Nature and Science of Sleep

Elevate Series

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RAPID COMMUNICATION

Management of CPAP Follow-up by Telemonitoring in Obstructive Sleep Apnea: The PROTEUS Project

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Purpose: CPAP is the standard treatment for obstructive sleep apnea (OSA), but as many as 50% of patients discontinue its use, within three years. The PROTEUS project aims to enhance CPAP adherence through telemonitoring.

Patients and Methods: OSA patients undergoing CPAP treatment since July 2018, had an in-person reassessment after three months, followed by quarterly telemonitoring by providers, who intervened in cases of poor adherence (less than 4 h·night^{-1} or less than 70% of days), excessive mask leakage, or elevated residual apnea-hypopnea index ($rAHI_{CPAP}$).

Results: A total of 486 (~87%) out of 558 patients analyzed remained adherent to CPAP after five years. The average $rAHI_{CPAP}$ was 3.95 ± 5.25 events·h^{-1}, the average CPAP usage was 6.35 ± 1.72 hours. Elevated mask leakage occurred in 25% of patients. No significant differences were found between sexes.

Conclusion: The PROTEUS project showed promising results in supporting long-term CPAP adherence. However, further research is needed to validate its long-term impact and wider applicability in OSA management.

Keywords: CPAP, management, OSA, real-life study, telemonitoring

Introduction

Continuous positive airway pressure (CPAP) is the first-line therapy for obstructive sleep apnea (OSA).[1] Despite its well-documented benefits—such as enhancing quality of life, reducing daytime sleepiness, and mitigating the risk of cardiovascular complications—adherence to CPAP therapy is alarmingly low, with 50% to 70% of patients discontinuing its use within three years.[2] This is particularly concerning given the significant health risks associated with untreated OSA, including cardiovascular disease, cognitive decline, and increased mortality.[3–6] CPAP adherence remains a challenge. Discomfort with the mask, device-related noise, and inadequate patient education on the benefits of long-term usage contribute to the high discontinuation rates observed globally.[2]

In response to the challenges of maintaining long-term adherence to CPAP therapy, telemedicine has emerged as a promising tool to support the management of OSA. Telemedicine systems encompass a variety of approaches, including remote consultations, telephone follow-ups, parametric telemonitoring through connected devices, and automated messaging systems, all designed to enhance patient engagement and adherence.[7] However, the literature presents mixed results regarding the effectiveness of telemedicine in improving CPAP adherence and long-term management, likely due to differing definitions of adherence and the variety of telemedicine interventions employed.[8]

Motivated by these challenges and the limited evidence from Italy regarding the role of telemedicine in CPAP management, this study aims to contribute to the growing body of knowledge by reporting on the experience of the PROTEUS project. Specifically, we seek to elucidate the role of telemedicine in managing CPAP treatment, leveraging real-world data obtained through the use of telemonitoring systems. To our knowledge, this study

Received: 19 October 2024
Accepted: 11 February 2025
Published: 27 February 2025

provides, for the first time, insights from a 5-year follow-up of Italian patients, highlighting the long-term impact of telemedicine on adherence and treatment outcomes.

Materials and Methods

PROgetto TelemEdicina UlsS 2 (PROTEUS) Protocol

Patients diagnosed with OSA since July 2018, began CPAP treatment following either in-lab polysomnography (PSG) titration or home-based APAP titration, according to AASM recommendations[9] from four Italian Pulmonology Units (Treviso (VE), Italy). Those with sleep-disordered breathing other than OSA or requiring ventilatory support other than CPAP were excluded from the PROTEUS project. Patients for "just cause", ie, OSA transferred to another center, those who had been switched to another ventilatory modality, patients who no longer needed CPAP treatment, and those who had died were also excluded from the analyses.

CPAP devices were provided by the local health authority through third-party suppliers, companies responsible for distributing and selling various CPAP devices. Patients were followed up with telemonitoring for 5 years. After initiating treatment, patients received an in-person follow-up pulmonology consultation after 3 months, followed by quarterly telemonitoring consultations (telemonitoring platforms dedicated to individual CPAP supplies companies) performed by third-party suppliers. These telemonitoring follow-ups included checks for CPAP adherence (hours of use per night), residual apnea-hypopnea index ($rAHI_{CPAP}$), and air leakage. Patients were encouraged to maintain CPAP adherence through periodic reminders and personalized feedback provided during telemonitoring consultations. The suppliers also provided technical support for device-related issues. In the case of more serious or persistent issues (over two consecutive follow-ups) — $rAHI_{CPAP}$ greater than 10 events·h^{-1}, excessive air leakage, or poor adherence (less than 4 hours per night or less than 70% of days[10]) — the suppliers would notify the medical staff (designated physicians or nurses), to handle clinically relevant situations (Figure 1).

CPAP discontinuation was only considered after all efforts to restore adherence had failed and the patient opted to discontinue treatment.

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board. Patients provided informed consent.

Statistical Analysis

All statistical analyses were performed using SPSS (version 26, IBM Software, CA, USA). Data from the 5th year of telemonitoring were analyzed. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as percentages. The analysis included only patients with valid CPAP adherence data; dropouts, such as those with "just cause" and patients with incomplete annual follow-up, were excluded. Continuous data were analyzed by Wilcoxon or Kruskal–Wallis tests. Categorical variables were analyzed by Chi-square test. For the multiple comparison, the Bonferroni correction was used. A p-value<0.05 was considered statistically significant.

Results

The flowchart of the study is detailed in Figure 2. A total of 486 CPAP-adherent patients were included (340 males and 146 females), with a mean age of 68.53 ± 12.06 years. General characteristics, $rAHI_{CPAP}$, CPAP adherence and leakage are summarized in Table 1. Specifically, mean $rAHI_{CPAP}$ was 3.95±5.25 events·h^{-1}, mean adherence was 6.35±1.72 h·$night^{-1}$, and high air leakage was present in 25% of cases.

No significant differences in $rAHI_{CPAP}$, CPAP adherence and air leakage were found between sexes (Table S1). However, when patients were stratified by CPAP usage hours, a greater incidence of air leaks was observed in those using CPAP for longer durations (Table S2 and S3). Additionally, analysis based on the $rAHI_{CPAP}$ threshold revealed that $rAHI_{CPAP}$ >10 events·h^{-1} was associated with poorer adherence and older age (Table S4 and S5).

After 5 years, approximately 85% of OSA patients continued the nighttime CPAP treatment (Figure 3).

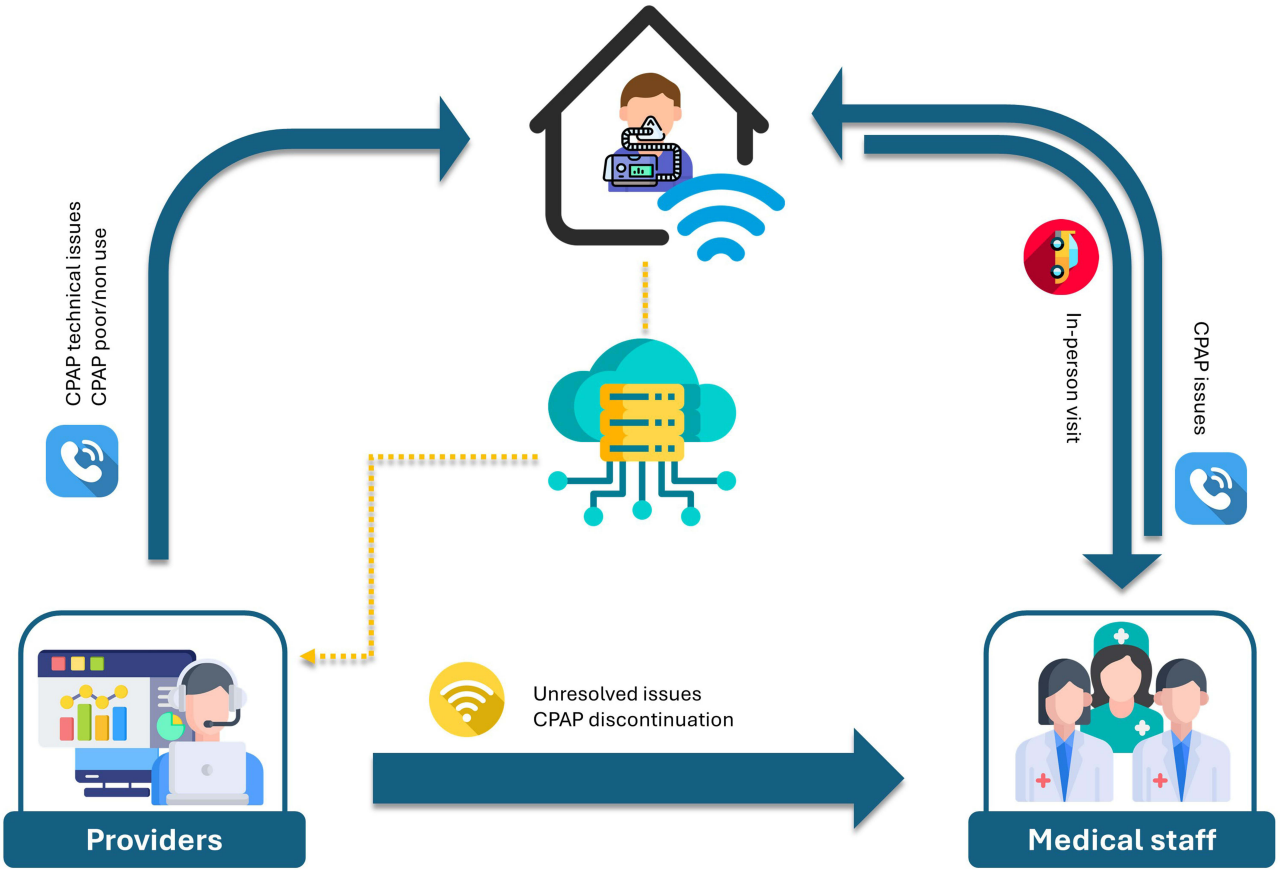

Figure 1 Steps of the management procedure for patients undergoing CPAP therapy. CPAP data via telemonitoring systems (yellow arrow) were viewed by providers of CPAP companies who contacted (via telephone) patients in case of technical problems or poor/non-use of CPAP (blue arrow - blue dot with telephone). If providers failed to resolve the problems and patients discontinued CPAP, medical staff were alerted (blue arrow - yellow dot) who contacted the patient and tried to resolve the problems by phone (blue arrow - blue dot with phone) or, in more complex cases, patients returned to the referring pulmonology center for an in-person visit (blue arrow - red dot with car).

Discussion

The PROTEUS project achieved a 5-year CPAP adherence rate exceeding 85%, with minimal residual events, regardless of age or sex.

While the study demonstrates high adherence rates, the absence of a control group precludes definitive conclusions about the exclusive impact of telemedicine on these outcomes. A key factor contributing to the higher adherence rates compared to studies outlined in Table S6 (55%-76%) was the integration of telemonitoring interventions, which included regular follow-ups and immediate troubleshooting. Additionally, patients were provided with targeted counseling, emphasizing the health benefits of long-term CPAP usage, which likely improved motivation and engagement. Although a small subset of patients used CPAP for less than 4 hours per night, their numbers were too low to significantly impact the overall high adherence rate, affirming the robustness of our findings. Notably, more than two-thirds of our patients used CPAP for over 6 hours per night, a critical factor, as the extended use has been shown to significantly reduce cardiometabolic risks and improve overall health outcomes in patients with OSA.[11,12]

No significant sex differences were found in residual AHI or CPAP adherence, aligning with other studies that report similar outcomes.[13] However, older patients experienced more frequent respiratory alterations during sleep, which was correlated with a lower adherence and a higher incidence of unintentional air leaks. A possible hypothesis behind this finding could be related to the higher prevalence of physiological central apneas in the elderly, a phenomenon that is not always responsive to standard CPAP therapy.[14] Our data do not provide us with a distinction between the nature of breathing events during sleep, but if our hypothesis were true, this would suggest that that older adults might benefit from

https://doi.org/10.2147/NSS.S501341

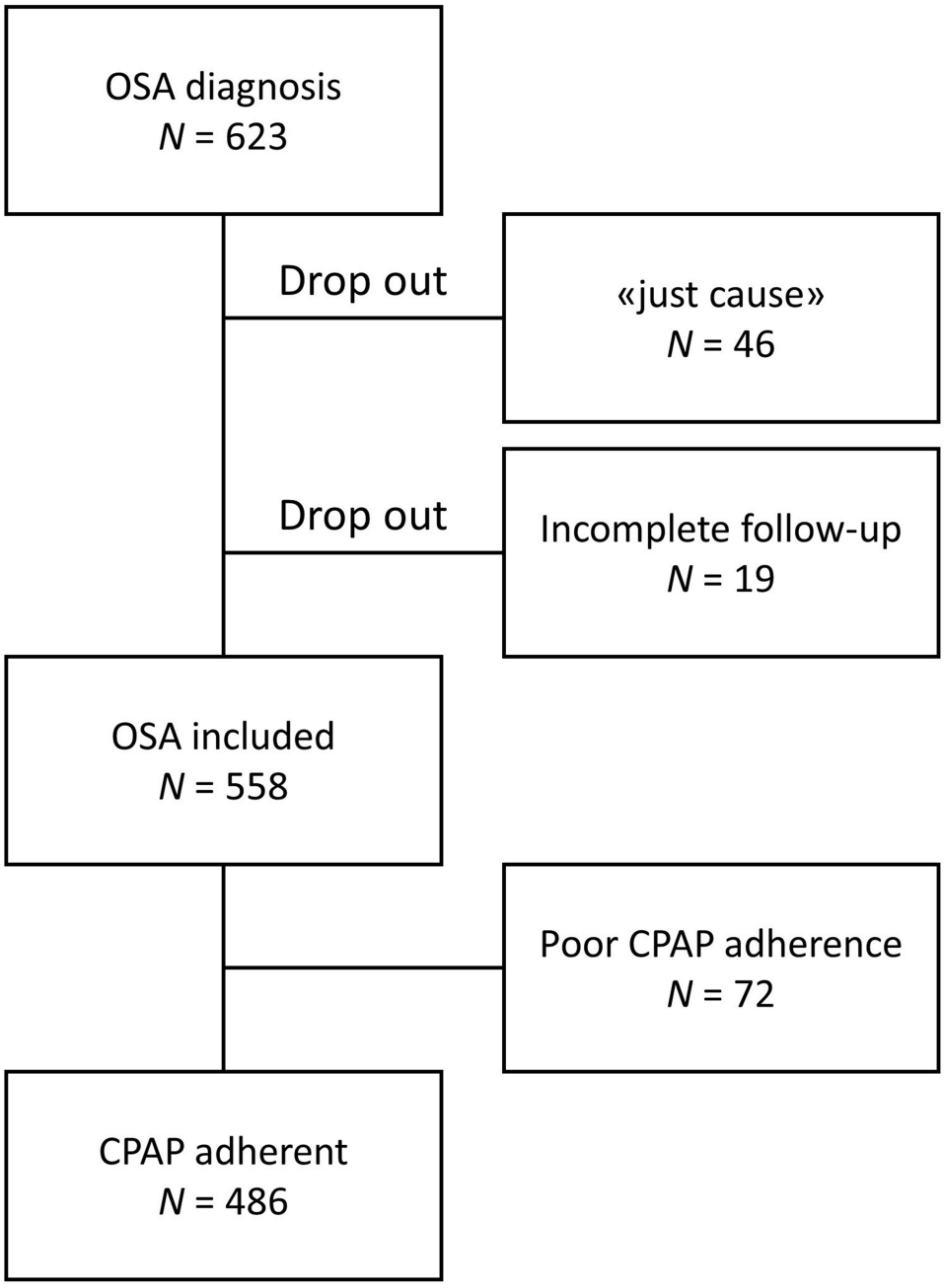

Figure 2 Flowchart of the study.
Notes: OSA patients who were transferred to another center, those who had been switched to another ventilatory mode, patients who no longer needed CPAP treatment, and those who had died were defined as "just cause".

alternative treatments, such as adaptive servo-ventilation (ASV) or bilevel positive airway pressure (BiPAP), which have been shown to be more effective in treating complex sleep apnea.[15]

Study limitations: One of the primary limitations of this study is the lack of additional clinical information beyond CPAP data. CPAP usage alone does not provide a full picture of the patient's respiratory patterns or comorbid conditions, which could influence adherence and treatment efficacy. Additionally, the absence of body mass index (BMI) data, a crucial factor in OSA prognosis, limits the ability to assess its impact on adherence and treatment outcomes. Baseline AHI from diagnostic PSG was not included in the main analysis, which limits our ability to correlate disease severity with adherence.[16]

Table 1 General Characteristics of Population

	Total
	N=486
Demographics	
Sex (male)	70%
Age (years)	68.53±12.06
Age >65y (%)	66%
CPAP data	
rAHI (events $\cdot h^{-1}$)	3.95±5.25
rAHI >10 events $\cdot h^{-1}$ (%)	9%
Usage hours (h)	6.35±1.72
Adherence (%)*	88.36±17.73
High leakage (%)	25%

Notes: Continuous data are expressed as mean ±standard deviation, while categorical as percentage. *The CPAP adherence data are for the overall mean percent CPAP usage.

Moreover, the lack of a control group makes it difficult to directly compare the effectiveness of telemonitoring with other potential interventions. Future studies should incorporate more comprehensive clinical data, including polysomnographic results, cardiometabolic assessments, BMI data, and a control group, to better understand the long-term impact of CPAP therapy and telemedicine interventions.

Study strengths: This is the first long-term, multicenter study in Italy involving a large cohort patients with OSA. Key strengths include the use of well-defined adherence criteria, a relatively high representation of women (>20%) and elderly patients, the exclusion of dropouts for valid reasons", and a detailed evaluation of CPAP efficacy and air leakage. The integration of telemonitoring allowed timely interventions, which may have contributed to the high adherence rate.

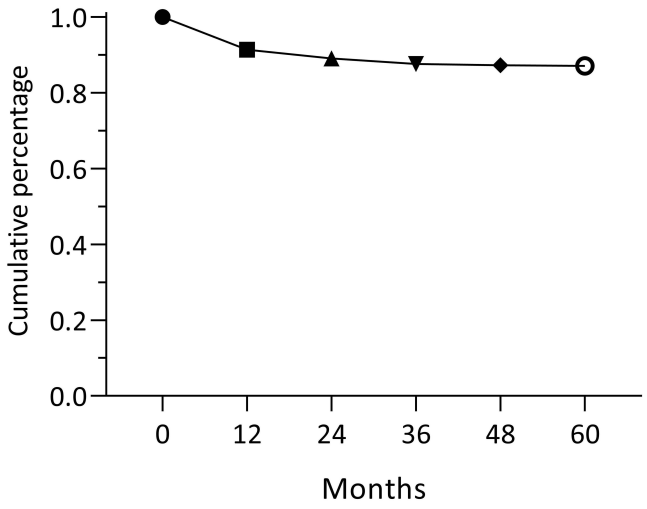

Figure 3 Adherence curve at 60 months of OSA patients treated with CPAP. The different symbols correspond to different (12, 24, 36, 48, 60) months of follow-up.

https://doi.org/10.2147/NSS.S501341

This supports the growing body of evidence that telemedicine can play a pivotal role in improving CPAP adherence through consistent monitoring and early troubleshooting.[17,18]

Conclusion

The PROTEUS project has proven highly effective in managing OSA patients in CPAP treatment, with an adherence rate exceeding 85% after 5 years. Prompt resolution of technical issues played a key role, and over two-thirds of patients used the device for more than 6 hours per night, a key factor in reducing cardiometabolic risk. Expanding the telemedicine network could further improve patient care and optimize healthcare resources, though additional studies are needed to evaluate the long-term effectiveness of this approach. In addition, further analysis is needed to explore how telemedicine interventions specifically impacted subgroups, such as patients with low adherence or high residual AHI. These data could inform personalized strategies for improving compliance and outcomes in challenging cases.

Abbreviations

AHI, apnea-hypopnea index; CPAP, continuous positive airway pressure; OSA, obstructive sleep apnea; $rAHI_{CPAP}$, residual AHI obtained from CPAP device.

Acknowledgments

The authors would like to thank Thomas Bustreo (provider 's technical staff) and Jessica De Bortoli (head nurse coordinator) for their support to the project. Thanks to Dr. Anela Hoxhallari for editing the text's English.

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M. Chizzolini: Data curation, Investigation, Resources, Writing – review and editing.

P. Tondo: Data curation, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review and editing.

All authors have agreed on the journal to which the article was submitted. Reviewed and agreed on all versions of the article before submission, during revision, the final version accepted for publication, and any significant changes introduced at the proofing stage. Agree to take responsibility and be accountable for the contents of the article.

Funding

The authors have no funding to disclose.

Disclosure

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests. Dr R Drigo collaborates with Vivisol, Vitalaire, Sico and Vedise. The authors have no other conflicts of interest to declare.

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