and communication measures for personal safety.

Sleep study data is livestreamed back to the hospital hub, and studies are virtually attended and monitored by trained sleep scientists. This allows for monitoring of signal adequacy and if an electrode adjustment is required, parents can step in to assist with remote guidance from the sleep scientist. The following day, a sleep nurse visits to remove electrodes and collect the PSG equipment. The hospital-based sleep scientist completes sleep staging and scoring in real time, and reporting of the PSG is done by the Sleep paediatrician the next morning. Follow up telehealth consultation for results can occur the next day.

Our new optimised virtual home PSG process has already been tested on 5 patients with 100% success in data acquisition from the Patient's home. Whilst improving the technical accuracy of the level 2 equipment and bringing it up to gold standard level 1 PSG, the overall virtual care model will also improve access to patients previously disadvantaged by distance or circumstance. We believe our new model of care is patient-centred; a positive experience in a safe and familiar environment. The new model ensures timely access to healthcare as it does not depend on waiting for a hospital bed or travel to the hospital. The quality and rigour of the study ensures clinical excellence. Furthermore, by re-designing the service delivery as an inpatient model of care from start to finish, a single more substantial funding stream ensures more consistent valuation of the service, resulting in higher total provider reimbursement which leads to sustainable healthcare.

This is the first time to our knowledge that this model has been described in paediatric sleep medicine. This model of care disrupts the existing care model for the diagnosis and management of obstructive sleep apnoea in children. It satisfies the triple aim of the change agent's mission.

WHERE TO FROM HERE:

After establishment of this new service, with quality improvement as we see fit, we plan to extend the service to rural and remote areas in our home state and potentially across Australia, right into the furthest reaches of the continent. The RCH tertiary hospital will serve as the study hub, with quality assessments and reports, but transport to and from the patient's home can be taken on by trained local teams. The final step will be to engage with industry

to make this new virtual model of care scalable, sustainable and accessible worldwide.

Situation Analysis

<u>The Royal Children's Hospital</u> (RCH), Melbourne has been providing outstanding care for Victoria's children and their families for 150 years, see Figure 1. We are the major specialist paediatric hospital in the state of Victoria and our care extends to children from Tasmania, southern New South Wales and other states around Australia and overseas.



Figure 1: The Royal Children's Hospital, Melbourne, Australia

Victoria's population was estimated at the last census (2016) at <u>5,926,624 people</u>, 70% of whom live in the metropolitan Melbourne the rest of the population lives in regional and remote areas of the state, see Figure 2. The land mass of Victoria is 227,444 km² (87, 816 sq miles) and hence is similar to the state of Minnesota in the United States in terms of population numbers (<u>5,639,632 people</u>) and size (225,163 km² (86,936 sq miles), see Figure 2.



Figure 2: Comparison of Victoria, Australia and Minnesota, United States of America (source https://acme.com/same_scale/)

The RCH sleep medicine service was established in 2015 and is embedded in the Respiratory and Sleep Medicine Department. Our hospital is a tertiary referral public paediatric hospital and our sleep service specifically caters to the sleep and ventilation needs of children with complex medical conditions, many of which require ventilatory support. Generally, the patients studied include those with complex airways, neuromuscular conditions, genetic or metabolic disorders, craniofacial malformations or complex syndromes (see Figure 3 for eligibility criteria). With an ever-increasing complex paediatric population and limited resources and access to our service, our strategic goals for the development of the service have always been to innovate rather than just play catchup with other more established services. Given our requirement to study patients in multiple locations throughout the hospital, including the neonatal and high dependency respiratory ward, we have always operated as a mobile sleep service rather than a sleep laboratory in a single physical place. We are adept at running the equipment with an atypical plug-and-play setup rather than the traditional fixed-to-the-wall sleep laboratory. Our service also runs a complementary homebased level 2 paediatric sleep service, however these studies have until now been restricted to less medically complex patients older than 5 years given the known potential limitations of this test in children (12).



Figure 3: Eligibility criteria for polysomnography at the RCH Sleep Medicine Service

At present we have prolonged waiting lists for patients to be seen in the paediatric sleep medicine clinic. Currently, there are 200+ new patients awaiting a clinic appointment to see a sleep specialist and the average wait time is 468 days. We also have long waiting lists for our inpatient level 1 PSG's (~10 months) and relatively long waiting lists for home-based level 2 PSG's (~4 months), see Figure 4. Due to funding restrictions, we only have capacity for one level 2 home PSG per week. These waiting lists have been severely impacted by the COVID-19 pandemic.



Figure 3: PSG Waitlist 2019 to 2021

COVID-19 in Victoria, Australia (see Figure 5):

In early 2020 we started seeing locally acquired COVID-19 cases in Victoria. We had a small first wave in March and April that resulted in a severe restriction in the number of studies we were able to conduct with only urgent cases being performed. In May and June we were able to increase the studies being performed, with the exclusion being non-urgent studies involving aerosol generating procedures e.g. PAP studies. Given the nature of our service, the majority of our patients have significant sleep disordered breathing, many are on NIV and subsequently, COVID-19 restrictions caused a serious impact on the service. In Victoria, we had a significant second wave for a further 4 months from July to November, and during this time we were able to continue with reduced capacity and redeploy our staff using the Hospital-in-the-Home (HITH) service to provide surrogate in-home portable monitoring (e.g. oxycapnography or oximetry) for our Patients who are on positive airway pressure (PAP). This ensured their safety

in the setting of restricted access to our service and titration level 1 PSG's. It also "planted the seed" in our minds in

regards to how much more could be achieved in the home environment in paediatric sleep medicine.



Figure 5: COVID-19 impact on the Sleep Service

Despite our best intentions, plans to resume 100% of normal Sleep Unit activity were further delayed by the COVID-19 infection Screening clinic occupation of the usual space where we perform the lower acuity level 1 PSG's. In June 2021 we are finally moving these studies to a new location in the hospital however as a consequence the waiting list for these studies has also blown out (by 150%).

Our current sleep service business case allows for 12 inpatient PSG beds and 1 home PSG per week. The model is based on State government funding for inpatients. It is an activity-based model where cost weights are calculated as the ratio of the average cost of all episodes in a diagnosis related group (DRG) to the average cost of all episodes across all DRGs. The Weighted Inlier Equivalent Separation (WIES) is a cost weight (W) that is adjusted for time spent in hospital (IES), and represents a relative measure of resource use for each episode of care in a DGR. WIES allocated to an episode depends upon the episode's DRG, the amount of time spent in hospital and the episode's eligibility for WIES co-payments. Victorian cost weights are developed each year using the costs of treating patients as reported to the Department of Health & Human Services by public hospitals. The department pays a price per unit of WIES. WIES prices vary between hospitals to account for differences in specialisation, economies of scale and levels of remoteness. The current WIES rate using a DRG for OSA or hypoventilation is worth \$2,283.67\$2,283.67per night for a PSG patient admitted to our hospital. HITH is an alternative to an inpatient/in-hospital stay. Patients are still regarded as hospital inpatients and remain under the care of their hospital doctor. Care may be provided by nurses, doctors, or allied health professionals, and additional home supports arranged as required. Patients can be offered this option if care can be delivered safely at home. Like all acute admitted activity HITH admissions are funded through case mix payments and the unit of payment is a WIES, as per in-hospital in-patients. These "beds" funded through the HITH model are not limited in the same way as they are in-hospital in-patient beds in homes. Our model uses the HITH based funding model as this will ease the PSG waitlist pressures that we are experiencing, see Figure 6.



Figure 6: RCH sleep medicine service capacity limits

The level 1 PSG (in-laboratory PSG) is the gold standard in the diagnosis of SDB in children. Unfortunately, PSG is expensive and setup can be challenging and time consuming, as the placement of numerous electrodes can be difficult in paediatrics. Access is difficult as waiting lists for in laboratory PSG are long. Furthermore, access to PSG can be limited based on geographic location and proximity to tertiary care centres, such as the RCH. Recently, there has been increased interest in the use of level 2 home PSG studies in children, using portable equipment with fewer

sensors (12). Home sleep studies are a well-accepted method for evaluating adult patients for sleep-disordered breathing as part of an overall sleep evaluation. In fact, home sleep studies are becoming the primary modality to evaluate OSA in adults as they have been shown to be comparable to in-laboratory PSG in the adult population(14). However, there is a considerable knowledge gap in the use of home level 2 PSG's for the evaluation of paediatric sleep-disordered breathing.

The American Association of Sleep Medicine (AASM) in 2017 in their position paper (12) on the use of a home sleep apnoea test for the diagnosis of OSA in children suggested that home PSG is technically feasible in the paediatric population under carefully controlled conditions (e.g., electrodes placed by a trained clinician). The working group also noted that the success of the home PSG's would significantly decrease if the sensors and electrodes were placed by parents or carers rather than sleep trained staff or when more stringent criteria are used to define acceptable studies. The AASM scoring rules for marking respiratory events in children includes the option to score a hypopnea if the event is associated with an arousal, not just a 3% oxygen desaturation; marking arousals requires electroencephalogram (EEG) monitoring, which generally is not available with all home PSG equipment. These paediatric respiratory scoring rules also recommend monitoring hypoventilation in children during a diagnostic PSG study, this requires carbon dioxide (CO₂) monitoring, which generally is not available with home PSG equipment. In the AASM position paper they recommend the parameters ideally captured during a home PSG, see Table 1.

Table 1: Ideal home PSG parameters (12)

Ability to estimate total sleep time (TST, requires EEG or Actigraphy)
Arousal identification (requires EEG)
Electrocardiogram (ECG)
Oxygen saturation (SpO ₂)
Body position
Respiratory excursion
Nasal airflow pressure
Oronasal thermistry
CO ₂ monitoring

Thus, because these devices measure fewer physiologic variables than the gold standard PSG (e.g., no EEG, absence of carbon dioxide measurement, video and audio), use of home level 2 PSG may lead to underestimation of the presence or severity of disease, which may result in differing diagnoses and clinical management strategies. Without a sleep scientist monitoring the quality of the PSG acquisition, the likelihood of inadequate test results is significantly higher.

In our current sleep service, we run level 2 unattended PSG's with a telehealth consultation prior to the Patient's usual bedtime. This service uses commercially available portable PSG equipment. The data from the PSG is recorded to an SD card, which is then downloaded the next day to our software. Currently, after these patients are set up by the sleep trained nurse and prior to their usual bedtime, a Sleep Scientist who is working on-site at the RCH in the sleep medicine service contacts the family through the <u>telehealth platform</u>. Using this service, the Sleep Scientist visually checks that all the electrodes and sensors are in the correct position and the portable PSG equipment is recording correctly. The telehealth service is also available overnight for the families to contact the Sleep Scientist who is rostered in the hospital for any troubleshooting issues, if required. All parents are advised to sleep in the same room as the child having the PSG as a safety precaution and to assist with electrode and/or sensor replacement.



Figure 5: Current RCH telehealth-assisted home sleep studies set-up with Patient and sleep trained Nurse

Currently, our telehealth-assisted home sleep studies are Level 2 (unattended) with the following acquired signals:

- ECG (electrocardiogram)
- EOG (electrooculogram)
- EMG (electromyogram)
- EEG (electroencephalogram) F3, F4, C3, C4, M1, M2, O1, O2 and CZ (i.e., 9 electrodes)
- Airflow thermistor (airflow)
- Nasal pressure cannula (airflow)
- SpO2 (oxygen saturation level)
- Abdominal respiratory effort (RIP band)
- Thoracic respiratory effort (RIP band)
- Body position sensor

In a recent audit of our telehealth-assisted home PSG service, 94 children were eligible and recruited from outpatients based on the following eligibility criteria; aged 5 to 18 years with a history of uncomplicated OSA and living in the HITH geographic catchment area. We found that minor signal loss occurred for < 20% of total sleep time, including periods of nasal pressure loss (which could also be due to mouth breathing). This is in keeping with other published data (10). Although this minor signal loss did not affect the final outcome diagnosis, it may have led to some underestimation of the OSA severity in 19% of our home PSGs. A major degree of signal loss is considered a failed study and occurred in approximately 13% of our home PSGs. If the study failed, a repeat in lab study was offered due to the risk of significant underestimation of the diagnosis of OSA (a false negative test). In those that were successful, 94% had a total sleep time (TST) > 6 hours, normal sleep architecture and very good sleep efficiency (mean 85%). The families involved reported that the home environment is more convenient and were supportive of the service.

Following this audit, we concluded that we needed to improve our service to increase the proportion of successful PSG's and diagnostic yield. We realised that it was essential to move beyond simply adding video, audio and transcutaneous CO₂, rather, we envisaged "virtual attendance" by livestreaming the whole study to the sleep scientist in the hospital. This optimisation would enable the scientist to view the study occurring in the patient's home in real time and to make contact for sensor adjustment with the parents where needed to improve technical accuracy.

Solution Framework

The business model is a virtual paediatric sleep service encompassing all aspects of the patient consultation including telehealth sleep physician consultations, in-home virtual level 1 PSG and follow up telehealth appointments. The key stakeholders are the RCH Sleep specialists (Mandie Griffiths and Moya Vandeleur) and the chief sleep scientist (Anne-Marie Adams). The RCH sleep scientist team also play a role in the service.

The funding model is inpatient hospital-based WIES funding for a period of 48 hrs (admission to the HITH) to incorporate both appointments and the overnight PSG. This compares to the current model which is a combination of inpatient funding (for PSG, staff time) and outpatient funding (for appointments). The latter stream is federally

derived, with very minimal provider reimbursement (new consultation derives \$134-244 per patient depending on complexity, and review \$64 per patient). This new model potentially brings in \$2,283.67 x 2 = **\$4567.34** per patient journey, compared to the current funding model \$2,283.67 + \$134 + \$64**=\$2481.67**.

The costs for running the service will include staffing:

- Sleep physicians for initial and follow up consultation and PSG reporting
- Senior scientist for staging and scoring of studies and overall coordination
- Sleep scientists for patient visits and overnight monitoring
- Hospital-in-the-home fleet cars with overarching security, health and safety protocols and procedures
- PSG equipment, further details to follow.

The new patient journey starts by admission to the HITH service. The family then meet the paediatric sleep physician virtually by telehealth. History and examination are performed (if necessary, with the assistance of a local GP), and the need for a PSG assessed, see Figure 7. Appropriateness for the PSG will be pre-triaged prior to commencement of the admission to minimise last minute cancellations. Two home PSG's patients are scheduled each night. A sleep scientist or sleep trained nurse then goes out to the patient's home with the suitcase equipment, sets up the patient and sleep area, establishes connection with the hospital sleep service (hub and spoke style) and then travels back to the hospital. When the patient is ready for "lights out", the study acquisition is commenced remotely. During the study, the hospital-based sleep scientist monitors the livestreamed real time signals, video and audio.. Where signal disruption is detected, the parent is contacted and sensor replacement is re-established either by Telehealth or via a short video detailing correct replacement of the specific sensor. In the morning, the incoming sleep scientist will travel out to the patient's home, remove electrodes/sensors, collect equipment and return to the hub. Staging and scoring is performed by the senior sleep scientists the following day. Sleep study analysis is completed and sleep physician reporting then occurs. A scheduled telehealth follow up appointment is made for the patient with the sleep physician later in the day to discuss the PSG results and subsequent management.



Figure 7: Virtual paediatric, in-home, portable, level 1 PSG delivery model

The PSG equipment in this care model uses AASM compliant portable PSG equipment with digital video, audio and transcutaneous CO₂ all of which will livestreamed to the in-hospital sleep scientist. These additional channels and virtual attendance directly address the deficits highlighted in the AASM paediatric home PSG position statement (12). The equipment required for PSG acquisition has been fitted into a hard-suitcase to enable protection of the equipment during transport and whilst it is in the Patient's home, see Figure 8.



Figure 4: Optimised home PSG equipment in a hard case with Oxycapnography device

Utilising the RCH HITH service for the admission allows access to established protocols and procedures for safety and security purposes. The HITH service will contact families on the day of their HITH admission and go through a standard set of COVID-safe checks and a risk assessment to ensure that the family's home is a safe environment for staff to enter. The HITH service has RCH fleet cars, each fleet car is tracked live from the hospital by the HITH team when staff are out in them. Each staff member is allocated with a smart phone & monitored personal duress button, these are linked to each of the fleet cars. Once a staff member comes on shift within the HITH service they must activate their personal duress button, and then each hour they must make contact with the monitoring service to let them know that they are safe. Prior to entering and also upon leaving the Patients house staff will complete a health and safety survey and a call or text is made to the HITH service to let them know a staff member is about to enter the house. At any point if the staff member feels unsafe they can leave the house and/or press their duress button

and the monitoring service will respond to ensure the staff member is safe. The staff member must say a certain phrase "All Clear" in response to the monitored service, if they don't say the exact phrase or do not respond the police will be dispatched to the address, see Figure 9.



On – Charging Flashing 1 second – No GPS fix or initializing Blinking once every 3 seconds – GPS fix Fast flashing 3 times per second – Low battery

Green light (Telstra Network) On – Control room call in progress Flashing 1 second – Telstra not connected Blinking once every 3 secs – Telstra connected



Figure 9: HITH personal duress "button" device

Privacy issues

We have developed protocols together with RCH Social Work team relating to the livestreaming of sleep studies from the patient home, particularly the video and audio. In Australia, Sleep Scientists are not mandated reporters for child protection related matters, however at the RCH we have a duty of care to report incidents that would constitute a child protection issue. Patients and families are told during the consultation with the Sleep Physician that during the "livestreaming sleep studies" we will be watching, listening and recording all video and audio for the purposes of the study so they need to be mindful about what happens in front of the camera or within the vicinity of microphone, e.g. they shouldn't have private conversations in the room where the PSG is occurring (similar advice is given for in-lab studies). Patients referred for these types of PSG's will be triaged by our Sleep Nurse Coordinator who will review the Patients medical record and any red flags that may indicate risk for child protection issues will be referred for an in-hospital PSG. If, during the study a sleep scientist witnesses a serious incident where the child's wellbeing is in imminent danger the police will be called to the address and other over-arching hospital policies will be followed as they relate to this type of incident. During the consultation the sleep physician will document that they have explained the procedure including the digital and audio livestreaming and recording, but that also that the Sleep Scientists will contact them where necessary to respond to signal quality issues. It is also possible to call an ambulance to the patient's home if we see anything in the PSG data that constitutes a medical emergency.

Equipment

Within the suitcase we have the following equipment:

- Hard-shell rolling suitcase with an extendable handle, to house all of the required equipment, similar to that used for camera equipment with smooth surfaces for infection control purposes.
- Pneumatic hinge, to allow the lid of the case to remain open and not drop closed, for health and safety reasons.
- Laptop with proprietary PSG acquisition software plus software unlock dongle. The Laptop must meet the
 portable sleep equipment manufacturer's specifications for the acquisition of PSGs with digital video and
 audio capture, in terms of RAM and storage capacity. The laptop also needs to be compatible with a 4G SIM
 card to allow for internet connectivity, have the hospital virtual private network (VPN) and remote access
 software installed.
- Digital Power over the Ethernet (PoE) Infra-Red camera.
- PoE Network Switch, to power the PoE camera and connect it to the laptop, to connect the data logger to the laptop and connect to the in-hospital network for data transfer to the hospital server.
- Datalogger with Bluetooth capability, to allow transfer of data from the portable sleep equipment to the propriety sleep acquisition software via Bluetooth. The data logger will also allow connection of peripheral devices such as the Transcutaneous CO₂ monitor.
- RCD power board.
- Transcutaneous CO₂ monitor (could also use an end-tidal CO₂ monitor as long as it has digital or analog outputs).

The patient below (see Figure 10) has been setup with the following channels being recorded:

- EEG (F3/F4, C3/C4, O1/O2, M1/M2)
- EOG (LEOG, REOG)
- CHIN EMG (LEFT, RIGHT, CENTRAL)
- ECG (2-LEAD)
- LEG EMG (L-LEG, R-LEG)
- ABDO and THORACIC RIP Bands
- Thermistor and Nasal Pressure
- Oxygen Saturation (SpO2)
- Position sensor
- Digital Video and Audio
- Transcutaneous CO₂ (not yet attached to the Patient)



Figure 10: Patient setup with portable home sleep equipment recording on the laptop in the suitcase via Bluetooth.

The picture below (see Figure 11) shows the livestreaming view from within the hospital.



Figure 11: Livestreaming PSG data as view within the hospital

Anticipated Impact

We have thus created a virtual paediatric sleep laboratory with gold standard polysomnography in the patient's home. Based on this and the recent advances in connectivity and telehealth acceptance stemming from the COVID-19 pandemic we have begun to move our gold standard-level 1 PSG's into the Patient's home. Our approach specifically addresses the deficiencies noted by the AASM with respect to level 2 PSG's in paediatrics. We livestream the PSG data, video and audio from the Patients bedroom to the hospital in real time. Using telehealth consultations with a multidisciplinary team, including sleep physicians, respiratory nurse consultants and other allied health practitioners we are able to provide a fully comprehensive online paediatric sleep service to patients in metro, rural and remote locations within the state and other states within Australia.

This virtual paediatric sleep service aligns strategically with the five pillars of great care which are the basis of our mission at the Royal Children's Hospital. "Great care everywhere" is the catch phrase of our Great care triangle (Figure 12). The five pillars of great care include clinical excellence, positive experience, timely access, a safe place and sustainable healthcare.

Great Care, Everywhere





Figure 12: The RCH "Great Care, Everywhere" policy.

Our model of care is:

- patient-centred (delivered at home which is convenient, a positive experience, and a safe place)
- efficient for families as it does not depend on waiting for a hospital bed, nor does it entail travel to the hospital (positive experience, timely access) and the whole process occurs within a 48 hour period (compared to many months)
- effective (delivers gold standard PSG results, improving on level 2 study capability and providing clinical excellence)
- provided higher total reimbursement by cost shifting to an admission model and almost doubling the funding per patient (resulting in sustainable healthcare).

We already have evidence that patients and families prefer to have sleep studies done at home and sleep in their own bed (previous aforementioned audit). There is also mounting evidence during the COVID-19 pandemic from around the world that the convenience of telehealth consultations improves efficiency in already busy family life. However, the most significant impact of this service is the ability to obtain gold standard PSG data in a potentially remote environment by livestreaming to the hospital hub. It is accessible and scalable. This is the first time this has been done in paediatric sleep medicine. This model of care re-invents (disrupts) the care model for the management of obstructive sleep apnoea in children. It satisfies the triple aim of the change agent's mission.

Business model

Estimated financial schedule - 12 months								
Item	12 months @ 0.4541 WEIS							
	Virtual Home PSGx 2 patients per night							
Revenue (assumes 1 WEIS = \$5029, \$ equvialent for sleep disordered breathing 0.4541 WIES = \$2283.67)	2 Day Admission to HITH	\$438,464.64						
Item								
Costs - Salaries		\$108,655.03						
Costs - Consumables		\$11,666.67						
Costs - Equipment (one-off payment)		\$21,344.55						
TOTAL OUTGOINGS - 12 months	\$141,666.25							
TOTAL INCOMINGS - 12 MONTHS @ 0.4541 WEIS	\$438,464.64							
Effect on RCH (INCOMINGS - OUTGOINGS)	\$296,798.39							

Salary Costs

Sieep Onic Salary Cosc									
Classification	Hours (per week)	FTE	Rate Based on Classification	Annual Salary Based on 1.0 FTE	Salary Cost Based of actual FTE	Salary On-Costs @ 14%	Infrastructure Costs (If applicable *)	Total F of E	Recurrent Cost mployment
Sleep Consultant (HN58/Specialist Yr 9)	4	0.11	\$198.90	\$ 361,998.00	\$ 41,371.20	\$ 5,791.97	Includes CME	\$	47,163.17
Reporting Scientist (RY9)	5	0.13	\$1,872.50	\$ 97,370.00	\$ 12,811.84	\$ 1,806.51	N/A	\$	14,618.35
Set-up Scientists (RX1-RX7 costed on RX7 rate)	6	0.16	\$1,571.60	\$ 81,723.20	\$ 12,903.66	\$ 1,806.51	N/A	\$	14,710.18
Overnight Scientists (RX1-RX7 costed on RX7 rate)	10	0.26	\$1,571.60	\$ 81,723.20	\$ 21,506.11	\$ 3,010.85	N/A	\$	24,516.96
Administrator (AO31)	1	0.03	\$1,304.60	\$ 67,839.20	\$ 1,785.24	\$ 249.93	N/A	\$	2,035.18
	22	0.55					TOTAL	\$	103,043.83
							TOTAL		
							(INCLUDING ALLOWANCES)	\$	108,655.03
Allowances	Value	Number per week	Total over 48 weeks						
Night shift	\$89.50	1	\$4,296.00						
Set-up (Afternoon)	\$27.40	1	\$1,315.20						

Equipment costs

Two sets of Sleep Equipment (to facilitate 2 Virt	ual Home PSG's per night, 1 night per week)								
Software									
Remote access licence	\$156.28								
Proprietary sleep acquisition software (manufacture	specific) \$0.00	RCH has thi	s already						
Sleep acquisition proprietary software unlock dongle	tion proprietary software unlock dongle \$0.00 RCH has this alread								
Hospital approved VPN, no cost to us directly - hospit	ed VPN, no cost to us directly – hospital operating costs \$4,430.00								
Telehealth Service, no cost to us directly – hospital or	erating costs \$0.00	RCH has thi	s already						
Hardware									
Hard Suitcase for sleep equipment	\$250.00								
POE Network Switch, TP-Link TL-SG2210P : 8-Port giga	bit Ethernet Switch PoE and 2 SFP \$242.55								
Data Logger with Bluetooth capability	\$1,295.00								
Laptop with enough RAM and memory to store PSG d	ata and video locally \$1,350.72								
FD9167-HT Fixed Dome Network Camera	\$1,120.00								
Transcutaneous CO2 monitor	\$12,500.00								
Fleet vehicle									
Leased Fleet Vehicle (HITH) \$955.20 per month	\$11,462.00								
TOTAL COST EQUIPMENT	\$21,344.55								

Equipment list

Software

- Remote access licence: AUS\$156.28 (US\$122.04) per annum, no cost to us directly hospital operating costs
- Proprietary sleep acquisition software (manufacturer specific), for the purposes of this project we used our existing sleep acquisition software and hence incurred no costs (Approximate cost AUS\$2,500.00 (US\$1946.50)
- Sleep acquisition proprietary software unlock dongle AUS\$4430.00 (\$3499.79)
- Hospital approved VPN, no cost to us directly hospital operating costs
- Telehealth Service, no cost to us directly hospital operating costs

Hardware

- Hard Suitcase for sleep equipment, AUS\$250.00 (US\$155.75)
- POE Network Switch, TP-Link TL-SG2210P : 8-Port gigabit Ethernet Switch PoE and 2 SFP AUS\$242.55 (US\$188.88)
- Data Logger with Bluetooth capability (ExLink), AUS\$1295 (US\$1008.19)
- Laptop with enough RAM and memory to store PSG data and video locally AUS\$1,350.72 (US\$1051.70)
- FD9167-HT Fixed Dome Network Camera, AUS\$1120.00 (US\$871.95)
- Transcutaneous CO₂ monitor \$12,500.00 (US\$9,716.00)

Flow Chart of current PSG pathway



Flowchart of virtual paediatric sleep service



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