The use of 3D laparoscopic imaging systems in surgery: EAES consensus development conference 2018

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(Article begins on next page)

The use of 3D in laparoscopic surgery. EAES consensus development conference 2018

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Abstract

After a Health Technology Assessment on 3D vision technology completed last year, the aim of one of the consensus meetings 2018 of the EAES was to generate a guideline on the same topic based on best available evidence and expert opinions of EAES Technology Committee members. After a systematic review of the literature by an international group of research fellows, an expert panel with extensive engineering and clinical experience in the use of 3D vision technology discussed statements and recommendations. Twenty-two statements and 2 recommendations were obtained unanimously by the experts and were discussed and voted at the consensus meeting of the EAES in London in May 2018 by the attendees of the meeting. The most important regarding general topics were: a) 3D vision improves outcomes for junior trainees in performing standardized tasks in box trainers, only when 3D systems with HD screen and passive polarized glasses are used and only when properly set up; b) The use of 3D imaging systems improves laparoscopic box trainer task completion time and error rate but this benefit has not been studied in clinical practice. The most important regarding clinical setting were: a) 3D laparoscopy shortens the operating time in all the analysed surgical settings (general surgery, urology and gynaecology); b) The pooling of data from the different settings seems to suggest a lowering in the overall rate of complications after surgical procedures involving suturing in 3D laparoscopy, especially in the gynaecology setting; indeed data are too heterogeneous and weak to sustain any recommendation, other than implications for future research. These produced 2 recommendations: a) 3D laparoscopy might shorten operative times; b) Future research is recommended to demonstrate that 3D vision may lower complications rate in laparoscopy. The majority of the EAES members supported these statements. These consensus proceedings provide additional guidance to surgeons and surgical residents providing help when using 3D vision technology.

Keywords

3D Laparoscopy, 3D vision, Laparoscopic training, Consensus

Introduction

Stereopsis is the perception of depth that arises from comparison of slight differences, called disparities, in the images that project to two laterally separated eyes [1]. Most Surgeons (except those who are stereo blind) use this stereovision effect in open surgery. But in conventional two-dimensional (2D) minimally invasive surgery (MIS), this effect is lost because the surgical image is captured by a one-channel endoscope, e.g. like viewing with one eye, and the captured image is displayed on a 2D screen. The three-dimensional (3D) systems used in MIS capture separate left- and right-eye images with a dual-channel laparoscope and simulate the binocular images that would result if the viewer were positioned at the tip of the laparoscope. In modern 3D laparoscopy, images are viewed via passive polarization in which the viewer wears lightweight glasses that polarize horizontal rows of pixels on the display, with alternate pixel rows corresponding to the right- and left-eye images.

The technology used to capture the 3D image vary from single channel systems attempt to extract two perspectives of the operative field from a single point of view by splitting the image either with a prism or filter. The result is therefore not a true binocular image. Dual channel systems, consisting either of two separate rod lenses or two separate chips at the end of the scope, provide two horizontally separated images and thus produce two truly different perspectives of the operative field. There is significant variety in the design of the video capture systems, which results in differences in the quality of the perceived image. 3D displaying systems vary from shuttering projection in the early days, where alternate left and right views are displayed at high frequency on a display, to display onto two different screens corresponding right or left eye image, either by a Head Mounted Display or like in robotic systems using a fixed viewing environment. The latest commercial projection systems use passive polarizing technology, which allows for two images to be projected simultaneously in different polarized waveforms. Most studies presented in this review used these latest systems.

Three-dimensional imaging was first tested in a randomized controlled trial (RCT) 20 years ago [2], but did not show significant differences between 2D and 3D visualization. Twenty years of technology development have lead to better quality, which is now promoted by different companies. Several studies appeared in recent years, both in experimental and clinical settings, with controversial results in different environments. The European Association of Endoscopic Surgery (EAES) initiated a consensus development conference meeting on the management of acute appendicitis for its 2018 meeting in London. The present consensus was based on a systematic review and meta-analysis of the literature available for both experimental and clinical trials. The aim of this consensus meeting was to develop practical guidelines based on the available evidence combined with the expertise of a selected panel of EAES surgeons. The findings are reported in this manuscript.

Materials and methods

The coordinating team (AA, YM and NV) invited surgeons and engineers members of the Technology Committee of the EAES from nine different countries to serve as experts in this consensus development conference. An international research team of 10 young surgical researchers was formed to evaluate and process the existing literature on the use of 3D technology for laparoscopy. A senior expert followed each young surgical researcher. The coordinators generated a list of topics regarding the use of 3D to be addressed (Table 1). An exploratory literature search was conducted in order to identify any additional topics of interest. All topics were approved by the experts and subsequently divided among the teams, in such a way that each topic was referred to 2 young researcher and their relative tutors. The list included three main parts: general topics, organ specific and ongoing trials. Based upon the topics, research questions were formulated, reviewed and approved by the panel of experts.

Literature search and processing of the literature

Research questions were used as guidance to conduct literature searches. The searches were conducted in cooperation with a medical information specialist of the University of Torino. Searches were performed in both PubMed and Embase libraries on September 22nd, 2017 for each topic with no limitation used regarding year of publication. Searches have been attached in Table 2. All prospective peer-reviewed studies published in English language were included in the search.

All articles were screened and reviewed by teams of two research fellows for eligibility, based on title and abstract. If eligible for inclusion, full text articles were obtained. If no full text was available, the article was excluded. In case of disagreement between the two research fellows, the two coordinators dedicated to the topic acted as referee. Full text articles were summarized, evaluated and discussed at research meetings to assess their eligibility for inclusion in the review process. All included studies were evaluated according to the GRADE system [3-5]. The highest levels of evidence (systematic reviews) were assessed first. If the systematic review was of sufficient quality, it was used to answer the research question with a statement. When data were considered sufficient, a recommendation was prepared by the team, each scored with a grade of recommendation (GoR).

A face-to-face consensus meeting among the experts was held in London on the January 20th 2018 to discuss the final statements and recommendations, followed by two further virtual meetings to refine statements and recommendations. The coordinating team, all experts and members of the international research team attended the meeting. A modified Delphi method was used, as anonymity was not applicable in our situation [6-8]. All statements and recommendations were shared with proposed levels of evidence (LoE) with the entire group. After displaying the statements and recommendations, the experts casted their votes of agreement or disagreement. No discussion was allowed between the experts at this point of time. In case of 100% consensus, the statement and recommendation were accepted without further voting or discussion. In case of lack of consensus, the research team responsible for the statement presented the underlying considerations. After discussion between the experts, a second voting round was conducted till unanimous agreement was reached.

All finalized recommendations and statements with LoE were presented at a plenary session of the 26th annual meeting of the EAES on the June 1st, 2018 in London. Recommendations underwent live voting using a digital voting system. Voting options were “Do you agree with the above mentioned recommendation?” and “Will this recommendation likely change your practice?”.

The results from the London meeting are presented in the following section.

Results

The literature search yielded 9,967 articles. The title, abstract and full text were reviewed. In total, 36 articles were selected and reviewed in detail to define 22 statements and 2 recommendations, which were subsequently discussed at the London meeting.

The 2018 EAES congress in London was attended by …… delegates. During the plenary consensus meeting, …… delegates voted. ….. per cent were surgeons, ….. % surgical residents and …. % scientists, physician assistants and others.

General topics

1. Basics

Statement. *3D vision improves outcomes for junior trainees in performing standardized tasks in box trainers, only when 3D systems with HD screen and passive polarized glasses are used and only when properly set up. (LoE:…)*

We included 16 studies, of which about half RCT, comparing outcome of basic experiments uses either 2D or 3D [9-24]. Most RCTs are performed in proper manner, providing a high level of evidence. Some studies however used complete different imaging systems for 2D versus 3D, only few studies dealt with specific conditions of 3D setup (monitor height, monitor distance and viewing angle) and finally some studies tested participants for their stereovision abilities, but some studies did not, which might hamper outcomes.

Outcome measures of the reviewed articles vary from; time to complete tasks, quality of task results, errors made and subjective findings with questionnaires, like comfort, headache etc.

Reading through all the studies, including those deal with the basics of 3D vision, some observations can be made: 3D in all studies reviewed, consider only stereovision. Motion-based 3D cues (parallax and zooming) are not reviewed. 2D images have also important depth (3D) cues: Shadow, Interposition, relative size and texture. Also these cues are not reviewed in any study.

2. Training

Statement. *The use of 3D imaging systems improves laparoscopic box trainer task completion time and error rate but this benefit has not been studied in clinical practice (LoE moderate).*

We considered 72 primary studies from 19 countries across four continents [2, 12-14, 17, 21-23, 25-89]. Publication dates varied from 1996-2017 suggesting a spectrum of 3D systems were used although 57% were reported in 2014 onwards. Studies included 2452 participants: 1367 (55.8%) were laparoscopically naïve, primarily medical students, with 644 trainees (26.3% [486 junior (26.3%), senior 186 (7.6%)]) and 404 expert surgeons studied. Primary endpoints were time (95.8%), enacted errors (62.5%), task specific score (22.2%), instrument path length (13.9%), repetitions performed (5.6%) and instrument movement speed (4.2%).

The vast majority of included studies were single centre and utilised crossover designs where participants completed the same tasks in 2D and 3D. 68 studies (94.4%) were performed in box trainer simulators with three animal experiments (2 ex-vivo, one live [84]). Only two studies included operating room performance of laparoscopic cholecystectomies [2, 73] . Participants performed an average of three tasks (IQR 2-4, range 1-10). Only 36% of studies used previously validated tasks mainly taken from the Fundamentals of Laparoscopic Surgery (FLS), McGill Inanimate System for Training and

Evaluation of Laparoscopic Skills (MISTELS) or European training in basic laparoscopic urological skills (E-BLUS) systems. The selection of the tasks within each simulation was not fully explained and only three studies assessed all tasks from their chosen programme. The 33 identified RCTs were assessed for bias using the Cochrane risk tool [90]. Primarily due to insufficient reporting, selection bias could not be excluded. Only 30% were deemed to have a low randomisation bias risk of with 15% of studies maintaining allocation concealment. Blinding of participants to imaging modality is not possible although one group had students wear 3D glasses before entering the testing room. Only two studies were assessed as low risk of outcome assessment bias [40, 73]. One reviewed deidentified 2D videos of performance and one used automated tracking technology to record instrument metrics. All other assessments were performed by an external assessor observing performance and therefore not blinded to allocation. The use of laboratory-based studies meant attrition bias was low but inadequate reporting meant that selective reporting and other bias could not be fully assessed. Overall compliance with the CONSORT statement was low across all included trials.

Pooling all 145 endpoints from included studies, 3D was significantly better in 90 (62.1%). 3D imaging was associated with a significant reduction in time taken to complete tasks by 44 (63.8%) of 69 studies. In the 45 studies where it formed a primary outcome, 28 (62.2%) observed a significant reduction in enacted error when using 3D. Task specific scores were significantly higher in the 3D arm in 56.3% of the 16 studies. Instrument path length, repetitions needed and instrument movement speeds were significantly improved by 3D in 50%, 50% and 100% studies respectively. It is noteworthy that both clinical studies did not show any time or error count differences between 2D and 3D modalities. Across all papers and endpoints, 2D was seen to be significantly quicker in two studies (1.4% of all endpoints).

3. Cognitive load

Statement. *3D laparoscopy does not introduce a higher cognitive workload and may result in decreased experienced cognitive workload provided that the viewing setup is optimal. (LoE: moderate).*

The systematic literature search retrieved a total of 1684 articles, which were screened by two of the authors (MJ and MS), with no case of disagreement on inclusion. A total of seven articles was found eligible for inclusion [2, 20, 45, 48, 61, 84, 91]

The concept of cognitive workload assumes that there is finite mental capacity available in humans.[91] Increase in cognitive workload during task performance may lead to an increase in error.[45] Quantification of cognitive workload in the operating room is of interest since it relates to human- and team performance. Hence, it relates to task outcome and possibly to patient safety. The NASA Task Load Index (NASA TLX), originally developed to analyse the workload of pilots in order to redesign work processes and to reduce technical errors, is one of the most widely cited tools to assess workload.[45, 61, 91]

Performing surgery requires optimal allocation of mental resources of the surgeon towards the primary task, consequently, mental resources are then depleted for the completion of possible secondary tasks. Three-dimensional laparoscopy has potential benefits [20, 61, 91], but also introduces new potential hazards to the surgeon.[45, 84]

4. Pitfalls

Statement. *3D systems may produce increasing visual fatigue, discomfort and headache when setup is not optimal. (LoE: moderate).*

The systematic literature search retrieved a total of 481 articles, which were screened by two of the authors (MB and MD), with no case of disagreement on inclusion. A total of 3 articles was found eligible for inclusion.

3D laparoscopic systems provide an improved stereoscopic vision, which facilitates tasks performance, especially in less experienced subjects [92]. Nevertheless signs of visual discomfort, such as headache and visual fatigue, dry eyes or double vision, are reported in all studies [1, 92, 93]. Interestingly Zhou [93] found that whereas individuals experienced the above-mentioned discomfort symptoms, objective visual functional parameters (distance and near exophoria and esophoria, fusion range, accommodative convergence/accommodation, and tear film breakup time) did not worsen during 3D laparoscopy. Sakata [1] suggested that looking at the screen from eccentric positions causes variable degrees of double vision, whereas an optimal position results when the centre of the screen is aligned with the eyes of the viewer.

5. Costs

Statement. *No statement can be made relating to the cost effectiveness of 3D systems compared to 2D systems. (LoE:…)*

No prospective study or RCT dealing directly with the costs of the 3D laparoscopy could be found. A meta-analysis comparing 2-D and 3-D laparoscopy based on retrospective studies [94] points out a significant decrease in surgical time, blood loss, perioperative complications and hospital stay among the patients of the 3-D groups. This might suggest a diminution of the cumulative surgical costs when performing surgery with a 3-D laparoscopic system.

Clinical assessment

1. Operative Time

Statement. *3D laparoscopy shortens the operating time in all the analysed surgical settings (general surgery, urology and gynaecology). (LoE: high).*

Recommendation. *3D laparoscopy might shorten operative times (GoR: Low).*

The Recommendation was voted by ….

To the question whether this recommendation was likely change their practice …. members answered yes, … no and … answered they already use 3D.

We considered 18 primary studies from 9 countries across 3 continents [2, 19, 95-110]. The flow-chart is described in Figure 1. All but one study were published after 2013 suggesting a relatively limited variability of 3D systems used. Studies included 1729 individuals: 487 (25.5%) regarded procedures on solid organs, 1289 (74.5%) on hallow organs; 875 (50.6%) procedures included a laparoscopic suture, 794 (45.9%) not; 647 procedures regarded the "general surgery" field, while the others consisted of urology and gynaecology procedures. The 7 identified RCTs were assessed for bias using the Cochrane risk tool [90] (Table 3). Primarily due to insufficient reporting, selection bias could not be excluded. All were deemed to have a low randomisation bias risk with 57% of studies maintaining allocation concealment. Blinding of participants to imaging modality is not possible. Overall compliance with the CONSORT statement was low across all included trials.

Pooling all data deriving from the 18 included studies, 3D was significantly better in terms of operative time. The analysis of the operative time overall shows a MD of 11.01 minutes or 8% [95%CI 20.29-1.72] in favour of 3D with a high heterogeneity (I^2 96%) (Figure 2). Similarly the analysis of the operative time in procedures including a laparoscopic suture, shows a MD of 14.95 minutes or 11% [95%CI 27.2-2.70] in favour of 3D with a high heterogeneity (I^2 87%) (Figure 3). On the other hand, the analysis of the operative time in procedures not including a laparoscopic suture, shows a MD of 5.95 minutes or 5% [95%CI 11.79-0.11] in favour of 3D with a high heterogeneity (I^2 80%) (Figure 4). Furthermore, the analysis of the operative time in procedures performed on hallow organs, shows a not significant MD of 2.71 minutes or 3.8% [95%CI 8.33-2.91] in favour of 3D with a high heterogeneity (I^2 80%). On the other hand, the analysis of the operative time in procedures performed on solid organs, shows a MD of 21.70 minutes or 14% [95%CI

36.94-6.45] in favour of 3D with a high heterogeneity (I2 88%) (Figure 5). Finally, the analysis of the operative time in procedures performed by general surgeons, shows a MD of 7.44 minutes or 4% [95%CI 14.23-0.66] in favour of 3D with a high heterogeneity (I^2 85%) (Figure 6).

2. Complications

Statement. *The pooling of data from the different settings seems to suggest a lowering in the overall rate of complications after surgical procedures involving suturing in 3D laparoscopy, especially in the gynaecology setting; indeed data are too heterogeneous and weak to sustain any recommendation, other than implications for future research (LoE low).*

Recommendation. *Future research is recommended to demonstrate that 3D vision may lower complications rate in laparoscopy (GoR: High)*.

The Recommendation was voted by ….

To the question whether this recommendation was likely change their practice …. members answered yes, … no and … answered they already use 3D.

We considered 18 primary prospective and retrospective studies from 8 countries across 2 continents [19, 95-97, 99, 100, 102-106, 108, 111-116]. The flow-chart is described in Figure 1. Risk of bias was assessed and reported in Table 4. All studies were published after 2013 suggesting a relatively limited variability of 3D systems used. Studies included 1733 individuals. 12 prospective studies included 1039 patients, 6 retrospective studies included 694 patients. 10 studies including 713 patients regarded procedures including a laparoscopic suture; 9 studies including 958 patients regarded the “general surgery” field, while the others consisted of urology and gynaecology procedures. Not all the reported complications were considered for the analysis, as some appeared unrelated to the surgical gesture. A list of complications considered for the analysis is available in Table 5. The 5 identified RCTs were assessed for bias using the Cochrane risk tool [90]. Primarily due to insufficient reporting, selection bias could not be excluded. All were deemed to have a low randomisation bias risk of with 60% of studies maintaining allocation concealment. Blinding of participants to imaging modality is not possible. Overall compliance with the CONSORT statement was low across all included trials.

Pooling all data deriving from the 18 included studies, significant difference was observed in overall complications when considering all surgical procedures (RR 0.75, 95CI 0.60-0.94, I^2 0%). But no significant difference was observed when considering only “general surgery” procedures (RR 0.78, 95CI 0.60-1.02, I^2 0%). But, 3D shows a reduction of RR

0.57 [95%CI 0.35-0.90] in favour of 3D with no heterogeneity (I^2 0%) when considering only procedures including laparoscopic suture (Figure 7). Omitting one study each time the RR varied from 0.54 to 0.61 but without any statistically significant variation for the I^2, demonstrating that no trial was a potential source of inconsistency. This is also confirmed in a subgroup analysis. When including only RCTs and prospective studies, the benefit of the use of 3D increases, as RR is 0.50 [95%CI 0.25-0.97] while maintaining no heterogeneity (I^2 0) (Figure 8).

3. Cholecystectomy

Statements. *There is no evidence that 3D is superior or inferior to 2D in laparoscopic cholecystectomy in terms of intra and post-operative complications (LoE: moderate).*

Less experienced surgeons could benefit from 3D imaging resulting in shorter operative time in laparoscopic cholecystectomy (LoE: low)

We analysed 402 abstracts and after further review only 6 studies met inclusion criteria (4 prospective studies [73, 110, 117, 118], 2 RCTs [2, 109]). Publication dates varied from 1998-2017, although 84% were reported from 2013 onwards.

The 6 primary studies included 309 patients all affected by symptomatic gallstone disease undergoing elective surgery. All the studies had operative time as primary endpoint. Three studies demonstrated a reduction in operative time in favour of 3D [109, 110, 118] , but in 2 this was reported only in novices while in the expert group no differences were noticed. In all the studies rate of conversion to open cholecystectomy and intra- and post-operative complication rate were not different between the two groups. Four studies analysed the error rates during laparoscopic procedures, with no difference between the groups [2, 73, 109, 118].

4. Colorectal surgery & Appendectomy

Statement: *3D visualization shortens operating time in right colectomy compared to 2D (LoE: low).*

For the topic of appendectomy a total of 75 articles were found, but no article met the inclusion criteria. Only one study using an experimental porcine model was found, in which a stereoscopic, insertable, remotely controlled prototype camera was presented during a simulated laparoscopic appendectomy [119]. Therefore, further studies with actual clinical cases are needed in order to analyse the relevance of 3D imaging in laparoscopic appendectomy.

A total of 552 articles were retrieved related to the topic of 3D colorectal surgery, of which

6 met the inclusion criteria [115, 116, 120-123], with only one RCT [122]. The procedures analysed in the articles where heterogeneous: Ji [120] shows a reduction of the time for obturator lymph node dissection (23.5±2.5 min vs. 25.0±3.0 min p<0.05) during anterior resection of the rectum, of operative time (206.0±26.0 min vs. 222.5±27.5 min p<0.005), of wrong grasping, and of blood loos all in favour of the use of 3D. Tao [116] shows a shorter operative time performing right colectomy in the 3D group (130.5±27.6 vs. 152.2±28.9 min, p=0.005), with similar postoperative complication rate (14.8% versus 9.7%). Ji [121] shows a shorter operative time while performing either anterior resection of the rectum or right colectomy in the 3D group (185±25 min versus 190±27 min, p<0.05). Curro [115] shows a reduction of operative time (105±7.5 min vs. 110±6.25 min) in a series of right colectomies performed with 3D vision, while no statistical difference was observed in complications. Avram [123] shows a decrease in operative time using 3D for right hemicolectomies and sigmoid resections, but no difference in conversion rate and postoperative complication rate. The only RCT was performed by Curro [122] and includes 40 right colectomies, 40 sigmoidectomies and 40 anterior resection of the rectum, showing a reduction of operative time (109.3±11.3 min. versus 113.3±12.3 min.), but no difference in terms of complications. The meta-analysis of these trials highlights a significant reduction of surgery time (-13.44 min CI: -26.05, -0.83) but not a significant difference in terms of overall complications or number of lymph node dissected.

5. Upper GI & Bariatrics

Statements. *3D systems shortens operative time in Hiatal hernia repair (LoE: …).*
There are no significant advantages in 3D vs. 2D gastrectomy (LoE: …).
3D laparoscopy in Sleeve Gastrectomy offers no advantage over 2D (LoE: …).
3D laparoscopy in Mini Gastric By-pass significantly decreases operative time compared to 2D (LoE: …).
Literature search yielded 656 articles. Through the screening, 3 RCTs [106-108], 3 retrospective cohort studies [113, 114, 124] and 2 meta-analyses [68, 94] were included in this review. The subjects of surgical procedures were hiatal hernia repair in 1 RCT, 1 bariatric surgery in 1 RCT and 1 retrospective cohort study, gastric cancer surgery in 1 RCT and 1 retrospective study, and esophagectomy in 1 retrospective study, respectively. Operative time was discussed in 6 studies showing a statistically significant advantage for 3D in 4 studies (2 RCTs and 2 retrospective studies). Surgical complication was also discussed in 6 studies but there was no significant difference between the two groups. There was significant time reduction in 3D group for bariatric surgery or hiatal repair

compared to 2D, thus 3D laparoscopy might be more effective in these surgical procedures. The superiority of 3D laparoscopy for gastric cancer surgeries has not been shown at the moment.

6. Liver, Pancreas, Spleen and Adrenal Surgery

Statements. *There is no sufficient evidence to support advantages of 3D over 2D in Liver, Pancreas, Spleen and Adrenal surgery (LoE: …).*

There are no published RCTs or prospective studies dealing with 3D laparoscopic surgery of the liver, pancreas, spleen and adrenal surgery. Only one single prospective comparative study was found, focusing on different kind of anatomical liver resections. The study [105] shows a significant reduction of blood loss (1255 ml vs. 654 ml) and complications (33% vs. 14%) in favour of the use of 3D. Further studies need to be performed using 3D laparoscopy in liver, pancreas, spleen and adrenal surgery before a statement can be made.

7. Abdominal wall

Statements. *Further studies need to be performed using 3D laparoscopy in Abdominal wall surgery before a statement can be made (LoE: …).*

There are no published RCTs or prospective studies dealing with 3D laparoscopic abdominal wall surgery. Further studies need to be performed using 3D laparoscopy in abdominal wall surgery before a statement can be made.

8. Gynaecology

Statements. *3D laparoscopy could provide a more accurate view of the surgical field (subjective surgeon assessment), although it did not impact on surgical outcomes (LoE: …).*

3D surgical techniques could be of benefit in terms of EBL and operative time in more complex procedures, for example hysterectomy, lymph node dissection and in the management of locally advanced cervical cancer (LoE: …).

3D surgical techniques could be of benefit in enhancing surgical precision for ''novice'' surgeons (evaluated as operative time shortening) (LoE: …).

The literature search yielded 1273 documents until September 22, 2017. A total of 5 articles met inclusion criteria [101-104, 125]; 3 of them were RCTs [101, 103, 125]. A total of 693 patients were included and analysed: 371 in 2D group and 322 in 3D group. All the interventions described in the selected articles required sutures in the reconstructive phase (in all the cases for uterine surgery). Considering the operative time two studies reported a shorter operative time in favour of 3D group ($p<0.05$) [102, 104]. No differences were found in terms of blood losses. Concerning the length of hospital stay only in one study a shorter hospital stay in the 3D group was reported (p-value 0.004) [102]. The meta-analysis on suture complication related to hysterectomy showed a significant advantage in favour of 3D group, despite the heterogeneity of the studies included.

9. Urology

Statements. ***3D laparoscopy did not result in significant benefit in terms of operative time, blood loss, and perioperative complications when used for prostatectomy and renal lodge surgeries (LoE: …).***

3D surgical techniques could be of benefit in terms of EBL and operative time in more complex procedures, for example hysterectomy, lymph node dissection and in the management of locally advanced cervical cancer. (LoE: …).

3D surgical techniques could be of benefit in enhancing surgical precision for ''novice'' surgeons (evaluated as operative time shortening). (LoE: …).

The literature search yielded 1653 documents. A total of 7 papers met inclusion criteria [19, 97-100, 126, 127]. Four of them were RCTs [19, 98-100]. A total of 460 patients were included and analysed: 224 in the 3D Group and 236 in the control 2D group. The urological procedures considered were 122 donor nephrectomies, 121 radical prostatectomies, 93 partial nephrectomies, 54 simple nephrectomies, 40 pyeloplasties, 21 radical nephrectomies, 6 radical cystectomies and 3 other laparoscopic surgeries. The operative time resulted significantly shorter in 2 of the 4 RCTs (Whaba [99] and Patankar [98], $p=0.036$ and $p<0.0003$) whilst the blood loss resulted significantly different in 2 of the 3 RCTs (Ruan [19] and Patankar [98], $p<0.01$ and $p=0.028$). Focusing on the suture time in case of surgery including a laparoscopic suturing 2 of the 3 RCTs demonstrated shorter suture time for the 3D group (Ruan [19] and Patankar [98], $p<0.01$ and $p<0.0001$). For this specific purpose, also 2 retrospective comparative studies about radical prostatectomy were included in the analysis, showing similar results (Bove […] and Aykan […], $p<0.001$ and $p=0.03$). Meta-analysis did not show any significant difference in operative time or blood loss. When considering complications in case of surgeries with a suturing phase, a total of 11/179 and 18/223 for the 3D and 2D group were recorded respectively. Meta-analysis did not show any difference in terms of complications when including both all the papers and when considering radical prostatectomy papers only.

Commentato [AA1]: 111

Commentato [AA2]: 112

Ongoing Trials

There are currently 18 ongoing RCT trials [128-145] registered on CLINICALTRIALS.GOV and ISRCTN.COM: 3 in the United States, 12 in Europe and 3 in Asia. Five have completed recruiting, while 3 did not start recruiting yet. Four deal with cholecystectomy, 3 with colorectal surgery, 2 with gastrectomy, 2 with hernia repair, 6 with gynaecology surgery and 1 with urology specific for radical prostatectomy. In 10 studies the primary outcome is the operative time, in 3 the number of errors, in 2 VAS and QoL, in 1 the number of lymph-nodes dissected, in 2 complications. Common secondary outcomes are conversion rate, assessment of fatigue, bleeding and blood loss, readmission, mortality, oncologic appropriateness and specimen quality, nerve sparing and functionality.

Discussion

This EAES consensus development conference regarding the possible advantages of the use of 3D technology for vision resulted in 22 statements and 2 recommendations based upon the available evidence. Results from the London meeting led to this paper, which can be used as a guideline for surgeons treating patients with laparoscopy. This consensus follows the work done by the SICE (Società Italiana di Chirurgia Endoscopica e nuove tecnologie — Italian Society of Endoscopic Surgery and new technologies, which is affiliated to the European Society of Endoscopic Surgery—EAES) last year regarding the Health Technology Assessment of 3D technology [146]. Those results showed that 3D laparoscopy has advantages for both the patients and the surgeons, and is confirmed to be a safe, efficacious and sustainable vision technology. With this consensus meeting, we managed to gather experts from different European nations to compare and debate management of patients under 3D laparoscopic vision. The transfer of knowledge between the member countries, the opportunity to discuss views and above all, the creation of a widely supported paper appears valuable.

Our list of topics was created by the coordinating team and expert panel and was thought to cover the most important topics in the field of 3D vision for laparoscopy. Despite local differences, the general idea within the consensus group on the use of 3D vision was comparable. In some cases, differences of opinion between members of the expert panel were due to interpretation of the few prospective data available. This is reflected for instance on mitigating some statements and recommendations such as those related to the rate of complications.

Our findings are in keeping with the available 2D/3D systematic reviews on this topic [68, 147], which found similar performance results and methodological concerns. There is a clear need for further randomised training studies that use validated and reproducible tasks. Wherever possible equipment, viewing distance, table height and ergonomics should also be standardised. Compliance with the CONSORT statement, A-priori sample size calculations, homogenous participant groups, stereopsis visual assessment, validated blinded assessment methods and robust randomisation tools are additionally required. Results of the experimental trials in labs show a majority of technical tasks in which 3D perform significantly better than 2D, with a significant reduction in time to complete tasks and significantly higher task specific scores, with an equivalence between 3D and 2D vision in almost all the remaining. Consideration for the learning effect when repeating identical tasks with a different imaging modality should be made as performance could higher irrespective of imaging used. Whilst affected by the risk of bias and methodological flaws, our findings suggest that 3D technology improves laparoscopic box trainer simulator task performance. This could speed time to competency with fewer enacted error events in laparoscopically naïve or junior participants. There is no data on whether these benefits translate to operating room performance or patient outcomes. Although completing the FLS program (in 2D) has been shown to improve surgical performance [148], presently it cannot be assumed that 3D also provides this benefit. Only one study used all five FLS simulator tasks and no study incorporated simulator and real world operative performance assessment. It is noteworthy that both laparoscopic cholecystectomy studies did not show any time or error count differences between 2D and 3D modalities. A Cochrane review concluded that the benefits of box training have not been shown to translate to real world performance [149]. As improved operating performance represents the goal of all minimal access training, further dedicated translational and longitudinal studies are clearly indicated.

We then evaluated the cognitive load and discovered that the existing literature although limited, shows that 3D laparoscopy does not introduce a higher cognitive workload and may result in decreased experienced cognitive workload provided that the viewing setup is optimal. This is of major importance because an increase in cognitive workload during task performance may lead to an increase in error. Signs of visual discomfort, such as headache and visual fatigue, dry eyes or double vision, are reported in all studies and should be avoided to prevent pitfalls.

Moving into the analysis of clinical trials we could prove that 3D vision represents an advantage compared to 2D in terms of reduced operative time. This is true not only overall, but even more consistently when a laparoscopic suture is part of the procedure, reaching a reduction of 11% of the total time, second only to the gain observed in procedures performed on solid organs. The indication to use 3D vision when suturing is part of the procedure is strengthened by the observation of a halving of the complications. Due to the lack of data available it should be underlined that this is true especially in the gynaecology setting. Indeed data are too heterogeneous and weak to sustain any recommendation, other than implications for future research, and/but the vote of the ….

Commentato [3]: to be completed after voting in London

All this suggested that there is a need for further studies and investigation in order to better point out such drawbacks. Today 18 ongoing clinical trials related to this topic are registered (http://www.clinicaltrials.gov, https://www.clinicaltrialsregister.eu, http://www.anzctr.org.au), mostly RCTs. We hope these as well as further studies will contribute to assess if 3D vision represents an advantage. If this would be the case, it should be also determined at which cost the implementation of the new technology should take place, without the need of significant economic additional investment for the Healthcare Systems. The HTA suggests that this would not require additional investment, thus resulting in a substantial economic neutrality and sustainability, so that 3D vision could be considered not only a privilege for centres of excellence, but instead the norm even in public or private healthcare contexts.

There are significant methodological flaws present in the included studies that limits our ability to draw firm conclusions on whether 3D imaging benefits laparoscopic training. Meaningful meta-analysis of systematic review findings was not possible given the wide variation in study methodological design, number of tests, non-standardized tasks, repetitions performed, primary endpoints, assessment measures, analyses performed, participant experience, 3D technology and simulators utilised.

The literature review was ended in September 2017. No studies after that were integrated for the consensus meeting as this was decided in our methodology. Therefore, new studies might have been published in the meanwhile on some topics. The literature was quite vast in analysing general topics such as basics, training, cognitive load and pitfall. No specific literature was found regarding the topic of costs. An organ specific analysis was possible only in few cases, such as cholecystectomy, or merging data of colorectal surgery in general, as well as upper GI surgery, in a similar way to gynaecology and urology. Future research should be focused on clinical application in specific districts, in order to assess an eventual advantage of the use of 3D in defined procedures. We therefore propose that these statements are updated on a regular basis.

In conclusion, the consensus meeting of the EAES resulted in several statements and recommendations regarding the use of 3D vision in laparoscopy, based upon available evidence and expert opinion and was supported by the European surgical community. It provides guidance to surgeons and surgical residents approaching the use of this newly available technology.

Notes

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Compliance with ethical standards

This article does not contain any original study with human or animal subjects

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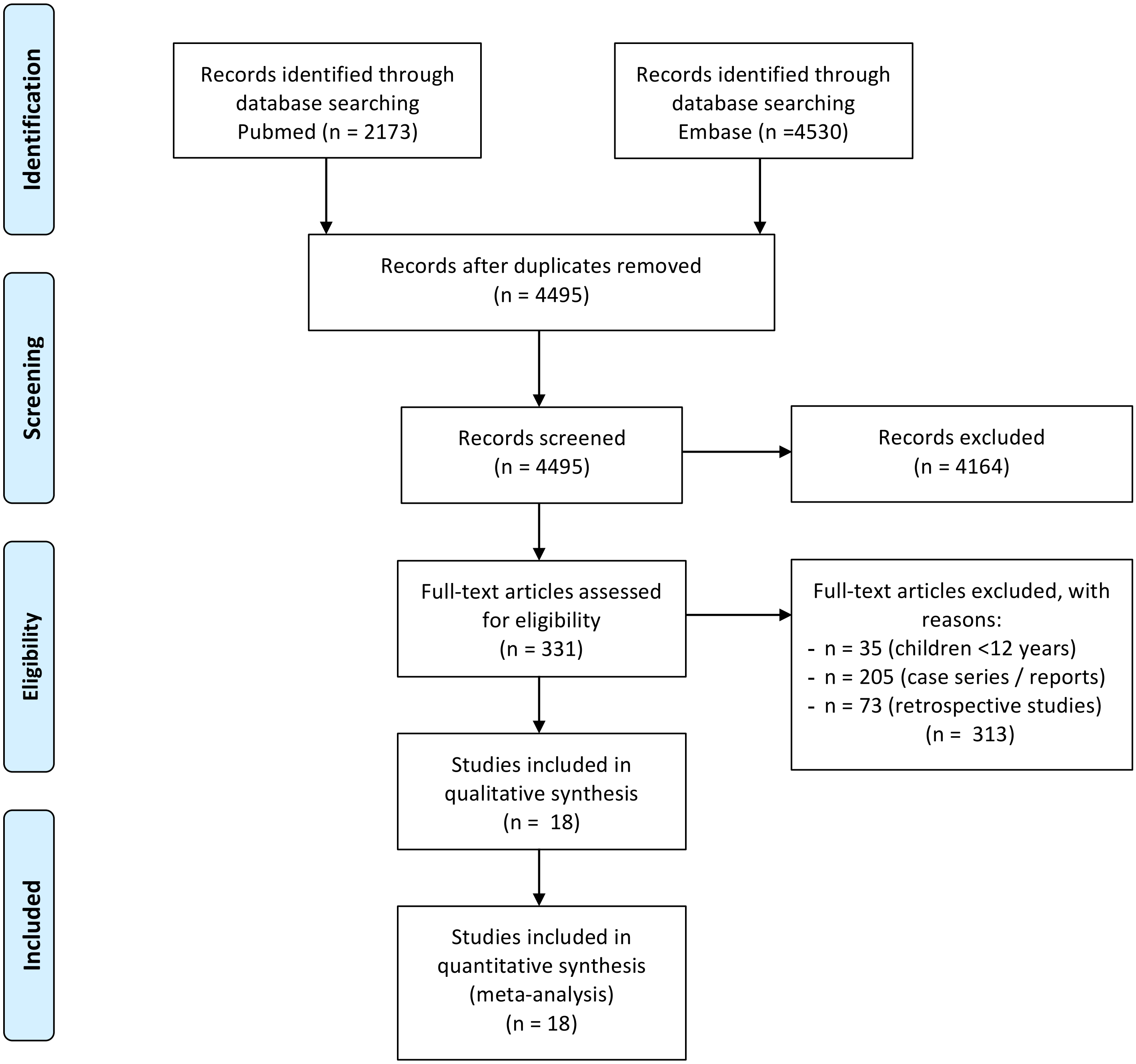
PRISMA 2009 Flow Diagram – September the 22nd, 2018

OPERATIVE TIME



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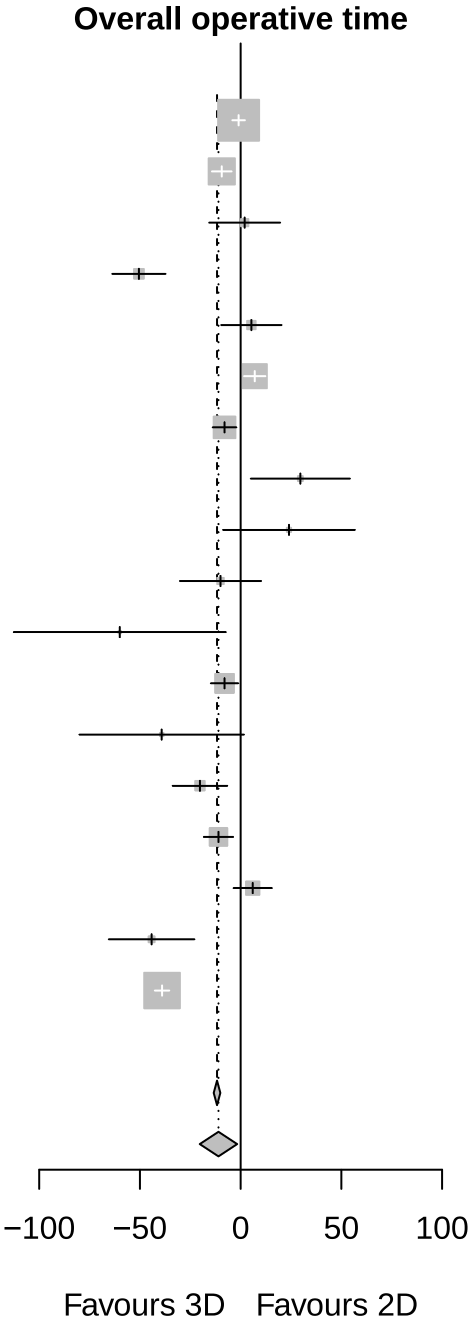
For more information, visit www.prisma-statement.org

Study	3D Total	3D Mean	3D SD	2D Total	2D Mean	2D SD	MD	95%−CI	Weight (fixed)	Weight (random)
Hanna 1998	30	51.67	5.55	30	52.67	6.67	−1.00	[−4.10; 2.10]	28.1%	6.8%
Bilgen 2013	11	20.63	5.60	11	30.00	6.03	−9.37	[−14.23; −4.51]	11.5%	6.7%
Kinoshita 2015	57	150.00	53.00	59	148.00	43.00	2.00	[−15.60; 19.60]	0.9%	5.5%
Ruan 2015	45	97.50	13.80	45	148.00	43.00	−50.50	[−63.69; −37.31]	1.6%	6.0%
Kyriazis 2015	11	81.00	20.79	30	75.67	23.75	5.33	[−9.61; 20.27]	1.2%	5.8%
Curro 2015	40	50.00	14.44	40	43.00	8.94	7.00	[1.74; 12.26]	9.8%	6.7%
Curro 2015	20	78.00	8.50	20	86.00	10.30	−8.00	[−13.85; −2.15]	7.9%	6.7%
Dominiguez 2016	31	96.71	49.75	29	67.06	47.43	29.65	[5.06; 54.24]	0.4%	4.6%
Fanfani 2016	42	168.00	74.50	48	144.00	83.75	24.00	[−8.70; 56.70]	0.3%	3.7%
Agrusa 2016	13	110.00	27.50	26	120.00	35.00	−10.00	[−30.11; 10.11]	0.7%	5.2%
Velayutham 2016	20	225.00	109.00	40	285.00	71.00	−60.00	[−112.59; −7.41]	0.1%	2.1%
Whaba 2016	41	98.00	19.00	81	106.00	16.00	−8.00	[−14.78; −1.22]	5.9%	6.6%
Raspagliesi 2017	15	176.70	74.60	60	215.90	61.60	−39.20	[−80.04; 1.64]	0.2%	2.9%
Leon 2017	19	69.90	21.50	17	90.10	19.90	−20.20	[−33.73; −6.67]	1.5%	6.0%
Hoffman 2017	190	90.00	36.00	190	101.00	36.00	−11.00	[−18.24; −3.76]	5.2%	6.6%
Lu 2017	115	184.00	36.00	113	178.00	37.00	6.00	[−3.48; 15.48]	3.0%	6.4%
Qiu 2017	37	312.50	52.60	45	356.70	43.80	−44.20	[−65.44; −22.96]	0.6%	5.0%
Patankar 2017	55	111.18	11.60	53	150.19	6.80	−39.01	[−42.58; −35.44]	21.3%	6.8%
Fixed effect model	**792**			**937**			**−11.72**	**[−13.37; −10.08]**	**100.0%**	**--**
Random effects model							**−11.01**	**[−20.29; −1.72]**	**--**	**100.0%**

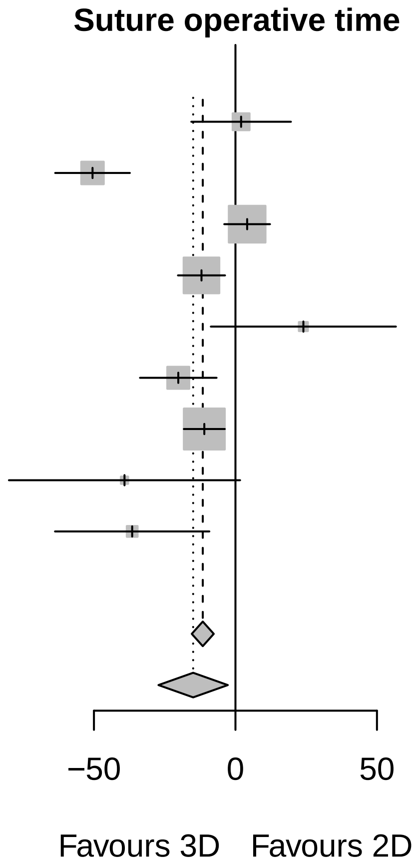


Heterogeneity: $I^2 = 96\%$, $\tau^2 = 328.4$, $p < 0.01$

Test for overall effect (fixed effect): $z = -13.95$ ($p < 0.01$)

Test for overall effect (random effects): $z = -2.32$ ($p = 0.02$)

Study	3D Total	3D Mean	3D SD	2D Total	2D Mean	2D SD	MD	95%−CI	Weight (fixed)	Weight (random)
Kinoshita 2015	57	150.00	53.00	59	148.00	43.000	2.00	[−15.60; 19.60]	4.9%	11.4%
Ruan 2015	45	97.50	13.80	45	148.00	43.000	−50.50	[−63.69; −37.31]	8.7%	12.7%
Kyriazis 2015	8	90.38	9.53	20	86.25	10.625	4.13	[−3.95; 12.21]	23.1%	14.0%
Curro 2015	10	88.00	8.70	10	100.00	10.200	−12.00	[−20.31; −3.69]	21.9%	13.9%
Fanfani 2016	42	168.00	74.50	48	144.00	83.750	24.00	[−8.70; 56.70]	1.4%	7.2%
Leon 2017	19	69.90	21.50	17	90.10	19.900	−20.20	[−33.73; −6.67]	8.3%	12.6%
Hoffman 2017	190	90.00	36.00	190	101.00	36.000	−11.00	[−18.24; −3.76]	28.8%	14.1%
Raspagliesi 2017	15	176.70	74.60	60	215.90	61.600	−39.20	[−80.04; 1.64]	0.9%	5.6%
Patankar 2017	21	121.19	39.60	19	157.68	47.530	−36.49	[−63.76; −9.22]	2.0%	8.6%
Fixed effect model	**407**			**468**			**−11.55**	**[−15.44; −7.66]**	**100.0%**	**--**
Random effects model							**−14.95**	**[−27.20; −2.70]**	**--**	**100.0%**

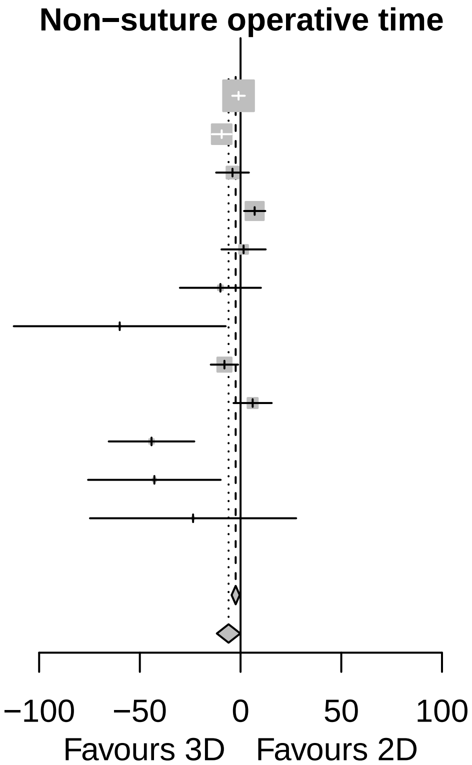


Heterogeneity: $I^2 = 87\%$, $\tau^2 = 262.8$, $p < 0.01$

Test for overall effect (fixed effect): $z = -5.82$ ($p < 0.01$)

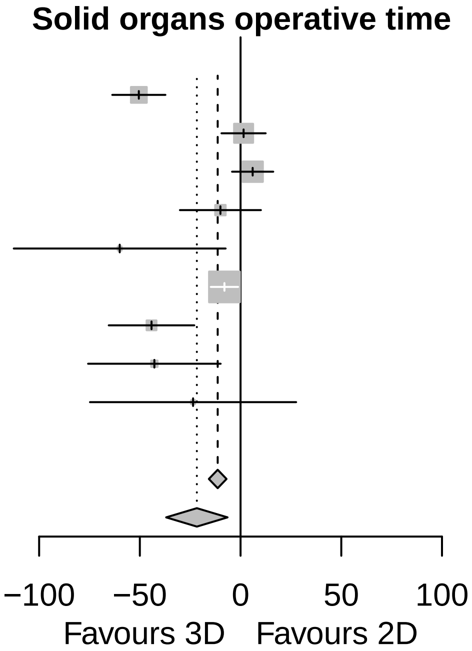
Test for overall effect (random effects): $z = -2.39$ ($p = 0.02$)

Study	3D Total	3D Mean	3D SD	2D Total	2D Mean	2D SD	MD	95%−CI	Weight (fixed)	Weight (random)
Hanna 1998	30	51.67	5.55	30	52.67	6.67	−1.00	[−4.10; 2.10]	42.4%	14.1%
Bilgen 2013	11	20.63	5.60	11	30.00	6.03	−9.37	[−14.23; −4.51]	17.3%	13.4%
Curro 2015	10	68.00	8.10	10	72.00	10.30	−4.00	[−12.12; 4.12]	6.2%	11.5%
Curro 2015	40	50.00	14.44	40	43.00	8.94	7.00	[1.74; 12.26]	14.7%	13.2%
Kyriazis 2015	3	56.00	8.78	10	54.50	7.50	1.50	[−9.47; 12.47]	3.4%	9.7%
Agrusa 2016	13	110.00	27.50	26	120.00	35.00	−10.00	[−30.11; 10.11]	1.0%	5.4%
Velayutham 2016	20	225.00	109.00	40	285.00	71.00	−60.00	[−112.59; −7.41]	0.1%	1.1%
Whaba 2016	41	98.00	19.00	81	106.00	16.00	−8.00	[−14.78; −1.22]	8.9%	12.3%
Lu 2017	115	184.00	36.00	113	178.00	37.00	6.00	[−3.48; 15.48]	4.5%	10.6%
Qiu 2017	37	312.50	52.60	45	356.70	43.80	−44.20	[−65.44; −22.96]	0.9%	5.0%
Patankar 2017	28	96.79	46.18	26	139.58	73.15	−42.79	[−75.70; −9.88]	0.4%	2.6%
Patankar 2017	6	143.30	37.29	8	166.88	60.01	−23.58	[−74.76; 27.60]	0.2%	1.2%
Fixed effect model	**354**			**440**			**−2.43**	**[−4.45; −0.41]**	**100.0%**	**−−**
Random effects model							**−5.95**	**[−11.79; −0.11]**	**−−**	**100.0%**



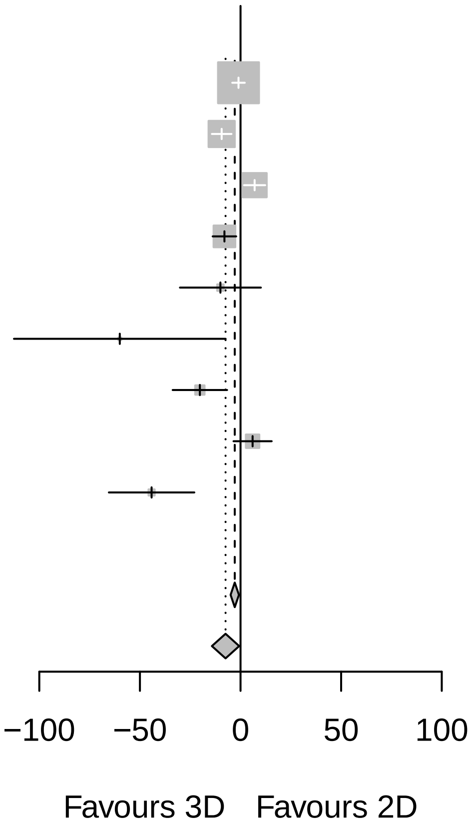
Heterogeneity: $I^2 = 80\%$, $\tau^2 = 60.2026$, $p < 0.01$
Test for overall effect (fixed effect): $z = -2.36$ ($p = 0.02$)
Test for overall effect (random effects): $z = -2.00$ ($p = 0.05$)

Study	Total (3D)	Mean (3D)	SD (3D)	Total (2D)	Mean (2D)	SD (2D)	MD	95%−CI	Weight (fixed)	Weight (random)
Ruan 2015	45	97.50	13.80	45	148.00	43.00	−50.50	[−63.69; −37.31]	11.1%	13.6%
Kyriazis 2015	3	56.00	8.78	10	54.50	7.50	1.50	[−9.47; 12.47]	16.1%	14.0%
Kyriazis 2015	3	107.00	5.00	10	101.00	13.75	6.00	[−4.23; 16.23]	18.5%	14.2%
Agrusa 2016	13	110.00	27.50	26	120.00	35.00	−10.00	[−30.11; 10.11]	4.8%	12.0%
Velayutham 2016	20	225.00	109.00	40	285.00	71.00	−60.00	[−112.59; −7.41]	0.7%	5.4%
Whaba 2016	41	98.00	19.00	81	106.00	16.00	−8.00	[−14.78; −1.22]	42.1%	14.7%
Qiu 2017	37	312.50	52.60	45	356.70	43.80	−44.20	[−65.44; −22.96]	4.3%	11.7%
Patankar 2017	28	96.79	46.18	26	139.58	73.15	−42.79	[−75.70; −9.88]	1.8%	8.9%
Patankar 2017	6	143.30	37.29	8	166.88	60.01	−23.58	[−74.76; 27.60]	0.7%	5.6%
Fixed effect model	**196**			**291**			**−11.35**	**[−15.75; −6.96]**	**100.0%**	**--**
Random effects model							**−21.70**	**[−36.94; −6.45]**	**--**	**100.0%**



Heterogeneity: $I^2 = 88\%$, $\tau^2 = 399.9342$, $p < 0.01$
Test for overall effect (fixed effect): $z = -5.06$ ($p < 0.01$)
Test for overall effect (random effects): $z = -2.79$ ($p < 0.01$)

Study	3D Total	3D Mean	3D SD	2D Total	2D Mean	2D SD	Operative time	MD	95%−CI	Weight (fixed)	Weight (random)
Hanna 1998	30	51.67	5.55	30	52.67	6.67		−1.00	[−4.10; 2.10]	44.5%	16.4%
Bilgen 2013	11	20.63	5.60	11	30.00	6.03		−9.37	[−14.23; −4.51]	18.2%	15.6%
Curro 2015	40	50.00	14.44	40	43.00	8.94		7.00	[1.74; 12.26]	15.5%	15.4%
Curro 2015	20	78.00	8.50	20	86.00	10.30		−8.00	[−13.85; −2.15]	12.5%	15.1%
Agrusa 2016	13	110.00	27.50	26	120.00	35.00		−10.00	[−30.11; 10.11]	1.1%	6.8%
Velayutham 2016	20	225.00	109.00	40	285.00	71.00		−60.00	[−112.59; −7.41]	0.2%	1.5%
Leon 2017	19	69.90	21.50	17	90.10	19.90		−20.20	[−33.73; −6.67]	2.3%	10.1%
Lu 2017	115	184.00	36.00	113	178.00	37.00		6.00	[−3.48; 15.48]	4.8%	12.7%
Qiu 2017	37	312.50	52.60	45	356.70	43.80		−44.20	[−65.44; −22.96]	1.0%	6.4%
Fixed effect model	**305**			**342**				**−2.87**	**[−4.94; −0.80]**	**100.0%**	**--**
Random effects model								**−7.44**	**[−14.23; −0.66]**	**--**	**100.0%**

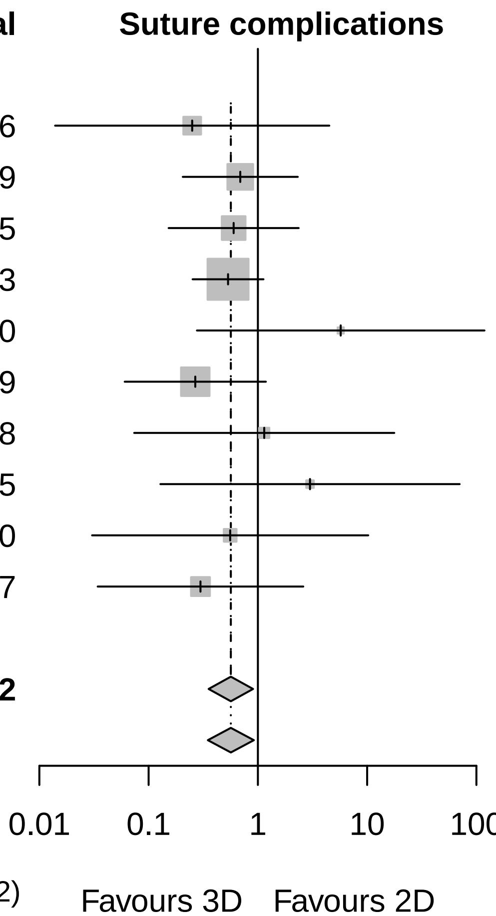


Heterogeneity: $I^2 = 85\%$, $\tau^2 = 70.73$, $p < 0.01$

Test for overall effect (fixed effect): $z = -2.72$ ($p < 0.01$)

Test for overall effect (random effects): $z = -2.15$ ($p = 0.03$)

Study	3D Events	3D Total	2D Events	2D Total	RR	95%−CI	Weight (fixed)	Weight (random)
Aykan 2013	0	29	4	66	0.25	[0.01; 4.50]	6.6%	2.8%
Kinoshita 2015	4	57	6	59	0.69	[0.21; 2.32]	13.9%	16.0%
Ruan 2015	3	45	5	45	0.60	[0.15; 2.36]	11.8%	12.5%
Bove 2015	8	43	15	43	0.53	[0.25; 1.13]	35.4%	42.2%
Kyriazis 2015	1	5	0	10	5.73	[0.28; 118.51]	0.8%	2.6%
Dominguez 2016	2	31	7	29	0.27	[0.06; 1.18]	17.1%	10.6%
Fanfani 2016	1	42	1	48	1.14	[0.07; 17.71]	2.2%	3.1%
Currò 2016	1	25	0	25	3.00	[0.13; 70.23]	1.2%	2.4%
Raspagliesi 2017	0	15	3	60	0.56	[0.03; 10.24]	3.4%	2.8%
Leon 2017	1	19	3	17	0.30	[0.03; 2.60]	7.5%	5.0%
Fixed effect model		**311**		**402**	**0.57**	**[0.35; 0.90]**	**100.0%**	**--**
Random effects model					**0.57**	**[0.35; 0.92]**	**--**	**100.0%**



Heterogeneity: $I^2 = 0\%$, $\tau^2 = 0$, $p = 0.81$

Test for overall effect (fixed effect): $z = -2.38$ ($p = 0.02$)

Test for overall effect (random effects): $z = -2.30$ ($p = 0.02$)

Study	3D Events	3D Total	2D Events	2D Total	RR	95%−CI	Weight (fixed)	Weight (random)
Kinoshita 2015	4	57	6	59	0.69	[0.21; 2.32]	24.9%	32.0%
Ruan 2015	3	45	5	45	0.60	[0.15; 2.36]	21.1%	25.0%
Dominguez 2016	2	31	7	29	0.27	[0.06; 1.18]	30.5%	21.2%
Fanfani 2016	1	42	1	48	1.14	[0.07; 17.71]	3.9%	6.3%
Raspagliesi 2017	0	15	3	60	0.56	[0.03; 10.24]	6.1%	5.5%
Leon 2017	1	19	3	17	0.30	[0.03; 2.60]	13.4%	10.0%
Fixed effect model		**209**		**258**	**0.50**	**[0.25; 0.97]**	**100.0%**	**−−**
Random effects model					**0.51**	**[0.26; 1.01]**	**−−**	**100.0%**

Heterogeneity: $I^2 = 0\%$, $\tau^2 = 0$, $p = 0.90$

Test for overall effect (fixed effect): $z = -2.04$ ($p = 0.04$)

Test for overall effect (random effects): $z = -1.92$ ($p = 0.05$)

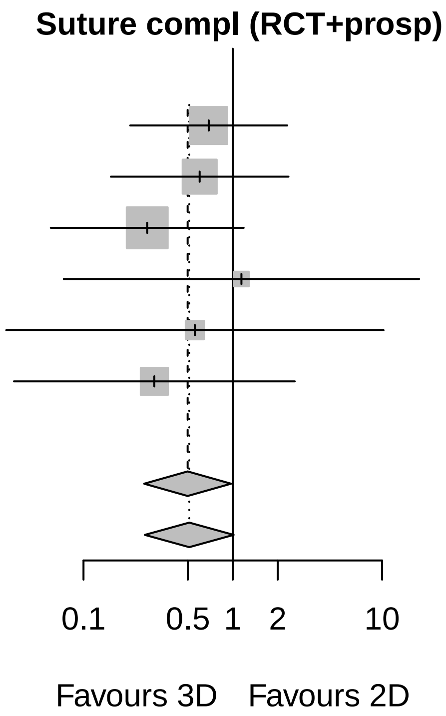


Table 1. List of topics regarding the use of 3D to be addressed

1. General Topics

a. Basics of 3D vision in laparoscopy

b. Impact on training

c. Impact on Cognitive load

d. Pitfalls

e. Costs & cost/effectiveness

2. Organ specific

a. Cholecystectomy

b. Appendectomy

c. Colon & Rectum

d. Bariatrics

e. Spleen

f. Adrenal

g. Liver

h. Pancreas

i. Upper GI benign

j. Upper GI malignant

k. Abdominal Wall

l. Urology

m. Gynecology

3. Ongoing trials

Table 2. Searches

	Pubmed	Embase
1. General Topics		
a. Basics of 3D	**("Imaging, Three-Dimensional"[Mesh] OR 3D OR 3-D OR three-dimension* OR 3-dimension*) AND ("Laparoscopy"[Mesh] OR "Laparoscopes"[Mesh] OR laparosc* OR laparoendosc* OR celioscop* OR "Minimally Invasive Surgical Procedures"[Mesh:NoExp] OR minimally-invasive-surg*) AND (equipm*[title] OR instrument*[title] OR methods*[title] OR methodol*[title] OR standard*[title] OR basic*[title] OR techniq*[title] OR technic*[title] OR technologi*[title] OR principles[title] OR practices[title] OR advances[title])**	**('three dimensional imaging'/exp OR 3d OR '3 d' OR 'three dimension*' OR '3 dimension*') AND ('laparoscopy'/exp OR 'laparoscope'/exp OR laparosc* OR laparoendosc* OR celioscop* OR 'minimally invasive surgery'/de OR 'minimally invasive surg*') AND (equipm*:ti OR instrument*:ti OR methods*:ti OR methodol*:ti OR standard*:ti OR basic*:ti OR techniq*:ti OR technic*:ti OR technologi*:ti OR principles:ti OR practices:ti OR advances:ti)**
b. Training	**("Imaging, Three-Dimensional"[Mesh] OR 3D OR 3-D OR three-dimension* OR 3-dimension*) AND ("Laparoscopy"[Mesh] OR "Laparoscopes"[Mesh] OR laparosc* OR laparoendosc* OR celioscop* OR "Minimally Invasive Surgical Procedures"[Mesh:NoExp] OR minimally-invasive-surg*) AND ("Education"[Mesh] OR education[sh] OR educat* OR train* OR teach*)**	**('three dimensional imaging'/exp OR 3d OR '3 d' OR 'three dimension*' OR '3 dimension*') AND ('laparoscopy'/exp OR 'laparoscope'/exp OR laparosc* OR laparoendosc* OR celioscop* OR 'minimally invasive surgery'/de OR 'minimally invasive surg*') AND ('education'/exp OR educat* OR train* OR teach*)**
c. Cognitive load	**("Imaging, Three-Dimensional"[Mesh] OR 3D OR 3-D OR three-dimension* OR 3-dimension*) AND ("Laparoscopy"[Mesh] OR "Laparoscopes"[Mesh] OR laparosc* OR laparoendosc* OR celioscop* OR "Minimally Invasive Surgical Procedures"[Mesh:NoExp] OR minimally-invasive-surg*) AND ("Cognition"[Mesh] OR "Learning"[Mesh] OR "Task performance and Analysis"[Mesh] OR cognitive-load* OR workload* OR working-load* OR work-load* OR task* OR learn* OR memor* OR effort* OR instruction* OR skill*[title] OR competenc*[title] OR proficien*[title] OR performance*[title])**	**('three dimensional imaging'/exp OR 3d OR '3 d' OR 'three dimension*' OR '3 dimension*') AND ('laparoscopy'/exp OR 'laparoscope'/exp OR laparosc* OR laparoendosc* OR celioscop* OR 'minimally invasive surgery'/de OR 'minimally invasive surg*') AND ('cognition'/exp OR 'learning'/exp OR 'task performance'/exp OR cognitive-load* OR workload* OR working-load* OR work-load* OR task* OR learn* OR memor* OR effort* OR instruction* OR skill*:ti OR competenc*:ti OR proficien*:ti OR performance*:ti)**
d. Pitfalls	**("Imaging, Three-Dimensional"[Mesh] OR 3D OR 3-D OR three-dimension* OR 3-dimension*) AND ("Laparoscopy"[Mesh] OR "Laparoscopes"[Mesh] OR laparosc* OR laparoendosc* OR celioscop* OR "Minimally**	**('three dimensional imaging'/exp OR 3d OR '3 d' OR 'three dimension*' OR '3 dimension*') AND ('laparoscopy'/exp OR 'laparoscope'/exp OR laparosc* OR laparoendosc* OR celioscop* OR 'minimally invasive**

	Invasive Surgical Procedures"[Mesh:NoExp] OR minimally-invasive-surg*) AND ("Intraoperative Complications"[Mesh] OR "adverse effects"[sh] OR pitfall*[title] OR hazard*[title] OR failure*[title] OR complicat*[title] OR adverse[title] OR difficult*[title] OR disadvantag*[title])	**surgery'/de OR 'minimally invasive surg*') AND ('peroperative complication'/exp OR pitfall*:ti OR hazard*:ti OR failure*:ti OR complicat*:ti OR adverse:ti OR difficult*:ti OR disadvantag*:ti)**
e. Costs & cost/effectiveness	**("Imaging, Three-Dimensional"[Mesh] OR 3D OR 3-D OR three-dimension* OR 3-dimension*) AND ("Laparoscopy"[Mesh] OR "Laparoscopes"[Mesh] OR laparosc* OR laparoendosc* OR celioscop* OR "Minimally Invasive Surgical Procedures"[Mesh:NoExp] OR minimally-invasive-surg*) AND ("Costs and Cost Analysis"[mesh] OR cost OR costs OR economics[sh] OR econom* OR cost-effect* OR cost-benef* OR cost-util*)**	**('three dimensional imaging'/exp OR 3d OR '3 d' OR 'three dimension*' OR '3 dimension*') AND ('laparoscopy'/exp OR 'laparoscope'/exp OR laparosc* OR laparoendosc* OR celioscop* OR 'minimally invasive surgery'/de OR 'minimally invasive surg*') AND ('cost'/exp OR 'health economics'/exp OR cost OR costs OR econom* OR cost-effect* OR cost-benef* OR cost-util*)**
Organ specific		
a. Cholecystectomy	**("Imaging, Three-Dimensional"[Mesh] OR 3D OR 3-D OR three-dimension* OR 3-dimension*) AND ("Laparoscopy"[Mesh] OR "Laparoscopes"[Mesh] OR laparosc* OR laparoendosc* OR celioscop* OR "Minimally Invasive Surgical Procedures"[Mesh:NoExp] OR minimally-invasive-surg*) AND (“Gallbladder”[Mesh] OR “Gallbladder Diseases”[Mesh] OR “Cholecystectomy”[Mesh] OR cholecyst* OR gallbladder* OR gall-bladder* OR gallstone* OR gall-stone*)**	**('three dimensional imaging'/exp OR 3d OR '3 d' OR 'three dimension*' OR '3 dimension*') AND ('laparoscopy'/exp OR 'laparoscope'/exp OR laparosc* OR laparoendosc* OR celioscop* OR 'minimally invasive surgery'/de OR 'minimally invasive surg*') AND ('gallbladder'/exp OR 'gallbladder disease'/exp OR 'cholecystectomy'/exp OR cholecyst* OR gallbladder* OR 'gall bladder*' OR gallstone* OR 'gall stone*')**
b. Appendectomy	**("Imaging, Three-Dimensional"[Mesh] OR 3D OR 3-D OR three-dimension* OR 3-dimension*) AND ("Laparoscopy"[Mesh] OR "Laparoscopes"[Mesh] OR laparosc* OR laparoendosc* OR celioscop* OR "Minimally Invasive Surgical Procedures"[Mesh:NoExp] OR minimally-invasive-surg*) AND (“Appendix”[Mesh] OR "Appendiceal Neoplasms"[Mesh] OR “Appendectomy”[Mesh] OR “Appendicitis”[Mesh] OR append*)**	**('three dimensional imaging'/exp OR 3d OR '3 d' OR 'three dimension*' OR '3 dimension*') AND ('laparoscopy'/exp OR 'laparoscope'/exp OR laparosc* OR laparoendosc* OR celioscop* OR 'minimally invasive surgery'/de OR 'minimally invasive surg*') AND ('appendix'/exp OR 'appendix disease'/exp OR 'appendectomy'/exp OR append*)**
c. Colon & Rectum	**("Imaging, Three-Dimensional"[Mesh] OR 3D OR 3-D OR three-dimension* OR 3-dimension*) AND ("Laparoscopy"[Mesh] OR "Laparoscopes"[Mesh] OR laparosc* OR laparoendosc* OR celioscop* OR "Minimally Invasive Surgical Procedures"[Mesh:NoExp] OR minimally-**	**('three dimensional imaging'/exp OR 3d OR '3 d' OR 'three dimension*' OR '3 dimension*') AND ('laparoscopy'/exp OR 'laparoscope'/exp OR laparosc* OR laparoendosc* OR celioscop* OR 'minimally invasive surgery'/de OR 'minimally invasive surg*') AND**

	invasive-surg*) AND (“Colon”[Mesh] OR “Colonic Diseases”[Mesh] OR “Rectum”[Mesh] OR “Rectal Diseases”[Mesh] OR “Colorectal Surgery”[Mesh] OR “Anal Canal”[Mesh] OR “Colectomy”[Mesh] OR “Ileostomy”[Mesh] OR “Colostomy”[Mesh] OR colon OR colonic* OR colectom* OR ileostom* OR colostom* OR polypect* OR rectum* OR rectal* OR colorect* OR colo-rect* OR polyposis-coli OR sigmoid* OR anus OR anal)	('colon'/exp OR 'colon disease'/exp OR 'rectum'/exp OR 'rectum disease'/exp OR 'anus'/exp OR 'colorectal surgery'/exp OR 'colon surgery'/exp OR 'ileostomy'/exp OR 'rectum surgery'/exp OR colon OR colonic* OR colectom* OR ileostom* OR colostom* OR polypect* OR rectum* OR rectal* OR colorect* OR 'colo rect*' OR 'polyposis coli' OR sigmoid* OR anus OR anal)
d. Bariatrics	("Imaging, Three-Dimensional"[Mesh] OR 3D OR 3-D OR three-dimension* OR 3-dimension*) AND ("Laparoscopy"[Mesh] OR "Laparoscopes"[Mesh] OR laparosc* OR laparoendosc* OR celioscop* OR "Minimally Invasive Surgical Procedures"[Mesh:NoExp] OR minimally-invasive-surg*) AND (“Bariatric Surgery”[Mesh] OR “Obesity, Morbid”[Mesh] OR “Gastric Balloon”[Mesh] OR obes* OR bariatr* OR weight-loss-surg* OR metabolic-surg* OR biliopancreatic-diver* OR bilio-pancreatic-diver* OR gastroplast* OR stomach-stapl* OR gastric-band* OR sleeve-gastrectom* OR gastric-sleeve* OR intragastric-balloon* OR gastric-balloon* OR gastric-bypass* OR jejunoileal-bypass* OR jejuno-ileal-bypass* OR intestinal-bypass*)	('three dimensional imaging'/exp OR 3d OR '3 d' OR 'three dimension*' OR '3 dimension*') AND ('laparoscopy'/exp OR 'laparoscope'/exp OR laparosc* OR laparoendosc* OR celioscop* OR 'minimally invasive surgery'/de OR 'minimally invasive surg*') AND ('bariatric surgery'/exp OR 'morbid obesity'/exp OR 'gastric balloon'/exp OR obes* OR bariatr* OR 'weight loss surg*' OR 'metabolic surg*' OR 'biliopancreatic diver*' OR 'bilio pancreatic diver*' OR gastroplast* OR 'stomach stapl*' OR 'gastric band*' OR 'sleeve gastrectom*' OR 'gastric sleeve*' OR 'intragastric balloon*' OR 'gastric balloon*' OR 'gastric bypass*' OR 'jejunoileal bypass*' OR 'jejuno ileal bypass*' OR 'intestinal bypass*')
e. Spleen	("Imaging, Three-Dimensional"[Mesh] OR 3D OR 3-D OR three-dimension* OR 3-dimension*) AND ("Laparoscopy"[Mesh] OR "Laparoscopes"[Mesh] OR laparosc* OR laparoendosc* OR celioscop* OR "Minimally Invasive Surgical Procedures"[Mesh:NoExp] OR minimally-invasive-surg*) AND (“Spleen”[Mesh] OR “Splenic Diseases”[Mesh] OR “Splenectomy”[Mesh] OR spleen* OR splenic* OR splenect*)	('three dimensional imaging'/exp OR 3d OR '3 d' OR 'three dimension*' OR '3 dimension*') AND ('laparoscopy'/exp OR 'laparoscope'/exp OR laparosc* OR laparoendosc* OR celioscop* OR 'minimally invasive surgery'/de OR 'minimally invasive surg*') AND ('spleen'/exp OR 'spleen disease'/exp OR 'spleen surgery'/exp OR spleen* OR splenic* OR splenect*)
f. Adrenal	("Imaging, Three-Dimensional"[Mesh] OR 3D OR 3-D OR three-dimension* OR 3-dimension*) AND ("Laparoscopy"[Mesh] OR "Laparoscopes"[Mesh] OR laparosc* OR laparoendosc* OR celioscop* OR "Minimally Invasive Surgical Procedures"[Mesh:NoExp] OR minimally-invasive-surg*) AND (“Adrenal Glands”[Mesh] OR “Adrenal Gland Diseases”[Mesh] OR “Adrenalectomy”[Mesh] OR	('three dimensional imaging'/exp OR 3d OR '3 d' OR 'three dimension*' OR '3 dimension*') AND ('laparoscopy'/exp OR 'laparoscope'/exp OR laparosc* OR laparoendosc* OR celioscop* OR 'minimally invasive surgery'/de OR 'minimally invasive surg*') AND ('adrenal gland'/exp OR 'adrenal disease'/exp OR 'adrenalectomy'/exp OR adrenal* OR adrenocortic* OR

	adrenal* OR adrenocortic* OR adreno-cortic* OR adrenal-cortic*)	**'adreno cortic*' OR 'adrenal cortic*')**
g. Liver	**("Imaging, Three-Dimensional"[Mesh] OR 3D OR 3-D OR three-dimension* OR 3-dimension*) AND ("Laparoscopy"[Mesh] OR "Laparoscopes"[Mesh] OR laparosc* OR laparoendosc* OR celioscop* OR "Minimally Invasive Surgical Procedures"[Mesh:NoExp] OR minimally-invasive-surg*) AND (“Liver”[Mesh] OR “Liver Diseases”[Mesh] OR “Hepatectomy”[Mesh] OR liver* OR hepatic* OR hepatocel* OR hepatect*)**	**('three dimensional imaging'/exp OR 3d OR '3 d' OR 'three dimension*' OR '3 dimension*') AND ('laparoscopy'/exp OR 'laparoscope'/exp OR laparosc* OR laparoendosc* OR celioscop* OR 'minimally invasive surgery'/de OR 'minimally invasive surg*') AND ('liver'/exp OR 'liver disease'/exp OR 'liver surgery'/exp OR liver* OR hepatic* OR hepatocel* OR hepatect*)**
h. Pancreas	**("Imaging, Three-Dimensional"[Mesh] OR 3D OR 3-D OR three-dimension* OR 3-dimension*) AND ("Laparoscopy"[Mesh] OR "Laparoscopes"[Mesh] OR laparosc* OR laparoendosc* OR celioscop* OR "Minimally Invasive Surgical Procedures"[Mesh:NoExp] OR minimally-invasive-surg*) AND (“Pancreas”[Mesh] OR “Pancreatic Diseases”[Mesh] OR “Pancreatectomy”[Mesh] OR pancreas* OR pancreatic* OR islet-cell*)**	**('three dimensional imaging'/exp OR 3d OR '3 d' OR 'three dimension*' OR '3 dimension*') AND ('laparoscopy'/exp OR 'laparoscope'/exp OR laparosc* OR laparoendosc* OR celioscop* OR 'minimally invasive surgery'/de OR 'minimally invasive surg*') AND ('pancreas'/exp OR 'pancreas disease'/exp OR 'pancreas surgery'/exp OR pancreas* OR pancreatic* OR 'islet cell*')**
i. Upper GI benign	**("Imaging, Three-Dimensional"[Mesh] OR 3D OR 3-D OR three-dimension* OR 3-dimension*) AND ("Laparoscopy"[Mesh] OR "Laparoscopes"[Mesh] OR laparosc* OR laparoendosc* OR celioscop* OR "Minimally Invasive Surgical Procedures"[Mesh:NoExp] OR minimally-invasive-surg*) AND (“Upper Gastrointestinal Tract”[Mesh] OR “Esophageal Diseases”[Mesh] OR “Stomach Diseases”[Mesh] OR “Duodenal Diseases”[Mesh] OR esophag* OR oesophag* OR stomach* OR duodeno* OR duodena* OR gastroesophag* OR gastro-esophag* OR gastro-oesophag* OR duodenogastr* OR duodeno-gastric OR paraesophag* OR paraoesophag* OR hiatal-hernia* OR hiatus-hernia* OR gastric) NOT ("Esophageal Neoplasms"[Mesh] OR "Stomach Neoplasms"[Mesh] OR "Duodenal Neoplasms"[Mesh] OR neoplas* OR tumor OR tumors OR tumora* OR tumour OR tumours OR tumoura* OR cancer OR cancers OR cancero* OR carcinoma* OR malignan* OR oncol*)**	**('three dimensional imaging'/exp OR 3d OR '3 d' OR 'three dimension*' OR '3 dimension*') AND ('laparoscopy'/exp OR 'laparoscope'/exp OR laparosc* OR laparoendosc* OR celioscop* OR 'minimally invasive surgery'/de OR 'minimally invasive surg*') AND ('upper gastrointestinal tract'/exp OR 'stomach'/exp OR 'esophagus'/exp OR 'duodenum'/exp OR 'upper gastrointestinal disease'/exp OR 'stomach disease'/exp OR 'esophagus disease'/exp OR 'duodenum disease'/exp OR 'stomach surgery'/exp OR 'esophagus surgery'/exp OR 'duodenum surgery'/exp OR esophag* OR oesophag* OR stomach* OR duodeno* OR duodena* OR gastroesophag* OR 'gastro esophag*' OR 'gastro oesophag*' OR duodenogastr* OR 'duodeno gastric' OR paraesophag* OR paraoesophag* OR 'hiatal hernia*' OR 'hiatus hernia*' OR gastric) NOT ('stomach tumor'/exp OR 'esophagus tumor'/exp OR 'duodenum tumor'/exp OR neoplas* OR tumor OR tumors OR tumora* OR tumour OR tumours OR tumoura* OR cancer OR**

		cancers OR cancero* OR carcinoma* OR malignan* OR oncol*)
j. Upper GI malignant	**("Imaging, Three-Dimensional"[Mesh] OR 3D OR 3-D OR three-dimension* OR 3-dimension*) AND ("Laparoscopy"[Mesh] OR "Laparoscopes"[Mesh] OR laparosc* OR laparoendosc* OR celioscop* OR "Minimally Invasive Surgical Procedures"[Mesh:NoExp] OR minimally-invasive-surg*) AND ("Esophageal Neoplasms"[Mesh] OR "Stomach Neoplasms"[Mesh] OR "Duodenal Neoplasms"[Mesh] OR ((“Upper Gastrointestinal Tract”[Mesh] OR esophag* OR oesophag* OR stomach* OR duodeno* OR duodena* OR gastroesophag* OR gastro-esophag* OR gastro-oesophag* OR duodenogastr* OR duodeno-gastric OR gastric) AND (neoplas* OR tumor OR tumors OR tumora* OR tumour OR tumours OR tumoura* OR cancer OR cancers OR cancero* OR carcinoma* OR malignan* OR oncol*)))**	**('three dimensional imaging'/exp OR 3d OR '3 d' OR 'three dimension*' OR '3 dimension*') AND ('laparoscopy'/exp OR 'laparoscope'/exp OR laparosc* OR laparoendosc* OR celioscop* OR 'minimally invasive surgery'/de OR 'minimally invasive surg*') AND ('stomach tumor'/exp OR 'esophagus tumor'/exp OR 'duodenum tumor' OR (('upper gastrointestinal tract'/exp OR 'stomach'/exp OR 'esophagus'/exp OR 'duodenum'/exp OR esophag* OR oesophag* OR stomach* OR duodeno* OR duodena* OR gastroesophag* OR gastro-esophag* OR gastro-oesophag* OR duodenogastr* OR duodeno-gastric OR gastric) AND (neoplas* OR tumor OR tumors OR tumora* OR tumour OR tumours OR tumoura* OR cancer OR cancers OR cancero* OR carcinoma* OR malignan* OR oncol*)))**
k. Abdominal Wall	**("Imaging, Three-Dimensional"[Mesh] OR 3D OR 3-D OR three-dimension* OR 3-dimension*) AND ("Laparoscopy"[Mesh] OR "Laparoscopes"[Mesh] OR laparosc* OR laparoendosc* OR celioscop* OR "Minimally Invasive Surgical Procedures"[Mesh:NoExp] OR minimally-invasive-surg*) AND (“Abdominal Wall”[Mesh] OR “Hernia, Abdominal”[Mesh] OR abdominal-wall* OR inguinal-hernia* OR ventral-hernia* OR incisional-hernia*)**	**('three dimensional imaging'/exp OR 3d OR '3 d' OR 'three dimension*' OR '3 dimension*') AND ('laparoscopy'/exp OR 'laparoscope'/exp OR laparosc* OR laparoendosc* OR celioscop* OR 'minimally invasive surgery'/de OR 'minimally invasive surg*') AND ('abdominal wall'/exp OR 'abdominal wall defect'/exp OR 'abdominal wall*' OR 'inguinal hernia*' OR 'ventral hernia*' OR 'incisional hernia*')**
l. Urology	**("Imaging, Three-Dimensional"[Mesh] OR 3D OR 3-D OR three-dimension* OR 3-dimension*) AND ("Laparoscopy"[Mesh] OR "Laparoscopes"[Mesh] OR laparosc* OR laparoendosc* OR celioscop* OR "Minimally Invasive Surgical Procedures"[Mesh:NoExp] OR minimally-invasive-surg*) AND (“Urinary Tract”[Mesh] OR “Genitalia, Male”[Mesh] OR “Male Urogenital Diseases”[Mesh] OR “Urologic Diseases”[Mesh] OR “Urologic Surgical Procedures”[Mesh] OR urol* OR kidney* OR renal OR nephrect* OR nephropex* OR nephroureter* OR ureter OR ureteral* OR ureterect* OR bladder* OR prostate* OR**	**(('three dimensional imaging'/exp OR 3d OR '3 d' OR 'three dimension*' OR '3 dimension*') AND ('laparoscopy'/exp OR 'laparoscope'/exp OR laparosc* OR laparoendosc* OR celioscop* OR 'minimally invasive surgery'/de OR 'minimally invasive surg*') AND ('urinary tract'/exp OR 'male genital system'/exp OR 'urinary tract disease'/exp OR 'male genital system disease'/exp OR 'urologic surgery'/exp OR urol* OR kidney* OR renal OR nephrect* OR nephropex* OR nephroureter* OR ureter OR ureteral* OR ureterect* OR bladder* OR prostate* OR cystectom* OR varicocele* OR cryptorchid* OR**

	cystectom* OR varicocele* OR cryptorchid* OR retroperitoneal-lymph-node* OR pelvic-lymph-node*)	'retroperitoneal lymph node*' OR 'pelvic lymph node*')) NOT 'gynecologic surgery'/exp
m. Gynecology	("Imaging, Three-Dimensional"[Mesh] OR 3D OR 3-D OR three-dimension* OR 3-dimension*) AND ("Laparoscopy"[Mesh] OR "Laparoscopes"[Mesh] OR laparosc* OR laparoendosc* OR celioscop* OR "Minimally Invasive Surgical Procedures"[Mesh:NoExp] OR minimally-invasive-surg*) AND (“Genitalia, Female”[Mesh] OR “Female Urogenital Diseases”[Mesh] OR “Gynecologic Surgical Procedures”[Mesh] OR gynecol* OR gynaecol* OR tubes OR tubal OR endometri* OR ovary OR ovaries OR ovarian OR ovaric* OR hysterect* OR uterin* OR pelvic-floor OR myomectom*)	('three dimensional imaging'/exp OR 3d OR '3 d' OR 'three dimension*' OR '3 dimension*') AND ('laparoscopy'/exp OR 'laparoscope'/exp OR laparosc* OR laparoendosc* OR celioscop* OR 'minimally invasive surgery'/de OR 'minimally invasive surg*') AND ('female genital system'/exp OR 'gynecologic disease'/exp OR 'gynecologic surgery'/exp OR gynecol* OR gynaecol* OR tubes OR tubal OR endometri* OR ovary OR ovaries OR ovarian OR ovaric* OR hysterect* OR uterin* OR pelvic-floor OR myomectom*)

Table 3. Risk of bias (Cochrane Risk Tool) for RCTs selected for Operative time assessment

	Selection bias		Performance bias	Detection bias	Attrition bias	Reporting bias	Other bias
	Random sequence generation	**Allocation concealment**					
Ruan 2015	Low	Low	Low	High	Low	Low	Unclear
Kinoshita 2015	Low	Unclear	Low	High	Low	Low	Unclear
Fanfani 2016	Low	Low	High	Unclear	Low	Low	Unclear
Leon 2017	Low	Low	Low	Unclear	Unclear	Low	Unclear
Lu 2017	Low	Unclear	Low	Low	Unclear	Unclear	Unclear
Hoffman 2017	Low	Low	Low	Low	Low	Low	Unclear
Petankar 2017	Low	Unclear	Unclear	Unclear	Low	Unclear	Unclear

Table 4. Risk of bias (Cochrane Risk Tool) for RCTs selected for Complications assessment

	Selection bias		Performance bias	Detection bias	Attrition bias	Reporting bias	Other bias
	Random sequence generation	**Allocation concealment**					
Ruan 2015	Low	Low	Low	High	Low	Low	Unclear
Kinoshita 2015	Low	Unclear	Low	High	Low	Low	Unclear
Fanfani 2016	Low	Low	High	Unclear	Low	Low	Unclear
Leon 2017	Low	Low	Low	Unclear	Unclear	Low	Unclear
Lu 2017	Low	Unclear	Low	Low	Unclear	Unclear	Unclear

Table 5. List of complications considered for the analysis

Author, year	Total complications		Description	
	3D	2D	3D	2D
Aykan 2013	0	4	0	3 rectal tears 1 anemia
Kinoshita 2015	4	6	4 anastomotic leakage	6 anastomotic leakage
Ruan 2015	3	5	3 hematuria	1 pseudoaneurysms 4 hematuria
Bove 2015	2	6	1 anastomotic stenosis 1 urinary fistula	1 hematuria 2 anemia 1 epididymitis 2 anastmotic stenosis
Dominiguez 2016	0	2	0	1 vascular injury 1 anemia
Fanfani 2016	1	1	1 intraoperative bleeding	1 dehiscence of vaginal cuff
Currò 2016	1	0	1 anastomotic leakage	0
Raspagliesi 2017	0	3	0	1 bladder injury 1 hemoperotoneum 1 urethero-vaginal fistula
Leon 2017	1	3	1 intraoperative bleeding	3 intraoperative bleeding