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Nasal function and CPAP compliance

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ABSTRACT

Objective: Continuous positive airway pressure (CPAP) is the mainstay therapy for patients with obstructive sleep apnea (OSA) however compliance with CPAP is variable. Nasal ailments, such as nasal congestion are frequently mentioned as a cause for CPAP non-compliance, and potentially could be addressed prior to CPAP initiation, however, no specific criteria or recommendations for the evaluation and management of these patients exist. The aim of this retrospective study is to evaluate the effects of nasal anatomic features and disease on adherence to CPAP therapy for patients with OSA and determine the indications for pre-CPAP nasal treatment by using data obtained at clinical examination.
Methods: In total, 711 adult patients with initial diagnosis of OSA and an apnea–hypopnea index of $\geq$20 who were amenable to CPAP were included. We analyzed nasal parameters, past history of nasal disease, subjective symptoms, and disease severity in addition to whether CPAP therapy had been initiated, rate of CPAP therapy use (initial and 1 year), treatment continuation rate at 2 months and 1 year, and nasal treatments for all patients.
Results: CPAP therapy was initiated in 543 of 711 patients. Nasal resistance was significantly higher in patients who discontinued therapy soon after CPAP initiation. Nasal disease and nasal parameters were not found to be predictors of treatment adherence at 1 year.

Allergic rhinitis, moderate to severe nasal congestion at bedtime, slight or extensive sinus opacification, and a high nasal septum deviation score were found to be independent predictors of nasal treatment, while strong awareness of nasal congestion, a past history of sinusitis, and a total nasal resistance (supine position) of $\geq$0.35 Pa/cm^3/s were independent predictors of surgical treatment.
Conclusion: Long-term CPAP therapy adherence in patients with OSA can be predicted from initial CPAP adherence. Nasal disease and nasal parameters are important factors for early CPAP therapy discontinuation and should be adequately treated before therapy initiation to ensure long-term adherence. Indications for pre-CPAP nasal treatment and nasal surgery for patients with OSA can be predicted from the data obtained at the first examination, and these patients should be treated differently from those without OSA.

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1. Introduction

Continuous positive airway pressure (CPAP) therapy is a standard treatment for patients with moderate to severe obstructive sleep apnea (OSA), however its high efficacy tends to be limited by individual compliance with therapy. In the Apnea Positive Pressure Long-term Efficacy Study cohort, the adherence of patients with OSA to CPAP therapy was favorable on the first day of treatment; worsened with time, and stabilized after 1 or 2 months [1]. In the Home Positive Airway Pressure study, the rate of CPAP therapy use was not more than 50% at 1 and 3 months after the beginning of therapy in OSA patients with an apnea–hypopnea index (AHI) of $\geq$15 and an Epworth sleepiness scale (ESS) of $\geq$12 [2].

Several studies have described factors associated with dropout from CPAP therapy. The Sleep Apnea Cardiovascular Endpoints study showed that CPAP therapy use was evidently decreased at 1 year in patients with moderate to severe OSA associated with cardiovascular disease. The authors reported that adherence to CPAP and side effects of the therapy at 1 month (dry mouth, nasal symptoms, eye problems, claustrophobia, hearing problems, facial pain, skin irritation due to the mask, and the mask fit and leakage) were predictors of a decreased rate of CPAP therapy use [3]. Therefore, a high usage rate in the initial introductory period is a key factor for continued adherence to this therapy.

Nasal complaints and findings associated with decreased CPAP compliance have been previously described. Sugiura et al. reported that nasal resistance was significantly increased while AHI was significantly decreased, in patients who complained of discomfort and sleeplessness during CPAP titration [4]. Brander et al. reported that nasal symptoms (nasal obstruction, nasal drainage) were present in 42% of the patients who dropped out within 6 months after the introduction of CPAP therapy [5]. According to a report by Redline et al., a significant improvement in well-being, mood, and functional status was more frequent when there were no sinus problems in patients with sleep respiratory disturbances and a respiratory disturbance index of <30 who were receiving CPAP therapy [6]. Clinical guidelines issued by the American Academy of Sleep Medicine (AASM) in 2006 noted that the treatment of nasal airway problems in the introductory phase of CPAP therapy is important [7]. Guidelines for the long-term management of patients with OSA also indicate that the nasal airway should be the preferred delivery route to CPAP [8]. In addition, the rate of CPAP therapy use at 1 year was 71% for patients who exhibited nose breathing during sleep, whereas it was 30% for those who exhibited mouth breathing during sleep [9]. These findings suggest that oral breathing due to nasal congestion or habitual mouth breathing may be associated with decreased adherence to CPAP therapy.

Therefore, nasal congestion, oral breathing and nasal pathologies are well known risk factors for decreased CPAP usage, however specific nasal findings, disease states, and the impact of treating such conditions on CPAP compliance prior to its initiation is less clear. The aims of this retrospective study are to evaluate nasal disease states and clinical findings that could potentially affect adherence to CPAP therapy for patients with OSA and determine the indications for pre-CPAP nasal treatment for these patients.

2. Materials and methods

The protocol of the investigation was approved by the Institutional Review Board of Ota General Hospital (No.18013). A retrospective analysis of adult patients who underwent polysomnography (PSG) between April 2014 and March 2016, newly diagnosed with OSA, exhibited an AHI of $\geq$20 and were amenable to CPAP therapy were selected. All included patients had complete data pertaining to nasal anatomic findings, past history of nasal disease, subjective symptoms, and disease severity. Patients with psychiatric comorbidities like narcolepsy and needed not CPAP but psychiatric therapy the first or those who were preferable to undergo other therapy like bi-level positive airway pressure therapy to CPAP were excluded because we intend to know the compliance of the patients who need CPAP therapy for the first choice for their OSA. Patients without adequate follow-up visits, transferred to another medical centers, and those who underwent pharyngeal surgery with resulting post-operative AHI <20 were excluded as well.

Active anterior rhinomanometry and acoustic rhinometry were performed with an RM nozzle (Rhino Metrics, Denmark) and AR (oval type) [10]. Both examinations were performed after 20 min of rest in sitting and supine positions, on the day of PSG. The nasal cross-sectional areas (CSA 1, 2), nasal cavity volume (on measurement curve 0–5 cm), and total nasal resistance (100 Pa, during inspiration) were measured during a fixed period of time before PSG (19:00 to 21:00). The use of antiallergic drugs and intranasal medication was discontinued 24 h before measurement. Patients with a nasal resistance of 0 and $\geq$1 were excluded as these measurements are considered unreliable. PSG was performed under the supervision of a certified sleep medicine technician. The sleep stage was determined according to the R & K international criteria [11], and respiratory events were determined by visual scoring according to the 2012 AASM guidelines [12].

Adequate CPAP compliance was defined as the use of CPAP therapy for at least 4 h for $\geq$70% of the nights in the previous month. The initial rate of CPAP use was determined at 0.5–1.5 months after therapy initiation.

The Japanese-version of Epworth Sleepiness Scale (JESS), which is a modification of Johns' original ESS for use in Japan [13,14], was used as a measurement of daytime sleepiness. Sleep quality was self-evaluated using the Japanese version of the Pittsburgh Sleep Quality Index (PSQI-J) [15]. Nasal congestion at bedtime was scored using a visual analog scale (VAS), where a score of 0 indicated the absence of nasal congestion and a score of 10 indicated complete congestion. Nasal septum deviation was graded on a 5-point scale on the basis of anterior rhinoscopy findings as follows: 0, no deviation; 1, mild deviation with the crista not overlapping the vertical line of the inferior turbinate on the convex side and not exceeding the midline on the concave side; 2, moderate deviation with the crista contacting the vertical line of the inferior turbinate on the convex side and exceeding the midline on the concave side; 3,

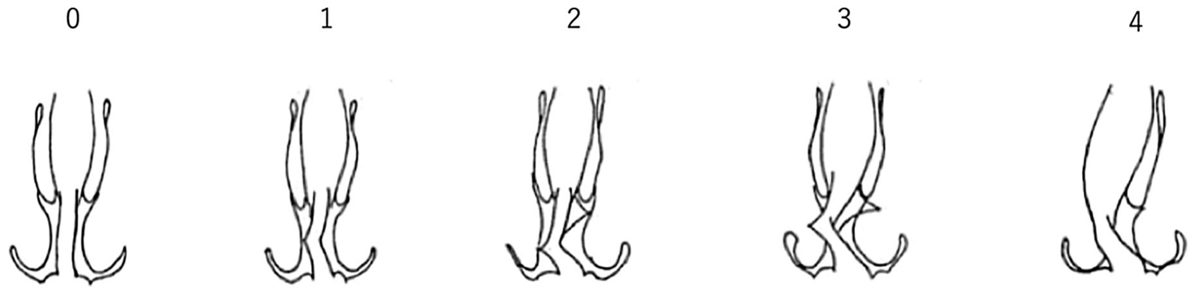


Fig. 1. The grade of Nasal septum deviation.

severe deviation with the crista caved in the mucosa of the inferior turbinate on the convex side; and 4, extreme deviation with the overall nasal septum overlapping the vertical line of the inferior turbinate and interfering with visual observation of the backward middle nasal turbinate and middle meatus (Fig. 1). Sinusal opacification on computer tomography scan were scored using the Lund–MacKay classification [16]. Nasal treatment was defined as treatment with intranasal or oral medications, including over-the-counter drugs at the time of CPAP therapy initiation (0 months after the beginning of CPAP for the sake of convenience) or initiated at a later date during therapy. The major oral medications included antihistamines and leukotriene antagonists, while the major intranasal medications included corticosteroids and vasoconstrictors. Surgical treatment associated with the use of CPAP was defined as CPAP-related surgical treatment performed before or after CPAP therapy initiation. History of upper airway surgery – nasal surgery in isolation (e.g., septoplasty, endoscopic intranasal sinus surgery, nasal laser surgery) or simultaneous nasal and pharyngeal surgery was evaluated as well. The following parameters were evaluated for all patients: rate of CPAP therapy use (initial and 1 year), continuation rate at 2 months and 1 year, and nasal treatments (oral or intranasal medications, surgery). All data were statistically analyzed using SPSS 11.0 J for Windows (International Business Machines Corporation, Armonk, NY, USA). A p-value of <0.05 was considered statistically significant.

CPAP compliance was evaluated at first visit, 2 months and 1 year. The patient data mentioned above were compared in each group using the Mann–Whitney U test. Then, stepwise binomial logistic regression analysis was performed in each group to determine independent variables.

3. Results

3.1. Overall patients (Table 1)

A total of 711 patients were included. The background characteristics of these patients are shown in Table 1. The subjective symptom of nasal congestion was biphasic. The median JESS score was 9. Sinus opacification was not observed in 61% of the patients (Fig. 2). The total nasal resistance was greater in the sitting position than in the supine position, however, there was significant correlation between the total nasal resistance in sitting position and that supine positions (correlation coefficient, 0.668; significance probability, 0.000), whereas there was a weak correlation between the total nasal resistance and subjective symptoms of nasal congestion (correlation coefficient, 0.181; significance probability, 0.000). The course of treatment is shown in Fig. 3.

3.2. CPAP therapy use (Tables 2a and 2b)

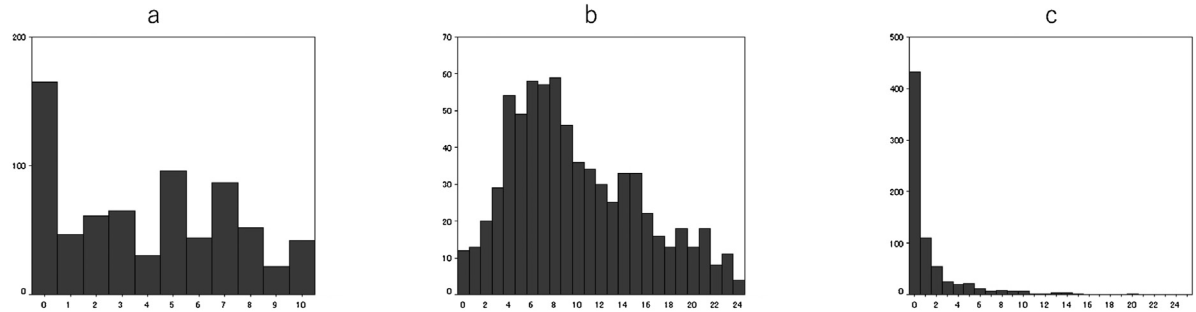
CPAP therapy was introduced for 543 of the 711 patients, and the initial rate of CPAP use was high in 219 of the 543 patients (40.3%). When compared with those with a low initial use rate (poor initial use group); body mass index (BMI) and JESS score at the first examination were lower ($p = 0.004$, $p = 0.001$). The frequency of nasal treatment within the first 2 months after CPAP therapy initiation was lower and the patient age was higher in the good initial use group than in the poor initial use group ($p = 0.047$, $p = 0.000$) (Table 2a). Binomial logistic regression analysis with the good and poor initial use rates as objective variables showed that a JESS score of <11 at the first examination (≥11: $p = 0.001$, exp(B) 0.555, 95%CI 0.597–1.220) and the absence of nasal treatment within the first 2 months after CPAP therapy initiation (with treatment: $p = 0.032$, exp(B) 0.598, 95%CI 0.373–0.957) were independent predictors of a good initial use rate (Table 2b).

3.3. Treatment continuation rate at 2 months (Tables 3a and 3b)

Two months after CPAP therapy initiation, 484 of the 518 patients available for evaluation — 19 patients were

Table 1
Overall patients.

	n = 711
Sex(male/female)	604/107
Pollinosis(with/without)	230/481
Perennial allergic rhinitis(with/without)	188/523
A history of sinusitis(with/without)	73/638
	Median value
Age(year)	50
AHI	43.6
BMI(kg/m^2)	25.5937
JESS at the first examination	9
PSQI-J at the first examination	7
VAS score of nasal congestion at bedtime	4
Total nasal resistance (supine position)(pa/cm^3/sec)	0.214
Total (right plus left) nasal cavity volume(supine position)(cm^3)	12.549



a. VAS score of nasal congestion at bedtime, b. JESS at the first examination, c. Nasal sinus shadow on computer tomography

Fig. 2. Each scores of overall patients (Total 711).

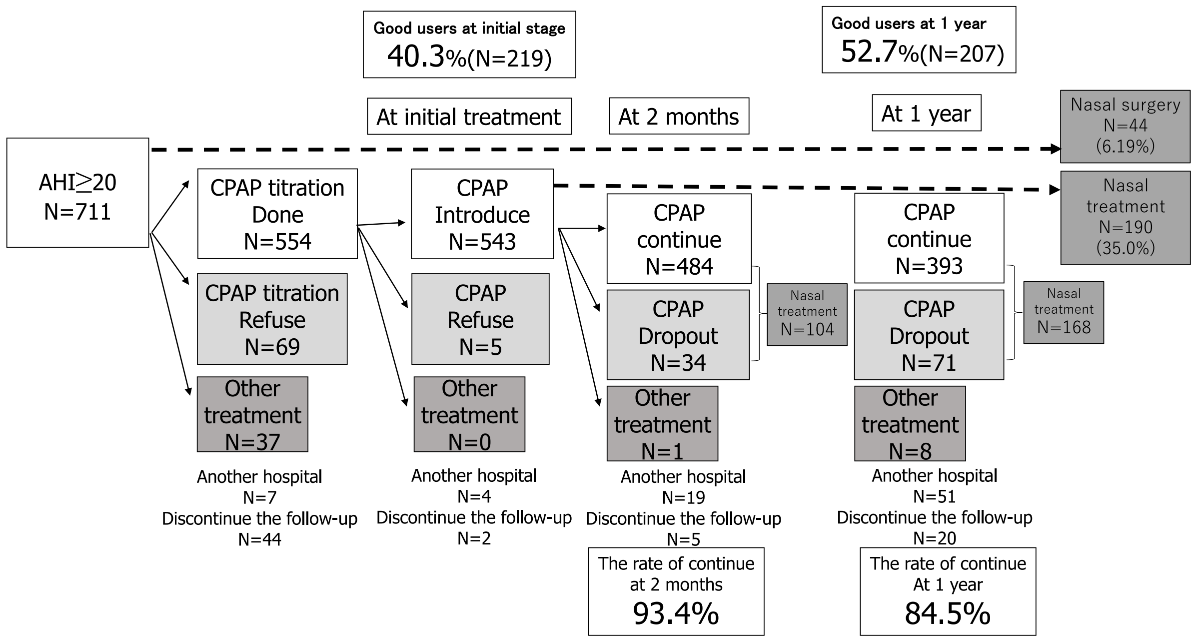


Fig. 3. CPAP continuation and the rate of CPAP use (N = 711).

transferred to another hospital, five discontinued follow-up visits, and one underwent pharyngeal surgery and exhibited a postoperative AHI of <20 — were using the device, therefore the continuation rate was 93.4%. The CPAP continuation group and the dropout group were compared, and the former showed a higher AHI, higher BMI, higher initial JESS score, lower total nasal resistance, and higher initial use rate than did the latter ($p = 0.001$, $p = 0.001$, $p = 0.002$, $p = 0.027$, $p = 0.000$). Moreover, patient age was lower and the proportion of women was greater in the CPAP continuation group than in the dropout group ($p = 0.018$, 0.000) (Table 3a). Binomial logistic regression analysis with the treatment continuation and dropout rates at 2 months as objective variables revealed that a BMI of ≥ 25 kg/m^2 (≥ 25: $p = 0.006$, exp(B) 2.827, 95%CI 1.342–5.956), an initial JESS score of ≥ 11 (≥ 11: $p = 0.045$, exp(B) 2.292, 95%CI 1.018–5.160), a total nasal resistance (supine position) of <0.4 Pa/cm^3/s (≥ 0.4: $p = 0.011$, exp(B) 0.188, 95%CI 0.052–0.678), and an initial use rate of ≥ 70% (≥ 70: $p = 0.000$, exp(B) 8.675, 95%CI 2.577–29.204) were independent predictors of a good treatment continuation rate at 2 months (Table 3b).

3.4. Treatment continuation rate at 1 year (Tables 4a and 4b)

From 543 patients to whom CPAP therapy was introduced, at the 1 year landmark 51 were transferred to another hospital, 19 discontinued the follow-up visits, and eight exhibited an AHI of <20 after pharyngeal surgery. All of these patients were excluded from analysis. From the remaining available patients, treatment continuation rate at 1 year was 82.5% (393/465). When CPAP continuation and dropout groups were compared, the former exhibited a higher AHI, higher BMI, higher initial JESS score, and higher initial use rate than did the latter ($p = 0.005$, $p = 0.006$, $p = 0.030$, $p = 0.000$). In addition, the proportions of men and patients who underwent oral medication and total nasal treatment were higher in the CPAP continuation group than in the dropout group ($p = 0.027$, $p = 0.033$) (Table 4a). Binomial logistic regression analysis with the

Table 2a
Univariate analysis: variables influencing good CPAP use at initial stage.

	Good use(n = 219)	Poor use(n = 324)	p Value
	Median value	Median value	
The rate of CPAP use at initial stage(≧4 h)(%)	87	32.5	
Sex(male/female)	190/29	279/45	0.830
Pollinosis(with/without)	78/141	112/212	0.802
Perennial allergic rhinitis(with/without)	54/165	95/229	0.233
A history of sinusitis(with/without)	29/190	30/294	0.144
	Median value	Median value	
Age(year)	55	48	0.000
AHI	44.7	29.2	0.146
BMI(kg/m^2)	25.4779	26.6032	0.004
JESS at the first examination	8	10	0.001
PSQI-J at the first examination	7	7	0.706
VAS score of nasal congestion at bedtime	3	5	0.056
Total nasal resistance(supine position)($pa/cm^3/sec$)	0.209	0.2155	0.137
Total (right plus left) nasal cavity volume(supine position)(cm^3)	12.676	12.4125	0.245
The ratio of right and left of nasal cavity volume(supine position)	1.4836	1.4627	0.715
Nasal sinus shadow on computer tomography	0	0	0.192
Nasal septal deviatory score	1	1	0.175
Nasal treatment within the first 2 months			
Surgery(required/not required)	3/216	4/320	0.084
Intranasal medication(required/not required)	26/193	56/268	0.174
Paroral medication(required/not required)	11/208	26/298	0.891
Total(required/not required)	33/186	71/253	0.047

Table 2b
Multivariate analysis: independent variables influencing good CPAP use at initial stage.

	Cutoff	p Value	Exp(B)	95%CI		
				Lower		Upper
JESS at the first examination	>11	0.001	0.555	(0.597	–	1.220)
Total nasal treatment within the first 2 months	required	0.032	0.598	(0.373	–	0.957)

treatment continuation and dropout rates at 1 year as objective variables revealed that a BMI of ≥25 kg/m^2 (≥25: p = 0.006, exp(B) 2.138, 95%CI 1.248–3.662), an initial JESS score of ≥11 (≥11: p = 0.036, exp(B) 1.832, 95%CI 1.040–3.227), an initial use rate of ≥70% (≥70: p = 0.000, exp(B) 6.714, 95%CI 3.257–13.842), and total nasal treatment within 1 year after CPAP therapy initiation (with treatment: p = 0.009, exp(B) 2.220, 95%CI 1.218–4.045) were independent predictors of a good treatment continuation rate at 1 year (Table 4b).

3.5. CPAP use rate at 1 year (Tables 5a and 5b)

Among the 393 patients who continued CPAP therapy for 1 year, 207 (52.7%) showed adequate compliance. When the adequate x poor compliance groups were compared, the former exhibited a higher initial use rate, lower BMI, lower initial JESS score, lower total nasal resistance (supine position), higher total (right plus left) nasal cavity volume (supine position), and lower nasal septum deviation score than did the latter (p = 0.000, p = 0.000, p = 0.001, p = 0.006, p = 0.024, p = 0.029). In addition, the patient age was higher (p = 0.000), while the frequencies of oral or intranasal medication and those who underwent any nasal treatment were lower in the good use rate group than in the poor use rate group (p = 0.000, p = 0.000, p = 0.000) (Table 5a). Binomial logistic regression analysis with the good and poor use rates at 1 year as objective variables revealed that an initial use rate of ≥70% (≥70: p = 0.000, exp (B) 14.432, 95%CI 8.617–24.172), a BMI of <25 kg/m^2 (≥25: p = 0.018, exp(B) 0.538, 95%CI 0.322–0.899), and no nasal treatment within 1 year after CPAP therapy initiation (with treatment: p = 0.005, exp(B) 0.480, 95%CI 0.289–0.799) were independent predictors of a good use rate at 1 year (Table 5b).

3.6. Subjects with medical management (Tables 6a and 6b)

Among the 543 patients who received CPAP therapy, 190 (35.0%) received concomitant nasal treatment within 1 year after CPAP therapy initiation. Compared with patients who did not receive nasal treatment, those who received nasal treatment showed a higher VAS score for nasal congestion at bedtime, higher total nasal resistance (supine position), higher total (right plus left) nasal cavity volume (supine position), higher sinus CT score at the first examination, higher nasal septum deviation score, and lower initial rate of CPAP use (p = 0.018, p = 0.015,

Table 3a
Univariate analysis: variables influencing CPAP continuation at 2 months.

	Continue(n = 484)	Dropout(n = 34)	p Value
Sex(male/female)	425/59	43427	0.001
Pollinosis(with/without)	169/315	13/21	0.696
Perennial allergic rhinitis(with/without)	135/349	43368	0.858
A history of sinusitis(with/without)	54/430	43190	0.675
	Median value	Median value	
Age(year)	51	60	0.018
AHI	47	32.9	0.001
BMI(kg/m^2)	26.3542	23.8646	0.001
JESS at the first examination	9	6	0.002
PSQI-J at the first examination	7	6.5	0.369
VAS score of nasal congestion at bedtime	4	4.5	0.625
Total nasal resistance(supine position)(pa/cm^3/sec)	0.214	0.24	0.027
Total (right plus left) nasal cavity volume(supine position)(cm^3)	12.564	11.915	0.358
The ratio of right and left of nasal cavity volume(supine position)	1.4673	1.4247	0.969
Nasal sinus shadow on computer tomography	0	0	0.477
Nasal septal deviatory score	1	1	0.212
The rate of CPAP use(≧4 h)(%)	62	0	0.000
Nasal treatment within the first 2 months			
Surgery(required/not required)	7/477	0/34	0.481
Intranasal medication(required/not required)	74/410	43249	0.927
Paroral medication(required/not required)	34/450	2/32	0.800
Total(required/not required)	96/388	43249	0.466

Table 3b
Multivariate analysis: independent variables influencing CPAP continuation at 2 months.

	Cutoff	p Value	Exp(B)	95%CI		
				Lower		Upper
BMI(kg/m^2)	≧25	0.006	2.827	(1.342	–	5.956)
JESS at the first examination	≧11	0.045	2.292	(1.018	–	5.160)
Total nasal resistance(supine position)(pa/cm^3/sec)	≧0.4	0.011	0.188	(0.052	–	0.678)
The rate of CPAP use at initial stage(≧4 h)(%)	≧70	0.000	8.675	(2.577	–	29.204)

p = 0.001, p = 0.012, p = 0.001). In addition, patients with pollinosis or perennial allergic rhinitis, those with a history of sinusitis, and younger patients were more common in the nasal treatment group than the group without treatment (p = 0.000, p = 0.000, p = 0.034, p = 0.001) (Table 6a). Binomial logistic regression analysis with the presence and absence of nasal treatment as objective variables revealed that the presence of pollinosis (with pollinosis: p = 0.000, exp(B) 2.989, 95%CI 1.967–4.541), the presence of perennial allergic rhinitis (with perennial allergic rhinitis: p = 0.008, exp(B) 1.826, 95%CI 1.171–2.847), a VAS score for bedtime nasal congestion of ≥6 (≥6: p = 0.000, exp(B) 2.179, 95%CI 1.452–3.271), a sinus CT score of ≥7 (≥7: p = 0.001, exp(B) 4.339, 95%CI 1.803–10.441), a nasal septum deviation score of ≥3 (≥3: p = 0.048, exp(B) 2.262, 95%CI 1.006–5.085), and an initial use rate of <50% (≥50: p = 0.013, exp(B) 0.619, 95%CI 0.424–0.905) were independent predictors of nasal treatment (Table 6b).

3.7. Nasal surgery (Tables 7a and 7b)

Among the 711 patients with OSA who required CPAP therapy, 44 (6.19%) eventually underwent nasal surgery. Compared with patients who did not require surgery, those who underwent surgery exhibited a lower BMI, higher VAS score for bedtime nasal congestion, higher total (right plus left) nasal cavity volume (supine position), and higher sinus CT score at the first examination (p = 0.038, p = 0.000, p = 0.000, p = 0.005). In addition, patients with pollinosis or perennial allergic rhinitis, those with a history of sinusitis, and younger patients were more common in the nasal surgery group than the group that did not require surgery (p = 0.004, p = 0.000, p = 0.000, p = 0.000) (Table 7a). Binomial logistic regression analysis with the presence and absence of nasal surgery as objective variables revealed that an age of <45 years (≥45: p = 0.001, exp(B) 0.305, 95%CI 0.151–0.619), a BMI of <25 kg/m^2 (≥25: p = 0.001, exp(B) 0.270, 95%CI 0.129–0.566), a past history of sinusitis (with a past history of sinusitis: p = 0.045, exp(B) 2.477, 95%CI 1.022–6.002), a VAS score for bedtime nasal congestion of ≥9 (≥9: p = 0.000, exp(B) 4.684, 95%CI 1.989–11.031), a total nasal resistance (supine position) of ≥0.35 Pa/cm^3/s (≥0.35: p = 0.014, exp(B) 3.286, 95%CI 1.272–8.485), and a sinus CT score of ≥7 at the first examination (≥7: p = 0.000, exp(B) 12.281, 95%CI 5.014–30.082) were independent predictors of nasal surgery (Table 7b).

Table 4a
univariate analysis: variables influencing CPAP continuation at 1 year.

	Continue(n = 393)	Dropout(n = 72)	p value
Sex(male/female)	347/46	56/16	0.016
Pollinosis(with/without)	144/249	22/50	0.322
Perennial allergic rhinitis(with/without)	109/284	19/53	0.814
A history of sinusitis(with/without)	45/348	6/66	0.437
	Median value	Median value	
Age(year)	51	53.5	0.672
AHI	47.4	42.25	0.005
BMI(kg/m^2)	26.4236	24.809	0.006
JESS at the first examination	9	7.5	0.030
PSQI-J at the first examination	7	7	0.771
VAS score of nasal congestion at bedtime	4	4	0.735
Total nasal resistance(supine position)(pa/cm^3/sec)	0.213	0.2315	0.065
Total (right plus left) nasal cavity volume(supine position)(cm^3)	12.562	12.1095	0.420
The ratio of right and left of nasal cavity volume(supine position)	1.4672	1.4201	0.746
Nasal sinus shadow on computer tomography	0	0	0.129
Nasal septal deviatory score	1	1	0.759
The rate of CPAP use at initial stage(≧4 h)(%)	66.7	7.5	0.000
Nasal treatment within the 1 year			
Surgery(required/not required)	18/375	2/70	0.489
Intranasal medication(required/not required)	113/280	15/57	0.167
Paroral medication(required/not required)	82/311	7/65	0.027
Total(required/not required)	150/243	18/54	0.033

Table 4b
Multivariate analysis: independent variables influencing CPAP continuation at 1 year.

	Cutoff	p value	Exp(B)	95%CI		
				Lower		Upper
BMI(kg/m^2)	≧25	0.006	2.138	(1.248	–	3.662)
JESS at the first examination	≧11	0.036	1.832	(1.040	–	3.227)
The rate of CPAP use at initial stage(≧4 h)(%)	≧70	0.000	6.714	(3.257	–	13.842)
Total nasal treatment within 1 year	required	0.009	2.220	(1.218	–	4.045)

4. Discussion

In the present study, we found that the initial adherence to CPAP therapy in patients with OSA had a major influence on long-term adherence and that treatment adherence gradually decreases in patients with nasal complaints. Nasal disease and nasal parameters were important factors influencing the early discontinuation of CPAP therapy.

The nasal cavities were reported to exhibit a cycle whereby the morphology of the cavities varies over time [17]. Therefore, we tried our best to perform nasal cavity examinations at the same time of the day for all patients. Nasal resistance slightly increases in healthy individuals in the supine position [18,19]. In addition, the rate of change in nasal resistance from sitting to supine position was shown to be increased in patients with sleep related breathing disorders due to obstruction due to nasopharyngeal soft tissue and in patients with allergic rhinitis. [20,21]. Therefore, we examined nasal resistance in the supine position to simulate the condition during sleep. In the present study, there was a significant correlation between nasal resistance in the supine position and that in the sitting position. In the future, nasal resistance in the sitting position could be used for analysis of the air permeability. There is a deviation between subjective nasal congestion and nasal resistance [22]. In the present study, there was a weak correlation between these two parameters, which indicates that they should be considered independent factors.

Consistent with previous findings [23], the JESS score was significantly higher for the CPAP continuation groups at 2 months and 1 year than for the dropout groups at the respective time points. However, the JESS score at the first examination was significantly lower for the good initial use group than for the poor initial use group. It has been reported that adherence is favorable in individuals with a subjective improvement in daytime sleepiness with the use of CPAP therapy [24]. It seems that awareness of the effects of CPAP is also associated with improved treatment adherence.

Among the 543 patients who used CPAP therapy in the present study, 190 (35.0%) underwent concomitant nasal treatment. Patients with OSA accompanied by moderate or severe nasal congestion and nasal diseases such as allergic rhinitis, pollinosis, sinusitis, and nasal septum deviation were considered amenable to nasal treatment. Therefore, it is necessary to make an accurate diagnosis of nasal disease by

Table 5a
Univariate analysis: variables influencing good CPAP use at 1 year.

	Good use(n = 207)	Poor use(n = 186)	p value
	Median value	Median value	
The rate of CPAP use at 1 year(≧4 h)(%)	91	29	
The rate of CPAP use at initial stage(≧4 h)(%)	83	34.15	0.000
Sex(male/female)	182/25	165/21	0.809
Pollinosis(with/without)	73/134	71/115	0.551
Perennial allergic rhinitis(with/without)	53/154	56/130	0.320
A history of sinusitis(with/without)	27/180	18/168	0.296
	Median value	Median value	
Age(year)	55	48	0.000
AHI	45.3	52.05	0.172
BMI(kg/m^2)	25.3934	27.3982	0.000
JESS at the first examination	8	10	0.001
PSQI-J at the first examination	7	7	0.424
VAS score of nasal congestion at bedtime	3	5	0.526
Total nasal resistance(supine position)(pa/cm^3/sec)	0.201	0.2205	0.006
Total (right plus left) nasal cavity volume(supine position)(cm^3)	12.842	12.129	0.024
The ratio of right and left of nasal cavity volume(supine position)	1.4608	1.4854	0.090
Nasal sinus shadow on computer tomography	0	0	0.391
Nasal septal deviatory score	1	1	0.029
Nasal treatment within the 1 year			
Surgery(required/not required)	9/198	9/177	0.816
Intranasal medication(required/not required)	43/169	70/116	0.000
Paroral medication(required/not required)	28/179	54/132	0.000
Total(required/not required)	61/146	89/97	0.000

Table 5b
Multivariate analysis: independent variables influencing CPAP continuation at 1 year.

	Cutoff	p Value	Exp(B)	95%CI		
				Lower		Upper
The rate of CPAP use at initial stage(≧4 h)(%)	≧70	0.000	14.432	(8.617	–	24.172)
BMI(kg/m^2)	≧25	0.018	0.538	(0.322	–	0.899)
Total nasal treatment within 1 year	required	0.005	0.480	(0.289	–	0.799)

subjective assessments based on the patient's past history, inquiries about subjective symptoms, anterior rhinoscopy, and computed tomography examinations, among other modalities. The regulation of sleep and wakefulness may be influenced by inflammatory cytokines in patients with allergic rhinitis [25,26]. In addition, it has been suggested that nasal congestion and nasal disease are factors that impede the acceptance of CPAP therapy [5,6]. Interestingly, patients who underwent nasal treatment were significantly more common in the poor use group immediately after CPAP therapy initiation and at 1 year than in the good use group at these times. Although nasal resistance was a predictor of CPAP therapy continuation at 2 months, no nasal parameter was a predictor of treatment continuation at 1 year. This may suggest that the gradual dropout of patients with inadequately treated nasal congestion influenced the results at 1 year. In other words, it is necessary to identify and adequately treat patients with OSA who require nasal treatment before CPAP therapy initiation. Weaver et al. reported the hours of CPAP use per night for consistent users who used CPAP on ≥90% of the days during the first 3 months and intermittent users. Although there was no distinct difference between the two groups on day 1, the hours of CPAP use significantly decreased from day 3 onwards in the intermittent users [27]. Budhiraja et al. reported that patients who showed a low use rate at 1 month also showed a significantly lower use rate on day 3 than those with a high use rate at 1 month [28]. These reports indicate that the initial CPAP therapy use rate greatly influences the long-term adherence rate.

Among the 711 patients for whom CPAP was considered necessary, 44 (6.19%) eventually underwent nasal surgery. Predictors of nasal surgery included severe nasal congestion at bedtime, a past history of sinusitis, slight or extensive sinus shadows, and a total nasal resistance (supine position) of ≥0.35 Pa/cm^3/s. A total nasal resistance of 0.35 Pa/cm^3/s is not a high value during daytime wakefulness, and surgery may not be required if these patients do not have OSA. Therefore, indications for nasal surgery should be evaluated differently for patients with OSA who require CPAP therapy and patients without OSA. Li et al. reported that surgery for improving the morphology of the nasal cavities was associated with a high subjective feeling of satisfaction, including decreased daytime sleepiness [29]. Friedman et al. reported that nasal surgery for

Table 6a
Univariate analysis: variables influencing requirement of concomitant nasal treatment for CPAP users.

	Required(n = 190)	Not required (n = 353)	p value
Nasal treatment within the 1 year			
Surgery(required/not required)	27/163	0/353	
Intranasal medication(required/not required)	147/43	0/353	
Paroral medication(required/not required)	94/96	0/353	
Total(required/not required)	190/0	0/353	
Sex(male/female)	165/25	304/49	0.815
Pollinosis(with/without)	103/87	87/266	0.000
Perennial allergic rhinitis(with/without)	82/108	67/286	0.000
A history of sinusitis(with/without)	28/162	31/322	0.034
	Median value	Median value	
Age(year)	47	52	0.001
AHI	46.7	46.9	0.210
BMI(kg/m^2)	25.4266	26.2188	0.350
JESS at the first examination	9	9	0.427
PSQI-J at the first examination	7	7	0.785
VAS score of nasal congestion at bedtime	5	3	0.000
Total nasal resistance(supine position)(pa/cm^3/sec)	0.2215	0.211	0.018
Total (right plus left) nasal cavity volume(supine position)(cm^3)	11.99	12.866	0.015
The ratio of right and left of nasal cavity volume(supine position)	1.5117	1.4594	0.241
Nasal sinus shadow on computer tomography	0	0	0.001
Nasal septal deviatory score	1	1	0.012
The rate of CPAP use at initial stage(≧4 h)(%)	47.5	64	0.001

Table 6b
Multivariate analysis: independent variables influencing requirement of concomitant nasal treatment for CPAP users.

	Cutoff	p Value	Exp(B)	95%CI		
				Lower		Upper
Pollinosis	With	0.000	2.989	(1.967	–	4.541)
Perennial allergic rhinitis	With	0.008	1.826	(1.171	–	2.847)
VAS score of nasal congestion at bedtime	≧6	0.000	2.179	(1.452	–	3.271)
Nasal sinus shadow on computer tomography	≧7	0.001	4.339	(1.803	–	10.441)
Nasal septal deviatory score	≧3	0.048	2.262	(1.006	–	5.085)
The rate of CPAP use at initial stage(≧4 h)(%)	≧50	0.013	0.619	(0.424	–	0.905)

patients with OSA receiving CPAP therapy did not result in an improved AHI; however, it achieved enhanced activity levels, a significant improvement in the ESS score and decreased CPAP pressure level [30]. A recent report showed that nasal surgery in patients with nasal congestion who could not use CPAP even for 1 h per night resulted in a significant increase in the hours of CPAP use [31]. Furthermore, in one prospective study on 12 male patients with CPAP intolerance, nasal surgery significantly improved nasal resistance, applied pressure, and the rate of CPAP use [32]. The purpose of CPAP therapy is to prevent collapse of the upper respiratory tract by positive pressure, and the pressure should ideally be low. If the prescribed pressure is higher than required, it may lead to discomfort and cause discontinuation of CPAP therapy. There is a fundamentally poor association between AHI and the morphology of the nasal cavities. However, management of nasal diseases, especially by using corrective surgery for the nasal cavity, may improve CPAP therapy adherence, with regard to both duration of use at night and daily usage rate, by eliminating nasal congestion, resolving daytime sleepiness and decreasing the prescription airway pressure.

By combining CPAP therapy with the use of a humidifier patient satisfaction could be increased, and the hours of CPAP use could increase significantly [33,34]. In addition, controlled heated humidification inhibits intranasal inflammation [35] and decreases applied airway pressure [36]. As stated in the introduction, CPAP compliance is not good; therefore, we recommend adopting the use of humidifiers as an intervention for improving CPAP compliance.

This study has several limitations. First, as this study was a retrospective study, it only reflected the current status of CPAP therapy. Future prospective studies are necessary to examine the validity of our findings in other populations. Second, there is no established method to measure nasal resistance during sleep. In the present study, daytime measurements were used as substitutes to reflect the status of the nasal cavity during sleep, and hence, further investigation using more reliable measures is necessary.

Table 7a
Univariate analysis: variables influencing requirement of nasal surgery for overall patients.

	Required(n = 44)	Not required(n = 667)	p value
Sex(male/female)	15036	563/104	0.115
Pollinosis(with/without)	23/21	207/460	0.004
Perennial allergic rhinitis(with/without)	23/21	165/502	0.000
A history of sinusitis(with/without)	12/32	61/606	0.000
	Median value	Median value	
Age(year)	42	50.86	0.000
AHI	40.25	49.3556	0.328
BMI(kg/m^2)	24.11	26.4212	0.038
JESS at the first examination	8	9	0.781
PSQI-J at the first examination	6	7	0.181
VAS score of nasal congestion at bedtime	6	4	0.000
Total nasal resistance(supine position)(pa/cm^3/sec)	0.25	0.212	0.000
Total (right plus left) nasal cavity volume(supine position)(cm^3)	12.189	12.576	0.729
The ratio of right and left of nasal cavity volume(supine position)	1.4526	1.462	0.964
Nasal sinus shadow on computer tomography	0.5	0	0.005
Nasal septal deviatory score	1	1	0.265

Table 7b
Multivariate analysis: independent variables influencing requirement of nasal surgery for overall patients.

	Cutoff	p Value	Exp(B)	95%CI		
				Lower		Upper
Age(year)	≧45	0.001	0.305	(0.151	–	0.619)
BMI(kg/m^2)	≧25	0.001	0.270	(0.129	–	0.566)
A history of sinusitis	with	0.045	2.477	(1.022	–	6.002)
VAS score of nasal congestion at bedtime	≧9	0.000	4.684	(1.989	–	11.031)
Total nasal resistance(supine position)(pa/cm^3/sec)	≧0.35	0.014	3.286	(1.272	–	8.485)
Nasal sinus shadow on computer tomography	≧7	0.000	12.281	(5.014	–	30.082)

Further studies assessing the value of nasal interventions, medical or surgical for patients at OSA patients at a high risk for early CPAP discontinuation are needed.

5. Conclusion

We found that long-term CPAP therapy adherence in patients with OSA can be predicted from the status of use (adherence and duration of use) in the early stages of treatment. Nasal disease and nasal parameters are important factors for early CPAP therapy discontinuation and should be adequately treated before therapy initiation.

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