Complete response to anti-interleukin-5 biologics in a real-life setting: results from the nationwide Danish Severe Asthma Register

Marianne Baastrup Soendergaard 1, Susanne Hansen 1,2, Anne-Sofie Bjerrum3, Ole Hilberg4, Sofie Lock-Johansson5, Kjell Erik Julius Håkansson6, Truls Sylvan Ingebrigtsen7, Claus Rikard Johnsen8, Linda Makowska Rasmussen8, Anna von Bülow1, Karin Dahl Assing9, Johannes Martin Schmid3, Charlotte Suppli Ulrik 6 and Celeste Porsbjerg1,10

1Dept of Respiratory Medicine, Copenhagen University Hospital – Bispebjerg, Copenhagen, Denmark. 2Centre for Clinical Research and Prevention, Frederiksberg Hospital, Copenhagen, Denmark. 3Dept of Respiratory Diseases and Allergy, Aarhus University Hospital, Aarhus, Denmark. 4Sygehus Lillebalt – Vejle Sygehus, Vejle, Denmark. 5Dept of Respiratory Medicine, Odense University Hospital, Odense, Denmark. 6Dept of Respiratory Medicine, Copenhagen University Hospital – Hvidovre, Hvidovre, Denmark. 7Dept of Respiratory Medicine, Gentofte University Hospital, Hellerup, Denmark. 8Allergy Clinic, Gentofte University Hospital, Hellerup, Denmark. 9Dept of Respiratory Medicine, Aalborg University Hospital, Aalborg, Denmark. 10Institute of Clinical Medicine, University of Copenhagen, Copenhagen, Denmark.

Corresponding author: Marianne Baastrup Soendergaard (marianne.bastrup.soendergaard@regionh.dk)

Shareable abstract (@ERSpublications)
More than half of all Danish patients with severe asthma receiving anti-IL-5 in a real-life setting achieve a complete response to treatment, i.e. they become free from exacerbations and the need for oral corticosteroids https://bit.ly/3zMMB75

Cite this article as: Soendergaard MB, Hansen S, Bjerrum A-S, et al. Complete response to anti-interleukin-5 biologics in a real-life setting: results from the nationwide Danish Severe Asthma Register. ERJ Open Res 2022; 8: 00238-2022 [DOI: 10.1183/23120541.00238-2022].

Abstract

Background Phase III regulatory trials show that anti-interleukin (IL)-5 biologics efficiently reduce exacerbations and the use of maintenance oral corticosteroids (mOCS) in patients with severe eosinophilic asthma. However, patients eligible for these trials differ significantly compared with real-life severe asthma populations. Therefore, our aim was to explore efficacy in a real-life setting. The Danish Severe Asthma Register (DSAR) is a complete, nationwide register that comprises all Danish patients on biological therapy for severe asthma.

Methods This prospective study identified patients in the DSAR who were complete responders to anti-IL-5 biologics after 1 year of treatment. A complete response was defined as resolution of the parameter setting the indication, i.e. recurrent exacerbations and/or use of mOCS.

Results A total of 289 out of 502 (58%) patients were complete responders to anti-IL-5 biologics after 12 months. Complete responders had greater improvements in forced expiratory volume in 1 s and Asthma Control Questionnaire (ACQ) score compared with noncomplete responders (Δ 210 versus 30 mL; p<0.0001 and Δ −1.04 versus −0.68; p=0.016, respectively). A complete response was predicted by age at onset, less severe disease at baseline (i.e. no mOCS and lower ACQ score) and higher blood eosinophils.

Conclusions More than half of Danish patients treated with anti-IL-5 biologics for severe asthma achieve a complete response to treatment, thereby becoming free from asthma exacerbations and the need for mOCS. Complete responders also achieved superior effects on lung function and symptoms compared with noncomplete responders.

Introduction

Most asthma patients have mild-to-moderate disease that remains under control on low- or medium-dose inhaled corticosteroids (ICS) with or without a second controller. However, some patients have severe disease that requires both high-dose ICS and a second controller. It is estimated that 4–8% of asthma patients have severe asthma [1, 2]. These patients have a higher burden of symptoms and exacerbations,
and uncontrolled severe asthma is associated with higher healthcare costs and more frequent admissions to hospital, compared with patients with mild or moderate disease [3].

Severe asthmatic subjects with an eosinophilic phenotype are potentially candidates for treatment with anti-interleukin (IL)-5 biologics. Currently, three anti-IL-5 biologics, targeting IL-5 or its receptor, are marketed: mepolizumab, reslizumab and benralizumab. Phase III randomised controlled trials (RCTs) show that anti-IL-5 biologics efficiently reduce exacerbation rates [4–8] and the need for maintenance oral corticosteroids (mOCS) [9–11] compared with placebo. However, it is unclear if these results can be transferred to real-life patients with severe asthma. Patients included in regulatory trials are subjected to strict inclusion and exclusion criteria, and can often differ significantly from real-life patients in terms of baseline characteristics such as age, comorbidities, lung function and smoking status [12, 13]. Because of this potentially significant discrepancy, the effects of anti-IL-5 biologics should be evaluated in a real-life setting.

Data from real-life patients suggest that anti-IL-5 biologics have a similar or even superior effect to that shown in RCTs; however, these observations are mostly based on fairly small and selected populations [14–26]. Real-life experience of anti-IL-5 biologics has brought the recognition that some patients have a much better response to therapy compared with others and the term “super-responder” has emerged. There is at present no international consensus on what constitutes a “super-responder” to biological therapy in severe asthma [27], but the term has been used in several papers with varying criteria, including, but not limited to, exacerbation rate, symptom control and lung function [28–31].

In the present study, we aimed to describe the proportion of patients with severe eosinophilic asthma having received anti-IL-5 treatment for at least 12 months, who obtained a complete response in a representative nationwide cohort. A complete response was defined as a complete resolution of the clinical problems that set the indication for treatment, i.e. exacerbations and/or use of mOCS.

We utilised data from the Danish Severe Asthma Register (DSAR), consisting of all Danish patients treated with biologics for severe asthma, and assessed the proportion of patients with a complete response after 12 months of treatment, together with the effect on other clinical outcomes and biomarkers, as well as baseline predictors of a complete response.

**Methods**

**Study participants**

The DSAR was established in 2017 and comprises all Danish patients receiving biological treatment (anti-IgE, anti-IL-5 and anti-IL-4/13) for severe asthma [32]. In the present study, we analysed data for all patients with available data after 12 months of anti-IL-5 therapy, to evaluate the effectiveness of anti-IL-5 biologics after the first 12 months of treatment, and identified predictors of a complete response. Only patients who completed 1 year of treatment are included in this article.

Informed consent was collected electronically along with patient-reported outcomes (PROs).

The DSAR has been approved by the Capital Region of Denmark (VD-2018-31) and all patients provide informed consent that their data can be used for research purposes.

**Indication for biologics in the DSAR**

In Denmark, the decision to start an asthma patient on biological therapy is made by an asthma specialist. Initiation of biological treatment should be preceded by a systematic assessment to differentiate severe asthma from difficult-to-treat asthma [33]. According to the Danish Medicines Council, anti-IL-5 therapy is indicated for patients with severe asthma with lack of disease control together with evidence of eosinophilic inflammation. Lack of disease control is defined as an annual rate of exacerbations, requiring rescue OCS, of ≥2 or a need for daily OCS >50% of the time. Efficacy of anti-IL-5 therapy is initially assessed by an asthma specialist after 4 months of treatment and again after 12 months. If the treatment is not efficacious or well tolerated, it is stopped.

**Measurements**

In the DSAR, information is collected prospectively and according to a set protocol, with all patients being evaluated thoroughly at baseline prior to commencing biological treatment. Subsequently, information is collected prospectively at 4 and 12 months after initiation of treatment. Information about lung function, exacerbations, medications, comorbidities, PROs and inflammatory markers before initiation of biological treatment was used to identify predictors of complete responders, and information at 12-month follow-up
was used to evaluate the treatment efficacy. The use of mOCS is registered in the DSAR; however, the precise indication (e.g. asthma control or adrenal insufficiency) is not.

**Definition of a complete response**

In this study, we defined a complete response to anti-IL-5 biologics as no rescue courses of OCS for exacerbations and no use of mOCS after 12 months of treatment. These outcomes are shown to be significantly improved by anti-IL-5 biologics in several RCTs and therefore are key elements of the clinical indication for initiation of anti-IL-5: indications include either recurrent exacerbations or regular use of mOCS [34], as opposed to a high symptom score or impaired lung function which in themselves do not suffice to qualify the patient for anti-IL-5 treatment. Therefore, a complete response to treatment was defined as a resolution of the clinical parameter setting the indication, *i.e.* recurrent exacerbations and/or use of mOCS.

**Statistical analyses**

To assess the proportion of responders and their characteristics, patients were categorised into complete responder and noncomplete responder groups using the aforementioned definitions. Baseline patient characteristics of the two responder groups were compared using descriptive statistics: the Chi-squared test or Fisher’s exact test where applicable for categorical variables, and the t-test and Mann–Whitney U-test for normally distributed and skewed continuous variables, respectively. To evaluate effectiveness of anti-IL-5 biologics on specific outcomes, within-group changes were evaluated by the paired t-test and signed-rank test for normally and nonnormally distributed continuous variables, respectively, whereas categorical variables were compared using McNemar’s test.

To describe potential predictors of complete response to anti-IL-5 and adjust for potential confounders, patient characteristics with a p-value <0.20 in univariate analyses were furthermore tested in multivariate logistic regression models, adjusting for age and sex, with response status (complete versus noncomplete) as the dichotomous outcome.

p-values were two-sided with a threshold of p<0.05 to denote statistical significance. All analyses were performed using SAS Enterprise Guide 7.1 (SAS Institute, Cary, NC, USA).

**Results**

We identified 502 patients who had completed at least 1 year of anti-IL-5 treatment, and for whom information about exacerbations and use of mOCS was available (figure 1 and table 1). Of these, 289 patients (58%) were classified as complete responders with no exacerbations and no use of mOCS after the first year of treatment, and 213 patients (42%) were noncomplete responders, with either use of mOCS and/or exacerbations requiring rescue courses of OCS after the first year of treatment (figure 2). Of the 213 noncomplete responders, 123 (58%) did not fulfil the definition for complete response due to still being on mOCS, while the remaining 90 (42%) still had exacerbations after 12 months of treatment.

**Danish Severe Asthma Register**

1055 patients on biologics

658 patients on anti-IL-5

557 patients on anti-IL-5 ≥12 months

502 patients with data on exacerbations and OCS use at 1-year follow-up

101 patients discontinued anti-IL-5 before 12 months:
16% side-effects
46% lack of efficacy
38% unknown reason

**FIGURE 1** Flowchart of patients from the Danish Severe Asthma Register categorised as complete responders and noncomplete responders. IL: interleukin; OCS: oral corticosteroids.
Overall, we saw a significant reduction of 80% in exacerbations and the proportion of patients on mOCS was reduced from 37% at baseline to 25% at 1 year (p<0.0001) (table 2). Asthma Control Questionnaire (ACQ) score was also significantly reduced, from 2.49±1.31 to 1.61±1.21 (p<0.0001) at follow-up, with the reduction reaching the minimal clinically important difference of 0.5 [35]. After 1 year of treatment, 55% of patients had well-controlled asthma (ACQ ⩽1.5) versus only 28% at baseline (p<0.0001).

**TABLE 1** Patient characteristics at baseline

|                          | n   | Baseline          |
|--------------------------|-----|-------------------|
| Age, years               | 502 | 57±12             |
| Female                   | 502 | 244 (47)          |
| BMI, kg·m⁻²              | 498 | 27.8±6.6          |
| Duration of disease, years | 308 | 22±18             |
| Duration of disease >10 years | 308 | 194 (63)          |
| Age at onset, years      | 308 | 35±21             |
| Onset during childhood ≤18 years | 321 | 93 (29)           |
| Late onset ≥40 years     | 321 | 144 (45)          |
| Exacerbations in year before biologic, n | 391 | 3.08±3.1         |
| Budesonide-equivalent dose, μg | 350 | 1600 (1600–1600) |
| mOCS                     | 502 | 187 (37)          |
| Median dose, mg          | 137 | 10 (5–15)         |
| Biologic                 | 502 |                   |
| Mepolizumab              | 355 | 355 (71)          |
| Reslizumab               | 26  | 26 (5)            |
| Benralizumab             | 121 | 121 (24)          |
| Switchers                | 502 | 129 (26)          |
| FEV₁, L                  | 436 | 2.23±0.85         |
| FEV₁, % pred             | 432 | 69±21             |
| FEV₁/FVC                 | 421 | 0.65±0.13         |
| ACQ score                | 312 | 2.48±1.29         |
| Blood eosinophils, ×10⁹ L⁻¹ | 415 | 0.32 (0.12–0.6)  |
| Blood eosinophils ≥0.3×10⁹ L⁻¹ | 415 | 227 (55)          |
| IgE, IU·mL⁻¹             | 258 | 128 (55–350)      |
| IgE >150 IU·mL⁻¹         | 258 | 119 (46)          |
| FENO ppb                 | 353 | 32 (17–64)        |
| Smoking status           | 486 |                   |
| Never-smoker             | 252 | 252 (52)          |
| Ex-smoker                | 225 | 225 (46)          |
| Current smoker           | 9   | 9 (2)             |
| Pack-years               | 292 | 17.7±13.8         |
| Allergic rhinitis        | 480 | 214 (46)          |
| Atopic dermatitis        | 476 | 63 (13)           |
| Chronic rhinosinusitis   | 474 | 275 (58)          |
| Nasal polyps             | 478 | 208 (44)          |
| Aspirin sensitivity      | 475 | 39 (8)            |
| Bronchiectasis           | 478 | 99 (21)           |
| Vocal cord dysfunction   | 471 | 10 (2)            |
| ABPA                     | 475 | 14 (3)            |
| EGPA                     | 473 | 20 (6)            |
| Dysfunctional breathing  | 474 | 27 (6)            |
| COPD                     | 470 | 116 (25)          |
| GORD                     | 474 | 146 (31)          |
| Cardiovascular disease   | 475 | 149 (31)          |
| Diabetes                 | 477 | 55 (12)           |
| OSA                      | 475 | 55 (12)           |

Data are presented as mean±SD, n (%) or median (interquartile range), unless otherwise stated. BMI: body mass index; mOCS: maintenance oral corticosteroids; FEV₁: forced expiratory volume in 1 s; FVC: forced vital capacity; ACQ: Asthma Control Questionnaire; FENO: exhaled nitric oxide fraction; ABPA: allergic bronchopulmonary aspergillosis; EGPA: eosinophilic granulomatosis with polyangiitis; COPD: chronic obstructive pulmonary disease; GORD: gastro-oesophageal reflux disease; OSA: obstructive sleep apnoea.

**Effects of anti-IL-5 in the entire population**

Effects of anti-IL-5 in the entire population

Overall, we saw a significant reduction of 80% in exacerbations and the proportion of patients on mOCS was reduced from 37% at baseline to 25% at 1 year (p<0.0001) (table 2). Asthma Control Questionnaire (ACQ) score was also significantly reduced, from 2.49±1.31 to 1.61±1.21 (p=0.0001) at follow-up, with the reduction reaching the minimal clinically important difference of 0.5 [35]. After 1 year of treatment, 55% of patients had well-controlled asthma (ACQ ⩽1.5) versus only 28% at baseline (p<0.0001).
Overall, FEV\textsubscript{1} significantly improved, from a mean±SD of 2.25±0.8 L and 69% predicted at baseline to 2.37±0.88 L and 74% predicted at 12-month follow-up (p<0.0001).

**Difference in baseline characteristics between complete responders and noncomplete responders**

Complete responders and noncomplete responders were similar in age, body mass index and lung function at baseline (table 3). Fewer women were complete responders (45% versus 54% female noncomplete responders; p=0.038). Complete responders had fewer exacerbations prior to initiation of biologics (2.8 versus 3.43; p=0.049) and a smaller proportion were on mOCS at baseline (18% versus 63%; p<0.0001). Complete responders were generally older at asthma onset (38 versus 32 years; p=0.02) and a larger proportion had late onset >40 years (48% versus 40%; p=0.13). Moreover, complete responders also had shorter duration of disease (20 versus 24 years; p=0.04).

Allergic rhinitis, chronic rhinosinusitis and aspirin sensitivity tended to be more prevalent among complete responders, whereas diabetes and obstructive sleep apnoea were more prevalent among noncomplete responders. However, there were no statistically significant differences in comorbidities between the two groups.

Inflammatory markers were similar in complete responders and noncomplete responders with respect to baseline exhaled nitric oxide fraction (F\textsubscript{ENO}) and IgE, whereas complete responders had higher blood eosinophils at baseline (0.40 versus 0.23×10\textsuperscript{9} L\textsuperscript{−1}; p=0.0002).

| TABLE 2 Outcomes after 1 year of treatment with anti-interleukin-5 biologics for severe asthma |
| n | Baseline | n | 1 year | p-value |
|---|---|---|---|---|
| Clinical outcomes | | | | |
| Exacerbations in previous 12 months, n | 391 | 3.08±3.1 | 391 | 0.62±1.27 | <0.0001 |
| mOCS | 502 | 187 (37) | 502 | 123 (25) | <0.0001 |
| Median dose, mg | 63 | 10 (7.5–15) | 63 | 7.5 (5–10) | <0.0001 |
| Budesonide-equivalent dose, µg | 297 | 1600 (1600–2000) | 297 | 1600 (1200–1600) | <0.0001 |
| FEV\textsubscript{1}, L | 365 | 2.25±0.85 | 365 | 2.37±0.88 | <0.0001 |
| FEV\textsubscript{1}, % pred | 362 | 69±21 | 362 | 74±21 | <0.0001 |
| FEV\textsubscript{1}/FVC | 347 | 0.65±0.13 | 347 | 0.66±0.12 | <0.0001 |
| FEV\textsubscript{1} >80% | 362 | 110 (30) | 362 | 140 (39) | <0.0001 |
| ACQ score | 242 | 2.49±1.31 | 242 | 1.61±1.21 | <0.0001 |
| ACQ ≤1.5 | 242 | 67 (28) | 242 | 132 (55) | <0.0001 |
| Biomarkers | | | | |
| Blood eosinophils, ×10\textsuperscript{9} L\textsuperscript{−1} | 280 | 0.31 (0.12–0.60) | 282 | 0.06 (0.02–0.10) | <0.0001 |
| F\textsubscript{ENO}, ppb | 280 | 35 (18–65) | 280 | 30 (16–59) | <0.0001 |

Data are presented as mean±SD, n (%) or median (interquartile range), unless otherwise stated. mOCS: maintenance oral corticosteroids; FEV\textsubscript{1}: forced expiratory volume in 1 s; FVC: forced vital capacity; ACQ: Asthma Control Questionnaire; F\textsubscript{ENO}: exhaled nitric oxide fraction. Only patients with paired data at baseline and 12 months are included.
Type of anti-IL-5 biologic did not differ significantly between the two groups ($p=0.125$). In the complete responder group 72%, 25% and 3% were on mepolizumab, benralizumab and reslizumab, respectively, whereas among noncomplete responders the distribution was 69%, 23% and 8%, respectively. There was also a similar proportion of switchers in the two groups (23% versus 29%; $p=0.08$). Smoking status and

| TABLE 3 | Complete responder versus noncomplete responder characteristics at baseline |
|---------|--------------------------------------------------------------------------------|
| n       | Complete responders (n=289) | Noncomplete responders (n=213) | p-value |
| Age, years | 289 58±12 | 213 56±13 | 0.12 |
| Female | 289 129 (45) | 213 115 (54) | 0.038 |
| BMI, kg·m$^{-2}$ | 287 28±5 | 211 28±6 | 0.28 |
| Duration of disease, years | 179 20±17 | 129 24±19 | 0.04 |
| Duration of disease >10 years | 179 107 (60) | 129 87 (67) | 0.169 |
| Age at onset, years | 179 38±20 | 129 32±21 | 0.02 |
| Onset during childhood ≤18 years | 186 46 (25) | 135 47 (35) | 0.131 |
| Late onset >40 years | 186 90 (48) | 135 54 (40) | 0.131 |
| Exacerbations in year before biologic, n | 219 2.80±2.61 | 172 3.43±3.61 | 0.049 |
| Budenside-equivalent dose, µg | 213 1600 (1200–1600) | 155 1600 (1600–2000) | 0.23 |
| mOCS | 289 52 (18) | 213 134 (63) | <0.0001 |
| Median dose, mg | 46 7.5 (5–10) | 91 10 (7.5–15) | 0.03 |
| Biologic | 289 | 213 | 0.125 |
| Mepolizumab | 207 (72) | 148 (69) |
| Reslizumab | 10 (3) | 16 (8) |
| Benralizumab | 72 (25) | 49 (23) |
| Switchers | 289 66 (23) | 213 63 (29) | 0.08 |
| FEV,$_1$, L | 248 2.26±0.65 | 188 2.18±0.83 | 0.31 |
| FEV,$_1$, % pred | 246 70±21 | 186 68±21 | 0.41 |
| FEV,$_1$/FVC | 237 0.64±0.13 | 184 0.65±0.13 | 0.70 |
| ACQ score | 168 2.32±1.32 | 144 2.67±1.24 | 0.01 |
| Blood eosinophils, ×10$^9$ L$^{-1}$ | 234 0.40 (0.18–0.65) | 181 0.23 (0.1–0.54) | 0.0002 |
| Blood eosinophils ≥0.3×10$^9$ L$^{-1}$ | 234 146 (62) | 181 81 (45) | 0.0003 |
| IgE, IU·mL$^{-1}$ | 146 141 (66–399) | 112 70 (54–83) | 0.09 |
| IgE ≥150 IU·mL$^{-1}$ | 146 71 (49) | 112 48 (43) | 0.35 |
| $F_{ENO}$, ppb | 201 32 (18–64) | 151 32 (14–63) | 0.65 |
| Smoking status | 281 | 205 | 0.62 |
| Never-smoker | 151 (54) | 101 (49) |
| Ex-smoker | 125 (44) | 100 (49) |
| Current smoker | 5 (2) | 4 (2) |
| Pack-years | 15.9±13 | 17.7±14.4 | 0.33 |
| Allergic rhinitis | 277 132 (48) | 203 82 (41) | 0.11 |
| Atopic dermatitis | 274 37 (14) | 202 26 (13) | 0.84 |
| Chronic rhinosinusitis | 273 166 (61) | 201 109 (54) | 0.15 |
| Nasal polyps | 276 122 (44) | 202 86 (43) | 0.72 |
| Aspirin sensitivity | 274 27 (10) | 201 12 (6) | 0.13 |
| Bronchiectasis | 276 53 (19) | 202 46 (23) | 0.34 |
| Vocal cord dysfunction | 272 5 (2) | 199 5 (3) | 0.61 |
| ABPA | 275 9 (3) | 200 5 (3) | 0.62 |
| EGPA | 273 11 (4) | 200 9 (5) | 0.80 |
| Dysfunctional breathing | 273 17 (6) | 201 10 (5) | 0.56 |
| COPD | 270 61 (23) | 200 55 (28) | 0.22 |
| GORD | 272 83 (31) | 202 63 (31) | 0.87 |
| Cardiovascular disease | 274 82 (30) | 201 67 (33) | 0.42 |
| Diabetes | 275 25 (9) | 202 30 (15) | 0.05 |
| OSA | 273 26 (10) | 202 29 (14) | 0.10 |

Data are presented as mean±SD, n (%) or median (interquartile range), unless otherwise stated. BMI: body mass index; mOCS: maintenance oral corticosteroids; FEV,$_1$: forced expiratory volume in 1 s; FVC: forced vital capacity; ACQ: Asthma Control Questionnaire; $F_{ENO}$: exhaled nitric oxide fraction; ABPA: allergic bronchopulmonary aspergillosis; EGPA: eosinophilic granulomatosis with polyangiitis; COPD: chronic obstructive pulmonary disease; GORD: gastro-oesophageal reflux disease; OSA: obstructive sleep apnoea.
TABLE 4: Outcomes for complete versus noncomplete responders after 1 year of treatment with anti-interleukin-5 biologics

| Clinical outcomes | Complete responders | Noncomplete responders | Δ complete versus Δ noncomplete responders p-value |
|-------------------|---------------------|------------------------|-----------------------------------------------|
| Exacerbations in previous 12 months, n | 2.80±2.61 | 3.43±3.61 | 0.008 |
| At baseline | 0 | 1.48±1.71 | <0.0001 |
| p-value | <0.0001 | <0.0001 | |
| mOCS | 53 (18) | 134 (63) | <0.0001 |
| At baseline | 0 | 123 (58) | 0.0009 |
| p-value | <0.0001 | 0.0009 | |
| Budesonide-equivalent dose, µg | 1600 (1200–1600) | 1600 (1600–2000) | 0.0006 |
| At baseline | 1600 (800–1600) | 1600 (1600–2000) | |
| p-value | 0.002 | 0.17 | |
| FEV₁, L | 2.26±0.85 | 2.18±0.83 | <0.0001 |
| At baseline | 2.47±0.87 | 2.21±0.85 | |
| Δ from baseline | 0.21 | 0.03 | |
| p-value | <0.0001 | 0.63 | |
| FEV₁ % pred | 70±21 | 68±21 | <0.0001 |
| At baseline | 76±20 | 70±22 | |
| Δ from baseline | 6 | 2 | |
| p-value | <0.0001 | 0.20 | |
| FEV₁/FVC | 0.64±0.13 | 0.65±0.13 | 0.014 |
| At baseline | 0.67±0.10 | 0.65±0.13 | |
| p-value | <0.0001 | 0.69 | |
| ACQ score | 2.32±1.32 | 2.67±1.24 | 0.016 |
| At baseline | 1.28±1.11 | 1.99±1.26 | |
| Δ from baseline | −1.04 | −0.68 | |
| p-value | <0.0001 | <0.0001 | |
| ACQ ≤1.5 | 33 | 21 | <0.0001 |
| At baseline | 44 | 31 | |
| p-value | <0.0001 | 1.00 | |
| Blood eosinophils, ×10⁹ L⁻¹ | 0.40 (0.18–0.65) | 0.23 (0.1–0.54) | <0.0001 |
| At baseline | 0.06 (0.02–0.10) | 0.06 (0.02–0.10) | |
| p-value | <0.0001 | <0.0001 | |
| FENO, ppb | 32 (18–64) | 32 (14–63) | 0.71 |
| At baseline | 29 (16–54) | 30 (16–60) | |
| p-value | 0.04 | 0.14 | |

Data are presented as mean±sd, n (%), % or median (interquartile range), unless otherwise stated. mOCS: maintenance oral corticosteroids; FEV₁: forced expiratory volume in 1 s; FVC: forced vital capacity; ACQ: Asthma Control Questionnaire; FENO: exhaled nitric oxide fraction.

https://doi.org/10.1183/23120541.00238-2022
accumulated lifetime tobacco exposure in ever-smokers did not differ between complete responders and noncomplete responders.

**Differences in outcomes between complete responders and noncomplete responders**

Outcomes other than those that defined a complete response varied significantly between complete responders and noncomplete responders (table 4). Complete responders had better outcomes with regard to lung function, with FEV1 2.47 L (76% predicted) versus 2.21 L (70% predicted) for noncomplete responders (p<0.0001) (figure 3). Complete responders also had better symptom control after 1 year of treatment, with an ACQ score of 1.28 versus 1.99 for noncomplete responders (p=0.016), and a significantly larger proportion of complete responders had ACQ ≤1.5 (67% versus 40%; p<0.0001) (figure 3).

**Significant predictors of complete response**

In a logistic regression model, younger age at onset of asthma, concomitant diabetes and use of mOCS at baseline predicted not achieving a complete response to anti-IL-5 biologics (figure 4). Furthermore, allergic rhinitis, lower ACQ at baseline and blood eosinophils ≥0.3×10^9 L^{-1} predicted a complete response to therapy.

**Discussion**

In this nationwide prospective real-life cohort of all Danish severe asthma patients treated with anti-IL-5 biologics, 58% were complete responders after 12 months, with abrogation of exacerbations and cessation of mOCS. Complete responders also experienced superior improvements in lung function and symptom control compared with noncomplete responders. Complete responders to therapy had less severe disease at baseline (i.e. less use of mOCS, fewer exacerbations and lower ACQ), higher blood eosinophils and later onset of disease.

---

**FIGURE 3** Change in secondary outcomes in complete responders and noncomplete responders after 12 months of anti-interleukin-5 treatment: a) Asthma Control Questionnaire (ACQ) ≤1.5, b) forced expiratory volume in 1 s (FEV1) >80% predicted, c) exhaled nitric oxide fraction (\(F_{ENO}\)), d) blood eosinophils, e) FEV1, and f) ACQ score. *: significant difference (p<0.05) in change from baseline to 12 months between complete responders and noncomplete responders.
A British group recently published real-life data from relatively large cohorts of patients on mepolizumab [29] and benralizumab [28] (n=99 and n=130, respectively). In these studies, the term “super-responder” matched our definition of a complete responder. However, the proportions of complete responders in these cohorts were much smaller. Only 28% of patients on mepolizumab and 39% of patients on benralizumab were complete responders compared with 58% in our combined cohort. Noticeably, requirements for initiation of anti-IL-5 are stricter in the UK than in Denmark. Three or four exacerbations, depending on levels of blood eosinophils, are mandatory in the UK if patients are not on mOCS; however, only two are required in Denmark, with the latter criteria of two exacerbations being similar to eligibility criteria in the regulatory RCTs. This difference in response pattern between the cohorts indicates that patients with more severe disease upon commencement of anti-IL-5 treatment are less likely to achieve a complete response to treatment. The British cohorts’ data also revealed that being on mOCS at baseline is a negative predictor of a complete response to anti-IL-5 biologics, just as our data show. A negative influence of mOCS on response to treatment is also reported in other real-life studies of anti-IL-5 biologics [28–30, 36]. This further supports that severity of disease upon commencement of treatment could be a key factor for response, but potentially also longer duration of disease. Additionally, in patients with long-term use of OCS, weaning completely off OCS may be more difficult due to adrenal insufficiency, thereby rendering these patients less likely to achieve a complete response that is defined by cessation of use of mOCS. Additional studies are needed to understand whether initiating biological treatment earlier would lead to improved treatment outcomes, with more patients achieving complete control of their asthma. In our study, we saw a reduction in exacerbations far superior to those shown in the regulatory trials. This superior reduction has also been reported from other larger real-life cohorts [28, 30, 37–39]. This is perhaps to a certain degree due to a placebo effect that is not corrected by a control group receiving placebo. However, it is also likely that real-life patients undergo a systematic assessment of factors contributing to a lack of asthma control prior to commencement of biological treatment. An individual assessment is not easily replaced by a predefined set of inclusion and exclusion criteria that controls which patients are eligible for RCTs, and real-life clinicians may be better at selecting patients who will benefit from treatment.

We also found that higher blood eosinophils predicted a complete response to anti-IL-5 biologics. This is in line with several other studies based on both real-life data [28, 39] and data from RCTs [40, 41].

This study offers, to the best of our knowledge, the largest, complete nationwide anti-IL-5 cohort to date. The cohort is unique in being both nationwide and with prospectively collected data, from prior to initiating treatment and at set time-points. The group is furthermore clearly defined as there are set and agreed indications for initiation of biological treatment for patients in the cohort and they undergo...
systematic evaluation of other factors driving poor asthma control, e.g. comorbidities, adherence to ICS, etc. However, there are also limitations. Data are reported by healthcare personnel in the clinics providing the treatment and therefore it is not always complete. Furthermore, the decision to initiate biological treatment is up to the clinician and therefore it is possible that some patients do not meet formal requirements for treatment. The effects from treatment that we report, which are mostly superior to results in phase III trials, might be biased by the lack of blinding and placebo control that constitutes real-life data. Poor adherence to ICS may affect the outcome of treatment with biologics negatively [42]. Information on adherence to ICS was not available in the present study, but adherence is routinely checked, at each consultation in all patients on biologics, by assessing redemption of prescriptions for asthma medications in the online Danish medication registry. Hence, we believe that nonadherence to ICS is unlikely to be a major contributor to noncomplete response. Furthermore, our analyses do not include patients who discontinued anti-IL-5 before 12 months of treatment (figure 1). It is also important to note that this study is not appropriate as a head-to-head comparison of the anti-IL-5 biologics because our data include switchers that may have changed from one anti-IL-5 to another for various reasons, including availability, nonresponse or convenience.

Our data suggest that perhaps, in particular, a phenotype of late-onset disease, short duration and with higher blood eosinophils benefits from anti-IL-5 treatment. It may be speculated that this phenotype is associated with a clearer IL-5 drive, as opposed to others, e.g. early-onset, allergic asthma, that perhaps activate more pathways of type 2 inflammation. Our data further suggest that severity of disease (i.e. need for mOCS, number of exacerbations and ACQ) is a key factor in determining response to anti-IL-5 treatment. Very severe asthma (i.e. need for mOCS, an increasing number of exacerbations and high symptom score) was associated with a poorer response to treatment, suggesting that there is a window of severity between qualifying for anti-IL-5 treatment and needing mOCS where patients have optimised effects from treatment. We also found that presence of diabetes predicts a noncomplete response, which could be interpreted as a surrogate marker of severity as it is a well-known side-effect of prolonged OCS use. More severe disease and mOCS were associated with noncomplete response to anti-IL-5, which could be linked to a switch from an eosinophilic drive to an autoimmune drive [36].

Our study shows that complete responders to anti-IL-5 not only achieve remission of outcomes related to the indication for treatment, but they also have superior improvements of symptom score and lung function, which emphasises the importance of identifying patients who will benefit from this treatment. These patients may furthermore potentially fulfill criteria for remission of asthma [43] and describing their long-term prognosis will be an important future research goal. A further important question is obviously whether these patients would be able to stop or down-titrate their biological treatment [44] and studies examining this question are urgently needed. These results also highlight the possible importance of timely intervention with biologics in severe asthma in appropriate candidates and further research is needed to consolidate whether earlier initiation of biologics improves the overall prognosis. Finally, our study shows that blood eosinophils are, for now, the best biomarker to identify patients who particularly benefit from anti-IL-5 biologics, whereas FENO and IgE are not helpful.

**Conclusions**

More than half of Danish patients on anti-IL-5 were complete responders to treatment, and this group of patients also experienced superior improvements in lung function and symptoms. Complete response is predicted by high blood eosinophils and less severe disease at baseline.

Provenance: Submitted article, peer reviewed.

Conflict of interest: M.B. Soendergaard has received lecture fees from GlaxoSmithKline, outside the submitted work. S. Hansen has nothing to disclose. A.S. Bjerrum has received lecture fees from AstraZeneca and GlaxoSmithKline, outside the submitted work. O. Hilberg has nothing to disclose. S. Lock-Johansson has nothing to disclose. K.E.J. Håkansson has received unrestricted research grants, paid to his institution, from AstraZeneca and Sanofi Genzyme, outside the submitted work; and payment or honoraria for lectures, presentations, speakers’ bureaus, manuscript writing or educational events from AstraZeneca, Teva, GlaxoSmithKline and Sanofi Genzyme, outside the submitted work. T.S. Ingebrigtsen has nothing to disclose. C.R. Johnsen has nothing to disclose. L.M. Rasmussen has received payment or honoraria for lectures, presentations, speakers’ bureaus, manuscript writing or educational events from AstraZeneca, GlaxoSmithKline, Teva and ALK, outside the submitted work; support for attending meetings and/or travel received from AstraZeneca and Chiesi, outside the submitted work; and participation on data safety monitoring or advisory boards for AstraZeneca, GlaxoSmithKline, Teva and Sanofi, outside the submitted work. A. von Bülow has done consultancy work for Novartis DK, outside the submitted work. A. von Bülow has done consultancy work for Novartis DK, outside the submitted work.
work; lectures and speakers fees received from AstraZeneca, Novartis and GlaxoSmithKline, outside the submitted work; and advisory boards for AstraZeneca and Novartis, outside the submitted work. K.D. Assing has nothing to disclose. J.M. Schmid has nothing to disclose. C.S. Ulrik received payment or honoraria for lectures, presentations, speakers’ bureaus, manuscript writing or educational events from AstraZeneca, GlaxoSmithKline, Teva, Sanofi, Orion Pharma, Novartis and Chiesi, outside the submitted work. C. Porsbjerg has received grants or contracts from AstraZeneca, GlaxoSmithKline, Novartis, Teva, Sanofi, Chiesi and ALK, outside the submitted work; consulting fees from AstraZeneca, GlaxoSmithKline, Novartis, Teva, Sanofi, Chiesi and ALK, outside the submitted work; payment or honoraria for lectures, presentations, speakers’ bureaus, manuscript writing or educational events, received from AstraZeneca, GlaxoSmithKline, Novartis, Teva, Sanofi, Chiesi and ALK, outside the submitted work; and participation on data safety monitoring or advisory boards for AstraZeneca, Novartis, Teva, Sanofi and ALK, outside the submitted work.

References
1 von Bülow A, Kriegbaum M, Backer V, et al. The prevalence of severe asthma and low asthma control among Danish adults. J Allergy Clin Immunol Pract 2014; 2: 759–767.
2 Hekking P-PW, Wener RR, Amelink M, et al. The prevalence of severe refractory asthma. J Allergy Clin Immunol 2015; 135: 896–902.
3 Zeiger RS, Schatz M, Dalal AA, et al. Utilization and costs of severe uncontrolled asthma in a managed-care setting. J Allergy Clin Immunol Pract 2016; 4: 120–129.
4 Haldar P, Brightling CE, Hargadon B, et al. Mepolizumab and exacerbations of refractory eosinophilic asthma. N Engl J Med 2009; 360: 973–984.
5 Pavord ID, Korn S, Howarth P, et al. Mepolizumab for severe eosinophilic asthma (DREAM): a multicentre, double-blind, placebo-controlled trial. Lancet 2012; 380: 651–659.
6 Ortega HG, Liu MC, Pavord ID, et al. Mepolizumab treatment in patients with severe eosinophilic asthma. N Engl J Med 2014; 371: 1198–1207.
7 Castro M, Zangrilli J, Wechsler ME, et al. Reslizumab for inadequately controlled asthma with elevated blood eosinophil counts: results from two multicentre, parallel, double-blind, randomised, placebo-controlled, phase 3 trials. Lancet Respir Med 2015; 3: 355–366.
8 Bleecker ER, FitzGerald JM, Chanez P, et al. Efficacy and safety of benralizumab for patients with severe asthma uncontrolled with high-dosage inhaled corticosteroids and long-acting β₂-agonists (SIROCCO): a randomised, multicentre, placebo-controlled phase 3 trial. Lancet 2016; 388: 2115–2127.
9 Nair P, Pizzichini MMM, Kjarsgaard M, et al. Mepolizumab for prednisone-dependent asthma with sputum eosinophilia. N Engl J Med 2009; 360: 985–993.
10 Bel EH, Wenzel SE, Thompson PJ, et al. Oral glucocorticoid-sparing effect of mepolizumab in eosinophilic asthma. N Engl J Med 2014; 371: 1189–1197.
11 Nair P, Wenzel S, Rabe KF, et al. Oral glucocorticoid-sparing effect of benralizumab in severe asthma. N Engl J Med 2017; 376: 2448–2458.
12 Bagnasco D, Milanese M, Rolla G, et al. The North-Western Italian experience with anti IL-5 therapy and comparison with regulatory trials. World Allergy Organ J 2018; 11: 34.
13 Pahus L, Alagha K, Sofalvi T, et al. External validity of randomized controlled trials in severe asthma. Am J Respir Crit Care Med 2015; 192: 259–261.
14 Ibrahim H, O’Sullivan R, Casey D, et al. The effectiveness of reslizumab in severe asthma treatment: a real-world experience. Respir Res 2019; 20: 289.
15 Kalieri M, Zervas E, Katsoulis K, et al. Mepolizumab in severe eosinophilic asthma: a 2-year follow-up in specialized asthma clinics in Greece: an interim analysis. Int Arch Allergy Immunol 2020; 181: 613–617.
16 Pelaia C, Busceti MT, Crimi C, et al. Real-life effects of benralizumab on exacerbation number and lung hyperinflation in atopic asthma. Biomed Pharmacother 2020; 129: 110444.
17 Pelaia C, Crimi C, Pelaia G, et al. Real-life evaluation of mepolizumab efficacy in patients with severe eosinophilic asthma, according to atopic trait and allergic phenotype. Clin Exp Allergy 2020; 50: 780–788.
18 Pelaia C, Busceti MT, Solinas S, et al. Real-life evaluation of the clinical, functional, and hematological effects of mepolizumab in patients with severe eosinophilic asthma: results of a single-centre observational study. Pulm Pharmacol Ther 2018; 53: 1–5.
19 Renner A, Marth K, Patocka K, et al. Effectiveness of mepolizumab therapy in patients with severe eosinophilic asthma: Austrian real-life data. Pulm Pharmacol Ther 2020; 64: 101946.
20 Kotitsalmi E, Hakulinen A, Mäkelä M, et al. A comparison of biologicals in the treatment of adults with severe asthma – real-life experiences. Asthma Res Pract 2020; 6: 2.
21 van Toor JJ, van der Mark SC, Kappen JH, et al. Mepolizumab add-on therapy in a real world cohort of patients with severe eosinophilic asthma: response rate, effectiveness, and safety. J Asthma 2020; 58: 651–658.
22 Pertsov B, Avraham U, Osnat S, et al. Efficacy and safety of mepolizumab in a real-world cohort of patients with severe eosinophilic asthma. J Asthma 2020; 58: 79–84.
Voelker D, Scrodin MD, Lim K, et al. Newer biological agents in the treatment of severe asthma: real world results from a tertiary referral center. *Chest* 2019; 156: A25.

Enríquez-Rodríguez AI, Hermida Valverde T, Romero Álvarez P, et al. Results in clinical practice in the treatment of severe eosinophilic asthma with mepolizumab: a real-life study. *J Asthma* 2021; 59: 1005–1011.

Drick N, Seeliger B, Weite T, et al. Anti-IL-5 therapy in patients with severe eosinophilic asthma – clinical efficacy and possible criteria for treatment response. *BMC Pulm Med* 2018; 18: 119.

Bjerrum AS, Skjold T, Schmid JM. Oral corticosteroid sparing effects of anti-IL5/anti-IL5 receptor treatment after 2 years of treatment. *Respir Med* 2021; 176: 106260.

Upham JW, Lievre CL, Jackson DJ, et al. Defining a severe asthma super-responder: findings from a Delphi process. *J allergy Clin Immunol Pract* 2021; 9: 3997–4004.

Kavanagh JE, Hearn AP, Dhariwal J, et al. Real world effectiveness of benralizumab in severe eosinophilic asthma. *Chest* 2020; 56: 2261.

Kavanagh JE, d’Ancona G, Elstad M, et al. Real-world effectiveness and the characteristics of a “super-responder” to mepolizumab in severe eosinophilic asthma. *Chest* 2020; 158: 491–500.

Harvey ES, Langton D, Katelaris C, et al. Mepolizumab effectiveness and identification of super-responders in severe asthma. *Eur Respir J* 2020; 55: 1902420.

Eger K, Kroes JA, Brinke AT, et al. Long-term therapy response to anti-interleukin-5 biologics in severe asthma – a real-life evaluation. *J Allergy Clin Immunol Pract* 2020; 9: 1194–1200.

Hansen S, Hilberg O, Ulrik CS, et al. The Danish Severe Asthma Register: an electronic platform for severe asthma management and research. *Eur Clin Respir J* 2021; 8: 1842117.

Porsbjerg C, Ulrik C, Skjold T, et al. Nordic consensus statement on the systematic assessment and management of possible severe asthma in adults. *Eur Clin Respir J* 2018; 6: 1440868.

Holguin F, Cardet JC, Chung KF, et al. Management of severe asthma: a European Respiratory Society/American Thoracic Society guideline. *Eur Respir J* 2020; 55: 1900588.

Bonini M, Di Paolo M, Bagnasco D, et al. Minimal clinically important difference for asthma endpoints: an expert consensus report. *Eur Respir Rev* 2020; 29: 190137.

Mukherjee M, Forero DF, Tran S, et al. Sub-optimal treatment response to anti-IL-5 monoclonal antibodies in severe eosinophilic asthmatics with airway autoimmune phenomena. *Eur Respir J* 2020; 56: 2000117.

Bagnasco D, Caminati M, Menzella F, et al. One year of mepolizumab. Efficacy and safety in real-life in Italy. *Pulm Pharmacol Ther* 2019; 58: 101836.

Schleich F, Graff S, Nekoe H, et al. Real-word experience with mepolizumab: does it deliver what it has promised? *Clin Exp Allergy* 2020; 50: 687–695.

Taille C, Chanez P, Devouassoux G, et al. Mepolizumab in a population with severe eosinophilic asthma and corticosteroid dependence: results from a French early access programme. *Eur Respir J* 2020; 55: 1902345.

Fitzgerald JM, Bleecker ER, Menzies-Gow A, et al. Predictors of enhanced response with benralizumab for patients with severe asthma: pooled analysis of the SIROCCO and CALIMA studies. *Lancet Respir Med* 2018; 6: 51–64.

Albers FC, Licskai C, Chanez P, et al. Baseline blood eosinophil count as a predictor of treatment response to the licensed dose of mepolizumab in severe eosinophilic asthma. *Respir Med* 2019; 159: 105806.

d’Ancona G, Kavanagh J, Roxas C, et al. Adherence to corticosteroids and clinical outcomes in mepolizumab therapy for severe asthma. *Eur Respir J* 2020; 55: 1902259.

Menzies-Gow A, Szeffler SJ, Busse WW. The relationship of asthma biologics to remission for asthma. *J Allergy Clin Immunol Pract* 2021; 9: 1090–1098.

Hamada K, Oishi K, Murata Y, et al. Feasibility of discontinuing biologics in severe asthma: an algorithmic approach. *J Asthma Allergy* 2021; 14: 1463–1471.