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Impact of obesity on outcomes following lumbar spine surgery: A systematic review and meta-analysis

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ABSTRACT

The influence of obesity on spine surgery outcomes is highly controversial with a current clinical equipoise. Several studies suggest higher perioperative morbidity with obesity while other studies suggest otherwise. To address this gap in the literature, we conducted a systematic review and meta-analysis in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines with the objective of better defining the impact of obesity on outcomes following lumbar spine surgery. Risk of bias assessment was performed using the Newcastle-Ottawa Scale. Strength of evidence was assessed using the Grades of Recommendation, Assessment, Development and Evaluation (GRADE) Working Group system. Surgical outcomes such as blood loss, operative time, length of stay, complication and reoperation rates and functional outcomes represented by the change in Oswestry Disability Index and Visual Analog Scale-Back Pain were compared between obese and non-obese patients. A total of 32 studies with 23,415 patients were analyzed. Obese patients had slightly higher surgical blood loss (Mean Difference [MD]: 46.15 ml, CI: 20.21–72, p-value < .001, I^2 = 85%) and longer operative times (MD: 17.17 min, CI: 9.91–24.43, p-value < .001, I^2 = 95%), but similar length of stay as compared to non-obese patients. Higher complication (OR = 1.34, C.I. = 1.13–1.58, p = 0.01, I^2 = 45%) and reoperation rates (OR = 1.40, C.I. = 1.19–1.64, p < 0.001, I^2 = 20) were observed in obese patients. The differences, however, were not significant for obese patients undergoing MIS surgery. Functional outcomes (change in ODI and VAS-BP) were similar between the two groups. Overall confidence in GRADE estimates was either low or very low for all outcomes. Obesity might be linked to higher adverse events following lumbar spine surgery. Minimally invasive spine surgery, however, might offer comparable outcomes between obese and non-obese patients. However, further studies are needed to evaluate whether these findings remain valid for morbidly obese (BMI > 40) patients as well.

1. Introduction

According to World Health Organization (WHO) estimates, the prevalence of obesity has nearly tripled since 1975 [50]. In the United States alone, it remains an important public health issue that affects nearly one-third of the population [49]. Although the mechanism is not yet fully elucidated, previous studies have linked obesity to musculoskeletal morbidity, spinal degeneration and low back pain [16,25,26,38]. As a consequence, spine surgeons are increasingly faced with a growing subset of obese patients with degenerative disease of the lumbar spine.

The relationship between obesity and outcomes following elective lumbar spine surgery is not well defined. A growing body of observational studies suggests that a higher body mass index (BMI) might be associated with worse outcomes following spine surgery [17,45]. Obesity has been independently linked to higher blood loss and longer operative times [23,40,44,47] as well as to an increased risk of perioperative complications, including wound infection, deep venous thrombosis, pseudarthrosis and need for revision surgery [35]. Nevertheless, some studies have disputed these findings and suggest no relationship between obesity and adverse surgical outcomes [36,42]. To address this equipoise, we conducted a systematic review and meta-

Abbreviations: ODI, Oswestry Disability Index; VAS-BP, Visual Analog Scale-Back Pain

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analysis of available literature in an attempt to decipher the differences in outcomes between obese and non-obese patients following lumbar spine surgery for degenerative spine disease [3].

2. Methods

2.1. Literature search strategy

This systematic review was conducted according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [30]. The literature search strategy was designed around the PICO format- Is there a difference in perioperative and functional outcomes (outcome) between obese (population of interest) and non-obese patients (comparison) following elective lumbar spine surgery (intervention)? Electronic searches were performed using Ovid Medline, PubMed, Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, American College of Physicians Journal Club and Database of Abstracts of Review of Effectiveness from their dates of inception to November 2017 by two independent reviewers (A.G. and V.M.L.). We combined the search terms “BMI”, “obesity”, “lumbar”, “spine surgery” as either keywords or MeSH terms in order to achieve maximal sensitivity. In addition, we reviewed the list of references from retrieved articles for identification of potentially relevant studies.

2.2. Selection criteria

The inclusion criteria used to screen all identified articles were the following: 1) original studies in human subjects, written in the English language, 2) clearly defined BMI threshold for obesity 2) distinct discernible cohorts of obese and non-obese patients in the same study, 3) all patients underwent elective lumbar spine surgery following a diagnosis of degenerative lumbar spine disease. Studies were excluded if the main cohort comprised of patients with a primary diagnosis of adult or adolescent spinal deformity, patients underwent cervical or thoracic spine surgery and the data derived from a national database/registry, such as the National Surgical Quality Improvement Program (NSQIP) and Medicare, due to concerns of cohort duplication and coding bias. Among duplicate studies by the same institution with an accumulated number of patients or extended follow up, only the most complete and updated reports were selected for quantitative synthesis.

2.3. Data extraction and critical appraisal

All data were extracted from article texts, tables and figures with any estimates made based on the presented data and figures. Two investigators (A.G. and M.E.) independently reviewed each included article; any discrepancy resolved by discussion to reach consensus. Primary outcomes of interest consisted of perioperative parameters, including estimated blood loss (EBL), operative time and length of stay (LOS), postoperative complications and reoperation rate at last follow up. Secondary outcomes included functional outcomes, as measured by the change in Oswestry Disability Index (ODI) and Visual Analog Scale-Back Pain (VAS-BP) scores respectively and incidence of dural tears between the two groups.

Risk of bias in each study was evaluated using the Newcastle-Ottawa Scale (NOS). Overall confidence in the estimates for each outcome was assessed based on the Grades of Recommendation, Assessment, Development and Evaluation (GRADE) Working Group system for limitations in study design, evidence directness, consistency, precision of results and publication bias [3]. The GRADEpro Guideline Development Tool (GDT) was employed to generate a Summary of Findings (SoF) table. (https://gradepro.org/)

2.4. Statistical analysis

All statistical analyses were conducted using Review Manager version 5.3.3 (Cochrane Collaboration, Software Update, Oxford, United Kingdom). Odds ratios (OR) and mean differences (MD) were used as summary statistics for dichotomous and continuous outcomes, respectively. Meta-analyses for all outcomes were presented as forest plots with summary statistical estimates, 95% confidence intervals and relative weights represented by the middle of the square, the horizontal line, and the relative size of the square, respectively. For the overall summary statistic, the mean and 95% confidence interval were represented by the middle and width of the diamond, respectively. The I^2 statistic was used to estimate heterogeneity across studies, with values greater than 50% considered as substantial heterogeneity. It can be calculated as $I^2 = 100\% \times (Q - df)/Q$, with Q defined as Cochrane’s heterogeneity statistics and df defined as degrees of freedom. Pre-specified subgroup analysis was performed to assess the influence of surgical approach (Minimally invasive (MIS) vs Open) on overall difference in outcomes between obese and non-obese patients when more $\geq$ 2 studies could be included in each of the subgroups. In the present meta-analysis, we used a *random-effects model* in order to take into account the methodological variation and diverse clinical definitions of obesity across studies. *Leave-one out sensitivity analysis* was performed when cohort size bias was suspected. Each study was sequentially removed, and the overall trend reassessed for any significant change. All p-values were 2-sided. For studies where the standard deviations for change in VAS and change in ODI were not reported, they were imputed using correlation coefficients calculated as per the Cochrane Handbook for Systematic Reviews [22].

3. Results

3.1. Literature search

The electronic literature search identified a total of 703 studies while 12 articles were identified from additional sources [Fig. 1]. After removal of 63 duplicates and 31 non-English articles, the remaining studies underwent primary screening of title and abstract. Following removal of 587 articles on screening, 70 studies underwent full-text review and 32 were included in the final qualitative and quantitative synthesis. With the exception of two prospective trials, included studies were either prospective (n = 7) or retrospective (n = 16) observational studies or retrospective analyses of prospectively collected data (n = 7). Majority of the studies were from the US (n = 19), while the remaining were from UK (n = 2), Switzerland (n = 2), Israel (n = 1), Korea (n = 1), Norway (n = 1), Canada (n = 1), Austria (n = 1), Finland (n = 1), Iran (n = 1), Brazil (n = 1) and Japan (n = 1). The individual characteristics of included studies are summarized in Tables 1 and 2.

3.2. Cohort description

The definition of obesity was study specific with majority using a definition of BMI $\geq$ 30 or BMI $\geq$ 95th percentile as per height and age (n = 28), while some used BMI $\geq$ 35 (n = 2) and BMI $\geq$ 25 (n = 1) as a threshold for high BMI. Table 1 summarizes the definitions used by each study. When a study classified patients into multiple subgroups as per the BMI, demographics and outcomes were pooled into two subgroups using preferably a BMI threshold of 30 or the 95th percentile wherever possible. The overall cohort consisted of 23,415 patients with 7274 patients (31%) classified as obese. Sex distribution was reported in 30 studies (n = 22,115) with 62.7% (n = 13,873) of subjects being females. Table 2 summarizes the demographics of all included studies.

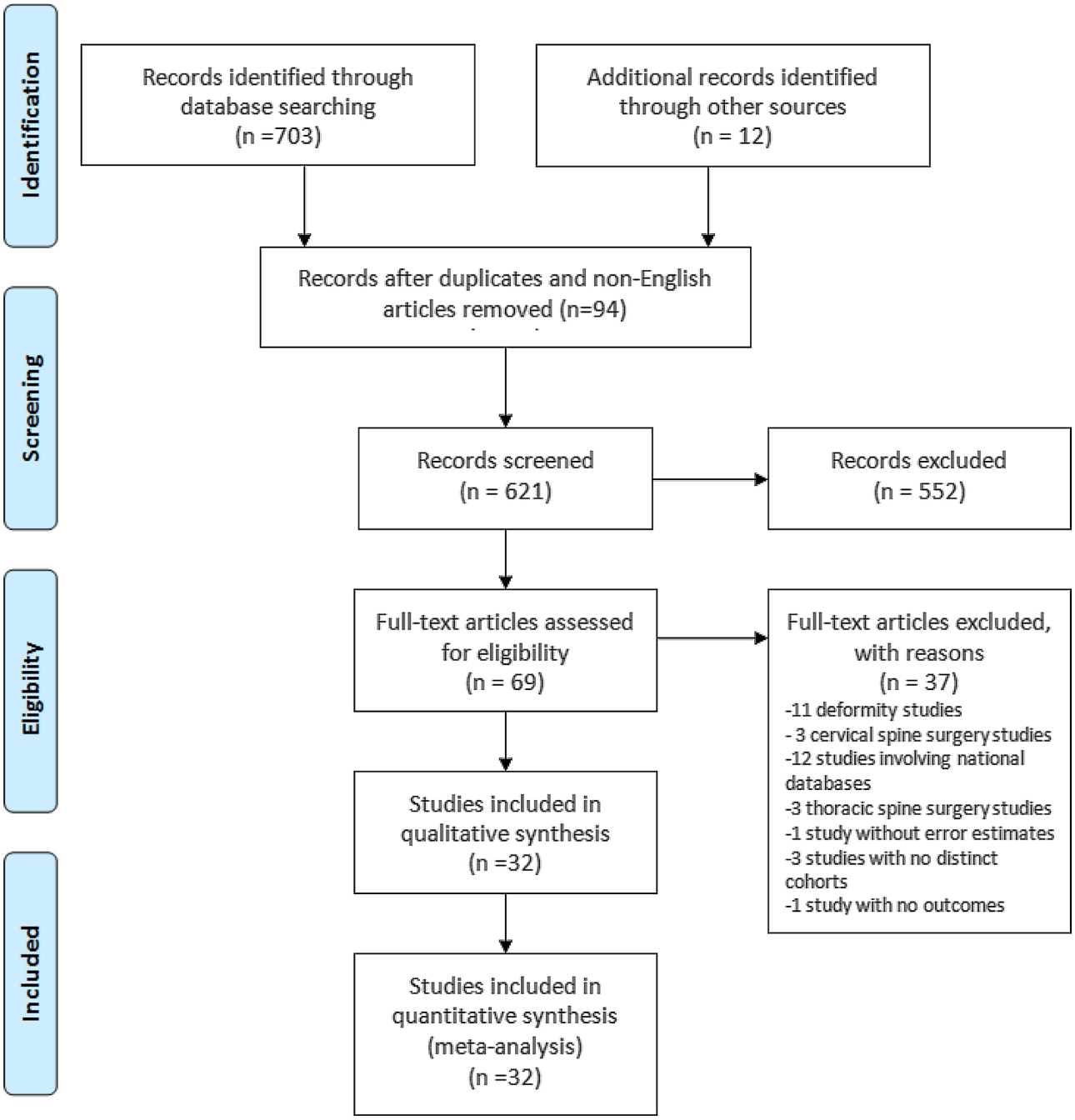


Fig. 1. PRISMA flow diagram of search strategy and study selection.

3.3. Primary outcomes

3.3.1. Estimated blood loss

Based on 12 studies (n = 6,751), our analysis revealed that obese patients had significantly higher EBL compared to non-obese patients (MD = 46.15, 95% CI = 20.21–72, p < 0.001, I^2 = 85%). On subgroup analysis, there was no statistically significant difference between obese and non-obese patients undergoing MIS. (MD = 7.47, 95% CI = -13.63-28.56, p = 0.10, I^2 = 52%) [Fig. 2A].

3.3.2. Operative time

Based on 14 studies (n = 6,368), we found that obesity was also associated with significantly higher operative times (MD = 17.17, 95% CI = 9.91–24.43, p < .001, I^2 = 95%). The difference remained significant for both MIS (MD = 11.15, 95% CI = 3.45–18.85, p = 0.005, I^2 = 29%) and open spine surgery subgroups (MD = 19, 95% CI = 9.7–28.3, p < 0.00, I^2 = 95%) [Fig. 2B].

3.3.3. Length of stay

Analysis of 13 included studies (n = 7,069) revealed no significant difference in length of stay in obese patients compared to non-obese patients (MD = 0.23, 95% CI = -0.06-0.51, p-value = 0.12). Further subgroup analysis confirmed these findings and revealed no statistically significant difference in outcomes for the two subgroups (MIS: MD = 0.61, 95% CI = -0.38-1.6, p = 0.22, I^2 = 87%, Open: MD = 0.12, 95% CI = -0.14-0.37, p = 0.36, I^2 = 62%) [Fig. 2C].

3.3.4. Complications

Overall, obesity was associated with significantly higher perioperative complication rates (OR = 1.34, 95% CI = 1.13–1.58,

Table 1
Study Characteristics.

Study	Year	Country	Period	Study Design	No. of Institutions	Definition of Obesity
Andreshak [2]	1997	USA		Prospective observational	single	BMI > 20% of ideal body weight
Burgstaller [7]	2016	Switzerland		Prospective observational	multicenter	BMI > 30
Elsamadicy [25]	2016	USA	2008-2010	Retrospective observational	single	BMI > 30
Giannadaki [20]	2015	Norway	2006-2012	Retrospective observational	multicenter	BMI > 30
Lau [24]	2013	USA	2006-2009	Retrospective observational	single	BMI > 35
McGuire [29]	2014	USA	2000-2005	Prospective trial	multicenter	BMI > 30
Owens [33]	2016	USA	2004-2008	Retrospective observational	single	BMI > 30
Park [34]	2008	USA	2006-2007	Retrospective observational	single	BMI > 25
Pereira [37]	2014	Brazil	2013-2014	Retrospective observational	single	BMI > 30
Rihn [41]	2012	USA	2000-2005	Retrospective observational	single	BMI > 30
Rihn [8]	2013	USA		Prospective trial	multicenter	BMI > 30
Sorimachi [7]	2016	Finland	2008-2014	Prospective observational	multicenter	BMI > 30
Narain [31]	2017	USA	2005-2014	Prospective observational	single	BMI > 30
Senker [9]	2011	Austria		Retrospective observational	single	BMI > 30
Kashani [32]	2014	Iran	2008-2011	Retrospective observational	single	BMI > 30
Furukawa [6]	2010	Japan	1998-2005	Retrospective observational	single	BMI > 30
McAnany [28]	2016	USA	2011-2013	Retrospective observational	single	BMI > 30
De la Garza-Ramos [18]	2014	USA	1992-2012	Retrospective observational	single	BMI > 30
Djurasovic [21]	2008	USA	2001-2005	Retrospective of Prospective observational study	single	BMI > 30
Elsayed [13]	2017	USA	2012-2014	Retrospective of Prospective observational study	single	BMI > 30
Fakour [14]	2015	UK	Jan 2004-June 2007	Retrospective of Prospective observational study	single	BMI > 30
Tomasino [11]	2009	USA	2004-2007	Retrospective observational	single	BMI > 30
Rosen [43]	2008	USA	September 2002-June 2006	Retrospective of Prospective observational study	single	BMI > 30
Rodgers [14]	2010	USA	October 2006-July 2008	Retrospective of Prospective observational study	single	BMI > 30
Quah [39]	2014	UK	2008-2012	Retrospective observational	single	BMI ≥30
Peng [13]	2009	USA	May 2007-January 2008	Prospective observational	single	BMI ≥30
Flippin [23]	2017	USA	Jan 2009-September 2013	Retrospective of Prospective observational study	multicenter	BMI ≥30
Hanigan [21]	1987	USA	February-September 1984	Retrospective of Prospective observational study	single	BMI > 95th percentile for height and age
Bae [4]	2016	Korea	January 2011-December 2011	Retrospective observational	single	BMI ≥30
Gaudelli [18]	2012	Canada	July 2007- June 2009	Retrospective observational	single	BMI ≥35
Gepstein [22]	2004	Israel	1990-2000	Prospective observational	single	BMI ≥30
Stienen [46]	2016	Switzerland	September 2013-December 2015	Prospective observational	multicenter	BMI ≥30

p = 0.01, I^2 = 45%) based on 21 studies (n = 20,868). However, MIS surgery was associated with a similar incidence of complications between the two groups (OR = 1.58, 95% CI = 0.77–3.26, p = 0.1, I^2 = 45%) while open spine surgery was associated with significantly higher incidence of complications in obese patients (OR = 1.31, 95% CI = 1.10–1.55, p = 0.002, I^2 = 47%) [Fig. 3A].

3.3.5. Reoperations

Compared to non-obese patients, obese patients had significantly higher incidence of reoperation (OR = 1.40, 95% CI = 1.19–1.64, p < 0.001, I^2 = 20) based on 12 studies(n = 17,861). However, the reoperation rate was similar between obese and non-obese patients undergoing MIS spine surgery (OR = 3.17, 95% CI = 0.44–22.65, p = 0.25, I^2 = 30%) but was significantly higher for obese patients undergoing open procedures (OR = 1.38, 95% CI = 0.1.18-1.60, p < 0.001, I^2 = 19%) [Fig. 3B].

3.4. Secondary outcomes

3.4.1. Oswestry Disability Index

Based on 9 studies (n = 4,484), no significant difference was found in mean change in ODI scores between the two groups of patients (MD = -1.56, 95% CI = -5.09–1.97, p-value = 0.39, I^2 = 98%). Similar trends were observed on subgroup analysis for MIS (MD = 6.34. 95% CI = -0.47-13.16, p = 0.07, I^2 = 0%) and open spine surgery (MD = -2.77, 95% CI = -6.53 to 1, p = 0.15, I^2 = 98%) [Supplementary Fig. 1A].

3.4.2. Visual Analog Scale-Back Pain

Pain outcome was assessed using the change in VAS-BP. Based on 9 studies (n = 2,200), no statistically significant difference was found in the mean improvement in VAS scores for Back Pain between the two groups (MD = -0.19, 95% CI = -1.53-1.15, p-value = 0.78, I^2 = 70%). Difference in surgical approach (MIS: MD = -0.19, 95% CI = -1.53-1.15, p = 0.78, I^2 = 68% vs open: MD = -0.11, 95% CI = -0.7 to 0.48, p = 0.71, I^2 = 75%) did not seem to influence change in VAS between obese and non-obese patients [Supplementary Fig. 1B].

3.4.3. Dural tears

Incidence of dural tears was not significantly different between obese and non-obese patients (MD = 0.83, 95% CI = 0.56–1.23, p = 0.48, I^2 = 64%). Subgroup analysis for MIS(MD = 0.47, 95% CI = 0.11–2.02, p = 0.31, I^2 = 0%) and open surgery (MD = 0.86, 95% CI = 0.56–1.31, p = 0.48, I^2 = 64%) did not reveal any significant difference [Supplementary Fig. 2]

3.5. Evaluation of studies

3.5.1. Bias assessment

The risk of bias assessed using the Newcastle-Ottawa Scale (NOS) was found to be high in 22 and medium in 10 studies [Supplemental Table 1]. Funnel plots were generated for publication bias and no

Table 2
Study characteristics and cohorts.

Study	Primary Diagnosis	Surgery	Overall Cohort			Obese			Non Obese		
			Size	Female (n, %)	Mean age (range/SD)	Size	Female (n, %)	Mean age (range/SD)	Size	Female (n, %)	Mean age (range/SD)
Andreshak [28]	Lumbar disk herniation, lumbar spinal stenosis	Laminectomy and/or fusion	150	71 (47.3)		55	27 (49.1)	47.9 (25-81)**	95	44 (46.3)	46.8 (17-85)
Burgstaller [29]	Lumbar spinal stenosis	Decompression	166	80 (48.2)	74 (12)*	44	20 (45.5)	73.5 (12.5)*	122	60 (49.2)	
Elsamadicy [25]	Spondylolisthesis with central or foraminal stenosis	Decompression and fusion	500	272 (54.4)	56.5 (14.4)	219	126 (57.5)	56.23 (13.34)	281	146 (52)	56.74 (15.1)
Giannadakis [30]	Lumbar spinal stenosis	Laminectomy or lumbar microdiscectomy	1473	725 (49.2)		353	167 (47.3)	63.5	1120	558 (49.8)	66.9
Lau [31]	Spondylolisthesis	MI TLIF	16	10 (62.5)		9	5 (55.6)	58.8 (43-77)**	7	5 (71.4)	51.4 (19-79)**
McGuire [32]	Lumbar spinal stenosis, Degenerative spondylolisthesis (DS), and lumbar disc herniation (IDH)		2425	1168 (48.2)	53.7 (11.1)	822	442 (53.8)	54.0 (10.1)	1603	726 (45.3)	53.6 (11.5)
Meredith [33]	Recurrent herniation of nucleus pulposus	Lumbar discectomy	75	29 (39)	46 (16-79)*						
Owens [34]		PLIF	246	161 (65.4)		82	51 (62.2)	59.91	164	110 (67.1)	
Park [35]	Lumbar spinal stenosis	Laminectomy, lumbar discectomy or fusion	77	37 (48.1)	51.3 (15.4)	56	24 (42.9)	54.1 (15.5)	21	13 (61.9)	43.7 (15.2)
Pereira [36]	Degenerative spine disease		100	48 (48.0)	52.7	39	19 (48.7)	51.1 (15.8)	61	29 (47.5)	53.9 (13.8)
Rihn [37]	Lumbar stenosis and degenerative spondylolisthesis		1235	661 (53.5)	65.3 (10.8)	486	281 (57.8)	62.9 (10)	749	380 (50.7)	66.8 (11.3)
Rihn [8]	Lumbar disc herniation	Lumbar discectomy	1190			336			854		
Sorimachi [7]	Degenerative spine disease, degenerative spondylolisthesis, spinal stenosis, scoliosis, spondylolysis	Lumbar Fusion	805	544 (67.6)	61.3 (11.9)	236	168 (71)	63 (10)	569	376 (66.1)	60.6 (12.7)
Narain [38]	Degenerative spine disease	MI TLIF	274	119 (43.4)	52.6 (12.7)	121	56 (46.3)	52.3 (12.7)	153	63 (41.2)	52.8 (12.8)
Senker [9]	Lumbar spinal stenosis	Lumbar MIS fusion	72	42 (58.3)	61.8 (13.1)	27			45		
Kashani [39]	Lumbar disc herniation		206	94 (45.6)	37.5 (3.1)	45	21 (46.7)	38.3 (1.4)	161	73 (45.3)	37.3 (3.06)
Furukawa [6]	Lumbar spinal stenosis	Posterolateral lumbar fusion (PLF)	118	58 (49.2)	69.8 (14.6)	50	19 (38.0)	72.1 (15.9)	68	39 (57.4)	61.3 (11.5)
McAnany [40]		MI TLIF	38	(55.3)	60.13 (2.4)	19	12 (63.2)	60.26 (1.6)	19	9 (47.4)	60 (3.26)
De la Garza-Ramos [18]	Degenerative spine disease	Posterolateral lumbar fusion (PLF)	732	403 (55)	55.11 (14.2)	70	45 (64.3)	51 (12.94)	662	358 (54.1)	55.45 (14.3)
Djurasovic [21]	Degenerative spine disease	Lumbar fusion	270	162 (60)	56.7 (13.6)	109	67 (61.4)	56.18 (12.24)	161	95 (59)	57.11 (14.4)
Elsayed [41]	lumbar spinal stenosis	Lumbar decompression	101	37 (36.6)	61.5 (13.2)	31	7 (22.5)	60.72 (11.67)	70	30 (42.86)	61.86 (13.8)
Fakouri [42]	Lumbar disk herniation	lumbar microdiscectomy	63	24 (54)		31	13 (42)	39 (22–58)†	32	11 (34.4)	37 (28–51)†
Tomasino [11]	lumbar disc herniation or degenerative spinal stenosis	lumbar microdiscectomy (LMD) or laminectomy	115	55 (48)	50.1 (13.4)	36	19 (52.7)	48.8(22-76)**	79	36 (45.6)	54.1 (24–90)**
Rosen [43]	Degenerative spine disease	MIS lumbar fusion	110		56.4 (13.9)	69			38		
Rodgers [14]	Degenerative spine disease, herniated nucleus pulposus	XLIF	313	178 (56.8)	60.9(24-88)**	157	92 (58.6)	58.9 (30-87)**	157	86 (54.7)	62.9 (24-88)**
Quah [44]		lumbar microdiscectomy	283	158 (56)	48 (14-83)†	93			190		
Puvanesarajah [45]	Degenerative spine disease	Posterolateral lumbar fusion (PLF)	56338	34149 (60)		8128	5298 (65)		48,210	28851 (59.8)	
Peng [13]	Degenerative spine disease, lumbar spinal stenosis, degenerative spondylolisthesis, scoliosis	ALIF, artificial disk replacement (ADR), ALIF + ADR	74	39 (52.7)	46.6	33	17 (51.5)	47.3	41	22 (53.6)	44.7
Flippin [23]	Degenerative spine disease	lumbar spinal fusion or total disc replacement (TDR)	8049	4,628 (57.5)	63 (53.0–71.0)‡	3,037	1778 (58.5)	60 (11.7)	5012	2850 (56.8)	62.1 (13.3)
Hanigan [46]	lumbar disc herniation	lumbar discectomy	105	39 (37.1)	40.7 (1.7)	17	4 (23.5)	42.7 (1.6)	88	35 (39.7)	40.4 (1.8)
Bae [47]	lumbar disc herniation	Transforaminal full-endoscopic lumbar discectomy	48	22 (46)		21	7 (33.3)	37.8 (20-60)**	27	15 (55.5)	38.1 (17-75)**
Gaudelli [48]	Degenerative spine disease, lumbar disk herniation	decompression only, decompression with instrumented fusion, deformity correction, or arthroplasty	3388	1620 (47.8)		332	184 (55.4)		3056	1436 (47)	

(*continued on next page*)

Table 2 (*continued*)

Study	Primary Diagnosis	Surgery	Overall Cohort			Obese			Non Obese		
			Size	Female (n, %)	Mean age (range/SD)	Size	Female (n, %)	Mean age (range/SD)	Size	Female (n, %)	Mean age (range/SD)
Gepstein [22]	Degenerative spine disease, lumbar disk herniation	Decompressive laminectomy, discectomy, or both	298	153 (51.3)	71.4 (5.4)	67	40 (59.7)	69.6 (4.5)	231	113 (49)	72 (5.5)
Stienen [49]	Degenerative spine disease, lumbar disk herniation	lumbar fusion	375	162 (43.2)	58.9 (15.7)	94	45 (47.9)	58.9 (14.7)	281	117 (41.6)	58.9 (16.0)

*median (IQR) ‡ mean (IQR) ** mean (range) †median (range).

obvious asymmetry was found on visual inspection.

3.5.2. Quality of evidence

Quality of evidence for each outcome was assessed using the GRADE system. The strength of evidence was found to be low for estimated blood loss, operative time, length of stay, complications and dural tears and very low for reoperations, change in ODI and change in VAS-Back Pain. Table 3 summarizes the overall findings on confidence in GRADE estimates.

3.5.3. Leave one-out sensitivity analysis

For all outcomes involving more than two studies, leave one-out sensitivity analysis was performed to account for cohort size bias. No significant change in outcome trends was observed after omission of each study.

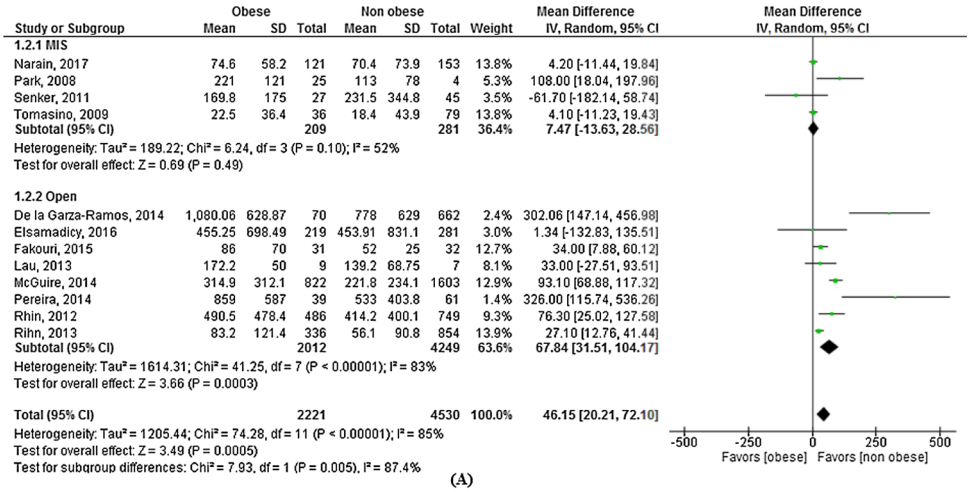
4. Discussion

This is the largest meta-analysis to date exploring the impact of obesity on surgical and functional outcomes following lumbar spine surgery for degenerative spine disease. While Wang et al previously compared outcomes of obese and non-obese patients undergoing minimally invasive spine surgery, the analysis was limited to MIS [48]. Herein, we provide an indirect comparison of outcomes between MIS and open surgery using subgroup analysis. Overall, we found that obese patients had significantly higher blood loss and longer operative duration. Furthermore, obesity was associated with higher odds of perioperative complications and revision surgery. We found preliminary evidence in favor of a trend towards minimally invasive surgery providing equivalent outcomes in obese patients, which can be a useful consideration in decision making for spine surgeons for a MIS vs open approach in this population.

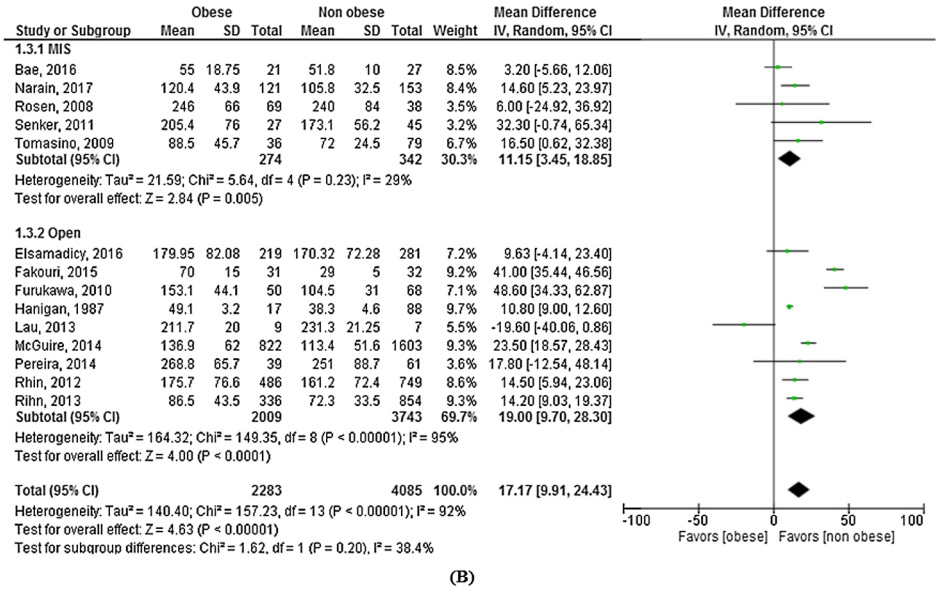
Although the mean differences in estimated blood loss and operative time between the obese and non-obese patients were statistically significant, the effect sizes were quite small and hence not clinically meaningful. These findings might be attributed to the larger dissection required to gain access through the adipose tissue in obese patients; an observation that was found to be true for both MIS and open spine procedures.

Of greater interest was the significantly higher incidence of complications and reoperations with obesity. Hence, this meta-analysis becomes important in the background of several previous studies arguing in favor of similar overall complication rates between the two groups. The primary postoperative complications that have been linked to obesity include deep venous thrombosis [10,27] and wound related complications, such as surgical site infections (SSIs) [1,11,19,27,44]. Differences in rates of other complications such as dural tears, epidural hematomas etc are more controversial [15]. This was also confirmed in our meta-analysis which found no difference in incidence of dural tears between the two groups. Although larger national databases were excluded from our study, our results corroborate the findings of multiple retrospective analyses performed using the NSQIP registry which suggest higher 30-day complication rates with higher BMI following lumbar spine surgery [6,10,27]. Also, in their retrospective study of 500 patients, Elsamadicy et al found patient BMI to be an independent predictor of 30-day readmissions following lumbar spine surgery [12].

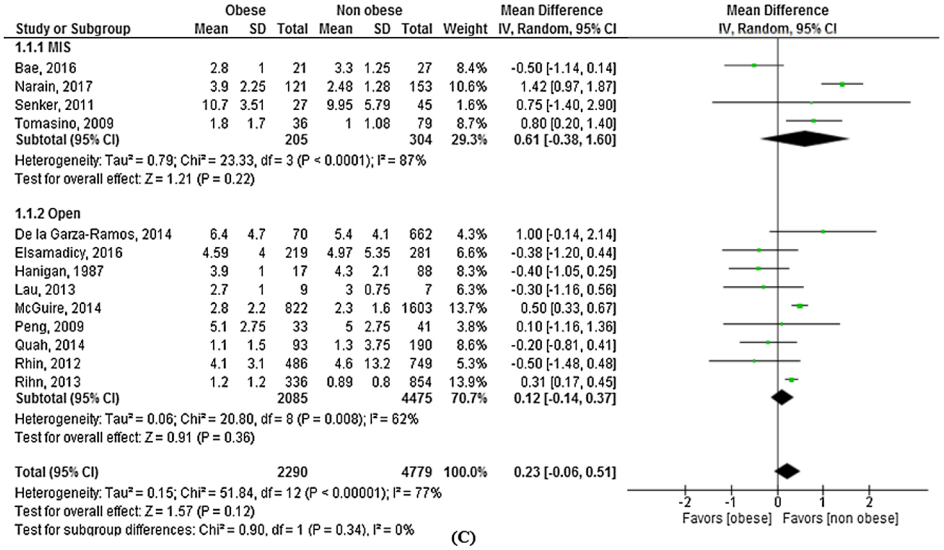
Interestingly, in our analysis, the incidence of complications between the two groups was *similar* for patients undergoing MIS surgery but higher for obese patients undergoing open spine surgery. In a retrospective analysis of 31,763 patients using NSQIP, Bono et al showed that the impact of BMI on complication rates in lumbar spine surgery is related to surgical invasiveness [5]. Also, since most complications linked to obesity might be wound related, it is possible that, as a result, MIS procedures might offer equivalent outcomes between the two groups due to the smaller wound size and limited surgical corridor required to gain access, thereby, avoiding approach related morbidity.



(A)



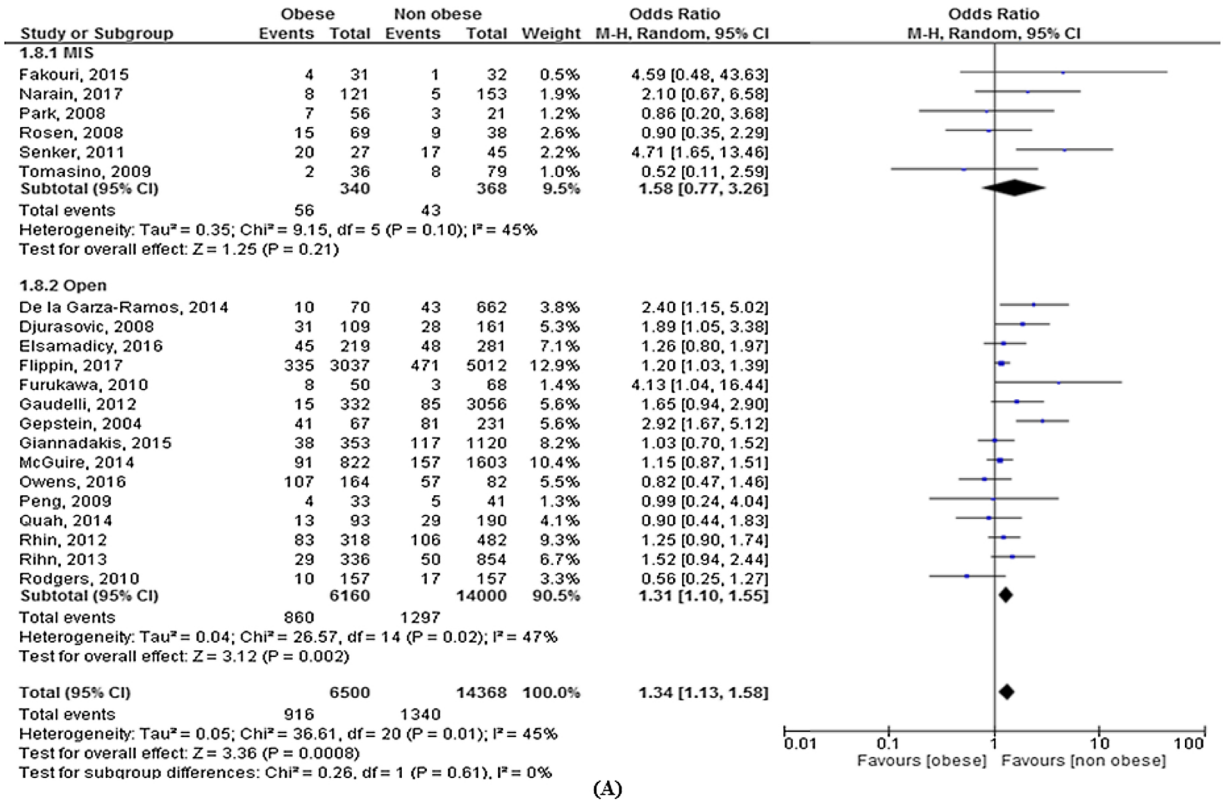
(B)



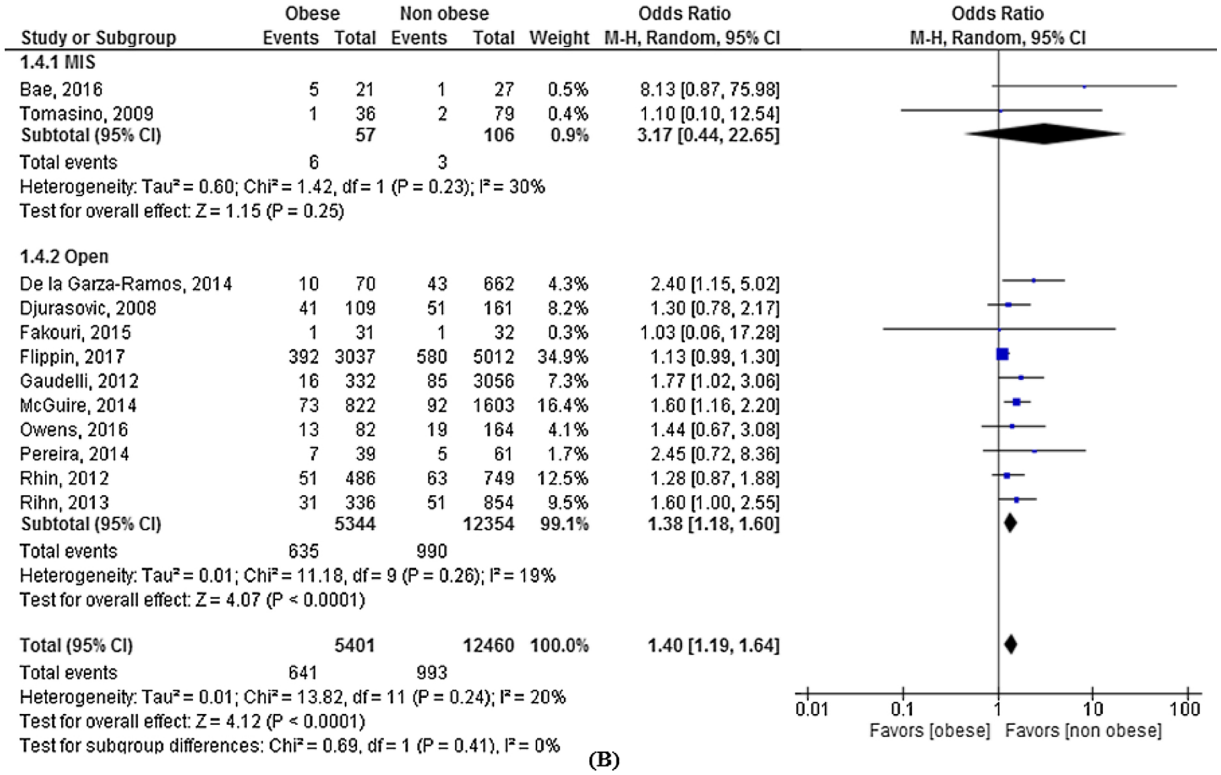
(C)

Fig. 2. Forest plots comparing (A) Estimated Blood Loss(EBL) (B) Operative time and (C)Length of stay(LOS) between obese and non-obese patients.

In a previous meta-analysis by Cao et al, obesity was shown to have no impact on the rate of revision surgery [8]. In contrast, in our updated analysis, we also found higher reoperation rates with obesity. It is important, however, to further assess this finding in the context of cause of reoperation ranging from complications such as surgical site infections and pseudarthrosis or a failure to achieve desired functional



(A)



(B)

Fig. 3. Forest plots comparing (A) complication rates and (B) reoperation rates between obese and non obese patients.

outcomes thereby obviating the need for further revision surgery. In this meta-analysis, given that functional improvement between the two groups was similar, it is possible that higher reoperations were directly related to the higher incidence of complications in obese patients. Similar to complications, it was found that obesity did not influence reoperation rates for patients undergoing MIS procedures while higher rates were found for obese patients undergoing open surgery. The timing of reoperation (short term vs long term) is also important to

Table 3
GRADE Summary of Findings (SoF) table.

Certainty assessment								No. of patients		Effect		Certainty
Outcome	No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Obese	Non obese	Relative (95% CI)	Absolute (95% CI)	
Length of stay(days)	14	observational studies	Serious	Very serious	Not serious	Not serious	none	10418	52989	–	MD 0.28 higher (0.08 higher to 0.48 higher)	⨁⨁◯◯ LOW
Estimated Blood Loss (mL)	12	observational studies	Serious	Serious	Not serious	Not serious	none	2221	4530	–	MD 46.15 higher (20.21 higher to 72.1 higher)	⨁⨁◯◯ LOW
Operative time(min)	14	observational studies	Serious	Very serious	Not serious	Not serious	none	2283	4085	–	MD 17.17 higher (9.91 higher to 24.43 higher)	⨁⨁◯◯ LOW
Reoperations	12	observational studies	Serious	Not serious	Not serious	Not serious	none	641/5401 (11.9%)	993/12460 (8.0%)	OR 1.27 (1.14 to 1.42)	19 more per 1,000 (from 10 more to 30 more)	⨁◯◯◯ VERY LOW
Change in ODI	9	observational studies	Serious	Serious	Not serious	Very serious	none	1234	3250	–	MD 1.56 lower (5.09 lower to 1.97 higher)	⨁◯◯◯ VERY LOW
Complications	21	observational studies	Serious	Not serious	Not serious	Not serious	none	916/6500 (14.1%)	1340/14368 (9.3%)	OR 1.26 (1.14 to 1.38)	21 more per 1,000 (from 12 more to 31 more)	⨁⨁◯◯ LOW
Change in VAS-Back Pain	9	observational studies	Serious	Serious	Not serious	Very serious	none	660	1540	–	MD 0.13 lower (0.65 lower to 0.38 higher)	⨁◯◯◯ VERY LOW

CI: Confidence interval; **MD**: Mean Difference; **OR**: Odds Ratio.

consider, given the occurrence of different etiologies at different time points. Perioperative complications might lead to the need for early reoperations while complications such as adjacent segment disease (ASD) and pseudarthrosis necessitate surgical revision in the long term. The type of surgical procedure, also determines the etiology of long term surgical revision ranging from recurrent disc herniations with decompressive procedures to ASD and pseudarthrosis with fusion. Subgroup analysis of obese patients from the Spine Patient Outcomes Research Trial revealed similar rates of recurrent disc herniations compared to non-obese patients [40]. Unfortunately, due to lack of granularity, neither the incidence of these long term complications nor the effect of timing could be assessed in our study.

Functional improvement, as measured by the *change* in ODI and VAS-BP, was found to be similar between the two groups. This indicates that surgery might offer similar functional outcomes in obese patients. This is in corroboration with the majority of previously published studies, which suggest similar improvement in patient reported outcomes in obese patients following elective lumbar spine surgery as compared to non-obese patients. On subgroup analysis, the higher change in ODI for obese patients undergoing MIS surgery was trending in favor of statistical significance ($p = 0.07$), indicating equivalent, if not slightly higher improvement in obese patients. Similarly, in a small cohort study of 32 obese patients undergoing MIS discectomy, a 97% patient satisfaction rate was reported [9]. All these findings suggest that body habitus may not influence improvement in PROs and obesity shouldn't be a contraindication to surgical management for patients where the main goal is to obtain adequate functional improvement.

4.1. Study strengths and limitations

Our review represents the largest, most updated review on the influence of obesity on lumbar spine surgery outcomes; nevertheless it has several limitations that need to be mentioned. First, only observational studies were found to be available for this analysis resulting in a serious risk of bias and either low or very low confidence in GRADE estimates for all outcomes. Second, findings of this study need to be interpreted with caution, as insufficient evidence exists to suggest these findings hold true in morbidly obese patients undergoing elective lumbar spine surgery. In our review, while studies utilizing MIS surgery did not stratify outcomes separately for morbidly obese patients, a few studies reporting outcomes for these patients following open surgery reported a significantly higher perioperative complication and re-operation rate [24,33,36,45]. Therefore, the influence of BMI on surgical outcomes also needs to be assessed as a continuous variable instead of plain patient categorization into obese and non-obese. Third, studies using national databases and patients with a primary diagnosis of spine deformity were not included in this analysis, thus, representing, potential selection bias. Fourth, obese and non-obese cohorts in each study were not necessarily consistently matched for all characteristics leaving some possible residual confounding. Fifth, standard deviations for change in ODI and change in VAS had to be *imputed* for a few studies which resulted in an additional source of error. Sixth, there was a significant degree of heterogeneity in study design. Although a majority defined obesity as BMI ≥ 30, some studies employed a different definition such as BMI ≥ 35 or 25. Seventh, the definition of complications was also study specific representing an additional source of bias. Functional improvement could be further assessed using outcomes such as the odds of achieving minimum clinically important difference instead of simply comparing the overall change in PROs. Eighth, the length of follow up was variable across studies, thus, making information about change in functional outcomes, harder to interpret. Ninth, assessment of outcomes was not uniform between studies. Also, comparison of costs and hospital resource utilization between the two groups was not performed.

5. Conclusions

In summary, obese patients had slightly longer operative time, higher blood loss, complications and reoperations with lumbar spine surgery but similar functional outcomes as compared to non-obese patients. However, the adverse influence of obesity on surgical outcomes seems to be offset by minimally invasive spine surgery. While complications and reoperations were higher for obese patients with similar functional outcomes as compared to non-obese patients, these differences tended to be insignificant for patients undergoing MIS surgery. Caution must be exercised before generalizing these findings to morbidly obese patients, as the amount of evidence for the same is insufficient. Larger prospective studies and trials are needed to further validate these findings and provide insights into essential elements of preoperative counseling and tailoring of decision making.

Disclosures

No conflicts of interest to disclose

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.clineuro.2018.12.012.

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