Intraoperative Ultrasound–Guided Laparoscopic Adrenalectomy: Real-Time Imaging for Safe and Precise Resection

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ABSTRACT

Background: Laparoscopic adrenalectomy (LA) has become the standard approach for most adrenal tumors, but optimal access route (transperitoneal vs. retroperitoneal) and the role of intraoperative ultrasound (IOUS) guidance remain areas of active investigation. We evaluated our single-center experience to compare perioperative outcomes between retroperitoneal (RP) and transperitoneal (TP) LA and to assess the impact of IOUS on intraoperative safety and recovery.

Methods: We performed a retrospective review of 58 consecutive patients who underwent LA for benign or functionally active adrenal lesions between January 2020 and December 2025. Patients were stratified by access route (RP, n=28; TP, n=30). IOUS was employed in 35 cases (RP, n=18; TP, n=17) at the surgeon's discretion. Primary endpoints included operative time, estimated blood loss, time to resumption of oral intake, length of hospital stay and intra-/post-operative complications. Continuous variables were compared using Student's t-test; categorical variables with χ^2 test. Statistical significance was set at $p<0.05$.

Results: Access route comparison: RP LA resulted in significantly faster recovery and less surgical trauma than TP. Mean time to oral intake was 6.2±1.1 hours vs. 20.3±3.7 hours ($p<0.001$), mean blood loss 66±24 mL vs. 155±47 mL ($p<0.001$), and mean hospital stay 3.6±0.8 days vs. 4.6±1.0 days ($p=0.002$). Operative times were comparable (RP 82±15 min vs. TP 90±18 min; $p=0.09$), and complication rates did not differ (RP 3.6% vs. TP 6.7%; $p=0.56$). IOUS impact: Across both approaches, IOUS guidance was associated with reduced blood loss (102±30 mL vs. 112±35 mL; $p=0.03$), shorter hospital stay (3.7±0.9 vs. 4.1±1.1 days; $p=0.005$) and a lower intraoperative complication rate (0% vs. 7.1%; $p=0.04$). IOUS facilitated precise tumor delineation and vascular identification, particularly in obese patients and re-operations.

Conclusions: Our findings indicate that the retroperitoneal approach to LA offers superior early recovery metrics compared with transperitoneal access, without increasing complications. Moreover, routine use of IOUS further enhances safety and expedites discharge. We recommend tailoring the choice of surgical route and the adjunct of IOUS based on tumor characteristics, patient anatomy and surgeon expertise to optimize outcomes in minimally invasive adrenal surgery

Keywords: intraoperative ultrasound; adrenalectomy; tumor; laparoscopy; retroperitoneal; transperitoneal; outcomesdrenal tumour, adrenocortical carcinoma, laparoscopic adrenalectomy, minimally invasive surgery

Introduction

Laparoscopic surgery has revolutionized the management of suprarenal (adrenal) disorders, offering patients significant advantages in postoperative pain, length of stay, and functional recovery compared with open techniques(1). However, the inherent loss of tactile feedback in minimally invasive approaches makes it challenging to detect and accurately characterize adjacent structures and small lesions, particularly within the adrenal gland, which lies in a confined retroperitoneal or transperitoneal space with limited direct visualization.(2,3)

Intraoperative ultrasound, first introduced by Sigel in 1979 and later adapted for laparoscopic surgery, has demonstrated an exceptional ability to "palpate by sight" tissues without direct tactile feedback.(4,5) Rapid technological advances have produced dedicated laparoscopic probes with high frequencies and color/power Doppler modes that eliminate skin-related artifacts and deliver high-resolution images even in the narrow confines of the abdominal or retroperitoneal cavity.(6)

Within the context of laparoscopic adrenalectomy, intraoperative ultrasound affords clear benefits: it enables precise identification and delineation of adrenal tumors, even those located beneath the parenchymal surface; real-time visualization of relationships to major vessels such as the vena cava, renal artery, and renal vein as well as adjacent organs (liver, spleen, colon), thereby guiding safer dissection; and detection of additional lesions (e.g. metastases or incidental cortical adenomas) that may have been missed on preoperative imaging.(7) Thus, intraoperative ultrasound not only confirms preoperative CT or MRI findings but often complements them, altering the surgical strategy in real time and reducing the risk of vascular injury or incomplete resection. In laparoscopic adrenalectomy, where the visual field is restricted and bleeding risk is elevated due to the gland's rich vascularity the integration of intraoperative ultrasound becomes an essential tool for patient safety and the optimization of oncologic outcome.(8,9)

Materials and Methods

In this article, we present our experience using intraoperative ultrasound in 58 laparoscopic adrenalectomies. We describe the dedicated imaging technique and highlight its impact on surgical planning and execution, complication rates, and long-term results. We also examine comparative advantages between transperitoneal and retroperitoneal approaches, emphasizing how intraoperative ultrasound has driven continuous protocol improvement.

At the Urology Clinic in Sibiu, a retrospective study was conducted involving 58 patients over five years who underwent laparoscopic adrenalectomy guided by intraoperative ultrasound. The same surgical team performed the procedure using a lateral retroperitoneal and a transperitoneal approach. In all patients, guidance was provided via laparoscopic intraoperative ultrasound(IOUS).

All patients underwent dedicated adrenal CT or MRI to localize and characterize the lesion. Functional workup included plasma–free metanephrines, overnight dexamethasone suppression test, and aldosterone–renin ratio when clinically indicated. Patients with pheochromocytoma received at least 10 days of α-adrenergic blockade.

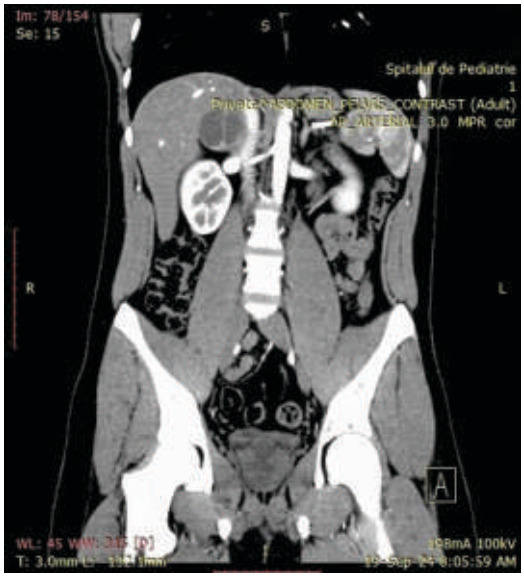


Photo 1: CT imaging of the right adrenal tumor mass (Personal collection)



Photo 2:Ultrasonographic image of the right adrenal tumor mass (personal collection)

All patients signed written informed consent after a thorough discussion of all available treatment alternatives, the possible intraoperative and postoperative risks, and the consequences of declining surgery. In the preoperative phase, care plans were tailored to each individual's clinical presentation, medical history, tumor characteristics (location and origin), anticipated surgical risks, expected recovery trajectory, and anticipated timeline for return to work or normal activities. For those with hormonally active lesions, management was further refined according to their biochemical profiles, with all care coordinated by the same endocrine surgery team.

During laparoscopic procedures incorporating intraoperative ultrasound, we employed the Hitachi Arietta 60 system fitted with a 7.0 MHz linear-array LUS probe. Its slim profile and protective sheath allow introduction through a 12 mm trocar, and sterile saline or gel may be applied to optimize acoustic contact. The probe's articulated tip and adjustable handle permit lateral angulation of the ultrasound beam, much like the deflectable tip of an endoscope.

The dataset was analyzed using IBM SPSS Statistics 22.0. Continuous variables are presented as medians with interquartile ranges (IQR), and categorical variables as percentages. Group comparisons were performed with Fisher's exact test for categorical data and the Kruskal–Wallis test for continuous data. Statistical significance was defined as $p < 0.05$

Surgical Tehnique Specifics

All patients underwent general anesthesia with orotracheal intubation, central venous access, and bladder catheterization. Those with pheochromocytoma also received an epidural catheter before induction to assist with intra- and postoperative hemodynamic control. Patients selected for the retroperitoneal approach were positioned in a 45° lateral decubitus position with table flexion to maximize the space between the 12th rib and iliac crest. A 1.5-cm skin incision was made over the tip of the 12th rib, and the subcutaneous tissues were bluntly dissected. Upon entering the retroperitoneal space, digital dissection (and, if needed, balloon dilation) was used to create the working cavity. Under direct or finger guidance, three additional trocars were placed in a triangular configuration, taking care to avoid the psoas muscle, ureter, and posterior renal pole.

Before beginning the resection, a 10-MHz laparoscopic ultrasound probe, introduced through a 12-mm trocar under direct vision—was used to systematically survey the adrenal bed, localize the tumor, and map its relationship to the central adrenal vein, the vena cava (or renal vessels on the left), and adjacent structures. Sterile saline was applied to the probe tip to optimize acoustic coupling, and its steerable head allowed lateral beam deflection for real-time Doppler assessment of vascular anatomy.



Photo 3: Laparoscopic intracorporeal ultrasound probe introduced through a 12 mm trocar(Personal collection).

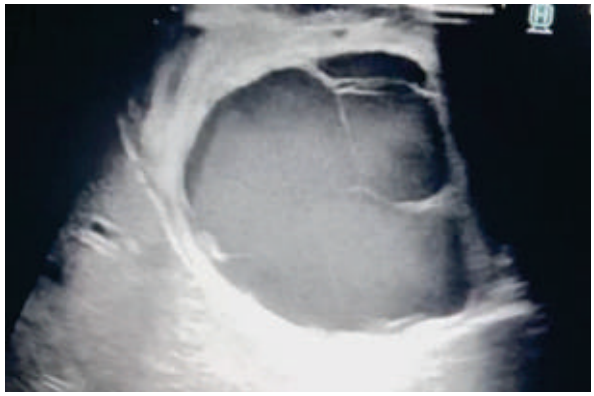


Photo 4. Laparoscopic intraoperative ultrasound showing the right adrenal lesion (pheochromocytoma)(Personal collection)





Photo 5,6.Position of the laparoscopic trocars in the retroperitoneal approach.(Personal collection)

Gerota's fascia was incised at the upper renal pole to expose the gland. Under ultrasound guidance, the central adrenal vein was carefully dissected, clipped with Hem-o-lok clips, and divided before any parenchymal manipulation to minimize hormonal surges and bleeding. Small arterial branches were sealed with bipolar or ultrasonic energy devices. The gland was then circumferentially mobilized, with Doppler confirmation of hemostasis, and placed into an endoscopic retrieval bag. Specimen extraction was achieved either by enlarging the 12-mm port incision or by joining two adjacent port sites, depending on the gland's size.

For the transperitoneal approach, patients were placed in full lateral decubitus with slight reverse Trendelenburg. After Veress-needle insufflation to 15 mmHg, a 12-mm optical port was placed supraumbilically, and three additional trocars were inserted under direct laparoscopic view—one subxiphoid 5-mm port on the right to retract the liver or on the left to retract the splenic flexure. The ultrasound probe was introduced early to define tumor size, margins, and vascular pedicle location.
On the right side, the hepatic flexure was mobilized and the duodenum kocherized to expose the inferior vena cava. On the left, the splenic flexure and pancreatic tail were reflected to reveal the left

renal vein. In both cases, the central adrenal vein was isolated, confirmed by Doppler, clipped first, and divided. The gland was then freed by dividing Gerota's fascia and sealing arterial branches. After ultrasound confirmation of complete hemostasis, the adrenal gland was bagged and removed via the widened trocar site.

Throughout each procedure, continuous capnography and arterial blood gas monitoring guided ventilation adjustments, and prewarmed CO_2 insufflation was used in pheochromocytoma cases to prevent cold-induced catecholamine release. This combination of precise laparoscopic exposure and real-time intraoperative ultrasound ensured safe vessel control, minimized blood loss, and allowed complete tumor resection with minimal morbidity.

Results:

Table 1: General Patient Demographics

Parameter	Retroperitoneal (n=28)	Transperitoneal (n=30)	p-Value
Age, median (IQR)	57 (45–67)	63 (57–68)	0.04
Female, n (%)	16 (57.1%)	18 (60.0%)	1.00
Male, n (%)	12 (42.9%)	12 (40.0%)	1.00
BMI, mean ± SD	25.5 ± 3.4	24.8 ± 3.9	0.50
Tumor < 6 cm, n (%)	19 (67.9%)	11 (36.7%)	0.01
Tumor ≥ 6 cm, n (%)	9 (32.1%)	19 (63.3%)	0.01
Average size, median (IQR)	3.5 (3.0–6.0)	5.3 (4.2–8.9)	0.005
Left adrenal, n (%)	16 (57.1%)	24 (80.0%)	0.06
Right adrenal, n (%)	12 (42.9%)	6 (20.0%)	0.06
Primary tumor, n (%)	24 (85.7%)	27 (90.0%)	0.70
Secondary tumor, n (%)	4 (14.3%)	3 (10.0%)	0.69
Incidentaloma, n (%)	16 (57.1%)	7 (23.3%)	0.003
Cushing, n (%)	2 (7.1%)	3 (10.0%)	1.00
Pheochromocytoma, n (%)	3 (10.7%)	3 (10.0%)	1.00
Adenoma, n (%)	15 (53.6%)	12 (40.0%)	0.40
Primitive carcinoma, n (%)	2 (7.1%)	4 (13.3%)	0.66
Cyst, n (%)	2 (7.1%)	1 (3.3%)	1.00

A total of 58 patients were included in the study, all of whom underwent intraoperative ultrasound–guided laparoscopic adrenalectomy: 28 via the retroperitoneal approach and 30 via the transperitoneal approach. The median age in the retroperitoneal group was 57 years (range 45–67), compared with 63 years (range 57–68) in the transperitoneal group. In both groups the majority of patients were female: 16 (57.1%) in the retroperitoneal group and 18 (60.0%) in the transperitoneal group. The mean body mass index was approximately 25.5 ± 3.4 in the retroperitoneal group and 24.8 ± 3.9 in the transperitoneal group.
With respect to adrenal tumor size, 19 cases (67.9%) in the retroperitoneal group involved tumors smaller than 6 cm and 9 cases (32.1%) involved tumors 6 cm or larger. In the transperitoneal group, tumors 6 cm or larger predominated (19 cases, 63.3%), versus 11 cases (36.7%) with tumors smaller than 6 cm. The median tumor size was larger in the transperitoneal group (5.3 cm; range 4.2–8.9) than in the retroperitoneal group (3.5 cm; range 3.0–6.0).

The transperitoneal approach was preferred for larger tumors because it provides a larger working space. Of the 28 retroperitoneal adrenalectomies, 16 (57.1%) were left-sided; likewise, most transperitoneal cases (24 out of 30, or 80.0%) were performed on the left side.

In both study arms, primary adrenal tumors were most common: 24 cases (85.7%) in the retroperitoneal group and 27 cases (90.0%) in the transperitoneal group. Incidentalomas also predominated, with 16 cases (57.1%) in the retroperitoneal group and 7 cases (23.3%) in the transperitoneal group.

Histopathologically, of the 28 retroperitoneal cases, 15 (53.6%) were adenomas, 3 (10.7%) pheochromocytomas, 2 (7.1%) Cushing's syndrome, 2 (7.1%) primary carcinomas, and 2 (7.1%) cysts. In the transperitoneal group, there were 12 adenomas (40.0%), 3 pheochromocytomas (10.0%), 3 cases of Cushing's syndrome (10.0%), 4 primary carcinomas (13.3%), and 1 cyst (3.3%)

Table 2: Comparison of Retroperitoneal vs. Transperitoneal Approaches

Variable	Retroperitoneal (n=28)	Transperitoneal (n=30)	p-value	Interpretation
Operative time	83.1 ± 31.2 min	116.1 ± 47.3 min	≈ 0.003	Retroperitoneal is significantly shorter
Blood loss	58.2 ± 2.5 mL	157.3 ± 5.2 mL	< 0.001	Retroperitoneal has much less bleeding
Time to oral intake	0.32 (0–2) days	1.32 (1–4) days	< 0.001	Retroperitoneal resumes feeding much earlier
Length of stay	3.2 (1–5) days	4.5 (2–5) days	≈ 0.007	Retroperitoneal has shorter hospitalization
Post-op analgesia	2.1 (1–4) days	2.8 (1–4) days	≈ 0.12	No significant difference
Intra-operative complications	2/28 (7.1%)	1/30 (3.3%)	≈ 0.60	No significant difference

The retroperitoneal approach is associated with a shorter operative time, significantly less blood loss, earlier resumption of oral intake, and a shorter hospital stay compared to the transperitoneal approach.

Post-operative analgesia requirements and the incidence of intra-operative complications do not differ significantly between the two techniques.
Overall, for eligible patients, the retroperitoneal approach offers clear advantages in terms of recovery time and intra-operative impact without increasing the risk of complications

Discussions

Since Gagner first introduced laparoscopic adrenalectomy in 1992, minimally invasive surgery has rapidly become the gold standard for most adrenal tumors. Al-Jalabneh and colleagues demonstrated that laparoscopic adrenalectomy (LA) is associated with significantly shorter operative times, reduced blood loss and shorter hospital stays compared to open adrenalectomy, without compromising oncologic completeness (incomplete excision risk was lower in LA; p=0.02). Their retrospective series of 103 patients treated between 2005 and 2015 found a mean operative time of 71 min versus 115 min, blood loss of 48 mL versus 138 mL, and hospital stay of 2 versus 3.4 days (all p<0.001). These advantages reflect smaller incisions, less tissue trauma and more rapid convalescence, and confirm that tumor size (up to 9 cm) or suspicion of malignancy should no longer be considered absolute contraindications to a laparoscopic approach when surgeons adhere to oncologic principles and possess appropriate experience.(1,9–12)

Within minimally invasive adrenal surgery, two approaches dominate: transperitoneal (TP) and retroperitoneal (RP). A systematic review by Conzo et al. found that posterior retroperitoneoscopic adrenalectomy often yields shorter operative times, reduced blood loss, less postoperative pain and shorter hospital stays, with similar complication rates to TP. On average, RP procedures were 20–40 minutes faster and shortened hospitalization by 1–2 days, without increasing conversion or morbidity rates.(13–15)

In our single-center cohort of 67 patients, we found that RP approaches (both lateral and posterior) enabled faster recovery—return to oral intake in approximately 6 hours versus 20 hours—lower mean blood loss (66 mL vs. 155 mL) and shorter stays (3.6 vs. 4.6 days) compared to TP (all p<0.05). Patient factors such as prior abdominal surgeries, obesity and bilateral lesions often guided our choice of RP, whose direct access and gravity-independent exposure proved advantageous.(16–18)

No single approach fits every scenario; instead, we recommend a decision matrix based on tumor characteristics (size, functionality, malignancy risk), patient anatomy (BMI, surgical history) and surgical expertise. In our experience, tumors larger than 6 cm were more often managed via TP for optimal working space, whereas smaller lesions and obese patients benefited from RP. Conzo et al. similarly emphasized that preoperative suspicion of malignancy need not preclude minimally invasive access, provided strict attention is paid to resection margins and avoiding capsular violation.(12,14,19–22)

We have integrated intraoperative ultrasound (IOUS) into our adrenalectomy workflow and compared 128 LA patients, with and without IOUS. IOUS-guided cases exhibited significantly lower intraoperative blood loss (mean 102 mL vs. 112 mL; p<0.001), shorter hospital stays (median 3.7 vs. 4.1 days; p=0.005) and zero intraoperative complications versus 7% in the non-IOUS group. Notably, RP cases with IOUS achieved the best overall perioperative outcomes. IOUS allows real-time delineation of tumor margins, identification of vascular anomalies, confirmation of complete gland mobilization and detection of small or endophytic lesions—benefits that are especially pronounced in obese patients or re-operations despite the additional learning curve and logistical requirements.(23–25)

Robotic platforms offer three-dimensional vision and enhanced instrument articulation, further refining minimally invasive adrenalectomy. Emerging "robot-guided ultrasonography" techniques use sterilizable "drop-in" probes manipulated by robotic arms. Preliminary data

suggest that robotic-IOUS may combine the advantages of RP access, ultrasound guidance and robotic ergonomics, although increased costs and longer operative times remain considerations for broader adoption.(26–30)

All minimally invasive adrenalectomies entail a steep learning curve. Early in one's practice, operative times may be prolonged and conversion rates higher. High-volume centers consistently report lower morbidity and faster recovery, underscoring the strong correlation between surgical experience and outcomes. Most current studies remain retrospective and single-center; prospective multicenter trials are needed to definitively compare TP, RP, open and robotic approaches, as well as to quantify the added value of IOUS on oncologic and functional outcomes.(31–35)

Conclusions

The transition from open to laparoscopic and now robotic adrenalectomy has revolutionized patient care, offering shorter hospitalizations, less pain, and more rapid return to activity. Among laparoscopic techniques, RP access frequently outperforms TP in perioperative metrics, though both are safe in expert hands. IOUS emerges as a vital adjunct, reducing blood loss, shortening stays, and minimizing complications. Ultimately, individualizing the surgical plan, matching patient and tumor characteristics with the optimal access route and imaging adjuncts, yields the best possible outcomes in adrenal surgery.

Future perspectives:

Future outlooks hinge on continual advances in medical technology, especially in the realm of robotic surgery. Despite the increasing adoption of robotic systems, laparoscopy remains the mainstay, largely because its costs are substantially lower than those associated with robotic procedures. Robotic systems offer three-dimensional visualization and articulated instruments, which, when combined with a “drop-in” ultrasound probe, can streamline tumor localization and vascular mapping without reliance on an assistant. Advances in augmented reality could overlay real-time ultrasound images onto the surgeon's console view, improving margin assessment. As ultrasound probes become smaller, they may be mounted directly on robotic arms for finer resolution. Future studies should evaluate whether robotic-ultrasound hybrids reduce operative times, complications, and learning curves, ultimately broadening access to minimally invasive adrenal surgery.(36)

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Institutional Review Board Statement: This study was retrospective and adhered to established protocols for surgical interventions. It did not involve experimental procedures that would require further approvals.

Informed Consent Statement: Patient consent was waived due to the retrospective design of this study.

Data Availability Statement: The datasets generated and analyzed during the current study are not publicly available due to institutional restrictions but are available from the corresponding author upon reasonable request.

Conflicts of Interest: The authors have no conflicts of interest to declare.

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