The Laryngoscope

Linking Chronic Otitis Media and Nasal Obstruction: A CFD Approach

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Objectives: To investigate a possible relationship between altered nasal flow and chronic otitis media (COM) using computational fluid dynamics (CFD).

Study Design: Retrospective case series.

Methods: Retrospective cohort sample of CT scans from patients with COM and controls without COM to compare the results of various nasal airflow parameters determined by CFD between a group of patients with COM (N = 60) and a control group of subjects without any evidence of ear disease (N = 81).

The CT were subjected to various procedures to carry out CFD studies, determining the resistance to nasal flow, the proportion of flow through the right and left nasal cavity, and two nondimensional estimators. The results of CFD studies between patients with COM and controls were compared.

Results: Whereas only 12.3% of the controls had CFD alteration (10 out of 81), 43.3% of the patients suffering COM displayed alterations of our nondimensional parameters $R-\phi$ (26 out of 60).

Conclusions: According to our results, the incidence of alterations in nasal airflow by studying with CFD is significantly higher in patients with COM than in controls. To our knowledge, this is the first article linking nasal cavity and COM using a CFD approach. Our results support the hypothesis that nasal flow alterations could be implicated in the etiopathogenesis of the COM.

Key Words: Chronic otitis media, middle ear cholesteatoma, computational fluid dynamics, CFD tools, nasal obstruction, deviated nasal septum, dimensionless estimators.

Level of Evidence: 4

***Laryngoscope*, 132:1224–1230, 2022**

INTRODUCTION

The middle ear is an air cavity excavated in the temporal bone, embryologically derived from the first pharyngeal pouch,[1] constituting an appendix of the upper respiratory tract. The close anatomical relationship of the middle ear with the nasopharynx, mediated by the Eustachian tube, it also gives the middle ear a great functional dependence of the upper respiratory tract.[2] Many causes of tubal dysfunction of nasal and/or nasopharyngeal origin have been described[3] and it is well known for the clinicians that Eustachian tube dysfunction has a role in chronic otitis media (COM) with effusion, adhesive otitis media, retraction pockets, and cholesteatoma pathogenesis.[2]

However, the relationship between the nose conditions and COM is controversial. While some authors have found a significant correlation between the incidence of nasal pathology and COM,[4–7] others do not find such a correlation.[8–11] Regardless of the role of alterations of the nose and/or nasopharynx on the middle ear, the intimate knowledge of this relationship would be of great interest for the treatment of patients with COM and concomitant nasal and/or nasopharyngeal alterations, a very common situation in the clinical practice. However, despite some study that sheds some light on this aspect,[11] no specific guidelines have been defined for the management of patients with COM and associated nasal and/or nasopharyngeal alterations.

As far as we know, no studies have been published on the relationship between nasal conditions and COM from the perspective of computational fluid dynamics (CFD). CFD allows to analyze and solve different problems about the flow of fluids,[12] constituting a basic discipline of research and development in practically all branches of science, including medicine. CFD has been proposed to study the flow in the nasal cavities for more than 25 years. However, only in recent years new software products have started to be available for the ENT specialist to use the techniques of CFD and the nasal virtual surgery in their own clinical practice.[13,14]

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Editor's Note: This Manuscript was accepted for publication on August 28, 2021.

Prof. Manuel A. Burgos is the creator of Flowgy©, and no others conflicts of interest exist, nor financial disclosure reported.

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DOI: 10.1002/lary.29882

The parameters commonly used in CFD to analyze the air flow inside the nose are pressure and pressure gradient, velocity, nasal resistance, wall shear stress, air flow through the right and left nasal cavity, the exchange of heat and humidity and, in case of nasal septum perforation, the exchange of air flow between one and another nasal cavity. In a previous article,[15] the authors presented two nondimensional estimators, based on data obtained from CFD analysis and geometric measures, which allow distinguishing between healthy and diseased nasal cavities. The first mathematical estimator ϕ is a function of geometric features and potential asymmetries between nasal passages, while the second estimator R represents in fluid mechanics terms the total nasal resistance that corresponds to the atmosphere-choana drop pressure. Later studies[15,16] suggest that this parameter allows guiding the surgery in a quantitative way, objectifying through virtual surgery the results of different alternatives, so that the surgeon can decide which is best suited to his patient and achieving success with a high probability.

OBJECTIVE

The aim of this research is to conduct CFD studies of the nose in a group of patients with COM and a control group of subjects without evidence of ear pathology, comparing the results of the parameters ϕ and R, to determine the incidence of alterations of such parameters in patients with COM and investigate the possible relationship between otitis and alterations in nasal airflow.

PATIENTS AND METHODS

This retrospective study was carried out with patients treated in the Otolaryngology Departments from Virgen del Rocío Hospital in Seville and Morales Meseguer Hospital in Murcia, between January 2014 and April 2019. The study was submitted to the evaluation of the Research Ethics Committee of the Morales Meseguer Hospital, which gave its endorsement. Institutional Review Board approval was not required for this retrospective study.

Control Group

This group included CT scans of patients with parotid tumors performed in the Department of Radiology of the Virgen del Rocío Hospital. Inclusion criteria were to be adult, and to have a complete nasal scan allowing the CFD analysis. Eighty-one CT were collected, of which 38 were male and 43 female, with a mean age of 39.2 ± 13.2 years (range, 19–68 years), including all of them in the CFD analysis.

Group With COM

The CT scans were obtained from the databases of both Otolaryngology Departments, after reviewing the studies of 406 patients with COM (cholesteatomatous COM undergoing mastoidectomy) and CT, of which only 60 CT allowed the study by CFD because in most cases the geometry of the nasal cavity was incomplete and/or the computed tomography was of poor quality. These CT corresponded to 28 men and 32 women, with a mean age of 38.7 ± 12.6 years (range 20–67 years).

Statistical Analyses

Statistical analyses were performed with R-3.6.3 (R Foundation for Statistical Computing, Vienna, Austria). Continuous variables were expressed as mean $\pm$ standard deviation, categorical variables as frequency and percent. Pearson's Chi-square test was used to evaluate the strength of association between abnormal cavities and COM. Statistical significance was set at $P < .05$.

COMPUTATIONAL FLUID DYNAMICS

Computational fluid dynamics (CFD) is very useful to assess nasal airways.[17] Common parameters used to analyze air flow within a nasal cavity such as temperature, wall shear stress, velocity… are dimensional parameters. In previous articles, the authors had introduced the use of nondimensional parameters[15] based on quantities obtained from CFD analysis and geometric quantities. Those parameters allow to distinguish between healthy or diseased nasal cavities, and had been used in a number of studies.[16,18] Both parameters $R - \phi$ were also used in the present work to investigate from an objective approach the relationship between COM and nasal obstruction.

All flow simulations were performed in Flowgy© (www.flowgy.com), which is the evolution of previous software versions (MeComLand©, DigBody© and NoseLand©)[13,14,16,18] reported in the literature. The three steps necessary for resolving the flow inside a nasal cavity, namely segmentation, mesh generation, and solving and postprocessing are described elsewhere.[13,14,16,19–22]

Airflow from 60 patients suffering COM and 81 from control groups was analyzed using Flowgy©. Using the CFD results and geometries from every nasal cavity the values for the parameters $R - \phi$ were calculated. Tables I and II show the results for CFD simulations and geometry data from the 60 patients with COM and 81 from control group respectively. All of CFD simulations were performed at the inspiratory phase, with compressible, steady, and laminar flow. For each simulation, a constant pressure drop between the atmosphere and the nasopharynx was set to mimic the natural respiration induced by the lungs.[20] This pressure drop was different for each patient, and it was adjusted so that the CFD result of the volumetric flow rate in all simulations was approximately the same. Furthermore, the volumetric flow rate Q was kept below $15\,L/min$ to ensure laminar flow.[21] The model was set to rigid body dynamics to omit the effect of respiratory-related soft-tissue deformation, which often involves fluid flow and structural solid coupling, particularly at the outer region of the nose, which are typically negligible.[22] The outer (atmosphere) temperature was set to 20°C, and the nasal inner wall was set to 37°C. Figure 1 shows a 3D nasal model and a detail of the surface mesh to perform the CFD simulation.

TABLE I.
Different Parameters Calculated in the Inspiration Phase by Numerical Simulation, for a Set of 60 Patients With Chronic Otitis Media (COM).

n	A_R	A_L	Q_R	Q_L	Q_T	Φ	R	n	A_R	A_L	Q_R	Q_L	Q_T	Φ	R
1	96.40	113.19	8.41	5.95	14.35	1.30	9.26	*31*	116.55	135.98	6.32	7.94	14.26	1.23	25.50
2	101.63	126.47	4.23	10.42	14.65	1.91	19.52	*32*	76.58	62.63	7.42	6.63	14.05	1.23	7.58
3	133.90	130.96	6.08	8.83	14.91	1.38	13.62	*33*	93.17	80.37	9.39	5.43	14.82	1.55	13.04
4	113.50	99.73	2.10	12.44	14.54	2.85	8.30	*34*	103.68	93.43	7.39	7.06	14.45	1.04	6.67
5	95.66	97.02	3.86	10.24	14.10	1.90	9.87	*35*	115.71	109.40	10.13	4.28	14.41	1.79	20.22
6	94.51	93.50	4.74	9.01	13.75	1.58	13.73	*36*	170.64	129.11	12.43	2.36	14.79	3.38	9.58
7	145.22	163.81	7.18	7.06	14.24	1.21	44.62	*37*	124.63	125.07	8.17	6.46	14.63	1.22	11.20
8	90.25	81.69	6.78	7.30	14.08	1.10	3.52	*38*	90.95	87.92	10.96	3.43	14.39	2.14	8.98
9	70.52	64.95	9.32	4.72	14.04	1.83	4.49	*39*	88.73	76.32	7.39	6.70	14.10	1.14	6.14
10	110.38	88.49	6.20	8.23	14.43	1.25	13.21	*40*	104.58	115.77	6.27	8.20	14.47	1.22	10.45
11	68.79	62.16	8.28	5.95	14.22	1.47	4.57	*41*	62.94	71.95	7.04	7.04	14.08	1.14	3.53
12	67.10	67.80	5.55	9.00	14.54	1.60	3.44	*42*	130.05	86.80	8.61	5.96	14.56	1.35	21.13
13	89.64	86.07	7.81	6.07	13.88	1.24	4.77	*43*	66.81	70.29	8.28	5.55	13.83	1.51	7.77
14	113.43	80.40	3.65	10.20	13.85	2.14	10.51	*44*	97.79	118.65	5.11	9.55	14.66	1.59	16.94
15	82.76	88.29	10.13	3.66	13.78	2.04	4.50	*45*	96.91	86.57	7.10	7.29	14.39	1.04	8.67
16	110.64	107.53	4.82	9.12	13.93	1.56	7.27	*46*	98.89	107.05	10.61	3.70	14.31	2.01	13.69
17	65.85	73.16	6.46	7.04	13.49	1.20	4.13	*47*	61.88	70.99	9.13	4.69	13.83	1.84	9.87
18	149.18	120.24	5.79	8.68	14.47	1.45	9.83	*48*	96.89	86.45	5.80	8.46	14.26	1.35	15.95
19	109.07	94.90	7.22	6.94	14.17	1.03	97.94	*49*	98.08	115.92	4.40	10.06	14.46	1.80	5.03
20	109.77	111.46	7.49	6.71	14.20	1.09	10.15	*50*	96.65	96.29	4.83	9.40	14.22	1.59	10.49
21	116.57	141.58	7.97	6.43	14.40	1.23	10.68	*51*	69.04	87.84	11.40	2.76	14.16	2.74	7.64
22	139.66	129.75	5.20	9.40	14.60	1.62	9.94	*52*	110.32	99.34	2.59	11.74	14.33	2.52	4.55
23	70.80	69.03	4.74	9.33	14.07	1.79	4.48	*53*	62.25	76.23	6.35	7.54	13.89	1.29	4.46
24	86.65	85.52	11.26	3.32	14.58	2.21	9.45	*54*	96.67	88.71	7.99	6.39	14.38	1.20	22.97
25	90.97	123.91	6.29	8.20	14.49	1.24	6.55	*55*	112.61	122.87	8.76	5.77	14.53	1.37	37.78
26	74.78	74.46	7.80	7.08	14.88	1.17	7.83	*56*	52.36	37.86	7.58	5.98	13.56	1.61	2.09
27	92.26	100.36	5.95	8.22	14.17	1.28	5.52	*57*	140.88	127.83	7.66	6.96	14.62	1.15	53.70
28	84.04	90.28	3.86	10.08	13.94	1.97	9.05	*58*	67.56	46.96	4.84	8.91	13.75	1.95	3.06
29	97.86	104.42	5.63	8.85	14.49	1.39	16.57	*59*	72.83	104.89	6.33	8.12	14.45	1.26	15.95
30	94.02	107.94	10.49	3.56	14.05	2.08	13.73	*60*	127.95	126.91	5.77	8.80	14.58	1.40	12.27

Flow rates (Q) in L/min. Nostril areas (A) in mm^2, and the dimensionless estimators Φ and R sub-indices: R (right nostril) and L (left nostril).

The first nondimensional parameter R represents the total nasal resistance or bilateral resistance, and is computed from the unilateral resistance of the two passages $R_R\,and\,R_L$, as follows:

$$\frac{1}{R}=\frac{1}{R_{\mathrm{R}}}+\frac{1}{R_{\mathrm{L}}}\Rightarrow R=\left(\frac{1}{R_{\mathrm{R}}}+\frac{1}{R_{\mathrm{L}}}\right)^{-1},$$

$$R_{\mathrm{R}}=\frac{\Delta P/Q_{\mathrm{R}}}{\frac{1}{2}\rho\;Q_{\mathrm{R}}/{A_{\mathrm{R}}}^{2}},R_{\mathrm{L}}=\frac{\Delta P/Q_{\mathrm{L}}}{\frac{1}{2}\rho\;Q_{\mathrm{L}}/{A_{\mathrm{L}}}^{2}},$$

where ΔP is the drop pressure between the atmosphere and the choana, Q_{R} and Q_{L} are the flow rates in the right and left nostrils, A_{R} and A_{L} are the areas of each nostril, and $\rho\approx 1.2\,\mathrm{kg/m^3}$ is the density of the atmospheric air.

The second nondimensional parameter ϕ provides a measure of nasal flow asymmetry. Normally, high asymmetries of nasal flow are associated with diseased nostrils. This parameter is defined as:

$$\phi=\frac{1+\left(\frac{A_{\mathrm{R}}+A_{\mathrm{L}}}{2A_{\mathrm{C}}}-1\right)^{2}}{(1-\varepsilon p)q\eta+\varepsilon p},$$

where $A_{\mathrm{C}}=107\,\mathrm{mm}^2$ is a mean value for the area of the nostrils.[23]; $p=A_{\mathrm{mi}}/A_{\mathrm{ma}}$ is the ratio between the minimum and maximum area of the nostrils; $q=Q_{\mathrm{mi}}/Q_{\mathrm{ma}}$ is the ratio between the minimum and maximum flow rates of the passages; η is a variable to take into account the septal perforations. For this study it takes the value of 1 in all cases because all of them lack septal perforations; $\varepsilon=0.25$ is a parameter to avoid the singularity of the parameter ϕ, so that we avoid that the numerator is null.

A more detailed description of these parameters can be found in the reference.[15]

In most cases, this parameter will take values of the order of 1 in nostrils with low asymmetry (typical of healthy nostrils), and high values in nostrils with high asymmetries (typical of diseased nostrils).

TABLE II.
Different Parameters Calculated in the Inspiration Phase by Numerical Simulation, for a Set of 81 Patients (Control Group).

n	A_R	A_L	Q_R	Q_L	Q_T	Φ	R	n	A_R	A_L	Q_R	Q_L	Q_T	Φ	R
1	97.06	137.10	7.19	7.05	14.25	1.03	16.96	*42*	87.79	61.90	8.29	6.02	14.31	1.41	6.53
2	93.90	106.36	4.92	8.91	13.82	1.54	7.97	*43*	69.00	63.45	7.01	6.91	13.92	1.16	5.41
3	106.47	118.01	6.29	8.36	14.65	1.24	8.46	*44*	180.17	114.65	9.02	5.57	14.59	1.68	11.10
4	90.53	68.08	6.83	6.72	13.55	1.08	4.67	*45*	84.79	89.05	7.35	6.78	14.13	1.10	7.21
5	154.70	156.26	6.13	8.13	14.27	1.48	11.21	*46*	88.87	81.99	8.20	6.10	14.30	1.30	4.70
6	91.91	84.74	4.61	9.33	13.94	1.69	9.43	*47*	128.56	120.98	4.88	9.61	14.49	1.65	10.84
7	99.78	110.86	5.16	9.13	14.29	1.51	12.69	*48*	111.26	120.89	7.15	7.39	14.54	1.03	6.87
8	121.60	125.26	7.59	6.64	14.23	1.13	11.64	*49*	110.92	95.16	6.38	7.88	14.26	1.18	13.58
9	94.65	100.46	6.61	7.41	14.02	1.10	5.23	*50*	84.57	71.49	6.55	7.79	14.35	1.23	12.75
10	75.60	82.26	7.45	6.39	13.83	1.20	6.87	*51*	125.31	131.48	7.57	7.00	14.57	1.10	12.95
11	62.84	66.04	7.02	6.41	13.42	1.24	5.76	*52*	103.88	110.41	7.04	7.54	14.58	1.05	8.42
12	63.71	73.88	5.46	8.72	14.18	1.60	5.92	*53*	105.15	99.59	8.62	5.80	14.41	1.34	5.94
13	124.90	127.22	6.66	8.12	14.78	1.19	18.21	*54*	81.27	121.94	7.51	6.51	14.02	1.13	5.80
14	83.15	84.48	5.04	8.51	13.55	1.51	6.08	*55*	80.29	127.37	6.66	7.41	14.08	1.09	16.93
15	82.11	79.65	7.71	6.64	14.35	1.18	4.95	*56*	80.60	91.00	6.40	7.50	14.08	1.17	2.75
16	90.00	83.41	6.62	7.50	14.12	1.14	5.33	*57*	97.00	108.20	6.50	7.60	14.08	1.13	9.55
17	78.22	111.62	8.19	6.31	14.51	1.25	6.35	*58*	63.50	55.60	6.70	7.30	14.08	1.28	11.00
18	103.26	97.44	8.63	5.99	14.62	1.31	6.13	*59*	77.09	80.27	9.68	4.38	14.08	1.83	19.82
19	113.77	111.36	7.60	6.39	13.99	1.14	5.41	*60*	95.25	89.32	7.95	6.26	14.08	1.22	7.58
20	117.70	121.89	9.00	6.61	15.61	1.27	12.29	*61*	165.80	134.00	9.30	4.90	14.08	1.86	14.72
21	109.52	107.04	6.63	7.53	14.16	1.10	8.36	*62*	111.00	94.00	8.00	6.70	14.08	1.15	12.85
22	94.92	99.73	6.92	7.39	14.31	1.06	14.99	*63*	86.70	104.00	7.20	7.30	14.08	1.02	14.21
23	88.77	82.36	7.34	6.62	13.96	1.12	9.02	*64*	103.40	95.00	7.70	6.80	14.08	1.10	15.75
24	81.33	76.20	7.18	6.77	13.95	1.12	6.12	*65*	60.40	62.00	7.20	7.10	14.08	1.20	6.37
25	91.68	90.98	8.40	5.57	13.96	1.37	10.88	*66*	122.20	129.10	4.00	10.78	14.08	1.98	12.68
26	94.65	91.24	5.16	8.91	14.07	1.49	8.15	*67*	87.80	120.00	8.50	6.10	14.08	1.30	9.53
27	168.33	141.58	8.97	5.45	14.42	1.74	13.88	*68*	93.30	93.00	8.40	6.10	14.08	1.28	20.31
28	90.83	100.70	8.39	5.67	14.06	1.35	8.72	*69*	121.70	127.00	4.18	10.20	14.08	1.86	11.01
29	77.23	86.26	7.35	6.39	13.74	1.18	7.01	*70*	60.30	71.00	5.50	8.40	14.08	1.58	5.11
30	122.85	110.32	6.93	7.46	14.39	1.07	10.83	*71*	122.70	119.70	6.40	8.00	14.08	1.20	15.03
31	68.58	83.28	7.08	6.69	13.77	1.13	10.52	*72*	128.00	124.00	7.00	7.80	14.08	1.12	8.64
32	109.49	130.68	7.13	7.28	14.41	1.03	7.35	*73*	96.60	99.50	5.30	8.90	14.08	1.45	12.53
33	110.24	130.04	6.57	7.83	14.39	1.16	7.53	*74*	99.80	83.30	7.70	6.40	14.08	1.18	6.07
34	105.65	118.64	5.64	8.46	14.10	1.35	6.80	*75*	115.00	114.10	6.80	7.50	14.08	1.08	9.98
35	100.52	101.29	8.63	5.52	14.16	1.38	12.75	*76*	161.70	178.80	8.20	6.30	14.08	1.64	26.75
36	104.15	121.21	4.75	9.72	14.47	1.68	21.17	*77*	115.20	115.50	7.70	6.50	14.08	1.14	12.57
37	122.18	95.06	7.47	6.77	14.24	1.08	12.25	*78*	87.70	88.00	6.60	7.60	14.08	1.15	8.69
38	77.09	80.27	9.68	4.38	14.07	1.83	19.82	*79*	121.50	111.80	4.70	9.70	14.08	1.67	13.30
39	95.25	89.32	7.95	6.26	14.21	1.22	7.58	*80*	91.10	96.40	4.50	9.90	14.08	1.74	9.24
40	108.63	119.66	5.84	8.37	14.21	1.31	9.25	*81*	103.00	86.80	5.50	8.80	14.08	1.44	7.77
41	85.13	84.33	7.92	6.29	14.20	1.23	5.91								

Flow rates (Q) in L/min. Nostril areas (A) in mm^2, and the dimensionless estimators Φ and R sub-indices: R (right nostril) and L (left nostril).

RESULTS

Data from the patients and control groups were included in Tables I and II.

The Figure 2 represents the values of the estimator R versus the estimator ϕ, for both sets of nasal cavities corresponding to patients with COM (red circles) and the control group (green circles). Figure 2 shows a rectangle whose dimensions were previously established[15] by comparing 49 caucasian subjects, 25 patients presented different nose problems, whereas 24 were included as normal controls, finding that the healthy nasal cavities were clustered inside the rectangle. Inside the rectangle there is a 99% probability to find a healthy nasal cavity.[15]

As can be seen, most of the parameters calculated for the 81 CT in the control group (88%) are within the central rectangle, suggesting that they do not have nasal obstruction. However, the parameters calculated in the

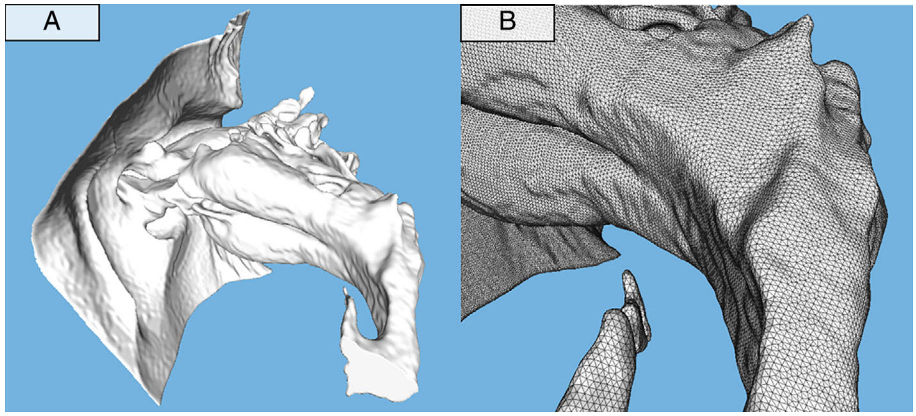

Fig. 1. (A) 3D model geometry. (B) Surface mesh detail. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

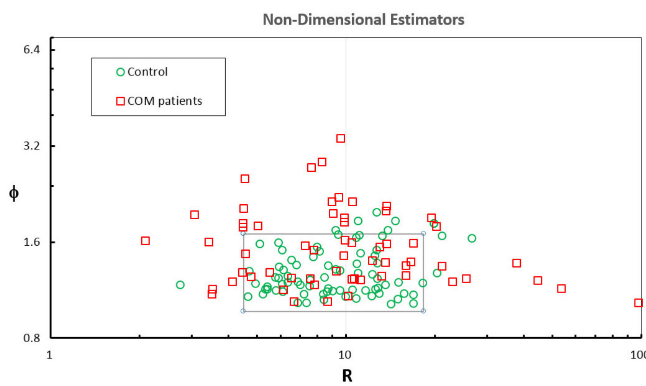

Fig. 2. Cartesian coordinate system in logarithmic scale. Inside the rectangle the probability to get a healthy cavity is higher than 99%. Patients with COM (red circles) and control group (green circles). [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

TABLE III.
Statistical Results.

	Control Group, *n* (%)	COM Group, *n* (%)	*P*
Normal	71 (87.6)	34 (56.7)	<.001†
Outside range	10 (12.4)	26 (43.3)	

Outside range: $R > 18.3 \parallel R < 4.5 \parallel \phi < 0.97 \parallel \phi > 1.7$. Pearson's Chi-square test was used.
†Statistically significant ($P < .05$).
COM = chronic otitis media; n = number of patients.

group of 61 CT of patients with COM show a high dispersion, with 43.3% of the cases being outside the rectangle.

Patients with COM presented abnormal CFD results when compared with controls, and this association is strongly significant. Therefore, in our sample, alterations in the results of nasal flow determined by CFD are much more frequent in patients with COM than in the control group, $P < .0001$ (Table III).

DISCUSSION

The close anatomical and functional relationship of the middle ear to the respiratory tract through the Eustachian tube determines a great dependence on the nasal cavity and nasopharynx.[2] However, although pathological findings in the nose or the nasopharynx are often said to be responsible for inadequate tubal function, this relationship is not clearly established and studies and evidence are scarce and contradictory. Different studies[24,25] suggest that in case of septal deviation, the development of the cavities of the middle ear is minor on the affected side. However, through studies with acoustic rhinometry and rhinomanometry, Güçlü et al.[26] determined that patients with COM have significantly higher nasal resistances than controls, but they did not find a clear correlation between the side of the nasal cavity and that of the affected ear.

Watson et al.[6] determined by anterior active rhinomanometry that in a sample of 15 patients with COM the nasal resistance on the side of the affected ear was significantly greater than in controls. But, using the same technique, Arsla et al.[8] did not find significant differences in nasal airway resistance between the COM sides and unaffected sides between 102 patients with unilateral COM and 40 individuals without any ear or nasal pathologies controls. And Toros et al.[10] did not observe correlation between the ear with COM and the side of nasal obstruction by acoustic rhinometric in a sample of 55 patient with COM. Studying 114 patients with COM, Ural et al.[5] suggested that septal deviation occurred more frequently on the same side of ear pathology in patients with tubotympanic chronic suppurative otitis media, but not in patients with atticoantral chronic suppurative otitis media. In our country, Suarez et al.[7] found in a sample of 5.414 children that the prevalence of secretory otitis was significantly related to infections of the upper respiratory tract and nasal obstruction. Harju et al.[3] noted that patients with hypertrophic turbinate have more tubal symptoms than controls, and Damar et al.[4] found that the incidence of septal deviation, hypertrophic turbinate and/or concha bullosa determined by CT was significantly higher in patients with COM (177 patients) than in healthy subjects (50). On the contrary, on a large-scale Korean epidemiological basis, Heo et al.[9] did not find any relationship between the prevalence of COM and septal deviation.

As far as we know, this is the first study that tries to shed light to determine the relationship between nasal and COM conditions from a CFD perspective. To obtain the reported results in this article, it was required to find 115 CT scans of subjects (60 from the COM group and 81 from the control group) that were suitable for a computational fluid mechanics (CFD) analysis. The task was especially tedious in recruiting CT into the COM group, as most studies did not include the nasal cavity, making the CFD study impracticable, forcing us to review more than 400 TCs to eventually get 60. To the authors' knowledge, there are no articles in which the results obtained with this kind of analysis and with such a high number of subjects are presented.

The high dispersion of the COM patients (Fig. 2) clearly indicates that, although from a computational point of view these patients cannot be strictly cataloged either as healthy or as diseased, it can be suspected that patients with COM present differences with those from the control group and that these differences are related to nasal obstruction, alterations and the flow and/or resistance, and indeed they deserve a further and deeper analysis in the future.

It can be seen how the results of patients of the COM group are scattered throughout the Cartesian coordinate system in the Figure 2. Abnormal values of R or ϕ are found in approximately equal percentage, so either parameter can lead—or be related—to COM. Although the results are scattered, it is interesting to mention two groups of patients. The first group of patients with significantly low values of resistance that allows the hypothesis to be made that high air velocities in the nasal cavity led to low pressures at the entrance of the Eustachian tube and may play an important role in causing its dysfunction. It is quite tempting to propose Eustachian tube collapse in the first group, whereas in the second could be asymmetry in a role which also needs further analysis.

If further studies confirm the relationship between COM and nasal air flow alterations, it is pending to determine the mechanism by which nasal flow alterations induce COM, thus the airflow current lines and pressures in nasopharynx would need to be studied in more detail.

CONCLUSION

According to our results, the incidence of alterations in nasal airflow determined by CFD is significantly higher in patients with COM than controls. Based on this finding, it is quite tempting to suggest a role for the nose in the origin of primary acquired cholesteatoma inside the chronic middle ear pathology.

IMPLICATIONS

To our knowledge, this is the first article linking nasal cavity and COM using a CFD approach. Our results support the hypothesis that nasal flow alterations could be implicated in the etiopathogenesis of the COM. Likewise, in the treatment of the COM, our findings suggest that management of nasal conditions should be considered.

ACKNOWLEDGMENTS

This work has been supported by the Ministerio de Ciencia e Innovacion of Spain (Grant No. PID2019-105097RB-I00/AEI/10.13039/501100011033). We appreciate the collaboration of the Department of Radiology of the Morales Meseguer Hospital in the task of compiling some of the CT scans, particularly to Silvia Torres and Carlos Vázquez.

DATA AVAILABILITY STATEMENT

The data generated and analyzed during the study are available from the corresponding author on reasonable request.

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