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Evaluation of a Hub-And-Spoke Model of Care for the Delivery of Sleep Disorder Services to a Remote Australian Community Using the RE-AIM Framework: A Controlled Before-And-After Implementation Outcome Study

Irene Szollosi[1,2] | Sophia Worley[1] | Sameera Senanayake[3,4] | Sanjeewa Kularatna[3,4] | Deanne Curtin[1]

[1]Sleep Disorders Centre, The Prince Charles Hospital, Queensland, Australia | [2]School of Biomedical Sciences, Faculty of Medicine, The University of Queensland, Brisbane, Australia | [3]Health Services and Systems Research, Duke-NUS Medical School, Singapore | [4]Australian Centre for Health Services Innovation and Centre for Healthcare Transformation, School of Public Health and Social Work, Faculty of Health, Queensland University of Technology, Brisbane, Australia

Correspondence: Irene Szollosi (i.szollosi@uq.edu.au; irene.szollosi@health.qld.gov.au)

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ABSTRACT

Objectives: To evaluate a Hub-and-Spoke design for providing sleep disorder services in a very remote community. The health service re-design aimed to provide unattended polysomnography at the Spoke site with access to attended laboratory studies at the Hub when clinically indicated.

Methods: Summative evaluation using the RE-AIM Framework including all adult patients referred for diagnosis and management of a suspected sleep disorder from Remote Health Service to Metropolitan Health Service 2 years pre-implementation and 1 year post-implementation.

Design: Controlled before-and-after implementation outcome study.

Setting: Public hospital in metropolitan South-East Queensland with a comprehensive accredited sleep disorder service (Hub), networked to a Community Health Centre (Spoke), located in a very remote region defined by the Modified Monash Model in central Queensland.

Main Outcomes Measures: Referral numbers (Reach), travel avoidance and consumer satisfaction (Effectiveness), number of referrers (Adoption), unattended sleep study data quality, timeliness to testing, health service costs (Implementation), and referral numbers beyond initial 12-month pilot (Maintenance).

Results: The Hub-and-Spoke model increased adoption five-fold by local referrers and resulted in a nine-fold increase in reach. Effectiveness was demonstrated through high levels of consumer satisfaction, and all implementation aims were met, including providing services at a lower cost. Sustainability was demonstrated through ongoing referrals and the transition of the model of care to business as usual.

Conclusion: Hub-and-Spoke designs for public sleep disorder services are effective at both the individual and organisational levels. Services can be delivered at a lower cost and, importantly, improve access to specialist services in remote and very remote communities.

The project was submitted to Metro North Health Human Research Ethics Committee (HREC) B (EC00168), confirmed to be a quality initiative and exempt from full ethical review (Project ID: 94587; EX/2023/MNHB/94587).

Summary

- What this paper adds
  - Implementing a Hub-and-Spoke model of care improves access to and reach of specialist sleep disorder services in very remote communities, at a lower cost to the health service.
  - The results of this paper provide evidence for health service clinicians and policymakers to support and adopt innovative models of care.
  - The scale and spread of Hub-and-Spoke designs can improve access to specialist care in the public health system.
- What is already known on this subject
  - People living in remote and very remote regions have poorer health outcomes.
  - Access to health services is a significant contributing factor to health inequities.
  - Hub-and Spoke models of care have been proposed to increase efficiencies and quality and importantly improve coverage and access to services.

1 | Introduction

Sleep is essential for optimal physical, mental, and social wellbeing and, along with exercise and nutrition, is the third pillar of health [1]. In Australia, it is estimated that in 2019–20, over 20 000 cases of heart disease and stroke, 44 000 cases of depression, 14 000 cases of type 2 diabetes, and 66 000 workplace injuries were directly attributable to sleep disorders, costing the Australian economy nearly $1 billion in direct health system costs, largely due to Obstructive Sleep Apnoea (OSA) [2] a condition in which repeated upper airway collapse during sleep results in sleep fragmentation and intermittent hypoxia.

Recent Australian epidemiological data report moderate–severe OSA prevalence of 20% in men and 10% in women [3]. Despite the high prevalence and effective available treatment options, it remains largely undiagnosed [4, 5] particularly in regional and remote areas where 31 sleep studies are conducted per year for every 100 000 people compared to the national testing rates of 575 per 100 000 people per year [6]. It is established that Australians living in regional and remote areas have poorer health outcomes, and although the reasons are multifactorial, access to health services is a significant contributing factor [7]. This health inequity is even more pronounced in First Nations people living in rural and remote areas [8].

We implemented a Hub-and-Spoke model of care to provide diagnostic sleep testing in a remote Queensland community to improve access to services at a lower cost than Standard Care. Standard Care required travel to a metropolitan hospital to access publicly funded services, and anecdotally, it was associated with low acceptance. Hub-and-Spoke models provide a central specialist facility (Hub) offering a full range of services networked to satellite sites (Spokes), providing a limited range of services with benefits including increased efficiencies, quality, and coverage [9]. We aimed to perform a robust evaluation using the RE-AIM Framework [10, 11], a widely utilised evaluation framework in implementation science [12], to evaluate outcomes at both the individual and organisational level.

2 | Methods

We report our findings according to the Standards for Reporting Implementation Studies (StaRI) [13].

2.1 | Study Design

Summative evaluation of a Hub-and-Spoke model for providing sleep disorder services to a very remote community using the RE-AIM Framework. Domains of Reach, Effectiveness, Adoption, Implementation, and Maintenance were evaluated and, where relevant, compared to Standard Care in a wholly provided specialist metropolitan public hospital. Service evaluation was limited from referral to provision of test results, given the common pathways for treatment and follow-up. A cost comparison was nested under the Implementation domain.

2.2 | Setting

The Remote Health Service (RHS) spans the largest geographical area in Queensland and provides health services to the smallest population with 10 391 residents spread across 382 000 km^2 [14]. Accessing public sleep disorder services in metropolitan cities located outside the health service requires 700–1000 km of travel and is subsidised by a government-funded Patient Travel Subsidy Scheme (PTSS). The Metropolitan Health Service (MHS) has a comprehensive accredited sleep disorder service, receiving > 2000 referrals per year, with approximately 15% out of catchment from health services that lack specialist sleep disorder services. The Hub in the New-MOC was MHS and the Spoke was located at a Community Health Centre in the RHS.

2.3 | Population

Adult patients aged 18 years and older, with accepted referrals from RHS to MHS for diagnosis and management of suspected OSA. Patients already on treatment when referred were excluded from the evaluation as established Telehealth pathways were in place for ongoing management. The New-MOC was implemented in July 2021 and all eligible patients referred 2 years pre-implementation and 1 year post-implementation were included in the evaluation. An additional year's referral data was used to evaluate the dimension of Maintenance.

2.4 | Standard Care (Historical Comparator)

Patients were arranged a two-night admission for level 1 attended polysomnography (PSG-1) which included continuous positive airway pressure (CPAP) titration on night 2 at MHS. Travel subsidies were provided via PTSS to assist with travel and accommodation costs associated with accessing specialist health services when unavailable locally. Polysomnography was analysed and reported at

MHS, with results and treatment plans provided to patients prior to discharge as part of the admitted episode of care.

2.5 | New Model of Care

Local nurses were trained to perform unattended sleep studies using level 2 polysomnography (PSG-2) from Community Health Centre. Patients went home to sleep, or if travelling large distances could elect to spend the night in a motel with PTSS subsidised accommodation. Monitoring equipment was returned and data was transferred to MHS for analysis and reporting.

Referrals were triaged to one of three pathways that considered both Medicare billing requirements and clinical guidelines for appropriate patient selection for unattended sleep studies [15].

1. DIRECT—Direct to PSG-2 pathway when Medicare criteria for unattended sleep study met, that is, high probability for symptomatic, moderate to severe OSA (ESS ≥ 8 and one of either STOP-Bang ≥ 3, OSA-50 ≥ 5, or 'high risk' on the Berlin Questionnaire), and an attended study was not clinically indicated. Sleep scientist screening preceded PSG-2 to ensure suitability.
2. DOCTOR—Initial Sleep Physician consultation in the first instance via Telehealth if Medicare criteria not met for PSG-2. Following the initial consultation, sleep physicians could:
   a. Request local unattended PSG-2
   b. Request attended PSG-1 requiring two-night inpatient admission
   c. Discharge patient if further evaluation was not required.
3. LAB—Laboratory study if referral indicated that unattended PSG-2 was not clinically appropriate.

Polysomnography was analysed and reported at the Hub with results and treatment plan provided to patients via Telehealth when PSG-2 was performed locally, or prior to discharge if admitted. Where laboratory CPAP titration was avoided, treatment settings were determined during the CPAP trial in an Automatic Positive Airway Pressure (APAP) mode.

Common to both Standard Care and New-MOC and outside the scope of evaluation, APAP and CPAP trials were provided by external providers in the community, including those willing to post trial equipment to patients. Ongoing treatment follow-up was provided remotely by MHS clinicians, using established Telehealth pathways, and Sleep Physicians made all fixed pressure determinations. See Figure 1 for triage and testing pathways. Unattended pathways using level 2 PSG and APAP are well validated and accepted in the management of OSA [16].

2.6 | Cost Comparison

A cost comparison was performed from the health service perspective that excluded patient out-of-pocket costs. The purpose was to support health service decisions regarding the economic sustainability and scalability of the New-MOC. Only direct costs associated with the provision of inpatient and outpatient care within Queensland Health facilities were considered, to the time point at which results were provided.

A decision tree analytic model was developed using TreeAge Pro 2024 (Healthcare Version) (Figure S1) to estimate the incremental costs associated with New-MOC compared to Standard Care. Cost inputs were estimated using service encounters associated with each pathway for a mixed billing model attracting Medicare Benefits Schedule (MBS) or Activity-Based Funding (ABF) and included staff costs to provide local PSG-2 testing. Detailed methods, including clinical activity and cost inputs, are found in Tables S1 and S2.

A simulated cohort of 100 patients was followed through different healthcare pathways, with transition probabilities calculated from primary administrative and clinical data sources to model and compare costs for 100 patients in each model of care.

2.7 | Data Collection

Data was collected from administrative and health records, including the Hospital-Based Corporate Information System (HBCIS) used in all Queensland public hospitals to keep track of all referrals and patient-related activity and the MHS's clinical database. De-identified data were collated on a password-protected Excel spreadsheet.

2.8 | Statistical Analysis

Data was imported to SPSS V28.0 (IBM Corp. Armonk, NY) for statistical analysis. Descriptive statistics were used to summarise data using mean, standard deviation, median, and interquartile range, and frequencies where appropriate. Independent samples *T*-tests were applied to compare continuous variables; where data were not normally distributed, the Mann–Whitney *U* test was utilised. Chi-square tests were applied to compare two or more categorical variables. Probabilistic sensitivity analysis (PSA) was performed to capture the uncertainty of the parameters used in the cost comparison model and its effect on incremental cost results. PSA was performed using the Monte Carlo simulation method with 1000 iterations using TreeAge Pro 2024 (Healthcare Version). The input parameters in the PSA were represented as probability distributions to reflect the full range of potential uncertainty arising from changes in patient complexity and billing mix.

2.9 | Ethics Statement

The project was submitted to the institutional Human Research Ethics Committee and confirmed to be a quality initiative and exempt from full ethical review.

3 | Results

3.1 | Reach

A total of 93 valid referrals were received in the first year post-implementation compared to 21 in the 2 years prior, representing a nine-fold increase in referrals. There was no significant difference in age or gender in people referred pre- and post-implementation (Standard Care age = 52.4 ± 17.9 years, 52% male; New-MOC age = 51.8 ± 15.6 years, 58% male).

27/93 (29%) of referred patients in the New-MOC were not contactable, declined testing or declined a consultation. However, this was not significantly different to Standard Care where 7/21 (33%) were not contactable or declined travel to access services. As such, when considering Reach in terms of those engaging with the service, the increase with the New-MOC was also nine-fold. Table 1 shows the characteristics for patients who engaged with the service. Although there was no difference in age and gender in those who were referred, patients who engaged with the service in the New-MOC trended to be younger with significantly more severe OSA compared to those who engaged with Standard Care.

The absolute number of First Nations people referred and engaged increased from 1.5 per year to 10 per year, representing

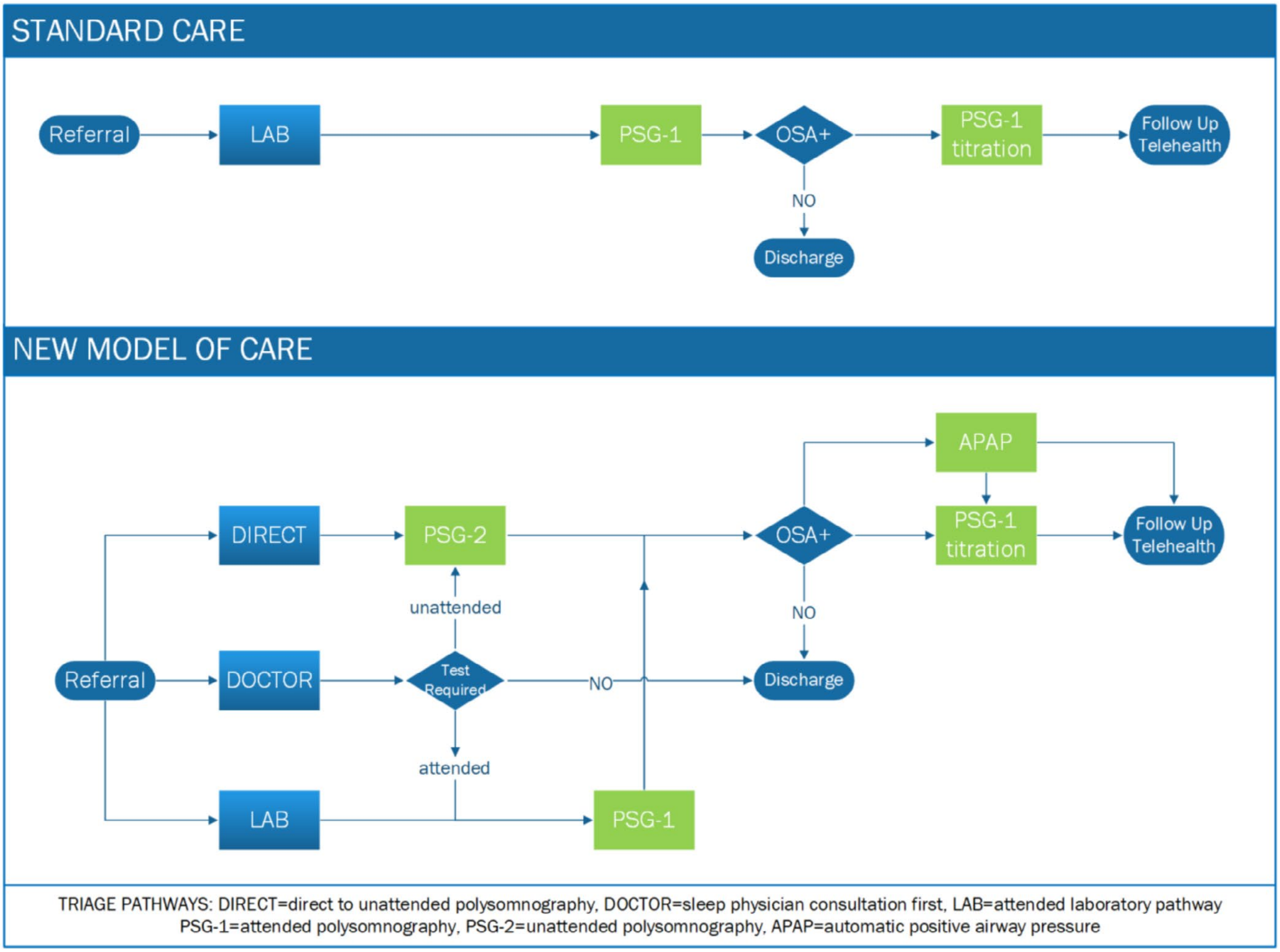

FIGURE 1 | Standard care and new model of care pathways.

TABLE 1 | Characteristics of patients who engaged with service (mean ± SD).

	Standard care	New-MO	*p* value	New-MOC travel	New-MOC no travel	*p* value
N	14	66		7	59	
Age (years)	57.4 ± 13.6	49.3 ± 15.6	0.075	51.0 ± 18.2	49.1 ± 15.4	0.794
Gender (% male)	7 (50%)	33 (50%)	0.918	3 (43%)	30 (51%)	0.628
First Nations (%)	3 (21%)	10 (15%)	0.072	0 (0%)	10 (17%)	0.237
AHI (per hour)	13.5 ± 11.4	24.0 ± 29.1	0.031	49.4 ± 43.0	20.9 ± 25.8	0.133
ESS	9.9 ± 7.2	10.2 ± 5.1	0.867	13.9 ± 2.9	9.8 ± 5.2	0.009
BMI (kg/m^2)	36.2 ± 8.7	35.2 ± 8.3	0.711	39.1 ± 5.7	34.8 ± 8.5	0.105

Abbreviations: AHI, Apnoea-Hypopnea Index; BMI, Body Mass Index; ESS, Epworth Sleepiness Scale.

a > 6-fold increase. However, as a percentage, there was a decline from 3/14 (21%) to 10/59 (15%) which did not reach statistical significance.

3.2 | Effectiveness

3.2.1 | Avoidance of Travel

All patients travelled to MHS under the Standard Care pathway for sleep testing. Under the New-MOC, 7 of 66 or 10.6% of patients who engaged with service travelled to MHS for a clinically indicated study (1 Diagnostic and 6 CPAP) and thus 89.4% avoided travel. Patients with a clinical indication for attended PSG-1 were significantly more symptomatic on the Epworth Sleepiness Scale (ESS) ($p = 0.009$) and had higher AHI and BMI, although these did not reach statistical significance (Table 1).

For 59 patients who avoided travel in the New-MOC, 116938 km of air travel and 12.2 Tonnes of CO_2 emissions were saved, estimated using the International Civil Aviation Organisation Carbon Emissions Calculator available online at ICAO Carbon Emissions Calculator (date of access 3 July 2024).

3.2.2 | Consumer Satisfaction

There were 28 respondents from RHS in the broader MHS's sleep laboratory consumer survey. 82% had PSG-2 locally and 11% travelled for a hospital sleep study. Of those who had a study locally, 91% reported it was more convenient than having a sleep study in hospital. Over 60% reported that they were unlikely to attend an overnight sleep study in MHS; the most cited reasons were that it was too far or too expensive to travel. Consumer satisfaction was high, with 93% agreeing or strongly agreeing that they were satisfied with the care received; the remaining reported neutral satisfaction.

3.3 | Adoption

An average of seven General Practitioners (GPs) referred per year under Standard Care. The New-MOC was associated with a five-fold increase in adoption, with 33 GPs referring in the first year post-implementation.

3.4 | Implementation

3.4.1 | Data Quality (Fidelity)

In 61 patients who had PSG-2 locally, there were three failed studies, all successfully repeated locally. This represented a technical failure rate of 4.9% similar to that reported elsewhere [15, 17].

3.4.2 | Timeliness

Time from referral to testing was significantly shorter for the New-MOC with a median of 57 days (IQR 43, 146 days) compared to Standard Care median of 148 days (IQR 62, 244 days) ($p = 0.48$). We report an unintended consequence evident from closer inspection of New-MOC triage pathways, which revealed that time to testing was longer when triaged to DOCTOR pathway with a median of 357 days (IQR 152, 401 days) compared to triage to DIRECT pathway with a median of 50 days (IQR 37, 62 days) ($p < 0.001$). See Figure 2.

3.4.3 | Costs

In the cost analysis comparing New-MOC with the Standard Care pathway, the average cost (based on the PSA results) for treating 100 patients with the New-MOC is $104562. In contrast, the Standard Care pathway costs $217457 for the same number of patients, indicating a cost saving of $112 895 when opting for the intervention. PSA indicates that the probability of the intervention not being cost saving is < 1%.

3.5 | Maintenance

Long-term sustainability and maintenance of New-MOC were demonstrated through sustained referral numbers in the second year. A total of 111 new referrals were received, and the service transitioned to business as usual.

4 | Discussion

This is the first comprehensive evaluation of a Hub-and-Spoke model for delivering sleep disorder services in the Australian context, specifically to provide services in a remote community as defined by geographical remoteness according to the Modified Monash Model. The RE-AIM evaluation demonstrated an effective model of care that met our aims to improve access to sleep disorder services at a lower cost to the health service. Access via a Hub-and-Spoke design resulted in a nine-fold increase in referrals for suspected OSA driven by a five-fold increase in model adoption by local GPs. Although the reach for First Nations people increased with the New-MOC, the six-fold increase was less than that observed for the whole cohort and therefore the proportion decreased, though it was greater than the 8% reported for the health service

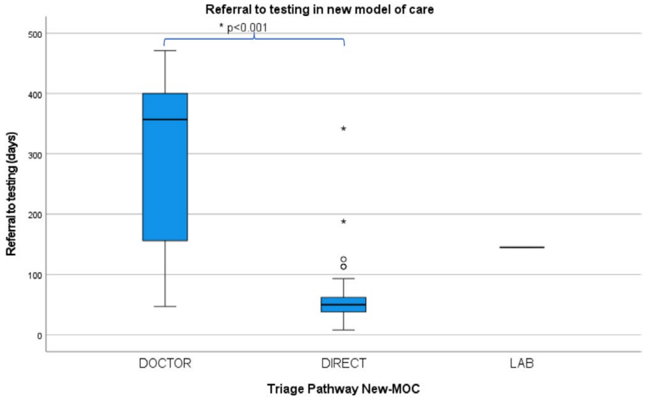

FIGURE 2 | Referral to testing time triage pathway in new model of care.

population [18]. Nevertheless, this raises important questions in relation to how further improvements could be made, given the higher prevalence and greater severity of OSA reported in First Nations people in regional and remote Australia [19, 20]. Modification to the model may be required to specifically address First Nations inequity with community consultation, engagement, and partnerships for the provision of sleep health services. Continued barriers to patient acceptance exist with nearly 30% of all referred patients being uncontactable or declining care. This may be due to geographical isolation with poor access to reliable telecommunications and the ongoing need for some residents to travel hundreds of kilometres to access services at the Spoke site.

Over 90% of patients engaging with the service avoided travel to a metropolitan hospital and were managed entirely in their local health service, saving significant travel kilometres, associated costs, time, and inconvenience. Although indirect costs were not assessed, it is likely that significant out-of-pocket costs were saved. The cost for the health service was reduced by over 50% per person compared to Standard Care, with savings attributed to a reduction of inpatient activity and associated Activity Based Funding and PTSS costs. Health services with significant expenditure on patient travel should consider the provision of care via a Hub-and-Spoke design, given the increase in reach and efficiencies that these models of care can deliver [9].

Effectiveness based on data fidelity and timeliness to testing was demonstrated, with opportunities to improve timeliness of diagnosis, specifically when triaged to an initial physician consultation for those not meeting MBS criteria for unattended sleep studies. Current MBS eligibility in Australia for an unattended polysomnography requires a high probability for symptomatic, moderate to severe OSA, based on risk stratification using the STOP-Bang, OSA50 or Berlin Questionnaire, and an ESS score of 8 or more to directly access testing; or a respiratory and/or sleep physician consultation to determine the necessity of the investigation following a professional attendance. Patients presenting with symptoms who do not meet definitions of high probability based on the required screening instruments, or who are not symptomatic based on ESS are disadvantaged in accessing timely local testing as they are ineligible for the specific item number without seeing a respiratory or sleep physician in the first instance, a criterion that may result in delays to accessing services. Whilst these screening tools are reported to have a high sensitivity in selected populations, very few studies have assessed these tools in the primary care setting where sensitivities may be lower [21]. More importantly, the majority of those with OSA do not report excessive sleepiness [22] and there is some evidence of a gender bias in OSA diagnosis, with women often presenting with atypical symptoms such as tiredness, fatigue, insomnia and headaches instead of the more typical male presentation of snoring, witnessed apnoea and excessive daytime sleepiness [23, 24]. In light of the limitations of existing screening instruments, more research is needed to develop effective screening tools, with some recent tools showing promise in the general practice setting [25].

Consumer satisfaction was high with the New-MOC, and survey data provided insightful information that significant costs associated with lengthy travel, despite travel subsidies, remain a key barrier to access when local testing options are not available.

The limitation of this evaluation is that we did not follow patients through to treatment compliance and thus a full economic evaluation of cost utility is not able to be presented with primary source data. However, given the models of care from treatment recommendation onwards were the same between new-MOC and Standard Care, using Telehealth for follow-up, we would not anticipate a difference in treatment uptake and compliance. The cost comparison was performed using a mixed billing model utilised by our health service, thus extrapolation to other services with different funding models requires adaptation. Similarly, the availability and size of health service travel subsidies would impact on cost savings.

5 | Conclusion

We have implemented a Hub-and-Spoke model for the provision of sleep disorder services in remote Australia. The evaluation demonstrates success at the consumer level, as well as the health service perspective. Significant increases in reach, including for First Nations people, have been demonstrated and driven by strong adoption of the service by local GPs. The service is well received by the community, with high levels of consumer satisfaction and effective service delivery that reduces travel burden for residents. The service is delivered at a lower cost, with demonstrated sustainability in the long term. Whilst success is demonstrated, there is scope to further improve access to services through scale and spread to additional areas within RHS, as well as in other regional and remote areas. Adaptations to the model of care to specifically address First Nations people require community consultation and engagement to bridge the current gaps in access and health inequity.

Author Contributions

I.S. conceptualization, Investigation, Funding acquisition, Methodology, Validation, Visualization, Writing – original draft, Project administration, Formal analysis, Data curation, Resources, Writing – review and editing. S.W.: Writing – review and editing, Investigation. S.S.: methodology, Formal analysis, Visualization, Writing – review and editing, Resources, Conceptualization. S.K.: conceptualization, Methodology, Writing – review and editing, Supervision, Resources. DC: Conceptualization, Writing – review and editing, Methodology, Resources, Supervision

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.