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Prevalence and risk factors of cough variant asthma in patients with chronic cough after COVID-19: findings from the real-world data

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Abstract

Background Chronic cough is one of the most common symptoms among post-COVID syndrome. However, limited information is available on the characteristics and possible etiology of the individuals presenting with chronic cough after COVID-19. This study aimed to investigate the prevalence and risk factors of cough variant asthma (CVA) among patients who developed chronic cough after COVID-19.

Methods In this multicenter cross-sectional observational study, a total of 530 patients who developed chronic cough after COVID-19 were included. Their demographic characteristics, clinical symptoms, comorbidities, medication history, COVID-19 vaccination history, blood laboratory findings and pulmonary function parameters were collected and summarized. The prevalence of CVA was calculated in this study, and potential risk factors associated with CVA were analyzed by logistic regression.

Results The patients with chronic cough after COVID-19 showed a high proportion of female (69.4%) and a median age of 37 (interquartile range 27–51) years old. Of these, 96.2% were non-smokers and 74.7% had no comorbidities. CVA accounts for 30.2% of cases with chronic cough after COVID-19. Compared with non-CVA group, the patients diagnosed with CVA exhibited markedly elevated incidence of small airway dysfunction ($P<0.001$), fractional exhaled nitric oxide ($P<0.001$), peripheral blood eosinophil count ($P<0.001$) and lymphocyte count ($P=0.012$), while lung function parameters, including FEV1% predicted value, FEV1/FVC%, and PEF% predicted value, were all significantly lower (all $P<0.001$). Female sex (OR 2.72, 95%CI 1.45–5.10, $P=0.002$) was an independent risk factor for the occurrence of CVA after COVID-19, while COVID-19 vaccination (OR 0.32, 95%CI 0.13–0.81, $P=0.016$) was identified as a protective factor for reducing the risk of CVA after COVID-19.

Conclusion Approximately 30% of patients who develop chronic cough following COVID-19 are newly diagnosed with CVA. Being female and lacking a history of COVID-19 vaccination are identified as independent risk factors for CVA in these patients.

Clinical trial number Not applicable.

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Keywords Coronavirus disease · COVID-19 · Post-COVID syndrome · Chronic cough · Cough variant asthma

Background

COVID-19 has led to over 7 million deaths since December 2019, as reported by the World Health Organization, posing a serious threat to human lives. Over the past four years, the sequelae of COVID-19 have emerged as a significant concern for the general public. It has been documented that over 10% of individuals infected with SARS-CoV-2 develop post-COVID syndrome [1, 2]. Post-COVID syndrome is characterized by the onset of new or persistent symptoms occurring three months after COVID-19 infection, lasting for at least two months in the absence of other illnesses [3, 4]. More than 200 post-COVID symptoms have been identified, involving multiple organ systems in the human body. Among them, chronic cough stands out as one of the most common symptoms [5, 6].

Cough variant asthma (CVA) was originally described as a subtype of asthma characterized by cough as the sole symptom and a favorable response of cough to bronchodilator therapy [7, 8]. Chronic cough is defined as a persistent cough lasting 8 weeks or longer, with common causes including cough variant asthma (CVA), postnasal drip syndrome, gastroesophageal reflux disease, etc [9–11]. Among them, CVA accounts for approximately 30% of the etiology of chronic cough. The treatment for chronic cough can vary significantly based on its underlying causes. Studies have shown that the percentage of patients experiencing lingering cough following COVID-19 infection ranges from 5.0% to 42.6%, with a meta-analysis suggesting an average of 18%, which has notable physical, psychological, social and economic implications [12, 13].

It has been reported that severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection elevates cough sensitivity in both peripheral and central nerves within the cough reflex pathway [14, 15]. Increased level of interferon-γ induced by viral infections can lead to heightened cough sensitivity [16, 17], potentially serving as a crucial mechanism for post-infection cough. Previous studies have indicated that various upper respiratory tract viral infections can trigger airway hyperresponsiveness or eosinophilic airway inflammation for weeks or even months [18, 19]. Some researchers also speculate that chronic cough after SARS-CoV-2 infection could be linked to neuroinflammation and neuroimmune interactions stemming from the impact of virus on sensory nerve function, but direct evidence is lacking [12, 20]. So far, there has not been specific analysis on the clinical features and underlying causes of chronic cough after COVID-19. Investigating specific causes, particularly the prevalence and risk factors of CVA, holds significant importance for the effective treatment of these patients.

Therefore, we retrospectively analyzed the demographic and clinical profiles of patients with post-COVID chronic cough who presented to our outpatient clinic, focusing on the prevalence and risk factors of CVA in this population.

Methods

Study design and participants

This cross-sectional observational study included patients who developed chronic cough after SARS-CoV-2 infection and were admitted to the outpatient departments of three tertiary hospitals (Xiangya Hospital, Changde Hospital, First People's Hospital of Chenzhou) from March 1, 2023 to November 30, 2023. Patients were enrolled if they met all the inclusion criteria listed as follows: (1) age ≥ 18 years old; (2) confirmed SARS-CoV-2 infection by a positive nucleic acid or antigen test before the onset of chronic cough; (3) persistent cough as the only or predominant symptom that lasts for more than 8 weeks after the disappearance of symptoms in the acute phase of SARS-CoV-2 infection; (4) no substantial abnormalities on chest radiograph or computerized tomography (CT)

scan of the thorax contributing to chronic cough. Patients who met any of the following criteria were excluded: (1) lack of pulmonary function results and CVA diagnostic tests (bronchial provocation test, bronchodilator reversibility test, or PEF diurnal variation rate); (2) confirmed diagnosis of respiratory diseases with chronic cough as the primary symptom before SARS-CoV-2 infection, such as CVA, allergic bronchitis, eosinophilic bronchitis, gastroesophageal reflux disease, chronic obstructive pulmonary disease, chronic bronchitis, bronchiectasis, interstitial lung disease, pulmonary/tracheo-bronchial tuberculosis, etc.; (3) female patients who are pregnant or lactating. Totally, 530 patients were continuously included in the study. The diagnosis of CVA was made if the patients met all the following criteria: (1) chronic cough, often accompanied by pronounced nocturnal coughing; (2) positive bronchial stimulation test, or average diurnal variation rate of peak expiratory flow (PEF) > 10%, or positive bronchial relaxation test; (3) effective response to anti-asthmatic treatment [8].

Clinical data collection

The demographic characteristics, clinical symptoms, comorbidities, medication history, COVID-19 vaccination history, and auxiliary test results of each patient were collected from the electronic medical record. The auxiliary tests included routine blood test, serum IgE, pulmonary function test, bronchial provocation test, bronchial dilation test, and exhaled nitric oxide. Based on the attending physician's clinical judgment and patient preferences, not all enrolled patients completed all of the above auxiliary tests, such as fractional exhaled nitric oxide (FeNO) and concentration of alveolar nitric oxide (CaNO). Approximately 33% of patients did not undergo FeNO and CaNO measurements in our cohort.

Procedures of pulmonary function test and exhaled nitric oxide

Pulmonary function tests were performed by trained technicians using a Jaeger MasterScreen pneumotachograph spirometer (CareFusion, Yorba Linda, CA, USA). Each participant was required to perform up to eight forced expiratory maneuvers until the forced vital capacity (FVC) and forced expiratory volume in 1 s (FEV1) were reproducible within 150 ml. All spirometry data were reviewed by an expert panel based on the criteria of the American Thoracic Society and European Respiratory Society [21].

A positive bronchial provocation test is defined as an FEV1 decrease of ≥ 20% after inhaling bronchial activator [22]. A positive bronchial dilation test is defined as an increase in FEV1 of more than 12% and an absolute increase of over 200 ml after inhaling bronchodilator [23]. Small airway dysfunction (SAD) was diagnosed on the basis of at least two of the following three indicators of lung function being less than 65% of predicted: maximal mid-expiratory flow (MMEF), forced expiratory flow at 50% of forced vital capacity (FEF50%), and forced expiratory flow at 75% of forced vital capacity (FEF75%) [24].

FeNO was sampled by pumping air from one nostril at a constant flow rate (10 ml/s) while exhaling orally keeping the soft palate closed (in a whistling fashion) to avoid lung gas entering the nose, and then analyzing the concentration of NO produced by the nose and sinuses. FeNO50 refers to the analysis of NO concentrations from atmospheric tracts by sampling at an oral expiratory flow rate of 50 ml/s. FeNO200 refers to the analysis of NO concentrations from atmospheric tracts by sampling at an oral expiratory flow rate of 200 ml/s. CaNO was determined using the measurements of FeNO50 and FeNO200 at flow rates of 50 ml/s and 200 ml/s, and calculated by a simplified version of the linear modeling equation [25].

Statistical analysis

All statistical analyses were *p*erformed using SPSS 26.0 software and GraphPad Prism 9.0 software. Continuous variables are expressed as median and interquartile ranges, and categorical variables are expressed as counts and percentages. The Mann-Whitney U test was used for continuous variables between the two groups, and the chi-square test were used for categorical variables between the two groups, and $P<0.05$ was considered statistically

significant. Both univariate and multivariate logistic regression analyses were conducted, with a significance level of $P<0.05$. Variables significant ($P<0.05$) in the univariate analysis and clinically relevant variables based on clinical knowledge and prior evidence were subsequently included in the multivariate logistic regression model. Model goodness-of-fit was assessed using the Hosmer-Lemeshow goodness-of-fit test, with $P>0.05$ indicating adequate fit.

Results

The demographics and baseline clinical characteristics of participants

As summarized in Table 1, a total of 530 patients who developed chronic cough after SARS-CoV-2 infection were included in our study. Of these patients, 368 (69.4%) were female, and the median age of all patients was 37 (interquartile range 27–51) years old. The majority (96.2%) were non-smokers. Of all participants, 96.0% had received at least one dose of SARS-CoV-2 vaccines before contracting COVID-19, while only a small proportion received anti-SARS-CoV-2 drugs. Additionally, 74.7% of patients had no comorbidities.

Table 1 The demographics and baseline clinical characteristics

Variables	All patients ($n=530$)	CVA group ($n=160$)	Non-CVA group ($n=370$)	*P* value
Duration of cough (months), median (25%-75% IQR)	4.00 (2.00–6.00)	4.00 (2.00–6.00)	4.00 (2.75-6.00)	0.223
Sex, n (%)				<0.001
Female	368 (69.4)	132 (82.5)	236 (63.8)	
Age (years), median (25%-75% IQR)	37.00 (27.00–51.00)	37.00 (27.00–50.00)	37.50 (27.00–51.00)	0.406
Age distribution, n (%)				0.246
≤29	156 (29.4)	45 (28.1)	111 (30.0)	
30–39	126 (23.8)	44 (27.5)	82 (22.2)	
40–49	91 (17.2)	26 (16.3)	65 (17.6)	
50–59	116 (21.9)	38 (23.8)	78 (21.1)	
60–69	33 (6.2)	7 (4.4)	26 (7.0)	
≥70	8 (1.5)	0 (0)	8 (2.2)	
Height (cm), median (25%-75% IQR)	160.75 (156.00-167.63)	159.50 (156.13–164.00)	161.50 (156.00-169.00)	0.014
Body weight (kg), median (25%-75% IQR)	60.00 (52.00–68.00)	59.50 (52.00–67.00)	60.00 (52.00–69.00)	0.441
BMI (kg/m^2), median (25%-75% IQR)	22.90 (20.60–25.60)	23.10 (20.60-25.75)	22.85 (20.50–25.60)	0.498
BMI distribution, n (%)				0.136
<18.5	38 (7.3)	13 (8.1)	25 (6.9)	
18.5–23.9	284 (54.4)	80 (50.0)	204 (56.4)	
≥24	200 (38.3)	67 (41.9)	133 (36.7)	
Smoking status, n (%)				0.709
Never	510 (96.2)	156 (97.5)	354 (95.7)	
Current smoker	15 (2.8)	3 (1.9)	12 (3.2)	
Former smoker	5 (0.9)	1 (0.6)	4 (1.1)	
COVID-19 vaccination, n (%)	509 (96.0)	147 (91.9)	362 (97.8)	0.001
Anti-SARS-CoV-2 drugs, n (%)	4(0.8)	2(1.3)	2(0.5)	0.588
Comorbidities, n (%)				0.105
None	396 (74.7)	127 (79.4)	269 (72.7)	
Yes	134 (25.3)	33 (20.6)	101 (27.3)	
Allergic diseases, n (%)	72 (13.6)	23 (14.4)	49 (13.2)	0.727

*Data are expressed as median (25%-75% interquartile range) or number (percentage)

*CVA, cough variant asthma; BMI, body mass index; COVID-19, Corona Virus Disease 2019; SARS-CoV-2, Severe Acute Respiratory Syndrome Coronavirus 2

Table 2 Laboratory findings

Variables	All patients ($n=530$)	CVA group ($n=160$)	Non-CVA group ($n=370$)	*P* value
Routine blood test, median (25%-75% IQR)				
White blood cell ($\times10^9$/L)	6.5 (5.6–7.6)	6.8 (5.7–7.8)	6.3 (5.5–7.4)	0.056
Neutrophil ($\times10^9$/L)	3.6 (3.0-4.4)	3.6 (3.0-4.4)	3.6 (3.0-4.5)	0.567
Lymphocyte ($\times10^9$/L)	2.1 (1.7–2.4)	2.2 (1.9–2.7)	2.0 (1.7–2.4)	0.012
Eosinophil ($\times10^9$/L)	0.2 (0.1–0.3)	0.2 (0.1–0.5)	0.1 (0.1–0.2)	<0.001
Serum IgE (U/ml), median (25%-75% IQR)	68.8 (41.6–157.0)	68.8 (41.6-208.6)	68.1 (41.7-129.8)	0.470
Small airway dysfunction, n (%)	145 (27.4)	74 (46.3)	71 (19.2)	<0.001

*Data are expressed as median (25%-75% interquartile range) or number (percentage)

*CVA, cough variant asthma

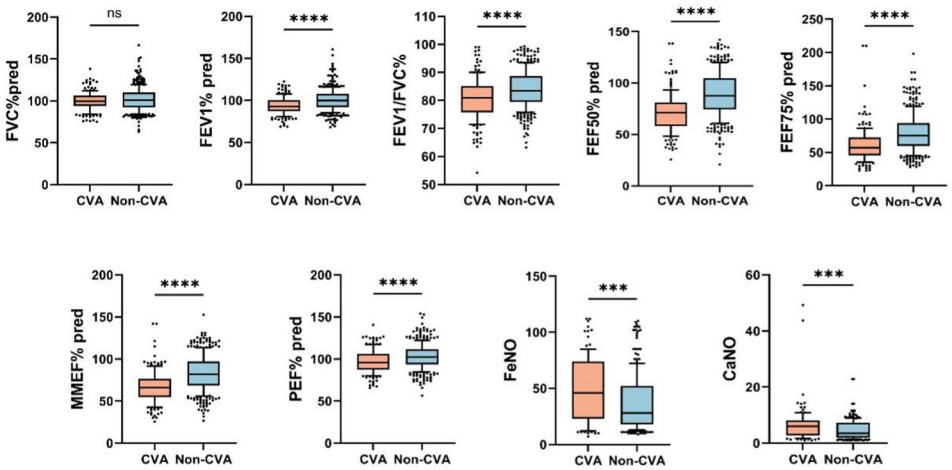


Fig. 1 Comparison of the pulmonary function parameters in patients of CVA and non-CVA groups

Among 530 patients, 160 (30.2%) were diagnosed with CVA, while the remaining 370 (69.8%) patients were classified as non-CVA. The proportion of females in the CVA group was significantly higher than in the non-CVA group (82.5% vs. 63.8%, $P<0.001$). The rate of COVID-19 vaccination differed significantly between patients with CVA and those without CVA ($P=0.001$), with vaccination rates of 91.9% and 97.8%, respectively.

Laboratory findings and pulmonary function parameters

As shown in Table 2, compared with the non-CVA group, patients diagnosed with CVA showed a significantly higher eosinophil ($P<0.001$) and lymphocyte ($P=0.012$) counts in peripheral blood, while no significant differences were found in white blood cell count ($P=0.056$), neutrophil count ($P=0.567$), and serum IgE level ($P=0.470$). There was no significant difference in the levels of FVC% predicted value ($P=0.171$) between the CVA and non-CVA groups. However, pulmonary function parameters, including FEV1% predicted value, FEV1/FVC%, FEF50% predicted value, FEF75% predicted value, MMEF% predicted value, and PEF% predicted value, were all significantly lower in patients with CVA compared to those without CVA (all $P<0.001$). The incidence of small airway dysfunction, FeNO, and CaNO were all significantly higher in the CVA group than in the non-CVA group (all $P<0.001$) (Fig. 1). The FEV1% change during the bronchial provocation or dilation test is presented in Supplementary Figures S1.

The FVC% predicted value, FEV1% predicted value, FEV1/FVC (%), MEF50% predicted value, MEF25% predicted value, MMEF% predicted value, PEF% predicted value, FeNO, and CaNO in patients with CVA and patients with non-CVA. Bars indicate the 10–90 percentile. CVA, cough variant asthma; FVC, forced vital capacity; FEV1, forced expiratory volume in one second; FEF50%, forced expiratory flow at 50% of forced vital capacity; FEF75%, forced expiratory flow at 75% of forced vital capacity; MMEF, maximal mid-expiratory flow;

PEF, peak expiratory flow; FeNO, fractional exhaled nitric oxide; CaNO, concentration of alveolar nitric oxide; ns, not statistically significant; ***, $P<0.001$; ****, $P<0.0001$.

Risk factors associated with CVA

The univariate logistic regression model identified three clinical variables associated with CVA in patients with chronic cough after COVID-19 (Fig. 2): female sex (OR 2.68, 95%CI 1.69–4.24, $P=0.001$), height (OR 0.97, 95%CI 0.95–0.99, $P=0.011$), and COVID-19 vaccination (OR 0.25, 95%CI 0.10–0.62, $P=0.003$). Variables that were significant ($P<0.05$) in the univariate analysis, together with clinically relevant variables (including allergic diseases, age, and duration of cough), were subsequently included in the multivariate logistic regression model. Furthermore, the multivariable logistic regression model suggested that female sex (OR 2.72, 95%CI 1.45–5.10, $P=0.002$) was independently associated with higher risk of CVA. COVID-19 vaccination (OR 0.32, 95%CI 0.13–0.81, $P=0.016$), on the other hand, was associated with lower risk of CVA (Fig. 3). The multivariable logistic regression model demonstrated adequate goodness-of-fit (Hosmer-Lemeshow $\chi^2=4.97$, df = 8, $P=0.761$).

Forest plot of risk factors associated with CVA in patients with chronic cough after COVID-19. Binary Dependent Variable: CVA (1), Non-CVA (0). BMI, body mass index; COVID-19, Corona Virus Disease 2019; Anti-SARS-CoV-2, Anti Severe Acute Respiratory Syndrome Coronavirus 2.

Forest plot of risk factors associated with CVA in patients with chronic cough after COVID-19. Binary Dependent Variable: CVA (1), Non-CVA (0). The Hosmer-Lemeshow test indicated that the model fitted the data well ($\chi^2=4.97$, df = 8, $P=0.761$). COVID-19, Corona Virus Disease 2019.

Discussion

Chronic cough is one of the most common post-COVID sequelae. To the best of our knowledge, this is the first study reporting the prevalence of CVA and its risk factors in a cohort of patients with chronic cough following COVID-19. In our study, the patients who develop chronic cough following COVID-19 were predominantly

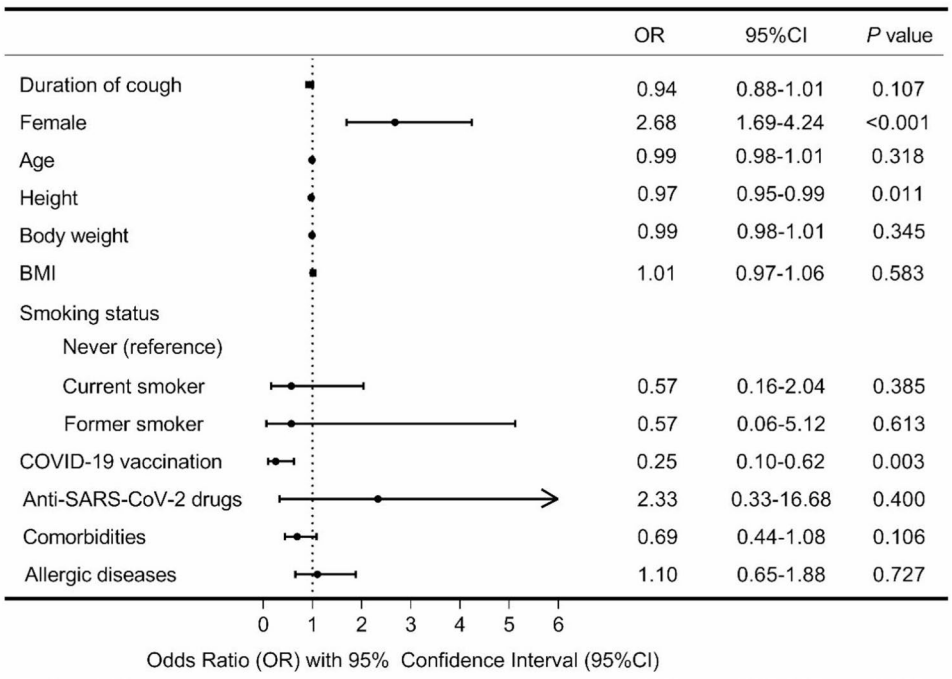


Fig. 2 Univariate logistic regression of risk factors associated with CVA in patients with chronic cough after COVID-19

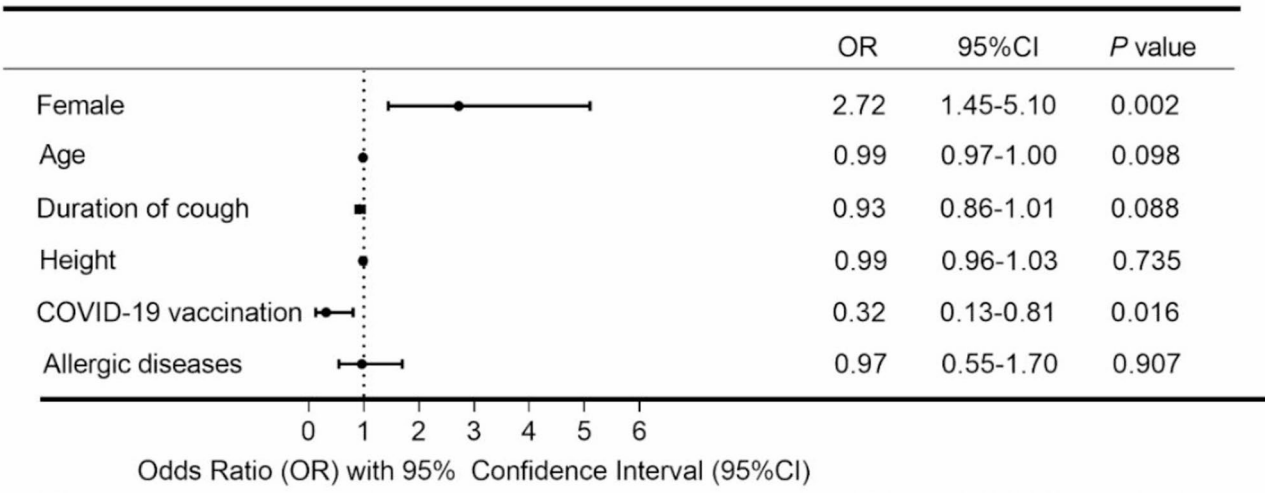


Fig. 3 Multivariable logistic regression of risk factors associated with CVA in patients with chronic cough after COVID-19

female, young to middle-aged, non-smokers, and without comorbidities. Among these patients, approximately 30% are diagnosed with CVA. Both being female and not receiving a COVID-19 vaccine were identified as independent risk factors of CVA after SARS-CoV-2 infection.

With the outbreak of the SARS-CoV-2 pandemic, numerous studies have highlighted that patients may endure persistent symptoms for months post-recovery from COVID-19, termed the post-COVID syndrome [12]. Common symptoms include dyspnea, fatigue, pain, and cough [26, 27]. In online surveys, cough was recorded in 20–30% of symptomatic patients 2–3 months following the onset of symptoms of COVID-19 [12]. Xu et al. [28] reported that persistent cough (> 3 weeks) occurred in 13.0% of individuals after COVID-19 during the Omicron variant pandemic by the end of 2022 in China; however, the prevalence of chronic cough were not analyzed in this study. Experiencing chronic cough is associated with a significant decrease in quality of life, leading to symptoms such as incontinence, chest pain, headache, and poor sleep. The pathological mechanism of chronic cough induced by SARS-CoV-2 infection is complex. Similar to other viral infections, SARS-CoV-2 infection may augment cough sensitivity in peripheral and central nerves along the cough reflex pathway [12, 29]. Previous studies have indicated that elevated levels of interferon-γ induced by viral infection can heighten cough sensitivity, potentially explaining why SARS-CoV-2 infections may result in chronic cough [12, 16]. However, existing researches have yet to scrutinize the characteristics and potential etiology of the specific population of patients with chronic cough after COVID-19.

In our study, the majority of enrolled patients with chronic cough after COVID-19 are female, young-to-middle aged, non-smokers, and having no comorbidities. The female predominance is observed in the chronic cough population, which could be related to the heightened cough sensitivity among female patients [30]. It has been suggested that increased cough sensitivity in females may be explained by gender-related differences in the processing of cough sensory centers [31]. However, further studies are required to determine if female patients also exhibit increased cough sensitivity through the same mechanism after COVID-19. Age distribution in the chronic cough population has substantial geographical variations. A survey of 10,032 participants in the UK, South Korea, Netherlands, the USA, Sweden, and China found that the most prevalent age for presentation was 60–69 years, while a lower age (30–39 years) was in China [31]. Further research has validated that individuals with chronic cough in China typically manifest under the fifty [30, 32]. In line with these data, our research demonstrates that over 90% of all the enrolled patients are between the ages of 18 and 59 years old. Although smoking has been reported as a risk factor of post-COVID syndrome [33], non-smokers tended to develop chronic cough in the present study. It is well acknowledged that there were very few smokers among young and middle-aged Chinese women, which may be the reason for non-smokers making up the vast majority of participants in our

study. These findings suggest that the pathological mechanisms of post-COVID chronic cough may be linked to the individual gender- and age-related differences.

CVA accounts for 30% of cases of chronic cough after COVID-19 in our study, and FeNO and CaNO levels are markedly elevated in the CVA group. It indicates that airway hyperresponsiveness and eosinophilic airway inflammation are important characteristics of patients with chronic cough after COVID-19. Viral infections can induce airway hyperresponsiveness or eosinophilic bronchiolitis [34]. FeNO reflects the inflammation of the bronchus and central airway, while CaNO reflects the inflammation of the small airway in the alveolar or acinar area [25, 35]. Moreover, eosinophil count in peripheral blood is a reliable indicator of eosinophilic asthma phenotype [36]. In our study, CVA group exhibits a significantly higher peripheral blood eosinophil count, FeNO, and CaNO compared with the non-CVA group, suggesting that eosinophilic inflammation may play a crucial role in the pathogenesis of CVA after COVID-19. Our findings suggest the clinical relevance of treatable traits in patients with chronic cough after COVID-19 infection. These patients should be systematically evaluated for treatable traits, particularly eosinophilic airway inflammation and elevated FeNO, as identifying such traits can guide individualized anti-inflammatory therapy. Targeted therapies such as inhaled corticosteroids and, in selected cases, biologic agents may improve cough control and quality of life while reducing unnecessary diagnostic testing. Future prospective studies should evaluate whether a treatable traits-based management strategy improves clinical outcomes in this population.

Female sex is the strongest independent risk factor associated with CVA after COVID-19. It has been reported that female individuals are more frequent to exhibit airway hyperresponsiveness for complex reasons, such as the impact of sex hormones [37]. But the underlying molecular mechanisms for female predominance in CVA following COVID-19 requires further investigations. In the present study, 96.0% of participants received at least one dose of SARS-CoV-2 vaccines. Interestingly, our data suggest that COVID-19 vaccination is identified as a protective factor associated with reduced risk of CVA after COVID-19. A recent systematic review and meta-analysis determined that at least one vaccine dose was associated with a protective effect against post-COVID syndrome [38]. Additionally, being female and COVID-19 vaccination have been identified as independent factors associated with persistent cough [28], which is consistent with our findings. Therefore, based on our data and previous studies, COVID-19 vaccination is strongly recommended for general susceptible population to SARS-CoV-2 infection regardless of their risk levels. Pulmonary function tests and FeNO measurements are necessary for the diagnosis and effective treatment of the patients with chronic cough after COVID-19, particularly in females.

There are several limitations in our study. First, it was a retrospective cross-sectional analysis thus intrinsic bias cannot be avoided even though our data was collected from multi centers. Moreover, we mainly focused on the occurrence of CVA among the patients with chronic cough after COVID-19, without analyzing the whole etiological profiles of chronic cough, such as postnasal drip syndrome and gastroesophageal reflux disease. Additionally, the interval from testing positive for SARS-CoV-2 to the time of the current study visit could not be reliably calculated, because the exact dates of positive testing were not systematically recorded in the medical record system and a substantial proportion of participants were unable to recall or confirm the date of their positive test. This limitation prevented us from assessing whether the time elapsed since SARS-CoV-2 infection was associated with the prevalence of CVA or modified the associations observed for other risk factors. Furthermore, detailed vaccination information, including the number of doses and specific vaccine types, was not available in our dataset, which precluded further analysis of potential differential effects by vaccine platform. Finally, we have not obtained follow-up data on the assessment of treatment efficacy yet. It would be interesting to illustrate the etiological profiles of chronic cough after COVID-19 and survey the whole duration of cough and treatment efficacy in future studies.

In conclusion, the patients who develop chronic cough following COVID-19, approximately 30% are newly diagnosed with CVA. Independent risk factors associated with CVA in patients with chronic cough after COVID-19 include being female and having no COVID-19 vaccination history. Further studies are warranted to investigate the mechanisms, effective treatment, and long-term prognosis of post-COVID chronic cough.

Abbreviations

COVID-19	Corona Virus Disease 2019
CVA	cough variant asthma
SARS-CoV-2	severe acute respiratory syndrome coronavirus 2
PEF	peak expiratory flow
FVC	forced vital capacity
FEV1	forced expiratory volume in 1 s
SAD	small airway dysfunction
MMEF	maximal mid-expiratory flow
FEF50%	forced expiratory flow at 50% of forced vital capacity
FEF75%	forced expiratory flow at 75% of forced vital capacity
FeNO	Fractional exhaled nitric oxide
CaNO	concentration of alveolar nitric oxide

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1186/s12890-026-04887-8.

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Author contributions YJ: data acquisition, data analysis, statistical analysis, manuscript preparation and editing. HQQ: data acquisition, data analysis, manuscript preparation and editing. CC: data acquisition, data analysis, manuscript review. QKL: data acquisition, manuscript review. YYL: manuscript review. JJ: conceptualization, statistical analysis, manuscript editing and review.

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Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethical approval and participation consent The study protocol was approved by the Institutional Review Board and Ethics Committee of Xiangya Hospital, Central South University (2024050208), following the Declaration of Helsinki. The ethics committee approved the waiver of informed consent owing to the retrospective nature of the study. All research data were de-identified and anonymously analyzed.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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