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RESEARCH

Comparative outcomes of laparoscopic vs robotic paraganglioma excision: a tertiary care center experience

Jay Mehta[a], Aditya Sharma[a, *], Jagadeep Ajmera[a], Sudheer Devana[a], Girdhar Bora[a], Ravimohan Mavuduru[a], Santosh Kumar[a], Uttam Mete[a,]

[a] *Department of Urology, Post Graduate Institute of Medical Education and Research, Chandigarh, India.*

Abstract

Background: Paragangliomas are rare neuroendocrine tumors that require complete surgical excision. While laparoscopic surgery has been the minimally invasive standard, robotic-assisted surgery offers potential advantages, including enhanced visualization and articulation. This study compares perioperative outcomes between laparoscopic and robotic approaches for paraganglioma excision.
Methods: A retrospective analysis of 24 consecutive patients who underwent minimally invasive excision of paragangliomas at our tertiary care center between 2015 and 2025 was conducted. Patients were divided into two groups: robotic-assisted (n = 6) and laparoscopic (n = 18) approaches. Demographics, biochemical markers, operative parameters, complications, length of hospital stay, and follow-up outcomes were compared between groups. Statistical analysis was performed using the Mann-Whitney U test for continuous variables and the chi-square test for categorical variables.
Results: The mean age was similar between groups (robotic: 38.3 ± 13.1 years *vs*. laparoscopic: 39.2 ± 16.7 years, P = 0.97). Operative duration was significantly longer in the robotic group (190.0 ± 31.0 min *vs*. 143.3 ± 43.1 min, P = 0.021). However, there were no significant differences in length of hospital stay (7.7 ± 1.8 *vs*. 5.9 ± 3.1 days, P = 0.23) or complication grades (Clavien-Dindo 2.17 ± 0.41 *vs*. 2.22 ± 0.43, P = 0.81). Both groups achieved 100% biochemical remission at follow-up with complete histopathological excision in all cases.
Conclusion: Both laparoscopic and robotic approaches for paraganglioma excision are safe and effective with comparable perioperative outcomes. While robotic surgery requires longer operative time, it offers an equivalent safety profile and oncological outcomes. The choice of approach may depend on tumor location, complexity, and surgeon experience.
Keywords: Paraganglioma, robotic surgery, laparoscopic surgery, minimally invasive surgery, neuroendocrine tumor, pheochromocytoma

Introduction

Paragangliomas are rare neuroendocrine tumors arising from extra-adrenal chromaffin cells of the autonomic nervous system, with an estimated incidence of 1-2 per 100,000 persons per year [1]. These tumors can be functional, secreting catecholamines, or non-functional, and may occur in various anatomic locations, including the retroperitoneum, pelvis, thorax, and head and neck regions [2]. Complete surgical excision remains the cornerstone of treatment for paragangliomas, offering the only potential for cure and long-term disease control [3].

The advent of minimally invasive surgical techniques has revolutionized the management of paragangliomas. Laparoscopic surgery, introduced in the 1990s, has become the standard approach for accessible retroperitoneal paragangliomas, offering advantages of reduced postoperative pain, shorter hospital stays, and improved cosmetic outcomes compared to open surgery [4, 5]. However, laparoscopic surgery can be technically challenging, particularly for tumors in difficult anatomic locations or those with complex vascular relationships.

Robotic-assisted surgery, representing the latest evolution in minimally invasive techniques, offers several advantages, including three-dimensional high-definition visualiza-

* Corresponding author: Aditya Sharma
Mailing address: Department of Urology, Post Graduate Institute of Medical Education and Research, Chandigarh, India.
Email: aditya.p.sharma@gmail.com
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tion, enhanced dexterity with articulating instruments, improved ergonomics for the surgeon, and tremor filtration [6, 7]. These features may be particularly beneficial for resecting paragangliomas, which often require meticulous dissection in confined spaces near critical vascular structures.

Despite the increasing adoption of robotic surgery for various urological and oncological procedures, comparative data on robotic versus laparoscopic approaches for paraganglioma excision remain limited, both due to the rarity of the disease and the application of robot-assisted surgery for paraganglioma excision. Most published literature consists of case series or small retrospective studies, with few direct comparisons between the two minimally invasive modalities [8, 9].

This study aims to compare the perioperative outcomes, safety profile, and efficacy of laparoscopic versus robotic-assisted surgical approaches for paraganglioma excision in a consecutive series of patients treated at our tertiary care center. Paraganglioma (irrespective of location) excision is routinely performed by urologists at our center.

Material and methods

Study design and patient population

This retrospective cohort study included 24 consecutive patients who underwent minimally invasive excision of paraganglioma at our institution. The patients underwent either laparoscopic or robotic excision: 6 patients underwent robotic excision, and 18 patients underwent laparoscopic excision. The selection of the surgical approach was based on multiple factors, including tumour location, surgeon's preference, and affordability of the robotic procedure/patient choice. For example, one patient with a urinary bladder paraganglioma and one patient with a thoracic component underwent robotic excision. Tumours located in narrow spaces, such as the pelvis or thorax, were deemed more suitable for a robotic approach than a laparoscopic approach. The decision to proceed with robotic surgery also considered surgeon preference, complex location, patient choice, and the ease of the robotic approach. However, robotic surgery is more costly than laparoscopic surgery, and due to poor insurance penetration for robotic surgery, most patients bear out-of-pocket expenses, which is another important factor influencing the choice of approach.

Ethical Considerations

The study was conducted in accordance with the Declaration of Helsinki. An exemption for full ethical review was obtained from the Institutional Ethics Committee (Postgraduate Institute of Medical Education and Research [PGIMER], Chandigarh, India; Vide letter No. Urol/2026/904). All patients provided informed consent for surgery, data collection, publication, and research.

Inclusion and exclusion criteria

All patients undergoing surgical excision had a complete preoperative workup, including biochemical and imaging evaluation, with a minimum follow-up of 3 months post-surgery. Patients who underwent open surgical excision, had incomplete medical records, presented with metastatic disease, or had prior surgical intervention for the same lesion were excluded from the study. None of the laparoscopically or robotically performed surgeries required conversion to open surgery.

Preoperative workup

All patients underwent a comprehensive preoperative assessment, including:

Biochemical testing in the form of either 24-hour urinary metanephrine and normetanephrine, Plasma-free metanephrine and normetanephrine. Additional hormonal workup as clinically indicated.

Imaging studies including either Contrast-enhanced computed tomography (CECT) of abdomen and pelvis, Functional imaging with ^{18}F-fluorodeoxyglucose positron emission tomography (FDG-PET) and/or ^{68}Ga-DOT-

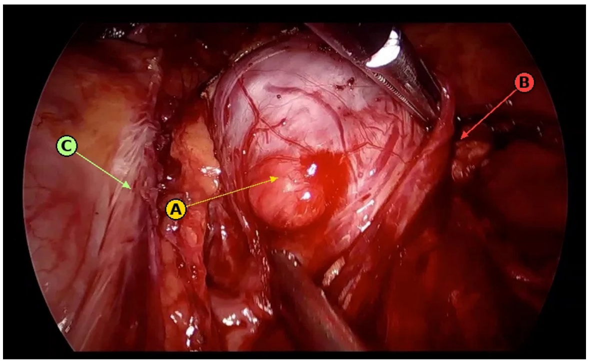

Figure 1. Dissection of paraganglioma. (**A**) Laparoscopic excision of left para aortic paraganglioma. (**B**) The image demonstrates a well-encapsulated, highly vascular retroperitoneal paraganglioma situated along the left renal vein. Circumferential dissection is being performed along the tumor capsule using sharp and blunt techniques while maintaining an avascular plane between the lesion and surrounding major vascular structures. Colon (**C**) has been reflected medially over the aorta.

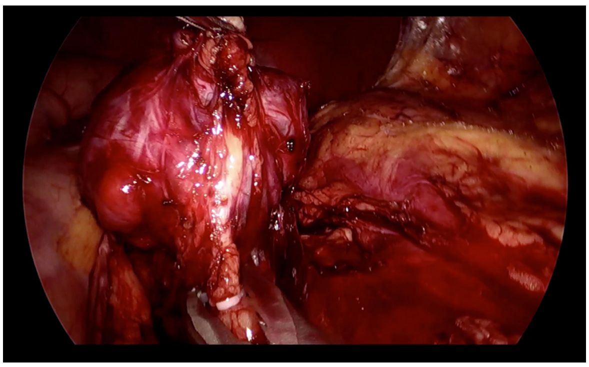

Figure 2. Clipping of the feeding vessel over the aorta (marked with an arrow). The figure is a later surgical step of the Figure 1 and shows clipping of the feeder vessel.

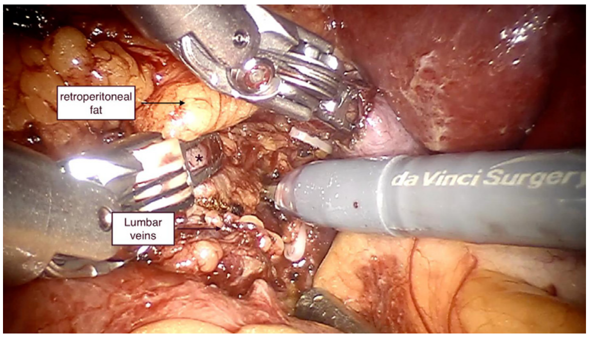

Figure 3. Robotic paraganglioma excision (*mark shows paracaval paraganglioma, Star mark demonstrates IVC).

ATATE PET-CT (DOTANOC PET). Additional imaging as required based on specific tumor locations.
Cardiovascular preparation: All patients with biochemically functional tumors received preoperative alpha-adrenergic blockade with adequate duration (minimum 10 -14 days) to achieve blood pressure control and prevent intraoperative hypertensive crises. Beta-blockers were added as needed after adequate alpha-blockade.
The surgical techniques followed in laparoscopic and robotic cases were as described.

Surgical techniques

Laparoscopic approach: The laparoscopic procedure was performed using a transperitoneal approach with 3–4 ports. Standard laparoscopic instruments were used for dissection, with careful identification and preservation of vital structures. Vascular control was achieved using clips or energy devices as appropriate.
The crucial steps during a retroperitoneal dissection are the identification of major vessels, including IVC, renal veins and their potential control. For functional paragangliomas, it is of utmost importance to achieve venous control first, followed by dissection of the tumor. Figure 1 and 2 depict an intraoperative image of paraaortic paraganglioma excision.
Robotic Approach: Robotic-assisted surgery was performed using the da Vinci Si Surgical System (Intuitive Surgical, Sunnyvale, CA, USA). A transperitoneal approach was utilized with 4-5 ports. The robotic system provided three-dimensional visualization and articulating instruments for precise dissection around critical structures. Figure 3 is the intraoperative picture of paracaval paraganglioma excision, showing paracaval paraganglioma dissection in the subhepatic/paracaval plane with liver retracted superiorly. The third arm is used for gall bladder retraction. Robotic technique offers advantages in difficult surgical locations (viz., thoracic and pelvic for bladder paraganglioma) with better surgical manoeuvrability.
In both approaches, the surgical principles included Careful dissection with minimal tumor manipulation, early vascular control when feasible, complete excision with intact tumor capsule and lymph node sampling when indicated.

Data collection

The following data were collected from electronic medical records:
Demographics and baseline characteristics: Age, sex, body mass index, Comorbidities, and ASA physical status classification.
Biochemical and imaging parameters: Preoperative catecholamine levels, Imaging findings including tumor size and location.
Perioperative outcomes (primary): Operative duration (skin incision to closure), Estimated blood loss, Intraoperative complications, Conversion to open surgery.
Postoperative outcomes: Length of hospital stay, Postoperative complications (graded using Clavien-Dindo classification), Pain scores, Time to oral intake.
Oncological outcomes: Histopathological diagnosis, Tumor size (on pathology), Margin status, GAPP score (Grading system for Adrenal Pheochromocytoma and Paraganglioma) when reported, PASS score (Pheochromocytoma of the Adrenal Gland Scaled Score) when reported.
Follow-up data: Biochemical remission (normalization of catecholamine levels), recurrence, disease-free survival.

Statistical analysis

Continuous variables were expressed as mean ± standard deviation (SD) or median with range, as appropriate. Categorical variables were presented as frequencies and percentages. The Mann-Whitney U test was used to compare continuous variables between groups, while the chi-square test or Fisher's exact test was used for categorical variables. A p-value of < 0.05 was considered statistically significant. All statistical analyses were performed using Python (version 3.10) with the SciPy library.
Some variables were not analysed between the two groups, including imaging modality used for diagnosis, tumour locations, histopathology reporting, and biochemical variables. This was due to the retrospective nature of the study, where investigations were not performed accord-

Table 1. Demographic data of patient cohorts.

	Robotic group (n = 6)	Laparoscopic group (n = 18)	P-value
Age (years)	38.3 ± 13.1 (27-62)	39.2 ± 16.7 (13-65)	0.973
Sex, n (%)			1.000
Male	3 (50.0%)	7 (38.9%)	—
Female	3 (50.0%)	11 (61.1%)	—
BMI, kg/m²	23.2 ± 3.1 (20-27)	24.4 ± 3.7 (21-28)	0.550
Comorbidities, n (%)	1 (16.7%)	1 (5.6%)	—
Comorbidity type, n (%)			0.437
Hypertension	6 (100%)	12 (66.7%)	
Diabetes	0	0	—
CAD	1 (16.7%)	0	—
Gilbert syndrome	0	1 (5.6%)	—

Table 2. Functional characteristics of tumors.

	Robotic group (*n* = 6)	Laparoscopic group (*n* = 18)
Elevated plasma free metanephrines, *n* (%)	2 (33.3%)	4 (22.2%)
Elevated plasma free normetanephrines, *n* (%)	6 (100.0%)	12 (66.7%)
Elevated 24 hr urinary free metanephrines, *n* (%)	1 (16.7%)	2 (11.1%)
Elevated 24 hr urinary free normetanephrines, *n* (%)	2 (33.3%)	3 (16.7%)
Functionally active tumors, *n* (%)	6 (100.0%)	14 (77.8%)

Table 3. Anatomical characteristics of tumors.

	Robotic group (*n* = 6)	Laparoscopic group (*n* = 18)
Imaging modality		
CECT abdomen, *n* (%)	4 (66.7%)	14 (77.8%)
DOTANOC PET, *n* (%)	4 (66.7%)	13 (72.2%)
FDG PET, *n* (%)	3 (50%)	5 (27.8%)
Tumor location		
Paraaortic, *n* (%)	3 (50%)	12 (66.7%)
Aortocaval, *n* (%)	1 (16.7%)	3 (16.7%)
Paracaval, *n* (%)	1 (16.7%)	2 (11.1%)
Urinary bladder, *n* (%)	1 (16.7%)	0
Other, *n* (%)	0	1 (5.6)
Tumor size (cm)	2.8 ± 1.3 (1.5-4.5)	2.5 ± 1.2 (1.2-4.0)

ing to a standardized protocol but depended on clinical indication, availability, and evolving institutional practice over the study period. Additionally, the small sample size made meaningful subgroup comparisons unreliable; these variables were therefore considered descriptive rather than comparative.

Results

A total of 24 patients underwent minimally invasive excision of paragangliomas during the study period. Six patients (25%) underwent robotic-assisted surgery, while 18 patients (75%) underwent conventional laparoscopic surgery. None of the cases required conversion to open surgery. Table 1 shows the demographic data of the patients in the two study groups.

The mean age of patients in the robotic group was 38.3 ± 13.1 years (range: 27-62 years) compared to 39.2 ± 16.7 years (range: 13-65 years) in the laparoscopic group (P = 0.97). There was an equal distribution of males and females in the robotic group (50% each), while the laparoscopic group had 38.9% males and 61.1% females (P = 1.00). Comorbidities other than hypertension (which was present in 18 patients) were uncommon, present in 1 patient (16.7%) in the robotic group and 1 patient (5.6%) in the laparoscopic group.

Table 4. Perioperative outcomes.

	Robotic group (*n* = 6)	Laparoscopic group (*n* = 18)	*P*-value
Operative duration (min)	190 ± 31.0 (150-240)	143.3 ± 43.1 (90-240)	0.021
Length of hospital stay (days)	7.7 ± 1.8 (6-11)	5.9 ± 3.1 (2-12)	0.226
Conversion to open surgery	0	0	—
Intraoperative complications	0	0	—

Table 5. Demographic data of patient cohorts.

	Robotic group (*n* = 6)	Laparoscopic group (*n* = 18)	*P*-value
Clavien-Dindo Grade	2.17 ± 0.41	2.22 ± 0.43	0.810
Grade distribution, *n* (%)			1.00
Grade 1	0	0	
Grade 2	5 (83.3%)	14 (77.8%)	
Grade 3	1 (16.7%)	4 (22.2%)	
Grade 4	0	0	
Grade 5	0	0	
Any complications, *n* (%)	6 (100%)	18 (100%)	—

Preoperative biochemical evaluation revealed that plasma-free normetanephrine was elevated in all 6 patients (100%) in the robotic group and in 12 of 18 patients (66.7%) in the laparoscopic group (Table 2). Plasma-free metanephrine elevation was documented in 2 robotic patients (33.3%) and 4 laparoscopic patients (22.2%).

The higher rate of biochemical functionality in the robotic group may reflect case selection.

Preoperative imaging evaluation included multiple modalities to accurately localize and characterize the tumors (Table 3). CECT abdomen was performed in 4 robotic patients (66.7%) and 14 laparoscopic patients (77.8%). Functional imaging with DOTANOC PET was utilized in 4 robotic cases (66.7%) and 13 laparoscopic cases (72.2%). FDG-PET was performed in 3 robotic cases (50.0%) and 5 laparoscopic cases (27.8%).

The majority of tumors were located in the para-aortic or paracaval regions in both groups. Specific anatomic locations are mentioned in Table 3, the most common site being Para-aortic (62.5%).

Robotic cases included Para-aortic (50%), Bladder (unique case with partial cystectomy), Aortocaval (17%), Paracaval (17%), with one case having thoracic extension, Adrenal + paraganglioma (synchronous).

Partial cystectomy was done for a paraganglioma involving the dome of the bladder; preoperative ureteric catheterization was not done for the case, and the surgical technique involved standard pelvic docking [10]. Lapa-

Table 6. Histopathological outcomes.

	Robotic group (*n* = 6)	Laparoscopic group (*n* = 18)
Histopathological diagnosis, *n* (%)		
Paraganglioma NOS	5 (83.3%)	17 (94.4%)
Neuroendocrine tumor grade 2	0	1 (5.6%)
Non- chromaffin paraganglioma	1 (16.7%)	0
Complete excision, *n* (%)	6 (100%)	18 (100%)
GAPP score		
reported, *n*	1	5
Range	2/9	0-2/9
PASS score		
reported, *n*	0	1
Score	-	7/20
Ki-67 index		
reported, *n*	1	0
Value, %	2%	-

Table 7. Follow-up outcomes.

	Robotic group (*n* = 6)	Laparoscopic group (*n* = 18)
Biochemical remission, *n* (%)	6 (100%)	18 (100%)
Recurrence, *n* (%)	0	0
Disease- free at last follow up, *n* (%)	6 (100%)	18 (100%)

roscopic cases included Para-aortic (67%), Aortocaval (17%), Paraduodenal (5.6%), and Pelvic (5.6%).

There was a similar tumor size distribution between groups (no significant difference). The primary perioperative outcomes are presented in Table 4. The mean operative duration was significantly longer in the robotic group compared to the laparoscopic group (190.0 ± 31.0 minutes *vs*. 143.3 ± 43.1 minutes, $P = 0.021$). The operative time ranged from 150 to 240 minutes in the robotic group and from 90 to 240 minutes in the laparoscopic group.

Despite the longer operative time, there was no significant difference in the length of hospital stay between the groups. The robotic group had a mean hospital stay of 7.7 ± 1.8 days (range: 6-11 days) compared to 5.9 ± 3.1 days (range: 2-12 days) in the laparoscopic group ($P = 0.23$). There were no conversions to open surgery in either group, and no intraoperative complications were reported.

Postoperative complications were graded using the Clavien-Dindo classification system (Table 5).

The mean complication grade was similar between groups: 2.17 ± 0.41 in the robotic group versus 2.22 ± 0.43 in the laparoscopic group ($P = 0.81$).

In the robotic group, 5 patients (83.3%) experienced Grade 2 complications, while 1 patient (16.7%) had a Grade 3 complication. In the laparoscopic group, 14 patients (77.8%) had Grade 2 complications, and 4 patients (22.2%) experienced Grade 3 complications. No Grade 4 or 5 complications occurred in either group.

Grade 2 complications (requiring pharmacological intervention) were mostly related to transient hemodynamic instability managed medically, wound infections, or minor medical issues. Grade 3 complications (requiring surgical, endoscopic, or radiological intervention) were managed successfully without long-term sequelae.

All specimens were confirmed as paragangliomas on histopathological examination, with the exception of one case in the laparoscopic group that was diagnosed as a neuroendocrine tumor grade 2 (Table 6). Complete excision with negative margins was achieved in all cases.

GAPP (Grading system for Adrenal Pheochromocytoma and Paraganglioma) scores were reported in 6 cases (5 laparoscopic, 1 robotic), with scores ranging from 0 to 2/9, indicating well-differentiated tumors with low metastatic potential. One laparoscopic case had a PASS (Pheochromocytoma of the Adrenal Gland Scaled Score) score of 7/20, which is below the threshold for predicting malignant behavior.

Ki-67 proliferation index, when reported, was low (2% in one robotic case), consistent with benign behavior.

All patients in both groups achieved biochemical remission at 3 months of follow-up, with normalization of plasma metanephrine and normetanephrine levels (Table 7). The robotic group had 100% biochemical cure rate (6/6 patients), as did the laparoscopic group (18/18 patients). Also, no recurrences were documented during the median follow-up period of 1 year in either group.

These excellent oncological outcomes confirm the efficacy of both minimally invasive approaches in achieving complete tumor excision and functional cure.

Discussion

This study represents one of the few direct comparisons between robotic-assisted and laparoscopic approaches for paraganglioma excision. Our findings demonstrate that both minimally invasive techniques are safe and effective, with comparable perioperative outcomes and excellent oncological results. While operative time was significantly longer in the robotic group, there were no significant differences in hospital stay, complication rates, or functional cure rates.

The most notable difference between the two approaches was operative duration, with robotic surgery requiring approximately 47 minutes longer on average than laparoscopic surgery (190 *vs*. 143 minutes, $P = 0.021$). This finding is consistent with several studies comparing robotic and laparoscopic approaches for adrenal and retroperitoneal tumors [7, 11]. The increased operative time in robotic surgery can be attributed to several factors. First, the initial docking and system setup inherently add extra time to the procedure. Second, a learning curve effect may play a role, as operative duration has been shown to decrease with accumulated surgeon experience

[12]. Third, case selection bias cannot be excluded: in our series, all patients in the robotic group had biochemically active, catecholamine-secreting tumors, which may have prompted surgeons to preferentially choose the robotic platform for anatomically challenging or high-risk cases. Importantly, the longer operative time did not translate into increased complications or prolonged hospital stay, suggesting that the additional time is well-tolerated by patients. As institutional experience with robotic surgery grows, operative times are expected to approach those of laparoscopic surgery [13].

The length of hospital stay showed a trend toward being longer in the robotic group (7.7 *vs*. 5.9 days), but this did not reach statistical significance ($P = 0.23$). The relatively longer hospital stays in both groups compared to some published series may reflect several factors. First, paragangliomas—particularly those that are biochemically active—require careful postoperative monitoring for hemodynamic stability and normalization of catecholamine levels. Second, conservative postoperative management with extended observation may reflect our institutional protocol. Third, the presence of catecholamine-secreting tumors in all robotic patients and in the majority of laparoscopic patients necessitated close monitoring of blood pressure and related symptoms. The comparable hospital stays between groups suggest that robotic surgery does not delay recovery or discharge readiness, despite the longer operative time.

Both approaches demonstrated excellent safety profiles with no intraoperative complications and no conversions to open surgery. All postoperative complications were Clavien-Dindo Grade 2 or 3, with no Grade 4 or 5 complications in either group. The similar complication rates (median grade 2 *vs* 2, $P = 0.81$) indicate that robotic surgery is as safe as laparoscopic surgery for paraganglioma excision.

The absence of major vascular injuries or significant bleeding complications in both groups is particularly noteworthy given the proximity of paragangliomas to major vessels such as the aorta and inferior vena cava. This highlights the suitability of minimally invasive approaches for these complex retroperitoneal tumors when performed by experienced surgeons.

The most important finding of this study is the achievement of 100% biochemical cure rates in both groups, with complete histopathological excision and no recurrences during follow-up. This demonstrates that both robotic and laparoscopic approaches are oncologically sound, providing adequate visualization and dexterity to achieve complete tumor excision with negative margins. The reported GAPP and PASS scores indicate low-risk tumors in both groups, which is consistent with the benign behavior of most paragangliomas. The low Ki-67 proliferation index further supports the non-aggressive nature of these tumors.

While our study did not demonstrate clear superiority of robotic surgery in terms of quantifiable outcomes, the robotic platform offers several qualitative advantages that may be particularly relevant for paraganglioma excision. These include: (1) enhanced three-dimensional visualization, especially advantageous when dissecting around major vessels; (2) articulating instruments with seven degrees of freedom, which may facilitate dissection in tight spaces and around complex vascular structures; and (3) reduction in surgeon fatigue during lengthy procedures, potentially maintaining precision throughout the operation. Specific anatomic challenges: For tumors in particularly challenging locations (*e.g.*, bladder paragangliomas, paracaval lesions or with thoracic extensions), the enhanced capabilities of robotic surgery may be more evident.

An important limitation of this study is the lack of cost analysis. Robotic surgery is associated with higher upfront costs related to equipment acquisition and maintenance, as well as higher per-case costs for disposable instruments [14]. This is one major limitation in the adoption of robot-assisted surgery for paraganglioma or adrenalectomies in our part of the world, where out-of-pocket expenditure deters its use in cases where the obvious advantage of the robot is still debatable. However, if the longer operative time does not translate into increased complications or hospital stay, and if robotic surgery enables more surgeons to safely perform minimally invasive paraganglioma excision, the overall cost-effectiveness may become favorable in the long term. Future studies incorporating cost-effectiveness analyses, quality of life assessments, and long-term oncological outcomes are needed to fully evaluate the value proposition of robotic surgery for paraganglioma excision.

This study has several limitations, such as retrospective design, small sample size, case selection bias, and short-term follow-up. Future research should focus on prospective randomized trials—while challenging, given the rarity of paragangliomas, multi-center collaborative efforts could enable adequately powered randomized comparisons—as well as long-term oncological outcomes with extended follow-up (5–10 years) to assess for late recurrences and metastases, cost-effectiveness analyses incorporating direct costs, indirect costs, and quality-adjusted life years, and tumor-specific analyses evaluating how specific tumor characteristics (size, location, functionality, vascularity) influence the relative advantages of each approach.

The findings of this study suggest that both laparoscopic and robotic approaches are viable options for paraganglioma excision, with the choice dependent on tumor factors (location, size, vascularity, and relationship to critical structures), surgeon expertise (experience and comfort level with each technique), and institutional resources (availability of robotic platform and cost considerations). To summarize, a robotic approach should be considered in cases of complex anatomic locations (bladder, paraduodenal, pelvic), difficult vascular anatomy requiring precise dissection, surgeon preference/expertise with the robotic platform and institutional resources available. Laparoscopic approach should be considered in standard para-aortic/paracaval locations, shorter operative time desired, limited robotic platform availability and financial constraints. Both approaches are equally appropriate for most retroperitoneal paragangliomas, functional tumors (with proper preparation), and tumors up to 7 cm. For centers with established robotic programs and surgeon expertise, robotic surgery represents a safe and effective option that may be particularly advantageous for complex or difficult-to-access tumors. Conversely, laparoscopic surgery remains an excellent choice with proven outcomes and potentially shorter operative times.

Conclusions

This comparative analysis demonstrates that both laparoscopic and robotic-assisted approaches for paraganglioma excision are safe, effective, and achieve excellent oncological outcomes. While robotic surgery is associated with longer operative duration, there are no significant differences in hospital stay, complication rates, or biochemical cure rates between the two approaches. Both techniques result in complete tumor excision with 100% biochemical remission at follow-up. Future prospective studies with larger sample sizes and longer follow-up are needed to definitively establish the comparative effectiveness and cost-effectiveness of these two minimally invasive approaches for paraganglioma excision.

Declarations

Author contributions: conceptualization: Sharma A; data collection: Mehta J, Ajmera J; data analysis: Mehta J, Ajmera J; manuscript writing: Mehta J, Sharma A; manuscript revision: Sharma A, Devana S, Bora G, Mavuduru R, Kumar S, Mete U, supervision: Sharma A.

Availability of data and materials: The datasets generated and/or analysed during the current study are not publicly available because they contain confidential patient information but are available from the corresponding author upon reasonable request and subject to institutional approval.

Financial support and sponsorship: None.

Conflicts of interest: Not applicable.

Ethical approval and informed consent: The study protocol was reviewed by the Institutional Ethics Committee, Postgraduate Institute of Medical Education and Research (PGIMER), Chandigarh, India, and was granted exemption from full ethical review because of its retrospective observational design (Vide letter No. Urol/2026/904) .The study was conducted in accordance with the Declaration of Helsinki and applicable institutional ethical guidelines..

Consent to participate and for publication: Written informed consent was obtained from all patients for the surgical procedure, participation in the study, and publication of anonymized clinical information and intraoperative images for research and educational purposes. All identifying details have been removed to ensure patient confidentiality. The use of anonymized data for research was approved by the Institutional Ethics Committee in accordance with institutional policy.

References

1. Lenders J, Eisenhofer G, Mannelli M, & Pacak K. Phaeochromocytoma. *Lancet*, 2005, 366(9486): 665-675. [Crossref]
2. Timmers H, Kozupa A, Eisenhofer G, Raygada M, Adams K, Solis D, *et al*. Clinical presentations, biochemical phenotypes, and genotype-phenotype correlations in patients with succinate dehydrogenase subunit B-associated pheochromocytomas and paragangliomas. *J Clin Endocrinol Metab*, 2007, 92(3): 779-786. [Crossref]
3. Plouin P, Amar L, Dekkers O, Fassnacht M, Gimenez-Roqueplo A, Lenders J, *et al*. European Society of Endocrinology Clinical Practice Guideline for long-term follow-up of patients operated on for a phaeochromocytoma or a paraganglioma. *Eur J Endocrinol*, 2016, 174(5): G1-g10. [Crossref]
4. Walz M, Alesina P, Wenger F, Deligiannis A, Szuczik E, Petersenn S, *et al*. Posterior retroperitoneoscopic adrenalectomy--results of 560 procedures in 520 patients. *Surgery*, 2006, 140(6): 943-948; discussion 948-950. [Crossref]
5. Conzo G, Musella M, Corcione F, De Palma M, Ferraro F, Palazzo A, *et al*. Laparoscopic adrenalectomy, a safe procedure for pheochromocytoma. A retrospective review of clinical series. *Int J Surg*, 2013, 11(2): 152-156. [Crossref]
6. Brandao L, Autorino R, Laydner H, Haber G, Ouzaid I, De Sio M, *et al*. Robotic versus laparoscopic adrenalectomy: a systematic review and meta-analysis. *Eur Urol*, 2014, 65(6): 1154-1161. [Crossref]
7. Morino M, Benincà G, Giraudo G, Del Genio G, Rebecchi F, & Garrone C. Robot-assisted vs laparoscopic adrenalectomy: a prospective randomized controlled trial. *Surg Endosc*, 2004, 18(12): 1742-1746. [Crossref]
8. Brunaud L, Ayav A, Zarnegar R, Rouers A, Klein M, Boissel P, *et al*. Prospective evaluation of 100 robotic-assisted unilateral adrenalectomies. *Surgery*, 2008, 144(6): 995-1001; discussion 1001. [Crossref]
9. Agcaoglu O, Aliyev S, Karabulut K, Mitchell J, Siperstein A, & Berber E. Robotic versus laparoscopic resection of large adrenal tumors. *Ann Surg Oncol*, 2012, 19(7): 2288-2294. [Crossref]
10. Bishnoi K, Bora G, Mavuduru R, Devana S, Singh S, & Mandal A. Bladder paraganglioma: safe and feasible management with robot assisted surgery. *J Robot Surg*, 2016, 10(3): 275-278. [Crossref]
11. Desai M, Berger A, Brandina R, Aron M, Irwin B, Canes D, *et al*. Laparoendoscopic single-site surgery: initial hundred patients. *Urology*, 2009, 74(4): 805-812. [Crossref]
12. Pahwa M, Pahwa A, Batra R, Abraham R, Chawla A, Kathuria S, *et al*. Robotic assisted laparoscopic adrenalectomy: Initial experience from a tertiary care centre in India. *J Minim Access Surg*, 2015, 11(1): 83-86. [Crossref]
13. Kim W, Lee Y, Chung K, Hong S, & Sung T. Comparison of Robotic Posterior retroperitoneal adrenalectomy over

laparoscopic posterior retroperitoneal adrenalectomy: a single tertiary center experience. *International Journal of Endocrinology*, 2019, 2019(1): 9012910. [Crossref]

14. Aksakal N, Agcaoglu O, Barbaros U, Tukenmez M, Dogan S, Kilic B, *et al*. Safety and feasibility of laparoscopic adrenalectomy: what is the role of tumour size? A single institution experience. *J Minim Access Surg*, 2015, 11(3): 184-186. [Crossref]

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