Systematic Review

Benefits of Transversus Abdominis Plane Block on Postoperative Analgesia after Bariatric Surgery: A Systematic Review and Meta-Analysis

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Background: Patients undergoing bariatric surgery present unique analgesic challenges, including poorly controlled pain, increased prevalence of obstructive sleep apnea, and opioid-induced respiratory depression. The transversus abdominis plane (TAP) has been demonstrated to be a safe and effective component of multimodal analgesia for a variety of abdominal surgeries.

Objective: To determine the benefits of the TAP block on postoperative analgesia and recovery in patients undergoing bariatric surgery.

Study Design: Systematic review and meta-analysis of randomized controlled trials (RCTs) and non-randomized studies.

Methods: We conducted a comprehensive search of MEDLINE, EMBASE, and Cochrane Central Register of Controlled Trials (CENTRAL) databases from inception to April 2020 for studies using TAP block in bariatric surgeries and reporting postoperative pain, opioid consumption, and recovery-related outcomes. Primary outcomes included postoperative pain scores, opioid consumption, and recovery-related outcomes (e.g., length of stay, time to ambulation). Outcomes were pooled using random effects model and reported as relative risks (RR) or mean differences (MD) with 95% confidence intervals (CI).

Results: Twenty-one studies (15 RCTs [n = 1410] and 6 nonrandomized studies [n = 1959]) were included. Among RCTs, the TAP block group required fewer opioid rescues (RR 0.28; 95% CI 0.18 to 0.42, $P < 0.001$) (moderate quality); reduced total opioid use over 24 hours (MD –8.33; 95% CI –14.78 to –1.89, $P = 0.01$); decreased time to ambulation (MD –1.12 hours; 95% CI –1.50 to –0.73, $P < 0.001$) (high quality); and had significantly lower pain scores at 6 hours (MD –1.52; 95% CI –1.90 to –1.13, $P < 0.01$) and 12 hours (MD –0.95; 95% CI –1.34 to –0.56, $P < 0.001$) on a 0-10 pain scale (moderate quality). No difference was observed for nausea and vomiting, or hospital length of stay. Meta-analyzed outcomes from observational studies supported these results, suggesting decreased postoperative pain and opioid consumption.

Limitations: Studies varied with respect to type of surgery and components of comparator multimodal analgesia, likely contributing to heterogeneity. Subgroup analyses by type of comparator group were conducted to address these differences. We were unable to extract data from all trials included due to variability in outcomes reporting, such as non-opioid drugs for postoperative pain management or invalid dosages. Pain-related outcomes may be affected by operative differences leading to variation in visceral pain. Observational studies have their inherent limitations, such as confounding due to lack of participant randomization and intervention blinding, potentially affecting subjective outcomes, such as pain scores, as well as provider-dependent outcomes, such as hospital length of stay. Lastly, there was significant variation of TAP block technique across all studies.

Conclusion: TAP block is an effective, safe modality that can be performed under anesthesia. It decreases pain, opioid use, and time to ambulation after bariatric surgeries and should be considered in multimodal analgesia for enhanced recovery in this high-risk surgical population.

Key words: Analgesia, bariatric surgery, enhanced recovery after surgery, multimodal analgesia, opioid-sparing analgesia, pain, postoperative, regional block, transversus abdominis plane block.

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Over the past 3 decades, the prevalence of obesity has nearly doubled worldwide (1). As of 2016, 13% of adults over 18 years were considered obese worldwide (2). Bariatric surgery has been shown to successfully achieve meaningful and sustainable weight-loss, with benefits across several metabolic disorders, and remains the mainstay treatment for severely obese patients (Class II obesity or greater; body mass index [BMI] > 35 kg/m^2) (3,4). Despite the increasing use of minimally invasive approaches, a significant number of patients experience moderate to severe pain following bariatric surgery (5,6). Obese patients are more likely to report pain compared to non-obese patients (7,8). There are unique perioperative analgesic challenges in the obese population including the increased prevalence of obstructive sleep apnea (OSA) and its associated concerns of opioid-induced respiratory impairment (9). Patients with obesity are also at increased risk of having poorly controlled postoperative pain which, when coupled with high pre-existing burden of opioid dependence, is a major risk factor for chronic post-surgical pain (10-12). Taken together, adequate management of postoperative pain remains a challenge in morbidly obese patients and is associated with a poorer quality of recovery and quality of life in the immediate postoperative period, with the potential for chronic opioid use in the long term (13,14).

The growing interest in opioid-sparing analgesic techniques stems from efforts to improve the safety of acute pain management, while at the same time facilitating early recovery and discharge (15). Multimodal opioid-sparing analgesia has been shown to adequately control pain, while reducing postoperative narcotic consumption after bariatric surgery (16,17). Enhanced Recovery After Surgery (ERAS) protocols for bariatric surgery recommend opioid-sparing analgesia (18) and regional anesthesia techniques form an important component of most opioid-sparing multimodal analgesia strategies (19). The transversus abdominis plane (TAP) block has demonstrated to be a safe and effective procedure to reduce postoperative pain and opioid consumption for a variety of abdominal surgeries (20-22). However, performance of TAP block in obese patients can be technically challenging, affecting its efficacy and safety. Results from randomized controlled trials (RCTs) have been generally suggestive of benefits for bariatric surgery patients, but include only a few small sized trials (23-25). This systematic review and meta-analysis will evaluate the benefits of performing TAP block in patients undergoing bariatric surgery in both randomized and nonrandomized comparative studies.

Methods

This protocol follows the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement and is guided by specifications outlined in the Meta-analysis of Observational Studies (MOOSE) recommendations (26,27). The protocol for this study was registered in the Prospective Register of Systematic Reviews (PROSPERO) CRD42020184850.

Eligibility Criteria

We included studies that evaluated the benefits of performing TAP blocks for bariatric surgical procedures compared to placebo, or any other analgesic modalities, considered as standalone or part of multimodal analgesia. Articles from both published studies and grey literature were considered for inclusion. We considered all studies with 2 or more comparative arms, and separately evaluated RCTs and non-RCTs (observational studies). Exclusion criteria included: 1) non-comparative studies, including reviews, letters, and editorials; and 2) nonhuman studies. Non-English language studies were included at the selection stage and excluded at the time of full text study selection.

Outcomes

Our primary endpoints were reflective of TAP block efficacy in the form of: 1) postoperative pain scores; and/or 2) postoperative opioid consumption. Secondary outcomes included: 3) hospital length-of-stay (LOS); 4) opioid-related adverse events; 5) antiemetic usage and/or antipruritic usage; 6) 30-day postoperative complications using the Clavien-Dindo classification, a widely used 5-level grading system evaluating the severity of surgical complications, where higher grade corresponds to greater severity with Grade I-II noted as minor complications and Grade III-V noted as major complications (28); and 7) recovery-related outcomes (time to first ambulation, first defecation, first flatus, first oral solid intake).

Search Strategy

We searched the following databases from database inception to April 2020: MEDLINE (via OVID), EMBASE, Cochrane Central Register of Controlled Trials (CENTRAL) databases; as well as looked for unreported or ongoing trials within major clinical trial registries (ClinicalTrials.gov: http://clinicaltrials.gov/; Interna-

tional Clinical Trials Registry Platform Search Portal: http://apps.who.int/trialsearch/). Our search strategy is provided in Supplementary Table 1.

Data Extraction

Two authors independently screened the titles and abstracts, followed by a full-text screening of selected abstracts, using pre-defined inclusion and exclusion criteria. Two reviewers independently extracted data from included studies onto a standardised data collection form designed a priori. The following items from included studies were extracted: 1) study characteristics; 2) patient characteristics; 3) perioperative characteristics: surgery type, TAP block technique; and 4) outcomes as described above.

Risk of Bias Assessment

Individual RCTs were assessed using the CENTRAL's modified tool for assessing risk of bias in randomized trials (29). The Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I) tool was used to assess observational studies (30). Risk of bias was independently assessed by 2 authors. Certainty of evidence for estimates derived from each meta-analyzed outcome from RCTs were assessed by the grading of recommendations, assessment, development, and evaluation (GRADE) approach (31).

Statistical Analysis

All statistical analyses and meta-analyses were performed using Cochrane Review Manager 5.4 (London, United Kingdom) and STATA, version 15 (StataCorp, College, TX) with significance set at $P < 0.05$. We performed pairwise meta-analyses using a DerSimonian and Laird random effects model for continuous and dichotomous variables. Pain scores collected using different scales (numeric rating scale [NRS] or visual analogue scale [VAS]) were converted into a common 0 to 10 scale (0 = no pain, 10 = maximum tolerable pain). Pooled-effect estimates were obtained by estimating the mean difference (MD) in outcomes for continuous variables and risk ratios (RR) for dichotomous variables with 95% CIs, as appropriate. Mean and SD were estimated for studies that only reported median and interquartile range using the estimation method proposed by Wan, et al (32,33), to allow for pooling of continuous outcomes. For missing outcomes or variables, we attempted to contact the original authors of the included studies by email. Statistical heterogeneity was assessed using the inconsistency (I^2) statistic, and interpreted as per Cochrane standards (34). Funnel plots were generated to assess potential publication bias for meta-analysis containing at least 10 studies, as fewer studies can lead to bias when distinguishing symmetry and asymmetry in the funnel plot (35). Subgroup analysis was planned based on the type of bariatric surgery and the major type of analgesic comparator (regional blockade versus intravenous). Sensitivity analysis was performed based on studies with potential for high risk of bias based on a particular domain, and if there were missing outcomes of > 20%.

Results

Study Characteristics

Out of 92 potentially relevant citations, 15 randomized studies (5,23-25,36-46) and 6 non-randomized studies (47-52) were selected (Fig. 1). Studies were conducted across 6 different countries from 2013 to 2020, with the majority of studies (n = 11) published over the past 2 years.

Among 15 RCTs, there were 12 trials having 1 comparison and 3 trials with 2 comparisons. Study characteristics are reported in Table 1.

The trial by Saber had 2 separate TAP groups using bupivacaine with or without epinephrine, which we combined as 1 group (37). In total, there were 17 comparisons in which TAP block was compared to various control groups, including placebo (n = 10) (Table 1).

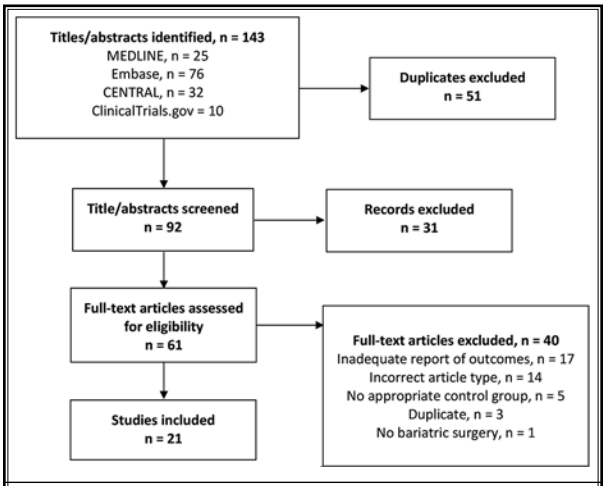

Fig. 1: *PRISMA reporting of systematic reviews and meta-analysis flow diagram outlining the search strategy results from initial search to included studies. PRISMA indicates Preferred Reporting Items for Systematic reviews and Meta-Analyses.*

Table 1. *Study Characteristics of randomized control trials.*

Study	Country	Surgery type (n)	Arm	N analyzed	% Women	Age (±SD)	BMI (kg/m^2)	ASA I/II/III (n)	Diabetes	Hypertension	Dyslipid-emia	Sleep apnea	Mean operative time (min)
Albrecht, 2013	Canada	LRYGB (27)	TAP*	27	74.07	44.8 ± 10.2	49.3 ± 9.3	0/2/25	-	-	-	-	-
		LRYGB (30)	Control*	30	86.67	38.8 ± 10.6	48.9 ± 7.9	0/4/26	-	-	-	-	-
Emile, 2019	Egypt	LSG (29) LGCP (6) LMGB (3) SASI (8)	TAP	46	93.48	35.8 ± 8.9	50.4 ± 7.9	21/23/2	12 (26.1)	15 (32.6)	-	24 (52.2)	80.9 ± 16.9
		LSG (35) LGCP (2) LMGB (4) SASI (5)	Control	46	91.30	33.6 ± 9.8	48.6 ± 5.3	18/24/4	14 (30.4)	18 (39.1)	-	27 (58.7)	78.3 ± 14.5
De Oliveira, 2014	USA	LGB (10)	TAP	10	80.00	46.3 ± 10.4	43.0 ± 5.0	0/3/7	-	-	-	-	77.8 ± 40.7
		LGB (9)	Control	9	77.78	46.7 ± 13.3	41.0 ± 4.3	0/5/4	-	-	-	-	91.0 ± 43.7
Gupta, 2020	India	LSG LRYGB	TAP	28	-	42.82 ± 11.2	45.05 ± 5.67	-	-	-	-	-	148.39 ± 44.66
		LSG LRYGB	Lidocaine infusion	28	-	40.89 ± 12.73	46.48 ± 9.34	-	-	-	-	-	142.50 ± 38.96
Ibrahim, 2014	Egypt	LSG (21)	TAP	21	76.19	38.26 ± 10.19	48.52 ± 10.39	0/16/5	-	-	-	-	119.34 ± 10.39
		LSG (21)	Control*	21	71.43	36.67 ± 9.34	46.14 ± 9.26	0/13/8	-	-	-	-	113.93 ± 18.39
		LSG (21)	Placebo	21	66.67	37.44 ± 11.34	46.4 ± 8.65	0/14/7	-	-	-	-	120.55 ± 13.34
Mittal, 2018	India	LSG (30)	TAP	30	-	-	45.22 ± 6.98	-	-	-	-	-	-
		LSG (30)	Control	30	-	-	44.94 ± 7.15	-	-	-	-	-	-
NCT 04051684	USA	LSG LRYGB LGB	TAP	12	91.7	42.4 ± 13.9	-	-	-	-	-	-	-
		LSG LRYGB LGB	Control	11	90.9	44 ± 12.6	-	-	-	-	-	-	-
Ruiz-Tovar, 2018	Spain	LRYGB (70)	TAP	70	57.14	41.9 ± 5.9	47.4 ± 5.2	-	25 (35.9)	29 (41.4)	27 (38.6)	44 (62.9)	83.3 ± 15.6
		LRYGB (70)	Control *	70	57.14	41.7 ± 7.2	46.5 ± 4.3	-	25 (35.7)	30 (42.9)	24 (34.3)	46 (65.7)	80.5 ± 14.4
Ruiz-Tovar, 2020	Spain	LRYGB	TAP *	70	71.4	43.1 ± 10.6	42.4 ± 3.2	-	26 (37)	35 (50)	24 (34.3)	44 (62.9)	78.5 ± 14
		LRYGB	Control*	70	71.4	43.9 ± 10.2	42.6 ± 3.6	-	24 (34.4)	33 (47)	23 (32.9)	46 (65.7)	75.9 ± 12.6

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Study	Country	Surgery type (n)	Arm	N analyzed	% Women	Age (±SD)	BMI (kg/m^2)	ASA I/II/III (n)	Diabetes	Hypertension	Dyslipid-emia	Sleep apnea	Mean operative time (min)
Saber 2019	USA	LSG (27)	TAP (bupivacaine with epi)	27	81.5	27 ± 11.2	43 ± 10.3	-	4 (14.8)	11 (40.7)	8 (29.6)	7 (25.9)	61 ± 21.9
		LSG (31)	TAP (bupivacaine only)	31	87.1	37 ± 10.7	44 ± 4.8	-	4 (12.9)	9 (29.0)	5 (16.1)	8 (25.8)	56.4 ± 13.5
		LSG (32)	Placebo	32	93.75	40 ± 11.2	44 ± 7.1	-	6 (18.8)	13 (40.6)	2 (6.3)	7 (21.9)	54.8 ± 17.5
Said, 2017	Egypt	LSG (45)	TAP†	45	68.9	32.1 ± 4.9	36.1 ± 2.4	29/16/0	5 (11.1)	4 (8.9)	-	-	158.4 ± 24.4
		LSG (45)	Control	45	62.2	32.8 ± 5.4	35.6 ± 2.7	33/12/0	4 (8.9)	3 (6.7)	-	-	151.4 ± 23.1
Sinha, 2013	India	LRYGB (50)	TAP	50	-	39.9 ± 13.3	48.1 ± 6.3	-	-	-	-	-	-
		LRYGB (50)	Control	50	-	39.1 ± 10.6	45.6 ± 6.6	-	-	-	-	-	-
Tulubas, 2019	Turkey	LSG (80)	TAP	80	62.5	37.97 ± 10.61	48.03 ± 6.77	0/0/80	20 (25)	10 (12.5)	-	-	-
		LSG (85)	Placebo	85	61.1	37.88 ± 10.14	50.96 ± 8.73	0/0/85	33 (38.8)	15 (17.6)	-	-	-
Wassef, 2013	USA	LSG (single port)	TAP	10	60	43 ± 12	42 ± 4	-	-	-	-	-	-
		LSG (single port)	Control	25	88	47 ± 13	47 ± 7	-	-	-	-	-	-
Wong, 2020	USA	LRYGB (15) LSG (55) LSG to LRYGB conversion (5)	TAP (liposomal bupivacaine)	75	80	42.1 ± 9.8	44.5 ± 7.6	-	26 (34.5)	-	17 (22.7)	23 (30.7)	-
		LRYGB (16) LSG (57)	TAP (regular bupivacaine)	73	78.1	39.4 ± 10.9	44.8 ± 5.5	-	14 (19.2)	-	18 (24.7)	28 (38.4)	-
		LRYGB (21) LSG (48) LSG to LRYGB conversion (2)	Control	71	90.1	40.4 ± 11.0	44.2 ± 5.5	-	15 (21.1)	-	18 (25.4)	25 (35.2)	-

LSG, laparoscopic sleeve gastrectomy; LRYGB, laparoscopic gastric bypass; LGSP, laparoscopic greater curvature plication; LMGB, laparoscopic mini-gastric bypass; SASI, single anastomosis sleeve ileal bypass; LGB, laparoscopic gastric banding

*included site infiltration with local anesthetic; †continuous TAP infusion

There were 705 patients in the TAP group versus 705 patients in the non-TAP group (74.2% women, median age 40.0 years [27.0-47.0]). As the comparators were clinically heterogenous, we separately pooled individual RCT outcomes based on distinct comparators. All patients had Class 2 obesity (BMI 35-40 kg/m^2 or higher[BMI > 40 kg/m^2]). The majority types of bariatric surgery performed in the trials were laparoscopic sleeve gastrectomy (LSG) (10 trials) and laparoscopic Roux-en-Y gastric bypass (RYGB) (7 trials). Due to the nature of TAP administration, most of the included trials did not have blinding of anesthesiologists. Two trials were rated as having the potential for risk of bias for measurement of outcomes due to patients being aware of their intervention allocation and the subjective reporting of pain scores (Supplementary Table 2).

All 6 observational trials (n = 1,959) included were prospective cohort studies and we considered them for subgroup pooling by type of surgeries, as reported by most studies. Among them, 986 patients received TAP block and 973 received non-TAP block analgesia (80.6% women, median age 44.8 years [38.7-49.0]). All patients underwent laparoscopic procedures, including LSG (n = 1,267, 64.5%) and RYGB (n = 671, 34.2%). Study characteristics of observational studies are reported in Supplementary Table 3. All observational trials were rated for having a moderate risk of bias for confounding (Supplementary Table 4).

TAP Block Techniques Across All Studies

The technique of TAP block varied significantly across both randomized and non-randomized studies. Fourteen studies used ultrasound-guided blocks, while 7 studies performed TAP block under laparoscopic visualisation by the surgeon. Timing of TAP block was reported as preoperatively (n = 3), intraoperatively (n = 15), and postoperatively (n = 1) (2 studies did not report the time). Of the intraoperative blocks, 5 were performed immediately after induction, 6 at the end of the surgery, and 4 studies did not specify. Most trials (n = 14) used some formulation of bupivacaine for the TAP block, with 4 studies using liposomal bupivacaine (43,47,50,52), 1 trial using bupivacaine with lidocaine (48), and 2 trials using bupivacaine with epinephrine (5,37). The remaining 7 trials used ropivacaine.

Opioid Sparing Effect of TAP

Individually, all 4 RCTs that measured the requirement for opioid rescue showed significantly lower incidence in the TAP block, with overall pooled RR: 0.28 (95% CI 0.18 to 0.42), $P < 0.001$, $I^2 = 0\%$ (Fig. 2A); absolute risk reduction of 24% and a number needed to treat (NNT) of 4, with moderate certainty (Table 2).

This effect was consistent with individual comparisons, with no significant subgroup effect. Seven RCTs and 7 cohort studies reported opioid consumption. Although the overall total opioid use over 24 hours (oral morphine milligram equivalents [OME]) after bariatric surgery was significantly less in the TAP group (MD: –8.33 [95% CI –14.78 to –1.89], $P = 0.01$), the effect was only significant in comparison with the non-TAP subgroup (Fig. 2B). Among cohort studies, there was a significant decrease in OME in the TAP group overall (MD: –72.49 [95% CI –91.22 to –53.75], $P < 0.001$), which remained consistent when stratified by surgical type. However, it was affected by substantial heterogeneity, thereby limiting its conclusions (Supplementary Fig. 1). A meta-analysis of time to first opioid use was not conducted due to limited reporting across included trials. In studies comparing TAP versus non-TAP, the TAP group had a significantly longer time to first opioid use, compared to the non-TAP group (38). However, when compared with placebo, or infiltration, there were no differences observed between the 2 groups (5, 38, 42).

Pain Scores and Recovery-related Outcomes from Randomized Trials

VAS were reported at 1-, 6-, 12-, and 24-hour timepoints in the included trials. Pooling of outcomes revealed a significant subgroup effect based on the comparator for scores at 1 hour and 24 hours (Supplementary Fig. 2A and 2B). At 6 hours (8 studies with 766 patients) the TAP group had significantly lower pain scores (MD: –1.52 [95% CI –1.90 to –1.13], Fig. 3A; moderate certainty, Table 2). At 12 hours the TAP group (7 studies with 551 patients) still had sustained significance in pain scores (MD: –0.95 [95% CI –1.34 to –0.56], Fig. 3B; moderate certainty, Table 2). At both time points, TAP versus non-TAP comparison had the most individual and overall studies supporting the effect estimate. There were fewer cohort studies comparing pain scores: for RYGB, there was only 1 comparison at 12 hours and 2 comparisons at 24 hours; for LSG, there were 2 comparisons at 12 hours and 4 at 24 hours. However, none of these comparisons favored the TAP group (Supplementary Fig. 3A and 3B).

Other Outcomes

Among RCTs, there was no difference between the TAP group versus the control group for the incidence

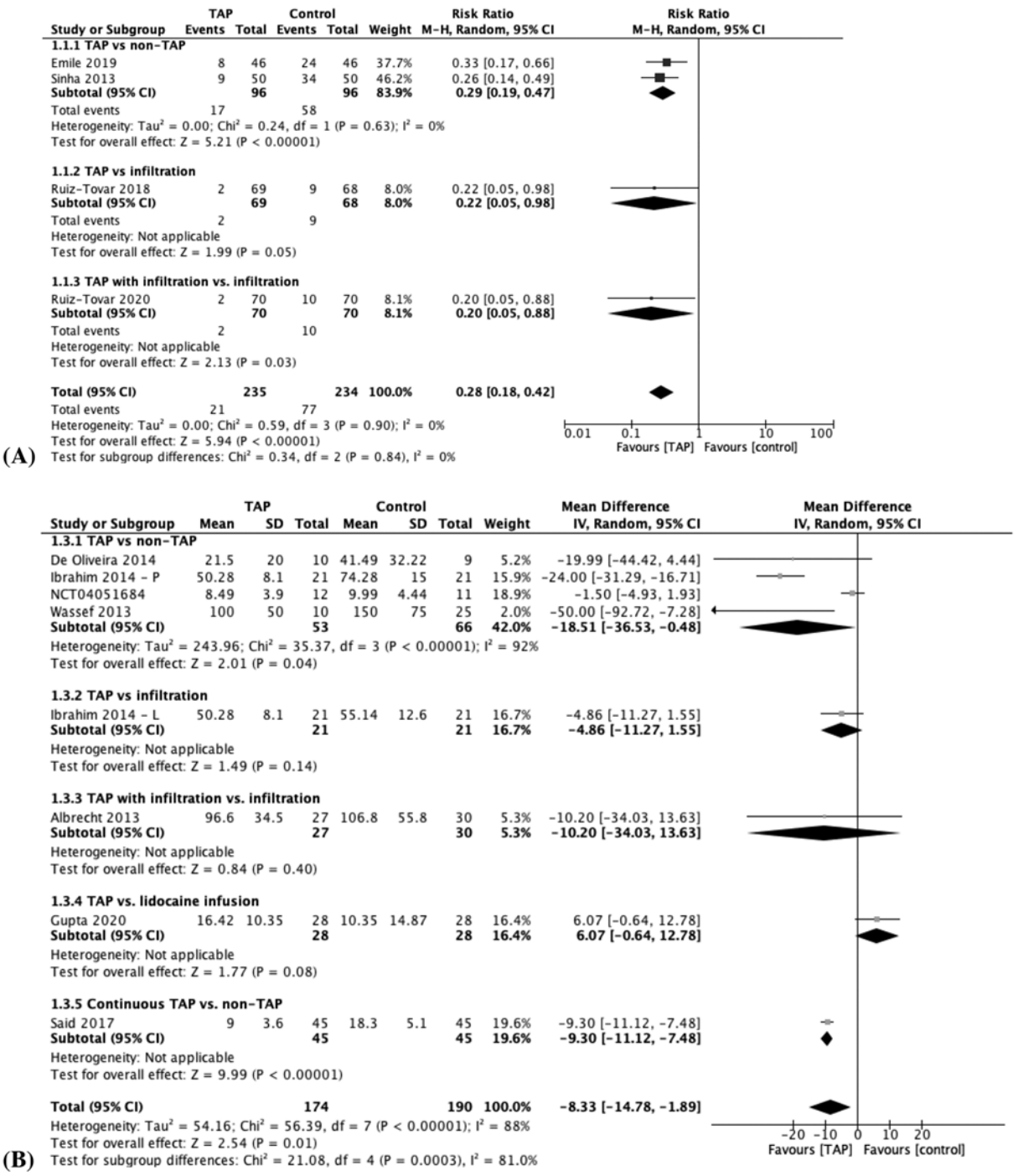

Fig. 2: *Random-effects meta-analysis forest plots for randomized controlled trials comparing transversus abdominis plane block, versus control group on (A) requirement of opioid rescue and; (B) 24-hour total opioid requirement in oral morphine equivalents. OME, oral morphine equivalents; RCT, randomized controlled trial; TAP, transversus abdominis plane*

Table 2. *Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) of meta-analyzed outcomes from randomized controlled trials.*

Certainty assessment						Summary of findings		
No. of Patients	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Publication Bias**	**Overall certainty of evidence**	**Pooled effect size (95% CI)**	**Anticipated Effects**
Number requiring opioid rescue								
469 (4 RCTs)	not serious*	not serious†	not serious§	serious¶	none	⊕⊕⊕◯ MODERATE	RR 0.28, 95% CI 0.18 to 0.42 $P < 0.001$, $I^2 = 0\%$	On average, every 4 patients receiving TAP probably prevents need for opioid rescue in one additional patient
Mean pain score at 6h								
766 (8 RCTs)	not serious*	serious‡	not serious§	not serious	none	⊕⊕⊕◯ MODERATE	MD -1.52, 95% CI -1.90 to -1.13 $P < 0.01$, $I^2 = 77\%$	TAP probably reduces absolute 6h pain scores by 15.2%
Mean pain score at 12h								
551 (7 RCTs)	not serious*	serious‡	not serious§	not serious	none	⊕⊕⊕◯ MODERATE	MD -0.95, 95% CI -1.34 to -0.56 $P < 0.001$, $I^2 = 84\%$	TAP probably reduces absolute 1h pain scores by 9.5%
Mean time to ambulation in hours								
722 (6 RCTs)	not serious*	not serious†	not serious§	not serious	none	⊕⊕⊕⊕ HIGH	MD -1.12, 95% CI -1.50 to -0.73 $P < 0.001$, $I^2 = 23\%$	TAP very likely reduces time to ambulation by 1.12 hours.
Patients with PONV								
778 (7 RCTs)	not serious*	serious‡	not serious§	serious¶	none	⊕⊕◯◯ LOW	RR 0.77, 95% CI 0.53 to 1.13 $P = 0.18$, $I^2 = 54\%$	There is probably no significant difference in the incidence of PONV
Mean LOS in days								
825 (7 RCTs)	not serious*	serious‡	not serious§	not serious	none	⊕⊕⊕◯ MODERATE	MD 0.00, 95% CI -0.16 to 0.17 $P = 0.96$, $I^2 = 68\%$	There is probably no significant difference in mean hospital LOS

CI, confidence interval; LOS, length of stay; MD, mean difference; PONV, postoperative nausea and vomiting; RCT, randomized controlled trial; TAP, transversus abdominis plane. *All of the trials included had adequate randomization, low attrition bias, and low reporting bias. However, the majority of studies did not blind healthcare providers and outcome assessors due to the nature of the intervention. Nonetheless, this limitation in healthcare provider blinding is less important for the outcomes analyzed in the present meta-analysis, such as patient-reported pain scores, opioids usage, and length-of-stay. Therefore, the quality of the evidence was not downgraded. †Low heterogeneity, I2 < 50% with similar point estimates and overlapping confidence intervals. ‡Quality of evidence was downgraded because high heterogeneity (I2 > 50%) was present in these meta-analyzed outcomes. §All included RCTs directly compare TAP analgesia to non-TAP analgesia in relevant patients and report common outcomes of interest. ¶Downgraded 1 point because the total number of events was less than 300 or the total number of sample size was less than 400.

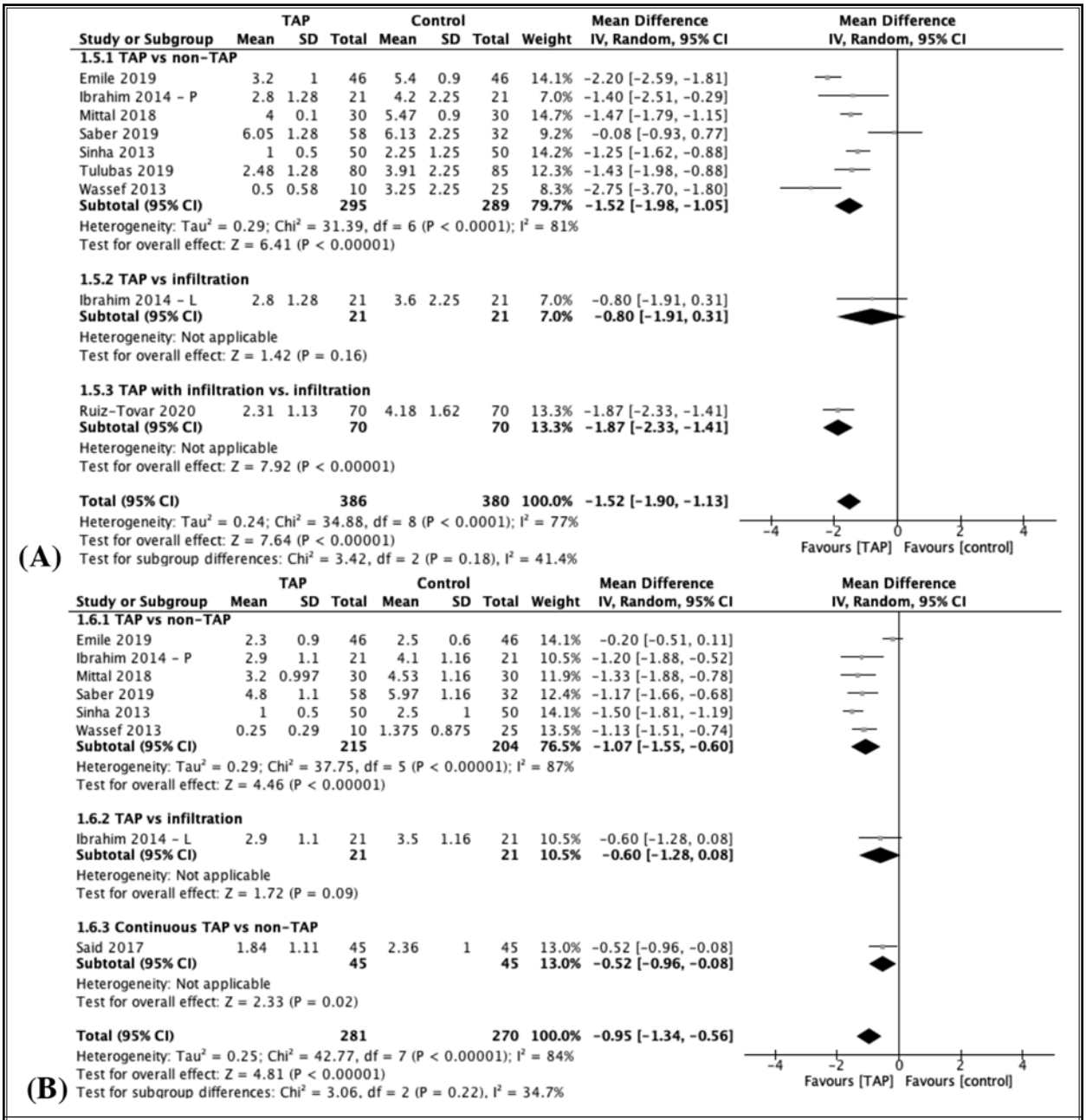

Fig. 3: *Random-effects meta-analysis forest plots for randomized controlled trials comparing transversus abdominis plane block versus control group on postoperative pain scores (numeric pain scale 0-10) at (A) 6 hours and (B) 12 hours. RCT, randomized controlled trial; TAP, transversus abdominis plane*

of postoperative nausea/vomiting within 24 hours of bariatric surgery (RR: 0.77 [95% CI 0.53 to 1.13], low certainty; Supplementary Fig. 4 and Table 2), but the overall time to ambulation (6 studies with 722 patients) after surgery was shorter in the TAP group by 1.22 hours (MD: –1.12 [95% CI –1.50 to –0.73], high certainty; Fig. 4 and Table 2). The length of stay after surgery was not observed to be different with RCTs (MD: 0.00 [95% CI –0.16 to 0.17]), except within study by Ruiz-Tovar, et al (24), Supplementary Fig. 5A and Table 2); within cohort studies the length of stay was decreased in the TAP block arm by a small but significant amount (MD: –0.31

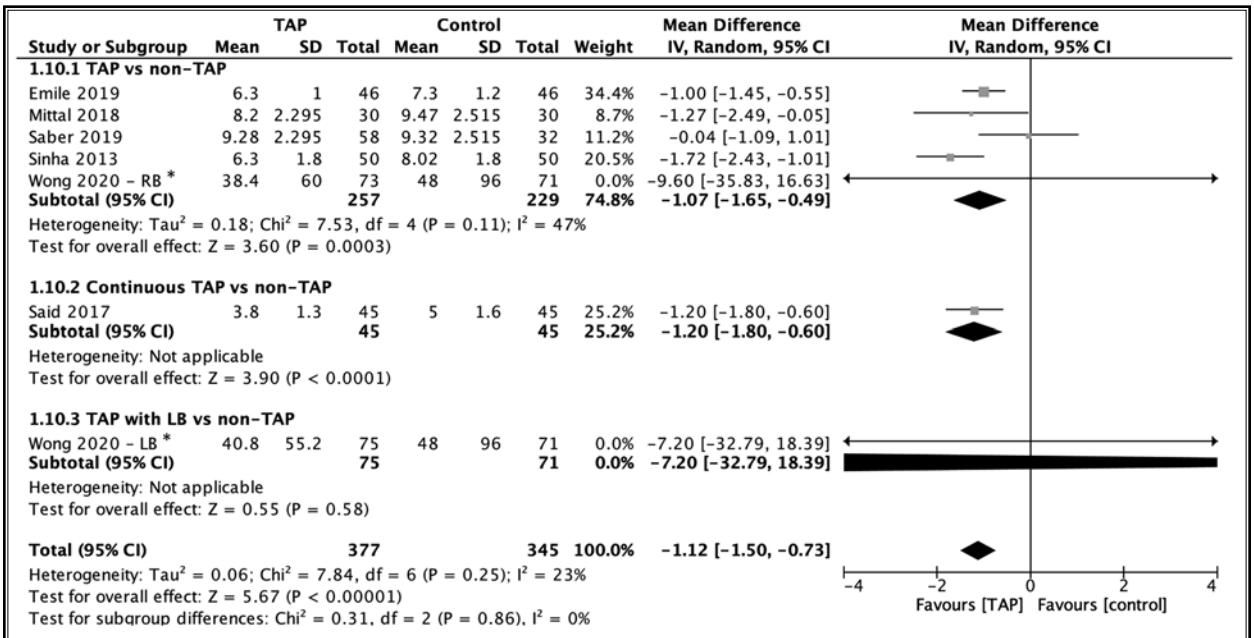

Fig. 4: *Random-effects meta-analysis forest plots for randomized controlled trials comparing transversus abdominis plane block, versus control group, on time to first ambulation in hours. LB, liposomal bupivacaine; RB, regular bupivacaine; RCT, randomized controlled trial; TAP, transversus abdominis plane.*
*The confidence intervals from Wong 2020 were extremely wide and not entirely displayed in the figure.

days [95% CI –0.56 to –0.06], *P* = 0.01; Supplementary Fig. 5B).

Discussion

To our knowledge, the present study presents the most comprehensive systematic review and meta-analysis to date investigating the TAP block in patients undergoing bariatric surgery. Among included studies were 15 RCTs and 6 non-randomized studies with 1,410 and 1,959 patients respectively. Findings from RCTs found that TAP block reduces opioid rescue administration, opioid consumption, postoperative pain scores, and time to ambulation. There was no difference in the incidence of postoperative nausea/vomiting, or hospital length of stay. Meta-analyzed outcomes from non-randomized studies showed reduced opioid consumption and shorter hospital length of stay.

First described by Rafi in 2001 (53), TAP block has been increasingly used and adopted, and later refined as an ultrasound-guided approach by Hebbard, et al, in 2007 (54). Tran, et al, (55) detail the anatomy, history, approaches, techniques, and clinical indications of TAP block in their narrative review. Based on its mechanism, TAP block provides analgesia for the somatic component, but not for the visceral component of pain after surgery. Hence, it was considered more appropriate and efficient for use in open surgeries, as compared to laparoscopic approaches. Around the conduct of this review, there were only 3 studies reporting the use of TAP blocks for bariatric surgery, with inconclusive results (55). Most existing reviews and meta-analyses have focussed on colorectal or other abdominal surgeries. Brogi, et al, (56) looked at all abdominal surgeries (n = 51), including three bariatric surgery trials. Within reviews that focussed on colonic surgeries, there is consistent evidence to suggest that TAP block reduces pain scores and also decreases opioid consumption, although the actual effect size has varied (57,58). From a clinical perspective, there are 2 important considerations: are these outcomes sufficient to recommend routine use; and are there any drawbacks. Compared to other surgical populations, pain management challenges in bariatric population are unique. Consideration of the need to avoid opioids take special importance, apart from the limitations in using known conventional opioid-sparing agents, such as nonsteroidal anti-inflammatory drugs (59). Although measures of pain are subjective, it has been suggested, across multiple studies investigating the clinical importance of changes in pain, that

pain score reductions of 20% or more (effectively a decrease of 1 point on a 0-10 scale) may be considered meaningful and important to the patient (60,61). In our analyses, we observed a decrease of greater than 1.5 points at 6 hours, but nearly 1 point at 12 hours. Importantly, when TAP was compared to non-TAP group, the result was more robust and consistent at both 6 and 12 hours, although no subgroup effect was observed. Studies included in the present study reported TAP block being performed at various timepoints in the perioperative setting, commonly immediately after induction or at the conclusion of the procedure, before emergence from anesthesia. Given the pharmacokinetics of local anesthetics, the most opportune time to perform TAP block would be at the end of the procedure, when there is less impact of variability in operative time, which may affect the bioavailability of agents and thus, postoperative analgesia duration is increased. The opioid consumption did show a decrease of 8.3 mg (OME) overall, but was significant only compared to the non-TAP subgroup. Known opioid-sparing agents reduce opioids in the range of 6 to 10 mg (55). Based on the need for rescue opioid analgesia as an outcome, we observed that 1 in 4 patients having TAP block would not need opioid rescue analgesia. We also observed that time to ambulate was significantly lower in the TAP group. Decreased time to ambulate facilitates recovery, hence we note that the ERAS society makes strong recommendations for its use in minimally invasive colonic surgery, even with moderate quality of evidence (62). This must be contrasted with other opioid-sparing agents, such as gabapentinoids (63) or infusions of dexmedetomidine (64,65), which can cause sedation and increase time of discharge from recovery, affecting ERAS negatively. TAP blocks have other advantages over fascial or plane blocks, as they can be safely performed under general anesthesia (66). Although our results suggest that TAP blocks should be considered for routine use, it is necessary and would be advantageous to look for larger RCTs to establish their evidence, such as the proposed study by Jarrar, et al (62).

Although this current study demonstrates the benefits of TAP block, there are still several questions regarding optimal TAP block technique. Performing TAP block is an operator-dependent procedure and can be associated with significant technical difficulties in obese patients (67, 68). To date, there has not been comparative studies assessing optimal TAP block technique in bariatric patients. Recent RCTs in colorectal surgery indicate laparoscopic-guided TAP to be superior to ultrasound-guided TAP (69), while another found non-inferiority between the 2 guided techniques (67). Moreover, advances such as laparoscopic-assisted performance can decrease dependency on trained anesthesiologists and allow surgeons to participate in analgesia to facilitate care and collaboration (55).

Limitations

Limitations we observed included studies varying with respect to type of surgery and components of comparator multimodal analgesia, likely contributing to heterogeneity. To address this, we performed subgroup analysis by comparator analgesia regimens reported among studies. Due to variability in outcome reporting, such as non-opioid drugs for postoperative pain management or invalid dosages, we were unable to extract data from all trials included. Pain-related outcomes may be affected by operative differences (5 laparoscopic ports for LSG and 6 for laparoscopic RYGB operative time) leading to variation in visceral pain. Observational studies have their inherent limitations, such as confounding due to lack of patient randomization and intervention blinding, potentially affecting subjective outcomes, such as pain scores, as well as provider-dependent outcomes, such as hospital length of stay. Lastly, there was significant variation of TAP block technique across all studies.

Conclusions

The present study suggests that performing the TAP block in bariatric surgery is safe and effective in reducing postoperative opioid requirements and lowering pain scores up to 24 hours after surgery, while reducing time to ambulation, with moderate to high certainty of evidence. These findings are of particular importance in the bariatric population, who are at increased baseline risk for opioid-induced complications, such as respiratory depression, and would benefit from an analgesia regimen aimed at limiting such risks in the postoperative period. Further research might aim to determine optimal TAP block technique and firmly establish high-quality evidence to support clinical decisions.

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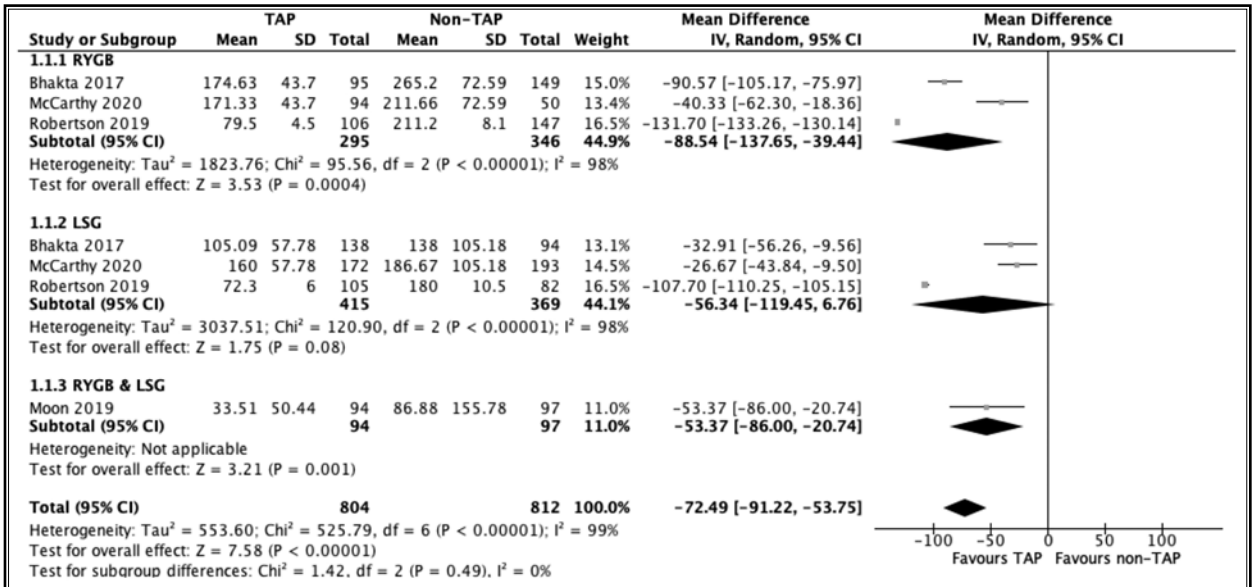
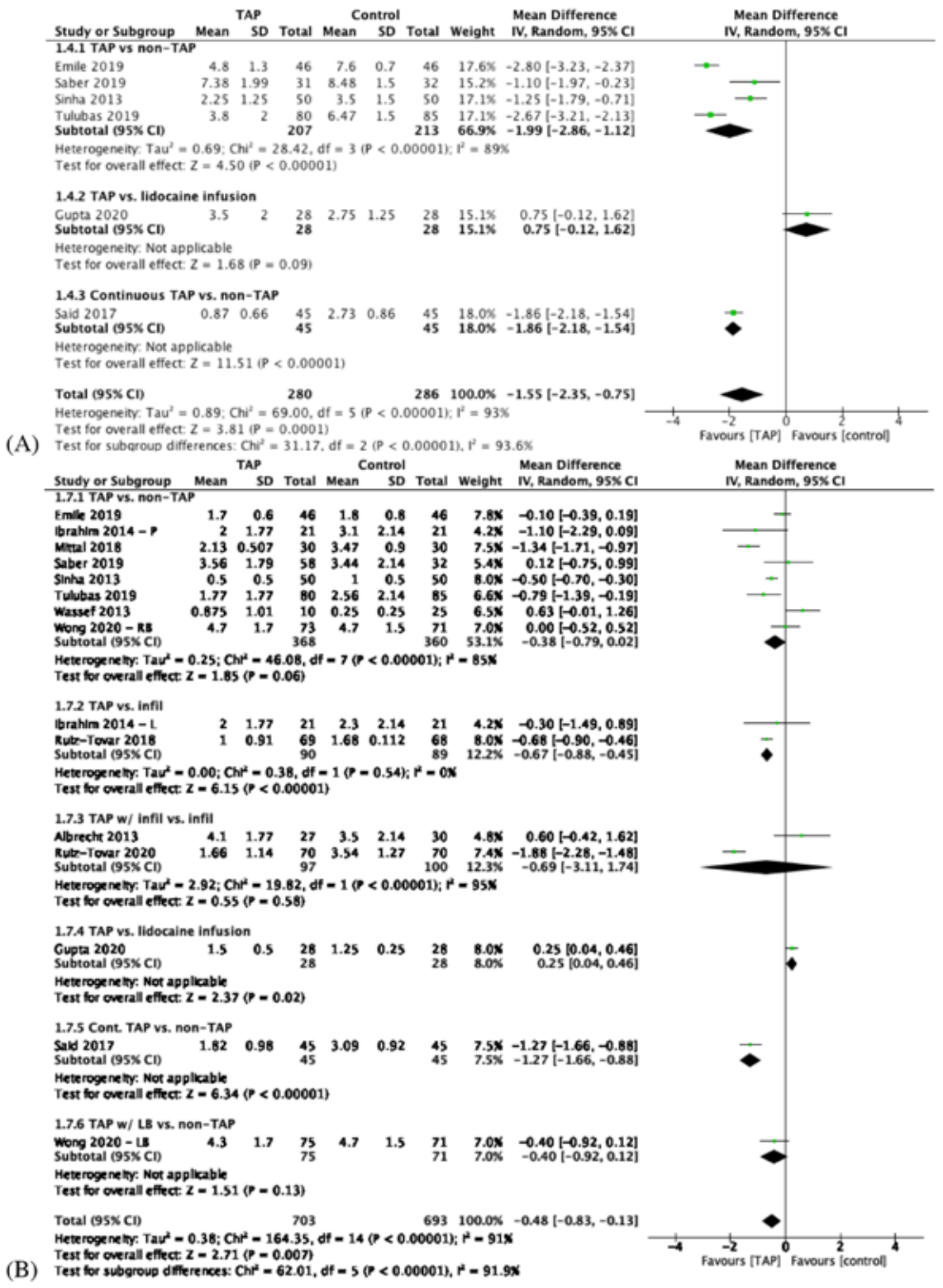
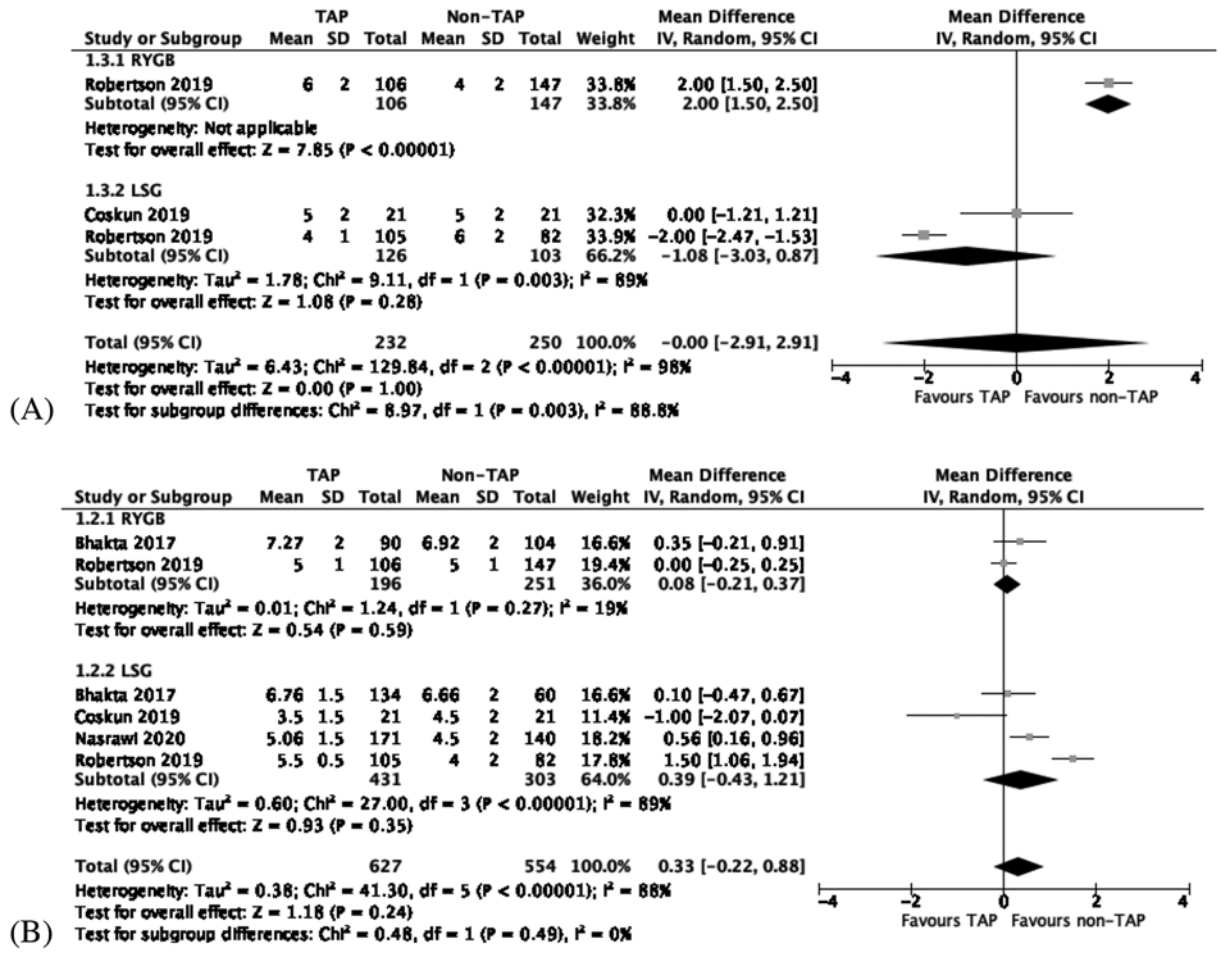


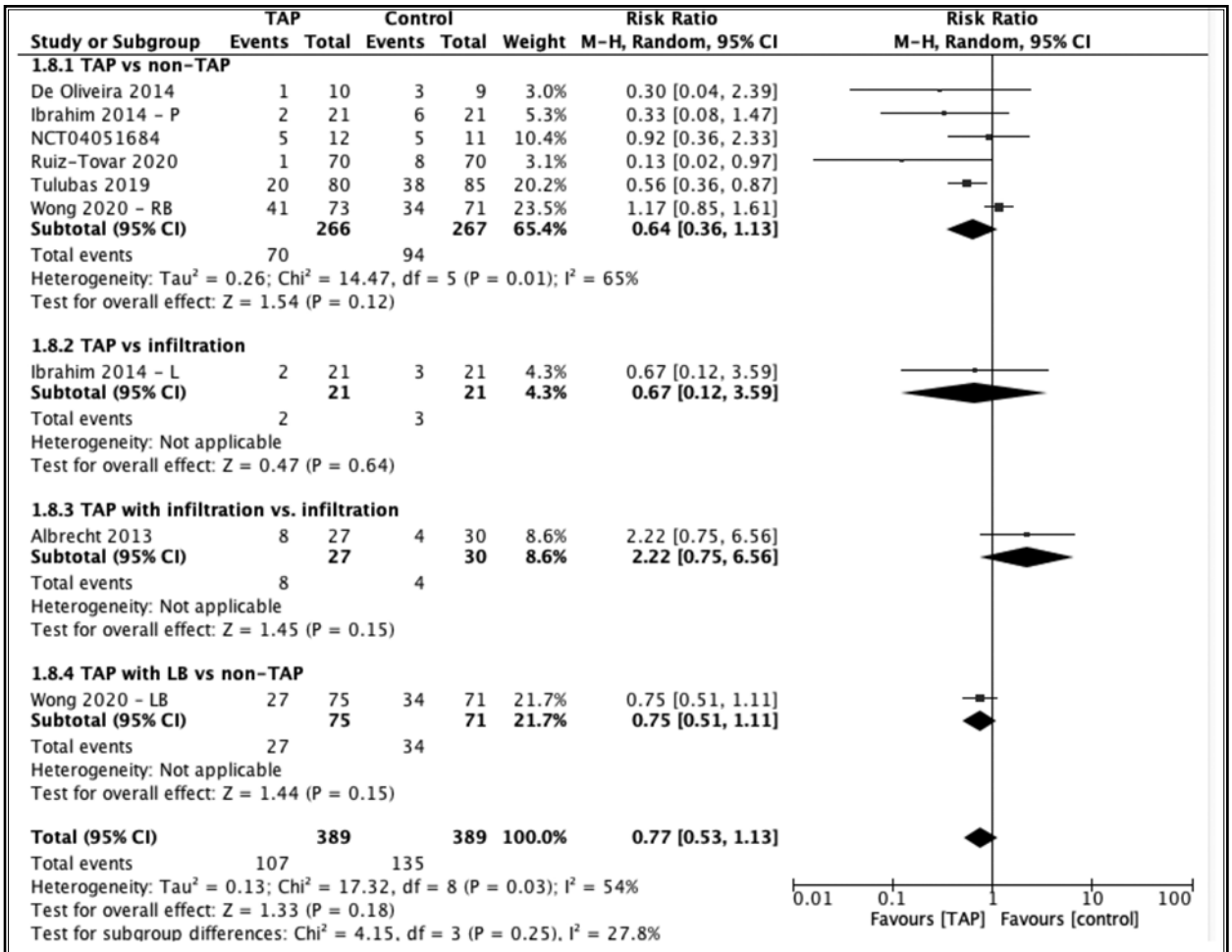
Supplemental Figure 1. *Random-effects meta-analysis forest plots for non-randomized studies comparing TAP block versus control group on total OME.*



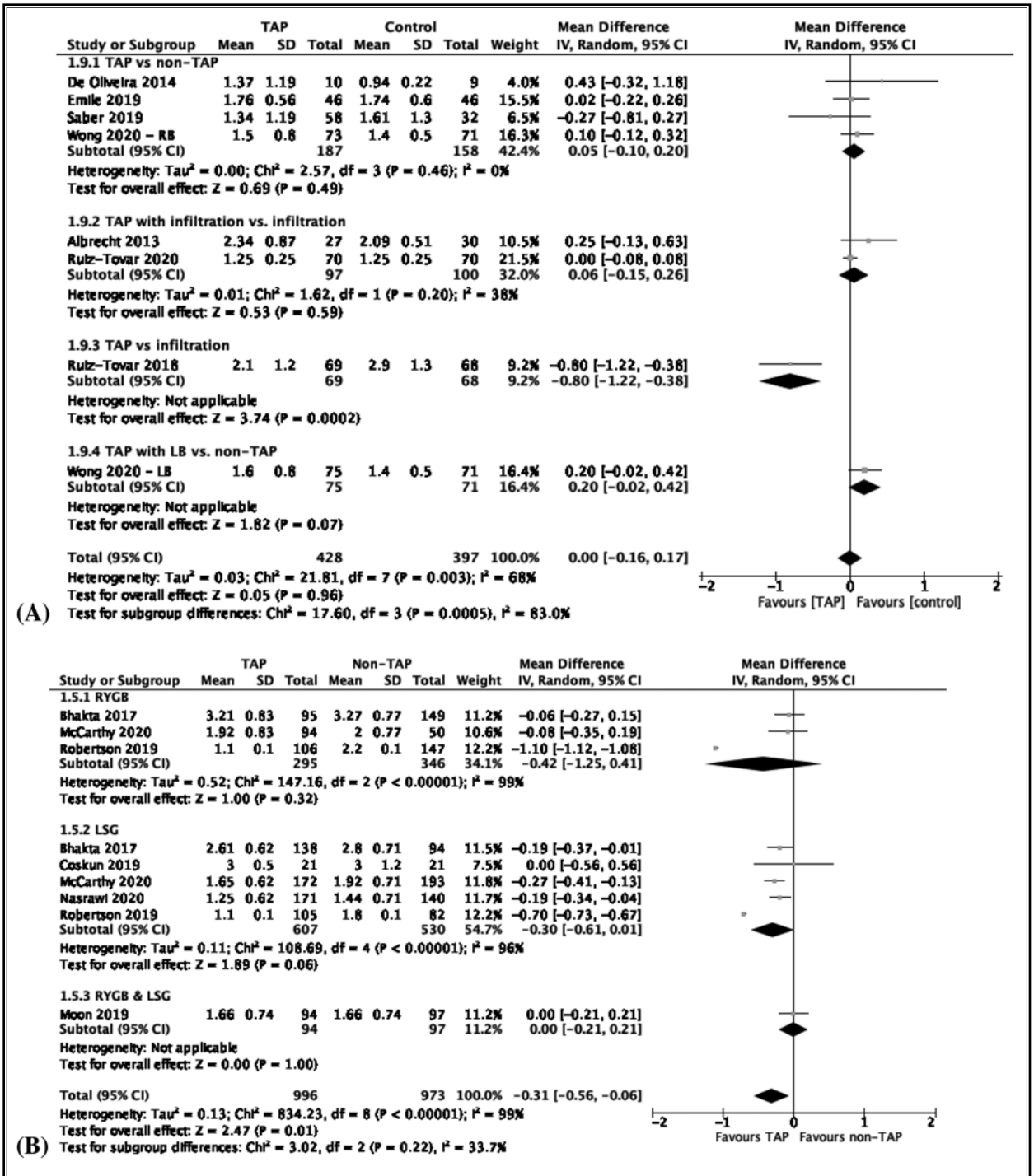
Supplemental Fig 2. *Random-effects meta-analysis forest plots for RCTs comparing TAP block versus control group on postoperative pain scores (numeric pain scale 0-10) at (A) 1 hour and; (B) 24-hours.*



Supplemental Fig. 3. *Random-effects meta-analysis forest plots for non-randomized studies comparing TAP block versus control group on postoperative pain scores (numeric pain scale 0-10) at (A) 12h; and (B) 24h.*



Supplemental Fig. 4. *Random-effects meta-analysis forest plots for RCTs comparing TAP block versus control group on occurrence of postoperative nausea and vomiting.*



Supplemental Fig. 5. *Random-effects meta-analysis forest plots comparing TAP block versus control group on hospital length of stay in days for (A) randomized studies and; (b) non-randomized studies.*

Supplementary Table 1. *Complete search strategy example for OVID Medline.*

OVID Medline Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily and Ovid MEDLINE(R) 1946 to April 2020	
1	TAP block.mp.
2	transverse abdominis plane block.mp.
3	bariatric surgery.mp. or exp Bariatric Surgery/
4	gastric bypass.mp. or exp Gastric Bypass/
5	exp Gastroplasty/ or gastric band.mp.
6	sleeve gastrectomy.mp.
7	3 or 4 or 5 or 6
8	1 or 2
9	7 and 8

Supplementary Table 2. *Revised Cochrane risk of bias tool for randomized trials (RoB 2).*

Study	Randomization process	Deviations from intended interventions	Missing outcome data	Measurement of the outcome	Selection of the reported result	Overall
Albrecht, 2013	+	+	+	+	+	+
De Oliveira, 2014	+	+	+	+	+	+
Emile, 2019	+	+	+	+	+	+
Gupta, 2020	+	+	+	– *	+	–
Ibrahim, 2014	+	+	+	+	+	+
Mittal, 2018	+	+	+	+	+	+
NCT04051684	? †	+	+	+	+	?
Ruiz-Tovar, 2018	+	+	+	+	+	+
Ruiz-Tovar, 2020	+	+	+	+	+	+
Saber, 2019	+	+	+	+	+	+
Said, 2017	+	+	+	– *	+	–
Sinha, 2013	+	+	+	+	+	+
Tulubas, 2019	? †	+	+	+	+	?
Wassef, 2013	+	+	+	+	+	+
Wong, 2020	+	+	+	+	+	+

† Unclear if allocation was concealed.
* Patient was not blinded to intervention which may affect reported pain scores.
Legend:
+ = low risk of bias;
? = some risk of bias;
– = high risk of bias

Supplementary Table 3. *Study characteristics of non-randomised studies*

Study	Country	Arm	Surgery type (n)	n analyzed	% Female	Age (± SD)	BMI (kg/m²)	ASA I/ II/III (n)	Diabetes	Hypertension	Dyslipidemia	Sleep apnea	Mean operative time (min)
Bhakta, 2017	USA	TAP	RYGB (95) LSG (138)	223	78.97	45.4	45.5	-	58 (25.8)	-	-	-	-
		Infiltration	RYGB (149) LSG (94)	243	77.37	45.22	44.9	-	59 (24.3)	-	-	-	-
Coskun, 2019	Turkey	TAP	RYGB (21)	21	80.95	42.4 ± 9.2	50.2 ± 7.2	-	5 (23.8)	6 (28.6)	-	-	144.5 ± 31
		Infiltration	LSG (21)	21	57.14	38.7 ± 10.4	48.4 ± 7.2	-	3 (14.3)	6 (28.6)	-	-	141.2 ± 28
McCarthy, 2020	USA	TAP	RYGB	94	84	45.2 ± 11.3	39.9 ± 8.4	0/37/57	28 (30)	-	-	36 (38)	113 ± 23
			LSG	172	79	44.9 ± 11.2	39.8 ± 6.9	0/71/99	-			-	74 ± 29
		Control	RYGB	50	74	43.7 ± 11.5	38.5 ± 9.2	0/13/37	21 (42)	-	-	11 (22)	125 ± 28
			LSG	193	83	44.1 ± 10.7	38.3 ± 6.8	0/65/126	46 (24)	-	-	37 (19)	83 ± 36
Moon, 2019	USA	TAP	LSG (64) RYGB (11) DS (17)	94	81.9	43.7 ± 11.4	45.6 ± 8.5	0/16/5	67 (71.3)	44 (46.8)	20 (24.1)	33 (35.1)	-
		Control	LSG (66) RYGB (19) DS (9)	97	72.2	41.1 ± 10.1	46.1 ± 7.2	0/13/8	71 (73.2)	43 (44.3)	29 (29.9)	34 (35.1)	-
Nasrawi, 2020	USA	TAP	LSG	171	87.8	42.0 ± 10.9	45.49 ± 6.67	-	-	-	-	-	49.1 ± 11.7
		Control	LSG	140	81.4	42.0 ± 11.9	46.00 ± 6.37	-	-	-	-	-	54.3 ± 14.1
Robertson, 2019	USA	TAP	RYGB	106	82.2	49.0 ± 1.0	46.4 ± 0.4	-	-	-	-	-	-
			LSG	105	85.4	47.0 ± 1.1	43.9 ± 0.6	-	-	-	-	-	-
		Control	RYGB	147	80.4	48.2 ± 1.0	45.7 ± 0.5	-	-	-	-	-	-
			LSG	82	82.9	45.3 ± 1.0	44.1 ± 0.3	-	-	-	-	-	-

LSG, laparoscopic sleeve gastrectomy; RYGB, Roux-en-Y gastric bypass; BMI, body mass index; SD, standard deviation; DS, duodenal switch

Supplementary Table 4. *ROBINS Tool for nonrandomised studies*.

Study	Confounding	Selection of participants	Bias in classification of interventions	Deviation of intended interventions	Missing data	Measurement of outcomes	Selection of reported results	Overall risk of bias
Bhakta, 2018	Moderate	Low	Low	Low	Low	Serious	Moderate	Serious
Coskun, 2019	Serious	Low	Low	Low	Moderate	Moderate	Moderate	Serious
McCarthy, 2020	Moderate	Low	Low	Low	Low	Serious	Moderate	Serious
Moon, 2019	Moderate	Low	Low	Low	Low	Serious	Moderate	Serious
Nasrawi, 2020	Moderate	Low	Low	Low	Low	Serious	Moderate	Serious
Robertson, 2019	Moderate	Low	Low	Low	Serious	Serious	Moderate	Serious