Retrospective Cohort Study

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3D versus 2D laparoscopy for adrenal surgery: an international multicentric retrospective cohort study

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Background: Laparoscopy is currently considered the standard of treatment for adrenal lesions but remains a challenging procedure. This retrospective cohort study aims to compare the use of 3D technology with traditional 2D laparoscopy for adrenalectomy through a large, multicentric, international patients' enrollment.
Materials and Methods: Data of this retrospective cohort study were collected from six high-volume European centers between January 2003 and December 2023. Eligible participants were adults between 18 and 85 years, candidates for laparoscopic adrenal surgery, stratified into two groups: those who underwent three-dimensional laparoscopic adrenalectomy (3D group) versus traditional two-dimensional vision system laparoscopic adrenal surgery (2D group). The incidence of overall complications was estimated and compared between two groups (main endpoint), in addition to comfort vision, surgical depth perception, and surgical strain of the surgical team (secondary endpoint). Other pre-, intra-, and postoperative data were reported as well.
Results: We included 356 patients: 108 (30.34%) underwent traditional laparoscopic surgery, and 248 (69.66%) underwent 3D laparoscopic surgery. The operative time was significantly shorter ($P < 0.001$), with an average of 100 minutes for the 3D technique compared to 125.4 minutes for traditional laparoscopy. The conversion rate was 2% in the 3D group versus 7.4% in the 2D group ($P = 0.026$). Blood loss was higher in the group treated with traditional laparoscopy (100.7 cc vs. 71.7 cc, $P < 0.001$), as well as the use of postoperative drainage (68.5% vs. 33.5%, $P < 0.001$). The postoperative hospital stay was longer for patients treated with the traditional technique, with an average of 4 days (SD = 2.7), compared to an average of 2.8 days (SD = 1.7) for patients treated with the 3D technique ($P < 0.001$). Postoperative overall complications were lower in the 3D group, with a 14.1% cumulative incidence of patients experiencing complications, compared to 16% in the traditional laparoscopy group, but not significantly ($P = 0.615$). Grade 3b complications, to the Clavien-Dindo classification, were negligible in both the 3D laparoscopic group (0.4%) and the traditional laparoscopic group (0.9%), without any statistically significant difference between the two groups. Based on the subjective assessment of the two techniques, we observed significantly better scores in the 3D procedure versus traditional laparoscopic surgery ($P < 0.001$).
Conclusion: The obtained results reinforced the safety and efficacy of the 3D approach. Furthermore, surgeons' positive opinion of 3D laparoscopy is evidence of increased operator comfort and justifies its use in training and clinical practice.

Keywords: 3D laparoscopy – surgical vision system, adrenalectomy, adrenal surgery, international multicentric retrospective cohort study

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Introduction

Laparoscopic adrenalectomy is currently considered the gold standard for the treatment of adrenal lesions. First introduced by Gagner in 1992[1], it has since been validated by numerous clinical studies, which have highlighted its efficacy and safety, evidenced by fewer intraoperative complications, shorter hospital stays, and improved postoperative outcomes[2,3]. Over time, the laparoscopic approach has evolved, with various techniques, such as anterior, lateral transperitoneal, and retroperitoneoscopic, being selected based on specific indications, advancements in technology, and growing surgical experience. Currently, the lateral transperitoneal approach is the most used, offering effective treatment for most adrenal lesions, including larger and/or malignant tumors. This is due to its ability to provide optimal exposure of the operative field and facilitate adequate mobilization of abdominal organs[4]. Technological advancements, such as high-energy devices, high-definition cameras, and efficient hemostats, have further enhanced the efficacy, safety, and precision of laparoscopic procedures. Nevertheless, laparoscopic adrenalectomy remains a challenging procedure due to the deep location of the adrenal glands, the confined operating space, and the lack of three-dimensionality inherent in traditional laparoscopic surgery. Surgeons must perform operations in a restricted three-dimensional area using only two-dimensional vision[5]. This limitation has driven the development of high-definition 3D laparoscopic systems, with the concept of 3D adrenalectomy emerging as a result. Several studies have explored the role of 3D laparoscopic vision in enhancing surgical maneuvers, showing improvements in performance, reduced operative time, and greater precision. Despite these promising findings from preclinical studies, the clinical application of 3D laparoscopy has primarily been assessed through retrospective reviews or prospective clinical studies with small samples[6]. This retrospective cohort study aims to evaluate the use of 3D technology in laparoscopic adrenalectomy through a large multicentric patient enrollment. The study has been reported in line with the STROCSS guidelines, and no artificial intelligence was used for research and manuscript development[7,8].

HIGHLIGHTS

- Identify the role and relevance of the 3D laparoscopic vision system versus traditional 2D laparoscopy in a multicentric study.
- 3D laparoscopy was associated with fewer intraoperative complications and improved postoperative outcomes compared to 2D laparoscopy.
- Assessed comfort vision, surgical depth perception, and surgical strain of the surgical team between 3D laparoscopic vision and traditional 2D laparoscopy. We observed significantly better scores in the 3D procedure to traditional laparoscopic surgery. There were no significant differences in surgical strain between the two groups.
- -The 3D group exhibited a significant reduction in the operative time, blood loss, and conversion rate.

Methods

We conducted a multicentric international retrospective cohort study using the databases of six high-volume centers of general and endocrine surgery and urology, located in Italy, Spain, and Romania, forming the *"3D is better"* Study Collaborative Group. Patients were stratified into two groups: those who underwent three-dimensional laparoscopic adrenalectomy (3D group) versus traditional two-dimensional vision system laparoscopic adrenal surgery (2D group). The incidence of overall complications (primary study endpoint), the main exposure (3D vs. 2D), the clinical characteristics of the subjects, and pre-, intra-, and postoperative data of the operating sessions, in addition to comfort vision, surgical depth perception, and surgical strain of the surgical team (secondary endpoint), were retrospectively investigated over the period between January 2003 (index date) and December 2023 (study end date). The study was registered on ClinicalTrial.gov, and the institutional ethics committee approved the study.

Patient's selection

In this retrospective analysis, we reviewed the medical and surgical records of adult patients, aged between 18 and 85 years, with functioning and non-functioning benign adrenal lesions and adrenal malignancies, who were candidates for laparoscopic adrenal surgery. We also included patients with previous abdominal surgery. Exclusion criteria were open adrenal surgery, robotic approach, bilateral adrenalectomies, preoperative signs of local periadrenal invasiveness, different intraoperative diagnosis, and the need for multi-visceral resection related to adrenal disease. After signing a specific written informed consent, all eligible patients underwent a radiological study with a preoperative abdominal computer tomography (CT) scan to identify the characteristic, side, and size of the adrenal lesion. Only selected cases with unclear features on the CT were subjected to abdominal magnetic resonance imaging[9]. At the same time, laboratory endocrine test was performed to investigate functioning adrenal lesions. Of note, urine free cortisol test, serum cortisol, and adrenocorticotropic hormone (ACTH) levels at 8 a.m. and 6 p.m., aldosterone serum concentration and plasma renin activity in the upright position, as well as fractionated urinary metanephrines and catecholamines, were used[10]. Patient data from the databases of the participating centers were consecutively included in the study at a 2:1 ratio to obtain more extensive information on the 3D technique. The sample size was calculated based on our previous studies and a literature review on the cumulative incidence of overall complications to guarantee 80% power and 0.05 Type I error[11,12]. Based on these results, the power analysis revealed that a minimum of 106 cases of 2D laparoscopic adrenalectomies and 212 cases of 3D laparoscopic adrenalectomies would be needed to detect significant differences in the proportion of overall complications.

Surgical procedure

Laparoscopic adrenalectomy was performed using a transperitoneal and retroperitoneal approach based on the characteristic of lesion, preoperative indications, and preference of single surgeon. In transperitoneal approach, the patients were positioned in lateral decubitus opposite the lesion. The operating table is often flexed to optimize access to the retroperitoneal space, and the arm on the operative side is positioned superomedially at a 90-degree angle to facilitate improved exposure.

The pneumoperitoneum was induced with Veress needle. We used four trocars for the right side and three or four trocars for the left side, situated along the subcostal region to obtain better triangulation (Fig. 1a-b). This is a multicentric study, and the different surgical teams of the European countries used different vision systems, in particular Storz for 2D laparoscopy and Storz and Olympus for 3D laparoscopy. The dissection was conducted with Harmonic ACE (Ethicon Endo Surgery INC, Johnson and Johnson, NJ, USA®), Thunderbeat (Olympus®), or Ligasure (Medtronic®). In the right adrenalectomy, the dissection began

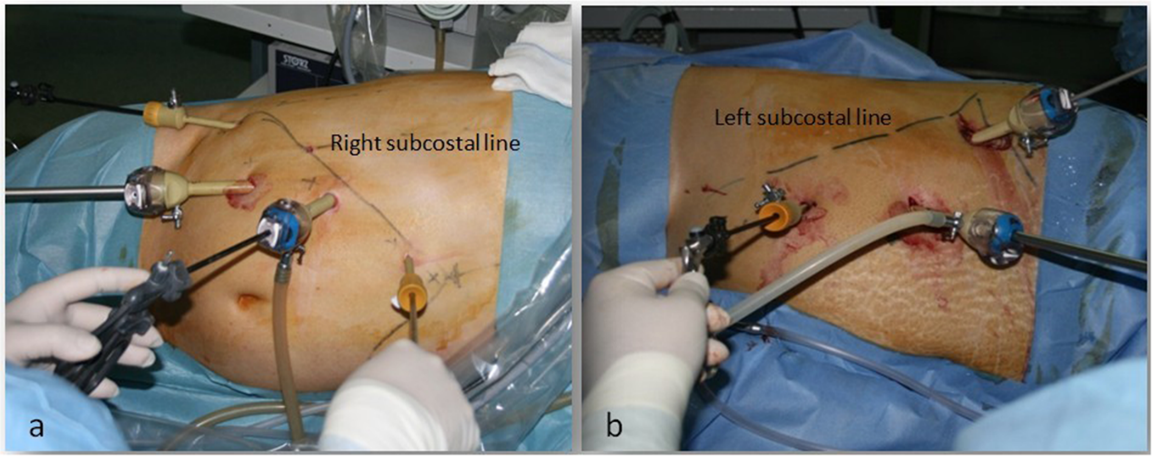

Figure 1. Placement of trocars in transperitoneal laparoscopic adrenalectomy: (A) four trocars for the right side along the subcostal line; and (B) three trocars for the left side.

with division of the hepatic ligament and peritoneum along the right side of the inferior vena cava (IVC) to access the space in the hepato-caval angle and identify the middle adrenal vein, which was clipped and divided. The other landmarks in dissection were the upper pole of the kidney and the psoas muscle to entirely remove the content of the adrenal loggia. On the left side, we started dissection with Jinney's maneuver and medialization of the splenopancreatic block to access the adrenal loggia and identify the left renal vein and adrenal vein, which was clipped and divided. Adrenalectomy was completed as previously described for the right adrenal gland on the posterior muscular plane from the upper pole of the kidney to the diaphragm with the aim of emptying the adrenal loggia[13]. In certain cases, the retroperitoneal approach is preferred over the transperitoneal approach because it provides direct access to the adrenal glands while minimizing risks to intra-abdominal organs[14]. This technique can be performed with the patient in either the lateral decubitus or prone position. The primary port is typically placed 2 cm anterior and inferior to the tip of the 12th costal margin, through a 2-cm muscle-splitting incision. After entering the retroperitoneal space, an inflatable balloon trocar is employed to expand this space. Subsequently, a 12 mm trocar is introduced in lieu of the balloon trocar to accommodate the camera or laparoscope, thereby providing visualization of the surgical field. A second trocar is positioned at the intersection of the posterior axillary line and the line of the first trocar. Under direct vision, the retroperitoneal space is inspected, then the third and fourth trocars are introduced along the same line as the previously placed trocars (Fig. 2). A balloon or sharp dissection technique is used to create a small pocket within the retroperitoneal space. This step involves careful separation of the posterior peritoneum from the muscular and fascial layers[15]. The dissection is executed in a controlled manner to prevent injury to adjacent structures. On the right side, Gerota's fascia is opened at the upper pole, and dissection proceeds toward the IVC to visualize the adrenal gland and the associated vascular structures. On the left side, the fascia is dissected until the renal vein is reached, and the superiorly located adrenal vein and other vascular structures are identified[16]. Once the blood supply is controlled, the adrenal gland is gently removed. In both surgical techniques (transperitoneal and retroperitoneoscopic), following gland removal, the operative field is meticulously inspected for any bleeding. Hemostasis is achieved through electrocoagulation or the application of hemostatic. The decision to use

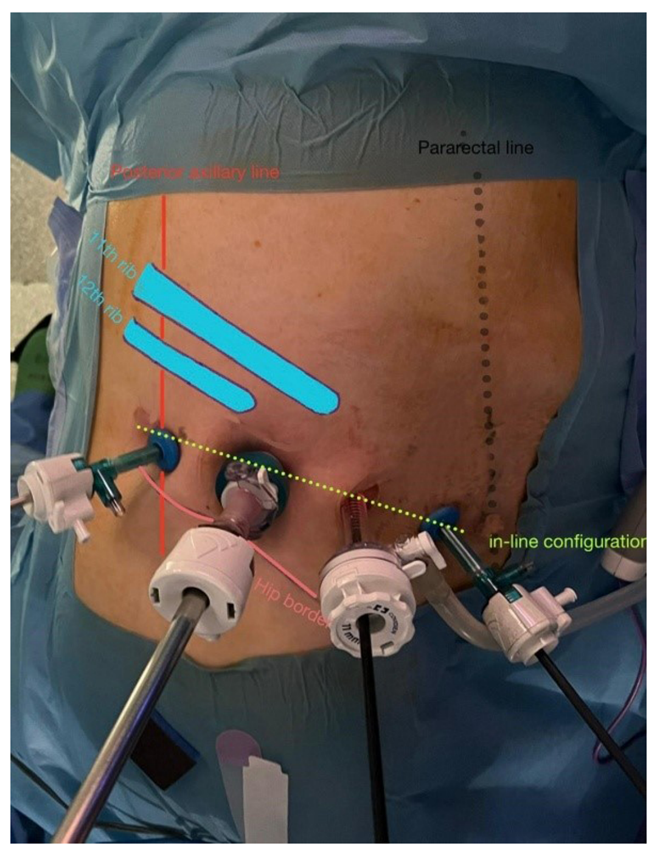

Figure 2. Position of trocars in retroperitoneal adrenalectomy with in-line configuration.

drainage in the adrenal loggia depends on intraoperative findings and the surgeon's experience and was registered in the retrospective cohort database for analysis of results.

Preoperative data

Country of procedure, age, gender, body mass index (BMI), and description of comorbidities (arterial hypertension, diabetes mellitus, dyslipidemia, cardiovascular diseases, chronic pulmonary disease, and cancer) were collected to assess the American Society of Anesthesiologists (ASA) score. Data regarding the surgical procedure including previous surgery, side of the lesion, pathology (functioning adenoma, benign non-functioning mass, and malignant), and major diameter of the lesion on CT scan imaging. In case of functioning adenomas, details about hormonal secretion were registered.

Intraoperative data

Operative time (min), experience of the surgeon (young or senior if >30 laparoscopic adrenalectomies), surgical approach (lateral transperitoneal or retroperitoneoscopic), surgical technique (radical or sparing surgery), vision system (2D laparoscopy or 3D laparoscopic vision system), estimated blood loss, and drainage. In intraoperative complications, we registered damage cause (trocar placement, surgical maneuver, instrument malfunction, and other); type of vascular injuries (major: renal artery, renal vein, aorta, vena cava, and sovrahepatic veins; and minor: adrenal vessels, accessory renal vessels, and others); lesion of hollow viscus (small bowel, colon, stomach, and urether); and parenchymatous viscus (kidney, adrenal gland, spleen, and diaphragm) with the details of treatment and/or conversion to open surgery.

Postoperative data

Patients were closely monitored postoperatively for potential complications such as bleeding, infection, or adrenal insufficiency. Particular attention was paid to blood pressure, serum electrolyte levels, and glucose levels in the early postoperative period. Patients who required corticosteroid replacement were observed 72–96 hours before discharge. We recorded the following postoperative data: length of hospitalization (days), unplanned intensive care unit (ICU) admission, postoperative blood transfusion, short-term postoperative complications (before discharge), and 30-days postoperative complications (overall complications). All postoperative complications were classified according to the Clavien-Dindo classification, with grades 1, 2, and 3a considered minor complications because they did not require revision under general anesthesia, while grade 3b required surgery under general anesthesia, grade 4 complications were life-threatening or required admission to intensive care, and grade 5 was patient death[17].

Evaluation of surgical visual comfort

We evaluated the role of 3D laparoscopic surgical vision in adrenalectomy for the specific deep location of the adrenal loggia with a limited surgical area. Adrenal surgery does not require intracorporeal sutures and knots but relatively simple dissection maneuvers. For this reason, the greatest advantage potentially lies precisely in 3D vision. At the end of surgery, the surgical team responded to questions regarding comfort vision, surgical depth perception, and surgical strain. The variables analyzed for surgical outcome were precision in surgical dissection, definition of planes, and depth perception (score 1–5; 5 = excellent). The variables for surgical strain included the presence or absence of wrist and hand strain, back strain, neck strain, eye strain, dizziness, and headache[18]. Answers were coded and included in the retrospective cohort database.

Statistical methods

We performed a descriptive analysis of demographic, clinical, and preoperative characteristics, as well as intraoperative data, including complications, and postoperative outcomes to obtain an objective assessment of the 3D versus 2D techniques. To obtain a subjective evaluation of the two techniques, quality of vision, depth perception, and surgical strain of the surgical team were also analyzed. In our statistical analysis, we initially planned to perform propensity score balancing between the two groups; however, descriptive statistics showed that the groups were already sufficiently balanced, particularly with respect to the control variables (age, sex, and BMI). Since no substantial imbalance was observed, and given the limited number of available variables, we decided not to apply propensity score matching. Categorical variables were expressed as counts and percentages, and quantitative variables were expressed as mean and standard deviation. The χ^2 or the Fisher's exact test was used to compare 3D versus 2D groups for categorical variables. Student's t test or the Wilcoxon-Mann-Whitney test was used to compare the two groups for continuous variables. Statistically significant differences were assessed using two-sided P -values below 0.05. In the multivariable analysis, logistic regression was estimated to compare the surgical techniques (3D vs. 2D) with respect to the complete set of demographic and clinical characteristics at the baseline. In addition, logistic regression was estimated, as well, to compare 3D vs 2D with respect to intra- and post-operative outcomes, chosen among those ones that resulted statistically significant at the univariate analysis. The statistical analysis was performed using the R Statistical Software.

Results

This multicentric retrospective cohort study included 356 patients (+38 than the expected sample size), 64 from Italy (17.97%), 70 from Romania (19.66%), and 222 from Spain (62.35%). Of these, 108 (30.34%) underwent traditional laparoscopic surgery, while 248 (69.66%) underwent 3D laparoscopic surgery. Although all procedures were performed in high-volume centers, we also preliminarily assessed whether there were differences in terms of individual surgeon experience (senior >30 adrenalectomies; junior <30 adrenalectomies). The preliminary analysis showed no differences in terms of intraoperative events or postoperative complications, and therefore, the patient group was evaluated as a without considering the experience of the individual surgeon. The univariable analysis (Table 1) suggested that there was a statistically significant difference between two groups for the treated pathology (P < 0.001), with the most of 3D patients being affected by functioning adenoma (57.3%) and patients treated by traditional laparoscopy uniformly distributed across three pathologies [benign non-functioning masses (38%),

Table 1

Association between surgical procedure and clinical variables in 356 patients: univariate analysis

Variables\surgical procedure	Total (n = 356)	Traditional laparoscopy (n = 108)	3D (n = 248)	OR [95%CI]	P-value
Age	56.0 (13.6)	57.3 (14.4)	55.5 (13.2)	0.99 [0.97–1]	0.261
Sex					
F	187 (52.5%)	51(47.2%)	136 (54.8%)		
M	169(47.5%)	57(52.8%)	112 (45.2%)	0.74 [0.47–1.16]	0.205
BMI (kg/m^2)	28.2 (5.0)	28.1 (4.7)	28.2 (5.1)	1 [0.95–1.05]	0.87
ASA	2.6 (0.7)	2.5 (0.7)	2.6 (0.7)	1.22 [0.88–1.69]	0.21
Comorbidity					
No	32 (9%)	16 (14.8%)	16 (6.5%)		<0.001***
Single	59 (16.6%)	29 (26.9%)	30 (12.1%)	1 [0.42–2.40]	1
Multiple	265 (74.4%)	63 (58.3%)	202 (81.5%)	3.21 [1.50–6.86]	0.003
Previous surgery					
No	203 (57%)	68 (63%)	135 (54.4%)		
Yes	153 (43%)	40 (37%)	113 (45.6%)	1.42 [0.9–2.27]	0.162
Side					
Right	161 (45.2%)	48 (44.4%)	113 (45.6%)		
Left	195 (54.8%)	60 (55.6%)	135 (54.4%)	0.96 [0.6–1.51]	0.908
Pathology					
Benign non-functioning masses	102 (28.7%)	41 (38%)	61 (24.6%)		
Functioning adenomas	176 (49.4%)	34 (31.5%)	142 (57.3%)	2.79 [1.62–4.85]	<0.001***
Malignant	77 (21.6%)	32 (29.6%)	45 (18.1%)	0.95 [0.52–1.73]	0.88
Number of lesions	1.1 (0.3)	1.0 (0.3)	1.1 (0.3)	1.12 [0.54–3]	0.77
Greatest dimension (mm)	5.1 (2.8)	4.9 (2.8)	5.2 (2.8)	1.04 [0.95–1.14]	0.312
Operative time (min)	107.6 (71.4)	125.4 (63.4)	100.0 (73.4)	0.99 [0.992–0.998]	<0.001***
Surgical approach					
Retroperitoneal	3 (0.8%)	1 (0.9%)	2 (0.8%)		
Transperitoneal	353 (99.2%)	107 (99.1%)	246 (99.2%)	1.15 [0.02–22.3]	1
Technique					
Adrenal sparing surgey	4 (1.1%)	3 (2.8%)	1 (0.4%)		
Adrenalectomy	352 (98.9%)	105 (97.2%)	247 (99.6%)	7 [0.56–371]	0.085
Overall complications					
No	305 (86%)	91(84%)	214 (86%)		
Yes	51 (14%)	17 (16%)	34 (14,1%)	0.85 [0.45–1.63]	0.62
CDC[1] 1 – 3a		49 (13.8%)	16 (14.8%)	33 (13.3%)	
CDC[1] 3b		2 (0.6%)	1 (0.9%)	1 (0.4%)	
Conversion to open surgery					
No	343 (96.3%)	100 (92.6%)	243 (98%)		
Yes	13 (3.7%)	8 (7.4%)	5 (2%)	0.26 [0.08–0.82]	0.026*
Associate procedures					
No	315 (88.5%)	94 (87%)	221 (89.1%)		
Yes	41 (11.5%)	14 (13%)	27 (10.9%)	0.82 [0.41–1.68]	0.59
Estimated blood loss (ml)	78.5 (118.9)	100.7 (182.2)	71.7 (91.0)	0.99 [0.99–1]	<0.001***
Drainage					
No	199 (55.9%)	34 (31.5%)	165 (66.5%)		<0.001***
Yes	157 (44.1%)	74 (68.5%)	83 (33.5%)	0.23 [0.14–0.38]	0
Postoperative stay days	3.2 (2.1)	4.0 (2.7)	2.8 (1.7)	0.77 [0.68–0.86]	<0.001***
Admission to ICU	No	322 (90.4%)	102 (94.4%)	220 (88.7%)	
Yes	34 (9.6%)	6 (5.6%)	28 (11.3%)	2.12 [0.9–5.89]	0.116
Postoperative blood transfusion					
No	352 (98.9%)	106 (98.1%)	246 (99.2%)		
Yes	4 (1.1%)	2 (1.9%)	2 (0.8%)	0.43 [0.03–6.03]	0.58
Surgical stress					
No	337 (94.7%)	104 (96.3%)	233 (94%)		
Yes	19 (5.3%)	4 (3.7%)	15 (6%)	1.63 [0.57–5.98]	0.45

CDC: Clavien-Dindo classification

functioning adenomas (31.5%), and malignant (29.6%)]. The operation time was significantly shorter (P < 0.001) with an average of 100 minutes (SD = 73.4) for the 3D technique compared to 125.4 (SD = 63.4) minutes for traditional laparoscopy. Postoperative overall complications were lower in the 3D group, with 14.1% cumulative incidence of patients experiencing complications, compared to 16% of the traditional laparoscopy group, but not

Table 2

3D versus traditional laparoscopy by clinical characteristics at the baseline: multivariate analysis

Characteristic[a]	adjOR[a]	95% CI[a]	*P*-value
Age	0.99	0.97, 1.01	0.36
Sex: male	0.69	0.38, 1.25	0.218
ASA	1.34	0.80, 2.26	0.26
BMI	0.97	0.91, 1.03	0.377
Lesion's side: left	1.07	0.60, 1.89	0.819
Greatest lesion's size	1.16	1.04, 1.31	0.007***
Previous surgery: yes	1.39	0.77, 2.51	0.274
Comorbidity	0.45	0.07, 2.66	0.389
• Single			
• Multiple	0.63	0.11, 3.04	0.574
Pathology	2.28	1.09, 4.78	0.028***
• Functioning adenomas			
• Malignant	1.35	0.56, 3.30	0.509

[a]Reference categories: sex (ref = female), Lesion's side (ref = right), previous surgery (ref = no), comorbidity (ref = none), pathology (ref = benign not functioning masses); OR, odds ratio; CI, confidence interval.

significantly ($P = 0.615$). Grade 3b complications, according to Clavien-Dindo classification, were negligible both in 3D laparoscopic group (0.4%) and in traditional laparoscopic group (0.9%), without any statistically significant difference between the two groups. Alternatively, the difference in the conversion rate to open surgery appeared statistically significant, with 2% in the 3D group versus 7.4% in the traditional surgery group ($P = 0.026$). Blood loss was higher in the group treated with traditional laparoscopy (100.7 cc vs. 71.7 cc, $P < 0.001$), as well as the use of postoperative drainage (68.5% vs. 33.5%, $P < 0.001$). Consequently, the postoperative hospital stay was longer for patients treated with the traditional technique, with an average of 4 days (SD = 2.7), compared to an average of 2.8 days (SD = 1.7) for patients treated with the 3D technique (P <0.001). From the multivariable analysis (Table 2), patients with the greatest lesion's size [adj OR = 1.16; 95% CI = (1.04–1.31) P = 0.007) and functioning adenomas pathology were more frequently submitted to the 3D technique [Adj OR = 2.28; 95% CI = (1.09–4.78) P = 0.028). In Table 3, we reported multivariate analysis of intra- and postoperative outcomes. Based on the subjective assessment of two techniques, we observed significant better scores in 3D procedure versus traditional laparoscopic surgery (Fig. 3) with mean score

Table 3

3D versus traditional laparoscopy by intra- and postoperative outcomes: multivariate analysis

Characteristic[a]	adjOR[a]	95% CI[a]	*P*-value
Operative_time	1.01	1.00, 1.02	0.098
Estimated_blood_loss	1.00	1.00, 1.00	0.936
Drainage	0.10	0.05, 0.22	<0.001***
Postoperative_stay_days	1.06	0.80, 1.42	0.684
Overall_complications	0.63	0.23, 1.71	0.361

[a]Reference categories: Drainage (ref = no), Overall complications (ref = no); OR, odds ratio; CI, confidence interval.

4.9 (SD 0.1) in 3D laparoscopy and mean score of 4.2 (SD 1.2) in 2D laparoscopy ($P < 0.001$). In contrast, there were no significant differences in surgical strain between the two groups ($P = 0.45$).

Discussion

Rationale of 3D laparoscopy

The first studies on the use of 3D vision technology date back to the 1990s and tended to have discouraging results due to the poor image quality and the need for active polarization glasses, which presented multiple inconveniences in addition to discomfort[19,20]. Only later did the improvement in image quality led to the use of 3D vision as a stage in the learning curve on the simulators of young surgeons[21]. These results were later confirmed by clinical studies on the subject that demonstrated the effectiveness of 3D technology in improving the learning curve and reducing the surgical training time[22]. The high-quality 3D systems currently in use allow better image magnification and stereoscopic vision[23]. Therefore, over the years, there has been an ever-increasing widespread use of 3D vision, which, however, to date does not represent the standard system for laparoscopic surgery. This condition is due to several factors, including the still relatively higher costs of the technology and therefore to the diffusion not being as widespread as is the case with traditional laparoscopic surgery. Another determining factor in the spread of 3D technology is the habits of the individual surgeon, who often "justifies" as uncomfortable the use of passive polarization glasses required for 3D vision[24]. In addition, the use of 3D laparoscopy needs some specific technical adaptation like more stability in the camera and slow movement, reduction in ambient lightness of the operating room to enhance the contrast on the 3D monitor, and identification of the right stereopsis comfort zone between the surgical field and monitor position[25].

Multicentric retrospective study

In this study, we evaluated the effects of 3D laparoscopy in adrenal surgery performed in high volume referral centers that can make use of this technology. The deep position of the adrenal gland, the restricted surgical field, and the relationships with the neighboring relevant anatomical structures should potentially enhance the advantages of 3D vision in surgical dissection especially during the isolation of the adrenal vein and the pancreatic tail or in case of intraoperative complications favoring their resolution without conversion to open surgery[26]. We carried out a multicentric retrospective cohort study involving several European high-volume centers with the aim of assessing the real efficacy and safety of 3D technology compared to traditional vision on several variables, especially postoperative complications, and acceptability by surgeons. The results showed that the overall complications rate was lower, but not significantly, in patients treated with 3D laparoscopy than in the traditional laparoscopic group. We observed a slightly higher complication rate compared to studies in the literature[27], respectively 14.1% complications rate in the 3D group versus 16% in the traditional laparoscopic group ($P < 0.615$). This data should be analyzed more critically because in this study we registered the overall complications, without any distinction between

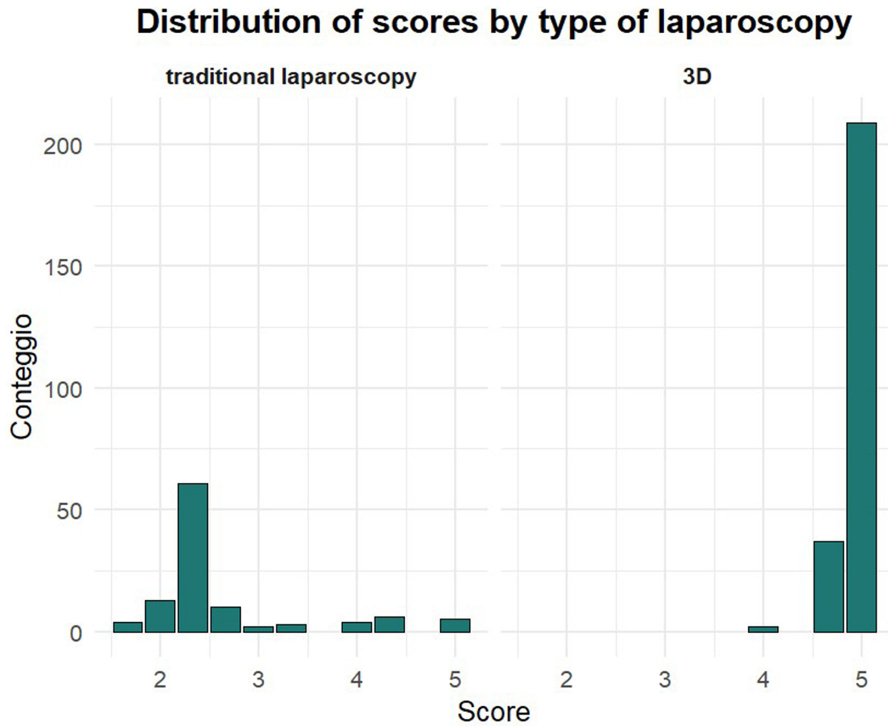

Figure 3. Distribution of scores by type of laparoscopy.

major and minor complications. Indeed, if we limit ourselves to the major complications according to Clavien-Dindo classification (3b and 4), which are those responsible for a dramatically worse outcome for the patient, the rate drops to 0.4% with no significant differences between the two groups. The clinical experience also justified that the higher number of minor complications in the 2D group can be attributed to the longer operative time and higher blood loss, which consequently affect the mean hospital stay. The reduction in the mean operative time associated with a lower, but not significant, rate of intra- and postoperative complications observed in the 3D group underlines the safety of the procedure and affects the final functional outcome of the patient, with earlier recovery and less postoperative hospitalization. It is precisely the prolonged operating time and consequent immobilization that are the factors behind the postoperative medical complications (atelectasis, pneumonia, pulmonary embolism, respiratory failure, prolonged ileus, fever, and request for analgesics) classified as types 1–2 according to Clavien-Dindo and that are greater in the 2D group[28]. At the same time, we can observe that the patients of 3D group had a higher rate of multiple comorbidities (81.5% in the 3D group vs. 58.3% in the 2D group) and presented larger adrenal lesions (5.2 cm in 3D group vs. 4.9 cm in 2D group). Despite the complexity of these cases, surgical procedures performed with 3D laparoscopy still resulted in reduced operative time and shorter postoperative stays, highlighting this technique's capacity to improve surgical outcomes under challenging conditions. This consideration reinforces the potential benefits and robustness of the 3D approach, even in a more complex patient population independently from the other outcomes.

In this study, we did not consider the level of communication between the medical and nursing staff in the operating room. It is conceivable that reducing mean operative times obtained with 3D technology is due not only to a strict surgical factor, related to improved depth perception, but also to greater interaction between the different components of the surgical team. At the same time, previous studies have suggested that the use of 3D laparoscopy improves organizational aspects such as staff training and an easier learning curve that has a positive impact on the diffusion of technology[29]. In this study, we observed that 96% of the procedures performed by young surgeons (49 cases, 13.7%) were performed using 3D technology, demonstrating the role of 3D vision in the learning curve of young surgeons and their greater familiarity with these systems. For these reasons, we believe that regardless of the absence of statistically significant differences in complications between 2D and 3D vision systems, 3D laparoscopy plays a fundamental role in the training of future generations of surgeons.

Surgical adaptation to 3D laparoscopy

Some authors have reported different negative effects related to adaptation to 3D vision and represented by fatigue, nausea, headache, disorientation, and physical discomfort[30]. In our study, at the end of the procedures, the surgical team responded to some questions to assess the advantages and possible problems of 3D vision compared to 2D vision. In particular, the surgeons expressed a qualitative judgment on the precision of the surgical dissection, plane definition, and depth perception, with significantly more favorable results in the 3D group. The presence of possible adverse effects was also assessed as a dichotomous variable (YES or NO), with overlapping frequencies in the two groups. In light of these results, surgical discomfort could be attributed to the duration and difficulty of the surgical procedure rather than to the vision system[26].

Strengths and limitations

At our knowledge, this is the first multicentric clinical retrospective cohort study that compared 3D laparoscopy with 2D conventional laparoscopic adrenalectomy, based on several variables including postoperative complications and acceptability by surgeons. Qualitative assessment by the surgical team suggested fair vision comfort and the absence of surgical strain related to 3D laparoscopic technology in adrenal surgery. However, the study has several limitations. First, the observational study design could have introduced some selection and assessment biases. Future efforts should address randomized clinical trials to draw definitive conclusions about the highest efficacy and safety of the novel 3D technique compared to traditional laparoscopy. On that occasion, we could also envisage the possibility of stratifying postoperative complications according to their severity. Second, the involvement of different European high-volume centers determined per se certain heterogeneity in the perioperative management of the patients and in the intraoperative surgical performances. Third, the study did not include a cost-effectiveness analysis, which could be important for evaluating the practical application of 3D laparoscopic vision system in other health care settings. On this specific point, a recent study endorsed by the Italian Society for Endoscopic Surgery reported a multi-dimensional evaluation and showed substantial economic neutrality and sustainability of 3D laparoscopic technology[29].

Conclusion

Our multicentric retrospective cohort study, which compared 3D and 2D laparoscopic techniques in adrenal surgery, demonstrated that the 3D group exhibited a significant reduction in operative time, blood loss, and conversion rate, which contributed to fewer postoperative complications and faster recovery, reinforcing the safety and efficacy of the 3D approach. Furthermore, surgeons' positive opinion of 3D laparoscopy is evidence of increased operator comfort, which justifies its use in training and clinical practice. While further studies are needed to establish the definitive cost-effectiveness and long-term benefits of 3D laparoscopy, our findings suggest that the technology holds considerable promise, particularly in high-risk, complex surgical cases. In light of these results, 3D vision may become a valuable tool in the optimization of surgical outcomes, enhancing both the safety of the procedure and the recovery process for patients.

Ethical approval

The study was registered on ClinicalTrial.gov, and the institutional ethic committee approved the study.

Consent

Written informed consent was obtained from the patients for publication and any accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal upon request.

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Author contributions

A.T. and G.D.B.: Study design, data collection, data analysis or interpretation, and writing the paper. D.M. and M.L.: Data analysis and interpretation and writing the paper. J.I.R-.H. and A.A.: Study design. L.C., M.R-.M., G.M., C.T., N.C., I.A., F.E., R.P., A.B., R.C., G.A., and G.R.: Data collection and data interpretation. 3D is better research collaborative study group: Data collection

Conflicts of interest disclosure

None.

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