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REVIEW

Laparoscopic right hemicolectomy with 2D or 3D video system technology: systematic review and meta-analysis

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Abstract

Background Standard laparoscopic colorectal surgery relies on 2D image systems in most centers. However, 3D vision has gained popularity and is used nowadays in a constantly rising number of units. Right hemicolectomy with intracorporeal anastomosis and lymph node dissection represents a surgical procedure that may benefit the most from 3D vision. The aim of the study was to summarize the available literature on the use of 2D vs. 3D video imaging in patients undergoing laparoscopic right hemicolectomy.

Methods A comprehensive literature review was conducted including Medline/PubMed, Embase, and Scopus (PROSPERO registration number CRD 42022344764) through October 2022. The systematic review and meta-analysis were conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines. The risk of bias was evaluated using the ROBINS-I tool. Certainty of evidence was assessed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) guidelines and GRADEpro to develop a summary of evidence tables. Random-effects meta-analyses were conducted.

Results Five observational retrospective studies (496 patients, 275 2D and 216 3D) were included. One study was rated as having a critical risk of bias; the remaining had low to moderate risk. 2D laparoscopic right hemicolectomy patients showed longer anastomotic time in 3/3 studies (MD = 3.32; 95%CI, 1.58–5.05; $p = 0.002$) and an upward trend in operative time in 4/5 studies (MD = 9.98; 95%CI, −1.42, 21.37; $p = 0.086$) compared to 3D. The two image video systems had similar short-term outcomes, including the number of lymph nodes harvested (MD = −0.67; 95%CI, −2.47, 1.13; $p = 0.47$), morbidity (OR postoperative complications = 1.12; 95%CI, 0.71–1.77; $p = 0.62$), and length of stay (MD = 0.27; 95%CI, −0.59, 1.13; $p = 0.9$).

Conclusions 2D and 2D laparoscopic right hemicolectomy had similar complications rate, with a shorter anastomotic time along with a downward trend in overall operative time for 3D. Larger prospective randomized trials are awaited before definitive conclusions can be drawn.

Keywords Two-dimension (2D) · Three-dimension (3D) · Video technology · Laparoscopy · Right hemicolectomy · Colon cancer

Introduction

Two-dimensional imaging has been, to date, the standard of care for laparoscopic colorectal surgery in the vast majority of centers worldwide. Its limitations have prompted the development of an already existing technology (3D) which has been significantly improved, made less expensive and—most important—eventually user-friendly, where the user is the operating surgeon. This implies a dual-lens system and light glasses with higher brightness and resolution and less discomfort for the surgeon (with reduced blurring, fatigue, nausea, and headache compared to those experienced using the early 3D systems introduced in the 1990s). Certainly, robotic platforms—especially those with dedicated articulated instruments besides the several degrees of freedom and 3D vision—represent a significant plus in technological equipment available for the surgeon, especially in difficult tasks such as suturing and knotting in limited spaces [1]. However, at the present time, in a period of increased attention to health economics, the implementation of technology

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should always be considered along with economic neutrality and sustainability. That is why 3D vision has gained popularity and is used nowadays in a constantly rising number of units [2]. Its use offers several potential advantages (lack of stereoscopic vision, depth perception, and spatial orientation of the traditional 2D technology are overcome) without the burden of the higher cost of a complete robotic device [1, 3].

Most colorectal procedures could potentially benefit from 3D vision. In particular, right hemicolectomy with intracorporeal anastomosis and lymph node dissection is the colorectal procedure that might take the most advantage of 3D vision [4–8]. The difficulties of suturing in deep location with sharp angles between approximated ileal and bowel loops might benefit from better spatial orientation provided by 3D vision.

The aim of this review was to summarize the available literature on the use of 2D vs. 3D video imaging in patients undergoing laparoscopic right hemicolectomy.

Materials and methods

Study design

This is a systematic review of studies investigating the role of 3D vision in laparoscopic right hemicolectomy. The systematic review and meta-analysis were conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines [9]. The completed PRISMA 2020 checklist is reported in Supplementary Table S1. The review protocol is available on PROSPERO, registration number CRD42022344764 (www.crd.york.ac.uk/PROSPERO).

Search strategy

To identify relevant studies, we systematically searched MEDLINE/PubMed, Embase, Scopus, and the Cochrane Database of Systematic Review between January 2010 and October 2022. Two researchers (GP and PB) independently reviewed search results and screened titles/abstracts. A third researcher (DA) resolved any inconsistency. The literature search included the following terms (with MeSH terms, synonyms, and closely related words), "two-dimension," "three-dimension," "2D," "3D," "laparoscopic," "colectomy," "hemicolectomy," and "colon," used in combination with Boolean operators AND or OR. This search strategy was adapted to suit the other electronic sources. The complete search strategy is reported in Supplementary Tables S2–S4. Only clinical studies in English were considered. Case reports and data from meeting abstracts were excluded. The reference lists of included articles were hand-searched to identify additional studies of interest.

Criteria for considering studies for this review

Only studies investigating patients undergoing laparoscopic right hemicolectomy for cancer with 2D or 3D video systems were considered eligible for this review. We excluded studies including only 2D or 3D patients or comparing 3D with robotic platforms.

Only the most recent and complete data were included when duplicate publications reporting on similar patients were found. Studies not including humans were excluded.

Study identification, risk of bias assessment, and quality of evidence

Two researchers (GP and PB) independently extracted key data from the selected studies. A third researcher (DA) checked the extracted data. For each study, we considered the following data: title, authors, journal, year of publication, country of origin, study design, sample size, age, body mass index (BMI), gender, American Society of Anesthesiology (ASA) score, tumor stage, tumor size, tumor localization, operative time, blood loss, anastomotic time, associated procedure, harvested nodes, intraoperative complications, conversion to laparotomy, time to first flatus, bowel movement, length of stay, number of patients with complications, number of patients with anastomotic leakage, number of patients with anastomotic bleeding, number of patients with intra-abdominal bleeding, and 30-day mortality. When queries arose or additional data were required, we contacted the study authors.

The authors independently assessed risk of bias using the risk of bias in non-randomized studies of interventions (ROBINS-I) tool, which considers an ideal randomized clinical trial and compares it with the given study [10]. No randomized clinical trials were included.

We further assessed the quality of evidence for the outcomes using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) guidelines [11, 12]. Based on GRADE, the outcome was rated in four levels (high, moderate, low, or very low). Finally, GRADEpro was used to develop a summary of findings table [13].

Statistical analysis

Statistical analysis was performed using the R System version 4.1.0 and packages, "meta" and "metafor." [14–17] Outcomes were analyzed using the mean difference (MD) and its 95% confidence interval (CI) for continuous data and odds ratio (OR) and its 95% CI for categorical ones. Random-effects model was applied to pool the data.

If no mean and/or standard deviation of continuous variables was provided, estimation was obtained using median, range, interquartile range, and size of the sample [18, 19].

As suggested by Borenstein et al., prediction intervals (PIs) for the pooled frequencies were reported [20]. Prediction interval is defined as the interval within which the true effect in similar study would fall if it was selected from the same population of the studies included in the meta-analysis [21]. It takes into accounts for the heterogeneity and helps apply the results to a future study or a study not included in the meta-analysis [22].

Publication bias was assessed with Begg's funnel plot and Egger's test [23]. A sensitivity analysis was performed by removing each study from the meta-analysis to verify the robustness of the obtained conclusions.

A p value less than 0.05 was considered statistically significant.

Results

Search results

Overall, the search yielded 353 non-duplicated articles; 337 articles were excluded based on title and/or abstract, while 16 articles were retrieved for full-text review. Four papers with missing or incomplete data, 3 abstract conferences, 3 systematic reviews, and 1 paper with missing full text were excluded. Ultimately, 5 observational studies [4–8] were included in the qualitative and quantitative synthesis (Fig. 1).

Quality assessment

ROBINS-I indicated that Currò et al. [4] had a critical risk of bias due to serious concerns regarding confounding factors. The remaining studies were rated from low to moderate risk of bias [5–8]. The detailed results of the risk of bias analyses are available in Fig. 2.

Study and patient characteristics

Publication time ranged from 2016 to 2022. A total of 5 retrospective studies [4–8] involving 491 patients (2D

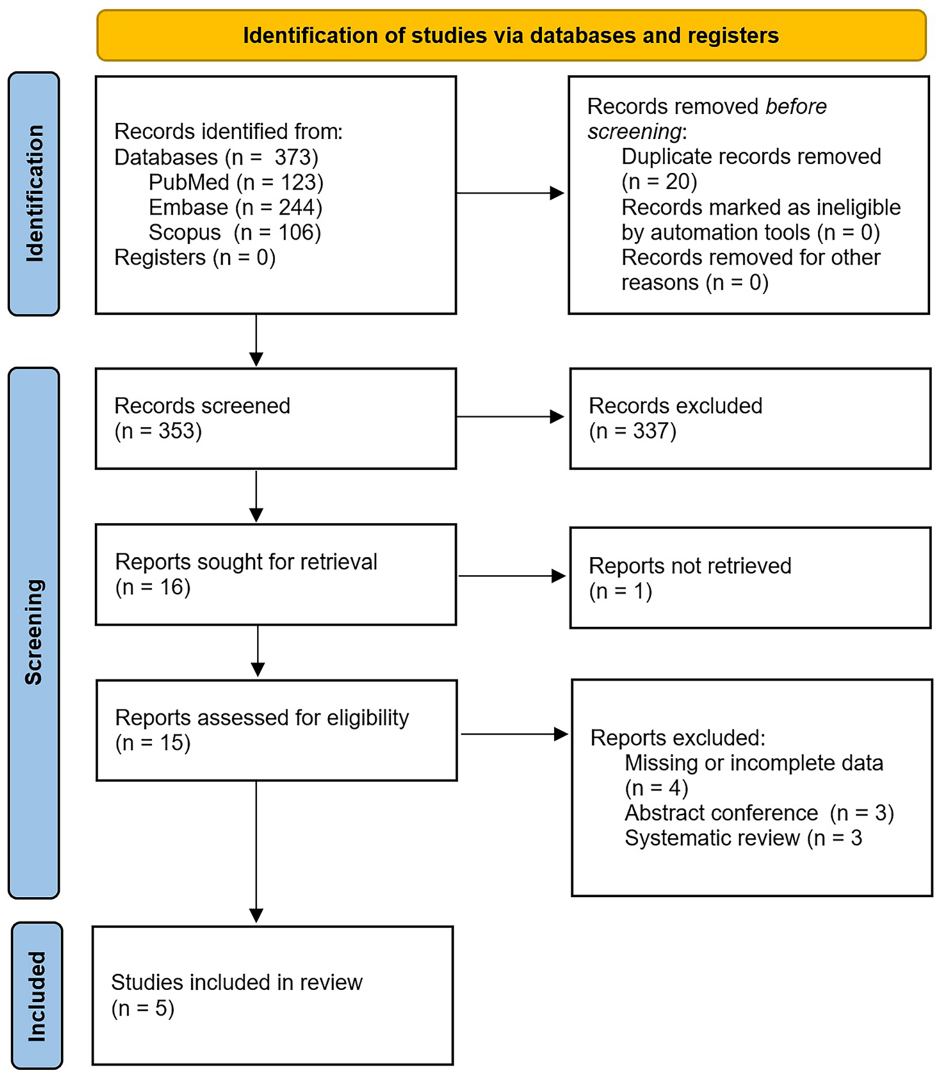

Fig. 1 PRISMA flow diagram of the study selection and retrieval

group = 275; 3D group = 216) meeting our criteria were included. The number of patients in the studies ranged from 100 to 163. Four studies were conducted in Italy and one in China.

Patient characteristics of the included studies are reported in Table 1. In all but one study ileo-colonic anastomosis was performed intracorporeally. Details on post-operative outcomes are shown in Table 2.

Operative time All the included studies reported the duration of the operative procedure. As shown in Fig. 3, a non-significant difference in operative time was found between the two groups (MD = 9.98; 95%CI, −1.42, 21.37; $p = 0.086$) with a large prediction interval (95% PI = −29.71, 49.66).

The sensitivity analysis (Supplementary Fig. S1B) showed significant changes in the pooled mean difference when we excluded the study conducted by Portale et al. [7] (MD, 13.63, 95%CI, 4.21–23.05, $p = 0.005$).

The funnel plot (Supplementary Fig. S1A) and Egger's test results ($p = 0.5$) did not suggest evidence of publication bias.

Anastomotic time Three [4, 6, 8] of the included studies reported the duration of the anastomotic procedure. As shown in Fig. 4, a significant difference in anastomotic time was found between the two groups (MD = 3.32; 95%CI = 1.58–5.05; $p = 0.002$) with a quite large prediction interval (95% PI, −16.92, 23.56). The sensitivity analysis (Supplementary Fig. S2B) showed no significant changes in the pooled mean difference. The funnel plot (Supplementary Fig. S2A) and Egger's test results ($p = 0.7$) did not suggest evidence of publication bias.

Harvested nodes The number of harvested lymph nodes was not reported in one study (Currò et al. [4]). As shown in Fig. 5, no significant difference in harvested lymph nodes was found between the two groups (MD = −0.67; 95%CI, −2.47, 1.13; $p = 0.47$) with a moderately wide prediction range (95% PI, −5.65, 4.31). The sensitivity analysis (Supplementary Fig. S3B) showed no significant changes in the pooled mean difference. The funnel plot (Supplementary Fig. S3A) and Egger's test results ($p = 0.14$) did not suggest evidence of publication bias.

Time to first flatus Three studies reported the time to first flatus [5, 6, 8]. As shown in Fig. 6, no significant difference in time to first flatus was found between the two groups (MD = −0.01; 95%CI, −0.26, 0.23; $p = 0.549$). All the

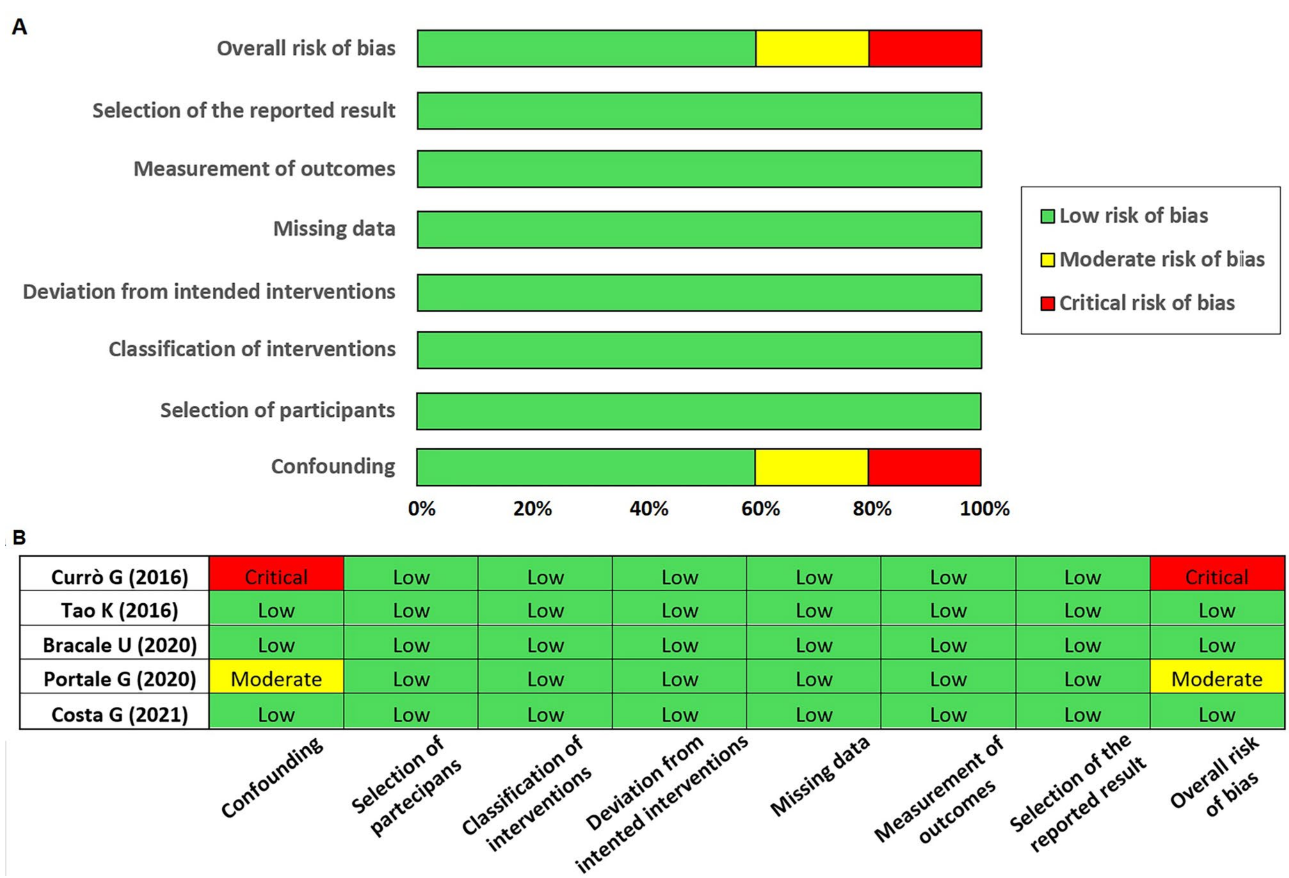

Fig. 2 Results of the risk of bias assessment using ROBINS-I: bar chart overview (**A**) and per-study (**B**) of bias rating for observational studies

Table 1 Main characteristics of the included studies

		Currò et al. (2016)	**Tao et al. (2016)**	**Bracale et al. (2020)**	**Portale et al. (2020)**	**Costa et al. (2021)**
Country		Italy	China	Italy	Italy	Italy
Study type		Retrospective	Retrospective	Retrospective	Retrospective	Retrospective
Sample size	2D	25	31	53	55	111
	3D	25	27	53	59	52
Age, years[a]	2D	68 (±8.1)	54.8 (±8.3)	68.6 (±9.5)	67.6 (±12.6)	68.6 (±12.9)
	3D	69 (±9.7)	56.4 (±9.8)	68.3 (±11.7)	66.7 (±16.1)	73.2 (±12.5)
Male[b]	2D	14 (56%)	20 (64.5%)	28 (52.8%)	29 (52.7%)	64 (57.7%)
	3D	12 (48%)	16 (59.3%)	28 (53.8%)	32 (54.2%)	25 (48.1%)
BMI, kg/m^{2}[a]	2D	30 (±2.8)	23.9 (±3.6)	26.7 (±4.8)	25.4 (±4.5)	25.0 (±3.1)
	3D	31 (±2.8)	22.7 (±4.2)	26.8 (±4.7)	25.5 (±4.9)	24.7 (±2.9)
ASA score[b]						
I + II	2D	NR	29 (93.5%)	33 (62.3%)	28 (50.9%)	79 (71.2%)
	3D	NR	26 (96.3%)	30 (56.6%)	41 (69.5%)	32 (61.5%)
III + IV	2D	NR	2 (6.5%)	20 (37.7%)	27 (49.1%)	32 (28.8%)
	3D	NR	1 (3.7%)	23 (43.4%)	18 (30.5%)	20 (38.5%)
CCI[b]	2D	NR	NR	NR	3.0 (±1.5)	4.0 (±3.22)
	3D	NR	NR	NR	2.9 (±1.5)	4.8 (±3.17)
Tumor size, cm[a]	2D	NR	5.7 (±2.4)	NR	3.9 (±1.5)	4.31 (±1.44)
	3D	NR	5.2 (±2.7)	NR	4.3 (±1.2)	4.21 (±1.90)
Tumor localization[b]						
Caecum	2D	NR	7 (22.6%)	21 (39.6%)	18 (32.7%)	NR
	3D	NR	6 (22.2%)	18 (34%)	22 (37.3%)	NR
Ascending colon	2D	NR	16 (51.6%)	22 (41.5%)	25 (45.5%)	NR
	3D	NR	14 (45.2%)	17 (32.1%)	21 (38.2%)	NR
Right colic flexure	2D	NR	8 (25.8%)	4 (7.5%)	7 (12.7%)	NR
	3D	NR	7 (25.9%)	8 (15.1%)	9 (15.3%)	NR
Proximal transverse colon	2D	NR	NR	6 (11.3%)	5 (9.1%)	NR
	3D	NR	NR	10 (18.9%)	7 (11.9%)	NR
Tumor stage[b]						
Stage 0	2D	NR	NR	3 (5.7%)	4 (7.3%)	5 (4.5%)
	3D	NR	NR	1 (1.9%)	4 (6.8%)	1 (1.9%)
Stage I–II	2D	NR	20 (64.5%)	36 (67.9%)	25 (45.5%)	76 (68.5%)
	3D	NR	18 (66.7%)	39 (73.6%)	35 (59.3%)	41 (78.8%)
Stage III–IV	2D	NR	11 (35.5%)	14 (26.4%)	26 (47.3%)	30 (27%)
	3D	NR	9 (33.3%)	13 (24.5%)	20 (33.9%)	10 (19.2%)

a mean (± standard deviation), *b* n (%), *BMI* body mass index, *CCI* Charlson comorbidity index, *NR* not reported

Table 2 Intra- and post-operative data

		Currò et al. (2016)	Tao et al. (2016)	Bracale et al. (2020)	Portale et al. (2020)	Costa et al. (2021)
Operative time, min[a]	2D	110 (±7.6)	152.2 (±28.9)	153.2 (±52.4)	159 (±48.8)	185.3 (±48.6)
	3D	105 (±6.4)	130.5 (±27.6)	131 (±51)	170.6 (±36)	169.8 (±32.4)
Blood loss, ml[a]	2D	NR	84.7 (±22.3)	NR	NR	NR
	3D	NR	80.8 (±29.0)	NR	NR	NR
Anastomosis time, min[a]	2D	30 (±3.1)	NR	21.7 (±6.2)	NR	19.3 (±2.9)
	3D	25 (±5.9)	NR	19.2 (±5.9)	NR	16.9 (±2.3)
Associated procedure[b]	2D	NR	NR	NR	16 (29.1%)	40 (36%)
	3D	NR	NR	NR	26 (44.1%)	25 (48.1%)
Harvested nodes[b]	2D	NR	19.3 (±5.6)	21 (±10.7)	22.9 (±9.3)	19.6 (±6.6)
	3D	NR	20.4 (±5.7)	23 (±16.8)	26.0 (±14.6)	18.8 (±7.4)
Intraoperative complications[b]	2D	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
	3D	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Conversion[b]	2D	0 (0%)	0 (0%)	0 (0%)	0 (0%)	10 (9%)
	3D	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1.9%)
Time to first flatus, days[a]	2D	NR	2.9 (±0.7)	2 (±1.5)	NR	3.21 (±1.26)
	3D	NR	2.9 (±0.8)	2 (±1.5)	NR	3.25 (±1.08)
Bowel movement, days[a]	2D	NR	NR	NR	4.0 (±1.4)	NR
	3D	NR	NR	NR	3.4 (±1.2)	NR
Length of stay, days[a]	2D	NR	10.1 (±3.6)	6 (±1.5)	8.4 (±2.6)	8.36 (±5.89)
	3D	NR	8.5 (±2.0)	6 (±3.0)	9.1 (±3.3)	7.69 (±2.17)
Patients with complications[b]	2D	NR	3 (9.7%)	15 (28.3%)	17 (30.9%)	25 (22.5%)
	3D	NR	4 (14.8%)	12 (22.6%)	15 (25.4%)	12 (23.1%)
Anastomotic leakage[b]	2D	0 (0%)	1 (3.2%)	2 (3.8%)	0 (0%)	1 (0.9%)
	3D	1 (4%)	0 (0%)	1 (1.9%)	0 (0%)	0 (0%)
Anastomotic bleeding[b]	2D	NR	0 (0%)	2 (3.8%)	3 (5.5%)	0 (0%)
	3D	NR	1 (3.7%)	3 (5.7%)	0 (0%)	1 (1.9%)
Intra-abdominal bleeding[b]	2D	NR	0 (0%)	NR	0 (0%)	0 (0%)
	3D	NR	0 (0%)	NR	1 (1.7%)	1 (1.9%)
30-day mortality[b]	2D	NR	0 (0%)	0 (0%)	0 (0%)	2 (1.8%)
	3D	NR	0 (0%)	0 (0%)	0 (0%)	1 (1.9%)

a mean (±standard deviation), *b n* (%), *NR* not reported

studies share a common effect size ($\tau^2 = 0$; 95%PI, −1.59, 1.56). The sensitivity analysis (Supplementary Fig. S4B) showed no significant changes in the pooled mean difference. The funnel plot (Supplementary Fig. S4A) and Egger's test results (*p* = *0.81*) did not suggest evidence of publication bias.

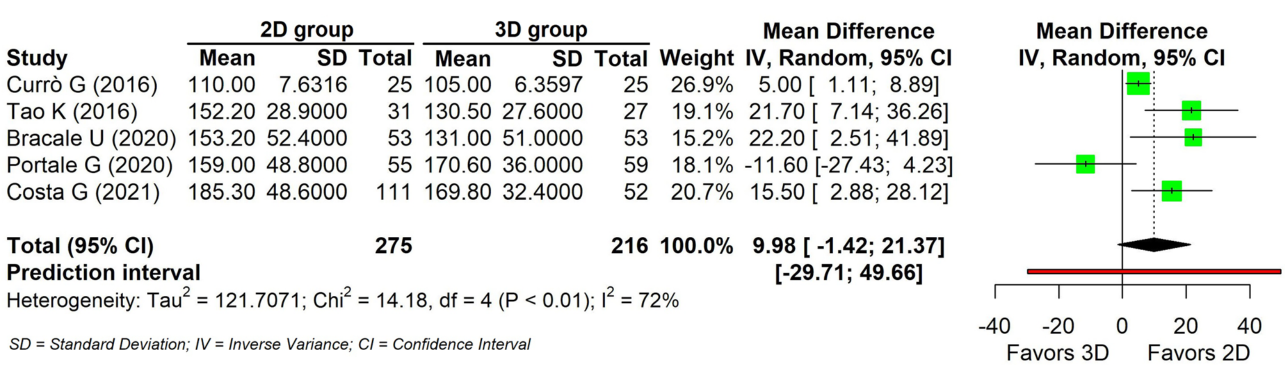

Fig. 3 Forest plots of difference in operative time

Post-operative complications The post-operative complications were analyzed using the odds ratios. All the studies reported the number of patients with anastomotic leakage. Four studies [5–8] reported both the number of patients with almost one post-operative complication and the number of patients with anastomotic leakage. Only three studies [5, 7, 8] reported the number of patients with intra-abdominal bleeding. As shown in Figs. 7, 8, 9, and 10, no significant differences were found between the 2D and the 3D groups (OR post-operative complications, 1.12; 95%CI, 0.71–1.77; $p=0.62$; 95%PI, 0.41–3.05; OR anastomotic leakage, 1.36; 95%CI = 0.31–6.00; $p=0.68$; 95%PI, 0.05–35.26; OR anastomotic bleeding, 0.72; 95%CI, 0.20–2.62; $p=0.62$; 95%PI, 0.04–12.22; OR intra-abdominal bleeding, 0.23; 95%CI, 0.02–2.27; $p=0.21$; 95%PI, not applicable). For each post-operative complication, the studies share a common effect size ($\tau^2=0$). The sensitivity analysis (Supplementary Figs. S5B, S6B, S7B, and S8B) showed no significant differences. The funnel plot (Supplementary Figs. S5A, S6A, S7A, and S8A) and Egger's test results ($p=0.34$, $p=0.59$, $p=0.95$, and $p=$not applicable, respectively) did not suggest evidence of publication bias.

Length of stay The length of stay was not reported in one study (Currò et al.) [4]. As shown in Fig. 11, no significant difference was found between the two groups (MD = 0.27;

Study	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Currò G (2016)	30.00	3.0527	25	25.00	2.0351	25	34.3%	5.00 [3.56; 6.44]
Bracale U (2020)	21.70	6.2000	53	19.20	5.9000	53	25.0%	2.50 [0.20; 4.80]
Costa G (2021)	19.30	2.9000	111	16.90	2.3000	52	40.7%	2.40 [1.57; 3.23]
Total (95% CI)			**189**			**130**	**100.0%**	**3.32 [1.58; 5.05]**
Prediction interval								**[-16.92; 23.56]**

Heterogeneity: $Tau^2 = 1.7525$; $Chi^2 = 9.64$, df = 2 (P < 0.01); $I^2 = 79\%$

SD = Standard Deviation; IV = Inverse Variance; CI = Confidence Interval

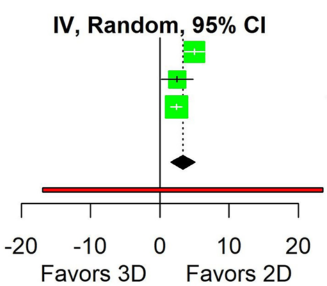

Fig. 4 Forest plots of difference in anastomotic time

	2D group			3D group				Mean Difference
Study	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
Tao K (2016)	19.30	5.6000	31	20.40	5.7000	27	31.1%	-1.10 [-4.02; 1.82]
Bracale U (2020)	21.00	10.6626	53	23.00	16.7555	53	10.6%	-2.00 [-7.35; 3.35]
Portale G (2020)	22.90	9.3000	55	26.00	14.6000	59	14.8%	-3.10 [-7.56; 1.36]
Costa G (2021)	19.60	6.6000	111	18.80	7.4000	52	43.4%	0.80 [-1.56; 3.16]
Total (95% CI)			**250**			**191**	**100.0%**	**-0.67 [-2.47; 1.13]**
Prediction interval								**[-5.65; 4.31]**

Heterogeneity: $Tau^2 = 0.4965$; $Chi^2 = 2.93$, df = 3 (P = 0.40); $I^2 = 0\%$

SD = Standard Deviation; IV = Inverse Variance; CI = Confidence Interval

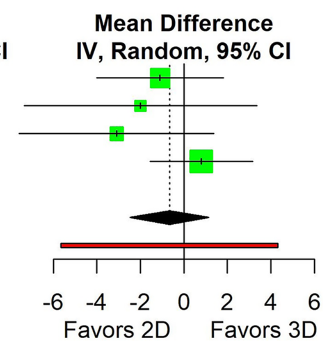

Fig. 5 Forest plots of difference in harvested nodes

	2D group			3D group				Mean Difference
Study	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
Tao K (2016)	2.88	0.7294	31	2.87	0.7506	27	40.5%	0.01 [-0.37; 0.39]
Bracale U (2020)	2.00	1.5232	53	2.00	1.5232	53	17.6%	0.00 [-0.58; 0.58]
Costa G (2021)	3.21	1.2600	111	3.25	1.0800	52	41.9%	-0.04 [-0.42; 0.34]
Total (95% CI)			**195**			**132**	**100.0%**	**-0.01 [-0.26; 0.23]**
Prediction interval								**[-1.59; 1.56]**

Heterogeneity: $Tau^2 = 0$; $Chi^2 = 0.04$, df = 2 (P = 0.98); $I^2 = 0\%$

SD = Standard Deviation; IV = Inverse Variance; CI = Confidence Interval

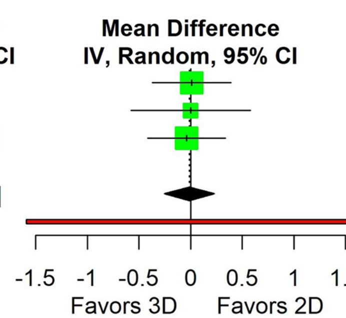

Fig. 6 Forest plots of difference in time to first flatus

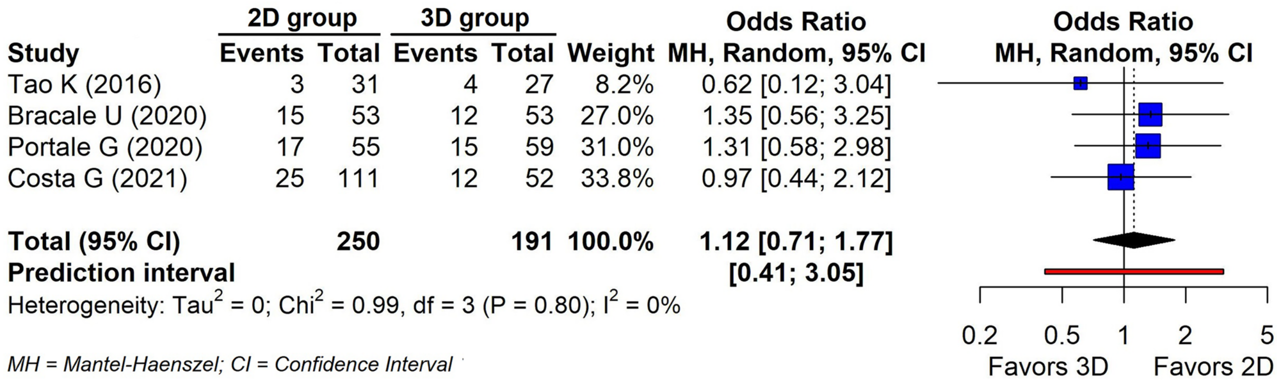

Fig. 7 Forest plots of odds ratio of post-operative complications (2D vs 3D)

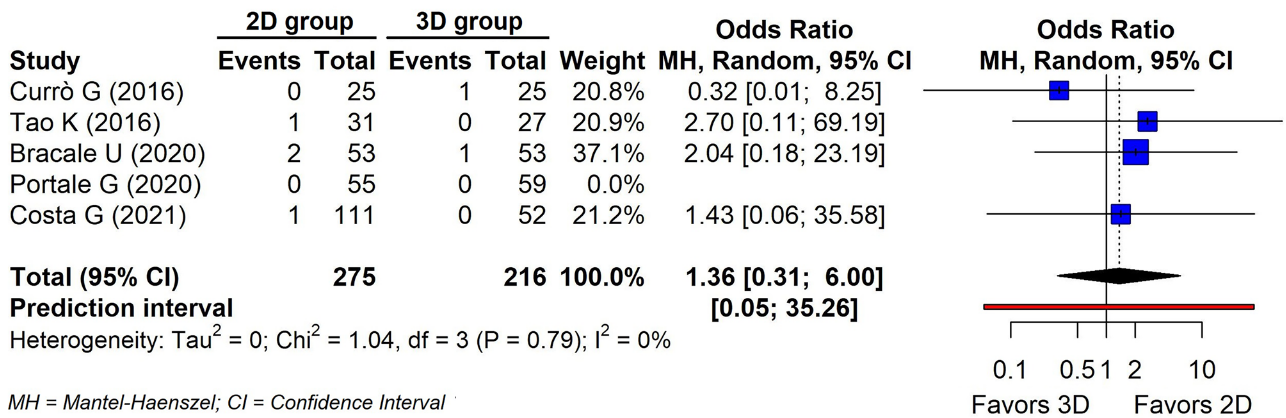

Fig. 8 Forest plots of odds ratio of anastomotic leakage (2D vs 3D)

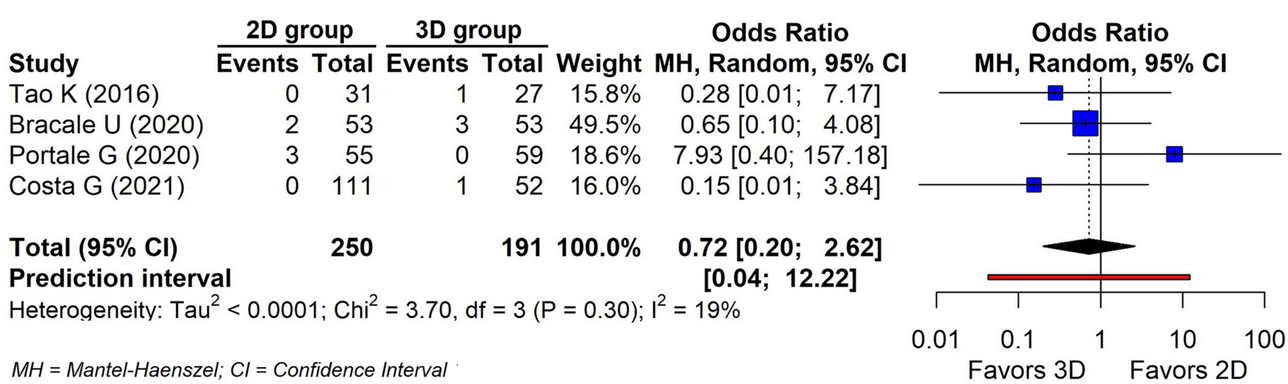

Fig. 9 Forest plots of odds ratio of anastomotic bleeding (2D vs 3D)

95%CI = −0.59, 1.13; $p = 0.9$) with a moderately wide prediction interval (95%PI = −3.09, 3.63). The sensitivity analysis (Supplementary Fig. S9B) showed no significant changes in the pooled mean difference. The funnel plot (Supplementary Fig. S9A) and Egger's test results ($p = 0.26$) did not suggest evidence of publication bias.

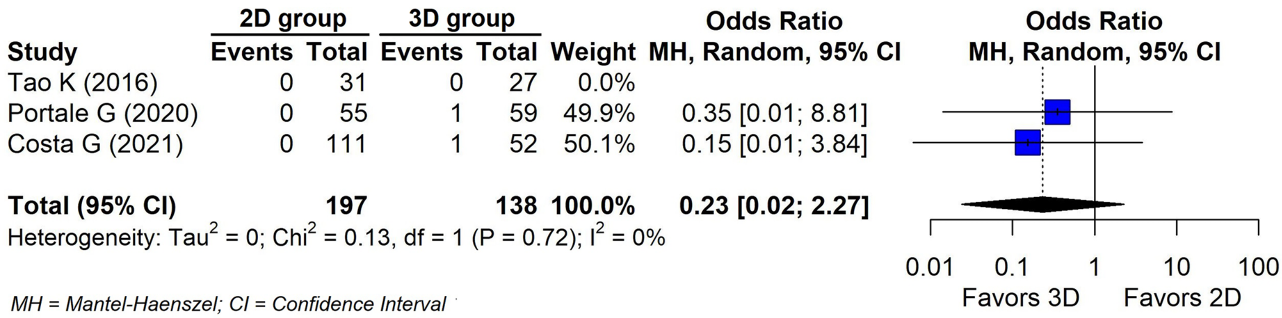

Fig. 10 Forest plots of odds ratio of intra-abdominal bleeding (2D vs 3D)

Certainty of evidence

Since all the selected studies were observational, the initial GRADE score of each one was "low" and was then downgraded according to the criteria indicated in the Grade Handbook [11]. The summary of findings and quality of evidence for study outcomes is reported in Table 3.

Discussion

The only review available so far in the literature comparing 2D vs. 3D laparoscopic right hemicolectomy for colon cancer, published in 2018, included two studies with 56 patients overall. The limited number of studies and patients allowed for only a partial analysis of the operative parameters and clinical results. In particular, the operative time was not significantly shorter for the 3D system and 2D/3D were similar in terms of anastomotic leakage rate. However, the authors were not able to aggregate the results of all the other outcomes evaluated because they were not present in both studies. In our review, we found out that the overall operative time was shorter for the 3D group (10 min, on average) although not statistically significant. Moreover, sensitivity analysis showed significant increasing of the mean difference between 2 and 3D group when study conducted by Portale et al. [7] was excluded (MD, 13.63, $p = 0.005$). This study was the only one among those investigated to report a longer mean operative time in the 3D group than in the 2D group, probably due to a higher prevalence of associated procedures in the first group.

The anastomotic time was significantly shorter for 3D group, with a mean difference of 3 min. All the other parameters analyzed, including number of lymph nodes harvested and morbidity (both considered overall and separately for each major surgical complication) were similar in the two groups. The same applied to the resume of intestinal function and length of stay.

The fact that 3D allows a shorter operative time—although not statistically significant—should be read "judiciously." Certainly, a shorter operative time translates into a lower cost for the procedure overall. This explains why in the SICE HTA report published in 2018, the 3D system reached economic neutrality compared to the 2D system. As a consequence, the introduction of 3D on a large scale of surgical units was therefore judged sustainable [24]. The hospital managers are certainly kind towards any type of new technology as long as it is clearly shown that the burden of a higher cost of the new machine is paid for in the long run by a shorter operative time and a

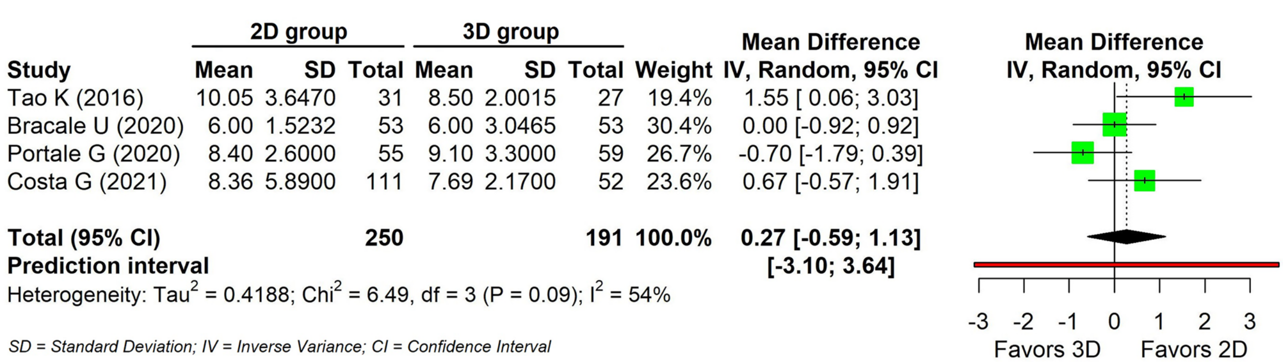

Fig. 11 Forest plots of difference in length of stay

Table 3 Summary of findings: 2D vs to 3D group

Outcome	Relative effect (95% CI)	Anticipated absolute effects (95% CI)	№ of participants (studies)	Certainty
Operative time	-	The mean operative time was 9.98 min higher in 2D group than in 3D group (1.42 lower to 21.37 higher)	491 (5 observational studies)	⨁◯◯◯ Very low[a,b,c]
Anastomotic time	-	The mean anastomotic time was 3.32 min higher in 2D group than in 3D group (from 1.58 higher to 5.05 higher)	319 (3 observational studies)	⨁◯◯◯ Very low[a,b]
Number of harvested nodes	-	The mean number of harvested nodes was 0.67 lower in 2D group than in 3D group (from 2.47 lower to 1.13 higher)	441 (4 observational studies)	⨁◯◯◯ Very low[a,c]
Time to first flatus	-	The mean time to first flatus was 0.01 days lower in 2D group than in 3D group (from 0.26 lower to 0.23 higher)	327 (3 observational studies)	⨁◯◯◯ Very low[a,c]
Post-operative complications	OR 1.12 (0.71 to 1.77)	The post-operative complications were 2.0% more in 2D group than in 3D group (from 5.4 fewer to 11.4 more)	441 (4 observational studies)	⨁◯◯◯ Very low[a,d]
Anastomotic leakage	OR 1.36 (0.31 to 6.00)	The anastomotic leakage was 0.3% more in 2D group than in 3D group (0.6 fewer to 4.4 more)	491 (5 observational studies)	⨁◯◯◯ Very low[a,d]
Anastomotic bleeding	OR 0.72 (0.20 to 2.62)	The anastomotic bleeding was 0.7% fewer in 2D group than in 3D group (2.1 fewer to 4 more)	441 (4 observational studies)	⨁◯◯◯ Very low[a,d]
Intra-abdominal bleeding	OR 0.23 (0.02 to 2.27)	The intra-abdominal bleeding was 1.1% fewer in 2D group than in 3D group (1.4 fewer to 1.8 more)	335 (3 observational studies)	⨁◯◯◯ Very low[a,d]
Length of stay	-	The mean length of stay was 0.27 days higher in 2D group than in 3D group (59 lower to 1.13 higher)	441 (4 observational studies)	⨁◯◯◯ Very low[a,c]

CI confidence interval, *OR* odds ratio

[a]Quality of study was rated as low prior to downgrading or upgrading as the included studies were observational studies

[b]Downgraded by 2 levels due to inconsistency (serious heterogeneity was observed in the analysis)

[c]Downgraded by 1 level due to imprecision; confidence intervals could not rule out the possibility of no effect (crosses null)

[d]Downgraded by 1 level due to imprecision; confidence intervals could not rule out the possibility of no effect (crosses 1)

higher number of procedures performed during the same period. However, the point of view of the operating surgeon is—or at least should be—different: the aim of a new technology, such as 3D video system or 4 K, and probably a few more made available by the medical companies in the next few years should not be, per se, to fast the operation. The new system, when applied to colorectal surgery, should provide a better view of the surgical area, allow an easier identification of the lymph nodes to remove, and provide a magnification of the anatomical structure to preserve (ureters, nerves, vessels). All these advantages (these and not the shorter operative time itself) are particularly awaited especially when surgery is performed in limited, narrow spaces such as the pelvis, or when the surgical task is difficult to accomplish, such as intracorporeal anastomosis in right hemicolectomy. The latter is a key step of the procedures analyzed in this review: the sharp and acute angles, between ileal and bowel loops, might be difficult to suture, and a better spatial orientation and depth perception improvement can be a great "plus" for the operating surgeon.

When dealing with a new device, video in this case, all the advantages deemed as potential should be verified "in vivo." With a better, magnified, tridimensional view, one would expect, as already mentioned above, a higher number of lymph nodes retrieved and a lower number of complications. This was not the case in our review, and the number of lymph nodes harvested was virtually superimposable in 2D and 3D groups with a mean difference of < 1 lymph node. However, in three out of four studies, the lymph node harvest was higher in 3D. Similarly, for anastomotic leak, the difference between the two groups was dismal with three out of four studies reporting a lower rate with 3D. The small number of patients with this complication (4/275, 1.5% in 2D, and 2/216, 0.9% in 3D) might explain the fact that a significantly higher number of patients is needed in order to find a difference—*if present*—in terms of complications between the two video systems.

All the parameters considered so far in the review are considered in terms of short-term outcomes. However, the number of lymph nodes retrieved, the blood loss, and the complications (in particular anastomotic leakage) may also affect oncological results [25, 26]. To date, there is only one study in the literature comparing mid-term survival for 3D and 2D systems at a median follow-up of 44 months (no significant difference), but their 91 patients included both right and left and anterior rectal resections cases [27]. Long-term data are awaited in order to have a better, and more complete picture of what the two video systems can accomplish and their differences to make a more meaningful comparison.

The findings of our study should be interpreted with its limitations. The quality of included studies was strongly affected by their retrospective nature (the initial GRADE score of each one was "low") and by imprecision and inconsistency of the results reported on them. It is interesting to note that four out of five studies come from Italy and only one from Eastern countries, China in this case, and none from other European countries or the USA. Therefore, we cannot speculate on the generalizability of the results of 2D vs 3D in laparoscopic right hemicolectomy for cancer. Further, the Chinese study was the only one reporting on extracorporeal and not intracorporeal anastomosis. The number of patients analyzed—491—was small but significantly higher compared to the only review available in the literature, which included only 2 studies and 56 patients overall, as already mentioned above [3]. The larger number of studies and patients included in the present review allowed to reach statistical significance in parameters such as operative time and to evaluate data on anastomotic time, lymph node retrieval, or morbidity. The review of 2018 had only three outcome measures in the two studies included in the analysis [3]. In a future review, it might be interesting to analyze data not available in the studies included in the present review on the operator's proficiency or qualification, as these parameters could contribute, in part, to differences in the results of 3D vs. 2D vision.

In conclusion, our analysis seems to suggest that laparoscopic 3D technology allows for shorter anastomotic time, a trend towards a shorter overall operative time, with a similar complication rate. The results obtained should be considered with caution because the very low grade of evidence of considered studies. Larger prospective randomized studies might confirm these results and add data on long-term oncological results to get a more complete picture of the new 3D video technology.

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Author contribution Giuseppe Portale conceptualized the study and prepared the first draft of the manuscript. Patrizia Bartolotta performed the data analysis. Danila Azzolina and Valentino Fiscon participated in the analysis and contributed to editing the manuscript. Dario Gregori contributed to revision and editing of the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Data Availability Data are available upon reasonable request to the corresponding author.

Declarations

Conflict of interest The authors declare no competing interests.

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