Telemedicine home CPAP titration and follow-up in the COVID-19 scenario

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Telemedicine home CPAP titration and early follow-up is equivalent to usual care in adaptation and compliance while achieving greater patient satisfaction. The use of the mHealth application may help patients self-empower and encourage increased CPAP use. https://bit.ly/3xwvwLX

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Abstract
Introduction Continuous positive airway pressure (CPAP) titration was dramatically affected by the coronavirus disease 2019 (COVID-19) pandemic due to increased biological risk. This study aimed to compare successful CPAP adaptation and compliance with home telemedicine CPAP titration with the usual method based on face-to-face visits.
Methodology A prospective cohort using telemedicine home CPAP titration and follow-up during the COVID-19 pandemic (TC) was compared with a retrospective cohort receiving face-to-face pre-pandemic home titration (RC). The TC included a subgroup with a smartphone application (TC-APP). Successful CPAP adaptation and compliance at 1 month of follow-up were the main endpoints, while patient satisfaction and costs were secondary endpoints.
Results 210 consecutive patients were evaluated (80 RC and 130 TC). 36 patients were in the TC-APP subgroup. CPAP titration was successful in 90% in RC *versus* 95% in TC and 100% in TC-APP. No compliance differences between groups were found at 1 month (4.79 $h \cdot night^{-1}$ RC, 4.33 $h \cdot night^{-1}$ TC and 4.59 $h \cdot night^{-1}$ TC-APP). Mean±SD patient satisfaction out of 10 was 7.69±2.05 in RC *versus* 9.02±0.64 in TC ($p<0.001$). 64% of the TC-APP subgroup reported that their telemedicine strategy influenced an increase in CPAP use ($p=0.011$). CPAP adaptation with follow-up had an estimated direct staff cost per patient of EUR 19.61±8.61 in TC with no smartphone application used *versus* EUR 23.79±9.94 in TC-APP ($p=0.048$).
Conclusions Telemedicine in CPAP titration and early follow-up is equivalent to the usual care in terms of successful adaptation and compliance, while achieving greater patient satisfaction.

Introduction
Obstructive sleep apnoea (OSA) is a highly prevalent chronic disease associated with important comorbidities such as traffic accidents, cardiovascular and metabolic diseases, and mortality [1]. Continuous positive airway pressure (CPAP), a first-line therapy in moderate–severe OSA [2], has proven successful in improving daytime sleepiness and quality of life, reducing traffic accidents [3], and improving hypertension and paroxysmal atrial fibrillation [4, 5]. However, 47% of successfully titrated patients abandon treatment within 3 years [5, 6]. Thus, early OSA and CPAP education with close follow-up is mandatory to achieve satisfactory CPAP compliance [6, 7]. In that context, telemedicine and telemonitoring through remote monitoring of CPAP have become promising strategies [8, 9]. Recently, smartphone applications [10] and wearable devices [11] have been added as new suggested tools for improving CPAP compliance.

The onset of the coronavirus disease 2019 (COVID-19) pandemic [12] saw a reduction in sleep unit activity of almost 80% in the first 2 months [13]. As severe acute respiratory syndrome coronavirus 2

(SARS-CoV-2) remains viable in aerosols for 3 h [14], CPAP titration is a challenging procedure as it generates droplet dispersion and involves a noteworthy increase of the biological risk for both medical staff and patients. Hence, home strategies for respiratory therapies with the implementation of telemedicine were encouraged by medical societies to diminish the risk of COVID-19 infection [15, 16]. Previous studies have shown satisfactory results in CPAP home titration [17] and CPAP follow-up by telemedicine [18]. The feasibility of smartphone applications, as well as the so-called mobile health (mHealth) application [10, 19, 20], has also been demonstrated. Nevertheless, to our best knowledge, there has been no study on CPAP titration by telemedicine in the new COVID-19 scenario comparing different telemedicine strategies including telemonitoring with and without a smartphone application for clinical CPAP follow-up.

Therefore, this study aims to compare telemedicine strategies for home CPAP titration initiated in the COVID-19 pandemic scenario with the previous standard CPAP home titration through hospital face-to-face visits.

Methods

Study design

A prospective telemedicine cohort (TC) undergoing CPAP titration and follow-up initiated to restart titrations during the COVID-19 pandemic scenario was compared with a retrospective cohort (RC) with the usual CPAP home titration and follow-up. The TC included subgroups using and not using a smartphone application (TC-APP and TC-noAPP, respectively).

The main endpoints were successful CPAP adaptation and CPAP compliance at 1 month of follow-up. Secondary endpoints were reported patient satisfaction and the direct staff costs of the different telemedicine approaches.

This study was approved by the ethics committee at our tertiary care level hospital (PR271/20). The prospective TC included patient signed informed consent, whereas for the RC patient oral informed consent was obtained *via* a telephone call and then registered in the clinical records.

Patients

Patients were consecutively recruited for both cohorts, from February to May 2019 for RC and from September 2020 to February 2021 for TC.

Eligible patients were adults (⩾18 years old) with a recent OSA diagnosis and CPAP treatment indication. Patients under CPAP treatment, and those with unstable acute or chronic diseases were excluded. A certain educational level or regular smartphone use was not required for inclusion. At baseline, all clinical, demographic and sleep variables were registered for the two cohorts.

Home CPAP titration strategies

The home CPAP titration workflow in the RC was initiated by scheduling an in-person visit to the hospital with a sleep unit nurse, who provided educational information with additional written support, performed individual CPAP training for 45–60 min and selected an appropriate mask. Then, autoCPAP was delivered to the patient, who returned it the next day and after the data was downloaded, a fixed pressure was prescribed. The optimal pressure was determined visually from the raw data as the pressure that covered 90% of the period without leaks [17]. The titration was considered unsuccessful when sleep time was subjectively <5 h or when significant leaks were observed during most of the night. The home titration procedure was repeated up to two additional times when the home CPAP titration circuit was considered unsuccessful. Those patients were excluded from further analysis in this study and in-laboratory full polysomnographic CPAP titration was performed. After a successful titration, the CPAP was supplied to the patient by the healthcare provider, and the sleep unit nurse's telephone number was given to the patient to use in case they required assistance. Face-to-face follow-up at 1 month by a sleep unit nurse was performed assessing CPAP compliance and adverse effects. Patient satisfaction was obtained by phone specifically for the study at inclusion.

Two TC strategies were implemented. The first was a nurse call-visit informing about CPAP titration procedure. Information was also sent by both post and e-mail. Information included an educational YouTube video regarding CPAP use and training. Additionally, the telephone number of the sleep unit nurse was given to the patient in case of requiring assistance. The healthcare provider supplied autoCPAP (Dreamstation CPAP Pro, Respironics) for three nights (pressure range: 6–12 cmH$_2$O), which was equipped with a modem for remote data transmission and titration. The sleep unit nurse telemonitored CPAP compliance, leaks, residual apnoea–hypopnoea index (AHI) and pressure through the

EncoreAnywhere platform and a telephone call or video conference visit was performed if required. A CPAP fixed pressure was prescribed as described previously according to the three-night raw data [17]. The healthcare provider supplied the CPAP device. Cases of unsuccessful home titration were referred for in-laboratory titration (and were also excluded from further analysis, as in the RC). A telephone call or video conference follow-up sleep unit nurse visit was performed at 1 month to assess adverse effects and patient satisfaction. Objective CPAP adherence as registered by the home CPAP device used by the patient was obtained by the healthcare provider.

The second TC strategy also included recommending the use of a smartphone application (Estoi®). A download link and written information were sent by letter and e-mail. Estoi is a smartphone application that provides: 1) educational information in text and video formats regarding CPAP use and frequent adverse effects or problems; 2) side-effect, tolerance and compliance questionnaires with weekly reminder notifications; 3) an algorithm that recommends educational text and videos based on the problems detected in the questionnaires; 4) telemonitoring of questionnaires by the medical team with an alarm system; and 5) an open messaging system between the patient and medical team.

Statistics

Demographic, clinical, OSA treatment and titration variables were analysed according to the type of variable, and are presented in tables according to the study group. The raw effect of the group on these variables was analysed using logistic regression models. The model was replicated by adding variables such as age, sex, body mass index (BMI), educational level and apnoea to observe the adjusted effect. The raw effect of the group on these variables was analysed using linear models according to the distribution of the variable. To observe the adjusted effect, the model was replicated by adding variables such as age, sex, BMI, educational level and apnoea. Staff direct costs were estimated using EUR 32.76 per h for the specialised sleep nurse and EUR 52.92 per h for the sleep doctor.

Results

210 consecutive patients were evaluated (80 RC and 130 TC). Nine were excluded in the RC and 13 in the TC (figure 1). From 188 analysed patients, 71 were RC and 117 were TC, of which 41 patients were not offered the smartphone application and 76 were offered it, and it was used by 36 patients (TC-APP subgroup).

The patients' characteristics are shown in table 1. No significant baseline differences were detected between the RC and TC, or between those who used the smartphone application and those who did not. Sleep study and OSA characteristics are presented in table 2; no relevant differences were found between the RC and TC. Baseline AHI was higher in TC-APP *versus* TC-noAPP (AHI 53.1 *versus* 36.8 events per h, respectively; p=0.022).

CPAP was successfully titrated and adapted in 90% of the RC, while for TC the corresponding figure was 94.9%, with 100% in TC-APP. Despite the improvement in the TC, and especially in TC-APP, the differences did not reach statistical significance. However, successful single-time CPAP titration was significantly higher (p<0.001) in the TC (99%) than in the RC (78.9%). Attendance at the first follow-up visit was significantly higher in the TC than in the RC (100% *versus* 90%; p=0.0044).

No CPAP compliance differences were found between cohorts. When assessing the RC *versus* TC by multivariate logistic models, age was the only factor that increased by 5% the probability of 1-month CPAP compliance >4 h per night (OR 1.05, 95% CI 1.02–1.09; p=0.002) (table 3). In the two TC (TC-APP and TC-noAPP) multivariate logistic models, a high educational level increased the probability of 1-month CPAP compliance >4 h per night by 294% (OR 3.94, 95% CI 1.33–13.04; p=0.017) (table 3).

Patient satisfaction (scored out of 10) was significantly higher (p<0.001) in the TC (mean±SD 9.02±0.64) than in the RC (7.69±2.05) and 68.9% of RC patients were satisfied *versus* 98% TC (p<0.001) according to the survey of patients (table 4). Patient satisfaction remained significantly higher in TC when adjusted for other important parameters (table 3). Patients in the TC reported easier access to healthcare staff compared to patients in the RC (100% *versus* 59%; p<0.001). 36% of the patients in the RC would prefer a new CPAP adaptation to be performed using the telematic process, while 94% of the TC would have preferred a new telematic process (p<0.001). Finally, our telemedicine strategy would be recommended to others by 96% of the patients. Nonsignificant differences were detected in satisfaction between both telemedicine strategies. Nevertheless, 64% of the TC-APP reported that their telemedicine strategy influenced an increase in CPAP use compared to 45% in the TC-noAPP (p=0.011).

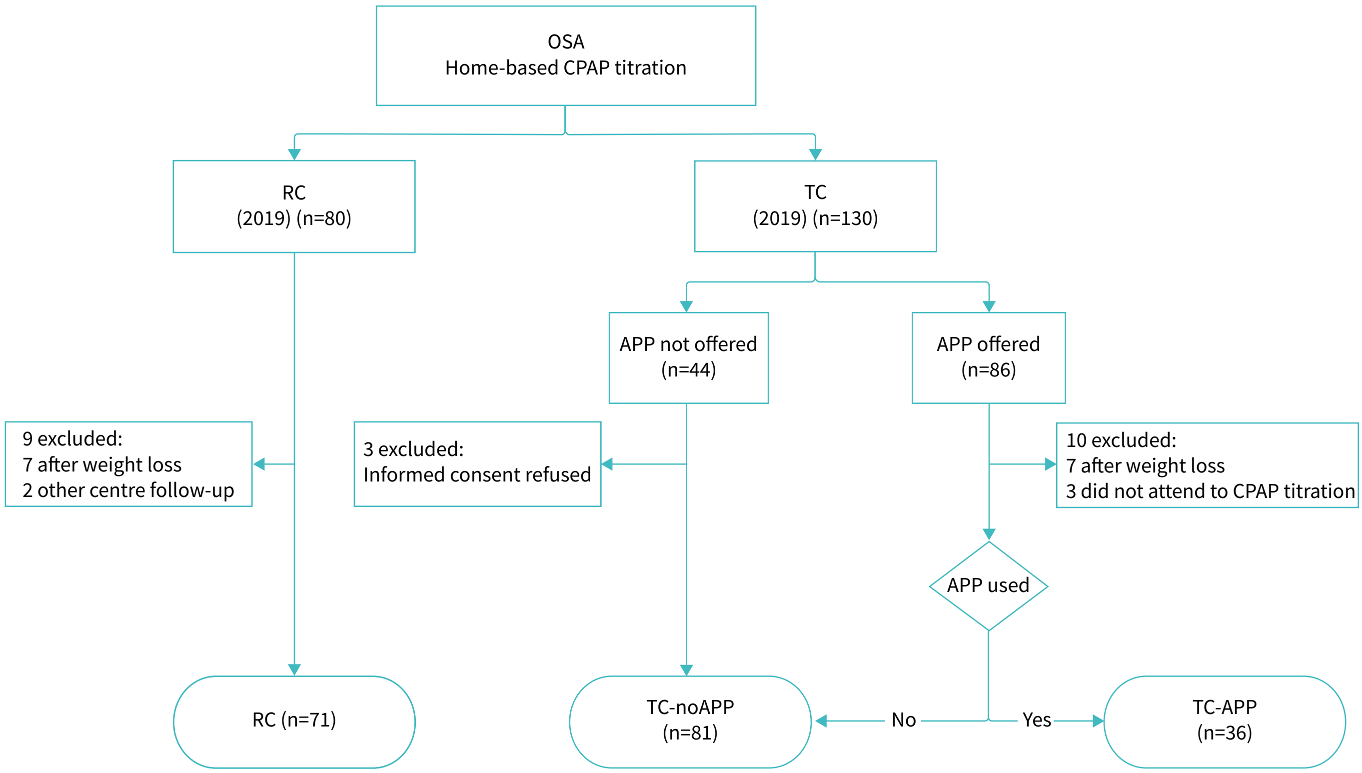

FIGURE 1 Study flow-chart. OSA: obstructive sleep apnoea; CPAP: continuous positive airway pressure; TC: telemedicine cohort; RC: retrospective cohort; APP: smartphone application; TC-noAPP: telemedicine cohort not using smartphone application; TC-APP: telemedicine cohort using smartphone application.

Regarding the patients in the TC-APP (table 5), 66% responded to the smartphone application questionnaires and 61% used the messaging system; 73% of the messages were initiated by the patient and 27% by the medical team because of an alarm in the system. Nine messages sent *via* the smartphone application (43%) resulted in an action to improve CPAP adaptation. The compliance reported by the application was, on average, 6.36±1.21 h per night, which did not correlate with objective CPAP compliance hours (r=0.58).

CPAP adaptation with follow-up had an estimated staff direct cost per patient of EUR 19.61±8.61 in TC-noAPP compared to EUR 23.79±9.94 in TC-APP (p=0.0483).

Discussion

To the best of our knowledge, this is the first CPAP titration and follow-up study performed entirely during the COVID-19 pandemic through two different telemedicine strategies, which are compared with the face-to-face standard of care in place before the pandemic. Our main results showed that telemedicine is equivalent to the previous standard care in terms of successful titration and in CPAP compliance at 1 month of follow-up, as well as providing higher patient satisfaction. The additional use of the smartphone application can facilitate compliance in the patients' opinion but no significant differences were demonstrated in this group.

The new COVID-19 scenario has presented unsuspected challenges and has advanced telemedicine implementation [13] responding to concerns of biological risk [14], especially in respiratory care units [15, 16]. The new strategies developed to maintain activity in the sleep units have been achievable as a result of previous experience in telemedicine [21–23] and, more than being a temporary solution, they could represent an option to be considered in regular activity.

Our data showed that successful CPAP adaptation and titration increased in TC (95%), especially in TC-APP (100%), against RC (90%), without achieving statistical significance, probably due to the small sample size. This telemonitored titration protocol based on sleeping several nights at home with the

TABLE 1 Patient characteristics

	RC *versus* TC			TC-noAPP *versus* TC-APP		
	RC	TC	p-value	TC-noAPP	TC-APP	p-value
Patients	71	117		81	36	
Males	48 (67.6%)	80 (68.4%)	1.000	57 (70.4%)	23 (63.9%)	0.631
Age, years	57.8±11.6	59.5±12.6	0.338	60.6±12.9	57.1±11.6	0.142
Smoking exposure			0.093			0.131
Never-smokers	25 (35.2%)	51 (43.6%)		34 (42.0%)	17 (47.2%)	
Smokers	17 (23.9%)	36 (30.8%)		22 (27.2%)	14 (38.9%)	
Former smokers	29 (40.8%)	30 (25.6%)		25 (30.9%)	5 (13.9%)	
BMI, kg·m^{-2}	36.6±9.63	34.8±7.21	0.181	34.9±7.05	34.7±7.66	0.884
BMI category			0.250			0.239
Normal or healthy weight	2 (2.82%)	7 (5.98%)		3 (3.70%)	4 (11.1%)	
Overweight	18 (25.4%)	19 (16.2%)		15 (18.5%)	4 (11.1%)	
Obese	51 (71.8%)	91 (77.8%)		63 (77.8%)	28 (77.8%)	
Arterial hypertension	44 (62.0%)	67 (57.3%)	0.629	48 (59.3%)	19 (52.8%)	0.652
Diabetes mellitus	16 (22.5%)	25 (21.4%)	0.995	18 (22.2%)	7 (19.4%)	0.925
Dyslipidaemia	32 (45.1%)	45 (38.5%)	0.459	32 (39.5%)	13 (36.1%)	0.887
Gastro-oesophageal reflux disease	4 (5.63%)	2 (1.71%)	0.201	1 (1.23%)	1 (2.78%)	0.523
Kidney disease	5 (7.04%)	4 (3.42%)	0.302	3 (3.70%)	1 (2.78%)	1.000
Heart disease	18 (25.4%)	18 (15.4%)	0.136	13 (16.0%)	5 (13.9%)	0.983
Respiratory disease			0.033			1.000
COPD	5 (7.04%)	10 (8.55%)		7 (8.64%)	3 (8.33%)	
Asthma	6 (8.45%)	2 (1.71%)		2 (2.47%)	0 (0.00%)	
Interstitial lung disease	2 (2.82%)	0 (0.00%)		0 (0.00%)	0 (0.00%)	
Neurological disease	6 (8.45%)	9 (7.69%)	1.000	8 (9.88%)	1 (2.78%)	0.271
Hypothyroidism	4 (5.63%)	3 (2.56%)	0.429	1 (1.23%)	2 (5.56%)	0.224
Migraine	0 (0.00%)	4 (3.42%)	0.299	3 (3.70%)	1 (2.78%)	1.000
Fibromyalgia	1 (1.41%)	3 (2.56%)	1.000	2 (2.47%)	1 (2.78%)	1.000
Depression/anxiety	7 (9.86%)	17 (14.5%)	0.481	14 (17.3%)	3 (8.33%)	0.325
Malignant disease history	5 (7.04%)	2 (1.71%)	0.106	2 (2.47%)	0 (0.00%)	1.000
Educational level			0.175			0.465
Reading and writing difficulties or no high school	40 (58.0%)	78 (69.0%)		56 (71.8%)	22 (62.9%)	
High school and associated degree or college and graduate degree	29 (42.0%)	35 (31.0%)		22 (28.2%)	13 (37.1%)	

Data are presented as mean±SD unless otherwise stated. RC: retrospective cohort; TC: telemedicine cohort; TC-noAPP: telemedicine cohort not using smartphone application; TC-APP: telemedicine cohort using smartphone application; BMI: body mass index.

autoCPAP device takes advantage of not requiring additional patient displacement, since adherence, air leakage and pressure are remotely managed, and daily sleep unit staff intervention can improve adaptation in consecutive days, increasing successful CPAP titration.

1-month CPAP compliance and sleepiness measured by Epworth Sleepiness Scale score was similar in the RC and TC. Therefore, the telemedicine strategy used is as useful as face-to-face management not only for achieving CPAP titrations, but also for achieving good compliance and clinical response at 1 month of follow-up, which is a predictor of good long-term CPAP compliance [24]. Likewise, in the multivariate analysis, neither RC nor TC, nor sex, basal AHI, BMI or Epworth Sleepiness Scale had an influence on compliance >4 h of CPAP per night. Only age was related to greater compliance. Therefore, this supports the idea of not limiting the use of titration by telemedicine in older patients.

Studies analysing different telemedicine strategies for CPAP follow-up have found that CPAP compliance was equivalent to that with usual care [18, 25–28]. Only a few studies were successful in increasing CPAP compliance up to 30 min per night through telephone coaching (26 min per night) [29] or other methods. Nevertheless, a recent CPAP telemonitoring meta-analysis [22] did not find differences in CPAP compliance with telemonitored and standard CPAP follow-up. In our study, it is worth noting that a sleep unit telephone number was already available to patients in our standard care system previous to COVID-19, so there was no improvement in TC in terms of adaptation or during follow-up.

Only one other study carried out during the COVID-19 pandemic [30] has evaluated the telemedicine approach of CPAP titration compared with face-to-face titration. Similar to this study, equivalence in

TABLE 2 Obstructive sleep apnoea (OSA) diagnosis, continuous positive airway pressure (CPAP) treatment and follow-up

	RC *versus* TC			TC-noAPP *versus* TC-APP		
	RC	TC	p-value	TC-noAPP	TC-APP	p-value
Patients	71	117		81	36	
OSA diagnosis						
Diagnostic test			**0.040**			0.697
Nocturnal pulse oximetry	1 (1.41%)	8 (6.84%)		6 (7.41%)	2 (5.56%)	
Respiratory polygraphy	44 (62.0%)	83 (70.9%)		59 (72.8%)	24 (66.7%)	
Polysomnography	26 (36.6%)	26 (22.2%)		16 (19.8%)	10 (27.8%)	
AHI, events per h	46.0 (32.5–67.6)	40.8 (26.8–57.5)	0.134	36.8 (25.1–53.0)	53.1 (31.5–71.1)	**0.022**
In supine position	57.5 (39.2–72.4)	53.6 (32.0–70.2)	0.157	47.3 (28.9–66.3)	58.5 (38.6–75.6)	0.146
TST90	22.4±26.1%	19.0±22.1%	0.356	18.8±22.1%	19.4±22.4%	0.889
Sleepiness			0.292			**0.019**
No	7 (9.86%)	23 (20.0%)		12 (14.8%)	11 (32.4%)	
Passive	46 (64.8%)	62 (53.9%)		50 (61.7%)	12 (35.3%)	
Active	13 (18.3%)	21 (18.3%)		15 (18.5%)	6 (17.6%)	
Driving	5 (7.04%)	9 (7.83%)		4 (4.94%)	5 (14.7%)	
Apnoea			**<0.001**			0.067
No	8 (11.3%)	6 (5.17%)		2 (2.47%)	4 (11.4%)	
Yes	50 (70.4%)	110 (94.8%)		79 (97.5%)	31 (88.6%)	
Does not know	13 (18.3%)	0 (0.00%)		0 (0.00%)	0 (0.00%)	
Fatigue			**<0.001**			0.461
No	25 (35.2%)	10 (8.62%)		6 (7.41%)	4 (11.4%)	
Yes	46 (64.8%)	85 (73.3%)		58 (71.6%)	27 (77.1%)	
Does not know	0 (0.00%)	21 (18.1%)		17 (21.0%)	4 (11.4%)	
Restorative sleep	14 (19.7%)	29 (25.7%)	0.454	21 (25.9%)	8 (25.0%)	1.000
Choking	28 (40.0%)	50 (45.0%)	0.608	34 (42.5%)	16 (51.6%)	0.514
Nocturia, events per night	2.00 (1.00–3.00)	2.00 (1.00–3.00)	0.882	2.00 (0.00–3.00)	2.00 (1.00–3.00)	0.842
Epworth Sleepiness Scale score at diagnosis	11.2±5.45	10.7±5.26	0.531	10.9±5.27	10.1±5.28	0.444
CPAP treatment						
CPAP adaptation	64 (90.1%)	111 (94.9%)	0.346	75 (92.6%)	36 (100%)	0.222
Number of CPAP titrations required			**<0.001**			1.000
1	56 (78.9%)	116 (99.1%)		80 (98.8%)	36 (100%)	
>1	15 (21.1%)	1 (0.85%)		1 (1.23%)	0 (0.00%)	
95th percentile pressure, cmH_2O	11.0±2.00	10.1±2.16	**0.006**	9.93±2.10	10.5±2.27	0.222
Residual AHI, events per h	1.60 (0.80–4.00)	4.00 (2.30–6.70)	**<0.001**	4.10 (2.20–7.55)	3.40 (2.58–4.62)	0.424
Early follow-up[#]						
Follow-up visit attendance	58 (90.6%)	111 (100%)	**0.004**	75 (100%)	36 (100%)	
CPAP compliance, $h \cdot night^{-1}$	4.79±2.85	4.33±2.62	0.292	4.21±2.76	4.58±2.30	0.470
CPAP compliance >4 $h \cdot night^{-1}$	45 (70.3%)	70 (63.1%)	0.419	44 (58.7%)	26 (72.2%)	0.240
CPAP compliance >5 $h \cdot night^{-1}$	40 (56.3%)	56 (47.9%)	0.329	37 (45.7%)	19 (52.8%)	0.611
Epworth Sleepiness Scale score change after CPAP treatment	7.12±7.24	5.29±4.70	0.104	5.00±4.73	5.90±4.66	0.380
Patient satisfaction[¶]	7.69±2.05	9.02±0.64	**<0.001**	9.00±0.64	9.06±0.64	0.665

Numbers in bold represent a p-value of <0.05. Data are presented as median (interquartile range) or mean±SD, unless otherwise stated. RC: retrospective cohort; TC: telemedicine cohort; TC-noAPP: telemedicine cohort not using smartphone application; TC-APP: telemedicine cohort using smartphone application; AHI: apnoea–hypopnoea index; TST90: total sleep time with oxygen saturation <90%. [#]: 1 month; [¶]: score out of 10.

1-month CPAP compliance was observed. Nevertheless, CPAP telemonitoring was performed throughout the entire study period [30], whereas in the present study, telemonitoring was only performed during the 3 days of CPAP titration. The equipment used after titration was chosen because of CPAP provider availabilities. Nevertheless, the present study demonstrated that telemonitoring titration plus standard CPAP after titration and telematic follow-up obtains equivalent results to in-person titration and contributes to building up new evidence supporting alternative telematic titration workflows.

Regarding perceived patient satisfaction, the TC reported greater satisfaction than RC. The patients probably perceived avoiding displacement to the hospital during the pandemic as a significant advantage. Moreover, one of the most promising reported telemedicine benefits was patient satisfaction, and especially when the mHealth application was incorporated. Using the "APPnea" smartphone application for CPAP self-monitoring, Isetta *et al.* [18] found that 83% of patients were very satisfied compared to 72% in the

TABLE 3 Multivariate models

	Univariate				Multivariate			
	Odds ratio	SE	95% CI	p-value	Odds ratio	SE	95% CI	p-value
RC–TC multivariate logistic model: CPAP adherence >4 h per night								
Predictors								
(Intercept)	2.37	0.65	1.41–4.14	**0.002**	0.04	0.06	0.00–0.83	**0.042**
TC *versus* RC	0.72	0.24	0.37–1.38	0.331	0.64	0.24	0.30–1.33	0.239
Age					1.05	0.02	1.02–1.09	**0.002**
Sex (female)					1.21	0.47	0.58–2.62	0.614
BMI					1.02	0.02	0.97–1.07	0.517
Educational level#					1.80	0.70	0.85–3.94	0.134
AHI (events per h)					1.00	0.01	0.98–1.01	0.731
ESS at diagnosis					1.05	0.04	0.98–1.12	0.152
Observations	175				160			
R^2 Tjur	0.005				0.088			
AIC	228.062				207.984			
TC-noAPP–TC-APP multivariate logistic model: CPAP adherence >4 h per night								
Predictors								
(Intercept)	1.42	0.33	0.90–2.27	0.135	0.00	0.00	0.00–0.01	**0.001**
TC-APP *versus* TC-noAPP	1.83	0.81	0.79–4.49	0.169	2.09	1.12	0.75–6.23	0.169
Age					1.10	0.03	1.05–1.16	**<0.001**
Sex (female)					0.97	0.50	0.35–2.74	0.956
BMI					1.06	0.04	0.98–1.15	0.148
Educational level#					3.94	2.28	1.33–13.04	**0.017**
AHI (events per h)					1.02	0.01	1.00–1.04	0.132
ESS at diagnosis					1.05	0.05	0.96–1.15	0.289
Observations	111				100			
R^2 Tjur	0.017				0.216			
AIC	148.248				125.753			

	Univariate				Multivariate 1				Multivariate 2			
	Estimate	SE	95% CI	p-value	Estimate	SE	95% CI	p-value	Estimate	SE	95% CI	p-value
RC–TC multivariate linear model: patient satisfaction												
Predictors												
(Intercept)	7.69	0.17	7.35–8.02	**<0.001**	7.64	0.18	7.29–7.99	**<0.001**	7.63	0.22	7.19–8.07	**<0.001**
TC *versus* RC	1.33	0.21	0.91–1.75	**<0.001**	1.38	0.22	0.94–1.82	**<0.001**	1.40	0.23	0.94–1.85	**<0.001**
Age					0.04	0.11	−0.18–0.25	0.745	0.03	0.12	−0.20–0.26	0.794
BMI					0.10	0.11	−0.12–0.32	0.364	0.09	0.12	−0.15–0.32	0.463
AHI (events per h)					−0.12	0.11	−0.33–0.09	0.242	−0.13	0.11	−0.34–0.09	0.248
ESS at diagnosis					0.24	0.11	0.02–0.45	**0.030**	0.24	0.11	0.02–0.45	**0.029**
Sex (female)									0.01	0.23	−0.45–0.47	0.967
Educational level#									0.02	0.24	−0.45–0.49	0.936
Observations	170				160				157			
R^2/R^2 adjusted	0.190/0.185				0.227/0.202				0.232/0.196			
AIC	582.165				553.937				157			

Numbers in bold represent a p-value of <0.05. RC: retrospective cohort; TC: telemedicine cohort; CPAP: continuous positive airway pressure; BMI: body mass index; AHI: apnoea–hypopnoea index; ESS: Epworth Sleepiness Scale; AIC: Akaike information criterion; TC-noAPP: telemedicine cohort not using smartphone application; TC-APP: telemedicine cohort using smartphone application. #: high school and associated degree or college and graduate degree.

control group and 82% of patients would integrate as part of follow-up. In the latest study [20] using "APPnea" for recovering patients with poor adherence to CPAP, mHealth was reported to be useful by 60% of patients, while 82% would recommend the application to other patients and 85% would integrate it as part of follow-up. Similarly, our patients' satisfaction was significantly greater in the TC with a mean±SD value of 9.02±0.64 against RC 7.69±2.05 out of 10 (p <0.001). In addition, only 6% of the patients in the TC reported that they would prefer to perform it face-to-face. Interestingly, 36% of our RC would prefer to perform it using the telematic process, and 96% of TC recommend our telemedicine programme to others. Patients in both telemedicine strategies reported easy access to healthcare professionals, felt confident about the security of their confidential data and would recommend the

TABLE 4 Patients' survey on continuous positive airway pressure (CPAP) adaptation and follow-up

	RC *versus* TC			TC-noAPP *versus* TC-APP		
	RC	TC	p-value	TC-noAPP	TC-APP	p-value
Patients	61	102		69	33	
Satisfaction with the follow-up			**<0.001**			0.103
No	9 (14.8%)	0 (0.00%)		0 (0.00%)	0 (0.00%)	
Partially	10 (16.4%)	2 (1.96%)		0 (0.00%)	2 (6.06%)	
Yes	42 (68.9%)	100 (98.0%)		69 (100%)	31 (93.9%)	
Easy access to healthcare professionals			**<0.001**			
No	12 (19.7%)	0 (0.00%)		0 (0.00%)	0 (0.00%)	
Partially	13 (21.3%)	0 (0.00%)		0 (0.00%)	0 (0.00%)	
Yes	36 (59.0%)	102 (100%)		69 (100%)	33 (100%)	
Confidence in the confidentiality of the data			**0.018**			
No	1 (1.64%)	0 (0.00%)		0 (0.00%)	0 (0.00%)	
Partially	3 (4.92%)	0 (0.00%)		0 (0.00%)	0 (0.00%)	
Yes	57 (93.4%)	102 (100%)		69 (100%)	33 (100%)	
Rather be followed telematically or in person, *i.e.* the opposite group			**<0.001**			1.000
No	25 (41.0%)	96 (94.1%)		65 (94.2%)	31 (93.9%)	
Partially	14 (23.0%)	0 (0.00%)		0 (0.00%)	0 (0.00%)	
Yes	22 (36.1%)	6 (5.88%)		4 (5.80%)	2 (6.06%)	
Increase in number of hours of CPAP because of the follow-up done			0.063			**0.011**
No	19 (31.1%)	50 (49.0%)		38 (55.1%)	12 (36.4%)	
Partially	15 (24.6%)	15 (14.7%)		5 (7.25%)	10 (30.3%)	
Yes	27 (44.3%)	37 (36.3%)		26 (37.7%)	11 (33.3%)	
Use of the telemedicine and telemonitoring system again or recommendation of it to others						0.390
No	0 (0%)	2 (1.96%)		1 (1.45%)	1 (3.03%)	
Partially	0 (0%)	2 (1.96%)		1 (1.45%)	1 (3.03%)	
Yes	0 (0%)	98 (96.1%)		67 (97.1%)	31 (93.9%)	

Numbers in bold represent a p-value of <0.05. RC: retrospective cohort; TC: telemedicine cohort; TC-noAPP: telemedicine cohort not using smartphone application; TC-APP: telemedicine cohort using smartphone application.

telemedicine strategy used to others. The loss of the in-person patient–doctor relationship is the greatest risk of telemedicine use [21, 23]; however, these studies show the potential of bringing the patient closer to the doctor when the technology is used appropriately.

Unlike other sleep telemedicine studies that used mobile applications [19, 20], in our methodological design, patients without technological skills were not excluded. Even though the percentage of patients who used the mobile application was not high (36 out of 76), there were no differences in the educational level or age between TC-APP and TC-noAPP. This fact contrasts with the well-known barriers to adopting telemedicine [31], such as resistance to change, cost, elderly age and educational level. The COVID-19 pandemic may have decreased telemedicine barriers by reducing resistance to change from elderly people when technology use became essential for staying in contact with their relatives, and avoiding social isolation and loneliness [32]. Nevertheless, the influence of educational level on CPAP compliance observed in telemedicine multivariable models suggests that it is more important than telemedicine itself. Patients who used the application and asked questions about side-effects had their questions answered before the 1-month visit (43% of the questions generated an action to improve CPAP adaptation, mostly change of mask). Moreover, most patients in the TC-APP group reported that telemedicine influenced an increasing CPAP use, although overall, no increase in compliance was found compared to TC-noAPP.

The other outstanding benefit of telemedicine is cost-efficiency. Previous studies demonstrated that telemedicine strategies for follow-up (without titration involvement) were cost-efficient: Isetta *et al.* [18] reported a cost of EUR 168.4 for website follow-up in a telemedicine group compared to EUR 180.4 for the control group, while Garmendia *et al.* [20] estimated a cost of EUR 103 per protocol patient, reaching EUR 152 for patients recovered in a rescue study of low CPAP compliance patients. We estimated only the direct medical staff time cost in the TC group and the cost was only slightly higher in the TC-APP group. This cost is very small and could be cost-effective if better compliance is demonstrated in further studies.

TABLE 5 Application server data (telemedicine cohort with smartphone application (APP) use)

Patients	36
Messages sent	
No	14 (38.9%)
Yes	22 (61.1%)
Follow-up questionnaires	
No	11 (34.4%)
Yes	21 (65.6%)
Message initiation through the APP	
No messages	0 (0%)
Patient	16 (72.7%)
Sleep unit staff	6 (27.3%)
Number of medical messages, median (interquartile range)	2.5 (1–5.75)
Message subject	
Greeting	1 (4.6%)
Adverse effect	15 (68.2%)
General question CPAP	2 (9.1%)
Question from the staff about an alert message	4 (18.2%)
Messages resulted in action to improve CPAP adaptation	
No	12 (57.1%)
Yes	9 (42.9%)
Nasal congestion or obstruction when using CPAP	
No	7 (63.6%)
Yes	3 (27.3%)
Does not know	1 (9.1%)
Air leaks with the use of CPAP	
No	9 (81.8%)
Yes	2 (18.2%)
Does not know	0 (0%)
Skin marks or irritation with CPAP use	
No	7 (63.6%)
Yes	4 (36.4%)
Does not know	0 (0%)
Dry mouth with CPAP use	
No	6 (54.6%)
Yes	5 (45.5%)
Does not know	0 (0%)
Excessive air pressure with the use of CPAP	
No	8 (80%)
Yes	2 (20%)
Does not know	0 (0%)
Chest or abdominal discomfort with CPAP use	
No	7 (70%)
Yes	3 (30%)
Does not know	0 (0%)
Sleep time using CPAP, h, mean±SD	6.36±1.21

CPAP: continuous positive airway pressure.

This study has several limitations, beginning with a retrospective control group and an unrandomised design. Nevertheless, these factors could also be considered a strength, since they allowed us to compare our TC findings with real-life retrospective usual care previous to the COVID-19 pandemic. Patient satisfaction questionnaires were obtained by telephone, which may constitute a bias *per se*, as this method precludes anonymity. Furthermore, for the RC, they were completed after 1 year, which may have altered the results compared to the 1-month evaluation. There was no bias in retrospective or prospective cohorts, all consecutive patients were included, as no differences were found between groups. This ensures that the results are reproducible in routine clinical practice. Patient self-selection in the use of the mobile application would be another limitation. However, it is also an opportunity to evaluate two different telemedicine strategies including smartphone application use, which is in contrast with other telemedicine studies that excluded patients without technological abilities. Finally, the cost analysis only includes direct staff cost using the rates provided by the accounting department of a hospital in the Spanish public healthcare system, and therefore cannot be extrapolated in absolute terms to private centres or to other countries. However, the cost analysis does serve to illustrate the small relative difference between the two strategies.

Conclusions

Telemedicine for CPAP adaptation and titration and early follow-up are equivalent to usual care face-to-face visits in terms of successful CPAP titration and compliance, with greater patient satisfaction, and can therefore be used independently of the COVID-19 pandemic. The use of the mHealth application could help patients to self-empower, as well as encouraging them to increase CPAP use. However, further studies are needed to confirm its value.

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