Meta-Analysis

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Surgeon Preference and Clinical Outcome of 3D Vision Compared to 2D Vision in Laparoscopic Surgery

Systematic Review and Meta-Analysis of Randomized Trials

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Objective: To assess the added value of 3-dimensional (3D) vision, including high definition (HD) technology, in laparoscopic surgery in terms of surgeon preference and clinical outcome.

Background: The use of 3D vision in laparoscopic surgery has been suggested to improve surgical performance. However, the added value of 3D vision remains unclear as a systematic review of randomized controlled trials (RCTs) comparing 3D vision including HD technology in laparoscopic surgery is currently lacking.

Methods: A systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines with a literature search up to May 2023 using PubMed and Embase (PROSPERO, CRD42021290426). We included RCTs comparing 3D versus 2-dimensional (2D) vision in laparoscopic surgery. The primary outcome was operative time. Meta-analyses were performed using the random effects model to estimate the pooled effect size expressed in standard mean difference (SMD) with corresponding 95% confidence intervals (CIs). The level of evidence and quality was assessed according to the Cochrane risk of bias tool.

Results: Overall, 25 RCTs with 3003 patients were included. Operative time was reduced by 3D vision (–8.0%; SMD, –0.22; 95% CI, –0.37 to –0.06; $P = 0.007$; n = 3003; 24 studies; $I^2 = 75\%$) compared to 2D vision. This benefit was mostly seen in bariatric surgery (–16.3%; 95% CI, –1.28 to –0.21; $P = 0.006$; 2 studies; n = 58; $I^2 = 0\%$) and general surgery (–6.7%; 95% CI, –0.34 to –0.01; $P = 0.036$; 9 studies; n = 1056; $I^2 = 41\%$). Blood loss was nonsignificantly reduced by 3D vision (SMD, –0.33; 95% CI, –0.68 to 0.017; $P = 0.060$; n = 1830; $I^2 = 92\%$). No differences in the rates of morbidity (14.9% vs 13.5%, $P = 0.644$), mortality (0% vs 0%), conversion (0.8% vs 0.9%, $P = 0.898$), and hospital stay (9.6 vs 10.5 days, $P = 0.078$) were found between 3D and 2D vision. In 15 RCTs that reported on surgeon preference, 13 (87%) reported that the majority of surgeons favored 3D vision.

Conclusions: Across 25 RCTs, this systematic review and meta-analysis demonstrated shorter operative time with 3D vision in laparoscopic surgery, without differences in other outcomes. The majority of surgeons participating in the RCTs reported in favor of 3D vision.

Keywords: 3D vision, laparoscopic surgery, minimally invasive surgery, operative time

INTRODUCTION

The use of laparoscopy in abdominal surgery aims to reduce the time to postoperative recovery and limit wound complications.[1] Hence, in many procedures, laparoscopy is now preferred over open surgery.[2,3] Although laparoscopy displays have improved, the loss of 3-dimensional (3D) vision is widely recognized as an important downside of laparoscopic surgery. The lack of depth perception hampers the more complex surgical steps such as intracorporeal anastomoses and other suturing.[4–11] In recent years, 3D vision laparoscopy systems have become widely available and aimed to overcome the disadvantage of 2-dimensional (2D) vision.

In 2016 and 2017, 2 systematic reviews concluded that more studies are needed to compare the clinical benefits of 3D over 2D vision, as only 3 clinical randomized controlled trials (RCTs) were available.[12,13] Retrospective comparative studies have suggested a decrease in surgical time, blood loss, complications, and

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In accordance with the guidelines, our systematic review was registered with the International Prospective Register of Systematic Reviews (PROSPERO) on December 12, 2021 (registration no. CRD42021290426).

Disclosure: The authors declare that they have nothing to disclose.

The data sets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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length of hospital stay with 3D vision.[14–20] However, side effects of 3D vision have been considered a major hurdle during the early implementation phase.[21] Stereopsis blindness is prevalent in 5% to 10% of the population and stereopsis declines with advancing age (1%–30%).[22] Furthermore, headache and tiredness were major side effects in the active shutter glasses used in displays before 2012.[21] It is only since the development of the high definition (HD) passive polarized display, implemented during 2012 to 2014, that a "near natural" 3D view could be reached.[21] Systematic reviews on 3D vision during laparoscopic surgery including HD passive polarized display are lacking.

This systematic literature review and meta-analysis aim to address the added value of 3D vision compared to 2D vision among patients undergoing laparoscopic gastrointestinal (GI) surgery in terms of surgical and clinical outcomes along with surgeon preference.

We hypothesized that 3D vision, as compared to 2D vision, would reduce operative time (OT) and estimated blood loss (EBL) attributed to the enhanced depth perception.

METHODS

Design

This is a systematic literature review with meta-analysis including only RCTs, using PubMed, Embase, and Cochrane Library databases up to May 26, 2023. Search terms are presented in Supplemental Material 1, see http://links.lww.com/AOSO/A318. We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (Supplemental Table 2, see http://links.lww.com/AOSO/A319).[23] This study protocol was submitted at PROSPERO (CRD42021290426). The PICOS question includes: (P) patients undergoing laparoscopic GI surgery, comparing (I) 3D vision to (C) 2D vision, in terms of (O) surgical and clinical outcomes along with surgeon preference using a (S) systematic review and meta-analysis.

Eligibility Criteria

We included studies with at least the abstract publicly available in English. We included RCTs of patients undergoing 3D vision laparoscopic GI surgery, including the following surgical specialties: upper GI, general (including cholecystectomy), colorectal, bariatric, and hepato-pancreato-biliary (HPB) surgeries compared to the 2D vision approach in terms of surgical and clinical parameters.

Excluded were non-GI studies (eg, gynecology and urology), studies assessing head-mounted interface systems, studies on biotissue/simulation, nonrandomized studies, studies comparing robotic surgical procedures with laparoscopic, and studies including only surgical residents. We excluded all non-English studies and there was no restriction on the publication year.

Study Selection and Data Extraction

The study selection was processed with the Rayyan.ai tool for systematic reviews. Two reviewers (R.A., M.J.W.Z.) independently screened the title and abstracts of all the collected references. In case of disagreement, a third author (L.R.J.) was consulted to resolve the conflicts. The duplicates were discarded. Subsequently, the potentially eligible articles were identified and assessed in full text for inclusion.

The following data were extracted if available: study characteristics (author, publication year, study design, study period, number of included patients, and follow-up time), patient characteristics (age, sex, and diagnosis), and surgical characteristics (surgical specialty, OT, and EBL). As the primary outcome, we collected the OTs in minutes. The most relevant secondary outcome parameter was defined as EBL. EBL was defined as the volume of blood collected (eg, in a drainage bag) during the surgical procedure, expressed in milliliters (mL). Other secondary outcomes included morbidity, mortality, conversion, length of hospital stay, and surgeon side effects with their preference, which is defined as any additional adverse effects (eg, dizziness, nausea, eye strain, and discomfort) experienced by the surgeon while using the 2D or 3D visual system. In line with the experience of the surgeon with the visual system, we collected the reported preference for a 2D or 3D visual system. Herein, explicit statement on the favorability for a particular visual system by the authors is counted in our analysis.

Quality Assessment

The quality of eligible studies was evaluated according to the Cochrane's risk of bias tool (ROBINS-I).[24] The studies are classified into no information/unclear, low, moderate, serious, and critical risk of bias based on the following domains: confounding bias, that is, a variable that predicts the outcome of interest; selection bias; classification bias; bias due to missing data, such as incomplete data collection or participants being excluded from analysis; bias due to deviation from the intended intervention, for example, conversion to an open approach; bias in measurement of outcome, for example, blinding of outcome assessment; bias in the reported outcomes, such as selective reporting; overall bias.

Statistical Analysis

A meta-analysis was performed for the primary and secondary outcomes of the applicable studies using SPSS version 28 (IBM CORP, Armonk, NY). Standard mean difference (SMD) was calculated from the mean, SD, and number of participants for both comparison groups as continuous measures. Continuous variables requiring conversion to a parametric representation (mean, SD) were converted using the formula and calculations described by Hozo et al.[25] The results are presented as a 95% confidence interval (95% CI). χ^2 test was applied to assess the heterogeneity of the studies. Statistical significance was defined as $P < 0.05$. The random effects model was used for all the outcomes. For the sensitivity analysis, we conducted 3 additional analyses: (1) excluding the critical risk of bias; (2) excluding high heterogeneity studies; and (3) excluding studies before 2017.

RESULTS

Search Results

The literature search identified 1108 studies, of which 430 were duplicates. References within the included studies were cross-examined. A total of 678 studies were screened of which 44 were assessed for eligibility, resulting in 25 RCTs to be included in the final analysis.[10,19,26–48] (Fig. 1).

Baseline Characteristics

Table 1 demonstrates the characteristics and results of the 25 included RCTs. The study period ranged from 1998 to 2022. A total of 3003 patients were included, 1575 (52%) of whom had 3D vision laparoscopic surgery and 1428 (48%) 2D vision. The included studies reported on procedures in upper GI surgery (n = 8, 32%; $n_{gastric} = 6$, $n_{esophagus} = 2$), general surgery (n = 9, 36%; $n_{gallbladder} = 7$, $n_{inguinal\ hernia\ repair} = 1$, $n_{appendix} = 1$), colorectal surgery (n = 5, 20%), bariatric surgery (n = 2, 8%), and HPB surgery ($n_{pancreas} = 1$, 4%).

Endpoints

The majority (20/25, 80%) of the RCTs had OT as the primary outcome.[10,16,19,26,27,29–32,36–44,46,47] Other reported primary

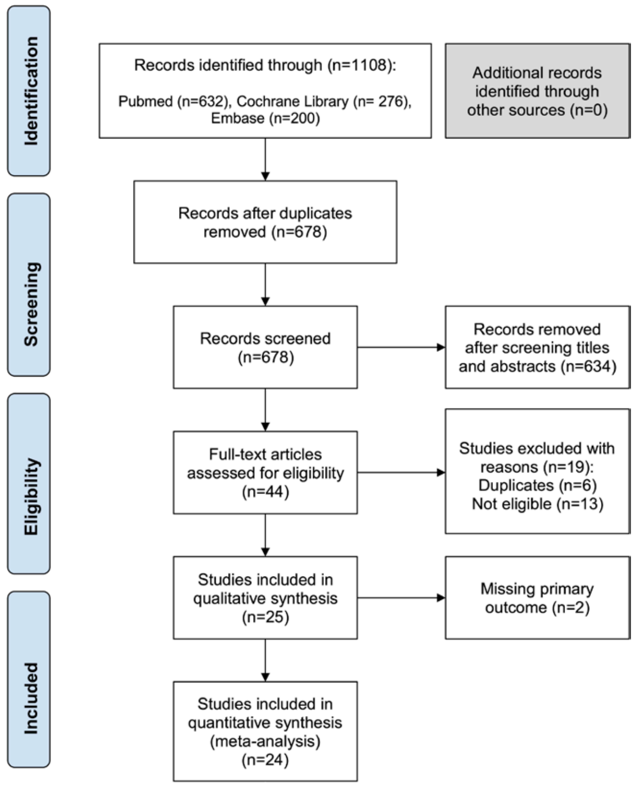

FIGURE 1. Flow diagram of included studies.

outcomes included visual workload,[34] intraoperative adverse events,[35] subjective assessment outcomes, and personal workload.[33] The primary outcome was not described in the remaining 2 trials.[28,45]

Operative Time

Studies comparing 3D and 2D vision in OT (n = 24) comprised 1575 versus 1428 patients, respectively. The mean OT was shorter with 3D vision: 113 (±31) versus 122 (±39) minutes, respectively (−8.0%; SMD, −0.22; 95% CI, −0.37 to −0.06; P = 0.007; n = 3003; I^2 = 75%). Subgroup analysis on the OT showed significant superiority in favor of 3D laparoscopy in bariatric and general surgery with subgroup overall effect sizes of −0.74 (−16.3%; 95% CI, −1.28 to −0.21; P = 0.006; 2 studies; n = 58; I^2 = 0%) and −0.18 (−6.7%; 95% CI, −0.34 to −0.01; P = 0.036; 9 studies; n = 1056; I^2 = 41%), respectively. The outcomes are summarized in Figure 2A.

Individual RCTs within the specializations showed significant effect size in OT, while the group effect size was not found to be significant. In upper GI, we identified 2 RCTs on gastric surgery,[42,47] 1 on esophagus surgery,[28] and 1 on hiatus hernia repair[10] in favor of 3D vision in terms of OT. Similarly, in colorectal surgery, we identified 2 RCTs[34,40] in favor of 3D vision in terms of OT. In general surgery, RCTs on inguinal hernia (n = 1) and appendectomy (n = 1) were in favor of 3D vision in terms of OT. None of the RCTs on cholecystectomy (n = 7) and HPB surgery (n = 1) showed a significant benefit in OT of 3D vision.

Estimated Blood Loss

For EBL, 10 RCTs with 3D vision in 913 patients and 2D vision in 917 patients were included. The pooled analysis demonstrated a nonsignificant reduction in blood loss with 3D vision: 60 (±37) versus 72 (±56) mL, respectively (−20.0%; SMD, −0.33; 95% CI, −0.68 to 0.017; P = 0.060; n = 1830; I^2 = 92%). The 5 individual RCTs that did find a significant reduction in blood loss with 3D vision were all in upper GI surgery.[30,32,37,42,47] In Figure 2B, the outcomes are summarized in a meta-analysis.

Other Clinical Outcomes

The reduction in the mean length of hospital stay with 3D vision was nonsignificant: 9.6 days (±5.1) and 10.5 days (±7.5) with 2D vision, P = 0.078. In 17 RCTs with 2539 patients, no differences in morbidity (14.9% and 13.5%, P = 0.644) and mortality (0% vs 0%) were reported. The conversion rate was 0.8% and 0.9%, P = 0.898 in 3D and 2D vision, respectively, including 1874 patients from 16 studies. From the 15 RCTs reporting on surgeons' preference, 13 (87%) RCTs were in favor of 3D laparoscopy, P = 0.010. The preference of the surgeon was based on the experience of the surgeon on various surgical outcomes (precision, in-depth perception, definition of the planes, etc.) and surgical strain outcomes (strain on the neck, back, eyes, wrists, hands, etc.).

Risk of Bias

In Figure 3, the risk of bias assessment is highlighted in the included studies. The risk of confounding bias was serious for 2 studies (8%) and for the greater part of the studies low (18/25) and unclear (4/25), accounting for 88%. Bias with respect to the selection of participants was low in the majority of the studies (88%) and unclear in the remaining 3 studies (12%). The bias in terms of classification of the interventions was serious in 2 studies and critical in 1 study (4%), while the greater portion was low (76%) and moderate (12%). Risk of bias due to missing data was critical in one study, whereas the majority were low (64%), moderate (16%), and unclear (16%). Moreover, the risk of bias with respect to deviation from intended interventions was critical in one study and the remaining were low (72%), moderate (4%), and unclear (20%). The risk of bias in the measurement of outcomes was predominately low (92%) and moderate in 2 studies. Finally, the risk of bias in the selection of the reported result was serious in 2 studies and generally low (68%) and moderate (16%). The overall risk of bias of the included studies was for the greater amount low (56%) and moderate (20%) with 4 studies having serious (16%) and 2 critical (8%) risks. For more details, see Supplemental Figure 3, see http://links.lww.com/AOSO/A320.

Sensitivity Analysis

Sensitivity analysis (1) excluding critical risk of bias studies and (2) excluding high heterogeneity studies did not have a major influence on the pooled effect size of both OT and EBL. In sensitivity analysis (3) excluding studies before 2017 (n = 5), the pooled effect size of OT slightly decreased (from −0.217 to −0.182). The pooled effect size of blood loss (−0.380) was not significant after exclusion (n = 2), P = 0.101.

DISCUSSION

This systematic review and meta-analysis including 25 RCTs with 3003 patients compared surgeon preference and clinical outcome of 3D vision with those of 2D vision in patients undergoing laparoscopic GI surgery. Our findings demonstrated that 3D vision, with mainly the newer HD technology, reduced OT by 8.0%. This benefit was especially seen in patients undergoing bariatric and general surgery. In 13 of 15 RCTs, most surgeons reported a preference for 3D vision. No impact of 3D vision on other clinical outcomes was detected.

The 2 previous systematic reviews, published in 2016 and 2017, included only 2 and 3 clinical RCTs and can therefore not be compared to the present systematic review, which included 25 clinical RCTs.[12,13] Our findings regarding reduced OT confirm the findings

TABLE 1.
Study Characteristics

Author, year	Vision (3D, 2D)	Surgical Specialty	Display Quality (Non-HD, HD, 4K)	Sample Size, n	Operative Time (min)	EBL (mL)	Morbidity	Mortality	Conversion	Hospital Stay (d)	Surgeon Preference*
Hanna et al, 1998[26]	3D	Gallbladder surgery	Non-HD	30	51 (16)	N/A	0	0	0	2	In favor of 2D
	2D		Non-HD	30	57 (19)					2	
Curro et al, 2015[27]	3D	Gallbladder surgery	HD	20	38 (18)	N/A	0	0	0	N/A	In favor of 3D
	2D		HD	20	40 (19)						
Hou et al, 2015[28]	3D	Esophagus surgery	N/A	78	176 (28)	124 (36)	10	0	N/A	11.8 (9.3)	N/A
	2D		N/A	76	203 (32)	127 (26)	11			12.6 (8.8)	
Currò et al, 2015[29]	3D	Bariatric surgery	HD	10	88	N/A	N/A	N/A	0	N/A	In favor of 3D
	2D		HD	10	100						
Currò et al, 2016[31]	3D	Colorectal surgery	HD	N/A	NS	N/A	N/A	N/A	N/A	N/A	In favor of 3D
	2D		HD								
Lu et al, 2017[30]	3D	Gastric surgery	HD	109	184 (36)	58 (75)	20	0	0	12.5 (4.8)	N/A
	2D		HD	112	178 (37)	78 (72)	18			12.6 (7.3)	
Leon et al, 2017[10]	3D	Hiatal hernia surgery	HD	19	70 (22)	NS	1	0	0	2	In favor of 3D
	2D		HD	17	90 (20)		3			2	
Buia et al, 2017[33]	3D	Gallbladder surgery	HD	39	50 (20)	N/A	0	0	N/A	N/A	In favor of 3D
	2D	Appendix surgery	HD	40	50 (28)						
Inama, 2018[34]	3D	Colorectal surgery	HD	231	160 (44)	N/A	52	1	1	7.8 (2.2)	In favor of 2D
	2D		HD	82	150 (44)		23	0	0	8.1 (3.0)	
Zheng et al, 2018[32]	3D	Gastric surgery	N/A	211	176 (35)	61 (83)	36	N/A	N/A	13.1 (8.4)	In favor of 3D
	2D			208	174 (33)	82 (119)	29			12.7 (7.4)	
Curtis et al, 2019[35]	3D	Colorectal surgery	HD	40	NS	NS	NS	0	2	7 (5–15)	In favor of 3D
	2D		HD	37					2	9 (6–18)	
Liu et al, 2019[37]	3D	Gastric surgery	N/A	77	178 (32)	66 (79)	14	0	N/A	13.6 (9.3)	In favor 3D
	2D		N/A	79	180 (34)	99 (120)	12			13.4 (8.7)	
Jun et al, 2019[19]	3D	Pancreatic surgery	HD	32	158 (41)	NS	NS	0	0	7.6 (3.5)	In favor of 3D
	2D		HD	29	159 (44)					6.5 (10)	
Koppatz et al, 2019[38]	3D	Gallbladder surgery	HD	105	51 (19)	5 (13)	21	0	1	NS	In favor of 3D
	2D		HD	104	49 (16)	12 (61)	22		0		
Rojano-Rodríguez et al, 2020[36]	3D	Bariatric surgery	HD	20	121 (12)	N/A	N/A	N/A	N/A	N/A	N/A
	2D		HD	18	142 (40)						
Dunstan et al, 2020[39]	3D	Gallbladder surgery	HD	54	26 (16)	N/A	NS	0	N/A	N/A	NS
	2D		4K	55	26 (15)						
Wang et al, 2020[40]	3D	Colorectal surgery	HD	60	123 (34)	39 (13)	4	0	0	7.6 (2.5)	N/A
	2D		HD	60	142 (24)	43 (10)	5			7.8 (3.2)	

(Continued)

TABLE 1.
Continued

Author, year	Vision (3D, 2D)	Surgical Specialty	Display Quality (Non-HD, HD, 4K)	Sample Size, n	Operative Time (min)	EBL (mL)	Morbidity	Mortality	Conversion	Hospital Stay (d)	Surgeon Preference*
Schwab et al, 2020[41]	3D	Gallbladder surgery	HD	49	20 (10)	NS	NS	0	0	N/A	In favor of 3D
	2D		HD	50	23 (11)						
Koppatz et al, 2020[43]	3D	Inguinal hernia surgery	HD	135	126 (28)	1.3 (3.4)	23	0	0	N/A	N/A
	2D		HD	137	137 (31)	1.8 (5.5)	20				
Lee et al, 2021[42]	3D	Gastric surgery	N/A	38	101 (35)	20 (3)	3	0	0	N/A	N/A
	2D		N/A	41	130 (40)	26 (4)	10		1		
Botteri et al, 2021[44]	3D	Appendix surgery	N/A	61	49.6 (16.9)	N/A	1	0	3	2.9 (1.2)	In favor of 3D
	2D		N/A	67	57.5 (19.9)		1		4	3.2 (1.2)	
Sapci et al, 2021[45]	3D	Colorectal surgery	N/A	27	75 (31)	45	8	0	N/A	N/A	In favor of 3D
	2D		N/A	26	83 (39)	42	8				
Parshad et al, 2021[46]	3D	Gallbladder surgery	HD	30	53 (20)	N/A	NS	0	0	1.1 (0.2)	NS
	2D		4K	30	56 (21)					1.2 (0.5)	
Mo and Zhao, 2021[47]	3D	Gastric surgery	N/A	79	98 (23)	209 (30)	4	0	N/A	13 (3)	N/A
	2D		N/A	79	86 (21)	200 (37)	6			14 (3)	
Kanaji et al, 2022[48]	3D	Gastric surgery	HD	21	271 (175)	17 (37)	3	0	0	15.3 (9.6)	N/A
	2D		4K	21	349 (299)	50 (111)	6			22.3 (28.2)	

*Surgeon preference was based on various outcomes related to the surgeon's experience during the surgery, consisting of, but not limited to surgical outcome parameters such as precision, depth perception, definition of the planes, and surgical strain parameters (strain on the neck, back, wrists, hands, eyes, etc.).

N/A indicates not addressed; NS, not significant; RS, retrospective study.

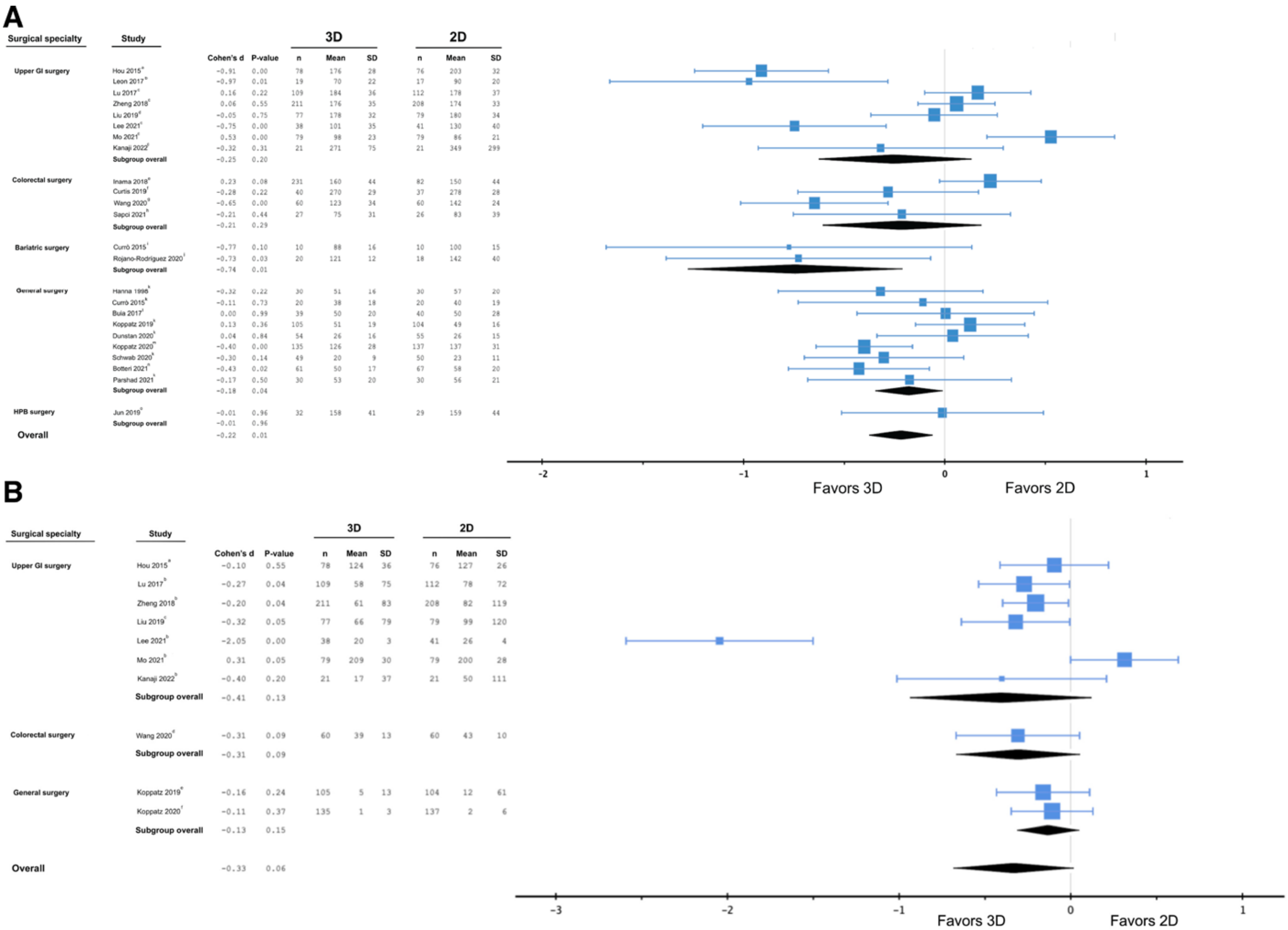

FIGURE 2. Forest plot demonstrating the impact of 3D versus 2D vision for operative time and blood loss in minimally invasive abdominal surgery. (A) Forest plot demonstrating the significant impact of 3D vision for operative time (SMD = −0.22, *P* = 0.01) in subgroup bariatric (SMD = −0.74, *P* = 0.01)[29,36] and general surgery[26,27,33,38,39,41,43,44,46] (SMD = −0.18, *P* = 0.04) and in several individual RCTs in upper GI[10,28,42,47] and colorectal surgeries.[34,40] Surgical procedure: [a]esophagectomy; [b]hiatal hernia repair; [c](radical) gastrectomy; [d]spleen preserving splenic hilar lymphadenectomy; [e]colorectal resection; [f]total mesorectal excision; [g]hemicolectomy; [h]total colectomy; [i]mini-gastric bypass; [j]Roux-en-Y gastric bypass; [k]cholecystectomy; [l]cholecystectomy and appendectomy; [m]transabdominal preperitoneal inguinal hernia repair; [n]appendectomy; [o]distal pancreatectomy. (B) Forest plot demonstrating the significant impact of 3D vision for estimated blood loss (SMD = −0.33, *P* = 0.06) in subgroup colorectal surgery[40] (SMD = −0.31, *P* = 0.09) and in several individual RCTs in upper GI surgery.[30,32,37,42,47] Surgical procedure: [a]esophagectomy; [b](radical) gastrectomy; [c]spleen preserving splenic hilar lymphadenectomy; [d]hemicolectomy; [e]cholecystectomy; [f]transabdominal preperitoneal inguinal hernia repair.

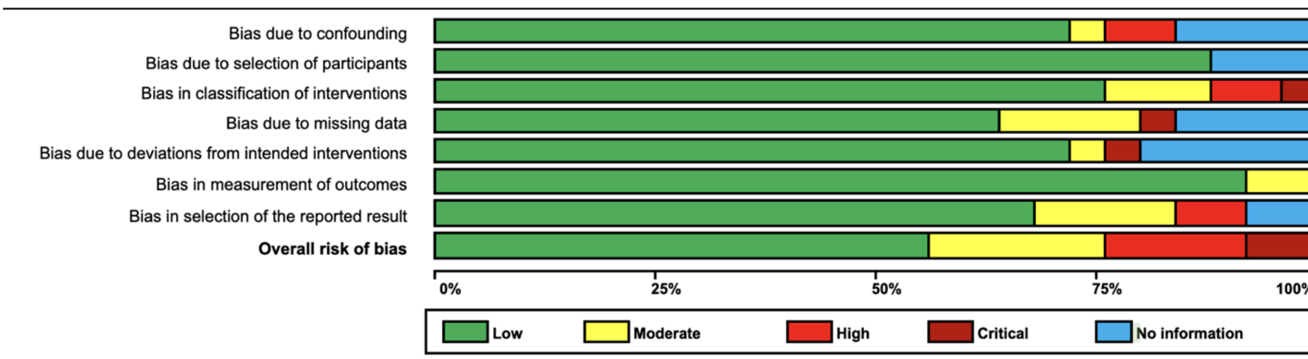

FIGURE 3. Risk of bias graph of the included studies.

of retrospective comparative studies, but the current study found no significant reduction in blood loss, complications, and length of hospital stay with 3D vision.[14–20] Clearly, the difference in procedures studied should be taken into account. It may well be that with future, larger RCTs, the differences observed, such as the nonsignificant reduction in blood loss, may prove to be significant. With regards to the intraoperative experience by the surgeons, some of the earlier reported complaints of 3D systems, such as dizziness, nausea, eye strain, and discomfort, were found to be associated with older 3D systems.[6] Moreover, a comparative study demonstrated lower visual fatigue severity score in experienced surgeons using 3D vision as compared to 2D vision.[49] The new HD systems for 3D vision do not have the previously reported disadvantages.[50] The current systematic review found that in 87% (13/15) of RCTs, surgeons reported in favor of 3D vision. Another point to consider is the impact of the stereoscopic base size, which determines the depth of the system. A wider base is suggested to improve the viewer's performance.[51] One study assessing videos of 252 laparoscopic bile duct injuries found that 97% of all errors were associated with visual misperception.[52] This finding underlines the notion that optimal vision during laparoscopic surgery may improve the quality and safety of laparoscopic surgery. In a retrospective study on laparoscopic gastrectomy, the preliminary outcome of the initial experience with 4K resolution showed comparable short-term effects to 3D vision.[53] Similarly, an RCT showed no difference in OT and error scores during laparoscopic cholecystectomy between HD 3D vision and 4K 2D vision.[39] In contrast, a simulation-based RCT with 66 participants showed better performance with 3D vision, even when compared to 4K 2D vision.[54] Notably, in the present study, RCTs comparing 3D vision to 4K 2D vision in the clinical setting showed no difference in outcomes.[39,46,48]

The implementation of 3D vision in laparoscopic GI surgery has demonstrated shorter OT and favorable experience over traditional 2D vision. This may suggest a potential rise in the use of the 3D visual system in GI laparoscopy. However, the technology has been available for several years, it has not been widely adopted in the field of surgery. While some surgeons attribute this to the low display resolution of the 3D system available in their hospital settings, it is important to note that the majority of the RCTs included in the present systematic review compared the performance of 3D vision and 2D vision using HD 3D imaging displays. Another contributing factor could be ascribed to the notion that growing up with a particular technology often involves becoming accustomed to the use of it. Therefore, experienced laparoscopic surgeons may be closely accustomed to 2D vision. Consequently, it is probable that the newer generation of surgeons will be more receptive to innovative technological systems of this era, such as 3D vision. Furthermore, as "less experienced" surgeons often have longer absolute OTs, 3D vision may have a larger beneficial impact in their hands.[4] The 2018 EAES consensus stated that 3D vision in laparoscopic surgery has advantages in reducing OTs, cognitive load, and possibly complications. However, there were 18 ongoing RCTs that were related to this topic and already registered.[55] Large surveys assessing surgeons' perspectives and practical utilization of 3D vision remain limited, so we currently are unclear on what trends are in the adoption of 3D vision in laparoscopic surgery. Despite this, it is anticipated that the 3D vision imaging market will experience a compound annual growth rate of approximately 4.5% during a 2022 to 2027 forecast.[56] Bariatric surgery is one of the domains driving the growth of 3D vision, especially with the increasing rates of obesity. An additional contributor is an increase in reimbursement of laparoscopic surgical procedures by insurance companies. Notably, Medicare covers up to 75% of laparoscopic procedures.[56]

The results of our study should be interpreted in light of some limitations. First, the heterogeneity of the included studies was high. We aimed to limit this impact through a sensitivity analysis excluding studies that contributed to heterogeneity (outside funnel plot standard error) showing no difference. Second, the reporting bias was high, as many studies reported nonparametric outcomes not suitable for meta-analysis. However, we converted the median and interquartile range to mean and SD using Hozo et al[25] method. Still, all of the RCTs were performed in a clinical setting, which improves the generalizability.

Our systematic review and meta-analysis suggest that 3D vision is associated with shorter OT for laparoscopic surgery and in 87% of RCTs, surgeons favored 3D over 2D vision. Future RCTs comparing 3D and 2D vision in terms of costs and in relation to robotic surgery are recommended to further validate our findings.

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