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Research article

Asthma control improves in Austrian severe asthma patients

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ABSTRACT

Introduction: The GAN Severe Asthma Registry, founded by German Asthma Net (GAN), is a prospective registry recording clinical parameters. A recent article described the baseline characteristics of severe asthma patients of participating Austrian centers. This article assesses changes in asthma control and lung function in the annual follow-up visits.

Methods: We analyzed all patients included in the GAN Severe Asthma Registry from participating Austrian centers.

Results: Follow-up visit data of years 1 and 2 were available for 130 and 91 patients, respectively. Follow-up visits of years 1 and 2 showed a statistically highly significant ($p < .001$) increase in mean FEV_1 (+265 and + 251 mL) compared to baseline. Both median ACT and ACQ-5 improved well beyond the minimal clinically important difference of 3 points (+4 and + 5, both $p < .001$) and 0,5 points (+1,6 and + 2,2, both $p < .001$), respectively, in follow-up visits years 1 and 2 compared to baseline visit. Relevant improvements in lung function and asthma control were limited to patients receiving monoclonal antibody treatments. Severe asthma monoclonal antibody treatment increased from 60.7% at baseline visit to 71.8% and 73.9% at yearly visits 1 and 2, respectively. Smoking history negatively impacted improvement in asthma control, but not lung function. Presence of a measurable T2 signal at baseline had no impact on changes of either asthma control of lung function.

Conclusions: This study provides the first Austria-wide longitudinal investigation of severe asthma patients. Asthma control and lung function improved well at 1 and 2 years after baseline. We observed an association between this improvement and an increased rate in monoclonal antibody treatments.

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1. Introduction

Patients with severe asthma have higher morbidity, costs and utilized healthcare resources compared to the overall asthma population [1]. While randomized controlled trials are necessary for the development of new treatments and to demonstrate efficacy, they poorly reflect real-life severe asthma patients. Less than 10% of severe asthma patients are eligible for randomized controlled trials [2]. Therefore, registry and real-life data is needed to assess outcomes and treatments in severe asthma patients. There is few clinical follow-up data of large, nationwide severe asthma registries [3,4]. The German Asthma Net (GAN) Severe Asthma Registry prospectively collects clinical parameters at baseline as well as subsequent annual visits from participating centers in Germany and Austria. We recently published the first baseline characterization of Austrian severe asthma patients [5]. The aim of this article is to assess changes in asthma control and lung function in the annual follow-up visits.

2. Methods

2.1. Dataset

We conducted an analysis of all patients from Austrian centers enrolled in the GAN Severe Asthma Registry. To be included in the registry, patients were required to provide written informed consent and have a confirmed diagnosis of severe asthma, as defined by the ERS/ATS criteria [6]. Diagnosis had to be performed by a respiratory specialist. The registry has ethics committee approval (national lead ethics committee: ethics committee of the medical university of Vienna; approval number: 1849/2019; most recent approval date: 2.10.2019), and it is being carried out in adherence to the principles outlined in the Declaration of Helsinki. Patients included in the registry provided written informed consent.

Presence of a measurable T2 Signal was defined as fraction of exhaled nitric oxide $\geq$20 ppb and/or of peripheral blood eosinophilic count $\geq$150 cells/µl.

Remission was defined as an ACT of at least 20, no exacerbations in the preceding 12 months, and no daily oral corticosteroids (OCS), in line with previous publications [7,8].

2.2. Statistical analysis

The data are reported as either mean $\pm$ standard deviation (SD), or median and interquartile ranges (IQR), depending on normality. Shapiro-Wilk test was utilized to assess the normality of the data. Categorical data are presented as numbers and/or percentages. For normally distributed data, a paired two-tailed *t*-test was used to compare baseline and follow-up visits. For non-normally distributed data, Wilcoxon signed-rank test was employed. Differences in mean/median from baseline to follow-up visits were calculated using listwise deletion to ensure comparability. For paired nominal data McNemar's test was used to compare baseline and follow-up visits, as well as follow-up visits between each other. Comparisons to baseline are to the individual's own baseline values rather than group analysis.

Analysis of the effect of measurable T2 signal and smoking status on changes in asthma control and FEV_1 from baseline visit to follow-up visits were performed using two-factor mixed model ANOVA. *P* values of $< .05$ were considered statistically significant. *P* values of $< .001$ were considered statistically highly significant. Statistical analyses were performed using SPSS Version 28 (IBM Corp

Table 1
Patients characteristics at baseline. Values are presented as either percent, mean $\pm$ standard deviation or median (interquartile range), as indicated. ACT, asthma control test; FEV_1, forced expiratory volume in 1 s; mAB, monoclonal antibody; OCS, oral corticosteroid; PBEC, peripheral blood eosinophilic count; FeNO, fraction of exhaled nitric oxide.

Patients (n)	214
Sex, female (%)	47.2
Age at first visit (years)	53.7 $\pm$ 15.4
BMI (kg/m^2)	26.4 $\pm$ 5.4
Age at diagnosis (years)	39 (24-54)
Time from asthma diagnosis until baseline (years)	12 (4-28.5)
Smoking status	
Never smokers (%)	*46.7*
Former smokers (%)	*49.1*
Current smokers (%)	*3.3*
Packyears of former smokers	*17.8 $\pm$ 14.4*
Number of exacerbations in the past 12 month	3 (2-5)
Patients on OCS at baseline (%)	23.4
Any mAB prior to baseline (%)	23.9
ACT (points, median)	17 (11-20.5)
FEV_1 (% predicted, mean)	61.9 $\pm$ 22.0
PBEC (cells/µL)	307 (110-606)
FeNO (ppb)	38.0 (22.0-63.5)
Any comorbid allergic disease (%)	59.8

oration, Armonk, NY).

3. Results

3.1. Baseline characteristics

Baseline visit data were available from 6 centers in Austria for a total of 214 severe asthma patients. Available data were from 2013 to 2022. See Table 1 for a summary of baseline data. A more comprehensive report and analysis of baseline characteristics of Austrian severe asthma patients including comorbidities, comorbid allergic disease, an analysis of skin prick test data, specific Immunglobulin E testing, and detailed description of the baseline medication regimens from the same dataset is available in Renner et al. (2023) [5].

3.2. Longitudinal follow-up

3.2.1. Overall longitudinal follow-up

Longitudinal follow up data were analyzed and reported for the yearly follow-up visits of years 1 and 2. Follow-up visit data of years 1 and 2 were available for 130 and 91 patients, respectively. Further visits were not analyzed due to a sharp decrease in patients. Follow-up visit data of years 3, 4, and 5 were available for 42, 18, and 4 patients, respectively. The decrease in patient numbers at follow-up visits is not due to treatment discontinuation or loss to follow-up but due to continuous enrolment of patients in the registry (see Fig. 1) A comparison of key clinical parameters at baseline between patients with and without available visits year 1 showed no significant differences (see e-Table 1).

All follow-up visits of years 1 and 2 showed an increase in mean FEV_1 (mL) compared to baseline. There is no commonly agreed minimal clinically important difference (MCID) for FEV_1, but all improvements were statistically significant and clinically relevant exceeding even the highest threshold for MCID commonly used for patients with asthma [9] (+265 and + 251 mL, respectively, both $p < .001$; see Fig. 2a and e-Table 2). Also, FEV_1 percent predicted showed persistent improvement after baseline visit in years 1 and 2 (see Fig. 2b and e-Table 2). Both median ACT and ACQ-5 improved well beyond the MCID of 3 points [10] (+4 and + 5, both $p < .001$) and 0,5 [11] points (+1,6 and + 2,2, both $p < .001$), respectively, in all follow-up visits years 1 and 2 compared to baseline visit (see Fig. 2c and d, and e-Table 2). ICS dose did not change between baseline visit and follow-up visits of years 1 and 2. Median daily beclometasone equivalent was 1000 mcg (1000-2000) at baseline, 1000mcg (1000-2000, $p = .622$) at year 1, and 1000mcg (1000-2000, $p = .054$) at year 2.

Analysing only patients who did not receive any monoclonal antibody at baseline visit and visit year 1 there was no change in ACT ($n = 20$; 18.0 [12.0-21.8] at baseline visit and 17.0 [12.3-21.8] at visit year 1; $p = .735$) or FEV_1 in mL ($n = 24$; 2032 ± 807 at baseline visit and 2170 ± 945; $p = .142$) between those visits.

3.2.2. Effect of measurable T2 signal on follow-up

Two-way mixed-method ANOVA was performed to measure the main effect of a measurable T2 signal at baseline on changes in ACT and FEV_1 (in % predicted) from baseline visit to follow up visit year 1. Based on assessments by Levene's test and Box's test, there was homogeneity of the error variances ($p > .05$ for all) and covariances ($p = .346$ for ACT and $p = .413$ for FEV_1), respectively.

There was no statistically significant interaction between changes in ACT from baseline to follow up visit year 1 and presence of measurable T2 signal at baseline, $F(1, 88) = 3.40$, $p = .069$. There was no statistically significant interaction between changes in FEV_1 from baseline to follow up visit year 1 and presence of measurable T2 signal, $F(1, 111) = 1.59$, $p = .210$.

A separate two-way mixed-method ANOVA was performed analysing only patients who had neither monoclonal antibody treatment nor OCS at baseline (n = 34). Also in these patients there was no statistically significant interaction between changes in ACT from baseline to follow up visit year 1 and presence of measurable T2 signal at baseline, $F(1, 26) = 1.62$, $p = .218$. There was no statistically significant interaction between changes in FEV_1 from baseline to follow up visit year 1 and presence of measurable T2 signal in this subset of patients, $F(1, 31) = 1.13$, $p = .336$.

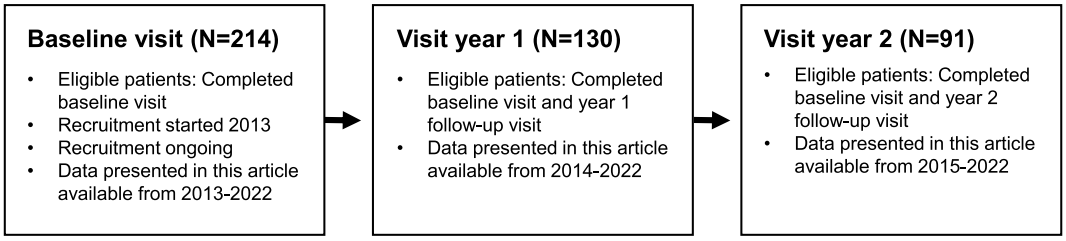


Fig. 1. Flowchart depicting recruitment with continuous enrollment. Only baseline visit, visit year 1 and visit year 2 are depicted in this flowchart as subsequent visits were not analyzed in this article due to low number of patients with completed visits. One patient had only data regarding treatment at year 1 and year 2, but no data on clinical outcome parameters. Therefore, this patient was not analyzed in the main cohort (and is not considered in visit year 1 and visit year 2 in this flowchart) but was included in the analysis of monoclonal antibody treatments. Otherwise, all patients with available visits were analyzed, regardless of missing data.

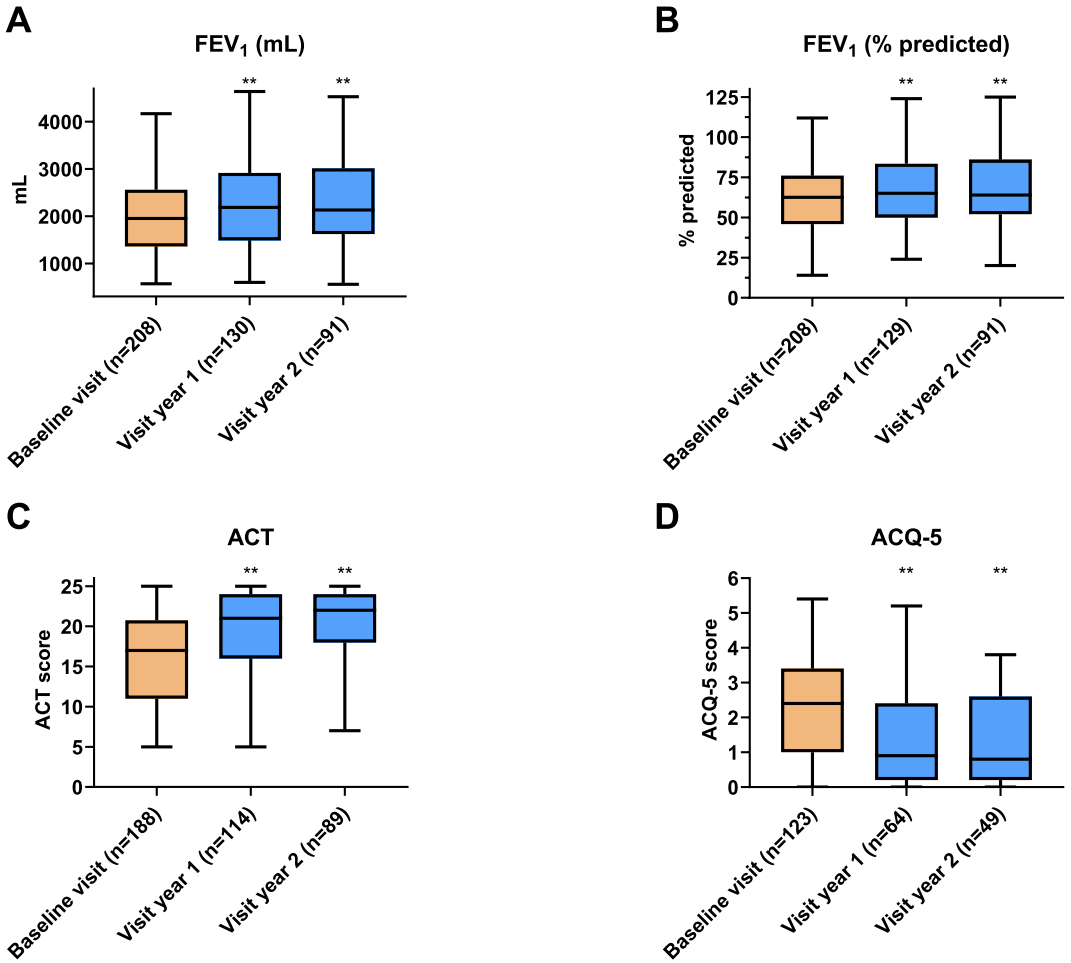


Fig. 2. Box and whiskers plots of a) FEV_1 (mL), b) FEV_1 (% predicted), c) ACT, and d) ACQ-5 at baseline and subsequent yearly visits. Boxes show median and interquartile range, whiskers maximum and minimum. ACT, asthma control test; ACQ-5, asthma control questionnaire 5-item scale; FEV_1, forced expiratory volume in 1 s; * indicates statistical significance of mean differences to baseline at $p < .05$; ** indicates statistical significance of mean differences to baseline at $p < .001$. Statistical significance of the differences between baseline and subsequent yearly visits were calculated using paired two-tailed *t*-test for FEV_1 (a and b) and Wilcoxon signed-rank test for asthma control parameters (c and d). Comparisons to baseline are to the individual's own baseline values rather than group analysis.

Table 2
Patients receiving monoclonal antibodies at the time of the baseline visit and subsequent yearly visits. N = patients with data available on monoclonal antibody treatments for this visit; n = number of patients receiving the monoclonal antibody at this visit.

	Baseline	N = 214	Year 1	N = 131	Year 2	N = 92
	%	n	%	n	%	n
Any severe asthma mAB treatment	60.7	130	71.8	94	73.9	68
Benralizumab	20.1	43	33.6	44	35.9	33
Reslizumab	3.3	7	5.3	7	3.2	3
Mepolizumab	8.9	19	7.6	10	7.6	7
Dupilumab	4.7	10	4.5	6	6.5	6
Omalizumab	23.8	51	20.6	27	20.7	19

3.2.3. Effect of smoking status on follow-up

Two-way mixed-method ANOVA was performed to measure the main effect of smoking status (never-smoker, ex-smoker) on changes in ACT and FEV_1 (in % predicted) from baseline visit to follow up visit year 1. One patient with data for baseline and visit year 1 was a current smoker and was excluded from this analysis. Based on assessments by Levene's test and Box's test, there was homogeneity of the error variances ($p > .05$ for all) and covariances ($p = .355$ for ACT and $p = .215$ for FEV_1), respectively.

There was a statistically significant interaction between changes in ACT from baseline to follow up visit year 1 and smoking status,

$F(1, 98) = 7.16$, $p = .009$. There was a significant main effect for time from baseline to visit year 1, $F(1, 98) = 31.80$, $p < .001$. There was a significant main effect for smoking status, $F(1, 98) = 4.28$, $p = .041$. This means that ACT improvements were greater in never-smokers. In both never-smokers and ex-smokers ACT improved statistically significantly, although in ex-smokers the improvement did not reach the threshold of clinical significance [10]. Median ACT in never-smokers improved from 17 (13.25-20) to 23.5 (19.25-25) $p < .001$, n = 44. Median ACT in ex-smokers improved from 17 (12-21) to 19 (14.25-23) $p = .019$, n = 56 (see also e-table 3).

There was no statistically significant interaction between changes in FEV_1 from baseline to follow up visit year 1 and smoking status, $F(1, 121) = 3.36$, $p = .069$. There was no relevant difference in monoclonal antibody use between the never-smokers and ex-smokers baseline visit or visit year 1.

3.2.4. Changes in monoclonal antibody treatment during follow-up

Use of severe asthma monoclonal antibody treatment increased from 60.7% at baseline visit to 71.8% and 73.9% at yearly visits 1 and 2, respectively. See Table 2 for changes in usage of individual monoclonal antibodies.

The vast majority of patients who received a monoclonal antibody at baseline visit continued with the same treatment through visits year 1 and 2, with the exception of patients receiving reslizumab at baseline. More than half of those patients switched to other biologic treatments, most likely due to the easier administration (s.c. Instead of i.v.). Once biologic treatment was initiated at baseline or later, no patients stopped a biologic without switching to another biologic until the end of data collection. See the online supplementary material for a summary of monoclonal antibody treatment switches.

Probably due to the majority of patients receiving biologic treatment starting from baseline improvements in these patients were comparable to the overall population in both pulmonary function testing (FEV_1 +273 mL, $p < .001$) and asthma control scores (ACT +4.2, $p < .001$; ACQ6 -1.61, $p < .001$).

3.2.5. Remission criteria during follow-up

At baseline visit 20 patients (9.3%) fulfilled the predefined criteria for remission. At visit year 1 41 of 130 (31.5%) and at visit year 2 42 of 91 patients (46.2%) fulfilled these criteria. These increases in remission rate compared to baseline were statistically significant for both year 1 and year 2 (both $p < .001$) as well as the increase in remission rate from year 1 to year 2 ($p = .023$). Of the patients fulfilling the remission criteria 55% (11 patients), 82.5% (34 patients), and 72.2% (32 patients) received a monoclonal antibody at baseline, year 1, and year 2 visit, respectively. Of the 20 patients who fulfilled criteria for remission at baseline visit, follow-up data at visit year 1 was available only for 6 patients, 4 of whom still fulfilled remission criteria at visit year 1. Of the 41 patients who fulfilled criteria for remission at visit year 1, follow-up data at visit year 2 was available for 30 patients. Of these 30 patients, 24 patients (80%) still fulfilled these criteria at visit year 2.

4. Discussion

At baseline only a third of the patients had asthma control classified as well controlled based on GINA criteria. Asthma control, as indicated by ACT and ACQ-5, improved well in the annual follow-up visits years 1 and 2, as did pulmonary function. This may be due to an increase in the usage of monoclonal antibodies from 23.9% prior to baseline, to 60.7% at baseline and 73.9% three years after inclusion. Another possible factor is the optimization of basic asthma treatment through regular check-ups and monitoring at the study centers. This effect is often used to explain clinical improvements in follow-up data of severe asthma registries [3,4] and it has been demonstrated that specialist care improves clinical outcome parameters in severe asthma patients independent of monoclonal antibody treatments [12]. We observed an association between clinical improvement (both in asthma control and pulmonary function) and an increased rate in monoclonal antibody treatments.

4.1. Discussion on the effect of measurable T2 signal on follow-up

There was no effect of presence of a measurable T2 signal at baseline on changes in asthma control or FEV_1 from baseline to visit year 1. As in the publication of the baseline data of our cohort [5], also these results provide indirect evidence to the paradigm that asthma patients should not be divided into patients with and without a T2 signal but that there are patients in whom a T2 signal has not yet successfully been identified. Known factors influencing T2 signal are OCS and mAB use but a separate analysis of patients receiving neither of the two showed no effect of presence of measurable T2 signal at baseline on changes in ACT or FEV_1.

4.2. Discussion on the effect of smoking status on follow-up

There was a statistically significant interaction of smoking status and changes in asthma control from baseline to visit year 1. While both never-smokers and ex-smokers showed a statistically significant improvement in asthma control from baseline to visit year 1 only never-smokers exceeded the threshold of minimal clinical significance [10]. There was no relevant difference in monoclonal antibody use between these groups that could explain this interaction. These results contrast results from previous German real-life studies of severe asthma patients treated with biologics [13,14]. In these studies, response to biologic treatment was independent of smoking status [13,14].

4.3. Discussion on changes in remission status

In the last years the concept of remission in severe asthma, especially as a result of monoclonal antibody use, has gained popularity [7,15–19]. In our study patients were classified as having remission based on the criteria of good asthma control (ACT of at least 20), no exacerbations in the previous 12 months and no maintenance OCS. Improvement in lung function was not included in our criteria as there is not yet a commonly agreed minimally clinically significant difference. Based on our predefined criteria patients with remission increased from 9.3% at baseline to 31.5% at visit year 1 and 46.2% at visit year 2. These improvements are most probably due to the increased rate in monoclonal antibody use, analogous to the improvements in asthma controls and lung function, as mentioned above. Notably, 20% of the patients classified as remission at visit year 1, for whom data at visit year 2 was available, did not fulfill the criteria for remission at visit year 2. This means that either a) the clinical state of remission, at least with the current criteria, is not as stable as the name implies to be, which would not be surprising in a disease with an often variable, and poorly understood, natural course [20] b) a waning of mAB efficacy over time in some patients c) ACT measuring asthma control in the previous month is perhaps not the best criterion defining a more longer-term concept such as remission or d) a combination of all of the above. Regarding c) it should be noted that ACT, measuring asthma control in the previous month, is superior compared to ACQ-5/6, which measure asthma control in the previous week. The latter was used in the post-hoc analysis of the SIROCCO, CALIMA, and ZONDA trials investigating remission under benralizumab treatment [21–23].A recent study analyzing data from both the American SARP III cohort and the European U-BIOPRED cohort found that asthma severity does not correlate well with exacerbations, asthma control and patient reported symptom burden [24]. The authors introduced a new composite burden score which might better predict remission in severe asthma [24]. New patient reported indicators of asthma control and asthma severity, like the new composite burden score, have the potential to better define and predict remission.

4.4. Limitations, strengths, and novelty

There are two main limitations of this study. 1) While a majority of centers and clinics treating patients with severe asthma in Austria are part of the GAN registry, this data does not account for patients with severe asthma who were never referred to a specialized center for evaluation. 2) Inherent to the study design there is no control group.

Furthermore, information on medication adherence and inhaler technique accuracy are not available.

The main strength of this study is the high quality of data collection. There are few missing data, and every patient is prospectively evaluated at every visit by a severe asthma expert and investigator of the GAN registry. This means that the data is potentially more precise than in registries derived from insurance claims data or electronic health records. The novelty of this study is that it provides high quality follow-up data from a reasonably large number of patients with severe asthma living in a socioeconomically relatively homogenous country with the same health care system, same insurance system, and same reimbursement criteria.

4.5. Conclusion

This study provides the first Austria-wide longitudinal investigation of severe asthma patients. At the time of inclusion in the GAN Severe Asthma Registry asthma control was unsatisfactory in a majority of the patients. Asthma control improved well, possibly due to an increased use in monoclonal antibodies.

CRediT authorship contribution statement

Andreas Renner: Writing – original draft, Visualization, Formal analysis, Data curation, Conceptualization. **Slagjana Stoshikj:** Writing – review & editing, Investigation. **Wolgang Pohl:** Writing – review & editing, Investigation. **Christina Bal:** Writing – review & editing, Investigation. **Judith Löffler-Ragg:** Writing – review & editing, Investigation. **Matthias Reisinger:** Writing – review & editing, Investigation. **Roland Buhl:** Writing – review & editing, Conceptualization. **Eckard Hamelmann:** Writing – review & editing, Conceptualization. **Christian Taube:** Writing – review & editing, Conceptualization. **Stephanie Korn:** Writing – review & editing, Conceptualization. **Marco Idzko:** Writing – review & editing, Supervision, Investigation, Conceptualization.

Ethics declaration

This study was reviewed and approved by the Ethics Committee of the Medical University of Vienna with the approval number: 1849/2019, dated 02.10.2019. All patients (or their proxies/legal guardians) provided written informed consent to participate in the study and for their data to be published.

Data availability statement

The data supporting the findings of this study are not publicly available. Patient data were collected as part of a prospective registry and pseudonymized; at the time of inclusion, participants did not provide informed consent for data sharing (including raw data or analysis code). Retroactive amendments to the consent process or attempts to re-consent already enrolled participants would fundamentally alter the prospective nature of the registry, compromising the integrity of the dataset. Data may be available from the corresponding author upon reasonable request, subject to institutional review board approval and applicable data protection

regulations.

Related publications disclosure

This article builds on previously published work [5]. The previously published article analyzed and presented baseline characteristics from the same cohort [5]. No text directly overlaps. No figures overlap. The content of Table 1 in this article overlaps with content of the previous article [5]. It is mentioned in the results section that a detailed description of the baseline characteristics from the same dataset is available in Renner et al. (2023) [5]. The abbreviated presentation of overlapping baseline characteristics is intended to provide the contextual framework necessary for interpreting the follow-up findings. All results beyond the abbreviated description of the baseline characteristics are novel and have not been published elsewhere.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Slagjana Stoshikj, Wolfgang Pohl, Christina Bal, Roland Buhl, Stefanie Korn reports a relationship with AstraZeneca Pharmaceuticals LP that includes: speaking and lecture fees. Marco Idzko reports a relationship with AstraZeneca Pharmaceuticals LP that includes: consulting or advisory and speaking and lecture fees. Wolfgang Pohl reports a relationship with Chiesi Pharmaceuticals Inc that includes: speaking and lecture fees. Marco Idzko reports a relationship with Chiesi Pharmaceuticals Inc that includes: consulting or advisory and speaking and lecture fees. Wolfgang Pohl, Stephanie Korn, Roland Buhl reports a relationship with GSK that includes: consulting or advisory. Marco Idzko reports a relationship with GSK that includes: consulting or advisory and speaking and lecture fees. Wolfgang Pohl, Roland Buhl, Stephanie Korn reports a relationship with Novartis that includes: speaking and lecture fees. Marco Idzko reports a relationship with Novartis that includes: consulting or advisory and speaking and lecture fees. Wolfgang Pohl, Roland Buhl, Stephanie Korn reports a relationship with Sanofi that includes: speaking and lecture fees. Marco Idzko reports a relationship with Sanofi that includes: consulting or advisory and speaking and lecture fees. Roland Buhl, Marco Idzko reports a relationship with Roche that includes: speaking and lecture fees. Roland Buhl reports a relationship with Cipla Inc that includes: speaking and lecture fees. Roland Buhl reports a relationship with Teva Respiratory LLC that includes: speaking and lecture fees. Marco Idzko reports a relationship with Bayer Pharma AG that includes: speaking and lecture fees. Marco Idzko reports a relationship with Berlin-Chemie AG that includes: consulting or advisory and speaking and lecture fees. Marco Idzko reports a relationship with Boehringer Ingelheim GmbH that includes: consulting or advisory and speaking and lecture fees. Marco Idzko reports a relationship with CSL Behring LLC that includes: consulting or advisory and speaking and lecture fees. Marco Idzko reports a relationship with A Menarini International Pharmaceutics that includes: consulting or advisory. Marco Idzko reports a relationship with Merck Sharp & Dohme Corp that includes: speaking and lecture fees. Marco Idzko reports a relationship with Thermo Fisher Scientific Inc that includes: speaking and lecture fees. Marco Idzko reports a relationship with Alkeus Pharmaceuticals Inc that includes: consulting or advisory. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2026.e45695.

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