Title & Authors

The Effects of Bariatric Surgery on Cardiovascular Outcomes and Cardiovascular Mortality: A Systematic Review and Meta-Analysis

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Introduction

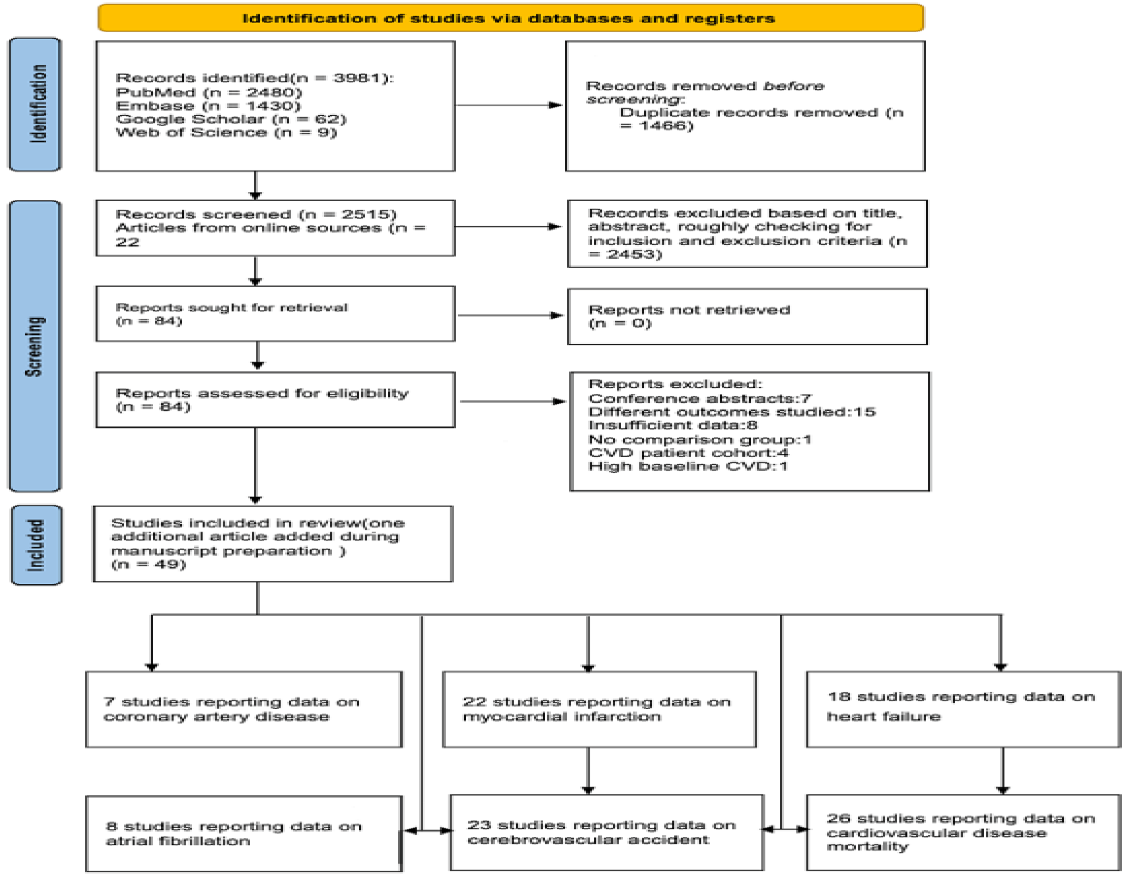
Obesity is a major public health problem that is associated with serious comorbidities and premature mortality. Cardiovascular disease (CVD) is the major cause of morbidity and mortality associated with obesity.

In this meta-analysis, we aim to assess the effects of bariatric surgery on CVD outcomes and cardiovascular mortality.

Our search included three types of bariatric surgery: Roux-en-Y gastric bypass (RYGB), sleeve gastrectomy, and gastric banding (GB).

All were searched in conjunction with “coronary artery disease,” “ischemic heart disease,” “myocardial infarction,” “cerebrovascular accident,” “stroke,” “atrial fibrillation,” “heart failure,” “arrhythmias,” and “mortality.”

Methods


Identification of studies via databases and registers
Identification
Records identified(n = 3981):
PubMed (n = 2480)
Embase (n = 1430)
Google Scholar (n = 62)
Web of Science (n = 9)
Records removed *before screening*:
Duplicate records removed (n = 1466)
Screening
Records screened (n = 2515)
Articles from online sources (n = 22
Records excluded based on title, abstract, roughly checking for inclusion and exclusion criteria (n = 2453)
Reports sought for retrieval (n = 84)
Reports not retrieved (n = 0)
Reports assessed for eligibility (n = 84)
Reports excluded:
Conference abstracts:7
Different outcomes studied:15
Insufficient data:8
No comparison group:1
CVD patient cohort:4
High baseline CVD:1
Included
Studies included in review(one additional article added during manuscript preparation) (n = 49)
7 studies reporting data on coronary artery disease
22 studies reporting data on myocardial infarction
18 studies reporting data on heart failure
8 studies reporting data on atrial fibrillation
23 studies reporting data on cerebrovascular accident
26 studies reporting data on cardiovascular disease mortality

Results

Effect on Coronary Artery Disease

Seven studies reported effects on CAD, of which six had adjusted HR ratio data and were included in the analysis (Figure 2). One study by Bouchard et al. [13] reported a combined HR for both CAD and MI. Since individual data were not available, it was excluded from the analysis to avoid duplication of data and bias. Of the included studies, there were 17423 bariatric surgery patients and 43507 controls. The effect on CAD was significant with a pooled HR of 0.68 (95% CI: 0.52-0.91) (p = 0.008).

Study or Subgroup	log[Hazard Ratio]	SE	Weight	Hazard Ratio IV, Random, 95% CI	Year
Fisher et al 2018	−0.4463	0.2149	17.7%	0.64 [0.42, 0.98]	2018
Alkharaiji et al 2019	−1.2379	0.3034	12.7%	0.29 [0.16, 0.53]	2019
Aminian et al 2019	−0.3711	0.1251	23.9%	0.69 [0.54, 0.88]	2019
Singh et al 2020	−0.1625	0.1693	20.8%	0.85 [0.61, 1.18]	2020
Ardissino et al 2021	−0.3734	0.3839	9.5%	0.69 [0.32, 1.46]	2021
Rassen et al 2021	0.0953	0.253	15.4%	1.10 [0.67, 1.81]	2021
Total (95% CI)			**100.0%**	**0.68 [0.52, 0.91]**	

Heterogeneity: $Tau^2 = 0.07$; $Chi^2 = 13.12$, $df = 5$ ($P = 0.02$); $I^2 = 62\%$

Test for overall effect: $Z = 2.63$ ($P = 0.008$)

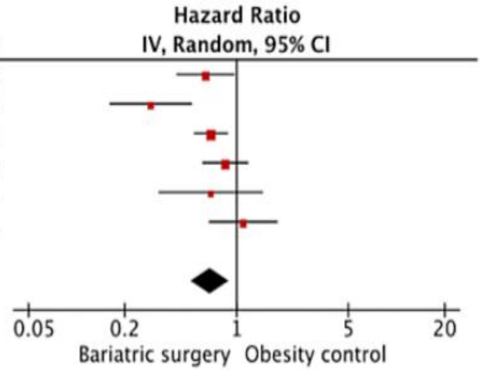


FIGURE 2: Forest plot with the included studies and the pooled hazard ratio for coronary artery disease

CI: confidence interval

Sources: [13,16-21]

Effect on Myocardial Infarction

Twenty-two studies reported myocardial infarction outcomes. Sixteen studies had adjusted HR data and were included in the analysis (Figure 3). These studies had 231503 patients in the intervention group and 487727 in the control group. The effect on MI was significant with a pooled HR of 0.53 (95% CI: 0.44-0.64) ($p < 0.01$). The studies showed high heterogeneity with an I 2 = 79%.

Study or Subgroup	log[Hazard Ratio]	SE	Weight	Hazard Ratio IV, Random, 95% CI	Year
Sampalis et al 2006	-0.3425	0.1789	8.9%	0.71 [0.50, 1.01]	2006
Romeo et al 2012	-0.5798	0.2546	6.7%	0.56 [0.34, 0.92]	2012
Douglas et al 2015	-1.273	0.5253	2.6%	0.28 [0.10, 0.78]	2015
Eliasson et al 2015	-0.7133	0.3642	4.5%	0.49 [0.24, 1.00]	2015
Benotti et al 2017	-0.1165	0.3954	4.0%	0.89 [0.41, 1.93]	2017
Alkharaiji et al 2019	-0.0202	0.3041	5.6%	0.98 [0.54, 1.78]	2019
Wong et al 2020	-0.6274	0.7409	1.5%	0.53 [0.12, 2.28]	2020
Brown et al 2020	-0.9416	0.0552	12.4%	0.39 [0.35, 0.43]	2020
Hoskuldsdottir et al 2020	-0.5621	0.4413	3.4%	0.57 [0.24, 1.35]	2020
Moussa et al 2020	-0.8916	0.1946	8.4%	0.41 [0.28, 0.60]	2020
Stenberg et al 2020	-0.6349	0.1187	10.8%	0.53 [0.42, 0.67]	2020
Hung et al 2021	-1.682	0.631	1.9%	0.19 [0.05, 0.64]	2021
Lundberg et al 2021	-0.5108	0.1943	8.4%	0.60 [0.41, 0.88]	2021
Yuan et al 2021	-1.4271	0.5948	2.1%	0.24 [0.07, 0.77]	2021
Dash et al 2021	-0.6559	0.278	6.1%	0.52 [0.30, 0.89]	2021
Mentias et al 2022	-0.462	0.0335	12.8%	0.63 [0.59, 0.67]	2022
Total (95% CI)			**100.0%**	**0.53 [0.44, 0.64]**	

Heterogeneity: $Tau^2 = 0.07$; $Chi^2 = 71.58$, df = 15 ($P < 0.00001$); $I^2 = 79\%$
Test for overall effect: Z = 6.67 ($P < 0.00001$)

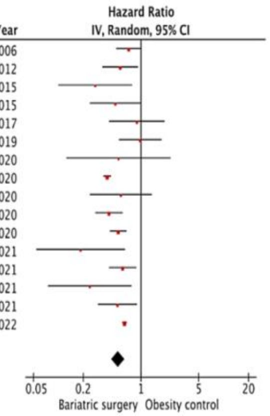


FIGURE 3: Forest plot with the included studies and the pooled hazard ratio for myocardial infarction

CI: confidence interval

Sources: [13,17,20,22-35,40]

Effect on Heart Failure

Eighteen studies reported heart failure outcomes. Fifteen studies had adjusted HR data and were included in the analysis (Figure 4). These studies amounted to a sample size of 180961 in the intervention group and 202891 in the control group. The effect on heart failure was significant with a pooled HR of 0.45 (95% CI: 0.37-0.55) (p < 0.01). The studies showed high heterogeneity with an I 2 = 87%.

Study or Subgroup	log[Hazard Ratio]	SE	Weight	Hazard Ratio IV, Random, 95% CI	Year
Persson et al 2017	-0.9943	0.1243	9.0%	0.37 [0.29, 0.47]	2017
Benotti et al 2017	-0.9676	0.2789	5.8%	0.38 [0.22, 0.66]	2017
Jamaly et al 2019	-0.4155	0.1315	8.8%	0.66 [0.51, 0.85]	2019
Alkharaiji et al 2019	-0.1165	0.3258	5.0%	0.89 [0.47, 1.69]	2019
Aminian et al 2019	-0.9676	0.1206	9.0%	0.38 [0.30, 0.48]	2019
Singh et al 2020	-0.5621	0.2636	6.1%	0.57 [0.34, 0.96]	2020
Wong et al 2020	-1.2623	0.7275	1.6%	0.28 [0.07, 1.18]	2020
Hoskuldsdottir et al 2020	-1.1394	0.3866	4.1%	0.32 [0.15, 0.68]	2020
Liakopoulos et al 2020	-1.1087	0.1625	8.2%	0.33 [0.24, 0.45]	2020
Moussa et al 2020	-0.9088	0.4084	3.8%	0.40 [0.18, 0.90]	2020
Hoskuldsdottir et al 2021	-1.3093	0.1793	7.8%	0.27 [0.19, 0.38]	2021
Rassen et al 2021	-0.1985	0.3176	5.1%	0.82 [0.44, 1.53]	2021
Dash et al 2021	-1.6195	0.3046	5.3%	0.20 [0.11, 0.36]	2021
Mentias et al 2022	-0.7765	0.0227	10.3%	0.46 [0.44, 0.48]	2022
Bouchard et al 2022	-0.2231	0.0681	9.9%	0.80 [0.70, 0.91]	2022
Total (95% CI)			**100.0%**	**0.45 [0.37, 0.55]**	

Heterogeneity: $Tau^2 = 0.10$; $Chi^2 = 107.02$, df = 14 (P < 0.00001); $I^2 = 87\%$
Test for overall effect: Z = 7.97 (P < 0.00001)

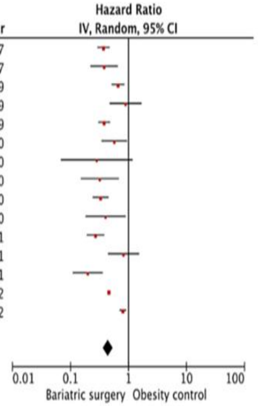


FIGURE 4: Forest plot with the included studies and the pooled hazard ratio for heart failure

CI: confidence interval

Sources: [13,17-19,21,23,26,29,32-36,40-45]

Effect on Atrial Fibrillation

Eight studies reported atrial fibrillation outcomes. Seven had adjusted HR data and were included in the analysis (Figure 5). These studies amounted to a sample size of 18309 in the intervention group and 32933 in the control group. The effect on atrial fibrillation was not significant with a pooled HR of 0.81 (95% CI: 0.65-1.01) (p = 0.07).

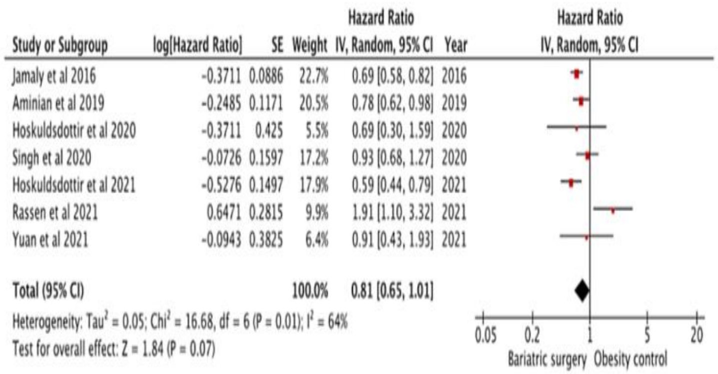


FIGURE 5: Forest plot with the included studies and the pooled hazard ratio for atrial fibrillation

CI: confidence interval

Sources: [18,19,21,35,39,45-47]

Effect on Cerebrovascular Accident

Twenty-three studies reported cerebrovascular accident (CVA) outcomes. Twenty-one studies had adjusted HR data and were included in the analysis (Figure 6). These studies amounted to a sample size of 238472 subjects and 513848 controls. The effect on CVA was significant with a pooled HR of 0.68 (95% CI: 0.59-0.78) ($p < 0.01$). The studies showed moderate heterogeneity with an I 2 = 72%.

Study or Subgroup	log[Hazard Ratio]	SE	Weight	Hazard Ratio IV, Random, 95% CI	Year
Romeo et al 2012	−0.3147	0.2943	3.9%	0.73 [0.41, 1.30]	2012
Sjostrom et al 2012	−0.4155	0.152	7.6%	0.66 [0.49, 0.89]	2012
Douglas et al 2015	−0.0943	0.3371	3.3%	0.91 [0.47, 1.76]	2015
Benotti et al 2017	−0.3147	0.2468	4.9%	0.73 [0.45, 1.18]	2017
Fisher et al 2018	−0.3711	0.3044	3.8%	0.69 [0.38, 1.25]	2018
Alkharaiji et al 2019	−0.1393	0.4502	2.1%	0.87 [0.36, 2.10]	2019
Aminian et al 2019	−0.4005	0.1702	7.0%	0.67 [0.48, 0.94]	2019
Hoskuldsdottir et al 2020	−1.7148	0.7674	0.8%	0.18 [0.04, 0.81]	2020
Moussa et al 2020	−0.6236	0.6042	1.3%	0.54 [0.16, 1.75]	2020
Singh et al 2020	−0.0202	0.2017	6.1%	0.98 [0.66, 1.46]	2020
Stenberg et al 2020	−0.2107	0.1045	9.2%	0.81 [0.66, 0.99]	2020
Wong et al 2020	−0.2095	0.4046	2.5%	0.81 [0.37, 1.79]	2020
Brown et al 2020	−0.5978	0.0385	11.1%	0.55 [0.51, 0.59]	2020
Dash et al 2021	−0.9039	0.4459	2.1%	0.40 [0.17, 0.97]	2021
Hung et al 2021	−1.8202	0.4067	2.5%	0.16 [0.07, 0.36]	2021
Lundberg et al 2021	−0.3857	0.1777	6.8%	0.68 [0.48, 0.96]	2021
Moussa et al 2021	−1.0441	0.3013	3.8%	0.35 [0.20, 0.64]	2021
Yuan et al 2021	0.207	0.3333	3.3%	1.23 [0.64, 2.36]	2021
Ardissino et al 2021	−3.7854	1.6468	0.2%	0.02 [0.00, 0.57]	2021
Mentias et al 2022	−0.3425	0.045	11.0%	0.71 [0.65, 0.78]	2022
Bouchard et al 2022	0.0488	0.1785	6.7%	1.05 [0.74, 1.49]	2022
Total (95% CI)			**100.0%**	**0.68 [0.59, 0.78]**	

Heterogeneity: $Tau^2 = 0.05$; $Chi^2 = 67.88$, df = 20 ($P < 0.00001$); $I^2 = 71\%$
Test for overall effect: $Z = 5.35$ ($P < 0.00001$)

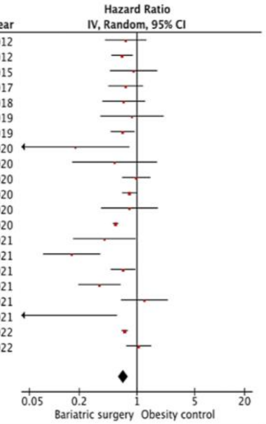


FIGURE 6: Forest plot with the included studies and the pooled hazard ratio for cerebrovascular accident

CI: confidence interval

Sources: [13,16-20,23-27,29,30,32-40,48]

Effect on Cardiovascular Mortality

Twenty-six studies reported cardiovascular disease-specific mortality. Fifteen studies had adjusted HR data and were included in the analysis (Figure 7). There were 157750 in the surgery group and 643770 in the control groups. The effect on cardiovascular disease (CVD) mortality was significant with a pooled HR of 0.48 (95% CI: 0.40-0.57) (p < 0.01). The studies showed high heterogeneity with an I 2 = 71%.

Study or Subgroup	log[Hazard Ratio]	SE	Weight	Hazard Ratio IV, Random, 95% CI	Year
Courcoulas et al - RYGB 2021	-1.3093	0.1531	9.4%	0.27 [0.20, 0.36]	
Courcoulas et al - SG 2021	-0.5621	0.5605	2.1%	0.57 [0.19, 1.71]	
Doumouras et al - RYGB 2020	-0.5447	0.2577	6.3%	0.58 [0.35, 0.96]	
Doumouras et al - SG 2020	-0.9416	0.5227	2.4%	0.39 [0.14, 1.09]	
Adams et al 2007	-1.0217	0.2513	6.4%	0.36 [0.22, 0.59]	2007
Sjostrom et al 2012	-0.755	0.2464	6.5%	0.47 [0.29, 0.76]	2012
Eliasson et al 2015	-0.9163	0.5004	2.6%	0.40 [0.15, 1.07]	2015
Davidson et al 2016	-0.6733	0.1777	8.6%	0.51 [0.36, 0.72]	2016
Kauppila et al 2019	-0.5621	0.0468	12.6%	0.57 [0.52, 0.62]	2019
Sheetz et al 2020	-0.755	0.1221	10.5%	0.47 [0.37, 0.60]	2020
Carlsson et al 2020	-0.3567	0.1048	11.1%	0.70 [0.57, 0.86]	2020
Hoskuldsdottir et al 2020	-1.8971	0.8212	1.1%	0.15 [0.03, 0.75]	2020
Liakopoulos et al 2020	-1.0217	0.2513	6.4%	0.36 [0.22, 0.59]	2020
Doumouras et al 2021	-1.1394	0.3866	3.8%	0.32 [0.15, 0.68]	2021
Lundberg et al 2021	-0.2485	0.1339	10.1%	0.78 [0.60, 1.01]	2021
Total (95% CI)			**100.0%**	**0.48 [0.40, 0.57]**	

Heterogeneity: $Tau^2 = 0.06$; $Chi^2 = 47.47$, df = 14 ($P < 0.0001$); $I^2 = 71\%$
Test for overall effect: Z = 8.22 ($P < 0.00001$)

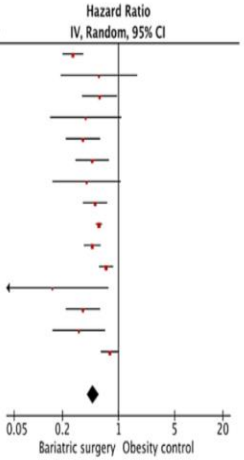
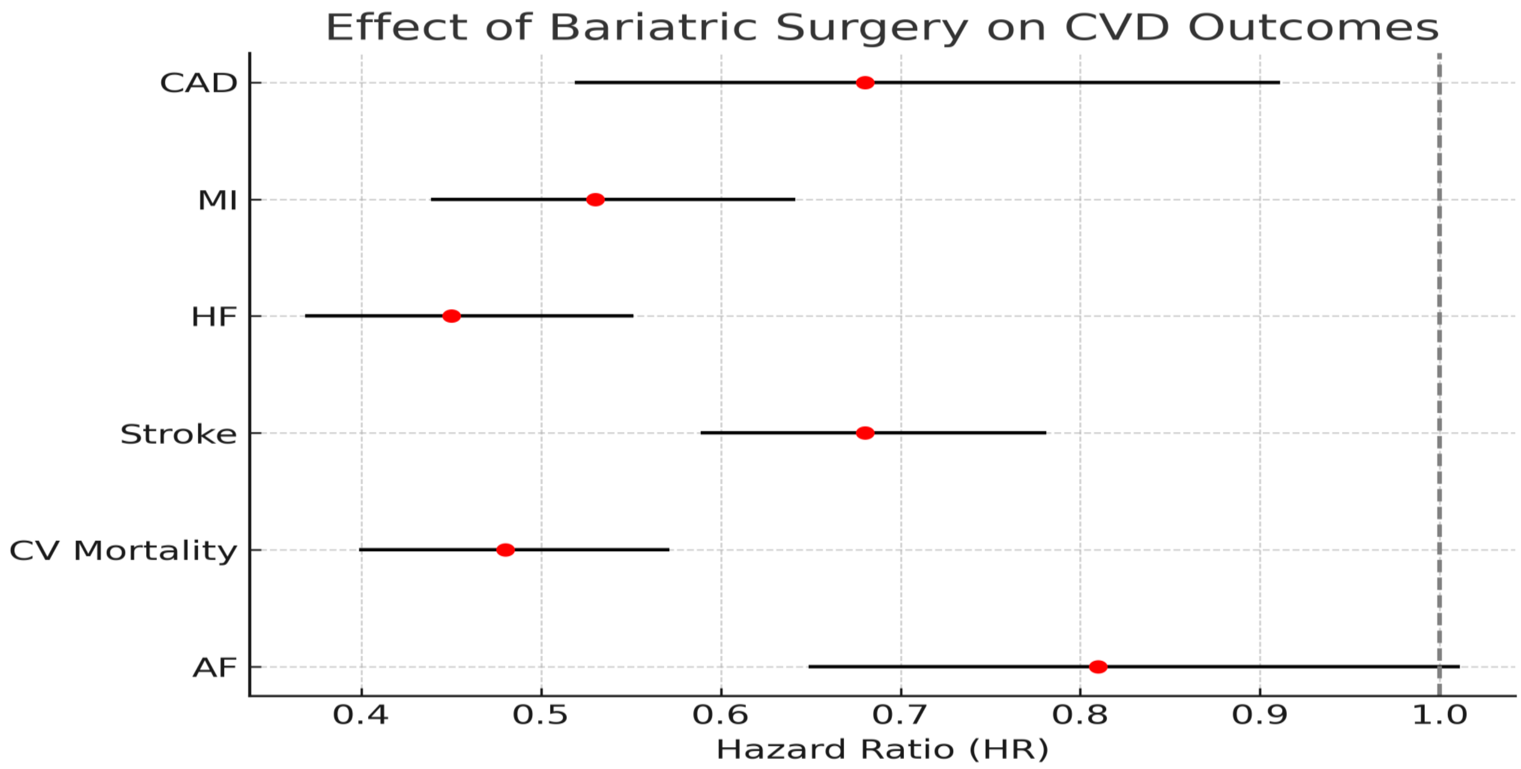


FIGURE 7: Forest plot with the included studies and the pooled hazard ratio for cardiovascular mortality

CI: confidence interval

Sources: [14,23,25-28,33,35-38,44,45,49-61]

Results – Hazard Ratios



Discussion

In this updated meta-analysis, we analyzed six major long-term cardiovascular outcomes post-bariatric surgery. Five outcomes including CAD, MI, HF, CVA, and CVD mortality showed a significant risk reduction, whereas atrial fibrillation showed a non-significant risk reduction.

Limitations

Firstly, the studies included are all nonrandomized cohort studies, which could involve selection and publication biases. Henceforth, longer randomized controlled trials are required. Secondly, most of the outcomes had high heterogeneity, which could be owed to the many smaller studies that were included. Thirdly, some studies had non-generalizable populations such as type 1 diabetes or type 2 diabetes specifically. However, we omitted populations that had cardiovascular diseases at baseline. Fourthly, only English studies were included owing to the ease of interpretation and analysis. Lastly, we failed to study the HR specific to each bariatric surgery, likely due to the scarcity of data for a pooled analysis.

Publication bias was assessed for MI, HF, CVA, and CVD. The studies included had a moderate-to-high amount of heterogeneity. This is likely from many smaller studies included leading to effect size variation. This is suggestive of likely publication bias in favor of positive studies. But the funnel plots (shown in Figures 8-11) show the studies being symmetrically scattered around the midline. This is in concordance with the inverted funnel appearance reassuring that there is no publication bias.

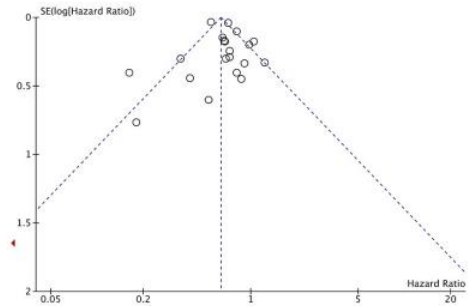


FIGURE 10: Funnel plot depicting symmetrical distribution for cerebrovascular accident

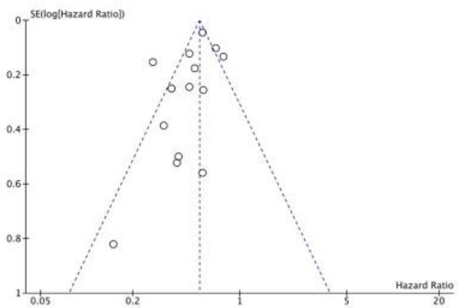


FIGURE 11: Funnel plot depicting symmetrical distribution for cardiovascular mortality

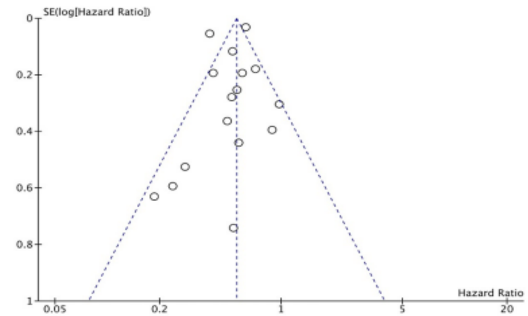


FIGURE 8: Funnel plot depicting symmetrical distribution for myocardial infarction

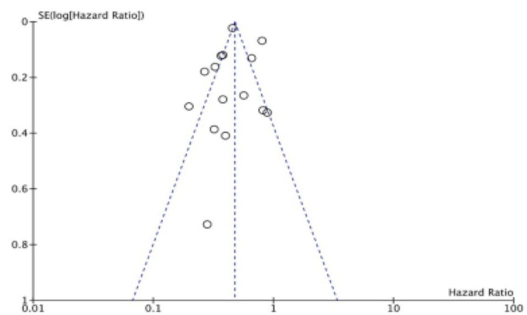


FIGURE 9: Funnel plot depicting symmetrical distribution for heart failure

Conclusion

Although the management of obesity requires a multimodal approach, recognizing the necessity for bariatric surgery early in the disease course is important. Both the physician and the patients should be aware of the treatment strategies to make a well-informed decision.

In conclusion, bariatric surgery showed a statistically significant risk reduction with CAD, MI, HF, CVA, and cardiovascular disease-specific mortality and a non-significant risk reduction of atrial fibrillation. However, these data are inclusive of RYGB, SG, and laparoscopic banding.