20-year experience with laparoscopic adrenalectomy at a high-volume center

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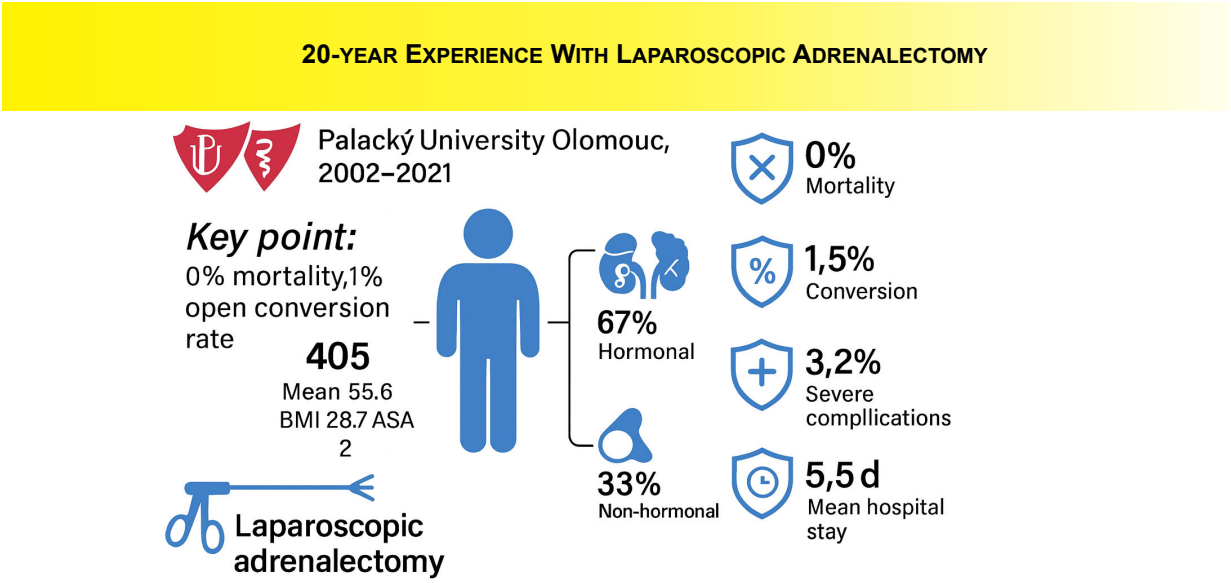
Objective. To evaluate transperitoneal laparoscopic adrenalectomies performed at the University Hospital, Olomouc over a period of 20 years**.**

Introduction. Thanks to the increased availability of imaging, the detection of adrenal disease is increasing. Laparoscopic adrenalectomy is now regarded as the gold standard for the treatment of adrenal disease due to its safety and efficacy despite the increasing popularity of robotic-assisted surgery.

Methods. Over a period of 20 years, from 2002 to 2021, we retrospectively evaluated a cohort of 405 patients who had undergone laparoscopic adrenalectomy. The indication criteria for laparoscopic adrenalectomy were hormonally active symptomatic tumours (pheochromocytoma, Conn's syndrome, Cushing's syndrome, etc.), symptomatic cysts or myelolipomas, carcinomas, metastatic disabling or incidentalomas, growing at a rate >1 cm or more per year. Data collected focused on sex, age, medical classification, imaging, operative time, side dominance, hormonal activity, complications associated with surgery, length of hospital stay, and histopathologic verification. No patient who had undergone laparoscopic adrenalectomy was excluded from the cohort. Patients in our cohort were not operated by a single surgeon.

Results. Women accounted for 52.1% (211) and men 47.9% (194). The mean age was 55.6 years, BMI 28.7, and median ASA score was 2. Preoperative imaging included abdominal CT in 352 (86.9%) patients, abdominal MRI with contrast agent in 8 (2.0%), and PET/CT in 45 (11.1%) patients. More frequent findings were on the right side in 223 (54.39%) patients. Hormonal activity was found in 271 patients (67 %). Hormone overproduction from the right adrenal gland was found in 120 (44.3%) patients, and from the left in 151 (55.7%). Adenoma was the most frequent histological finding, followed by hyperplasia. Conversion to open surgery was due to bleeding in 2 patients. There was no perioperative or postoperative mortality. According to the Clavien-Dindo classification, minor complications (Grade I) occurred in 375 patients (92.6%). Grade II complications were reported in 17 patients (4.2%). Grade III complications were identified in 13 patients (3.2%) due to operative field bleeding; in three cases (0.7%), surgical revision of the adrenalectomy bed was required.

Conclusion. Laparoscopic adrenalectomy is a safe surgical method for the management of adrenal disease and our retrospective follow-up confirmed that it remains the gold standard.



Laparoscopic adrenalectomy provides durable safety and efficacy over long-term follow-up, with low morbidity and zero mortality in a high-volume setting.

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Graphical Abstract

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INTRODUCTION

Adrenal conditions are among the less common diseases where widely available imaging modalities have a higher incidence of detection[1]. Surgical treatment as adrenalectomy is an effective surgical solution that should be directed to surgical and urological centres where at least 6 surgical procedures are performed per year, and novice surgeons should perform at least 20–40 surgical procedures to learn the technique[2].

The first transperitoneal laparoscopic adrenalectomy was performed in 1992. Since that time, the surgical technique has been refined, safety has improved, recovery time has shortened and return to normal patient activities is faster. As a result, this method has been rapidly adopted and is regarded as the gold standard worldwide[3]. It is now being gradually replaced by robotic-assisted adrenalectomy, the first cases being recorded since 2001 (ref.[4]), when the first right-sided robotic-assisted adrenalectomy was performed.

METHODS

A retrospective analysis of 405 patients who underwent laparoscopic adrenalectomy at the University Hospital Olomouc between 2002 and 2021 was performed. Each patient had a signed informed consent for the procedure, as well as a standard completed lateral surgical protocol. Patients underwent basic preoperative internal examination, anesthesiological examination, and endoscopic examination in case of hormonally active tumours. Indications for laparoscopic adrenalectomy were hormonally active tumours (pheochromocytoma, Conn's syndrome, Cushing's syndrome, etc.), symptomatic cysts or myelolipomas, carcinomas, metastatic lesions or incidentalomas. Relative contraindications to laparoscopic surgery are tumour size over 6 cm, obesity, pregnancy, abdominal adhesions after previous abdominal procedures.

The laboratory tests include the determination of basic ions (sodium, potassium), plasma renin activity, aldosterone, the ratio of aldosterone to plasma renin activity, plasma normetanephrines and metanephrines.

Endocrinological methodology and preoperative hormonal diagnostics

As part of the preoperative evaluation, patients with suspected hormonally active adrenal lesions were referred for comprehensive endocrinological assessment. The objective was to determine the tumour's hormonal activity (see Table 1.), recommend confirmatory tests when indicated, and select appropriate imaging modalities and preoperative preparation strategies.

Primary hyperaldosteronism (Conn's syndrome): The initial screening involved calculation of the aldosterone-to-renin ratio (ARR). A ratio >20–30 with an aldosterone concentration >15 ng/dL was considered suspicious. If needed, confirmatory testing (most commonly saline infusion test) was performed. To determine localization and lateralization of aldosterone production, selective adrenal venous sampling (AVS) was conducted via interventional radiology, including assessment of the selectivity index and lateralization index[5,6].

The primary indication for AVS is therefore the need to differentiate unilateral PA – potentially curable by surgical removal of the affected adrenal gland – from bilateral adrenal hyperplasia, which requires long-term treatment with mineralocorticoid receptor antagonists. AVS is recommended in most patients with biochemically confirmed PA who are potential candidates for unilateral adrenalectomy[7,8]. AVS is particularly important in middle-aged and older patients, in those with bilateral nodular adrenal lesions, in cases with normal CT/MRI findings despite unequivocal biochemical evidence of PA, and in patients with severe or resistant hypertension accompanied by pronounced aldosterone excess. Conversely, patients with mild forms of autonomous aldosteronism or those who are not surgical candidates generally do not benefit from AVS, as the result would not alter therapeutic management[9,10]. An exception is young patients (< 35 years) who present with unequivocal biochemical findings (spontaneous hypokalaemia, suppressed renin) and a typical unilateral adrenal adenoma ≥ 1 cm on CT with a normal contralateral gland. In these cases, direct unilateral adrenalectomy without AVS may be considered, as the likelihood of unilateral PA is high[9].

Cushing's syndrome (Cortisol-producing Adenoma)

Evaluation included assessment of the circadian cortisol rhythm (morning values and inpatient diurnal profile) and salivary cortisol, when available. Overall cortisol production was determined using 24-hour urinary free cortisol. A low-dose dexamethasone suppression test (1 mg) was routinely performed, with high-dose DST added in ambiguous cases. ACTH levels were measured to distinguish ACTH-dependent from ACTH-independent disease, the latter indicating an adrenal source.

Table 1. Endocrinological diagnosis of adrenal incidentalomas.

Syndrome	Diagnostic Tests
Conn's syndrome	Plasma renin activity (PRA); Plasma and urinary aldosterone (PA); PA/PRA ratio; Plasma cortisol; Stimulation and suppression tests for PRA/PA; Selective adrenal venous sampling (aldosterone and cortisol)
Cushing's syndrome	24-hour urinary free cortisol; Plasma cortisol rhythm; ACTH levels; Dexamethasone suppression tests
Pheochromocytoma	Plasma/urine metanephrines and normetanephrines; Clonidine suppression test

Pheochromocytoma

Diagnosis was based on plasma metanephrines and normetanephrines, obtained under controlled conditions to minimize stress and interfering substances. These metabolites provide high sensitivity due to continuous catecholamine turnover in tumour cells. In borderline cases, a clonidine suppression test was used. Preoperative management included alpha-adrenergic blockade, with beta-blockers added if tachycardia was present.

Imaging modalities

The standard first-line imaging technique for adrenal evaluation was adrenal CT with native density measurement and calculation of the washout index. In cases of pheochromocytoma, adrenal MRI was also employed – particularly in younger patients or during pregnancy. Functional imaging techniques, such as MIBG scintigraphy or PET/CT using ^18F-FDOPA or ^68Ga-DOTATATE, were utilized when indicated.

^123I-MIBG is taken up via the norepinephrine transporter and represents a traditional functional imaging modality for paraganglioma (PPGL). It is primarily indicated in patients with suspected or confirmed metastatic disease and in those with possible multifocality, complementing anatomical imaging. It is also essential for selecting candidates for ^131I-MIBG therapy, which is effective only in tumors with sufficient radiotracer uptake[11,12].

However, its sensitivity is limited, particularly in extra-adrenal paragangliomas and tumors associated with SDHx mutations, where MIBG uptake is often reduced[11,13].

PET/CT currently plays a central role in the staging and restaging of PPGL because of its superior sensitivity and higher accuracy in detecting metastatic sites. The optimal PET/CT radiotracer depends on the genetic background, the primary tumor location, and the biological behavior of the disease[12].

- **^68Ga-DOTA-SSA PET/CT** (somatostatin receptor imaging) is the method of choice for paragangliomas and metastatic PPGL, especially in SDHx-mutated tumors[14].
- **^18F-FDOPA PET/CT** demonstrates high sensitivity for adrenal pheochromocytomas and several hereditary PPGL syndromes (e.g., MEN2, VHL) (ref.[15]).
- **^18F-FDG PET/CT** is most useful in aggressive, poorly differentiated or rapidly proliferating tumors and in SDHB-mutated PPGL, reflecting increased glycolytic activity.[16].

PET/CT is indicated particularly in patients with suspected metastatic or multifocal disease, those with hereditary PPGL, in cases with indeterminate CT/MRI findings, and for treatment planning before radionuclide or systemic therapy. In localized, typical adrenal pheochromocytoma without hereditary predisposition, CT/MRI is usually sufficient, and functional imaging is used selectively[12].

Surgical Indication and Multidisciplinary Evaluation: The indication for surgical intervention was always determined by a multidisciplinary team consisting of a urologist, endocrinologist, radiologist, and anaesthesiologist. The team evaluated the hormonal activity, size, and morphology of the lesion, presence of clinical symptoms and the patient's overall condition.

Over the past two decades, there has been a significant shift in the criteria used to guide surgical management of incidentally discovered adrenal lesions – called adrenal incidentalomas. Earlier recommendations, applied until the early 2000s, were largely based on simplified criteria such as tumour size greater than 4 cm, clear evidence of hormonal activity (notably Cushing's syndrome, pheochromocytoma, or primary aldosteronism), and significant tumour growth over time (≥ 0.5–1 cm). In contrast, current guidelines reflect a more comprehensive and individualized approach, integrating clinical, biochemical, and imaging parameters.

According to the most recent Endocrine Society Clinical Practice Guidelines (2023), surgical intervention is generally recommended for lesions exhibiting suspicious radiological features including heterogeneity, unenhanced CT attenuation > 20 Hounsfield units (HU), or irregular margins in combination with a size ≥ 4 cm. Conversely, lesions < 4 cm with homogeneous appearance and low attenuation values (≤ 10 HU) are typically considered benign and are managed conservatively through surveillance[17].

In addition to structural imaging characteristics, current guidelines now emphasize the relevance of mild autonomous cortisol secretion (MACS), defined by a post-1 mg dexamethasone suppression test serum cortisol > 50 nmol/L, even in the absence of overt Cushingoid features. If MACS is accompanied by cardiometabolic comorbidities such as arterial hypertension, type 2 diabetes mellitus, or osteoporosis, adrenalectomy is recommended with the aim of improving metabolic outcomes and potentially reducing cardiovascular risk[17,18].

Tumour growth dynamics also play a key role in contemporary decision-making. A growth of ≥ 20% in volume and ≥ 5 mm in absolute size within 6 to 12 months is considered clinically significant and represents an indication for surgical consideration. Tumour size alone, in the

absence of other risk factors, is no longer viewed as an absolute surgical indication[17].

Operations are performed in an antibiotic prophylaxis – according to the practice of the department – here (if there is no allergy) potentiated Aminopenicillin. The patient is positioned and fixed on the side opposite to the operated side, in slight flexion about 25°. Until 2017, the urology clinic used the Veress needle, then exclusively open access. Subsequently, a capnoperitoneum is created using CO_2 and a transperitoneal adrenalectomy is performed using 3–4 trocars for the camera and instruments including an assistant. When performing adrenalectomy in hormonally active adrenal masses, it is essential to first interrupt the central suprarenal veins before any manipulation with the adrenal gland, especially in patients with pheochromocytoma. This minimizes the immediate supply of catecholamines into the bloodstream that would otherwise lead to accelerated hypertension. For this reason, continuous measurement of mean arterial pressure is necessary. If we perform a right-sided adrenalectomy, we usually start by incising the parietal peritoneum above the inferior vena cava at the level of the renal vein spacing. Traction of the liver is important, and we use an assist port for this. After careful mobilization of the duodenum, we completely mobilize and expose the confluence of the renal vein and the inferior vena cava up to the inferior surface of the liver.v We then interrupt all vascular supply to the gland. On the right side, the strongest central vein drains directly into the inferior vena cava. The adrenal gland is ideally removed from the body in a special plastic bag, using a dilator. As standard, we introduce a drain into the operated area, which we put on vacuum suction. It is usually removed after 24 hours. The standard operating tool during the operation is the harmonic scalpel, which has been available in our clinic since 2003. When interrupting blood vessels of a wider calibre, then plastic hem-o-lok clips or titanium clips. It is also worth mentioning that on the day of surgery the patient is monitored in the intensive care unit, and on the following days in the standard ward. The permanent urinary catheter and Redon drain are removed on the first postoperative day as standard.

Exclusion criteria for surgery

Contraindications to the surgical procedure include severe coagulopathy or a severe cardiopulmonary condition. In the past, relative contraindications to laparoscopic adrenalectomy included prior abdominal surgery, intra-abdominal adhesions, or morbid obesity. However, with continuous improvements in surgical techniques, the limitations of laparoscopic procedures have been gradually reduced. Currently, severe chronic obstructive pulmonary disease (COPD) in elderly patients is considered a relative contraindication, as diaphragmatic elevation during laparoscopy may significantly impair pulmonary ventilation.

RESULTS

Demographics

In the years 2002–2021, 405 laparoscopic adrenalectomies were performed at the Urology Clinic of the University Hospital Olomouc. Women accounted for 52.1% (211) men 47.9% (194). Bilateral adrenalectomy divided into two periods was performed in 2.5% (10) patients. Partial adrenal resection for solitary gland tumours was performed in 2% (8) of patients. Left-sided adrenalectomy was performed in 45.1% (182) of patients and right-sided adrenalectomy in 54.9% (223) of patients. Mean age was 55.6 years (19–79 years). Preoperative imaging was performed as standard CT, MR or PET/CT. Adrenal hormonal activity was demonstrated in 262 patients (64.8 %) (see Table 4). The mean operative time was 61 min (25–170 min). Blood loss averaged 80ml (0–1300 mL). The mean length of hospital stay was 5.5 days (see Table 2.).

In a cohort of 405 patients undergoing surgical treatment, perioperative and postoperative complications were systematically evaluated using the Clavien–Dindo classification.

Grade I complications were the most frequently observed, affecting 92.6% of patients (375/405). These included mild clinical symptoms such as postoperative pain, nausea, vomiting, and secondary wound healing. All cases were effectively treated with standard supportive care, including administration of analgesics and antiemetics, without requiring invasive procedures or extended hospitalization.

Grade II complications occurred in 4.2% of patients (17/405). These required pharmacological interventions beyond routine postoperative management. The most common conditions were postoperative anemia, managed by blood transfusion, and pulmonary embolism, treated with therapeutic anticoagulation. Despite their greater clinical significance, these complications did not necessitate surgical or endoscopic intervention. Grade III complications, which required surgical, endoscopic, or radiological intervention, were identified in 3.2% of patients (13/405). Of these, Grade IIIa complications (7/405) included cases of postoperative bleeding and myocardial infarction, which were successfully managed with selective vascular embolization and intracoronary stent placement, respectively, without the need for general anaesthesia. Grade IIIb complications (6/405) were more severe and necessitated reoperation under general anaesthesia; these included recurrent postoperative bleeding, injury to the hepatic flexure requiring bowel resection with the creation of a temporary diverting stoma, and pancreatic tail injury managed intraoperatively by direct suturing.

Notably, no Grade IV complications (life-threatening accident requiring intensive care unit management) or Grade V complications (postoperative mortality) were recorded in the studied population.

In summary, postoperative complications were predominantly low-grade and manageable with standard perioperative care. Severe complications requiring reintervention were rare, and no deaths occurred in this co-

hort, underscoring the safety and feasibility of the surgical approach employed.

Preoperative imaging methods

Imaging methods were used as standard in all patients before surgery. Specifically, 3 imaging modalities were used, namely CT in 89.5% (362) of patients, MR in 6.5% (27) and PET/CT in 4% (16) of patients. Preoperative imaging findings are included in the Table. The most frequently reported radiological diagnoses, in descending order of occurrence, included: adenoma/hyperplasia (60%), pheochromocytoma (9%), myelolipoma (7%), adrenal metastasis (6%), carcinoma (6%), cyst (5%), normal finding (3%), hematoma (3%), and paraganglioma (1%) (see Fig. 1).

Histological finding

The most common histological finding was adenoma, identified in 150 patients, representing the majority of cases. This was followed by hyperplasia in 101 patients. Other notable findings included pheochromocytoma (32 cases), carcinoma and metastases (29 cases each). Rare findings included paraganglioma and negative histology, both observed in only 4 cases. The average size of the specimen was 56 mm in the widest dimension (7–120 mm) (see Fig. 2.).

DISCUSSION

This large study, conducted at the Department of Urology, University Hospital, followed 405 patients over a 20-year period who had undergone laparoscopic adrenalectomy for various diagnoses. The study confirmed that it is effective and safe. All surgical procedures were performed transperitoneally at our centre by a close team of surgeons. The study revealed several key features that we would like to highlight and present below in the con-

Table 2. Characteristics of the study population.

Demographic data		
Gender	man	47.9% (194)
	woman	52.1% (211)
Age	man	51.3 years (20–79)
	woman	49.6 years (19–78)
BMI	≤ 19.9	9.9% (40)
	20–24.9	20.2% (82)
	25–29.9	40% (162)
	30–34.9	19.8% (80)
	≥ 35.0	10.1% (41)
Perioperative data		
Operated side	left	45.1% (182)
	right	54.9% (223)
Partial resection of the adrenal gland		2% (8)
Hormonal activity		67% (271)
	right	44.3% (120)
	left	55.7% (151)
Operating time		61 min (25–170 min)
Blood loss		80ml (0–1300 mL)
Operational conversion		1.48% (6)
Transfuse		0.99% (4)
Length of hospitalisation		5.5 days
Adrenal tumour size		56 mm (7–120 mm).
ASA score	I	11.1% (45)
	II	73% (295)
	III	15.5% (63)
	IV	0.4% (2)
Imaging methods	CT	86.9% (352)
	MR	2% (8)
	PET/CT	11.1% (45)

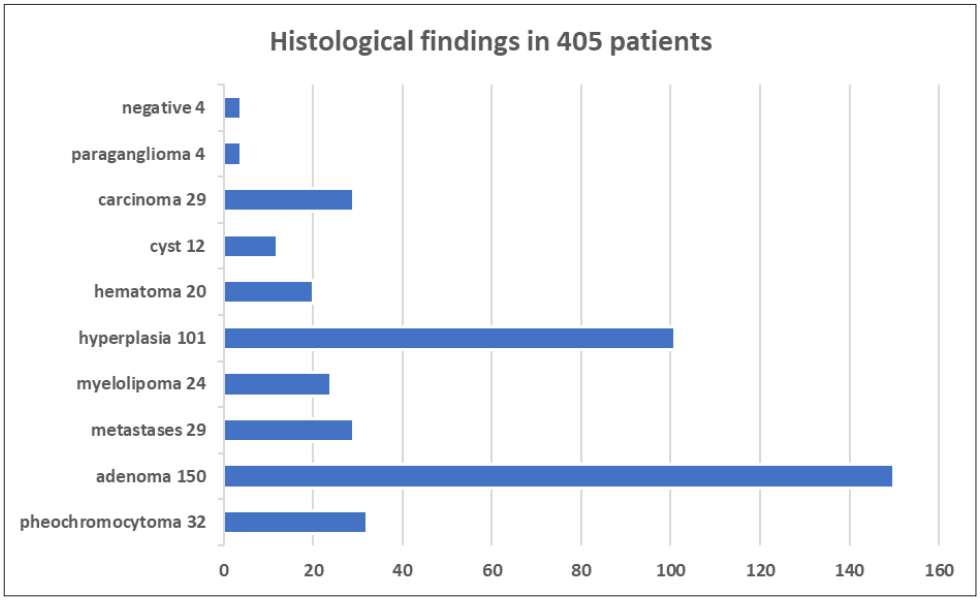

Fig. 1. Preoperative radiological description.

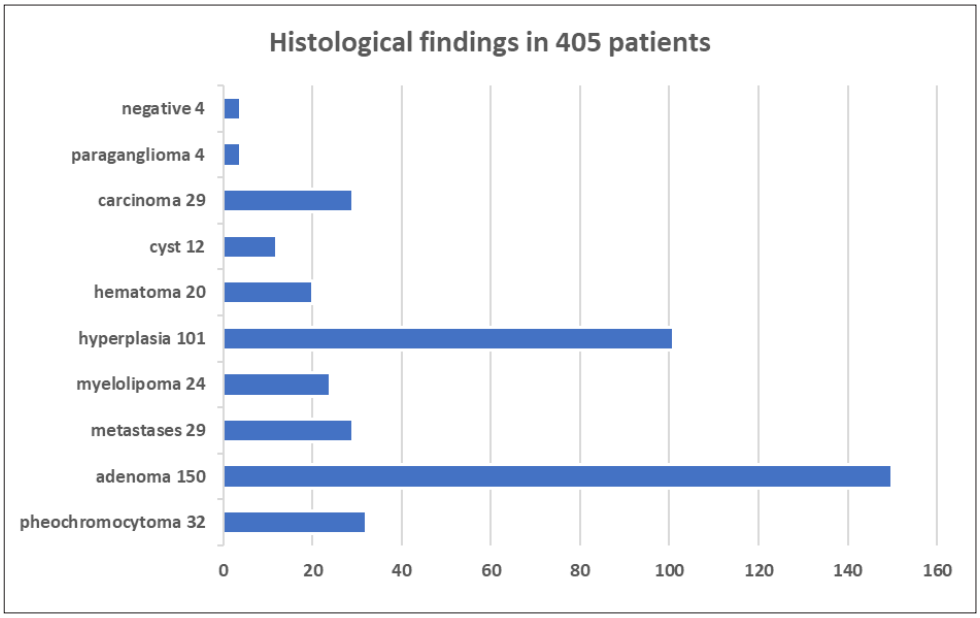

Fig. 2. Histological findings.

Table 3. Clavien-Dindo classification of perioperative and postoperative complications.

Clavien Grade	Incidence (n/total %)	Type of Complications	Management
Grade I	375 / 405 (92.6%)	Pain, vomiting, delayed/secondary wound healing	Analgesics, antiemetics
Grade II	17 / 405 (4.2%)	Anaemia, pulmonary embolism	Blood transfusion, anticoagulation therapy
Grade III	13 / 405 (3.2%)	– see subcategories	–
Grade IIIa	7 / 405	Postoperative bleeding, myocardial infarction	Selective arterial embolization, intracoronary stent
Grade IIIb	6 / 405	Postoperative bleeding, hepatic flexure injury, pancreatic tail injury	Surgical revision with bowel resection and temporary diverting stoma; intraoperative suturing
Grade IV	0	–	–
Grade V	0	–	–

text of worldwide studies. No patient died during the procedure or in the early postoperative period. There were no major perioperative or postoperative complications in 392 patients (96.8%) 375 patients (92.6%) were grade 1, 17 patients (4.2%) were grade 2. Grade 3 according to the Clavien scale was determined in 13 patients (3.2%), which involved bleeding from the surgical field, which was resolved by selective vessel embolization or in 3 cases (0.7%) surgical bed revision after adrenalectomy. Risk factors were BMI (mean BMI in these patients was 31.6 vs mean BMI in the whole cohort) and adrenal lesion size (mean adrenal lesion size 86 mm vs mean adrenal lesion size 40.5 mm in the whole cohort). Patients who had complications > grade 3 according to Clavien's classification had the following histological findings- carcinoma (7 times), adrenal mass (3 times) and pheochromocytoma (3 times). Surprisingly, a meta-analysis of the Danwang et al.[19] collective showed no connection between obesity and increased complication rates, but this conclusion is not consistent with our results. We also paid attention to the

Table 4. Preoperative hormonal activity.

Hormonal Activity	Incidence
Hypersecretion of aldosterone	37% (150)
Hypersecretion of cortisol	11% (44)
Hypersecretion of catecholamines	18% (73)
Non-secreting findings	33% (134)
Adrenogenital syndrome	1% (4)

length of hospitalization. According to Silvinito et al.[20], the mean length of hospitalization for laparoscopic adrenalectomy was 2.51 days with respect to histological findings. At our institution, the mean length of hospitalization was 5.61 days, and is in agreement with the publication by Duralska M. et al.[21] who reported on the experience of one high-volume centre over two decades and found that the conversion rate to open surgery was only 1.5% and perioperative complications were noted in 2.3% of cases. The length of hospital stay was 5.27 days, and the

mortality rate was negligible. The difference in length of hospitalization was due to the different scheme of counting from the time of admission to surgery.

The mean operative time (85.47 min) in the comparison of the Teksöz et al.[22] collective was similar and only six minutes longer. In the study of the collective of Duralska et all, the average operative time is 141 min. This fact is explained by the experience of a close circle of surgeons at our institution. In the literature, studies can be traced that range from 83 to 240 min and this favours of our department. The variables that most influence operative time are obesity, gender and tumour size.

According to Cavallaro et al.[23], tumor size is not the only criterion for the choice of laparoscopic solution. Even in our series, tumours larger than 10 cm, mostly carcinomas, without penetration into the surrounding tissues were found. In 6 patients (1.5%), surgical conversion was performed due to time constraints or high blood loss. Conversion rates in the literature range from 0.8% to 6.2%, with an average of over 3.5%. In our cohort, four patients (1%) required transfusion. As our institution is a major centre for a wide geographical area, further dispensing of patients is done at the place of residence, thus it is difficult to maintain long-term collection of individual postoperative data. Another significant finding of our analysis is the high proportion of hormonally active lesions, which accounted for 67% of all cases. The most common diagnosis was primary hyperaldosteronism (37%), followed by pheochromocytoma (18%) and Cushing's syndrome (11%). This proportion exceeds the prevalence of hormonally active adrenal tumours reported in comparable studies, where it typically ranges between 50–60% (ref.[24,25]). This may reflect the effectiveness of interdisciplinary preoperative collaboration between endocrinology, radiology, and surgery – particularly in functional diagnostics (aldosterone-to-renin ratio, selective adrenal venous sampling, LDDST, or plasma metanephrines) – allowing precise surgical targeting of clinically significant hormone-producing lesions.

Tumour size also merits discussion. In our cohort, lesion sizes ranged from 7 to 120 mm, with an average of 56 mm. The fact that tumours exceeding 10 cm were safely resected laparoscopically demonstrates that size alone is not an absolute contraindication for the minimally invasive approach. This aligns with current recommendations[23], including the most recent guidelines from the European Society of Endocrinology (ESE), which emphasize that malignancy risk is determined not only by size but also by radiologic features such as heterogeneity, unenhanced attenuation >20 HU, irregular margins, and growth kinetics[17]. Our results contribute to the ongoing discussion about redefining surgical thresholds for adrenal lesion size.

From the perspective of patient comorbidities, our outcomes were also favourable. An ASA score II was found in 73% and ASA III in 15.5% of patients. Despite this moderate systemic burden, laparoscopic adrenalectomy was performed safely without any increased complication rate. This supports findings in the literature that suggest laparoscopy remains a suitable approach even in ASA III patients, provided appropriate perioperative optimization is ensured[26]. Our data confirm the view that laparoscopic adrenalectomy can be considered both safe and effective even in patients with relevant internal comorbidities.

With the increasing trend of robotic-assisted surgery, 3 robotic-assisted adrenalectomies were performed in our department. The indications were combined procedures, e.g. during robot-assisted resection of renal tumour. According to the available data, robotic-assisted adrenalectomies have comparable results to laparoscopic adrenalectomies. The general advantages of robotic surgery – shorter learning curve, operator comfort, shorter length of hospital stay – compensate for the higher financial costs. Indications according to Nomine-Criqui et al.[27] are bilateral or partial adrenalectomies, complicated patients with larger tumours or truncal paragangliomas. However, larger and randomized studies are needed to comprehensively assess the real benefit of robotics in adrenalectomies. However, current experience from developed, high-volume healthcare systems consistently demonstrates several advantages of the robot-assisted approach, including enhanced operative precision, improved surgeon ergonomics, and potentially greater safety in anatomically complex or technically demanding adrenal lesions. These aspects are increasingly reflected in international data and should be more explicitly acknowledged when comparing the techniques.

CONCLUSION

Laparoscopic adrenalectomy has been unequivocally established as a safe and effective surgical technique for the management of adrenal pathology. Our long-term retrospective analysis reinforces its status as the gold standard, particularly in centres with multidisciplinary collaboration and substantial procedural volume. The experience gained at the University Hospital Olomouc over two decades highlights the value of a structured training environment for both senior and junior surgeons, ensuring consistent clinical outcomes. While the emergence of robotic-assisted adrenalectomy represents a promising adjunct with potential ergonomic and technical advantages, its broader implementation remains limited by economic constraints and restricted access to robotic platforms. Future research should continue to compare both modalities through large-scale, prospective studies to further delineate their respective roles in modern adrenal surgery.

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