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Robotic Versus Laparoscopic Adrenalectomy: The European Experience

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Abstract
Purpose of Review To summarize the current European-based literature and find answers regarding whether there is any specific condition in which robotic adrenalectomy is superior.
Recent Findings For the resection of the adrenal glands, laparoscopic adrenalectomy is the gold standard technique worldwide. With the widespread use of robotic technology in surgery, robotic adrenalectomy has become more popular. The safety and feasibility of robotic adrenalectomy has been shown in several studies. However, despite its technical advantages, robotic surgery has not yet shown a significant supremacy over laparoscopic surgery in terms of surgical outcomes.
Summary The robotic adrenalectomy is a safe and feasible technique, similar to conventional laparoscopic adrenalectomy. Patients with specific conditions may benefit from robotic surgery. Yet, the high-quality data are still scant.

Keywords Robotic surgery · Laparoscopy · Adrenalectomy · Minimally invasive surgery · European experience

This article is part of the Topical collection on *Robotic Surgery*.

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Introduction

Adrenalectomy is a technically challenging procedure due to the limited space in the retroperitoneum, closely neighboring major vessels and needing meticulous dissection [1]. Since the first case in 1992, the gold standard surgical technique for adrenal gland diseases is the minimally invasive approach [2]. To date, especially for benign lesions, laparoscopic adrenalectomy (LA) is the standard of care worldwide [3]. Compared to open surgery, laparoscopic technique provides less pain, better cosmetic results, decreased incidence of complications and decreased length of hospital stay [4]. However, there are inherent technical limitations of laparoscopic instruments.

Retroperitoneoscopic adrenalectomy was described for the first time by Mercan et al. [5] and discussed in the literature by large series by Walz et al. [6, 7]. Advantages include easier access to adrenal glands, decreased need for intra-abdominal organ mobilization, in bilateral cases and moreover avoiding the entrance to peritoneal cavity especially in previously operated patients [8]. On the other hand, this approach is limited by narrow space which may result in clashing instruments due to the rigidity of laparoscopic instruments, especially in obese patients and patients with large tumors [9].

Robotic technique was developed to overcome these limitations and offers 3D view, articulated instruments, more precise control, and less surgeon tremor. The first robotic adrenalectomy in Europe was reported by Piazza and Hubens et al. [10, 11] in 1999. Since then, robotic technique has started to gain popularity in the treatment of adrenal lesions and is shown to be safe and feasible by many studies [12].

Despite promising features of robotic instruments, most of the comparative studies to date have failed to show any

superior outcome compared to laparoscopy [13, 14]. Only one recent multicentric, international study from EUROCRINE surgical registry, showed improved outcomes after robotic adrenalectomy in terms of complication rate and duration of hospital stay [15••]. Yet, comparative data on the outcomes of robotic and laparoscopic adrenalectomy is still scarce and it is an ongoing matter of debate. The aim of this review is to present the current situation of adrenal gland surgery regarding robotics perspective in Europe and compare it to the minimally invasive adrenal surgery data in the literature.

Is Robotic Adrenalectomy Safe and Feasible?

Complication and Conversion Rate

Studies on robotic adrenalectomy (RA) conducted in Europe reported an intraoperative and postoperative complication rate of 0–20% and 0–16%, respectively [12, 15••, 16••–28] (Table 1). The complication rates of RA and LA were found to be similar in most studies (Table 2). In a recent retrospective multicentric study using data from a large European database (Eurocrine registry), Vatansever et al. compared 189 RA cases with 816 laparoscopic adrenalectomy cases and reported a lower complication rate in RA group (1.6% vs. 16.5%, $p < 0.001$). However, most of the complications in LA group were Clavien Dindo grade 1 and there was no statistically significant difference between study groups in terms of complications $\geq$ grade 2 [15••]. In a single center study including more than 300 patients who had undergone RA, the risk factors for intraoperative complication were found to be a previous history of mesocolic or retroperitoneal surgical procedure. In addition, the authors of this study mentioned that postoperative complications were higher, especially in patients who are older than 65 years of age and patients requiring conversion to open technique [23••].

The reported conversion rate from robotic procedures to laparoscopic or open surgery ranged between 0 and 40% (Tables 1, 2). Among these studies in the literature, the highest conversion rate was reported by Morino et al. in a randomized controlled trial in 2004 [16••]. However, this study is one of the first in the literature and the conversion rate has been decreased to 7% if this study is excluded. In our opinion, the significant decrease in conversion rate can be associated with increased experience and progression in the learning curve of the surgeons. The most common reasons for conversion reported in the literature were bleeding, adhesions and difficulties in exposing the adrenal vein. Regarding robotic surgery experience most of the conversions have been reported to be occurred during the initial cases of the series. In addition to the tumor size, malignant pathology and higher BMI were also reported as the other risk factors for conversion that are stated in the literature [17, 18, 23••, 30].

Estimated Blood Loss

Bleeding is an important factor to evaluate different surgical techniques for surgical safety. Compared to conventional open procedure, up-to-date data shows no difference between gold standard laparoscopic and robotic technique. Recent studies showed that the mean estimated blood loss in robotic technique is between < 50 and 200 ml which is similar to the standard laparoscopic technique (Tables 1, 2). Contrary to the data in the literature, Brunaud et al. reported lower blood loss in RA compared to LA [29]. Moreover Erdemir et al. reported increased blood loss in patients with malignant tumor and tumors smaller than 4 cm independent of the surgical technique [27].

Operative Time

Considering the current literature, two major disadvantages of robotic surgery have been reported as higher cost of robotic equipment and increased operative time. The duration of the procedure is known to be influenced by factors such as docking time, team experience, and surgeon experience, regardless of the robotic dissection time [31]. According to European literature, the mean operative time ranges from 89 to 222 min (Tables 1, 2). In subgroup analysis of these studies, Brunaud et al. reported surgeon experience, first assistant training level and tumor size as the factors associated with operative time. In every 10 cases, junior surgeons shortened the operative time by 5 min, while senior surgeons shortened by 2 min [17]. In another study, Nordenström et al. found that time consumed at robotic console as the number of procedures performed increases [18]. Parallel to this study, Greilsamer et al. also noted surgeon experience as the main factor effecting and related to the operative time. Moreover, in this study, the authors also mentioned a correlation between the tumor size and the operation time [23••].

Length of Hospital Stay

In adrenal surgery, the length of hospital stay can be directly affected by the functionality of the tumor (pheochromocytoma or non-functionality) and additional co-morbidities (e.g., chronic heart disease, diabetes mellitus, obesity) of the patient. Thus, these factors need to be taken into consideration as a bias when comparing length of hospital stay between surgical techniques. According to

Table 1 Robotic adrenalectomy series from Europe

Series	Year	Country	Patient number	Approach	Intraoperative complication (%)	Postoperative complication (%)	Conversion (%)	Operative time (min)	Blood loss (ml)	Length of stay (days)
Morino et al. [16••]	2004	Italy	10	TA	20.0	0.0	40.0	169	NR	5.7
Brunaud et al. [17]	2008	France	100	TA	NR	10.0	5.0	99	NR	6.4
Nordenström et al. [18]	2011	Sweden	100	TA	NR	13.0	7.0	113	NR	NR
D'Annibale et al. [19]	2012	Italy	29	TA	6.6	10.0	3.3	200	< 50	5.2
Raffaelli et al. [20]	2013	Italy, France	13	TA	18.7	12.5	0.0	222	NR	4.4
Akarsu et al. [21]	2014	Turkey	8	TA	12.5	0.0	0.0	98	50	4.1
Morelli et al. [12]	2016	Italy	41	TA	4.8	4.8	0.0	177	NR	3.3
Probst et al. [22]	2016	Germany	28	TA	7.1	7.1	0.0	129	NR	6.8
Greilsamer et al. [23••]	2018	France	303	TA	3.0	9.2	3.0	89	NR	5.5
Niglio et al. [24]	2019	Italy	40	TA	0.0	0.0	0.0	102	1.4 g/dl[a]	6.8
Ozdemir et al. [25]	2020	Turkey	111	TA	7.2	9.0	4.5	135	60	2.7
Piccoli et al. [26]	2021	Italy	76	TA	0.0	10.5	0.0	100	90	3.2
Erdemir et al. [27]	2022	Turkey	30	TA	NR	16.6	3.3	195	227	3.5
Knezevic et al.[b] [28]	2022	Croatia	12	TA	NR	8.4	8.4	165	47	4.5
Vatansever et al. [15••]	2022	EUROCRINE	189	TA	NR	1.6	0.5	NR	NR	NR

TA transabdominal; *NR* not reported

[a]Mean decrease in Hemoglobin level

[b]Senhance robotic system

the European literature, the mean length of hospital stay ranges between 2.7 and 6.8 days for RA series (Tables 1, 2). In patients who underwent bilateral adrenalectomy, Raffaelli et al. reported shorter hospital stay with robotic surgery compared to retroperitoneoscopic or lateral transabdominal laparoscopic surgery. However, the authors noted that, this can be directly related to differences in protocols among centers [20]. In the most recent study from EUROCRINE database, Vatansever et al. showed the superiority of RA, compared to LA, regarding hospital stay. In this study, authors also noted that the histopathology (pheochromocytoma), conversion to open surgery and patients with complications were associated with longer length of stay for minimally invasive adrenal surgery [15••].

Are There Any Specific Situations in Which the Robotic Approach is Superior?

Large Tumors

There is no clear consensus on the definition of a large tumor, but most studies set a threshold value between 5 and 6 cm. Regarding the challenge of large tumors, in a retrospective multicenter study on over 100 RA cases, Ozdemir et al. reported that larger tumors ($\geq$ 5 cm) were associated with more intraoperative and postoperative complications, conversion to laparoscopy or open surgery and re-hospitalisation [25]. Moreover, Morelli et al. also emphasized the positive impact of robotics for operative time in large tumors. In this study, RA resulted in shorter

Table 2 The comparative studies carried out in European centers

Case series	Year	Country	Patient (*n*)		Tumor size (cm)		Complication (%)		Conversion (%)		Blood loss (ml)		Operation time (min)		Hospital stay (day)	
			RA	LA	RA	LA	RA	LA	RA	LA	RA	LA	RA	LA	RA	LA
Morino et al. [16••]	2004	Italy	10	10	3.3	3.1*	20	0	40	0	NR	NR	169	115**	5.7	5.4
Brunaud et al. [29]	2008	France	50	59	2.8	3.4*	10	15*	8	7*	49	71**	104	87**	6.3	6.9*
Morelli et al. [12]	2016	Italy	41	41	4.9	4.7*	10	5*	0	2*	NR	NR	177	207**	3.3	3.4*
Niglio et al. [24]	2019	Italy	40	64	5.3	6.4*	NR	NR*	0	4*	1.4[a]	1.9*[,a]	102	129**	6.8	11.1**
Piccoli et al. [26]	2021	Italy	76	84	4.0	5.1**	11	21*	0	0	90	110*	100	90**	3.2	4.1**
Vatansever et al. [15••]	2022	International	189	816	3.5	3.5*	2	17**	1	2*	NR	NR	NR	NR	82%[b]	29%**[,b]

NR not reported

*$p > .05$; **$p < .05$

[a]Decrease in hemoglobin (g/dl)

[b]Frequency of ≤ 2 days

operative time for tumors larger than or equal to 6 cm, compared to laparoscopic surgery [12]. In addition, Brunaud et al. demonstrated that robotic surgery is superior to laparoscopic surgery in bigger tumors [29].

Obese Patients

Obesity is another challenging situation for adrenal surgery due to limited space. Agcaoglu et al. compared obese patients (BMI $\geq$ 30 kg/m^2) with non-obese patients (BMI $<$ 30 kg/m^2), who underwent RA. This study showed no significant differences between the two groups in terms of complication rate, conversion rate, operative time, estimated blood loss and length of hospital stay [32]. Moreover, two other studies showed no significant positive impact of robotics regarding adrenal surgery in obese patients [18, 23••]. However, another study by Morelli et al. reported that the operative time was shorter in the robotic surgery group compared with the laparoscopic group, for patients with BMI $\geq$ 30 kg/m^2 [12]. In addition, parallel to this study, Brunaud et al. reported that higher BMI was associated with longer operative time in LA patients, but this negative impact of obesity was not seen in robotic cases [29].

Adrenocortical Carcinoma

Adrenocortical carcinoma is probably the most challenging case among adrenal tumors. Even though minimally invasive techniques are gold standard in various malignant tumors of different organs (colon, rectum, prostate), open surgery is still the gold standard treatment for malignant adrenal tumors. Although the use of minimally invasive techniques for this indication has been increasing, there is still scant data regarding the role of robotic surgery for adrenocortical carcinoma.

According to the literature, minimally invasive techniques are more frequently preferred as surgeon experience increases. In the ESE guideline, it was stated that in experienced hands, tumors smaller than 6 cm and without local invasion can be performed by minimally invasive techniques [33]. Table 3 shows some European-based studies comparing minimally invasive techniques with open surgery in patients with ACC [34–39].

Bilateral Adrenalectomy

Bilateral adrenalectomy is one of the most uncommon operations, because it's indication are only limited to rare conditions, like bilateral pheochromocytomas and adrenocorticotropic hormone-dependent hypercortisolism. Although the largest series in Europe belongs to Walz et al., the number of bilateral adrenalectomies appears to be limited even in his series [8, 40].

In bilateral minimally invasive adrenalectomy, repositioning the patient in the transabdominal approach and adding docking and undocking times in robotic surgery results in great time disadvantage. In retroperitoneal surgery, with elimination of the repositioning, the operative time has been shown to decrease significantly.

Table 3 The comparative studies carried out in European centers in ACC patients

Case series	Year	Country	Patient (*n*)		Tumor size (cm)		Stage		DFS (months)		OS (months or %)	
			OA	LA	OA	LA	OA	LA	OA	LA	OA	LA
Porpiglia et al. [34]	2010	Italy	25	18	10.5	9.0*	I–II	I–II*	18	23*	84%	100%*
Lombardi et al. [35]	2012	Italy	126	30[a]	9.0	7.7*	I–II	I–II*	48	72*	60	108*
Fossa et al. [36]	2013	Norway	15	17	13.0	8.0**	I–III	I–III[b]	8	15*	37	104*
Donatini et al. [37]	2014	France	21	13	6.8	5.5*	I–II	I–II	47	46*	85%	81%*
Vanbrugghe et al. [38]	2016	France	9	16	11.6	6.3**	II–III	I–III*	40	61*	89%	69%*
Kastelan et al. [39]	2020	Croatia	23	23	12.0	7.5**	II–III	I–III[b]	129	109*	149	109*

DFS disease-free survival; *OS* overall survival

*$p > 0.05$; **$p < 0.05$

[a]29 transabdominal lateral approach and 1 posterior retroperitoneoscopic approach

[b]The stage was significantly higher in OA group

Raffaelli et al. compared robotic bilateral adrenalectomy (RA-BilA) with conventional retroperitoneoscopic (PR-BilA) and conventional laparoscopic adrenalectomy (TL-BilA). The operative time was shorter in PR-BilA group. The perioperative complication rates were similar in these groups with no conversion in all cases. Moreover, this study showed no significant advantage of RA in bilateral adrenalectomy [20]. In another recent multicenter study across Europe comparing conventional lateral transabdominal and posterior endoscopic techniques in patients with bilateral adrenal tumors, Tuncel et al. reported shorter operative time and less blood loss in the posterior approach. However, no significant difference in terms of intraoperative and postoperative complication rates were found [41].

Partial Adrenalectomy

Partial adrenalectomy or the so-called 'cortex-sparing adrenalectomy' is an alternative technique for preserving the gland in selective cases, including pheochromocytomas, bilateral disease, unilateral adrenal tumors in patients with hereditary disease that have higher risk of developing adrenal tumors. Even though not a very common procedure, Simone et al. shared prospectively collected data in 10 patients with aldosterone secreting tumors with a diameter of < 3 cm, who underwent robotic partial adrenalectomy. The results of this study showed safety and feasibility of the robotic technique with no conversion and a median operative time of 65 min. In addition to this, postoperative complication occurred in only 1 patient which is postoperative fever [42]. In a more recent study, Anceschi et al. compared 29 minimally invasive partial adrenalectomy (MIPA) cases (24 robotic and 5 endoscopic) with 61 minimally invasive total adrenalectomy (MITA) cases (41 laparoscopic and 20 retroperitoneoscopic). There were no intraoperative complications or conversions, and postoperative complication rates were similar in both groups. While the complete clinical success was higher, no patient needed steroid replacement in MIPA group [43].

Regarding European databases, other studies included case series with less than 10 patients or only single case presentations. The most common indications were aldosteronoma, Cushing's Syndrome, pheochromocytoma and non-functional tumors. The operative times ranged between 90 and 205 min [44–46]. The results of these studies showed neither negative nor positive effect of robotics in cortex-sparing adrenalectomy.

Laparoendoscopic Single-Site (LESS) Adrenalectomy

Looking at the largest series from Europe, in a retrospective case–control study, Walz et al. compared 47 single-access retroperitoneoscopic adrenalectomy (SARA) cases with 47 conventional retroperitoneoscopic adrenalectomy (CORA) cases. In this study, the operative time was significantly longer in SARA group compared to conventional technique. Even though there were no conversions to open surgery in both groups, authors noted that four conversions from SARA to CORA occurred. The estimated blood loss was minimal and overall complication rates were similar in both groups [47]. In a more recent study, Agcaoglu et al. reported the results of single-incision laparoscopic surgery (SILS) adrenalectomy procedure, performed in a single center. Author compared 44 SILS with 36 conventional LA cases. The mean operative time, estimated blood loss, perioperative complications and length of stay were similar between two groups [48].

Although series of LESS adrenalectomy, performed via robotic technology have been reported worldwide, there is lack of study on this issue in Europe. Using technological

advancements like the da Vinci Sp model, which has a flexible camera and three articulated working arms with only a 2.5 cm trocar, single-incision series is expected to increase.

Indocyanine Green (ICG) Fluorescence Imaging

The use of ICG fluorescence imaging in endocrine surgery is gaining popularity with the recent improvements in laparoscopic and robotic platforms that display ICG-enhanced images simultaneously [49].

In adrenal gland surgery, ICG offers several outstanding benefits. In addition to being easy to administer, ICG helps in the differentiation of the adrenal gland from retroperitoneal fat, determination of the resection plane by identifying the border between the tumor and normal adrenal tissue, preservation of nearby organs and vascular structures and the evaluation of the vascularization of the remnant tissue after partial adrenalectomy.

One of the major concerns might be lengthening of operative time due to the application of ICG. However, it reported not to significantly prolong the operative time [50]. Moreover, Agcaoglu et al. reported that ICG imaging had been used in the last 10 cases of 44 SILS adrenalectomy, and the mean operative time decreased from 79 to 51 min. The authors explained this difference with easier exposure of the adrenal vein [48].

Conclusion

In today's world, where innovations are dramatically increasing parallel to the technological developments, European-based articles were compiled in this review. The results of robotic surgery and its role in specific situations such as large tumors, obese patients, malignant tumors, bilateral adrenalectomy, partial adrenalectomy, and single-site surgery were evaluated. Research showed that robotic surgery can be applied safely and feasibly, similar to conventional gold standard laparoscopic surgery. However, the main disadvantage of robotic surgery is its higher cost.

European experience supports that robotic surgery may improve the surgical outcomes in specific patient groups, by its advantages including 3D and magnified image, enhanced mobility due to multi-articulated robotic arms, elimination of surgeon tremor and camera disorientation and increased ergonomics. However, it should be considered that there is a lack of high-quality data and more prospective randomized studies are needed to show whether RA has a significant advantage over LA.

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Compliance with Ethical Guidelines

Conflict of interest The authors declare no conflicts of interest.

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