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Original research

# Risk and predictors of heart failure in sarcoidosis in a population-based cohort study from Sweden

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► Additional supplemental material is published online only. To view, please visit the journal online (<http://dx.doi.org/10.1136/heartjnl-2021-319129>).

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Received 2 February 2021

Accepted 7 May 2021

## ABSTRACT

**Objectives** Previous studies showed a strong association between sarcoidosis and heart failure (HF) but did not consider risk stratification or risk factors to identify useful aetiological insights. We estimated overall and stratified HRs and identified risk factors for HF in sarcoidosis.

**Methods** Sarcoidosis cases were identified from the Swedish National Patient Register (NPR;  $\geq 2$  International Classification of Diseases-coded visits, 2003–2013) and matched to general population comparators. They were followed for HF in the NPR. Treated were cases who were dispensed  $\geq 1$  immunosuppressant  $\pm 3$  months from the first sarcoidosis visit (2006–2013). Using Cox models, we estimated HRs adjusted for demographics and comorbidity and identified independent risk factors of HF together with their attributable fractions (AFs).

**Results** During follow-up, 204 of 8574 sarcoidosis cases and 721 of 84 192 comparators were diagnosed with HF (rate 2.2 vs 0.7/1000 person-years, respectively). The HR associated with sarcoidosis was 2.43 (95% CI 2.06 to 2.86) and did not vary by age, sex or treatment status. It was higher during the first 2 years after diagnosis (HR 3.7 vs 1.9) and in individuals without a history of ischaemic heart disease (IHD; HR 2.7 vs 1.7). Diabetes, atrial fibrillation and other arrhythmias were the strongest independent clinical predictors of HF (HR 2.5 each, 2-year AF 20%, 16% and 12%, respectively).

**Conclusions** Although low, the HF rate was more than twofold increased in sarcoidosis compared with the general population, particularly right after diagnosis. IHD history cannot solely explain these risks, whereas ventricular arrhythmias indicating cardiac sarcoidosis appear to be a strong predictor of HF in sarcoidosis.

## INTRODUCTION

Heart failure (HF) is a leading cause of impaired functional capacity, low quality of life and premature death in the general population.<sup>1</sup> In sarcoidosis, a systemic granulomatous disease of unknown aetiology, HF is a common cause of excess mortality.<sup>2</sup> Recently, studies showed that rates of HF are about twofold higher in sarcoidosis compared with the general population,<sup>3–5</sup> with more than sevenfold higher risks observed close to sarcoidosis diagnosis.<sup>4</sup> It remains unknown, however, which patients are at the highest risk of HF and may benefit most from preventive interventions.

Also limited is the knowledge on risk factors that contribute to HF risks in sarcoidosis. Diabetes mellitus, ischaemic heart disease (IHD) and other

traditional risk factors for HF in the general population<sup>1</sup> are presumed to also play a role in sarcoidosis. Unique to sarcoidosis is that cardiac involvement may lead to HF.<sup>6</sup> Cardiac sarcoidosis overtly or covertly affects 5%–30% of patients and commonly manifests with ventricular arrhythmias (12-fold increased risk associated with sarcoidosis,<sup>7</sup> conduction anomalies, sudden cardiac arrest or death,<sup>6 8–10</sup> and rarely as atrial fibrillation).<sup>11 12</sup> Data on the relative contribution of traditional and sarcoidosis-specific risk factors to HF are scarce.<sup>6</sup> Because the underlying mechanisms leading to HF in sarcoidosis may vary greatly, it is critical to examine the factors that contribute the most to HF occurrence, which could aid early identification of at-risk patients who might be targeted with the appropriate preventive, diagnostic or therapeutic measures.

Our aim was therefore twofold: (a) to estimate HRs of HF associated with sarcoidosis, overall and by age, sex, sarcoidosis treatment status, time since sarcoidosis diagnosis and history of IHD; and (b) to identify which clinical risk factors confer the highest risk of HF in sarcoidosis.

## METHODS

### Study population

We conducted a cohort study using data from Swedish nationwide registers. The sarcoidosis cohort was comprised of individuals with  $\geq 2$  inpatient or outpatient International Classification of Diseases (ICD)-coded visits for sarcoidosis in the National Patient Register (NPR) between 2003 and 2013 (see online supplemental table S1 for ICD codes). The NPR, a valid resource for identifying sarcoidosis,<sup>13</sup> captures hospitalisations since 1964 (nationwide since 1987) and outpatient visits to secondary care since 2001. Individuals with any sarcoidosis visit before 2003 were excluded to focus on newly diagnosed disease.

At the second visit for sarcoidosis (index date), up to 10 general population comparators without any sarcoidosis visits in the NPR were randomly sampled from the Total Population Register and matched to each case on year of birth, sex and residential location. To reduce sarcoidosis misclassification, we restricted the study population to adults 18–85 years old at index date and to those without a haematopoietic or lung malignancy recorded in the Cancer Register  $\pm 6$  months from the first visit for sarcoidosis or corresponding date for comparators. Records across registers were linked using a



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**To cite:** Rossides M, Kullberg S, Grunewald J, et al. Heart Epub ahead of print: [please include Day Month Year]. doi:10.1136/heartjnl-2021-319129

participant's unique identification number which is allocated by authorities at birth or immigration.

### Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

### Follow-up for HF

The study population was followed for HF, which was defined as an inpatient or outpatient visit in the NPR listing an ICD code for HF or cardiomyopathy as the primary discharge diagnosis (see online supplemental table S1 for codes). This definition for HF yielded positive predictive values of >80% in validation studies.<sup>14</sup> Follow-up started at index date and ended at the earliest of hospital admission or outpatient visit for HF, emigration (Total Population Register), death (Cause of Death Register) or 31 December 2013. Individuals with a history of HF at the start of follow-up were excluded from all analyses.

### Other variables and predictors of HF

Demographic variables were evaluated at the start of follow-up using data obtained from the Total Population Register and the Longitudinal Integrated Database for Health Insurance and Labor Market Studies. They included age, sex, region of residence (grouped into six healthcare regions),<sup>15</sup> country of birth (Nordic, non-Nordic or missing), attained education ( $\leq 9$ , 10–12,  $\geq 13$  years or missing) and civil status (married or in registered partnership, or other).

Using nationwide data on filled prescriptions that first became available in the Prescribed Drug Register (PDR) in July 2005, we classified sarcoidosis cases who entered the cohort in 2006 or later as treated around diagnosis if they were dispensed  $\geq 1$  systemic corticosteroid, methotrexate or azathioprine  $\pm 3$  months from the first sarcoidosis visit. We aimed to capture sarcoidosis cases with debilitating or progressing disease at diagnosis for whom treatment with immunosuppressants is recommended (see codes in online supplemental table S1).<sup>2 15 16</sup>

To account for differences in general health status, we counted NPR visits within 2 years before the first sarcoidosis visit or the corresponding date for comparators (0, 1–3,  $\geq 4$  visits). In addition, we evaluated several clinical confounders and/or potential predictors of HF using data on healthcare visits or medical procedures from the NPR and/or medication dispensations in the PDR, as appropriate (see online supplemental table S1). Comorbidities included hypertension, diabetes mellitus, dyslipidaemia, IHD including acute myocardial infarction (AMI), heart valve disease, atrial fibrillation, other arrhythmias (a composite variable made up of ventricular arrhythmias, conduction anomalies, cardiac arrest, implantation of a cardioverter-defibrillator, receipt of cardiac resynchronisation therapy or  $\geq 2$  dispensations of a class I/III antiarrhythmic medication), pulmonary hypertension, chronic obstructive pulmonary disease, chronic kidney disease, alcohol-related disorders and autoimmune disease. When used as confounders, comorbidities were evaluated 3 months before the first sarcoidosis visit or the corresponding date in comparators to avoid surveillance bias favouring the sarcoidosis group.<sup>15</sup> Last, we defined use of medications that could have altered the risk of HF at baseline as  $\geq 1$  dispensation in the PDR between 3 and 9 months before the first sarcoidosis visit or the corresponding date for comparators.

### Statistical analysis

We estimated incidence rates and rate differences comparing sarcoidosis with the general population and their corresponding 95% CIs using Poisson regression models adjusted for age, sex and region of residence. We used Cox proportional hazards models with attained age as the time scale to estimate HRs of HF comparing sarcoidosis with the general population. Models were sequentially adjusted for: (1) age, sex and region of residence; (2) country of birth, education, civil status and calendar period; (3) hypertension, diabetes mellitus, dyslipidaemia, heart valve disease, atrial fibrillation, chronic obstructive pulmonary disease, chronic kidney disease, alcohol-related disorders, autoimmune disease, and healthcare visits within 2 years before the first sarcoidosis visit or corresponding period for comparators. Unless otherwise stated, the missing-indicator method was used to account for missingness in country of birth and education.

We further investigated differences in HRs comparing sarcoidosis with the general population among groups defined by age at start of follow-up (18–44, 45–64, or 65–85 years), sex, sarcoidosis treatment status around diagnosis (treated vs untreated), time since start of follow-up ( $\leq 2$  vs  $> 2$  years when sarcoid inflammation is expected to subside in about 50% of cases<sup>17</sup>), and by history of IHD/AMI, both causes of ischaemic HF. A two-tailed p value of  $< 0.05$  from a likelihood ratio test was considered indicative of significant differences among groups.

Restricting to the sarcoidosis cohort, we used a Cox model with years since sarcoidosis diagnosis as the time scale adjusted for age at sarcoidosis diagnosis, sex, region of residence, country of birth and education to examine whether predefined predictors evaluated at sarcoidosis diagnosis (second NPR visit) were independently associated with HF. To rank the clinical predictors according to their potential contribution of HF cases, we estimated the attributable fraction at 2 and 10 years after sarcoidosis diagnosis.<sup>18</sup>

We conducted several sensitivity analyses which are detailed in the online supplemental methods section.

We used SAS V.9.4 (SAS Institute) and R V.4.0.2 (R Foundation for Statistical Computing, Vienna, Austria) for data management and analyses.

### RESULTS

We followed 8574 individuals with sarcoidosis and 84 192 matched general population comparators for HF. Mean age at start of follow-up was 49 years (SD 14 years) and 45% of participants were women (table 1). Hypertension, diabetes, dyslipidaemia, atrial fibrillation, chronic obstructive pulmonary, chronic kidney and autoimmune disease were more prevalent in sarcoidosis. Of individuals with sarcoidosis who entered the cohort in 2006 and onwards with available data in the PDR, 41% were dispensed an immunosuppressant treatment around the time of diagnosis. Sarcoidosis cases were more likely to have been dispensed medications used to treat comorbidities (eg, diuretics or  $\beta$ -blockers) than comparators (online supplemental table S2).

### Association between sarcoidosis and HF

During a median follow-up of 4.8 years (IQR 2.3–7.6), 204 individuals with sarcoidosis and 721 general population comparators were diagnosed with HF. The incidence rate of HF was higher in sarcoidosis (2.2/1000 person-years (95% CI 1.9 to 2.6)) than in comparators (0.7/1000 person-years (95% CI 0.7 to 0.8); table 2). After adjusting for demographics and comorbidity, sarcoidosis was associated with a 2.4-fold higher risk of HF (HR 2.43 (95% CI 2.06 to 2.86); table 3). The proportional hazards

**Table 1** Demographic and clinical characteristics at start of follow-up in individuals with sarcoidosis and their matched general population comparators

	Sarcoidosis	General population
Individuals	8574	84 192
Age, years	49.5 (14.6)	49.3 (14.5)
Female	3824 (44.6)	37 606 (44.7)
Region of residence		
Stockholm	1761 (20.5)	17 323 (20.6)
Uppsala-Örebro	1897 (22.1)	18 620 (22.1)
West	1543 (18.0)	15 206 (18.1)
South	1447 (16.9)	14 198 (16.9)
Southeast	977 (11.4)	9565 (11.4)
North	949 (11.1)	9280 (11.0)
Country of birth*		
Nordic	7731 (90.2)	73 841 (87.7)
Non-Nordic	816 (9.5)	10 015 (11.9)
Missing	27 (0.3)	336 (0.4)
Education, years		
≤9	1732 (20.2)	16 974 (20.2)
10–12	4202 (49.0)	39 216 (46.6)
≥13	2493 (29.1)	26 842 (31.9)
Missing	147 (1.7)	1160 (1.4)
Married or in registered partnership	4153 (48.4)	40 366 (47.9)
Calendar period		
2003–2007	3540 (41.3)	34 804 (41.3)
2008–2013	5034 (58.7)	49 388 (58.7)
Healthcare visits within 2 years before the first sarcoidosis visit, n		
0	1462 (17.1)	43 268 (51.4)
1–3	2180 (25.4)	21 799 (25.9)
≥4	4932 (57.5)	19 125 (22.7)
History of morbidity†		
Hypertension	1586 (18.5)	12 104 (14.4)
Diabetes mellitus	586 (6.8)	3176 (3.8)
Dyslipidaemia	827 (9.6)	6218 (7.4)
Ischaemic heart disease or acute myocardial infarction	339 (4.0)	2735 (3.2)
Atrial fibrillation	199 (2.3)	1361 (1.6)
Heart valve disease	69 (0.8)	470 (0.6)
Chronic obstructive pulmonary disease	145 (1.7)	681 (0.8)
Chronic kidney disease	115 (1.3)	297 (0.4)
Alcohol-related disorder	184 (2.1)	2134 (2.5)
Autoimmune disease	629 (7.3)	3428 (4.1)

Data are n, n (%), or mean (SD). Category percentages may not sum up to 100 owing to rounding.

\*Nordic countries include Sweden, Denmark, Norway, Finland and Iceland.

†Evaluated in the period up to 3 months before the first sarcoidosis visit in the National Patient Register or the corresponding date for matched general population comparators.

assumption was visualised using Schoenfeld residuals plots and was found to hold in all analyses. The HR did not vary by age ( $p=0.77$ ), sex ( $p=0.38$ ) or treatment status around sarcoidosis diagnosis ( $p=0.29$ ). It was, however, higher during the first 2 years compared with the rest of follow-up (fully adjusted HR 3.74 (95% CI 2.93 to 4.77) vs 1.86 (95% CI 1.50 to 2.31);  $p<0.001$ ) and in individuals *without* compared with those with a history of IHD/AMI (HR 2.74 (95% CI 2.28 to 3.29) vs 1.70 (95% CI 1.19 to 2.44);  $p=0.02$ ; table 3).

In sensitivity analyses, we found a similar HR to the main analysis when we disregarded HF diagnoses during the first 6 months to account for potential surveillance bias in sarcoidosis (overall HR 2.30 (95% CI 1.94 to 2.74); HR within 2 years from sarcoidosis diagnosis (3.50 (95% CI 2.64 to 4.63)) and a slightly attenuated HR (1.87 (95% CI 1.62 to 2.15)) when we included secondary diagnoses in the HF definition (online supplemental table S3).

### Predictors of HF in sarcoidosis

As shown in table 4, individuals with sarcoidosis who developed HF were more likely to be older, have lower education and more comorbidity (eg, diabetes, IHD, etc) than those who did not develop HF. Arrhythmias were also more common at sarcoidosis diagnosis in those who were diagnosed with HF during follow-up. In a mutually adjusted Cox model including demographic and other clinical predictors, diabetes mellitus, atrial fibrillation, and other arrhythmias were each independently associated with a 2.5-fold increased risk of HF (table 4) and were each estimated to account for 20%, 16%, and 12% of HF cases at 2 years after sarcoidosis diagnosis, respectively (attributable fraction; figure 1). Although history of IHD was one of the most prevalent comorbidities in those who developed HF, it was associated with a 40% increased risk of HF diagnosis during follow-up (mutually adjusted HR 1.4 (95% CI 1.0 to 2.1); attributable fraction at 2 years 7%).

In separate analyses restricting to those diagnosed with sarcoidosis 2006–2013, sarcoidosis treatment status around diagnosis (treated/untreated) and cumulative defined daily doses (DDD) of systemic corticosteroids within 6 months before sarcoidosis diagnosis did not independently predict HF (online supplemental tables S4 and S5). However, dispensation of >300 DDDs (high tertile; one DDD prednisolone=10 mg) of systemic corticosteroids within 6 months after sarcoidosis diagnosis was associated with a twofold increased risk of HF after 6 months compared with ≤150 DDDs (low tertile; online supplemental table S5). Time-varying analyses resulted in a somewhat higher HRs than those from the main analysis for other arrhythmias and IHD (3.1 (95% CI 2.2 to 4.3) and 1.9 (95% CI 1.4 to 2.6), respectively), whereas associations for other predictors did not change markedly (online supplemental table S6).

### DISCUSSION

In this large study, sarcoidosis was associated with a 2.4-fold increased hazard of HF compared with the general population. The HR of HF was highest during the first 2 years after sarcoidosis diagnosis (HR 3.7) but did not vary by age, sex or sarcoidosis treatment status around diagnosis. A higher HR of HF associated with sarcoidosis was observed in individuals without a history of IHD compared with those diagnosed with IHD. Among patients with sarcoidosis, history of diabetes mellitus, atrial fibrillation and other arrhythmias or conduction anomalies at sarcoidosis diagnosis were the strongest independent contributors to HF diagnosis.

Although the overall rate of HF was low given the relatively young age of the sarcoidosis population (mean 50 years), they were markedly higher than those in the matched general population group, even after adjusting for several confounders. This observation was in line with previous investigations.<sup>3–5</sup> The highest rates of HF were observed in individuals ≥65 years old and in those with a history of IHD/AMI, but HF was also seen in younger patients with sarcoidosis and in those without a history of IHD. These findings together with an increased HR of HF

**Table 2** Incidence rates and rate differences of heart failure (per 1000 person-years) comparing sarcoidosis with the general population, overall and by age at start of follow-up, sex, sarcoidosis treatment status around sarcoidosis diagnosis, time since sarcoidosis diagnosis, and history of ischaemic heart disease or acute myocardial infarction

	Sarcoidosis		General population		Rate difference* (95% CI)
	Events/ N at risk	Incidence rate* (95% CI)	Events/ N at risk	Incidence rate* (95% CI)	
Overall	204/8574	2.2 (1.9 to 2.6)	721/84 192	0.7 (0.7 to 0.8)	1.5 (1.1 to 1.8)
Age at start of follow-up, years					
18–44	18/3699	0.8 (0.5 to 1.3)	53/36 549	0.2 (0.2 to 0.3)	0.6 (0.2 to 1.0)
45–64	68/3394	3.3 (2.6 to 4.3)	225/33 578	1.1 (0.9 to 1.3)	2.2 (1.4 to 3.1)
65–85	118/1481	19.0 (15.8 to 22.9)	443/14 065	6.6 (5.9 to 7.3)	12.5 (8.9 to 16.0)
Sex					
Female	90/3824	1.8 (1.4 to 2.4)	329/37 606	0.6 (0.5 to 0.8)	1.2 (0.8 to 1.6)
Male	114/4750	2.4 (2.0 to 3.0)	392/46 586	0.8 (0.7 to 0.9)	1.6 (1.2 to 2.1)
Sarcoidosis treatment around diagnosis†					
Treated	62/2696	3.0 (2.2 to 4.1)	161/26 479	0.7 (0.6 to 0.9)	2.3 (1.4 to 3.1)
Untreated	79/3889	2.1 (1.6 to 2.8)	234/38 120	0.6 (0.5 to 0.8)	1.5 (1.0 to 2.0)
Time since sarcoidosis diagnosis, years					
≤2	98/8574	1.2 (0.9 to 1.5)	223/84 192	0.5 (0.4 to 0.6)	0.7 (0.4 to 0.9)
>2	106/6585	1.0 (0.8 to 1.3)	498/65 949	0.2 (0.2 to 0.3)	0.8 (0.5 to 1.0)
History of ischaemic heart disease or acute myocardial infarction					
Yes	37/339	26.9 (19.4 to 37.4)	186/2735	13.6 (11.5 to 16.1)	13.3 (4.4 to 22.2)
No	167/8235	2.1 (1.8 to 2.5)	535/81 457	0.6 (0.6 to 0.7)	1.5 (1.1 to 1.8)

\*Rates and rate differences per 1000 person-years were estimated using Poisson regression models adjusted for age, sex (if applicable) and region of residence.

†Evaluated in individuals with start of follow-up from 2006 and onwards for whom medication dispensation data were available in the Prescribed Drug Register.

during the first 2 years since sarcoidosis diagnosis, a period of active inflammation in most individuals, suggested that HF and sarcoidosis may be linked by common pathogenetic mechanisms.

Interestingly and similar to a smaller investigation,<sup>3</sup> HRs of HF were not significantly different between sarcoidosis cases

who did and did not receive immunosuppressant treatment around diagnosis. Contrary to what we previously observed for mortality and infection risks,<sup>2, 16</sup> treatment status around diagnosis might not be useful for stratifying patients with sarcoidosis in terms of future HF risk. We should acknowledge,

**Table 3** HRs of heart failure comparing sarcoidosis with the general population, overall and by age at start of follow-up, sex, sarcoidosis treatment status around sarcoidosis diagnosis, time since sarcoidosis diagnosis, and history of ischaemic heart disease or acute myocardial infarction

	HR* (95% CI)		
	Multivariable model 1	Multivariable model 2	Multivariable model 3
Overall	3.03 (2.59 to 3.53)	3.05 (2.61 to 3.57)	2.43 (2.06 to 2.86)
Age at start of follow-up, years			
18–44	3.34 (1.96 to 5.70)	3.29 (1.93 to 5.61)	2.79 (1.63 to 4.78)
45–64	3.09 (2.35 to 4.05)	3.14 (2.39 to 4.12)	2.53 (1.92 to 3.34)
65–85	2.95 (2.41 to 3.62)	2.98 (2.43 to 3.65)	2.32 (1.88 to 2.87)
Sex			
Female	2.92 (2.31 to 3.68)	2.95 (2.33 to 3.72)	2.25 (1.77 to 2.86)
Male	3.12 (2.53 to 3.84)	3.14 (2.55 to 3.87)	2.59 (2.08 to 3.21)
Sarcoidosis treatment around diagnosis†			
Treated	4.23 (3.15 to 5.66)	4.24 (3.17 to 5.69)	3.35 (2.48 to 4.53)
Untreated	3.43 (2.66 to 4.43)	3.43 (2.66 to 4.43)	2.71 (2.08 to 3.52)
Time since sarcoidosis diagnosis, years			
≤2	4.69 (3.70 to 5.95)	4.73 (3.73 to 6.00)	3.74 (2.93 to 4.77)
>2	2.30 (1.87 to 2.84)	2.32 (1.88 to 2.86)	1.86 (1.50 to 2.31)
History of ischaemic heart disease or acute myocardial infarction			
Yes	2.05 (1.44 to 2.92)	2.06 (1.45 to 2.94)	1.70 (1.19 to 2.44)
No	3.32 (2.79 to 3.96)	3.35 (2.82 to 3.99)	2.74 (2.28 to 3.29)

\*HRs were estimated using Cox proportional hazards models with attained age as the time scale. The multivariable model 1 was adjusted for age at start of follow-up, sex and region of residence. The multivariable model 2 was further adjusted for country of birth, education, civil status and calendar period. The multivariable model 3 was further adjusted for healthcare visits within 2 years before inclusion, history of hypertension, diabetes mellitus, dyslipidaemia, heart valve disease, atrial fibrillation, chronic obstructive pulmonary disease, chronic kidney disease, alcohol-related disorders and autoimmune disease. Differences in HRs from the multivariable model 3 among groups were tested using likelihood ratio tests: age at start of follow-up ( $p=0.77$ ); sex ( $p=0.38$ ); sarcoidosis treatment around diagnosis ( $p=0.29$ ); time since sarcoidosis diagnosis ( $p<0.001$ ); history of ischaemic heart disease or acute myocardial infarction ( $p=0.02$ ).

†Evaluated in individuals with start of follow-up from 2006 and onwards for whom medication dispensation data were available in the Prescribed Drug Register.



**Table 4** HRs of heart failure in sarcoidosis associated with covariates evaluated at start of follow-up (second visit for sarcoidosis in the National Patient Register)

	Heart failure		HR* (95% CI)		
	Yes (n=204)	No (n=8370)	Univariable	Multivariable model 1	Multivariable model 2
Age at sarcoidosis diagnosis†, years	67 (59, 76)	48 (37, 60)	2.4 (2.2 to 2.7)	—	1.9 (1.7 to 2.2)
Male	114 (56)	4636 (55)	1.0 (0.8 to 1.3)	—	1.5 (1.1 to 2.0)
Education‡, years				—	
≤9	98 (48)	1781 (21)	4.1 (2.8 to 6.1)		1.9 (1.3 to 2.9)
10–12	73 (36)	4129 (49)	1.3 (0.9 to 2.0)		1.3 (0.9 to 2.0)
≥13	33 (16)	2460 (29)	1.0 (reference)		1.0 (reference)
Hypertension	107 (52)	1789 (21)	5.7 (4.3 to 7.5)	2.2 (1.6 to 2.9)	1.2 (0.9 to 1.7)
Diabetes mellitus	58 (28)	609 (7)	6.2 (4.5 to 8.4)	3.2 (2.3 to 4.4)	2.5 (1.8 to 3.6)
Chronic kidney disease	20 (10)	173 (2)	6.2 (3.9 to 9.9)	1.9 (1.2 to 3.1)	1.4 (0.8 to 2.2)
Alcohol-related disease	10 (5)	186 (2)	2.9 (1.5 to 5.5)	2.4 (1.3 to 4.5)	2.0 (1.0 to 3.9)
Chronic obstructive pulmonary disease	11 (5)	225 (3)	2.4 (1.3 to 4.4)	1.1 (0.6 to 2.1)	1.1 (0.6 to 2.1)
Heart valve disease	16 (8)	73 (1)	11.1 (6.6 to 18.5)	3.8 (2.2 to 6.4)	1.8 (1.0 to 3.1)
Ischaemic heart disease or acute myocardial infarction	47 (23)	343 (4)	7.7 (5.6 to 10.7)	2.4 (1.7 to 3.4)	1.4 (1.0 to 2.1)
Atrial fibrillation	49 (24)	214 (3)	13.6 (9.9 to 18.8)	4.6 (3.2 to 6.5)	2.6 (1.8 to 3.9)
Other arrhythmia or heart block	39 (19)	277 (3)	8.1 (5.7 to 11.5)	4.2 (2.9 to 6.0)	2.5 (1.6 to 3.7)
Pulmonary hypertension	≤5 (2)	7 (<1)	Not estimable	Not estimable	Not estimable
Autoimmune disease	27 (13)	674 (8)	2.0 (1.3 to 3.0)	1.7 (1.1 to 2.5)	1.1 (0.7 to 1.7)

Data are n (%) or median (IQR).

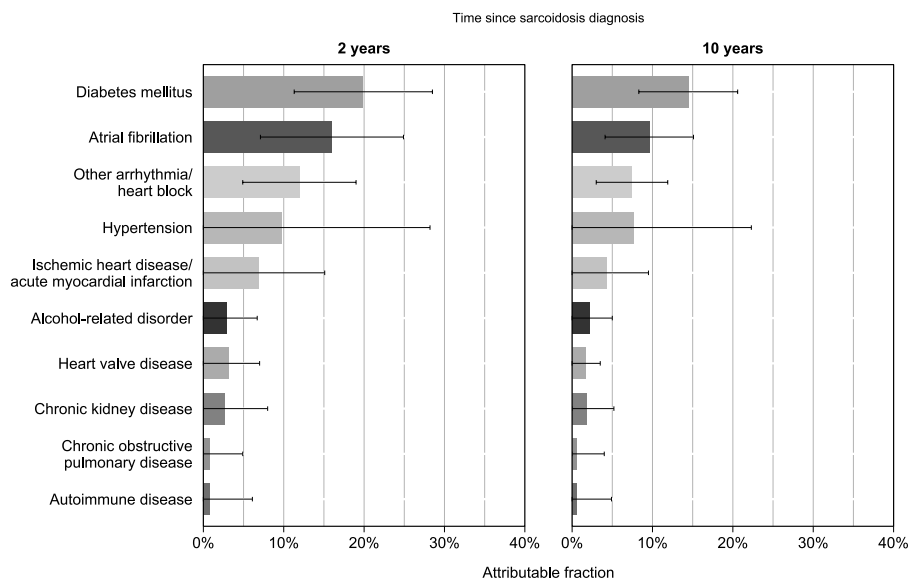
\*HRs were estimated from Cox proportional hazards models with years since sarcoidosis diagnosis as the time scale. The multivariable model 1 included age (continuous), sex, region of residence (six healthcare regions), country of birth (Nordic/non-Nordic) and education. The multivariable model 2 included the covariates age, sex, region of residence, country of birth, education and all comorbidities in the table except pulmonary hypertension due to small numbers.

†Effect per 10-year increase.

‡Category '≤9 years' includes <1% missing.

however, that a higher risk of death in the treated compared with the untreated<sup>2</sup> may have led to a slight underestimation of the true HR of HF in the first. In a separate analysis among treated patients with sarcoidosis, we found that a higher dose of systemic corticosteroids dispensed within 6 months after

sarcoidosis diagnosis was associated with a higher hazard of HF thereafter. The role of immunosuppressant treatment, especially that of corticosteroids, should be investigated further with larger numbers while accounting for disease severity that is an indication for treatment.



**Figure 1** Fraction of heart failure cases at 2 and 10 years after sarcoidosis diagnosis attributed to risk factors evaluated at start of follow-up (second visit for sarcoidosis in the National Patient Register). Attributable fractions were estimated using a Cox model with years since sarcoidosis diagnosis as the time scale and the following time-fixed covariates: age (continuous), sex, region of residence (six healthcare regions), country of birth (Nordic/non-Nordic), education (in three categories) and comorbidities listed in the figure. Error bars indicate 95% CIs.

Among patients with sarcoidosis, sociodemographic factors such as older age, male sex and lower education were associated with a higher hazard of HF. Diabetes mellitus and atrial fibrillation, two traditional risk factors of HF,<sup>19 20</sup> were among the strongest predictors of HF diagnosis also in sarcoidosis. However, no association was observed between hypertension and HF likely due to the inclusion of other predictors of cardiovascular disease. Risks of diabetes and atrial fibrillation peak immediately after sarcoidosis diagnosis<sup>4 21 22</sup> and although it is disputed whether the latter is a manifestation of cardiac sarcoidosis,<sup>11 12</sup> their presence might lead to diagnosis of HF. A large proportion of future HF cases (>35%) could therefore be attributed to factors unrelated to sarcoid heart involvement.

In our study, 19% of patients with sarcoidosis who developed HF had a diagnosis of a ventricular arrhythmia, heart block or cardiac arrest; their prevalence increased to 30% during follow-up. Presumed to be a consequence of cardiac sarcoidosis,<sup>6–8 23</sup> a composite predictor including these severe arrhythmias was independently and equally predictive of increased HF in sarcoidosis as other traditional HF risk factors. Although one study showed congestive HF was more common in patients hospitalised for sarcoidosis with than those without an arrhythmia,<sup>24</sup> data on HF risk factors from other populations are scarce to compare our findings.

IHD and AMI, strong predictors of HF in the general population and other inflammatory diseases,<sup>25–27</sup> were less predictive of HF in sarcoidosis accounting for 7% of HF cases 2 years after sarcoidosis diagnosis. Even though HF rates in our study were notably higher in those with IHD compared with those without irrespective of sarcoidosis status, a higher HR of HF associated with sarcoidosis was observed in those without a history of IHD (2.7 vs 1.7). This observation supports the notion that cardiac sarcoidosis and not IHD alone drives the increased HR of HF. Indeed, unpublished findings showing similar risks of AMI

between sarcoidosis and the general population are suggestive of a weaker role of IHD on HF in sarcoidosis.

Certain limitations of this study are worth considering. No data are available in the NPR to characterise the precise aetiology or severity of HF or define cardiac sarcoidosis. Moreover, because sarcoidosis and HF share symptoms and the diagnostic work-up for the first may reveal the latter, differential misclassification of HF was possible. However, our findings are unlikely to have been greatly affected by this bias as shown in a sensitivity analysis where we disregarded HF diagnoses during the first 6 months since sarcoidosis diagnosis, which yielded similar results to the main analysis. In addition, HF rates reported here may be somewhat underestimated as we have missed some HF cases treated solely in primary care data from which we did not have.<sup>28</sup>

Furthermore, we lacked data on obesity and smoking, two potential confounders of the association between sarcoidosis and HF. It is unlikely, however, that knowledge of these factors would have altered our conclusions by explaining away the strong association. That is because the magnitude of the positive association between obesity and sarcoidosis is the same to that of the inverse association between smoking and sarcoidosis.<sup>29 30</sup> Assuming also a similar effect on HF risk and in the absence of substantial interactions, we would expect a null net effect on the sarcoidosis–HF associations. Our findings are transportable to populations with similar prevalence and severity of cardiac sarcoidosis and other comorbidities predisposing to HF.

Overall, individuals with sarcoidosis are at a considerably higher risk of developing HF compared with the general population, especially during the first 2 years after sarcoidosis diagnosis. Traditional risk factors such as older age, diabetes mellitus and IHD are associated with an increased hazard of HF in sarcoidosis but are unlikely to explain all the observed risks in this population. Ventricular and other arrhythmias, which may be related to cardiac sarcoidosis, are one of the strongest independent predictors of HF and may be responsible for more than 10% of HF cases within 2 years after sarcoidosis diagnosis. Further studies are warranted to identify optimal measures that could help prevent HF in high-risk individuals with sarcoidosis.

## Key messages

### What is already known on this subject?

- ▶ Previous studies suggested that sarcoidosis is associated with notably high relative risks of heart failure. It remains unknown, however, whether risks are increased in specific patient groups or all patients, or if ischaemic heart disease, sarcoidosis-related complications or treatment are associated with heart failure in sarcoidosis.

### What might this study add?

- ▶ This large cohort study of individuals with sarcoidosis and matched general population comparators showed that sarcoidosis is associated with a more than twofold increased risk of heart failure. Relative risks are equally high in women and men and in all ages but are higher during the first 2 years after diagnosis, and in individuals who do not have a history of ischaemic heart disease at the time of sarcoidosis diagnosis. A high proportion of heart failure cases after sarcoidosis may be attributed to diabetes mellitus, atrial fibrillation and sarcoidosis-related arrhythmias.

### How might this impact on clinical practice?

- ▶ Awareness of the higher risks of heart failure in sarcoidosis compared with the general population and of the risk factors to tackle is needed among physicians who care for this patient group.

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**Contributors** MR—conceptualisation, data curation, formal analysis, methodology, software, visualisation, writing (original draft) and writing (review and editing). SK—conceptualisation and writing (review and editing). JG—conceptualisation and writing (review and editing). AE—conceptualisation and writing (review and editing). DDG—conceptualisation and writing (review and editing). JA—conceptualisation and writing (review and editing). EVA—conceptualisation, funding acquisition, resources, supervision and writing (review and editing).

**Funding** The study was supported by a grant from the Swedish Heart-Lung Foundation (Hjärt-Lungfonden; project no. 20170412). The data linkage used in this study was funded by a grant from the Swedish Society of Medicine (Svenska Läkaresällskapet). Sarcoidosis research at Karolinska Institutet is also supported by the Swedish Research Council (Vetenskapsrådet), the Strategic Research Area in Epidemiology at Karolinska Institutet (SfoEpi), and by a regional agreement on medical training and clinical research (ALF) between Region Stockholm and Karolinska Institutet.

**Competing interests** MR reports non-promotional speaker fees from Teva, outside the submitted work.

**Patient consent for publication** Not required.

**Ethics approval** Our study was approved by the Regional Ethics Review Board in Stockholm (2014/230-31), which waived the need to obtain informed consent.

**Provenance and peer review** Not commissioned; internally peer reviewed.

**Data availability statement** The datasets used for the conduct of this study are covered by ethics and secrecy agreements and are not publicly available.

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**SUPPLEMENTAL MATERIAL****Risk and predictors of heart failure in sarcoidosis in a population-based cohort study from Sweden**

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## SUPPLEMENTAL METHODS

### Sensitivity analyses

We conducted several sensitivity analyses. First, to test whether surveillance bias could explain higher risks of heart failure in sarcoidosis than in comparators, we disregarded heart failure diagnoses during the first six months since start of follow-up (second visit for sarcoidosis in the National Patient Register or corresponding date for comparators) in both groups. In addition, we changed our definition of heart failure to also include secondary discharge diagnoses (in addition to the primary) to test the robustness of the definition of heart failure used in our main analyses.

Second, to investigate the role of immunosuppressant treatment for sarcoidosis on the risk of heart failure, we repeated our analysis of heart failure predictors restricting to individuals diagnosed 2006 and onwards for whom data in the Prescribed Drug Register were available. As in the main analyses, we used a Cox model with time since sarcoidosis diagnosis (second visit for sarcoidosis in the National Patient Register) as the time scale and included treatment status around diagnosis in addition to demographic and clinical covariates.

Third, we examined the effect of systemic corticosteroids that patients were dispensed within six months before, and separately, six months after sarcoidosis diagnosis on the risk of heart failure. We used Cox models restricted to individuals who received at least one defined daily dose during the corresponding six-month period before or after sarcoidosis diagnosis to estimate hazard ratios of heart failure associated with dispensation of 50 defined daily doses of systemic corticosteroids, and separately, comparing high and middle to low tertiles of systemic corticosteroids DDDs. In the analysis of cumulative defined daily doses of systemic corticosteroids that were dispensed within six months before sarcoidosis diagnosis, time zero was the date of sarcoidosis diagnosis (second visit for sarcoidosis in the National Patient Register). In the analysis of cumulative defined daily doses within six months after sarcoidosis diagnosis, we started counting follow-up time six months after sarcoidosis diagnosis. Consequently, the latter analysis was restricted to individuals with sarcoidosis living in Sweden at start of follow-up who by that time had not developed heart failure. Due to small numbers, Cox models in both analyses were adjusted for age, sex, region of residence, country of birth (Nordic or non-Nordic including few missing), and education ( $\leq 9$  years including few missing, 10–12, or  $\geq 13$  years).

Last, in a separate analysis including all individuals with sarcoidosis irrespective of the year of diagnosis, we repeated the mutually adjusted Cox model from in the main analysis this time allowing clinical predictors of heart failure to change value during follow-up (time-varying predictors).

## SUPPLEMENTAL TABLES

**Supplemental Table S1.** International Classification of Diseases (ICD; 1964–2013), medical procedure codes (KVÅ; 1997–2013), and Anatomical Therapeutic Chemical (ATC) codes (July 2005–2013) used to define diseases in the National Patient Register and the Prescribed Drug Register.

Disease/Medication	Definition	ICD*, KVÅ, and/or ATC codes
Sarcoidosis	≥2 inpatient or outpatient visits in the National Patient Register	ICD-8/9: 135 ICD-10: D86
Hematopoietic or lung malignancy	≥1 diagnosis ±6 months from first sarcoidosis visit or corresponding date for comparators	ICD-7: 162; 163; 200–205
Sarcoidosis treatment status around diagnosis	≥1 dispensation ±3 months from first sarcoidosis visit	ATC: H02AB01/02/04/06/07; L01BA01; L04AX01/03
Heart failure	≥1 inpatient or outpatient visit where the ICD code for heart failure appears as the primary discharge diagnosis	ICD-8: 402,99; 425,08; 425,09; 427,00; 427,10; 428,99 ICD-9: 425A; 425B; 425E; 425X; 428 ICD-10: I42.0; I42.1; I42.8; I42.9; I43; I50
Hypertension	History of ≥1 visit or ≥2 dispensations evaluated at three months before the first sarcoidosis visit or corresponding date for comparators (or at start of follow-up when used as predictor)	ICD-8: 401–404 ICD-9: 401–405 ICD-10: I10–I15 ATC: C07; C08; C09
Diabetes mellitus	Same as hypertension	ICD-8/9: 250 ICD-10: E10; E11 ATC: A10
Dyslipidemia	Same as hypertension	ICD-8/9: 272 ICD-10: E78 ATC: C10
Stroke	History of ≥1 inpatient visit evaluated at three months before the first sarcoidosis visit or corresponding date for comparators	ICD-8: 430; 431; 432; 433; 434; 436 ICD-9: 430; 431; 433; 434; 436 ICD-10: I60; I61; I63; I64
Heart valve disease	History of ≥1 visit evaluated at three months before the first sarcoidosis visit or corresponding date for comparators (or at start of follow-up when used as predictor)	ICD-9: 424A–424D ICD-10: I34–I37 KVÅ: FMA; FMC; FMD; FMW; FK
Ischemic heart disease or acute myocardial infarction	Same as heart valve disease	ICD-8/9: 410–414 ICD-10: I20–I25
Atrial fibrillation	Same as heart valve disease	ICD-8: 427,92 ICD-9: 427D ICD-10: I48
Chronic obstructive pulmonary disease	Same as heart valve disease	ICD-8: 491; 492 ICD-9: 491A; 491B; 491X; 492; 496 ICD-10: J41–J43; J44.1; J44.8; J44.9

Supplemental Table S1. (Continued.)

Disease/Medication	Definition	ICD*, KVÅ, and/or ATC codes
Chronic kidney disease	Same as heart valve disease	ICD-8: 582–584 ICD-9: 585; 586 ICD-10: N18; N19; Z49.1 Z49.2 KVÅ: DR014; DR015; DR016; DR020; DR012; DR013; DR023; DR024; TJA33; TJA35; KAS00; KAS10; KAS20
Alcohol-related disorders	Same as heart valve disease	ICD-8: 303; 571,0; 577,1 ICD-9: 305A; 535D; 571A; 571B; 571C; 571D; 577B ICD-10: E24.4; F10; G31.2; G62.1; G72.1; K29.2; K70; K86.0; T51
Autoimmune disease	History of $\geq 2$ visits evaluated at three months before the first sarcoidosis visit or corresponding date for comparators (or at start of follow-up when used as predictor)	ICD-8: 136,07; 242,00; 245,30; 255,10; 269,10; 281,0; 283,90; 287,10; 340; 357; 446,20; 446,30; 446,38; 563; 694; 696; 704,00; 712; 716; 733,00; 734,0; 734,1; 734,9 ICD-9: 136B; 242A; 245C; 255E; 281A; 283A; 287D; 340; 357A; 358A; 446E; 446F; 555; 556; 571G; 579A; 694E; 694F; 696; 704A; 710; 714; 720 ICD-10: D51.0; D59.1; D68.6; D69.3; E06.3; E05.0; E10; E27.1; G70.0; G35; G61.0; K50; K51; K74.3; K90.0; L10; L12; L40; L63; M05–M09; M31.3; M31.5; M31.6; M32.1; M32.8; M32.9; M33; M34; M35.0; M35.1; M35.2; M45
Other arrhythmia or heart block	History of $\geq 1$ visit or $\geq 2$ dispensations evaluated at start of follow-up (and during follow-up depending on the analysis)	ICD-8: 426; 427,20–427,98 ICD-9: 416A; 416B; 426; 427 ICD-10: I27.0; I27.2; I44; I45–I47; I49; Z45.0; Z95.0 KVÅ: FPE; PPF; FPG ATC: C01B
Pulmonary hypertension	History of $\geq 1$ visit evaluated at start of follow-up (and during follow-up depending on the analysis)	ICD-8: 426 ICD-9: 416A; 416B ICD-10: I27.0; I27.2
Systemic corticosteroids (defined daily doses analyses)	No. dispensed defined daily doses within six months before/after start of follow-up	ATC: H02AB01/02/04/06/07
Angiotensin-converting enzyme inhibitors or angiotensin II receptor blockers	$\geq 1$ dispensation within the period -6 to -3 months from the first sarcoidosis visit or corresponding date for comparators	ATC: C09
$\beta$ -blockers		ATC: C07
Calcium channel blockers		ATC: C08
Aldosterone antagonists		ATC: C03DA
High-ceiling diuretics		ATC: C03C
Antidiabetics		ATC: A10
Lipid-lowering medications		ATC: C10

**Supplemental Table S1.** (Continued.)

<b>Disease/Medication</b>	<b>Definition</b>	<b>ICD*, KVÅ, and/or ATC codes</b>
Acetylsalicylic acid	≥1 dispensation within the period -6	ATC: B01AC06
Warfarin	to -3 months from the first	ATC: B01AA03
Nitroglycerin	sarcoidosis visit or corresponding	ATC: C01DA02/A14
Digoxin	date for comparators	ATC: C01AA05

ICD = International Classification of Diseases; ATC = Anatomical Therapeutic Chemical; KVÅ = Swedish classification of medical procedures (Klassifikation av vårdåtgärder).

\*The Swedish ICD classification system's 10<sup>th</sup> revision was in use starting 1997, the 9<sup>th</sup> revision between 1987 and 1996 (and 1997 in some healthcare practices) and the 8<sup>th</sup> revision between 1969 and 1986.



**Supplemental Table S2.** History of dispensation of medications related to heart failure risk at baseline ( $\geq 1$  dispensation in the Prescribed Drug Register within six to three months before the first sarcoidosis visit in the National Patient Register or corresponding period for matched general population comparators). Evaluated in individuals who entered the cohort from January 1, 2006 and onwards for whom data in the Prescribed Drug Register were available.

	<b>Sarcoidosis</b>	<b>General population</b>
Individuals	6585	64 599
Angiotensin-converting enzyme inhibitor or angiotensin II receptor blocker	689 (10.5)	5319 (8.2)
$\beta$ -blocker	647 (9.8)	4790 (7.4)
Calcium channel blocker	365 (5.5)	2727 (4.2)
Aldosterone antagonist	43 (0.7)	281 (0.4)
High-ceiling diuretic	212 (3.2)	931 (1.4)
Antidiabetic including insulin	385 (5.8)	2062 (3.2)
Lipid-lowering medication	572 (8.7)	4121 (6.4)
Acetylsalicylic acid	417 (6.3)	3199 (5.0)
Warfarin	95 (1.4)	554 (0.9)
Nitroglycerin	85 (1.3)	640 (1.0)
Digoxin	18 (0.3)	116 (0.2)

Data are n or n (%).

**Supplemental Table S3.** Hazard ratios of heart failure comparing sarcoidosis to the general population from sensitivity analyses.

	Sarcoidosis	General population
<b>Excluding diagnoses of heart failure during the first six months of follow-up</b>		
<b>Overall</b>		
Events/N at risk	182/7994	663/78 360
Incidence rate* (95% CI)	2.2 (1.8, 2.6)	0.8 (0.7, 0.9)
Hazard ratio† (95% CI)	2.30 (1.94, 2.74)	1.00 [Reference]
<b>≤2 years since sarcoidosis diagnosis</b>		
Events/N at risk	72/7994	172/78 360
Hazard ratio† (95% CI)	3.50 (2.64, 4.63)	1.00 [Reference]
<b>&gt;2 years since sarcoidosis diagnosis</b>		
Events/N at risk	110/6597	491/65 447
Hazard ratio† (95% CI)	1.90 (1.53, 2.35)	1.00 [Reference]
<b>Heart failure from main and contributory diagnoses in the National Patient Register</b>		
Events/N at risk	258/8465	1154/82 713
Incidence rate* (95% CI)	2.6 (2.3, 3.1)	1.2 (1.0, 1.3)
Hazard ratio† (95% CI)	1.87 (1.62, 2.15)	1.00 [Reference]

CI = confidence interval.

Data are n unless otherwise stated.

\*Rates per 1000 person-years were estimated using Poisson regression models adjusted for age, sex, and region of residence.

†Hazard ratios were estimated using Cox proportional hazards models with attained age as the time scale and adjusted for age at start of follow-up, sex, region of residence, country of birth, education, civil status, calendar period, healthcare visits within two years before inclusion, history of hypertension, diabetes mellitus, dyslipidemia, heart valve disease, atrial fibrillation, chronic obstructive pulmonary disease, chronic kidney disease, alcohol-related disorders, and autoimmune disease.

**Supplemental Table S4.** Hazard ratios of heart failure in individuals with sarcoidosis diagnosed 2006–2013 associated with covariates evaluated at start of follow-up (second visit for sarcoidosis in the National Patient Register).

	Heart failure		Hazard ratio* (95% CI)
	Yes (n=141)	No (n=6444)	
Median age at sarcoidosis diagnosis† (IQR), years	67 (58, 77)	48 (38, 61)	1.8 (1.6, 2.2)
Male	82 (58)	3557 (55)	1.7 (1.2, 2.4)
Education‡, years			
≤9	61 (43)	1357 (21)	1.8 (1.1, 3.0)
10–12	58 (41)	3207 (50)	1.4 (0.8, 2.3)
≥13	22 (16)	1880 (29)	1.0 [Reference]
Hypertension	86 (61)	1643 (25)	1.2 (0.8, 1.8)
Diabetes mellitus	46 (33)	519 (8)	2.4 (1.6, 3.6)
Chronic kidney disease	12 (9)	144 (2)	1.4 (0.7, 2.6)
Alcohol-related disease	7 (5)	167 (3)	1.6 (0.7, 3.5)
Chronic obstructive pulmonary disease	9 (6)	176 (3)	1.2 (0.6, 2.4)
Heart valve disease	10 (7)	68 (1)	1.5 (0.8, 3.0)
Ischemic heart disease or acute myocardial infarction	38 (27)	277 (4)	1.9 (1.2, 2.9)
Atrial fibrillation	32 (23)	183 (3)	2.2 (1.3, 3.6)
Other arrhythmia or heart block	28 (20)	242 (4)	2.2 (1.3, 3.5)
Pulmonary hypertension	≤5 (1)	7 (<1)	Not estimable
Autoimmune disease	24 (17)	554 (9)	1.5 (1.0, 2.5)
Sarcoidosis treatment around diagnosis	62 (44)	2634 (41)	1.2 (0.8, 1.7)

CI = confidence interval; IQR = interquartile range.

Data are n (%) or mean (standard deviation) unless otherwise stated. Category percentages may not sum up to 100 owing to rounding.

\*Hazard ratios were estimated from a Cox proportional hazards model with years since sarcoidosis diagnosis as the time scale that included the covariates age (continuous), sex, region of residence (six healthcare regions), country of birth (Nordic/non-Nordic), education, sarcoidosis treatment around diagnosis (yes/no), and all comorbidities in the table except pulmonary hypertension due to small numbers.

†Effect per 10-year increase.

‡Category “≤9 years” includes <1% missing.

**Supplemental Table S5.** Hazard ratios of heart failure in individuals with sarcoidosis diagnosed 2006–2013 associated with dispensed defined daily doses of systemic corticosteroids within six months before or six months after sarcoidosis diagnosis (second visit for sarcoidosis in the National Patient Register).

	Heart failure		Hazard ratio* (95% CI)
	Yes	No	
<b>Defined daily doses of systemic corticosteroids within six months before sarcoidosis diagnosis</b>			
Individuals	49	2000	
Mean† (SD)	180 (136)	172 (138)	1.0 (0.9, 1.1)
Median (IQR)	150 (100, 250)	150 (75, 208)	
Low tertile (≤100)	21 (43)	926 (46)	1.0 [Reference]
Mid tertile (101–≤200)	14 (29)	573 (29)	0.9 (0.4, 1.7)
High tertile (>200)	14 (29)	501 (25)	1.1 (0.6, 2.2)
<b>Defined daily doses of systemic corticosteroids within six months after sarcoidosis diagnosis</b>			
Individuals	59	2255	
Mean† (SD)	306 (221)	257 (191)	1.1 (1.0, 1.1)
Median (IQR)	300 (146, 400)	200 (100, 373)	
Low tertile (≤150)	18 (31)	839 (37)	1.0 [Reference]
Mid tertile (151–≤300)	15 (25)	772 (34)	0.8 (0.4, 1.6)
High tertile (>300)	26 (44)	644 (29)	2.1 (1.1, 3.8)

CI = confidence interval; SD = standard deviation; IQR = interquartile range.

Data are n (%) unless otherwise stated. Category percentages may not sum up to 100 owing to rounding.

\*Hazard ratios were estimated from Cox proportional hazards models with years since sarcoidosis diagnosis as the time scale and adjusted for age (continuous), sex, region of residence (six healthcare regions), country of birth (Nordic/non-Nordic including missing), and education (≤9 years including missing/10–12/≥13 years).

†Effect per 50 defined daily doses of systemic corticosteroids.



**Supplemental Table S6.** Hazard ratios of heart failure in individuals with sarcoidosis associated with covariates evaluated at start and during follow-up.

	Heart failure		Hazard ratio* (95% CI)
	Yes (n=204)	No (n=8370)	
Median age at sarcoidosis diagnosis† (IQR), years	67 (59, 76)	48 (37, 60)	1.6 (1.4, 1.8)
Male	114 (56)	4636 (55)	1.4 (1.0, 1.8)
Education‡, years			
≤9	98 (48)	1781 (21)	2.0 (1.3, 3.0)
10–12	73 (36)	4129 (49)	1.3 (0.9, 2.0)
≥13	33 (16)	2460 (29)	1.0 [Reference]
Hypertension	157 (77)	2971 (35)	1.8 (1.2, 2.6)
Diabetes mellitus	77 (38)	992 (12)	2.2 (1.6, 3.1)
Chronic kidney disease	31 (15)	324 (4)	1.5 (1.0, 2.3)
Alcohol-related disease	11 (5)	275 (3)	1.7 (0.9, 3.2)
Chronic obstructive pulmonary disease	22 (11)	387 (5)	1.6 (1.0, 2.6)
Heart valve disease	24 (12)	142 (2)	1.6 (1.0, 2.6)
Ischemic heart disease or acute myocardial infarction	70 (34)	540 (6)	1.9 (1.4, 2.6)
Atrial fibrillation	72 (35)	385 (5)	2.7 (1.9, 3.8)
Other arrhythmia or heart block	62 (30)	489 (6)	3.1 (2.2, 4.3)
Pulmonary hypertension	≤5 (2)	22 (<1)	Not estimable
Autoimmune disease	39 (19)	981 (12)	1.1 (0.8, 1.6)

CI = confidence interval; IQR = interquartile range.

Data are n (%) or mean (standard deviation) unless otherwise stated. Category percentages may not sum up to 100 owing to rounding.

\*Hazard ratios were estimated from a Cox proportional hazards model with years since sarcoidosis diagnosis as the time scale that included the covariates age (continuous), sex, region of residence (six healthcare regions), country of birth (Nordic/non-Nordic), education, and all comorbidities in the table as time-varying covariates except pulmonary hypertension due to small numbers.

†Effect per 10-year increase.

‡Category "≤9 years" includes <1% missing.