



Factors Affecting Visible Contamination of Positive Airway Pressure Devices in Patients With Obstructive Sleep Apnea

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A recent study estimated the global prevalence of obstructive sleep apnea (OSA) at 54%, suggesting that approximately half of the population may be affected [1]. Continuous positive airway pressure (CPAP) remains the most widely used and established treatment for OSA [2]. Despite its broad adoption and demonstrated efficacy, few studies have addressed the hygienic risks or contamination associated with CPAP devices. Although one report found positive cultures in 48.6% of cases [3], there has been little subsequent research. In particular, easily assessable contamination levels using non-experimental methods have not been adequately explored. We previously reported an attempt to evaluate visible CPAP contamination through comprehensive disassembly and cleaning services, which are clinically practical and do not require experimental procedures such as bacterial culture [4]. That study revealed substantial visible contamination across CPAP subunits, with several user-related and device-specific factors identified. However, the small sample size limited the findings. Therefore, in the present study, a larger sample was enrolled over an extended period to determine the extent of visible contamination and to identify contributing factors.

This study was approved by the Institutional Review Board of Chung-Ang University Hospital (No. 2503-018-19568), and the requirement for written informed consent was waived.

The medical records of patients with OSA who presented be-

tween January 2023 and March 2025 were reviewed. Patients who initiated CPAP therapy at the institution received education on device hygiene. The hygiene protocol included daily cleaning of the mask, humidifier, and tube using a neutral detergent, followed by air-drying, as well as periodic cleaning of the main body and routine dust removal as needed. Masks were replaced annually, and replacement of the tube and filter was recommended at intervals of at least 6 and 3 months, respectively. Since January 2023, the institution has offered a complimentary CPAP disassembly and cleaning service, performed by two trained technicians (TJK and KSK). This service requires highly specialized skills and takes several hours. The contamination levels of each component were documented via photographs and scored using a visual analog scale (0–10, with 0 indicating no contamination and 10 indicating severe contamination) (Supplementary Fig. 1, Fig. 1). Patients without cleaning records or contamination data were excluded, and clinical data from the enrolled patients were included in the statistical analysis.

A comprehensive descriptive analysis was conducted. Continuous variables are summarized as means and standard deviations, with ranges in parentheses, while categorical variables are reported as counts and frequencies. Multivariate linear regression with stepwise selection based on the Akaike Information Criterion was used to identify factors associated with visible contamination of CPAP components. Subgroup analyses for mask and tube contamination were performed according to duration of usage. Correlations among contamination scores were assessed using Pearson correlation coefficients and visualized with the “GGally” package in R. All statistical analyses were conducted using R version 4.4.3 (R Foundation for Statistical Computing).

Participant characteristics are presented in Supplementary Table 1. Multivariate regression analysis identified the duration of mask and tube usage as significant predictors of their respective

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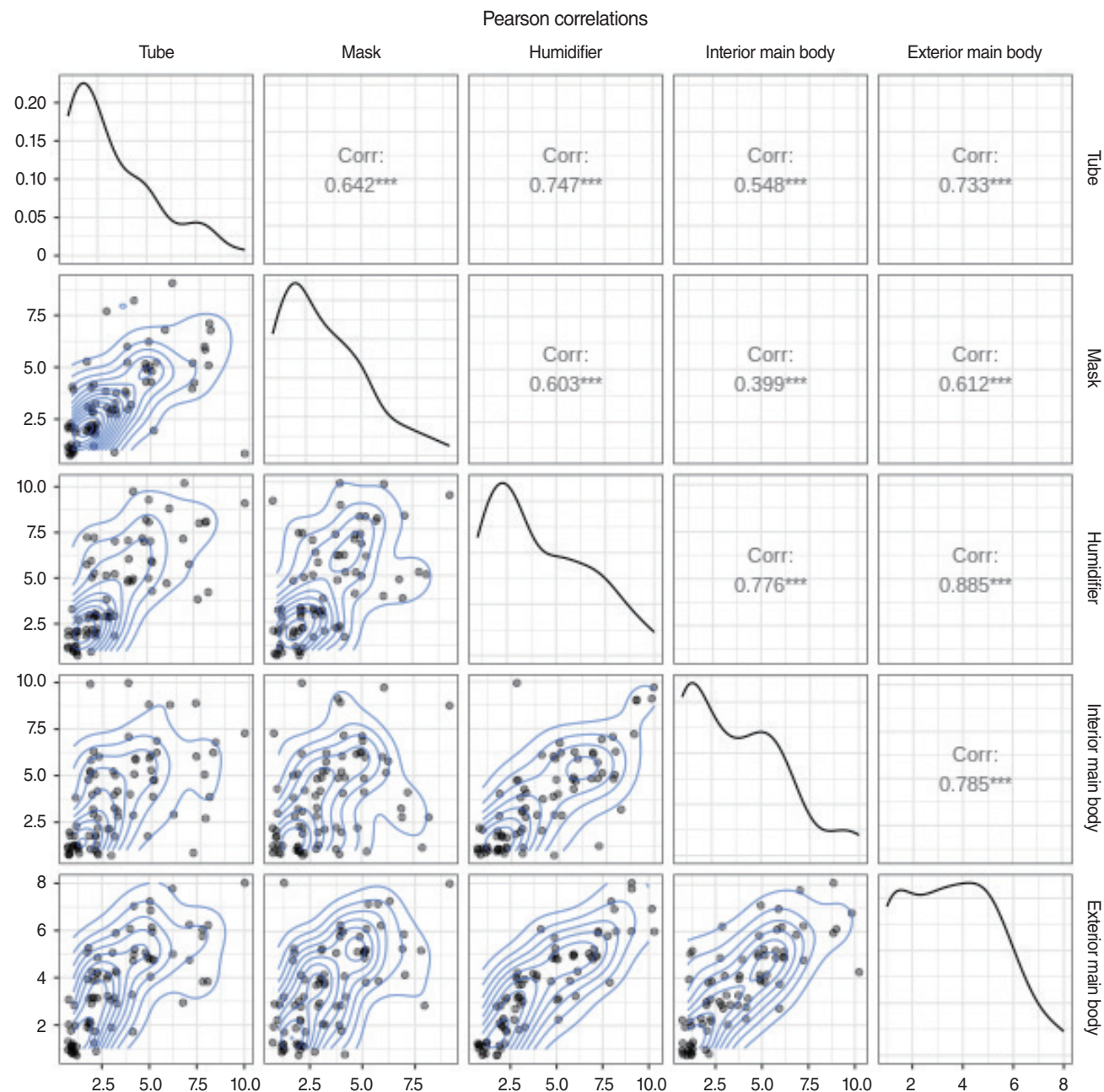


Fig. 1. Correlation between contamination levels of the mask, tube, humidifier, and the interior and exterior main body of continuous positive airway pressure devices. Pearson correlation coefficients (Corr) are shown in the upper-right triangle, while two-dimensional density plots of the jittered data are presented in the lower-left triangle. The diagonal elements depict the distribution density of each variable using kernel density estimation. The contour plot represents a three-dimensional surface by illustrating constant Z-level lines on a two-dimensional plane. ***Indicates statistical significance ($P<0.001$).

contamination levels (mask: $P=0.002$, $R^2=0.156$; tube: $P=0.013$, $R^2=0.077$) (Table 1). For humidifier contamination, the model included age and total duration of CPAP usage as explanatory variables; however, neither variable reached statistical significance ($P=0.118$ and $P=0.074$, respectively), and the model's explanatory power was limited ($R^2=0.066$). In the interior main body model, the total duration of usage showed a near-significant

trend ($P=0.061$), but this did not reach the conventional threshold for significance ($R^2=0.044$). By contrast, in the exterior main body model ($R^2=0.137$), age, apnea-hypopnea index, and total duration of CPAP usage were included as explanatory variables, but only duration of total CPAP usage was statistically significant ($P=0.006$, $R^2=0.137$). In the subgroup analysis (Supplementary Table 2), mask contamination showed a trend toward significance

Table 1. Multivariate linear regression models of associations between independent variables and contamination levels of the mask, tube, humidifier, and interior and exterior main body of continuous positive airway pressure devices

Parameter	Estimate±SE	95% CI	P-value
Mask (R^2/R^2 adjusted: 0.156/0.134)			
(Intercept)	1.61±0.53	0.56 to 2.66	0.003
Duration of mask usage (mo)	0.11±0.03	0.04 to 0.17	0.002
Total duration of usage (day)	0.0006±0.0004	−0.0003 to 0.0015	0.161
Tube (R^2/R^2 adjusted: 0.077/0.065)			
(Intercept)	2.19±0.47	1.26 to 3.12	<0.001
Duration of tube usage (mo)	0.10±0.04	0.02 to 0.17	0.013
Humidifier (R^2/R^2 adjusted: 0.066/0.040)			
(Intercept)	1.25±1.40	−1.53 to 4.03	0.374
Age (yr)	0.03±0.02	−0.01 to 0.08	0.118
Total duration of usage (day)	0.001±0.0006	−0.0001 to 0.0023	0.074
Interior main body (R^2/R^2 adjusted: 0.044/0.032)			
(Intercept)	2.67±0.59	1.48 to −3.85	<0.001
Total duration of usage (day)	0.001±0.0006	−0.0001 to 0.0023	0.061
Exterior main body (R^2/R^2 adjusted: 0.137/0.103)			
(Intercept)	0.23±1.21	−2.19 to 2.64	0.852
Age (yr)	0.03±0.02	−0.01 to 0.06	0.119
AHI	0.02±0.01	−0.002 to 0.036	0.083
Total duration of usage (day)	0.001±0.0004	0.0004 to 0.0021	0.006

SE, standard error; AHI, apnea-hypopnea index.

with duration of usage for ≤ 12 months ($P=0.063$, $R^2=0.064$), while both duration of usage ($P=0.044$) and average daily CPAP use ($P=0.021$) were significant for masks used >12 months ($R^2=0.285$). For tubes, neither variable reached statistical significance for those used ≤ 6 months ($P=0.093$, $R^2=0.123$), whereas duration of usage was significant in tubes used >6 months ($P=0.049$, $R^2=0.070$). Fig. 1 shows the correlations between contamination levels of the CPAP components. Most pairwise correlations were ≥ 0.6 , except for those involving the interior main body with the tube and mask. The strongest correlation was between the humidifier and the exterior main body ($r=0.885$).

This study found that longer durations of CPAP mask and tube usage were significantly associated with increased visible contamination. These findings differ from those of a previous study, in which contamination levels were not significantly associated with the duration of mask or tube usage but were instead related to clinical characteristics such as age [4]. The present study, conducted over a longer period and with a larger sample size, provides more robust and meaningful evidence supporting the need to establish replacement intervals for masks and tubes based on their duration of use. Furthermore, subgroup analysis revealed that prolonged use of masks for more than 12 months and tubes for more than 6 months requires particular attention due to the potential for increased contamination over time. Although no clinical factors, including duration of humidifier usage, were significantly associated with humidifier contamination, the strong correlation observed between humidifier and exterior contamination suggests that exterior contamination may serve as an indirect indicator of humidifier contamination.

There are limitations to the current study. Although the sample size was larger than in previous studies, it may still be insufficient to draw definitive clinical conclusions, as some variables only showed borderline significance (Supplementary Table 2). The present study identified different variables significantly associated with contamination levels compared to our previous research, which may reflect the influence of unidentified confounding factors. Additionally, the low overall adjusted R^2 values (ranging from 0.032 to 0.134) (Table 1) suggest that further unmeasured factors, such as environmental conditions including humidity and temperature, may contribute to contamination levels. Contamination was assessed subjectively in this study, without standardized criteria or inter-rater reliability assessment, representing a methodological limitation and underscoring the need for more objective evaluation protocols in future research. Nevertheless, these findings highlight the importance of further research on CPAP contamination and hygiene management practices.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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Conceptualization: HJM, KSK. Methodology: HJM, KSK, IYK. Formal analysis, Data curation: MHJ, IYK. Writing original draft: HJM, IYK. Writing-review & editing: HJM, KSK. All authors read and agreed to the published version of the manuscript.

SUPPLEMENTARY MATERIALS

Supplementary materials can be found online at <https://doi.org/10.21053/ceo.2025-00123>.

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