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Original Article

Effect of 2D vs. 3D laparoscopy on postoperative complications and operation time in a propensity-score-matched real-world data analysis

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SUMMARY

Background: Postoperative complication rates using 3D visualization are rarely reported. The primary aim of our study is to detect a possible advantage of using 3D on postoperative complication rates in a real-world setting.
Method: With a sample size calculation for a medium effect size difference that 3D reduces significantly postoperative complications, data of 287 patients with 3D visualization and 832 with 2D procedure were screened. The groups underwent an exact propensity score-matching to be comparable. Comprehensive complication index (CCI) for every procedure was calculated and Operation Time was determined.
Results: Including 1078 patients in the study, 213 exact propensity score-matched pairs could finally be established. Concerning overall CCI (3D: 5.70 ± 13.63 vs. 2D: 3.37 ± 9.89; $p = 0.076$) and operation time (3D: 103.98 ± 93.26 min vs. 2D: 88.60 ± 6 9.32 min; $p = 0.2569$) there was no significant difference between the groups.
Conclusion: Our study shows no advantage of 3D over 2D laparoscopy regarding postoperative complications in a real-world setting, the second endpoint operation time, too, was not influenced by 3D overall.

1. Introduction

The first laparoscopic cholecystectomy was performed in 1985 by the Böblingen surgeon Erich Mühe.[1]

In the meantime, minimally invasive surgery has conquered everyday clinical practice and has become an integral part of many surgical disciplines, both as a diagnostic procedure and for performing complex surgical interventions.[2]

The Surgical Association for Minimally Invasive Surgery (CAMIC) estimates that 92 to 98 percent of gallbladder surgeries, 55 to 70 percent of appendectomies, and 20 to 40 percent of inguinal hernia surgeries are performed minimally invasively. Meanwhile, 50 to 60 percent of colorectal surgery procedures are performed laparoscopically.[3]

The laparoscopic procedure has proven its worth not only for physicians and patients but also economically. For example, by using it as a diagnostic tool, diseases should be detected earlier and treated more quickly. Further costs are saved through reduced surgical trauma, less postoperative pain, and speedy hospital discharges. It is also postulated to reduce the risk of infection and prevent extensive intra-abdominal adhesions.[2,4]

However, laparoscopic surgery has also presented difficulties. For example, the surgeon must work in a three-dimensional field but is guided by two-dimensional images.[4]

The integration of technological advances in the electronics industry has given rise to 3D laparoscopy, which has continued to evolve since the 1990s. A large proportion of new laparoscopy systems incorporate this technology.

It allows for vivid, detailed images that are much closer to true anatomic conditions.[5,6]

This natural three-dimensional vision is postulated to improve hand-eye coordination and thus increase precision. The improved

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depth perception is also described by surgeons as increasing safety in the operating room.[3,5]

There is much debate on the advantages of 3D laparoscopy: it is said to accelerate the learning curve, especially for beginners, by faster comprehension of anatomical features, and thus surgical errors should be avoided.[7]

Thus, in simulator training, participants without surgical experience performed much better and faster when the 3D monitor was used. Again, the reasons given were improved depth perception and the ability to work more accurately.[7,8]

Disadvantages of 3D such as fatigue, dizziness, or headaches were also described, especially when the positioning of the 3D monitor was not optimal. However, these had become increasingly less important with newer technology. The acquisition of a 3D laparoscopy system is still associated with higher costs.[3,5]

1.1. Objectives

Clinical studies investigating the potential benefits of 3D laparoscopy have been almost exclusively concerned with intraoperative complications.

Thus, a recent EAES (European Association of Endoscopic Surgery) consensus conference on the use of 3D systems in laparoscopy concluded, with a high degree of strength of recommendation, that further clinical studies are needed to determine potential benefits in terms of avoiding postoperative complications.[6]

For this reason, the primary objective of the following study is to compare postoperative complication rates when using the 2D and 3D techniques for various laparoscopic procedures in clinical practice. The second aim of this study is to investigate the duration of surgery when using both techniques.

2. Methods

The study report was prepared according to the STROBE guidelines (Strengthening the Reporting of Observational Studies in Epidemiology).[9]

2.1. Setting

The Asklepios Clinic Langen (Germany) is a tertiary referral center in acute and standard care with 521 beds. The hospital is an academic teaching hospital of the Goethe- University Frankfurt/Main, Germany.

The Department of General, Visceral and Thoracic Surgery has a capacity of 60 beds distributed over two peripheral wards. A central interdisciplinary intensive care unit with 10 beds and 4 surgical intermediate care beds is available 24 h a day. The Department of General, Visceral and Thoracic Surgery focus on oncological, colorectal, minimally invasive and hernia surgery.

The department has a high experience concerning minimally invasive surgery and is certified since 2011 as “Center of Competence for minimally invasive surgery” from the CAMIC, the workgroup for minimally invasive surgery of the DGAV (German society for general and visceral surgery).

The department is integrated as a regional center into the surgical study network CHIR-Net of the German Society for Surgery (www.chir-net.de).

2.2. Study design

A study protocol was developed a priori and the study was registered in the German register of clinical trials (DRKS) under No. DRKS 00022469 (https://tinyurl.com/3jra3w4c) The study was approved 5.1.2021 by the ethics committee of the Hessen State Medical Association (Nr. 2020-2196-evBO).

We performed a retrospective observational study and included consecutive patients from 2017 to 2018 who underwent laparoscopic procedures with a 3D visualization.

For the control group, we included consecutive patients between 2011 and 2015 who underwent laparoscopic surgery with 2D HD visualization.

Exclusion criteria from the study were intraoperative conversion to laparotomy, postoperative transfer to another hospital, transfer to another department because of the intraoperative findings (e.g. gynecological department), intraoperative technical problems with the used visualization and a minor quantity of a performed surgical procedure in the 3D group with no corresponding procedure in the 2D visualization group.

In addition to basic data (age, gender) the type of surgical procedure, date, and duration of surgery, surgeon's qualification (resident/senior surgeon), ASA score (American Society of Anesthesiology risk score), elective/emergency surgery was collected. The postoperative complications were assessed, and the Comprehensive Complication Index[10] was calculated for each patient.

2.3. Surgical procedures

For a better comparison of the surgical procedures the type of operation was categorized into 3 groups considering the difficulty level of the procedure[11]:

2.3.1. Operation type 1

cholecystectomy, appendectomy, diagnostic laparoscopy, adhesiolysis, transabdominal preperitoneal hernia surgery one-sided (TAPP), resection/incision of simple liver cysts.

2.3.2. Operation type 2

adrenalectomy, fundoplication, incisional hernia repair with intraperitoneal onlay mesh (IPOM), transabdominal preperitoneal hernia surgery two-sided (TAPP).

2.3.3. Operation type 3

ileocaecal resection, partial gastric resection, gastric banding, colorectal surgery (e.g. hemicolectomy, sigmoid resection), rectal resection with total mesorectal excision (TME).

2.4. Primary endpoint

The main focus of the study is the assessment of the postoperative in-hospital complications in general surgery patients with the Comprehensive Complication Index (CCI-Score).[10] The CCI Score is a derivative of the Clavien Dindo Classification, which considers every occurrence of a postoperative complication and not only the gravest complication, so the overall morbidity of a patient is reflected on a scale from 0 (no complication) to 100 (death of the patient) (see Table 1)[12,13].

Every complication of the Clavien Dindo Classification is weighted (wC) and summarized, so the CCI can be calculated from all the occurred complications with this formula:

$$CCI = \frac{\sqrt{wC1 + wC2 + wC3 + \ldots + wCx)}}{2}$$

The CCI score was calculated with an online calculator from AssessSurgery (https://www.assessurgery.com/about_cci-calculator/).

2.5. Imaging

2D laparoscopy was performed with 10 mm 30° ENDOEYE HD I and ENDOEYE HD II cameras, 3D laparoscopy with a 10 mm 3D ENDOEYE 30°, both camera systems from Olympus Germany GmbH, Hamburg, Germany.

2.6. Statistical analysis

The primary hypothesis of this study is that 3D results in a significant reduction of postoperative in-hospital complications.

The minimum sample size was calculated with 210 patients (105 in each group) to achieve a power of 0.95 and a medium effect size d = 0.5 (G*Power 3.1, Heine University Düsseldorf, Germany). The effect size of d = 0.5 is motivated by an assumed standard deviation of 10 units of the primary endpoint and the aim to detect a clinically relevant difference of 5 units with high statistical power.

Statistical analysis was made with descriptive data analysis. For comparison of the two groups, an exact propensity score-matching with the following parameters was performed: age, sex, ASA, operation type,[1–3] type of surgery (emergency/elective) and surgeon's experience (resident/senior surgeon).

Resident surgeons were defined as surgeons in the year 1–5 of their surgical education, senior surgeons were defined as consultants with at least 5 years of practice and certified from the medical association board.

For the parameters age, CCI and operation time the Wilcoxon-Mann-Whitney-U test was used, for the parameters sex, operation type, surgeon's experience the Chi-squared test and for ASA, type of surgery the Chi-square-contingency-table-test. P-value < 0.05 were considered as statistically significant.

3. Results

Overall, 1119 Patients were screened for inclusion in this study, 287 in the 3D group and 832 patients in the 2D group. Patient allocation is shown in Fig. 1.

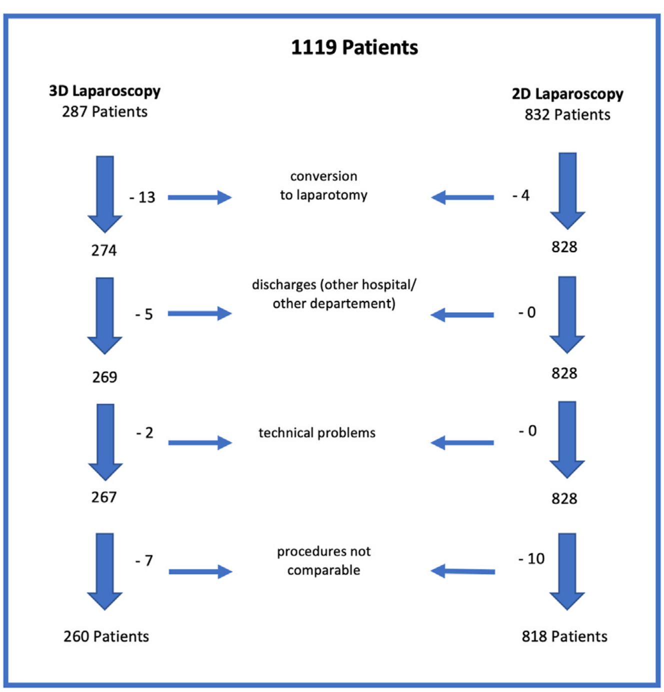

Fig. 1. Patient allocation (STROBE diagram).

Table 1
Weighted Clavien Dindo Classification grade – CCI Single value.

Clavien Dindo Classification	wC	CCI Single Value
Grade I	300	8.7
Grade II	1750	20.9
Grade IIIa	2750	26.2
Grade IIIb	4550	33.7
Grade IVa	7200	42.4
Grade IVb	8550	46.2

Clavien Dindo Grade V (death) always results in CCI 100.

After excluding 27 patients from the 3D and 14 patients from the 2D group because of the criteria shown in Fig. 1**,** finally, 1078 patients were included in this study. 260 patients in the 3D laparoscopy group and 818 patients in the 2D laparoscopy group for propensity score matching, as shown in Table 2.

Because there were significant differences in the groups affecting the target value CCI, we performed an exact propensity score-matching of gender, age, ASA classification, type of surgery, surgeon type, operation type, and surgeon's experience.

All parameters between the groups were balanced and the difference was not significant, there were 213 patients in both groups as shown in Table 3.

The CCI value overall in the 3D group was 5.70 (± 13.63; 95% CI [3.86; 7.55]), in the 2D group was 3.37 (± 9.89; 95% CI [2.03; 4.71]) and reaches no significance. Mean Operation time in both groups was for the 3D group 103.98 min (± 93.26 min; 95% CI [91.38; 116.57]) vs. 88.60 min (± 69.32 min; 95% CI [79.23; 97.86]) in the 2D group and showed no significance either.

Resident surgeons need significant more time for the operations when using a 3D visualization than using a 2D system (3D: 73.46 ± 22.80 min; 95% CI [65.86; 81.06] vs. 2D: 61.77 ± 20.31 min; 95% CI [55.60; 67.95]; $p = 0.0243$), but the complication rate is significant lower using 3D visualization (CCI 3D: 0.24 ± 1.43; 95% CI [−0.24; 0.71] vs. 2D: 1.66 ± 4.23; 95% CI [0.38; 2.95]; $p = 0.0487$).

Operation time for senior surgeons was not different for the two groups (3D: 110.39 ± 100.95 min; 95% CI [95.37; 125.41] vs. 2D: 95.58 ± 75.63 min; 95% CI [84.09; 107.07]; $p = 0.6239$).

Concerning complications, the CCI value was significant lower for the group of senior surgeons when using 2D visualization (3D: 6.85 ± 14.73; 95% CI [4.66; 9.05] vs. 2D: 3.82 ± 10.86; 95% CI [2.17; 5.46]; $p = 0.0192$) (see Table 4).

4. Discussion

4.1. Key results

Concerning overall CCI (3D: 5.70 ± 13.63 vs. 2D: 3.37 ± 9.89; $p = 0.076$) and operation time (3D: 103.98 ± 93.26 min. vs. 2D: 88.60 ± 9.89 min; $p = 0.2569$), there was no significant difference between the groups. Thus, the primary hypothesis of our study that 3D visualization reduces significantly postoperative in-hospital complications, could not be confirmed.

4.2. Interpretation

To clarify the different reports on 3D, the European Association for Endoscopic Surgery (EAES) organized a consensus conference elucidating the benefits of 3D imaging systems in laparoscopic surgery in 2018.[6] The authors concluded that the evidence for the ability to reduce operation time by 3D can only be stated with a low grade of recommendation, whereas a potential benefit for 3D on complication rate was seen with a high recommendation grade.

Clinical trials concerning 3D visualization techniques vary broadly in their results. In contrast to most of these trials, our study is one of the few with a focus on postoperative complications as the primary outcome parameter comparing 3D versus 2D in propensity-score matched groups.

Our results are supported by several authors.

Thus, Yoon et al,[14] comparing the outcome of *colonic resection* with D3 lymphadenectomy between 2D and 3D by a single surgeon inexperienced in 3D visualization, find **no differences in postoperative complications > grade III** according to the Clavien Dindo classification, but more lymph nodes could be harvested in the 3D group.

In *colorectal surgery*, **postoperative complications were not different for 3D and 2D laparoscopy.**[2] 3D laparoscopy unveils advantages in accuracy and reduction of the operation time, shown by Pantalos et al in a systematic review and meta-analysis concerning laparoscopic colonic cancer surgery. Furthermore, there was a minor reduction of operation time and a higher lymph node retrieval.

In *laparoscopic rectal cancer surgery* as shown by Li et al,[16] **3D laparoscopy appears to have no advantage in perioperative complication rate as one of the primary outcome parameters.** Again, these findings are similar to our results. 3D showed advantages over 2D in this study, resulting in less positive circumferential resection margin (CRM) and significantly less operation time.

In a randomized trial of *laparoscopic cholecystectomy*, Schwab et al describe also **no reduction of operation time nor the number of intraoperative consequential errors using 3D laparoscopy**, but in the important substep of the procedure, the dissection of Chalot's triangle was significantly faster with 3D.[15] In the 3D group, there were also fewer iatrogenic gallbladder perforations as proof for better accuracy.

On the contrary, the following authors do not corroborate our findings.

In a systematic review from Komaei et al 2017 for 3D in *laparoscopic cholecystectomy,* the authors find, opposite to our results, a significantly shorter operation time, but only in 60% of the included studies. At the same time, the subjective impression of better depth perception and image quality as primary outcome was fulfilled in 100% of the studies. Intraoperative detected errors occurred in 4 studies more often in 2D, intra and postoperative complications were not reported.[17]

Our results are contrary to the findings of Soerensen et al in a systematic review describing improved speed and fewer errors in the 3D group.[4] However, in this review, most of the included studies were in a simulating setting with intraprocedural errors assessed, only three studies were studies in a clinical setting with no focus on intraoperative or postoperative complications.

Also contrary to our findings, Cheng et al included in a

Table 2
clinical data of the patients before Propensity score matching.

	2D (n = 818)	3D (n = 260)	p
Age [years]; mean (standard deviation)	54.40 (15.75)	53.99 (17.58)	0.9244
Sex; n (%) male	387 (47.3%)	114 (43.8%)	0.3659
female	431 (52.7%)	146 (52.6%)	
ASA; n (%)			0.0297
1	151 (18.5%)	56 (21.5%)	
2	593 (72.5%)	168 (64.6%)	
3	71 (8.7%)	36 (13.8%)	
4	3 (0.4%)	0 (0.0%)	
Operation type; n (%)			<0.0001
1	553 (67.6%)	178 (68.5%)	
2	184 (22.5%)	16 (6.2%)	
3	81 (9.9%)	66 (25.4%)	
Type of surgery; n (%) elective	778 (95.1%)	185 (71.2%)	<0.0001
emergency	40 (4.9%)	75 (28.8%)	
Surgeon's experience; n (%)			0.5777
Senior surgeon	663 (81.1%)	206 (79.2%)	
Resident surgeon	155 (18.9%)	54 (20.8%)	

p-value.
Age: Wilcoxon-Mann-Whitney-U-test.
Sex, operation type, surgeon's experience: Chi-square-test.
ASA, type of surgery: Chi-square-contingency-table-test.

Table 3
clinical data of the patients after Propensity score matching.

	2D (n = 213)	3D (n = 213)	p
Age [years]; mean (standard deviation)	53.12 (17.78)	53.52 (17.45)	0.8690
Sex; n (%) male	94 (44.1%)	88 (41.3%)	0.6243
female	119 (55.9%)	125 (58.7%)	
ASA; n (%)			1
1	43 (20.2%)	43 (20.2%)	
2	148 (69.5%)	148 (69.5%)	
3	22 (10.3%)	22 (10.3%)	
4	0 (0.0%)	0 (0.0%)	
Operation type; n (%)			1
1	147 (69.0%)	147 (69.0%)	
2	16 (7.5%)	16 (7.5%)	
3	50 (23.5%)	50 (23.5%)	
Type of surgery; n (%) elective	174 (81.7%)	174 (81.7%)	1
emergency	39 (18.3%)	39 (18.3%)	
Surgeon's experience; n (%)			1
Senior surgeon	169 (79.3%)	176 (82.6%)	
Resident surgeon	44 (20.7%)	37 (17.4%)	

p-value.
Age: Wilcoxon-Mann-Whitney-U-test.
Sex, operation type, surgeon's experience: Chi-square-test.
ASA, type of surgery: Chi-square-contingency-table-test.

Table 4
CCI values and operation time overall and for the subgroups of senior and resident surgeons.

	2D	3D	p
CCI; n = 213 mean (standard deviation) [95% CI]	3.37 (± 9.89)	5.70 (± 13.63)	0.076
	95% CI [2.03; 4.71]	95% CI [3.86; 7.55]	
operation-time [min.]; n = 213	88.60 (± 69.32)	103.98 (± 93.26)	0.2569
mean (standard deviation) [95% CI]	95% CI [79.23; 97.86]	95% CI [91.38; 116.57]	
CCI	3.82 (± 10.86)/n = 169	6.85 (± 14.73)/n = 176	0.0192
mean (standard deviation)	95% CI [2.17; 5.46]	95% CI [4.66; 9.05]	0.0487
Senior surgeon;/n [95% CI]	1.66 (± 4.23)/n = 44	0.24 (± 1.43)/n = 37	
Resident surgeon;/n [95% CI]	95% CI [0.38; 2.95]	95% CI [-0.24; 0.71]	
operation-time [min.]	95.58 (± 75.63)/n = 169	110.39 (± 100.95)/n = 176	0.6239
mean (standard deviation)	95% CI [84.09; 107.07]	95% CI [95.37; 125.41]	0.0243
Senior surgeon;/n [95% CI]	61.77 (± 20.31)/n = 44	73.46 (± 22.80)/n = 37	
Resident surgeon;/n [95% CI]	95% CI [55.60; 67.95]	95% CI [65.86; 81.06]	

\p-value.
Age: Wilcoxon-Mann-Whitney-U-test.
Sex, operation type, surgeon's experience: Chi-square-test.
ASA, type of surgery: Chi-square-contingency-table-test.

systematic review and meta-analysis 21 studies and found that 3D laparoscopy is the preferred surgical option due to better surgical efficacy, finding significant advantages for 3D in operation time, blood loss, hospital stay, and perioperative complications.

Interestingly, **the analysis of our subgroup-data** demonstrate that residents seem to benefit from 3D due to a potentially higher accuracy leading to a lower postoperative complication score index. The effect size d_{Cohen}[18] for this finding is −0.44 (95% CI -0.64;-0.25) thus reflecting a promising moderate clinical impact. At the same time a sensitivity analysis gives an e-value of 2.38[19,20] indicating uncontrolled confounding.

The subgroup senior surgeons had significantly more postoperative complications using the 3D system. At the same time, the operation time was not different. The effect size d_{Cohen} for this finding is 0.23 (95% CI 0.04; 0.42), pointing to a minor clinical impact. The senisitvity analysis results in an e-value of 1.78 signalling confounding.

Taken together with the results of the post-hoc 50% study power for the residents/senior surgeons findings we interpret the subgroup findings with caution. Further clinical trials should resolve this issue.

5. Limitations and strengths

As we pointed already out in a previous paper of our research group,[21] using a propensity score-matched analysis of observational data, some limitations of our findings must be discussed:

In the retrospective 2D group there could be an influence on the study results due to unknown variables or unexpected fluctuation of the disease course. Also, there is a possibility of a selection-, treatment- or information bias that influenced the study results reliability. On the other side, treatment algorithms regarding laparoscopic operations were defined via standard operation procedures and did not change over the whole study period, as was the staff of senior surgeons, thus guaranteeing comparable time periods.

The complications in the 3D group were assessed prospectively, in the 2D group the data were taken from the electronically deposited discharge letters and the archived patient charts. So, the data quality and availability could be a concern on the one side, but on the other side, we can demonstrate that the documentation rate in our clinic is of a very high standard.

To check the quality of medical and nursing record documentation regular audits were established, so the validity of the relevant data by comprehensive, standardized documentation is proved by extern auditors, so we think that this data was robust and valid to minimize error sources and extraneous influence. Supplementary Table 1 and Supplementary Chart show an overview of these measures.

In our study, we include the in-hospital complications of our patients during their hospital stay without a structured follow-up. Thus, out-of-hospital complications could have been missed.

We have an excellent out-of-hospital network with registered doctors within their practice. These colleagues manage the postoperative care outside our hospital. Thus, we are well informed about any relevant complications that occur beyond the hospital stay in our clinic. This exchange of information also takes place at regular meetings participated by our surgeons and private practitioners.

In our experience complication rates after discharge does not increase significantly. Even we do not have any concrete numbers on how the complication rate would increase after inpatient discharge, Thompson 2003 et al[22] found that 76% of postoperative complications occur between day 1 and 7, 24% of postoperative complications between day 8–30. Therefore, even information from outside the hospital is incomplete, the majority of complications are recorded in our study.

We did not use a randomized controlled trial as a study protocol, even this is the gold standard. But the propensity score-matching was used to make the two groups as comparable as possible. The matching of the parameters balanced the data for analysis and interpretation, so we think that we generated robust data with reliable results.

And even though the groups cannot be as comparable as in a randomized study, the number of studies using propensity score-matching is increasing and seems to be a reliable alternative to randomization.[23,24]

Another criticism could be the heterogeneity of the included surgical procedures, i.e. no single operation like hemicolectomies was compared, possibly masking an effect of the 3D system. On the other side, our study approach reflects a real-world setting, i.e. a profound impact of the 3D vision should also be demonstrated in our study design. Moreover, as was demonstrated, observational studies like our propensity score-matched one, could have the potential for real-world evidence to complement clinical trials, both by examining the concordance between randomized experiments and observational studies and by comparing the generalizability of the trial population with the real-world population of interest.[25,26]

In our study we did not include the personal surgeons benefit like better view or ergonomic aspects using 3D visualization. Our Study group has examined these aspects as primary endpoint in previous papers[5,8,27] and we think that these points have already been proven in literature.[28–32] To the best of our knowledge it is the first time that the complication rate using a 3D Visualization System is the primary endpoint of a study.

6. Conclusion

In our data 3D visualization demonstrate no influence on postoperative complications nor on operation time in a propensity score-matched analysis compared with 2D, thus partly contradictory to the literature.

Primarily, we explain this finding as to the result of using a real-world scenario of unselected general surgery patients.

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Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors.

Authors contribution

A. Buia wrote the manuscript, did the literature research, data interpretation, and revised the manuscript. S. Oguz did the data acquisition and interpretation, literature research, wrote and revised the manuscript. A. Lehn and E. Herrmann did the statistical analyses, data interpretation, wrote the statistical part, and revised the manuscript. E. Hanisch did the literature research, and wrote and revised the manuscript.

Declaration of competing interest

Alexander Buia, Sibel Oguz, Anette Lehn, Eva Herrmann and Ernst Hanisch declare that they have no conflicts of interest.

Acknowledgment

not applicable.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.asjsur.2022.06.002.

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