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# Robotic-assisted partial nephrectomy with the Hugo-RAS system: Initial experience, surgical outcomes, and learning-curve assessment

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**Introduction** Robotic-assisted partial nephrectomy (RAPN) is a standard approach for nephron-sparing surgery. The Hugo-RAS system is an emerging platform, but data on its outcomes and learning curve are limited. This study evaluates the safety, efficacy, and learning curve of RAPN using Hugo-RAS in a high-volume laparoscopic center.

**Material and methods** We analyzed 42 consecutive RAPN cases performed with the Hugo-RAS system from May 2023 to October 2024. Perioperative outcomes, renal function, and the learning curve were assessed. The primary endpoint was the "trifecta" (warm ischemia time <25 min, negative surgical margins, and no major complications). Learning curve analysis used Cumulative Sum Control Chart (CUSUM) methodology.

**Results** The median console time was 88 minutes (IQR: 74–107), with a docking time of 5 minutes (IQR: 240–420s). The trifecta rate was 83.3%, and no conversions occurred. Docking proficiency was achieved by the 5th case, while console time proficiency was reached after 7–8 cases. Tumor complexity did not significantly impact surgical time ($p = 0.781$) but was associated with longer warm ischemia time ($p = 0.0037$).

**Conclusions** The Hugo-RAS system allows for safe and effective RAPN with a rapid learning curve. Surgeons adapt quickly, achieving proficiency within a short number of cases. Further studies are needed to validate long-term outcomes and broader applicability.

Key Words: nephrectomy ‹› kidney neoplasms ‹› robotic surgical procedures ‹› Hugo-RAS system ‹› learning curve ‹› surgical outcomes

## INTRODUCTION

Robotic-assisted surgery has been in development since the 1980s. The first surgical robot to be approved by the FDA was the Da Vinci system (Intuitive) in the year 2000. Since then, the Da Vinci system (Intuitive) has undergone several improvements and has dominated the global market of multi-arm surgical robots. The Hugo-RAS system (Medtronic Inc.) is a new robot system with some particular characteristics: The console has two arm-controllers with a grip akin to a pistol, it has an open console with 3D HD vision, and each robotic arm has its own cart enabling great flexibility in suiting trocar positioning for each patient. This platform is currently being used in urological procedures, as well as general surgery and gynecologic procedures, with reports of good surgical outcomes and safety [1–3].

Partial nephrectomy is the gold-standard for T1 renal tumors and the best option for some T2 tumors [4].


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Robotic-assisted technology provides a remarkable advancement in partial nephrectomy surgical technique, revolutionizing the approach to kidney-sparing procedures. However, most of the experience with this technique is using the Da Vinci (Intuitive) platform. The literature regarding RAPN with the Hugo-RAS system is scarce, and there are no data on the learning curve to achieve proficiency with this new surgical platform. In this study, we aim to analyze the outcomes, safety, and learning curve of Hugo-RAS RAPN in a center with high differentiation in laparoscopic kidney surgery.

## MATERIAL AND METHODS

### Patient population

A total of 42 consecutive patients were submitted to RAPN for renal tumors with the Hugo-RAS system in our hospital between May 2023 and October 2024. All included patients gave their written informed consent. Patients preoperative and baseline data were gathered, including renal function, hemoglobin concentration, and computed tomography (CT) or magnetic resonance imaging (MRI) imaging. The RENAL score was used to grade renal mass complexity [5].
Two experienced laparoscopic surgeons performed the procedures. Both surgeons had performed >100 laparoscopic partial nephrectomies and underwent structured training on Hugo-RAS; neither had prior robotic console experience with this platform. Bedside assistance was provided by both surgeons.

### Endpoints, data, and statistical analysis

The primary endpoint was defined as the trifecta: warm ischemia time (WIT) of less than 25 minutes, no positive surgical margins, and the absence of complications (Clavien-Dindo grade 2 or higher) [6]. We assessed the console time (the time the surgeon spent on the surgical console) and docking time (the time required to move the robot carts into the surgical field and connect the robotic arms to the trocars).
Renal function was evaluated using serum creatinine levels. The estimated glomerular filtration rate (eGFR) was calculated using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) formula.
Categorical variables were reported as frequencies, while continuous variables were presented as medians with interquartile ranges (IQR) for non-normally distributed data, and means with standard deviations for normally distributed data. Statistical analyses were conducted using Microsoft Excel and Prism 9.
To evaluate the learning curve of the surgeons and the docking time, we performed a Cumulative Sum Control Chart (CUSUM) analysis, employed as a quantitative tool. CUSUM tracks cumulative deviations from a target value: an upward slope indicates times above the target (slower performance), while a plateau reflects stabilization or proficiency. Console time was benchmarked against institutional laparoscopic partial nephrectomy data (95 minutes for Surgeon A, 100 minutes for Surgeon B), measured from trocar insertion to closure. The learning curve was divided into two phases (initial learning and proficiency), with transition points determined by visual inspection and confirmed statistically.
We used univariate regression to evaluate the impact of body mass index (BMI) and RENAL score on surgical time. In addition, WIT was compared across RENAL complexity groups (low: 4–6, intermediate: 7–8, high: 9–10) using non-parametric statistical tests to evaluate the relationship between tumor complexity and ischemia duration.

### Patient positioning

The patient is positioned in a full flank position at a 60° angle to the operating table. For left RAPN, the endoscope trocar is placed 1 cm below the costal margin along the mid-clavicular line using an 11 mm trocar. The robotic arm trocars are placed 8 cm apart along the pararectal line using 8 mm trocars, with the fourth arm trocar positioned 2 cm above the mid-clavicular line. The assistant trocar is placed beneath the endoscope trocar. For right RAPN, trocar placement is mirrored with similar distances and adjustments. The robotic carts are positioned to optimize access: the cranial cart is behind the patient's head at a 30° tilt, the endoscopic cart near the patient at a 90° docking angle, the fourth arm cart below the legs at a 135° angle, and the surgeon's right-hand cart in front at a 215° angle. A 2 cm distance is maintained between the robotic arms and bony prominences to prevent clashing, ensuring flexibility and precision throughout the procedure. Schematic illustrations of the robotic arm layout are shown separately for left and right RAPN in Figure 1 and Figure 2, respectively.

### Bioethical standards

The study was approved by the Ethics Committee of the ULS de Santo António (ULSSA) and the Instituto de Ciências Biomédicas Abel Salazar (ICBAS), under approval number N/REF.ª 2024.061(056-DEFI/056-CE).

## RESULTS

A cohort comprising 42 patients underwent RAPN at our hospital center. The summary of patient characteristics is presented in Table 1, providing a comprehensive overview of the demographics and clinical parameters.

Median console time was 88 minutes (IQR: 74–107), with a median docking time of 5 minutes and 1 second (301 seconds, IQR: 240–420s). Intra-operatively, the cohort experienced a median blood loss of 100 ml (IQR: 50–300), with a median WIT of 18 minutes (IQR: 15–22). Notably, no conversions were reported. Intraoperatively, only one patient experienced a minor complication – an iatrogenic splenic lesion – which was promptly managed with a hemostatic fibrin and thrombin patch without any further postoperative complications.

The median hospital stay was 3 days (IQR: 3–5). Postoperative complications, classified according to the Clavien-Dindo system, included a Grade II complication in one patient, who required antibiotics for a urinary tract infection, and a Grade IIIb complication in another patient due to a pseudoaneurysm that required a vascular embolization. No patient required a blood transfusion.

Renal function was evaluated at the last follow-up, with a median time of 8 months (IQR: 4–12). There was a statistically significant decline in renal function from 94.87 ml/min/1.73 m² (SD = 15.43) preoperatively to 92.44 ml/min/1.73 m² (SD = 15.58) postoperatively ($p = 0.0378$), reflecting a mean decrease of 2.43 ml/min/1.73 m² (95% CI: from –4.71 to –0.15). Five patients experienced an increase

**Table 1.** *Patients' characteristics*

| Variable | Cohort (n = 42) |
|---|---|
| Age (mean, SD) | 60 (12.39) |
| Gender (n, %) | |
| Male | 23 (55%) |
| Female | 19 (45%) |
| BMI (kg/m², mean, SD) | 25.81 (4.04) |
| ASA score (n, %) | |
| I | 2 (5%) |
| II | 27 (64%) |
| III | 13 (31%) |
| Preoperative eGFR (ml/min/1.73 m², mean, SD) | 94.87 (15.43) |
| Postoperative eGFR (ml/min/1.73 m², mean, SD) | 92.44 (15.58) |
| Clinical Tumor Size (mm, median, IQR) | 33 (21–41) |
| cT (n, %) | |
| T1a | 35 (83.3%) |
| T1b | 6 (14.3%) |
| T2a | 1 (2.4%) |
| Side (n, %) | |
| Right | 13 (31%) |
| Left | 29 (69%) |
| RENAL score (median, IQR) | 7 (6–8) |

ASA score – American Society of Anesthesiologists score; BMI – body mass index; IQR – interquartile range; SD – standard deviation

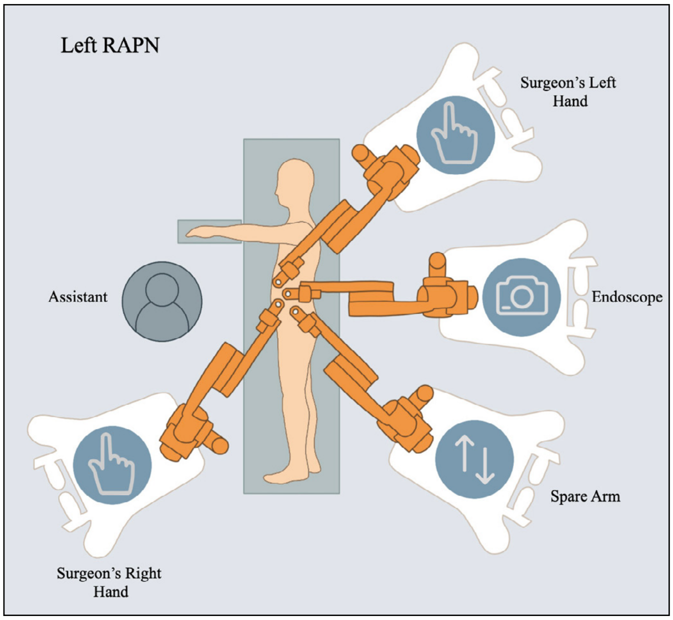


**Figure 1.** *Schematic illustration of robotic arm positioning for left-sided RAPN using the Hugo-RAS system.*

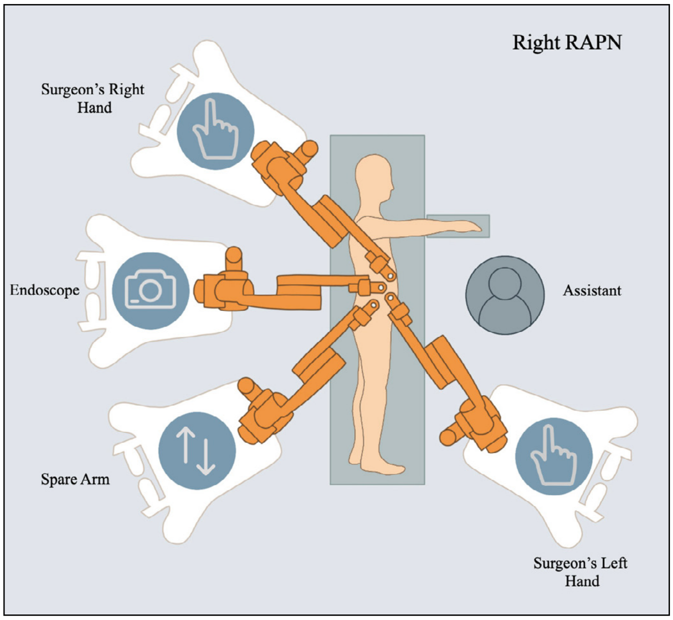


**Figure 2.** *Schematic illustration of robotic arm positioning for right-sided RAPN using the Hugo-RAS system.*

in their chronic kidney disease (CKD) stage, all progressing from stage 1 to stage 2.
Histological analysis revealed malignant pathology in 37 patients (88%), with clear cell renal carcinoma representing nearly half of the cases (45%). Two patients had positive surgical margins. One tumor had a RENAL score of 8 and occurred during the early learning phase; the other, with a score of 10, was resected during the post-proficiency phase. Neither patient has shown evidence of recurrence to date. Regarding the cohort's outcomes, 35 patients (83.3%) achieved the trifecta.

## Results of learning curve evaluation

The analysis of docking time demonstrated a clear trend of rapid skill acquisition, as illustrated in Figure 3. The CUSUM curve showed a rapid improvement, remaining relatively constant after the 5$^{th}$ surgery, with only occasional fluctuations thereafter. This stability suggests that the learning process for docking time was fast, and the team quickly reached a plateau in performance. We defined the cut-off in this setting at the 5$^{th}$ surgery because it was the point where visually the curve plateaued. The results showed a statistically significant value between both phases ($p = 0.0011$). So, our model predicts that the docking learning process is rapid, usually occurring around the 5$^{th}$ surgery.
Regarding console time, for surgeon A, the turning point was at the 7$^{th}$ surgery (Figure 4), after that point the surgeon achieves negatives values in the CUSUM analysis, which indicates that the time performance is actually superior in the robotic setting when compared to laparoscopy. Comparing the two phases of the learning curve (before and after the 7$^{th}$ surgery), the results showed that this was a highly statistically significant difference in total console time (<0.0001). Surgeon B demonstrated noticeable improvement around the 8$^{th}$ surgery (Figure 5). While their initial learning curve was slightly slower, their performance gradually improved. Similar to Surgeon A, fluctuations were observed as they approached a performance plateau. The comparison between the early and late phases (before and after the 8$^{th}$ surgery) revealed

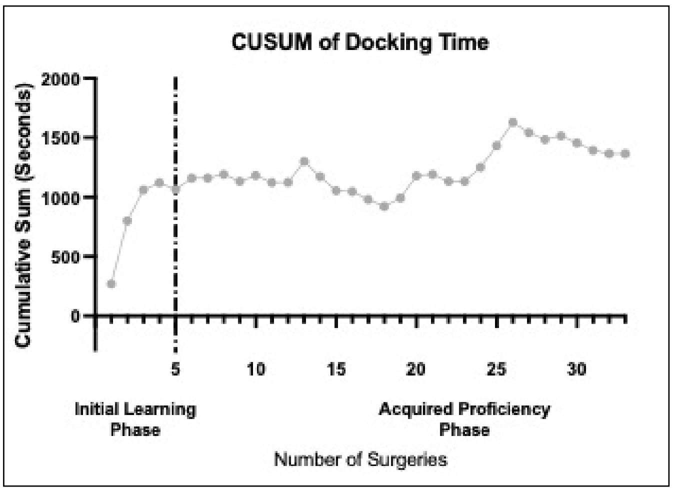


**Figure 3.** *CUSUM analysis of docking time. The dotted vertical line indicates the turning point.*
CUSUM – Cumulative Sum Control Chart

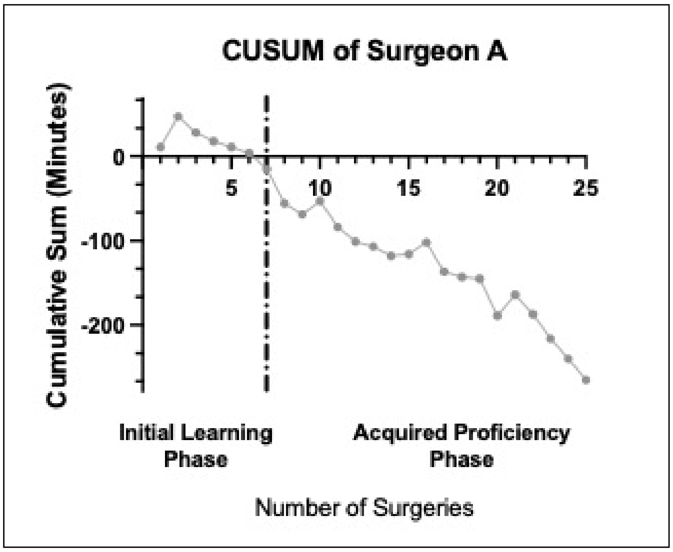


**Figure 4.** *CUSUM analysis of console time for Surgeon A. The dotted vertical line indicates the turning point.*
CUSUM – Cumulative Sum Control Chart

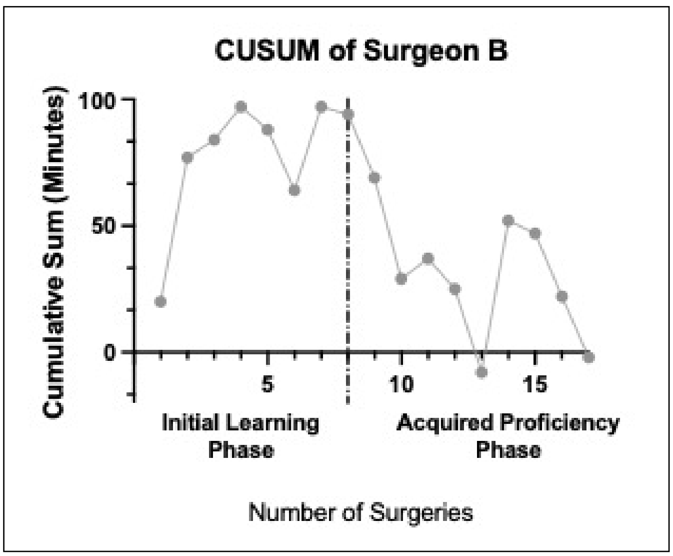


**Figure 5.** *CUSUM analysis of console time for Surgeon B. The dotted vertical line indicates the turning point.*
CUSUM – Cumulative Sum Control Chart

a significant difference (p = 0.0015), confirming measurable improvement over time.
Most importantly, no statistical significance in terms of surgery time was observed between both surgeons (p = 0.0706).
We also evaluated the effect of BMI and the RENAL score on surgery time. Our analysis showed a moderate positive correlation between BMI and surgery time (r = 0.402), with statistical significance (p = 0.008). However, the RENAL score did not show a significant influence on surgery time (p = 0.781).
Tumor complexity had a significant impact in WIT. Median WIT was 15 minutes (IQR: 13–18) for low-complexity tumors, 19 minutes (IQR: 15.75–22) for intermediate, and 24 minutes (IQR: 18.9–29.02) for high-complexity tumors. This trend was statistically significant (p = 0.0037), indicating that higher RENAL scores are associated with longer ischemia times and reflect increased technical difficulty during tumor excision.

## DISCUSSION

The initial experience with the Hugo-RAS system for robotic-assisted partial nephrectomy (RAPN) at our institution demonstrates promising surgical outcomes in terms of safety, efficacy, and feasibility. Our findings support that the Hugo-RAS platform can be effectively used for kidney-sparing surgery, achieving a high trifecta rate (83.3%) with minimal complications. While trifecta provides a useful standardized outcome metric, our data suggest that it remains relatively stable across early and later cases. Therefore, it may not fully capture the nuances of surgical learning. In this context, the use of process-based metrics – such as console and docking time – offers more sensitive tools to evaluate early surgeon adaptation.
The learning curve analysis revealed key insights into the adaption of this new robotic system. We observed a rapid acquisition of docking proficiency, with a plateau reached by the 5$^{th}$ surgery. This suggests that the docking process with Hugo-RAS is intuitive and quickly mastered by experienced laparoscopic teams. Statistical analysis confirmed this rapid learning phase, with a significant difference between pre- and post-turning point performance (p = 0.0011), reinforcing that docking time stabilizes early in the learning process.
Surgeon-specific learning curves showed progressive improvement in console time, with distinct adaptation patterns between the two surgeons. Surgeon A reached proficiency after the 7$^{th}$ procedure, and CUSUM analysis demonstrated a shift to negative values, indicating that RAPN performance exceeded laparoscopic benchmarks in terms of surgical time. This finding is particularly noteworthy because it suggests that the robotic-assisted approach can become more time-efficient than traditional laparoscopy after proficiency is achieved.
Surgeon B, while showing a slightly slower adaptation, exhibited noticeable improvements by the 8$^{th}$ surgery. Unlike Surgeon A, the CUSUM graph approached zero rather than becoming negative, indicating a learning curve that stabilized to match laparoscopic performance rather than surpassing it. However, statistical comparisons confirmed a significant improvement between early and late phases (p = 0.0015), validating the progression in procedural efficiency. Importantly, no significant difference was observed between the two surgeons (p = 0.0706), highlighting that both were able to reach comparable proficiency levels despite individual variations in adaptation speed.
We also explored whether patient-related variables influenced surgical performance. A moderate positive correlation was observed between BMI and operative time (p = 0.008), suggesting that higher BMI patients required longer procedures, likely due to increased technical difficulty. In contrast, the RENAL score did not significantly impact surgical time (p = 0.781), indicating that tumor complexity, at least in this cohort, did not prolong overall operative duration. However, when analyzing WIT, we found a significant association with tumor complexity, as categorized by the RENAL score. Patients with higher RENAL scores (9–10) had a median WIT of 24 minutes, compared to 15 minutes in the lowest complexity group, a statistically significant difference (p = 0.0037). This shows that in our cohort overall surgical time was not directly impacted by tumor complexity; however, warm ischemia time is influenced by the anatomical and technical challenges posed by more complex tumors, as previously published [7]. This also shows that the initial learning phase has no negative impact on functional outcomes as well as on oncological outcomes, because positive surgical margins were also low.
Our analysis further advances this discussion by incorporating surgeon-specific learning curves, comparisons with institutional laparoscopic benchmarks, and assessment of patient-related factors such as BMI and tumor complexity – elements not extensively addressed in previous studies [8, 9]. Importantly, while Gallioli et al. [8] found no significant impact of tumor complexity on performance, our findings suggest that higher RENAL scores are associated with longer warm ischemia times, highlighting the increased technical difficulty of complex tumors.
The Hugo-RAS system appears to be a viable alternative for RAPN, even in centers with established

laparoscopic programs. The short learning curve for docking supports its ease of integration into clinical workflow. Moreover, the potential for robotic-assisted RAPN to outperform laparoscopy in efficiency is promising, although this must be interpreted cautiously. Our comparison is based on console time for RAPN versus total operative time for laparoscopy, which could bias the perceived efficiency advantage.

From a training perspective, proficiency in console time was typically achieved within 7–8 procedures, but with inter-surgeon variability. These findings are consistent with the work of Prata et al. [10], who reported successful transfer of laparoscopic skills to the robotic platform. In contrast to that study, which primarily assessed global performance, our work offers a more granular evaluation of individual learning curves and stratified benchmarks, contributing novel insights into surgeon adaptation with the Hugo-RAS system.

Previous studies evaluating surgical skills development in RAPN with the Da Vinci system showed a longer learning curve [11].

This is not a fair comparison because some of these studies were published a long time ago, at the beginning of partial nephrectomy technique development, and with older versions of the Da Vinci platform, but we must also consider that the Open console and the 3D view, which are similar to laparoscopy, may ease the learning process. Also, this highlights the importance of structured learning programs and individualized training approaches to optimize proficiency acquisition.

This study has limitations, including a relatively small sample size and a single-center design. Larger, multi-institutional studies are needed to validate these findings and assess long-term outcomes. Time comparisons were made using total laparoscopic operative times as a reference, while robotic console time excluded docking and setup. This discrepancy may lead to an overstatement of robotic time efficiency. Additionally, further research should explore the economic impact, surgeon ergonomics, and patient-reported outcomes associated with the Hugo-RAS system, compared to other robotic and laparoscopic platforms.

## CONCLUSIONS

The Hugo-RAS system for robotic-assisted partial nephrectomy is a safe and effective alternative, with a rapid learning curve and promising surgical outcomes, warranting further investigation in larger studies.

### CONFLICTS OF INTEREST

The authors declare no conflict of interest.

### FUNDING

This research received no external funding.

### ETHICS APPROVAL STATEMENT

The study was approved by the Ethics Committee of the ULS de Santo António (ULSSA) and the Instituto de Ciências Biomédicas Abel Salazar (ICBAS), under approval number N/REF.ª 2024.061(056-DEFI/056-CE).

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