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Incidence and long-term outcome of severe asthma–COPD overlap compared to asthma and COPD alone: a 35-year prospective study of 57,053 middle-aged adults

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Background: Incidence and prognosis for severe asthma–COPD overlap is poorly characterized. We investigated incidence and long-term outcome for patients with asthma–COPD overlap compared to asthma and COPD alone.

Materials and methods: A total of 57,053 adults (aged 50–64 years) enrolled in the Danish Diet, Cancer, and Health cohort (1993–1997) were followed in the National Patients Registry for admissions for asthma (DJ45–46) and COPD (DJ40–44) and vital status. Asthma–COPD overlap was defined as at least one hospital admission for asthma and one for COPD (different time points), and incident asthma–COPD overlap as at least one of the diagnoses occurring after enrollment into the Diet, Cancer, and Health cohort.

Results: A total of 1,845 (3.2%) and 4,037 (7.1%) participants had admissions for asthma and COPD, respectively, with 662 (1.2%) participants with asthma–COPD overlap. Incidence rate of asthma–COPD overlap per 1,000 person-years was higher in women (0.73) than in men (0.54) (P<0.02). Mortality rate was higher in asthma–COPD overlap (25.9 per 1,000 person-years) compared to COPD (23.1, P<0.05) and asthma (7.9, P<0.001) alone. Compared to COPD alone, mortality was higher in women with asthma–COPD overlap (19.6 and 25.5, respectively; P<0.01), and the excess mortality rate for asthma–COPD overlap patients was most prominent for younger age groups (12.9 compared to 7.2 and 4.6 for COPD and asthma alone, respectively; P<0.01).

Conclusion: This large population-based study revealed a higher incidence of severe asthma–COPD overlap in women compared to men, and furthermore that all-cause mortality is higher in women and younger subjects with asthma–COPD overlap compared with those with asthma or COPD alone.

Keywords: asthma, COPD, asthma–COPD overlap, ACOS, outcome, mortality, incidence

Introduction

The occurrence of concomitant asthma and COPD, in recent years often referred to as asthma–COPD overlap syndrome (ACOS), is well recognized. However, despite much attention, no general consensus has been reached on defining features, or even the term itself, with some studies classifying ACO as a subphenotype of COPD,1,2 and some as a distinct phenotype by itself.3,4 The overlap between asthma and COPD, therefore, remains a controversial issue, possibly primarily because many conflicting aspects remain, which makes it difficult to summarize the distinctive features of this so-called syndrome.5,6 In line with this, the currently available national guidelines, including guidelines from Spain,7 Finland,8 and the Czech Republic,9 have defined...
ACO on the basis of various combinations of major and minor
criteria, including positive bronchodilator reversibility test,
airway hyperresponsiveness, sputum eosinophilia, elevated
total immunoglobulin E (IgE), atopy, and a clinical history of
asthma before age 40 years.

Previous studies have revealed wide variations in preva-
lence of ACO of 15%–20%\(^4,10,11\) (based on physician diag-
osis of both asthma and COPD) to 17%–60%\(^12–14\) (based
on chronic airflow limitation in subjects with a diagnosis of
asthma), clearly indicating the impact of the chosen definition,
which also compromises comparisons between studies. In the available (in most cases relatively small) studies, patients with features of both asthma and COPD seem to have more exacerbations,\(^15\) leading to more hospitalizations,\(^3,10,16,17\) and more comorbidity\(^16,18,19\) than patients with either disease alone, as well as poorer health-related quality of life\(^12\) and higher medical utilization.\(^19\) However, studies based on either small subpopulations, likely not to be representative of the general population, or on additional diagnostic criteria in a selected group of either asthma or COPD patients hamper the interpretation of the findings. Large-scale population-based studies are thus needed to characterize patterns of morbidity and mortality further in patients with overlap between asthma and COPD. Additionally, very limited observations are at present available regarding mortality in patients with ACO.

Materials and methods
Cohort
In 1993–1997, a total of 160,725 individuals (72,729 women)
50–64 years of age living in the two largest cities in Denmark
(Copenhagen and Århus), with no record of cancer in the
Danish Cancer Registry, were invited to participate in the
prospective Danish Diet, Cancer, and Health (DCH) study. In
total, 57,053 individuals (29,875 women [52.4%]) accepted
the invitation and were enrolled in the study. All participants
answered a detailed questionnaire on diet, health, education,
occupation, lifestyle, including smoking, reproductive char-
acteristics, and preexisting disease, including asthma, COPD,
diabetes, and cardiovascular disease. A detailed description
of the DCH cohort has been published previously.\(^20,21\)

Health-outcome definitions
Using the unique identification number assigned to all Danish
citizens,\(^22\) the DCH cohort was linked to the Danish National
Patient Registry (DNPR)\(^21\) to extract hospital contacts from
1978 until July 1, 2013. The DNPR includes all discharge
diagnoses from all Danish hospitals since 1978 and from
outpatient clinics since 1995.\(^23\) Admissions in the present
analyses also included emergency room visits and visits to
pulmonary outpatient clinics, and if not stated otherwise
referred to as admissions. COPD and asthma diagnoses were
classified according to the International Classification of
Diseases (ICD) as ICD-10 codes DJ40–44 (and 490.0–492.09,
according to the ICD-8 until 1994) and ICD-10 codes
DJ45–46 (and ICD-8 codes 493.00–493.09), respectively,
for COPD and asthma. To allow for variations in classification
procedures, patients with a primary diagnosis of DJ960
(acute respiratory failure) were also included, provided they
had a secondary diagnosis of asthma or COPD. Contacts
after baseline (ie, 1993–1997) for asthma and/or COPD were
classified as incident admissions.

Participants were defined as having asthma if during the
study period they exclusively had admissions for asthma,
and likewise for participants classified as having COPD.
Participants were defined as having ACO if they had at least
one hospital admission for asthma together with at least one
admission for COPD (two different time points, regardless
of which came first). In order to be classified as having
ACO at baseline, participants were required to have at
least one admission for asthma and also at least one admis-
sion for COPD before enrollment into the cohort. Incident
ACO was defined as at least one first admission for either
asthma or COPD occurring after baseline (1993–1997),
with date of earliest admission as date of ACO onset, and
likewise for participants classified as having asthma or
COPD alone.

Statistical methods and ethics
For each person, person-years of follow-up were calculated
separately for asthma, COPD, and ACO, with follow-up start-
ing at the date of inclusion into the cohort (between 1993 and
1997) and ending on July 1, 2013, date of death, emigration, or
at the first admission for asthma, COPD, or ACO, respectively,
whichever came first. Overall and age-specific incidence rates
and mortality rates were calculated for asthma, COPD, and
ACO, and separately for men and women. The ages were
stratified into four intervals, from age 50 years to age 75+
years. Incidence rates were calculated by dividing the number
of cohort participants with an event (asthma, COPD, or ACO)
in each age-group by the total person-years of observation
for all participants in that stratum, overall and separately by
gender, and reported as incidence rates per 1,000 person-years.
Age-specific mortality rates were calculated by dividing the number of deaths due to any cause – overall and in each age-group – by the number of person-years of observations for all participants in that stratum. Confidence intervals (95%) were calculated for incidence and mortality rates based on Poisson distribution, using the “stptime” command in Stata 13.1. The DCH-cohort study was approved by the Central Danish Ethics Committee, and the present study was approved by the Danish Data Protection Agency (2014-41-3468). All participants provided written informed consent.

Results
The participants (n=57,053) in the DCH cohort were registered with a total of 2,762,912 hospital discharge diagnoses in the DNPR between 1978 and 2013, with a total of 1,268,971 primary diagnoses. Of these primary diagnoses, 18,311 (1.4%) were for either asthma (n=3,961 [21.6%]) or COPD (n=14,350 [78.4%]) (Figure 1). Furthermore, a total of 1,445 admissions were identified with acute respiratory failure (DJ960) as the primary diagnosis, 871 of these with a secondary diagnosis of asthma (n=16) or COPD (n=855) (Figure 1). A total of 3,977 admissions for asthma and 15,205 admissions for COPD were thus included in the present analyses, with 1,845 participants having at least one admission for asthma and 4,037 at least one admission for COPD.

Participants with admissions for asthma or COPD
Of 57,053 subjects in the DCH cohort, 1,183 (2.1%) had had at least one admission for asthma (and none for COPD) between 1978 and 2013, with 368 (31.1%) and 815 (68.9%), respectively, before and after baseline (1993–1997), corresponding to an incidence rate of 0.9 per 1,000 person-years, with a higher asthma-incidence rate for women (1.07 per 1,000 person-years) than men (0.72 per 1,000 person-years) (P<0.02; Table 1). A total of 3,375 (5.9%) cohort participants had had at least one admission for COPD (and none for asthma), with 361 (10.7%) and 3,014 (89.3%), respectively, before and after baseline, and thus an incidence rate of 3.4 per 1,000 person-years. Incidence rates for COPD were similar for men (3.3 per 1,000 person-years) and women (3.4 per 1,000 person-years) (Table 1). Only a minor portion of the included admissions for asthma or COPD (14.2% and 12.7%, respectively) were emergency room visits.

Participants with ACO
A total of 662 participants (1.2% of the cohort) had had at least one admission for both asthma and COPD, ie, fulfilled the criteria for ACO. The subjects enrolled in the cohort with at least one admission for obstructive lung disease could thus be grouped into: asthma only (n=1,183), COPD only (n=3,375), asthma-COPD overlap (n=662), and COPD with at least one admission for asthma.
### Table 1 Total and gender-specific incidence of asthma, COPD, and asthma–COPD overlap among individuals enrolled in the Diet, Cancer, and Health cohort (n=57,053)

| Age group       | Totals                | Men                        | Women                      |
|-----------------|-----------------------|----------------------------|----------------------------|
|                 | New cases (n) | Person-years | IR (95% CI) | New cases (n) | Person-years | IR (95% CI) | New cases (n) | Person-years | IR (95% CI) |
| **COPD**        |                      |                           |                           |                           |                           |                           |                           |                           |                           |
| 50–55 years     | 3,014        | 895,338       | 3.37 (3.25–3.49)   | 1,390        | 417,449       | 3.30 (3.13–3.47)   | 1,624        | 481,637       | 3.37 (3.21–3.54)   |
| 55–65 years     | 93           | 61,606        | 1.51 (1.23–1.85)   | 45           | 29,801        | 1.51 (1.13–2.02)   | 48           | 31,806        | 1.51 (1.14–2.00)   |
| 65–75 years     | 909          | 394,688       | 2.30 (2.16–2.46)   | 427          | 187,803       | 2.27 (2.07–2.50)   | 482          | 207,065       | 2.33 (2.13–2.55)   |
| >75 years       | 1,589        | 376,546       | 4.22 (4.02–4.43)   | 189          | 26,726        | 7.07 (6.13–8.16)   | 1,879        | 203,427       | 4.23 (3.95–4.53)   |
| **Asthma**      |                      |                           |                           |                           |                           |                           |                           |                           |                           |
| 50–55 years     | 815          | 902,606       | 0.90 (0.84–0.97)   | 302          | 422,066       | 0.72 (0.64–0.82)   | 513          | 480,741       | 1.07 (0.98–1.16)   |
| 55–65 years     | 51           | 61,494        | 0.83 (0.63–1.09)   | 14           | 29,788        | 0.47 (0.28–0.79)   | 37           | 31,705        | 1.17 (0.85–1.61)   |
| 65–75 years     | 348          | 395,251       | 0.88 (0.79–0.98)   | 136          | 188,512       | 0.72 (0.61–0.85)   | 212          | 206,739       | 1.03 (0.90–1.17)   |
| >75 years       | 338          | 381,577       | 0.89 (0.80–0.99)   | 122          | 176,076       | 0.69 (0.58–0.83)   | 216          | 205,501       | 1.05 (0.92–1.20)   |
| **Asthma–COPD overlap** |          |                           |                           |                           |                           |                           |                           |                           |                           |
| 50–55 years     | 588          | 912,509       | 0.64 (0.59–0.7)    | 230          | 425,609       | 0.54 (0.47–0.61)   | 358          | 486,900       | 0.73 (0.67–0.79)   |
| 55–65 years     | 43           | 61,912        | 0.69 (0.52–0.94)   | 16           | 29,954        | 0.53 (0.33–0.87)   | 27           | 31,958        | 0.84 (0.58–1.23)   |
| 65–75 years     | 287          | 396,994       | 0.72 (0.64–0.81)   | 104          | 189,924       | 0.55 (0.45–0.66)   | 183          | 209,070       | 0.88 (0.76–1.01)   |
| >75 years       | 237          | 386,274       | 0.61 (0.54–0.70)   | 100          | 177,727       | 0.56 (0.46–0.68)   | 137          | 208,547       | 0.66 (0.56–0.78)   |

**Notes:** Asthma–COPD overlap defined as at least one hospital admission for asthma and one for COPD (two different time points), prevalence with at least one admission before baseline (1993–1997), and incidence with admissions between baseline and end of follow-up (ie, July 1, 2013). Incidence rate calculated in persons at risk; those without COPD (n=56,692), asthma (n=56,685), or ACOS (n=56,979) at baseline for COPD, asthma, and asthma–COPD overlap, respectively. Data from the Diet, Cancer, and Health cohort: Tjønneland et al. and according to gender.

**Abbreviations:** IR, incidence rate (per 1,000 person-years); CI, confidence interval; ACOS, asthma–COPD overlap syndrome.

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### Mortality

The overall mortality rate (all subjects included in the cohort) was 10.9 per 1,000 person-years, with men having a 63% higher mortality rate than women (13.7 vs 8.4 per 1,000 person-years). The mortality rate was 9.2 per 1,000 person-years, with men having a 67% higher mortality rate than women (10.9 vs 4.1 per 1,000 person-years). The difference in mortality between the three groups of subjects with obstructive lung disease was observed especially in women. After age 75 years, mortality was higher for COPD than for ACOS (25.6, 5.9 [P<0.01]), and 16.9, 4.4 [P<0.01], and 10.5, 2.7 [P<0.01], respectively, in the age group 55–65 years, 65–75 years, and >75 years, respectively. In subjects below age 55 years, no deaths were observed in the asthma group, whereas the mortality rate for ACOS (7.5 vs 5.7 per 1,000 person-years, respectively) was lower than that for COPD in each of the age groups. The total mortality rate was 6.7 per 1,000 person-years, with men having a higher death rate than women (13.7 vs 8.4 per 1,000 person-years). The difference in mortality between men and women (5.6% of all ACOS) was 10.9 per 1,000 person-years, with men having a 63% higher mortality rate than women (13.7 vs 8.4 per 1,000 person-years). The difference was less pronounced in the ACOS group, with only 4.3% higher mortality in men (not significant).
Table 2 Total, age-, and gender-specific all-cause mortality in total cohort, asthma, COPD, and asthma–COPD overlap

| Age group | Totals | Men | Women |
|-----------|--------|-----|-------|
|           | Deaths (n) | Person-years (n) | MR (95% CI) | Deaths (n) | Person-years (n) | MR (95% CI) | Deaths (n) | Person-years (n) | MR (95% CI) |
| Total     | 9,996 | 918,862 | 10.88 (30.64–33.37) | 5,886 | 428,096 | 13.7 (13.40–14.11) | 4,110 | 490,766 | 8.37 (8.12–8.63) |
| 50–55 years | 156 | 62,003 | 2.52 (2.15–2.94) | 107 | 29,995 | 3.57 (3.29–3.85) | 49 | 32,007 | 1.53 (1.16–2.03) |
| 55–65 years | 2,398 | 400,855 | 5.98 (5.75–6.23) | 1,508 | 190,617 | 7.91 (7.52–8.32) | 890 | 210,237 | 4.23 (3.96–4.52) |
| 65–75 years | 5,324 | 389,769 | 13.66 (13.30–14.03) | 3,093 | 179,102 | 17.27 (16.67–17.89) | 2,231 | 210,667 | 10.59 (10.16–11.04) |
| >75 years | 2,118 | 66,235 | 31.98 (30.64–33.37) | 1,178 | 28,381 | 41.51 (39.20–43.95) | 940 | 37,854 | 24.83 (23.29–26.47) |
| COPD      | 1,213 | 52,547 | 23.08 (21.82–24.42) | 652 | 23,917 | 27.26 (25.25–29.44) | 561 | 28,629 | 19.60 (18.04–21.29) |
| 50–55 years | 7 | 2,466 | 2.84 (1.35–5.95) | 5 | 1,184 | 4.22 (1.76–10.15) | 2 | 1,283 | 1.56 (0.39–6.24) |
| 55–65 years | 148 | 20,436 | 7.24 (6.16–8.51) | 77 | 9,471 | 8.13 (6.50–10.17) | 71 | 10,965 | 6.48 (5.13–8.17) |
| 65–75 years | 681 | 24,650 | 27.63 (25.63–29.78) | 377 | 11,105 | 33.95 (30.69–37.55) | 304 | 13,545 | 22.44 (20.06–25.11) |
| >75 years | 377 | 4,994 | 75.48 (68.24–83.50) | 193 | 2,158 | 89.44 (77.67–102.99) | 184 | 2,837 | 64.87 (56.14–74.95) |
| Asthma    | 152 | 19,516 | 7.79 (6.64–9.13) | 67 | 7,244 | 9.25 (7.28–11.75) | 85 | 12,273 | 6.93 (5.60–8.57) |
| 50–55 years | 0 | 1,297 | 0 | 0 | 494 | 0 | 0 | 803 | 0.0 |
| 55–65 years | 39 | 8,924 | 4.63 (3.38–6.33) | 20 | 3,213 | 6.22 (4.02–9.65) | 19 | 5,214 | 3.64 (2.32–5.71) |
| 65–75 years | 78 | 8,261 | 9.44 (7.56–11.79) | 32 | 3,026 | 10.58 (7.48–14.95) | 46 | 5,236 | 8.79 (6.58–11.73) |
| >75 years | 35 | 1,531 | 22.86 (16.41–31.84) | 15 | 511 | 29.36 (17.70–43.95) | 20 | 1,020 | 19.60 (12.65–30.39) |
| Asthma–COPD overlap | 255 | 9,829 | 25.94 (22.95–29.33) | 104 | 3,914 | 26.57 (21.92–32.20) | 151 | 5,915 | 25.33 (21.76–29.94) |
| 50–55 years | 2 | 460 | 4.35 (1.09–17.40) | 2 | 185 | 10.79 (7.37–14.15) | 0 | 274 | 0 |
| 55–65 years | 49 | 3,811 | 12.86 (9.72–17.01) | 21 | 1,452 | 14.47 (9.43–22.19) | 28 | 2,359 | 11.87 (8.20–17.19) |
| 65–75 years | 149 | 4,598 | 32.4 (27.3–38.05) | 58 | 1,873 | 30.97 (23.94–40.06) | 91 | 2,725 | 33.39 (27.19–41.01) |
| >75 years | 961 | 961 | 57.23 (43.94–74.54) | 23 | 404 | 56.92 (37.83–85.66) | 32 | 557 | 57.46 (40.63–81.25) |

Note: Mortality calculated as number of deaths divided by person-years from inclusion in the cohort in 1993–1997 until last follow-up at July 1, 2013.

Abbreviations: MR, mortality rate (per 1,000 person-years); CI, confidence interval.
These differences might be due to the use of self-reported and COPD, very similar to a previous study by Lange et al. Among their COPD patients, based on self-reported asthma–COPD overlap of 2.7%, corresponding to a prevalence of 43.8% Diaz-Guzman et al, several previous studies, including Sorino et al, of ACO used, we observed a prevalence of ACO similar to previous studies was hampered by the different definitions and underlying endotypes of obstructive lung disease. This compared with hazard ratios of 1.44 for COPD-only and 1.16 for asthma-only participants, the hazard ratio reported for COPD only being very similar to that reported by Lange et al for ACO with late-onset asthma. In contrast, Yamauchi et al found lower in-hospital, all-cause mortality in overlap patients than in COPD-only patients (2.3% vs 9.7%, respectively), based on physician diagnoses of both asthma and COPD. Furthermore, a recent study by Sorino et al, investigating 15-year mortality rates in 1,065 subjects aged >65 years, reported no difference in mortality.

**Discussion**

The major new findings of this prospective study of a large middle-aged population-based cohort are that incident severe ACO (also referred to as ACOS) is more common among females than males, and that patients with ACO have higher mortality rates compared to both asthma alone and COPD alone, especially among women and younger age-groups. Our study, therefore, emphasizes that individuals, and not least women, with ACO of such severity that it causes hospital admissions constitute a high-risk group for very poor outcome.

**Incidence of ACO**

Although we only studied individuals with ACO leading to hospital contacts, together with the fact that comparison with previous studies was hampered by the different definitions of ACO used, we observed a prevalence of ACO similar to several previous studies, including Sorino et al, Menezes et al, and Miravitlles et al. In contrast to our findings, Diaz-Guzman et al reported an overall prevalence of ACOS of 2.7%, corresponding to a prevalence of 43.8% among their COPD patients, based on self-reported asthma and COPD, very similar to a previous study by Lange et al. These differences might be due to the use of self-reported asthma as part of the ACOS definition, as participants might report COPD as asthma, and probably also differences in the age span of individuals studied. Our use of registry records (with discharge diagnoses) eliminated the risk of faulty reporting by participants, but of course did not eliminate the risk of doctor misclassification. The discrepancy in incidence and prevalence of ACO observed in different studies implies an intrinsic weakness in defining this “phenotype” of obstructive lung disease, and the future use of this umbrella term can be questioned, not only because it blurs the lines between asthma and COPD but also because it may allow an approach that simplifies therapy. This assumption may seem to be supported not only by recently published clinical treatment guidelines, which by definition are not based on evidence from randomized clinical trials, as individuals with ACO have not been eligible for inclusion, but also recently published reviews. Future studies should thus (by adding to existing knowledge, including the present study) seek to define new phenotypes and underlying endotypes of obstructive lung disease with characteristics of both asthma and COPD to replace the umbrella term “ACO”.

Our study revealed a higher incidence of ACO in women compared to men, which is in line with a previous study by Diaz-Guzman et al, but in contrast to the study by Lange et al, based on the Danish Copenhagen City Heart study. Incident hospital admissions for asthma are common in postmenopausal women, and we are thus confident that our observation was not caused by gender-related misclassification of obstructive lung diseases, but instead represents male–female difference in susceptibility to develop an overlapping phenotype, revealed in the present study by a combination of cohort size and disease severity studied.

**Mortality**

With regard to mortality in individuals with ACO, so far only limited evidence is available. Similar to our results, Diaz-Guzman et al found overlap patients to have a hazard ratio for mortality of 1.83 compared to subjects without obstructive lung disease. This compared with hazard ratios of 1.44 for COPD-only and 1.16 for asthma-only participants, the hazard ratio reported for COPD only being very similar to that reported by Lange et al for ACO with late-onset asthma. In contrast, Yamauchi et al found lower in-hospital, all-cause mortality in overlap patients than in COPD-only patients (2.3% vs 9.7%, respectively), based on physician diagnoses of both asthma and COPD. Furthermore, a recent study by Sorino et al, investigating 15-year mortality rates in 1,065 subjects aged >65 years, reported no difference in mortality.
between ACO and COPD only. In line with that, based on data from a large COPD cohort, Cosio et al identified patients with one major or two minor criteria for asthma, and reported a lower 1-year mortality for patients in the overlap group than COPD only (cumulative survival of 94.7% and 87.3%, respectively). This is again in accordance with a study by Fu et al, who studied prognoses in 99 adults with asthma, COPD, and ACO after a median follow-up of 4.2 years, where patients with COPD were found to have poorer prognoses than the two other groups. Possible explanations for the differences in findings, apart from the difficulties with diagnostic labeling already discussed, may be the size of the cohort and overall severity of obstructive lung disease in the studied cohort, as in the present study, where we only included individuals in the three groups of interest, provided the disease had caused admission to hospital. Our study of a very large population-based cohort focusing on individuals with obstructive lung diseases at the more severe end of the disease spectrum has shown that individuals with overlap between asthma and COPD have a poorer prognosis than individuals with either disease alone. Although, in relation to the latter, one limitation of the present study is the lack of information on cause-specific mortality.

Overall, we feel confident that our data are a sound representation of the actual hospital contacts for asthma and COPD, as we relied on physicians having seen and diagnosed the patients in a hospital setting with access to a full overview of each patient’s symptoms, clinical findings, and paraclinical results, including spirometry and imaging, and not relying on either alone.

Study limitations
The diagnoses in this study were physician-based assessments, from a registry, and might not have been confirmed by a specialist in respiratory medicine, although the diagnosis is highly likely to have been confirmed by objective assessment for patients attending a respiratory outpatient clinic. Data from registers might be vulnerable to errors, due to lack of time or clinical experience or to change in diagnostic practices over time, although diagnostic practices have been relatively stable over the years of the present study, including awareness of the differential diagnosis of asthma and COPD. Furthermore, Thomsen et al reported a 92% positive predictive value (PPV) for a discharge diagnosis of COPD in the DNPR, the same register as that used in the present study, and with respect to this, the diagnoses in the register are highly likely to be reliable. With regard to asthma, Jensen et al found sensitivity of a DNPR record of asthma to be 44%, but specificity to be 98%, with a positive predictive value of 65%. However, they found that the low sensitivity for asthma did not nullify any observed relative associations in the data set. In addition, we did not have available data on disease severity, eg, for patients with COPD according to the Global Initiative for Chronic Obstructive Lung Disease strategy document, but our classification criteria of hospital admission were highly likely to have excluded most patients with milder disease. On the other hand, although hospital admissions for obstructive lung disease represent the more severe end of the disease spectrum, the burden most likely reflects the total disease burden. Another limitation related to the use of a population-based cohort, and by that a more descriptive approach, was the lack of data for important clinical features, including level of lung function, degree of airflow limitation, type of airway inflammation, and disease-related physical limitations, all information that would have been useful to classify our patients further.

In conclusion, the present study of a large population-based cohort highlights differences in the long-term outcome of patients with more severe ACO compared to asthma and COPD alone. In particular, our study revealed important gender differences in incidence and long-term outcome of ACO, including a lower survival rate in individuals with ACO compared to both asthma and COPD only. Our findings, therefore, support the notion that patients presenting features of both asthma and COPD are at high risk of a poor long-term outcome.

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Author contributions
Camilla Boslev Baarnes and Charlotte Suppli Ulrik take overall responsibility for the content of the manuscript. Zorana Jovanovic Andersen had full access to all data in the study, analyzed the data, and takes responsibility for the accuracy of the data analysis. Camilla Boslev Baarnes wrote the first draft of the manuscript. Charlotte Suppli Ulrik, Zorana Jovanovic Andersen, and Anne Tjønneland contributed substantially to study design, data analysis and interpretation, and writing of the manuscript. All authors approved the manuscript in its final form, contributed toward data analysis, drafting and critically revising the paper, gave final approval of the version to be published, and agree to be accountable for all aspects of the work.

Disclosure
The authors report no conflicts of interest in relation to this work.
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