Reintervention or mortality within 90 days of bariatric surgery: population-based cohort study

J. H. Kauppila[1,2], G. Santoni[1], W. Tao[1], E. Lynge[5], V. Koivukangas[2], L. Tryggvadóttir[6,7], E. Ness-Jensen[1,8], P. Romundstad[8], E. Pukkala[3,4], M. von Euler-Chelpin[5] and J. Lagergren[1,9]

[1]Upper Gastrointestinal Surgery, Department of Molecular Medicine and Surgery, Karolinska Institutet, Karolinska University Hospital, Stockholm, Sweden, [2]Surgery Research Unit, Medical Research Centre Oulu, University of Oulu and Oulu University Hospital, Oulu, [3]Finnish Cancer Registry, Institute for Statistical and Epidemiological Cancer Research, Helsinki, and [4]Faculty of Social Sciences, Tampere University, Tampere, Finland, [5]Department of Public Health, University of Copenhagen, Denmark, [6]Icelandic Cancer Registry, Icelandic Cancer Society, and [7]Faculty of Medicine, Laeknagardur, University of Iceland, Reykjavik, Iceland, [8]Department of Public Health and Nursing, Norwegian University of Science and Technology, Trondheim, Norway, and [9]School of Cancer and Pharmaceutical Sciences, King's College London, and Guy's and St Thomas' NHS Foundation Trust, London, UK

Correspondence to: Dr J. Lagergren, Upper Gastrointestinal Surgery, NS 67, Second Floor, Department of Molecular Medicine and Surgery, Karolinska Institutet, Karolinska University Hospital, 17176 Stockholm, Sweden (e-mail: jesper.lagergren@ki.se)

Background: **Bariatric surgery carries a risk of severe postoperative complications, sometimes leading to reinterventions or even death. The incidence and risk factors for reintervention and death within 90 days after bariatric surgery are unclear, and were examined in this study.**

Methods: **This population-based cohort study included all patients who underwent bariatric surgery in one of the five Nordic countries between 1980 and 2012. Data on surgical and endoscopic procedures, diagnoses and mortality were retrieved from national high-quality and complete registries. Multivariable Cox regression analysis was used to calculate hazard ratios (HRs), adjusted for country, age, sex, co-morbidity, type of surgery and approach, year and hospital volume of bariatric surgery.**

Results: **Of 49 977 patients, 1111 (2·2 per cent) had a reintervention and 95 (0·2 per cent) died within 90 days of bariatric surgery. Risk factors for the composite outcome reintervention/mortality were older age (HR 1·65, 95 per cent c.i. 1·36 to 2·01, for age at least 50 years *versus* less than 30 years) and co-morbidity (HR 2·66, 1·53 to 4·62, for Charlson co-morbidity index score 2 or more *versus* 0). The risk of reintervention/mortality was decreased for vertical banded gastroplasty compared with gastric bypass (HR 0·37, 0·28 to 0·48) and more recent surgery (HR 0·51, 0·39 to 0·67, for procedures undertaken in 2010 or later *versus* before 2000). Sex, surgical approach (laparoscopic *versus* open) and hospital volume did not influence risk of reintervention/mortality, but laparoscopic surgery was associated with a lower risk of 90-day mortality (HR 0·29, 0·16 to 0·53).**

Conclusion: **Reintervention and death were uncommon events within 90 days of bariatric surgery even in this unselected nationwide cohort from five countries. Older patients with co-morbidities have an increased relative risk of these outcomes.**

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Introduction

Obesity, defined by a BMI of at least 30 kg/m^2, occurred in over 600 million adults in the world in 2015, and the prevalence continues to increase[1]. The main treatments are lifestyle interventions and medication, but bariatric surgery is considered an effective treatment for severe obesity[2]. Compared with non-surgical treatment, bariatric surgery in severely obese patients is associated with better survival and lower prevalence of cardiovascular diseases and diabetes during the early postoperative years[3–11], although the relative mortality might increase again in the long term[12]. These positive outcomes have contributed to a rapid increase in bariatric surgery. However, bariatric surgery carries a risk of severe postoperative complications, including those leading to reintervention and even death[13,14].

Some risk factors for 30-day reintervention and mortality have been suggested, including older age, male sex, tobacco smoking, high ASA fitness grade, co-morbidity, poor functional status and open surgery[13,15–17]. However, there is a lack of large-scale studies of unselected (population-based) cohorts, and short-term outcomes seem more relevant if assessed within 90 days rather than 30 days of upper gastrointestinal surgery[18,19]. Therefore, the present study aimed to estimate the incidence of, and identify risk factors for, reintervention or death within 90 days of bariatric surgery in a large and unselected cohort. It was hypothesized that rates of postoperative reintervention or death would be increased in older patients and men, patients with more co-morbidity, those who underwent open surgery or types of bariatric surgery other than gastric banding, and patients treated in lower-volume hospitals or during earlier years.

Methods

This population-based cohort study covered the 33-year interval between 1980 and 2012. The study examined the rate of reintervention and all-cause mortality within 90 days of bariatric surgery using nationwide data from well maintained health data registries in the five Nordic countries: Denmark, Finland, Iceland, Norway and Sweden. The source cohort, the Nordic Obesity Surgery Cohort (NordOSCO), has been described elsewhere[20]. The first analytical study based on data from NordOSCo examined bariatric surgery in relation to long-term survival[12]. All Nordic countries have similar and virtually complete records of hospital admissions and intervention codes, including diagnoses and surgical and endoscopic interventions[21]. Reporting of this information for each patient to the national health data registries is mandatory by law, and is linked to remuneration of the Nordic hospitals[21]. Follow-up for mortality is complete for all residents. At birth or on immigration, each Nordic resident receives a unique personal identity code, which enabled accurate linkage of individual data between registers for each participant[21–23]. The study was approved by all relevant ethical committees, data inspectorates and register holders in each of the participating countries[20].

Bariatric surgery cohort

The present study included individuals diagnosed with obesity combined with a bariatric surgery code recorded in any of the Nordic patient registries[20]. These registries hold complete nationwide information on in-hospital care and outpatient specialist care, including diagnoses and surgical and endoscopic procedures. The concordance of the diagnoses and procedures recorded in the patient registries is generally high compared with patient records[24–26], and is very high (97 per cent concordant) for bariatric surgery in particular[27]. The period of data retrieval varied between the countries: from 1996 to 2011 in Denmark, 1996 to 2012 in Finland, 1999 to 2012 in Iceland, 2007 to 2011 in Norway, and 1980 to 2012 in Sweden. The indications for bariatric surgery were similar among the participating centres, and the countries shared clinical guidelines. The bariatric procedures comprised mainly gastric bypass, followed by gastric banding and vertical banded gastroplasty. Sleeve gastrectomy was rarely performed in the Nordic countries during the study interval and had no separate code in the patient registries.

Potential risk factors

Seven potential risk factors were examined, categorized as follows: age (less than 30, 30–39, 40–49 or at least 50 years at the time of surgery), sex (male or female), co-morbidity (Charlson co-morbidity index score 0, 1 or at least 2), type of bariatric surgery (gastric bypass, vertical banded gastroplasty, gastric banding, malabsorptive procedures or other bariatric procedures), surgical approach (open or laparoscopic), calendar year of surgery (before 2000, 2000–2009, or 2010 or later) and hospital volume of surgery (in tertiles, 3 similar sized groups). The ten-year cut-off values for age were chosen because the number in each group was close to the quartiles. Co-morbidity was assessed using the most recent and well validated version of the Charlson co-morbidity index[28]. Diagnoses in the patient registries recorded up to 1 year before entry into the cohort were included to allow relevant co-morbidities to be included. The type of bariatric surgery and surgical approach were determined by the specific surgical codes in the patient registries. ASA fitness grade was not available in the registries. The code representing other bariatric procedures did not specify the type of bariatric surgery, but included sleeve gastrectomies, balloon procedures and some combined sleeve gastrectomy and duodenal switch procedures. The malabsorptive procedure codes included biliopancreatic diversion, duodenal switch and jejunoileal bypass procedures. Calculation of hospital volume of bariatric surgery was possible for data from Finland, Iceland and Sweden, because the hospital codes were available in these countries in NordOSCO, but not for Denmark or Norway. For each hospital and year, the annual hospital volume was calculated as the mean of any bariatric surgery procedures during the index year and previous 3 years in one specific hospital. This strategy was chosen to reduce random variations in the annual hospital volume variable[29]. If data for fewer than 3 previous years were available, calculation of the average was based on all available years.

Table 1 Characteristics of 49 977 patients who underwent bariatric surgery in any of the five Nordic countries

		Outcome within 90 days of surgery		
	Bariatric surgery (*n* = 49 977)	Reintervention/ mortality (*n* = 1192)	Reintervention (*n* = 1111)	Mortality (*n* = 95)
Country				
Denmark	3269 (6·5)	79 (6·6)	70 (6·3)	10 (11)
Finland	4429 (8·9)	118 (9·9)	114 (10·3)	5 (5)
Iceland	731 (1·5)	0 (0)	0 (0)	0 (0)
Norway	5507 (11·0)	93 (7·8)	84 (7·6)	9 (9)
Sweden	36 041 (72·1)	902 (75·7)	843 (75·9)	71 (75)
Age (years)				
< 30	7815 (15·6)	148 (12·4)	143 (12·9)	5 (5)
30–39	14 388 (28·8)	291 (24·4)	275 (24·8)	17 (18)
40–49	15 922 (31·9)	382 (32·0)	361 (32·5)	28 (29)
≥ 50	11 852 (23·7)	371 (31·1)	332 (29·9)	45 (47)
Sex				
M	12 730 (25·5)	331 (27·8)	296 (26·6)	40 (42)
F	37 247 (74·5)	861 (72·2)	815 (73·4)	55 (58)
Charlson co-morbidity index score				
0	46 648 (93·3)	1083 (90·9)	1021 (91·9)	74 (78)
1	3122 (6·3)	96 (8·0)	81 (7·3)	17 (18)
≥ 2	207 (0·4)	13 (1·1)	9 (0·8)	4 (4)
Type of bariatric surgery				
Gastric bypass	36 678 (73·4)	875 (73·4)	822 (74·0)	64 (67)
Vertical banded gastroplasty	5487 (11·0)	155 (13·0)	140 (12·6)	17 (18)
Gastric banding	5450 (10·9)	78 (6·5)	71 (6·4)	7 (7)
Other bariatric procedures	1578 (3·2)	53 (4·4)	50 (4·5)	4 (4)
Malabsorptive procedures	784 (1·6)	31 (2·6)	28 (2·5)	3 (3)
Surgical approach				
Open	13 601 (27·2)	393 (33·0)	348 (31·3)	53 (56)
Laparoscopic	36 376 (72·8)	799 (67·0)	763 (68·7)	42 (44)
Year of surgery				
Before 2000	9085 (18·2)	252 (21·1)	224 (20·2)	34 (36)
2000–2009	18 725 (37·5)	504 (42·3)	469 (42·2)	38 (40)
2010 onwards	22 167 (44·4)	436 (36·6)	418 (37·6)	23 (24)
Hospital volume				
Lowest (< 7 operations)	1692 (3·4)	59 (4·9)	53 (4·8)	8 (8)
Medium (7–25 operations)	6590 (13·2)	154 (12·9)	140 (12·6)	14 (15)
Highest (≥ 26 operations)	32 919 (65·9)	807 (67·7)	764 (68·8)	54 (57)
Missing*	8776 (17·6)	172 (14·4)	154 (13·9)	19 (20)
No. of reinterventions				
0	48 866 (97·8)	81 (6·8)	0 (0·0)	81 (85)
1	1010 (2·0)	1010 (84·7)	1010 (90·9)	14 (15)
2	88 (0·2)	88 (7·4)	88 (7·9)	0 (0)
≥ 3	13 (0·03)	13 (1·1)	13 (1·2)	0 (0)
First reintervention†				
Operative	813 (1·6)	813 (68·2)	813 (73·2)	13 (14)
Percutaneous drain	65 (0·1)	65 (5·5)	65 (5·8)	0 (0)
Tracheostomy	17 (0·03)	17 (1·4)	17 (1·5)	1 (1)
Endoscopic	295 (0·6)	295 (24·7)	295 (26·6)	0 (0)

Values in parentheses are percentages. *Hospital volume data were not available for Denmark and Norway. †Some reinterventions were done at the same time.

Table 2 Hazard ratios for the composite outcome reintervention/mortality within 90 days of bariatric surgery

	No. of patients with outcome* (*n* = 1192)	Hazard ratio for reintervention/ mortality†‡
Age (years)		
< 30	148 (12·4)	1·00 (reference)
30–39	291 (24·4)	1·07 (0·88, 1·31)
40–49	382 (32·0)	1·29 (1·06, 1·56)
≥ 50	371 (31·1)	1·65 (1·36, 2·01)
Sex		
M	331 (27·8)	1·00 (reference)
F	861 (82·2)	0·94 (0·83, 1·07)
Charlson co-morbidity index score		
0	1083 (90·9)	1·00 (reference)
1	96 (8·1)	1·34 (1·09, 1·66)
≥ 2	13 (1·1)	2·66 (1·53, 4·62)
Type of bariatric surgery		
Gastric bypass	875 (73·4)	1·00 (reference)
Vertical banded gastroplasty	155 (13·0)	0·73 (0·58, 0·92)
Gastric banding	78 (6·5)	0·37 (0·28, 0·48)
Other bariatric procedures	53 (4·4)	1·41 (1·05, 1·89)
Malabsorptive procedures	31 (2·6)	1·20 (0·82, 1·76)
Surgical approach		
Open	393 (33·0)	1·00 (reference)
Laparoscopic	799 (67·0)	0·87 (0·73, 1·04)
Year of surgery		
Before 2000	252 (21·1)	1·00 (reference)
2000–2009	504 (42·3)	0·77 (0·61, 0·97)
2010 onwards	436 (36·6)	0·51 (0·39, 0·67)
Hospital volume§		
Lowest (< 7 operations)	59 (5·8)	1·00 (reference)
Medium (7–25 operations)	154 (15·1)	0·70 (0·52, 0·95)
Highest (≥ 26 operations)	807 (79·1)	0·80 (0·61, 1·07)

Values in parentheses are *percentages and †95 per cent confidence intervals. ‡Adjusted for country, age, sex, Charlson co-morbidity index, type of surgery, surgical approach and year of surgery, but not the factor being analysed. §Hospital volume analysis includes data only from Finland, Iceland and Sweden, with categorization in tertiles, based on mean number of procedures in that hospital during the past 4 years.

Table 3 Stratified analyses for the composite outcome reintervention/mortality within 90 days of bariatric surgery for co-variables with a statistically significant interaction

	No. of patients with outcome*	Hazard ratio for reintervention/ mortality†‡
Open surgical approach		
Sex		
M	132 (33·6)	1·00 (reference)
F	261 (66·4)	0·66 (0·54, 0·82)
Year of surgery		
Before 2000	234 (59·5)	1·00 (reference)
2000–2009	130 (33·1)	0·73 (0·57, 0·94)
2010 or later	29 (7·4)	0·91 (0·60, 1·37)
Laparoscopic surgical approach		
Sex		
M	199 (24·9)	1·00 (reference)
F	600 (75·1)	1·13 (0·96, 1·33)
Year of surgery		
Before 2000	18 (2·3)	1·00 (reference)
2000–2009	374 (46·8)	0·59 (0·36, 0·96)
2010 or later	407 (50·9)	0·37 (0·23, 0·61)
Surgery before 2000		
Type of bariatric surgery		
Gastric bypass	58 (82·9)	1·00 (reference)
Other bariatric procedures	12 (17·1)	0·61 (0·33, 1·13)
Surgery in 2000–2009		
Type of bariatric surgery		
Gastric bypass	417 (95·6)	1·00 (reference)
Other bariatric procedures	19 (4·4)	1·59 (1·00, 2·55)
Surgery in 2010 or later		
Type of bariatric surgery		
Gastric bypass	400 (94·8)	1·00 (reference)
Other bariatric procedures	22 (4·8)	2·01 (1·29, 3·15)

Values in parentheses are *percentages and †95 per cent confidence intervals. ‡Adjusted for country, age, sex, Charlson co-morbidity index, type of surgery, surgical approach and year of surgery, but not the factor being analysed.

Outcomes

The primary outcome was the first occurrence of any reintervention or death from any cause within the first 90 postoperative days. This composite outcome (reintervention/mortality) was used to avoid bias owing to the competing risk of mortality when examining the risk of reintervention, that is patients might die from complications before reintervention was possible. Secondary outcomes were the separate outcomes reintervention within 90 days of surgery and all-cause 90-day mortality. Subanalyses were conducted by type of reintervention: operative intervention, defined as any abdominal or thoracic invasive operation; endoscopic intervention, defined as interventional endoscopy for bleeding, stenting or dilatation, but not gastroscopy without other intervention codes; percutaneous intervention; and tracheostomy (included because it is a surgical intervention typically needed because of postoperative complications). Data for reinterventions were collected from the national patient registries, using the relevant procedure codes (*Table S1*, supporting information). Validation studies have shown high completeness and accuracy of interventions in the patient registries[27,30,31]. Dates and causes of death were obtained from the national death registries until

Table 4 Adjusted hazard ratios for reintervention or death within 90 days, analysed separately, in obese individuals undergoing bariatric surgery

	Reintervention		Mortality	
	No. with outcome* (*n* = 1111)	Hazard ratio†‡§	No. with outcome* (*n* = 95)	Hazard ratio†‡¶
Age (years)				
< 30	143 (12·9)	1·00 (reference)	5 (5)	1·00 (reference)
30–39	275 (24·8)	1·05 (0·86, 1·29)	17 (18)	1·89 (0·69, 5·13)
40–49	361 (32·5)	1·26 (1·04, 1·52)	28 (29)	2·76 (1·06, 7·18)
≥ 50	332 (29·9)	1·54 (1·26, 1·89)	45 (47)	5·57 (2·18, 14·24)
Sex				
M	296 (26·6)	1·00 (reference)	40 (42)	1·00 (reference)
F	815 (73·4)	0·99 (0·86, 1·13)	55 (58)	0·57 (0·37, 0·86)
Charlson co-morbidity index score				
0	1021 (91·9)	1·00 (reference)	74 (78)	1·00 (reference)
1	81 (7·3)	1·21 (0·96, 1·52)	17 (18)	3·27 (1·89, 5·67)
≥ 2	9 (0·8)	2·00 (1·03, 3·87)	4 (4)	9·48 (3·33, 26·99)
Type of bariatric surgery				
Gastric bypass	822 (74·0)	1·00 (reference)	64 (67)	1·00 (reference)
Vertical banded gastroplasty	140 (12·6)	0·75 (0·59, 0·96)	17 (18)	0·43 (0·21, 0·86)
Gastric banding	71 (6·4)	0·38 (0·29, 0·50)	7 (7)	0·18 (0·08, 0·44)
Other bariatric procedures	50 (4·5)	1·48 (1·10, 2·01)	4 (4)	0·74 (0·26, 2·14)
Malabsorptive procedures	28 (2·5)	1·15 (0·84, 1·88)	3 (3)	0·48 (0·14, 1·62)
Surgical approach				
Open	348 (31·3)	1·00 (reference)	53 (56)	1·00 (reference)
Laparoscopic	763 (68·7)	0·95 (0·78, 1·14)	42 (44)	0·29 (0·16, 0·53)
Year of surgery				
Before 2000	224 (20·2)	1·00 (reference)	34 (36)	1·00 (reference)
2000–2009	469 (42·2)	0·80 (0·63, 1·02)	38 (40)	0·35 (0·17, 0·71)
2010 or later	418 (37·6)	0·54 (0·41, 0·71)	23 (24)	0·20 (0·09, 0·47)

Values in parentheses are *percentages and †95 per cent confidence intervals. ‡Adjusted for country, age, sex, Charlson co-morbidity index, type of surgery, surgical approach and year of surgery, but not the factor being analysed. §Censored at death or after 90 days; ¶censored after 90 days.

31 December, 2012. The completeness of all-cause mortality data in these registers is 100 per cent[32–34].

Statistical analysis

Patients entered the study at the time of bariatric surgery and remained until reintervention, death, emigration (unlikely within 90 days of surgery) or end of follow-up (90 days), whichever came first. The rates of reintervention and death within 90 days of bariatric surgery were estimated. To assess risk factors for these outcomes, multivariable Cox regression was used to calculate hazard ratios (HRs) with 95 per cent confidence intervals. The HRs were adjusted for each of the seven potential risk factors categorized as described above, as well as country (Denmark, Finland, Iceland, Norway or Sweden). Because none of these factors correlated strongly, all were included in the full multivariable model. Pairwise interaction terms between all variables were tested. The proportionality assumption was assessed using Schoenfeld residuals, and was met for all variables except calendar year and the surgery type vertical banded gastroplasty in relation to mortality as a separate outcome. There were no missing data for variables included in the models, because all data were derived from well validated national registries. All data management and statistical analyses followed a detailed study protocol and were conducted by a senior biostatistician, using Stata/MP™ version 15.1 (StataCorp, College Station, Texas, USA).

Results

The bariatric surgery cohort included 49 977 patients (*Table 1*). Of these, 1111 (2·2 per cent) underwent at least one reintervention and 95 (0·2 per cent) died within 90 days of surgery. Most of the bariatric surgery was conducted in Sweden (72·1 per cent). The median age was 41·6 years and

Table 5 Adjusted hazard ratios for specific reinterventions after bariatric surgery

	Hazard ratio*		
	Operative (*n* = 827)	Endoscopic (*n* = 308)	Percutaneous drainage (*n* = 72)
Age (years)			
<30	1·00 (reference)	1·00 (reference)	1·00 (reference)
30–39	1·14 (0·90, 1·44)	0·75 (0·52, 1·10)	1·38 (0·58, 3·28)
40–49	1·35 (1·00, 1·75)	1·01 (0·70, 1·44)	1·69 (0·73, 3·91)
≥ 50	1·49 (1·05, 1·90)	1·70 (1·20, 2·43)	1·79 (0·75, 4·28)
Sex			
M	1·00 (reference)	1·00 (reference)	1·00 (reference)
F	1·01 (0·86, 1·18)	0·92 (0·71, 1·18)	1·13 (0·67, 1·92)
Charlson co-morbidity index score			
0	1·00 (reference)	1·00 (reference)	1·00 (reference)
1	1·33 (1·02, 1·73)	0·95 (0·60, 1·50)	1·29 (0·28, 2·85)
≥ 2	1·94 (0·86, 4·36)	1·27 (0·31, 5·15)	2·76 (0·37, 20·45)
Type of bariatric surgery			
Gastric bypass	1·00 (reference)	1·00 (reference)	1·00 (reference)
Vertical banded gastroplasty	0·56 (0·42, 0·74)	1·92 (1·29, 2·86)	1·65 (0·52, 5·73)
Gastric banding	0·39 (0·29, 0·53)	0·24 (0·11, 0·52)	0·14 (0·02, 1·07)
Other bariatric procedures	1·08 (0·73, 1·58)	2·55 (1·47, 4·44)	6·99 (3·49, 14·00)
Malabsorptive procedures	1·40 (0·91, 2·16)	0·51 (0·13, 2·11)	1·64 (0·36, 7·46)
Surgical approach			
Open	1·00 (reference)	1·00 (reference)	1·00 (reference)
Laparoscopic	1·14 (0·97, 1·79)	0·93 (0·68, 1·26)	0·42 (0·21, 0·85)
Year of surgery			
Before 2000	1·00 (reference)	1·00 (reference)	1·00 (reference)
2000–2009	0·46 (0·34, 0·61)	3·27 (2·03, 5·27)	4·43 (1·34, 14·69)
2010 or later	0·37 (0·27, 0·51)	1·28 (0·74, 2·24)	5·38 (1·48, 19·53)

Values in parentheses are 95 per cent confidence intervals. One patient could have more than one type of reintervention. *Adjusted for country, age, sex, Charlson comorbidity index, surgery type, surgical approach and year of surgery.

the majority of patients were women (74·5 per cent) and without co-morbidity (93·3 per cent). The dominant type of bariatric procedure was gastric bypass (73·4 per cent) and the approach was mainly laparoscopic (72·8 per cent). The median annual hospital volume was 12·8.

Risk of 90-day reintervention/mortality

Older age was associated with an increased risk of the composite outcome reintervention/mortality within 90 days of bariatric surgery (HR 1·65, 95 per cent c.i. 1·36 to 2·01, for age at least 50 years *versus* less than 30 years), whereas no risk difference was observed between the sexes (*Table 2*). Co-morbidity was also associated with an increased risk (HR 2·66, 1·53 to 4·62, for Charlson co-morbidity index score 2 or more *versus* 0). Gastric banding was associated with a lower risk than gastric bypass (HR 0·37, 0·28 to 0·48). There was no significant association between the laparoscopic and open approach (HR 0·87, 0·73 to 1·04). The risk of reintervention/mortality decreased with calendar interval of surgery; the HR was 0·77 (0·61 to 0·97) in 2000–2009 and 0·51 (0·39 to 0·67) from 2010 onwards, compared with the interval before 2000. Higher hospital volume was not associated with a significantly decreased risk of 90-day reintervention/mortality (HR 0·80, 0·61 to 1·07, for highest *versus* lowest tertile) (*Table 2*). The addition of hospital volume to the adjusted analysis did not change the risk estimates for the other potential risk factors studied (*Table S2*, supporting information).

The stratified analyses showed some statistically significant interactions (*Table 3*). Among patients who had an open surgical procedure, women had a decreased risk of reintervention/mortality compared with men (HR 0·66, 0·54 to 0·82), whereas no sex difference was observed for patients who had laparoscopic surgery. More recent surgery was associated with a decreased risk of reintervention/mortality in the laparoscopic surgery group (HR 0·37, 0·23 to 0·61, for 2010 onwards *versus* before 2000), but not in the open surgery group (HR 0·91, 0·60 to 1·37) (*Table 3*).

Risk of 90-day reintervention

Reinterventions were more common than deaths, and the results for reinterventions alone were similar to those for the composite variable reintervention/mortality. Increasing age, co-morbidity, other bariatric surgery, and earlier year of surgery were risk factors, but sex and surgical approach were not (*Table 4*).

Of the 1111 patients who had any reintervention, 827 (74·4 per cent) had operative reintervention, 308 (27·7 per cent) had endoscopic reintervention, 72 (6·5 per cent) had percutaneous reintervention and 17 (1·5 per cent) underwent tracheostomy. These groups of reinterventions were analysed separately, except for tracheostomy because of the small number of patients requiring this. Older age increased the risk of operative and endoscopic reinterventions, whereas sex did not influence the risk of any type of reintervention (*Table 5*). Co-morbidity increased the risk of operative reintervention. Compared with gastric bypass, vertical banded gastroplasty was associated with a decreased risk of operative reintervention, but an increased risk of endoscopic reintervention. Gastric banding was associated with a lower risk of each type of reintervention than gastric bypass. Laparoscopic surgery was associated with a decreased risk of percutaneous reintervention compared with open surgery. During more recent years, the risk of operative intervention decreased, whereas the risk of percutaneous intervention increased (*Table 5*).

Risk of 90-day mortality

Older age was associated with an increased risk of death within 90 days (HR 5·57, 95 per cent c.i. 2·18 to 14·24, for age at least 50 *versus* less than 30 years), and women had lower risk than men (HR 0·57, 0·37 to 0·86) (*Table 4*). Co-morbidity was associated with an increased risk (HR 9·48, 3·33 to 26·99, Charlson co-morbidity index 2 or more *versus* 0). Compared with gastric bypass, both vertical banded gastroplasty (HR 0·43, 0·21 to 0·86) and gastric banding (HR 0·18, 0·08 to 0·44) were associated with a decreased risk. The laparoscopic approach was associated with a lower risk than the open approach (HR 0·29, 0·16 to 0·53). The risk of death was lower during more recent years (HR 0·20, 0·09 to 0·47, for 2010 onwards *versus* before 2000).

Discussion

This study showed a low incidence of 90-day reintervention and mortality after bariatric surgery in an unselected cohort in the Nordic countries. Risk factors for the composite outcome reintervention/mortality, as well as reinterventions and death analysed separately, were older age and co-morbidity, whereas female sex was associated with a decreased risk of death. Among surgical factors, the laparoscopic approach did not influence the risk of reintervention/mortality, but decreased the risk of death. Gastric bypass was followed by an increased risk of all outcomes compared with other bariatric procedures. The incidence of 90-day reintervention and mortality decreased over time.

Strengths of the study include the population-based design, large sample size, and complete data on bariatric surgery, potential risk factors, reinterventions and mortality. Numerous studies[23–27] have verified the high quality of the data in the registers used. The Nordic populations share sociodemographic characteristics, genetic background, cultural traditions and norms, and have similar and publicly funded healthcare, social and population registration systems, and overall mortality rates. The BMI and co-morbidity requirements for consideration of bariatric surgery were similar in these countries during the study interval: BMI over 40 kg/m^2, or BMI exceeding 35 kg/m^2 and at least one obesity-related co-morbidity[35,36]. Therefore, combining data from these countries should not introduce much heterogeneity, but increase the sample size and facilitate generalizability[21]. Because the reporting of surgical procedures to the national patient registries is mandatory by law and hospital reimbursement depends on this reporting, the completeness of registration of bariatric surgery is high. The main limitation is confounding, although the adjustment for several confounders should reduce such bias. Yet, there was a lack of data on some relevant variables that could not be assessed, particularly BMI, and also tobacco smoking and alcohol overconsumption. However, individuals selected for bariatric surgery constitute a relatively homogeneous group regarding BMI[35], and smoking and alcohol consumption were adjusted for indirectly using the Charlson co-morbidity index. Indications, techniques and devices used in bariatric surgery have evolved over the long study period, leading to changes in patient selection, including the proportion of co-morbidities. Therefore, the adjustment for calendar period of surgery was relevant. Although some procedures are currently not in use, the authors wanted to provide a comprehensive study showing the entire picture without exclusion of certain bariatric procedures. Five different bariatric surgery procedures were also analysed separately. Moreover, the period of surgery was taken into account, reducing confounding caused by these changes. Another weakness is the lack of data on sleeve gastrectomy, which has become increasingly common since the time period of the present study.

Most studies examining short-term outcomes of bariatric surgery have focused on 30-day outcomes. A multicentre study[13] of 4776 patients reported a 4·1 per cent incidence of the composite outcome postoperative complications/reoperations/failure to discharge/death within 30 days of bariatric surgery, whereas abdominal reoperations were undertaken in 2·6 per cent of patients and 0·3 per cent died. Poor functional status, history of deep vein thrombosis and sleep apnoea and gastric bypass (compared with gastric banding) were risk factors for the composite outcome. A meta-analysis[15] of 38 RCTs, including 4030 patients, reported a 30-day mortality rate of 0·18 per cent after bariatric surgery. This might not mirror clinical practice, however, because of the inclusion criteria of these trials. Additionally, the small sample size of these studies was a limitation[13,15]. In a large register-based study[16] of 96 538 patients undergoing bariatric surgery, 1·9 per cent had reintervention within 30 days of operation, and risk factors were age over 65 years, male sex, ASA grade above II, history of smoking, co-morbidity and poor functional status. In another large register-based study[17] of 243 747 patients, co-morbidity, smoking and high ASA grade were associated with an increased risk of reintervention within 30 days of bariatric surgery.

In contrast, the incidence of, and risk factors for, 90-day reintervention or mortality in patients undergoing bariatric surgery are less clear. Modern postoperative intensive care and perioperative management of surgical patients may reduce or postpone death from complications beyond 30 days, making 90-day outcomes more relevant in the modern era. The only previous large-scale study[14] examining 90-day outcomes after bariatric surgery was a large retrospective analysis of 297 688 patients that focused on centralization, but also showed that male sex, older age, co-morbidity and lower hospital volume were risk factors for death. However, that study did not examine reintervention, which was the main outcome of the present study.

The present results indicate that increasing age and co-morbidity are associated with an increased risk of reintervention and death within 90 days of bariatric surgery. These findings are in line with studies examining risk factors for 30-day reinterventions and mortality[14,15]. Sex was not identified as a risk factor for reintervention here, but women had lower risk of death than men. The typical male body fat distribution is centred around the abdomen. Speculatively, it could make open surgery more demanding in men than in women, whereas this may be of less concern in laparoscopic bariatric surgery. Furthermore, sex differences in lifestyle factors and health consciousness may influence the severity and consequences of complications, which could explain the higher mortality rate in men. The decreased risk of reintervention/mortality after gastric banding compared with gastric bypass has also been suggested previously[13,15]. Gastric banding was associated with a decreased risk of all reinterventions, whereas vertical banded gastroplasty was associated with an increased risk of endoscopic intervention, compared with gastric bypass. This could reflect differences in complexity of these procedures; gastric banding does not include any major reconstruction or anastomosis. Compared with open surgery, the laparoscopic approach was not associated with any decreased risk of reintervention in general, but it reduced the need for percutaneous interventions and risk of death.

The generally decreased risk of reintervention/mortality more recently is encouraging, indicating improvements over time. Another time trend was the shift from more operative reinterventions in the earlier time interval to an increased use of percutaneous and endoscopic reinterventions. Modern imaging techniques have reduced the need for exploratory surgery and enabled more tailored percutaneous interventions. It has been reported that high-volume bariatric surgery centres have lower short-term mortality rates than low-volume centres[8], which suggests that increasing experience of surgeons and frequency of bariatric procedures over time reduces the need for reintervention and risk of postoperative death. However, the volume–outcome association in complication risk after bariatric surgery is under debate, and surgery in higher-volume centres was not associated with any clearly decreased risk of reintervention/mortality in the present study, although the point estimate was decreased and there were few really high-volume centres. The volume–outcome association was assessed in only three of the five countries, but the analysis still included over 80 per cent of the patients in the cohort; estimates for other risk factors were unchanged after adjusting for hospital volume, supporting the validity of these findings. Higher-volume centres (often university clinics in Nordic countries) may more frequently operate on more vulnerable patients (extremely obese patients and those with more co-morbidity), which could explain the lack of a clear association in the present study. It is also possible that relatively few higher-volume surgeons undertake bariatric surgery in the lower-volume hospitals, whereas the individual surgeon volume could be relatively low in the higher-volume hospitals.

Some of the present findings might be helpful in clinical practice. Although operating on patients aged over 50 years with multiple co-morbidities is associated with an increased relative risk of poor postoperative outcomes, the absolute risk is still low. Of patients aged over 50 years and with any co-morbidity undergoing gastric bypass, 3·6 per cent experienced reintervention/mortality within 90 days of surgery, compared with 2·4 per cent among all other patients. Nevertheless, preoperative optimization of health status and meticulous follow-up during the initial postoperative period are recommended. Further research is needed to clarify the volume–outcome association in bariatric surgery, especially examining surgeon volume, and the risk of reintervention/mortality after sleeve gastrectomy.

This population-based cohort study with data from five countries showed a low absolute risk of reintervention and mortality within 90 days of bariatric surgery, which decreased over the study period. The main patient risk factors are older age and co-morbidity. Sex, surgical approach (laparoscopic *versus* open) and hospital volume did not influence the risk, although female sex and laparoscopic approach were associated with decreased risk of 90-day mortality.

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Supporting information

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