ORIGINAL ARTICLE

Surgical treatment of obesity and excess risk of developing heart failure in a controlled cohort study

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Abstract

Aim We aim to assess the risk of heart failure in patients with obesity with and without gastric bypass surgery compared with population controls.

Methods and results This cohort study included all patients aged 20–65 years with a first ever registered principal diagnosis of obesity in the Swedish Patient Register in 2001–2013. These patients were matched by age, sex, and region with two population controls from the general Swedish population without obesity diagnosis. The obesity cohort was divided into two groups: 27 882 patients who had undergone gastric bypass surgery within 2 years of obesity diagnosis and 39 564 patients who had not undergone such surgery. These groups were compared with 55 149 and 78 004 matched population controls, respectively. Cox regression provided hazard ratios (HR) with 95% confidence intervals (CI), adjusted for age, education, and sex. During follow-up (maximum 10 years, median 4.4 years, and interquartile range 2.5–7.2 years), 1884 participants were hospitalized for heart failure. Compared with population controls, gastric bypass patients had no excess risk of heart failure during the initial 0–≤4 years of follow-up (HR = 1.35 [95% CI = 0.96–1.91]) but a marked increased risk during the final >4–10 years of follow-up (HR = 3.28 [95% CI = 2.25–4.77]). Non-operated patients with obesity had a marked excess risk of heart failure throughout the study period compared with population controls.

Conclusions Gastric bypass for obesity seems to reduce the risk of heart failure to levels similar to the general population during the initial 4 years after surgery, but not thereafter.

Introduction

Heart failure is characterized by impaired quality of life and poor prognosis.[1] The frequent hospitalizations of heart failure patients represent a major health burden, constituting a significant proportion of overall healthcare expenditures.[2] The prevalence of heart failure is estimated to be 1–2% in the general adult population and 10–20% in elderly (>85 years) people.[3]

Obesity increases the risk of heart failure; for each unit increase of body mass index (BMI), risk of heart failure increases by 5–7%.[4] Obesity in young individuals is strongly associated with early heart failure, with 5-fold to 10-fold increases in risk in severely obese people aged <45 years compared with lean individuals.[5,6] To which extent the increase in risk is reversible has not been clarified.

Obesity is associated with risk factors for heart failure, including type 2 diabetes,[7] hypertension,[8] and cardiovascular

disease, such as myocardial infarction and atrial fibrillation.[4] A mechanism by which obesity might lead to heart failure[9] is through obesity-related hypertension and diabetes, contributing to diastolic dysfunction [heart failure with preserved ejection fraction (HFpEF)], reflected by atrial fibrillation. Another mechanism involves coronary heart disease and progression to systolic dysfunction leading to reduced ejection fraction (HFrEF).

Patients with obesity who lose a substantial weight over a sustained period can improve their risk of cardiovascular morbidity and mortality.[10] However, such a weight loss is difficult to achieve through lifestyle interventions.[11] To date, bariatric surgery, and gastric bypass in particular, has proven to be the most effective long-term weight-reducing intervention.[12] The weight loss achieved by gastric bypass reduces the incidence of heart failure,[13,14] likely because gastric bypass is associated with improved cardiac function,[15] along with reduction of major risk factors for heart failure, such as myocardial infarction, hypertension, and type 2 diabetes.[16] Because previous studies show a reduced risk of heart failure among gastric bypass patients compared with non-operated obese patients, it is of interest to further assess whether there is a persistent excess risk of heart failure among gastric bypass patients compared with the general population without obesity. The aim of the present study was therefore to assess the long-term risk of heart failure in patients with an obesity diagnosis with and without gastric bypass surgery and compare this risk with matched non-obese controls from the general population.

Methods

Data sources

The Swedish healthcare system offers publicly financed low-cost hospital care to all citizens, with outpatient visits and hospitalizations recorded in the National Patient Register. This register includes complete data on principal and contributory discharge diagnoses and surgical procedures for all hospitalizations in Sweden since 1987 and for specialist outpatient visits since 2001. In general, it has high accuracy and validity compared with patient records as well as for both gastric bypass surgery and heart failure.[17,18] Information on age, sex, diagnoses, surgical procedures, and hospitalization dates was collected from the Patient Register, which does not, however, include information on weight or height. All diagnostic codes are registered according to the International Classification of Diseases (ICD)-9 until 1996 and ICD-10 from 1997 and onwards. Surgical procedures are registered according to the Swedish version 1.9 of the Nordic Medico-Statistical Committees

Classification of Surgical Procedures. The Cause of Death Register, which documents all deaths among Swedish residents, was used to collect information on mortality. The Longitudinal integration database for health insurance and labour market studies (LISA) (80% coverage) was used to obtain information on the educational level. The data from the different registries were linked through the personal identity number, uniquely assigned to each resident in Sweden. The Swedish Prescribed Drug Register (Drug Register) contains information on all prescribed and dispensed medications in Sweden from 2005 onwards and was used to obtain data on dispensed antihypertensive and antidiabetic medication.

The regional ethical review board in Gothenburg approved this study (DNR: 579-15).

Study design and participants

This was a population-based cohort study including all patients between 20 and 65 years old who had a first recorded principal diagnosis of obesity in the Patient Register between 1 January 2001 and 31 December 2013. Obesity was defined using the ICD-10 codes E65 and E66. Gastric bypass surgery was defined with the Swedish Classification of Operations and Major Procedures codes JDF10 or JDF11.

To avoid immortal time bias, we used landmark analysis[19] and split the follow-up time at a prespecified time point (landmark) and set the study baseline 2 years after the obesity diagnosis. Thus, patients with an obesity diagnosis were divided into two groups; one that had undergone gastric bypass surgery within 2 years of obesity diagnosis (81% of all individuals who underwent gastric bypass surgery in Sweden during the study period) and a second with non-operated patients with an obesity diagnosis. All recorded diagnoses occurring during these 2 years were considered co-morbidities, while all diagnoses occurring after the 2 years were considered events. Population controls without any diagnostic code for obesity or surgical code for gastric bypass surgery were randomly selected from Swedish Registry of the Total Population and matched, by year of birth, sex, and area of residence, separately for gastric bypass patients and non-operated patients with an obesity diagnosis. Neither of the data sources used in this study contain data on individual's height or weight.

Individuals who underwent any type of bariatric surgery before the study period were excluded, and non-operated obese patients who underwent any type of bariatric surgery during follow-up were censored at the date of surgery (the procedural codes used for censoring are defined in the Supporting Information, *Table S1*). The inclusion and exclusion criteria are presented in *Figure 1*.

Figure 1 Flow chart of inclusion and exclusion criteria. HF, heart failure; PIN, personal identity number.
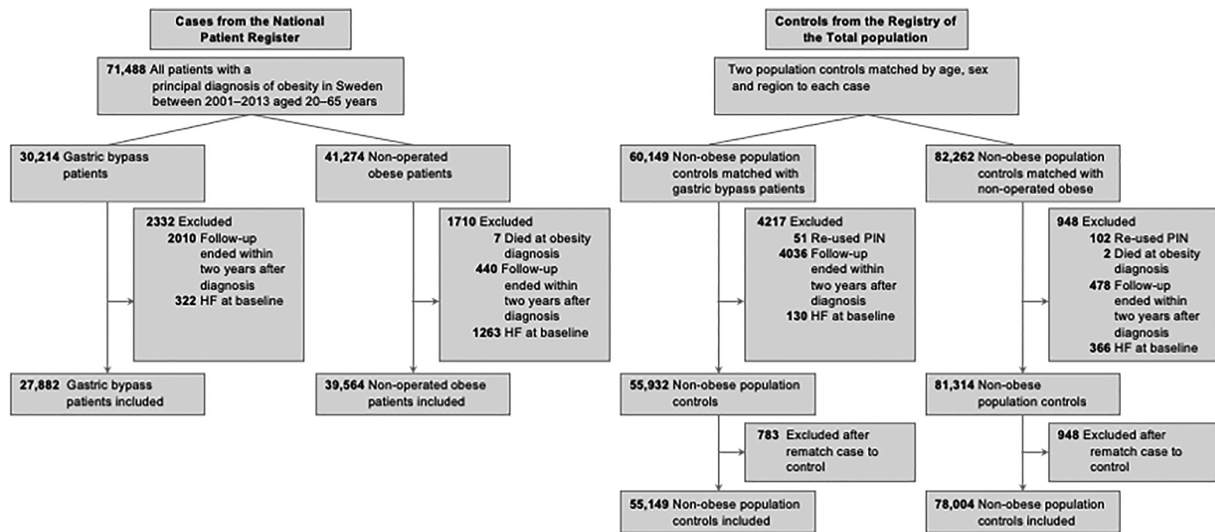
Definition of heart failure and co-morbidities

The outcome was a first recorded diagnosis of heart failure (ICD-10 code I50) in the Patient Register. We assessed both heart failure as a principal and secondary diagnosis because a large proportion of patients diagnosed with heart failure have other primary discharge diagnoses, for example, cardiomyopathy or congenital heart disease. In addition, incidence of heart failure was assessed with pre-existing or concomitant diagnosis of coronary heart disease and atrial fibrillation (ICD codes in the Supporting Information, *Table S2*).

Baseline co-morbidities of interest (prior to or at cohort entry, i.e. 2 years after obesity diagnosis) included hypertension, diabetes mellitus, coronary heart disease, myocardial infarction, atrial fibrillation, valvular disease, cardiomyopathy, malignancy, and ischaemic stroke were identified using ICD codes (Supporting Information, *Table S2*). Diabetes was, in addition to ICD-codes, also identified through medication use in the Prescribed Drug Register, defined as having a dispensed antidiabetic medication (ATC codes A10A or A10B).

Educational level at study baseline was categorized as ≤9 years, 10–12 years, or >12 years of formal education.

Statistical analysis

Baseline characteristics are presented as means and standard deviations (SD) for continuous variables and as numbers and percentages for categorical variables. Logistic regression models providing odds ratios (OR) with 95% confidence intervals (CI) were used to assess associations between baseline

characteristics and the risk of heart failure. The follow-up started at cohort entry and ended at date of heart failure diagnosis, death, reaching the maximum follow-up of 10 years, or end of study at 31 December 2016, whichever occurred first. Because more non-operated obese patients entered the study early compared with the gastric bypass patients, the follow-up time was restricted to a maximum of 10 years to ensure more equal follow-up times. All participants had the possibility of at least 1 year of follow-up.

Multivariable Cox proportional hazard regression models was used to calculate hazard ratios (HR) with 95% CIs and survival functions adjusted for age, education, and sex. The adjusted survival functions represented 41-year-old women with 10–12 years of education. Age-adjusted and sex-adjusted incidence rates were calculated per 1000 person-years, along with approximated 95% CIs. Multivariable Cox regression was also used to calculate HRs of heart failure hospitalization for gastric bypass operated and non-operated obese patients compared with population controls. We used contrast matrices to compare the HRs between the groups. Age and sex were included in the model as covariates, while educational level was included as an interaction term. The proportional hazard assumptions were investigated using methods based on weighted residuals. Because the risk was not proportional during the follow-up period, the follow-up time was split in two with 0–≤4 and >4–10 years of follow-up. After this, all final models fulfilled the proportionality assumptions.

Data management was performed using SAS version 9.4 (SAS Institute, Cary, NC, USA), and the analyses were performed in R version 3.6.2 (The R Project for Statistical Computing, Vienna, Austria).

Results

Study population

The study included 27 882 patients with an obesity diagnosis who had undergone gastric bypass surgery (mean age at landmark 40.7 years, SD 10.3, 75.9% women) and 39 564 non-operated patients with an obesity diagnosis (mean age 42.8 years, SD 11.7, 69.6% women) without any type of bariatric surgery before the landmark at 2 years after diagnosis. The patients that had undergone gastric bypass surgery were matched with 55 149 population controls, and the patients with an obesity diagnosis without surgery were matched with 78 004 population controls. Baseline characteristics of all four groups are shown in *Table 1*. Generally, the non-operated obese patients had more co-morbidities but, among the other groups, co-morbidities were equally distributed.

Risk of heart failure

During the maximum 10 years of follow-up [median 4.4 years; interquartile range (IQR) 2.5–7.2 years], there were 1884 cases of heart failure in total. A majority of these, or 1082, occurred in the non-operated obese category, representing 2.7% of this group, compared with 0.6% among their controls. Corresponding proportions among gastric bypass patients and their controls were 0.6% and 0.3%. The mean age at heart failure diagnosis among gastric bypass and non-operated obese patients was 55.1 years (SD 8.3) and 58.7 (SD 9.0), respectively (*Table 2*).

After adjustment for age, sex, and education level, the probability of heart failure for gastric bypass patients was fairly similar to that of their population controls during the first ≤4 years of follow-up. During the subsequent >4 to 10 years, gastric bypass patients had higher heart failure probability than population controls, however, never

Table 1 Baseline characteristics for gastric bypass patients, non-operated patients with an obesity diagnosis and their population control groups matched for age, sex, and region

Characteristics	Gastric bypass patients (n = 27 882)	Population controls (n = 55 149)	Non-operated patients with obesity (n = 39 564)	Population controls (n = 78 004)
Age (years)	40.7 (10.3)	40.6 (10.3)	42.8 (11.7)	42.6 (11.6)
Female sex	21 163 (75.9%)	41 879 (75.9%)	27 517 (69.6%)	54 397 (69.7%)
Hypertension	11 024 (39.5%)	7804 (14.2%)	15 779 (39.9%)	11 025 (14.1%)
Diabetes mellitus	4949 (17.7%)	1398 (2.5%)	7736 (19.6%)	2239 (2.9%)
Coronary heart disease	698 (2.5%)	510 (0.9%)	1865 (4.7%)	1093 (1.4%)
Myocardial infarction	296 (1.1%)	201 (0.4%)	711 (1.8%)	483 (0.6%)
Atrial fibrillation	313 (1.1%)	196 (0.4%)	666 (1.7%)	417 (0.5%)
Valvular disease	91 (0.3%)	170 (0.3%)	232 (0.6%)	280 (0.4%)
Cardiomyopathy	25 (0.1%)	32 (0.1%)	78 (0.2%)	42 (0.1%)
Malignancy	736 (2.6%)	1693 (3.1%)	1773 (4.5%)	2858 (3.7%)
Ischaemic stroke	223 (0.8%)	216 (0.4%)	506 (1.3%)	401 (0.5%)
Education level				
9 years or less	4788 (17.2%)	6452 (11.7%)	8015 (20.3%)	11 020 (14.1%)
10–12 years	17 118 (61.4%)	25 007 (45.3%)	21 407 (54.1%)	35 587 (45.6%)
>12 years	5854 (21.0%)	22 873 (41.5%)	9754 (24.7%)	30 284 (38.9%)

Data are presented as numbers (percentages) or means (standard deviation).

Table 2 Adjusted incidence rates of heart failure among gastric bypass patients, non-operated patients with an obesity diagnosis and their respective control groups matched for age, sex, and region

	Gastric bypass patients (n = 27 882)	Population controls (n = 55 149)	Non-operated patients with obesity (n = 39 564)	Population controls (n = 78 004)
Heart failure	166 (0.6%)	166 (0.3)	1082 (2.7)	470 (0.6)
Follow-up time (years)	4.0 [2.6; 5.9]	4.1 [2.6; 5.9]	4.8 [2.4; 8.6]	4.9 [2.4; 8.6]
Age at heart failure diagnosis (years)	55.1 (8.3)	53.1 (9.8)	58.7 (9.0)	59.8 (8.6)
Incidence rates	18.1 (15.2–21.5)	8.9 (7.5–10.6)	45.1 (42.4–47.9)	9.6 (8.8–10.5)
Heart failure with coronary heart disease	58 (0.2)	59 (0.1)	396 (1.0)	190 (0.2)
Age at heart failure diagnosis (years)	56.4 (6.9)	56.3 (7.9)	60.2 (7.8)	60.4 (7.8)
Incidence rates	6.5 (4.8–8.7)	3.6 (2.7–4.8)	15.9 (14.3–17.5)	3.8 (3.3–4.4)
Heart failure with atrial fibrillation	69 (0.2)	37 (0.1)	376 (1.0)	153 (0.2)
Age at heart failure diagnosis (years)	56.8 (7.5)	58.3 (5.8)	61.2 (7.7)	62.4 (7.1)
Incidence rates	7.8 (6.0–10.2)	2.4 (1.6–3.5)	14.9 (13.4–16.5)	3.0 (2.5–3.5)

Data presented as numbers (percentages), mean (standard deviation), median [interquartile range], or incidence rates per 1000 observation years (95% CI).

reaching the same levels as those of non-operated patients with an obesity diagnosis (*Figure 2*).

The incidence rate of heart failure in gastric bypass patients (18.1/1000 person-years) was lower than for non-operated obese patients (45.0/1000 person-years). Out of the 166 cases of heart failure among the gastric bypass patients, 35% had pre-existing or concomitant coronary heart disease and 42% had atrial fibrillation. Among the non-operated patients with an obesity diagnosis 40% had pre-existing or concomitant coronary heart disease and 33% had atrial fibrillation (*Table 2*).

The baseline predictors of developing heart failure in all groups included male sex, older age, diabetes mellitus, coronary heart disease, atrial fibrillation, and hypertension. Higher education was protective in all groups except in gastric bypass patients, where no difference was found (*Table 3*).

During the initial ≤4 years of follow-up, the gastric bypass patients had a risk of developing heart failure that was not significantly different to that of population controls (HR 1.35, 95% CI 0.96–1.91). However, after the first 4 years, there was a markedly increased excess risk of heart failure

Figure 2 Age-standardized, sex-standardized, and education-heart failure-free survival. The survival graph was created with multivariable Cox proportional hazard regression models (95% CI) and adjusted for age, education, and sex. The functions represent 41-year-old women with intermediate (10–12 years) education.
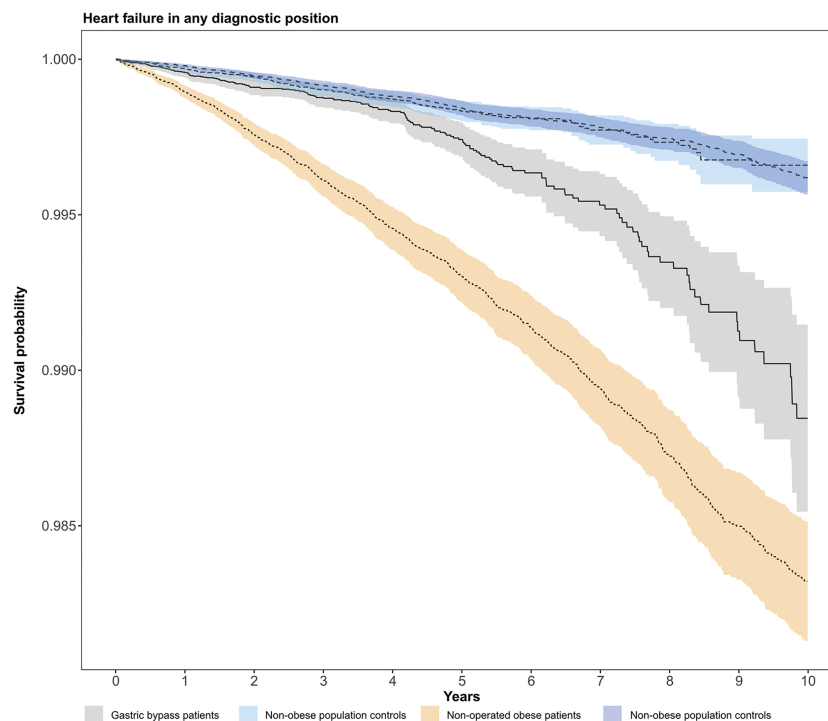

Table 3 Associations of selected baseline characteristics with the risk of heart failure

Characteristics	Gastric bypass patients OR (CI)	Population controls OR (CI)	Non-operated patients with obesity OR (CI)	Population controls OR (CI)
Age	1.08 (1.06–1.11)	1.07 (1.05–1.09)	1.09 (1.08–1.10)	1.10 (1.09–1.12)
Female sex	0.32 (0.23–0.45)	0.59 (0.43–0.81)	0.59 (0.52–0.67)	0.56 (0.46–0.67)
Hypertension	1.41 (0.98–2.03)	3.00 (1.94–4.55)	1.33 (1.15–1.53)	1.37 (1.04–1.79)
Diabetes	1.42 (1.01–1.99)	2.41 (1.49–3.76)	1.63 (1.43–1.87)	1.85 (1.37–2.45)
Coronary heart disease	2.21 (1.39–3.41)	3.31 (1.95–5.45)	2.09 (1.77–2.46)	2.86 (2.12–3.81)
Atrial fibrillation	3.82 (2.24–6.21)	4.03 (1.90–7.78)	2.91 (2.32–3.62)	3.76 (2.47–5.54)
Education				
Intermediate vs lower	0.78 (0.54–1.16)	0.56 (0.39–0.82)	0.59 (0.52–0.67)	0.64 (0.51–0.79)
Higher vs. lower	0.97 (0.61–1.54)	0.47 (0.31–0.73)	0.53 (0.44–0.64)	0.45 (0.35–0.58)

CI, confidence interval; OR, odds ratio.

relative that of their controls (HR 3.28, 95% CI 2.25–4.77). For non-operated patients with an obesity diagnosis, the risk of heart failure was increased relative to that of controls both during the initial follow-up period (HR 4.69, 95% CI 3.78–5.83) and after the first 4 years (HR 5.40, 95% CI 4.23–6.91). Compared with non-operated obese patients, gastric bypass patients had a marked reduced risk of heart failure during both follow-up periods (HR 0.29, 95% CI 0.21–0.39 and HR 0.61, 95% CI 0.43–0.85, respectively). In a sensitivity analysis, the model was further adjusted for pre-existing hypertension, diabetes, coronary heart disease, atrial fibrillation, and ischaemic stroke, and the results were similar to those of the main analysis (Supporting Information, *Table S3*).
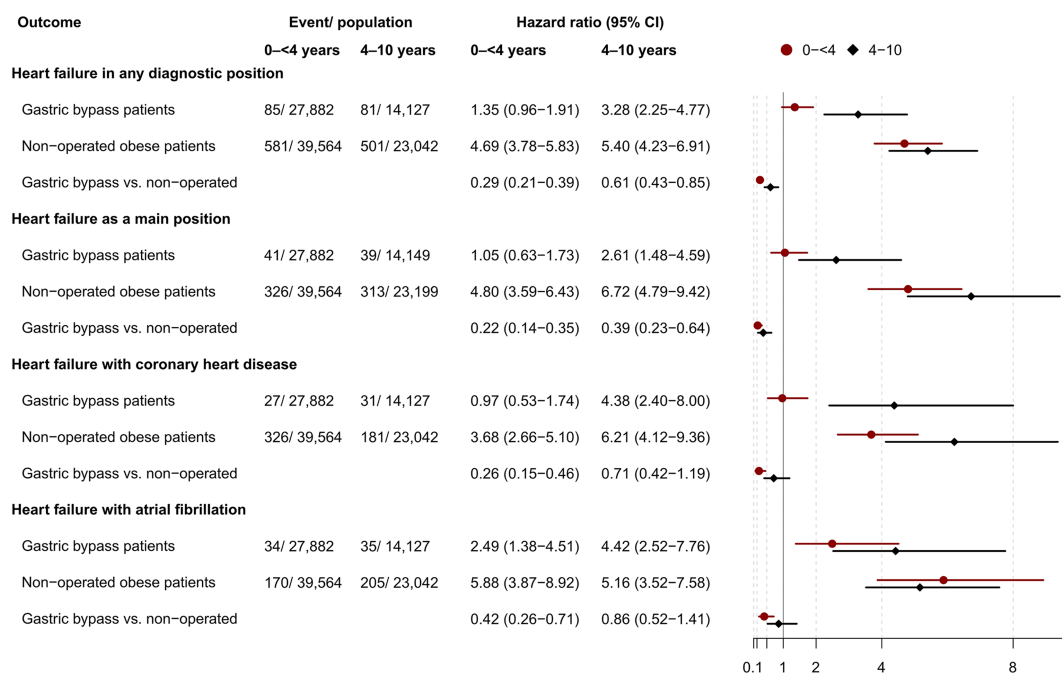
In gastric bypass patients with coronary heart disease, the short-term risk for heart failure was similar to that of population controls (HR 0.97, 95% CI 0.53–1.74), but in the long-term, there was a more than three-fold excess risk (HR 4.38, 95% CI 2.40–8.00). This pattern was not found for heart failure with atrial fibrillation, where gastric bypass patients had an excess risk throughout the study period, compared with population controls (*Figure 3*). Throughout the study period, the non-operated patients with an obesity diagnosis with either coronary heart disease or atrial fibrillation diagnosis had markedly higher risk of heart failure compared with their population controls (*Figure 3*).

Discussion

In this population-based cohort study, we found that obese patients who had undergone gastric bypass surgery had a similar risk of heart failure to that of population controls without an obesity diagnosis during the initial 4 years of follow-up, but after this period, they had a marked increased risk compared with population controls. The non-operated patients with an obesity diagnosis had a higher risk of heart failure than their population controls throughout the follow-up period. Gastric bypass patients had a marked reduced risk of heart failure compared with non-operated patients with obesity throughout the study period.

Our group[20] and others[13,14] have previously shown that bariatric surgery lowers the incidence of heart failure in patients with an obesity diagnosis. This was confirmed also in the present study. The largest weight loss occurs approximately 1 year after gastric bypass surgery, and is in the range of 31–38%[21] and the greater the weight loss the larger the risk reduction for heart failure.[13] This could be an explanation for the attenuated risk of heart failure among the gastric bypass patients during the first 4 years of follow-up, where the excess risk for heart failure during the second follow-up period (>4–10 years) could be due partly to a regain in weight after the initial weight loss[22]

Figure 3 Hazard ratios for all outcomes, during 0–<4 and >4–10 years of follow-up comparing gastric bypass and non-operated obese patients with non-obese population controls, and gastric bypass with non-operated obese. CI, confidence intervals.

Outcome	Event/ population		Hazard ratio (95% CI)		
	0–<4 years	4–10 years	0–<4 years	4–10 years	● 0–<4 ◆ 4–10
Heart failure in any diagnostic position					
Gastric bypass patients	85/ 27,882	81/ 14,127	1.35 (0.96–1.91)	3.28 (2.25–4.77)	
Non−operated obese patients	581/ 39,564	501/ 23,042	4.69 (3.78–5.83)	5.40 (4.23–6.91)	
Gastric bypass vs. non−operated			0.29 (0.21–0.39)	0.61 (0.43–0.85)	
Heart failure as a main position					
Gastric bypass patients	41/ 27,882	39/ 14,149	1.05 (0.63–1.73)	2.61 (1.48–4.59)	
Non−operated obese patients	326/ 39,564	313/ 23,199	4.80 (3.59–6.43)	6.72 (4.79–9.42)	
Gastric bypass vs. non−operated			0.22 (0.14–0.35)	0.39 (0.23–0.64)	
Heart failure with coronary heart disease					
Gastric bypass patients	27/ 27,882	31/ 14,127	0.97 (0.53–1.74)	4.38 (2.40–8.00)	
Non−operated obese patients	326/ 39,564	181/ 23,042	3.68 (2.66–5.10)	6.21 (4.12–9.36)	
Gastric bypass vs. non−operated			0.26 (0.15–0.46)	0.71 (0.42–1.19)	
Heart failure with atrial fibrillation					
Gastric bypass patients	34/ 27,882	35/ 14,127	2.49 (1.38–4.51)	4.42 (2.52–7.76)	
Non−operated obese patients	170/ 39,564	205/ 23,042	5.88 (3.87–8.92)	5.16 (3.52–7.58)	
Gastric bypass vs. non−operated			0.42 (0.26–0.71)	0.86 (0.52–1.41)	

and subsequent re-emerging risk factors, that is, hypertension and diabetes, in the long-term after surgery.[21] In contrast, individuals with obesity without surgical intervention tend to remain weight stable or gain weight over time,[23] which likely explains the observed persistent excess risk in this group compared with population controls throughout the follow-up period.

Heart failure associated with obesity may involve changes in the cardiac haemodynamics and metabolic derangement.[24] Excess body weight results in a higher metabolic demand, which requires an increase in blood volume and cardiac output.[25] This, in turn, leads to higher preload and development of left ventricular hypertrophy and left atrial enlargement.[26] Other obesity-related co-morbidities that can contribute to cardiac dysfunction include type 2 diabetes, hypertension, obstructive sleep apnoea, the metabolic syndrome, and atherosclerosis.[27] Some of these pathophysiological processes can be alleviated by substantial weight loss and reverse the haemodynamic overload, which could counteract left ventricular hypertrophy[28] with a subsequent reversal of diastolic dysfunction.[29] Weight loss following gastric bypass surgery may also reduce risk of other conditions predisposing for heart failure, including myocardial infarction,[12] atrial fibrillation,[22] diabetes, hypertension, and dyslipidaemia,[21] where studies have reported a 77% complete resolution in diabetes mellitus, 62% resolution in hypertension, and substantial improvement in hyperlipidaemia.[30] This could partly explain a low risk of heart failure in patients with coronary heart disease during the initial follow-up period post-surgery, comparable with the general population.

Notably, this study did not show any beneficial effect on the risk for heart failure in surgically treated patients with atrial fibrillation. This could have to do with the limited follow-up time because the favourable effects of bariatric surgery on cardiac remodelling and the primary preventive effect on development of atrial fibrillation have been shown to take several years.[22]

Strengths and limitations

Among main strengths of this study are the population-based design and large sample size, including almost all individuals in Sweden diagnosed with obesity who underwent gastric bypass surgery during the study period. Other strengths include the availability of matched controls from the general population and a long and complete follow-up, where a heart failure diagnosis has been demonstrated to have high validity.[18] The main limitations are the lack of data on height and weight and the observational nature of the study which precludes causal inferences because of the inherent risk of confounding. Lack of echocardiographic data and missing out on heart failure cases in primary care settings are other limitations. Because of lack of primary care data, there is a risk of detec-

tion bias of co-morbidities as patients with obesity are more likely to receive hospital inpatient or outpatient care than population controls. It should also be noted that the prevalence of pre-existing co-morbidities was not evenly distributed across groups. Gastric bypass patients had a lower prevalence of coronary heart disease compared with non-operated obese patients, and the prevalence of co-morbidities among population controls were approximately half of that of the patients with obesity. However, after adjustment for pre-existing co-morbidity, the relative risk of heart failure across groups persisted. In addition, within the age range of the present study, it is unlikely that heart failure would be managed without a hospital specialist consultation. Finally, a selection bias among patients who undergo bariatric surgery is likely and should be considered when interpreting the results.

Conclusions

Gastric bypass surgery in patients with obesity may substantially reduce the risk of heart failure during the initial 4 years after surgery to levels comparable with that of the general population. During >4–10 years of follow-up, the risk of heart failure increased but remained lower than that of non-operated patients with obesity. Atrial fibrillation and coronary heart disease were predictors of heart failure in all groups. Gastric bypass surgery was associated with a decreased risk of heart failure of ischaemic origin, but not of heart failure with atrial fibrillation. Longer follow-up periods, preferably >20 years, are necessary to depict the true risk reduction outcome from gastric bypass surgery.

Conflict of interest

None of the authors has any conflicts of interest to declare with respect to the present study.

Funding

Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. Codes from the Swedish version of the NOMESCO Classification of Surgical Procedures[a], used for censoring bariatric surgery patients before and during the study period.

Table S2. Codes from the International Classification of Diseases 9th and 10th Revision[a], used for censoring and to define comorbidity[b].

Table S3. Sensitivity analysis of hazard ratios for heart failure in any position, with additional adjustment for pre-existing hypertension, diabetes, coronary heart disease, atrial fibrillation, and ischemic stroke.

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