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Surgical Video Review of Warm Ischemia Time during Laparoscopic Partial Nephrectomy and Impact on Positive Surgical Margins and Postoperative Complications

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Abstract

Introduction: A surgical video review is an emerging tool for quality improvement, especially in complex surgeries such as laparoscopic partial nephrectomy (LPN). Assessing and measuring the warm ischemia time (WIT) during LPN by dividing it into the time used for resection (ResT), time used for reconstruction (RecT) and intermediate time (IntT) has not been performed before. This study aimed to analyze the factors that can influence all these surgical times and assess their impact on positive surgical margins (PSM) and complication rates. **Methods:** We evaluated 36 surgical video recordings from patients who underwent LPN and measured WIT, ResT, RecT and IntT with a stopwatch. Factors such as tumor characteristics and surgeon experience were also recorded. SPSS software was used to identify the predictor factors for all these surgical times and to correlate the ResT with PSM and RecT with the complication rate. **Results**: We recorded a mean WIT of 887 seconds. The mean ResT, RecT and IntT were 240 (27.2% of WIT), 473 (52.6% of WIT) and 173 s (20.2% of WIT), respectively. We found a moderate correlation between the WIT ($p = 0.030$), IntT and the R.E.N.A.L. score ($p = 0.019$). The surgeon with less than 100 LPN had significantly longer WIT, ResT, and RecT values, with means of 977 ($p = 0.015$), 268 ($p = 0.019$) and 530 seconds ($p = 0.015$), respectively. No correlation was found between ResT and PSM ($p = 0.418$); however, a strong correlation was found between RecT and the probability of developing complications ($p = 0.012$). **Conclusion:** The surgeon's experience influences WIT, ResT, and RecT, but not IntT, which depends on tumor complexity. RecT affects the probability of developing complications. IntT represents a fifth of the WIT and efforts to reduce the WIT should focus on reducing the IntT for complex tumors, by improving surgical planning.

Keywords

Surgical Video, Laparoscopic Partial Nephrectomy, Warm Ischemia Time

1. Introduction

Partial nephrectomy represents the standard of care for patients diagnosed with T1a kidney cancer and should be favored over radical nephrectomy in patients with T1b, whenever feasible [1]. Minimally invasive nephron-sparing surgery should be performed if this approach does not compromise oncological, functional and perioperative outcomes. However, these approaches are technically challenging and are associated with a high rate of complications reported in up to 30% of cases [2]. Another concern is the positive surgical margins (PSM) reported in up to 4% of cases [3].

Vascular clamping during partial nephrectomy (PN) is associated with kidney function impairment and attempts should be made to limit the warm ischemia time (WIT) to 20 minutes [4], as every minute counts when the renal hilum is clamped [5]. Efforts to reduce the WIT should not compromise the surgical margins and the potential rate of complications resulting from excessive reduction of the necessary resection and suturing time.

Surgical video review (SVR) is an emerging tool for quality improvement, especially in complex surgeries, such as PN, and laparoscopy enables high-quality video recordings by providing greater magnification and a closer view of anatomical details. In our study, we focused on assessing and measuring the WIT during laparoscopic partial nephrectomy (LPN) by dividing it into the time used for resection (ResT), time used for reconstruction (RecT) and intermediate time (IntT). This study aimed to measure all these surgical times as parts of the WIT, reviewing surgical video recordings and analyzing the factors that can influence them. A secondary aim was to assess the impact of the ResT on PSM and the impact of the RecT on the complications' rate.

2. Material and Methods

Recording and archival for a period of the surgical video is mandatory in Norway to provide evidence for lawsuits. This allowed us to review surgical video recordings of all 36 consecutive patients who underwent LPN at our institution between September 2021 and May 2022. As part of the kidney cancer surgical team, one surgeon (O.B.), oversaw the video review and measured the WIT, ResT, RecT and IntT in seconds using a digital stopwatch.

The WIT is the time taken from clamping of the artery until its unclamping. It is measured intraoperatively by the anesthesiologist on the surgeon's command using a stopwatch. This time was recorded on the operation form. In the case of bleeding and the need for reclamping, additional time was added to the initial measured time. If several arteries were involved, the time was measured from clamping until declamping of the main artery. At our institution, it is common

practice to clamp only the artery during hilar compression and the vein only for tumors situated centrally in the kidney especially on the right side and always after the artery is clamped. We performed an enucleoresection technique in all cases and used one V-loc 2/0 barbed suture for inner-layer renorrhaphy or two sutures, for a wide resection surface. This suture included all bleeding vessels and collecting system. Early declamping was attempted, and if hemostasis was achieved the surgeon proceeded to complete the outer-layer renorrhaphy using the sliding-clip technique. To minimize the WIT, we routinely simulated the resection angles using scissors and the reconstruction angles with a needle driver before resection. We also took a short time-out before clamping, involving all team members (assistant, nurse, anesthesiologist), specifying the role of each member during the WIT.

In this study, ResT was the time measured from the first cut in the kidney until the end of the resection. RecT was the time from the first needle passage into the kidney parenchyma until the hemolock clip was applied to the loose end of the inner-layer suture. In case of bleeding and the need for reclamping and resuturing, additional time was added to the initial measured time. IntT was defined as the time elapsed from clamping to unclamping of the artery that was not used to resect the tumor or for renorrhaphy.

Tumor anatomical aspects may influence WIT [6] and nephrometry scoring systems are widely used in surgical practice. In our unit, we used the RENAL score (Radius, Exophytic/endophytic, Nearness, Anterior/posterior, Location) to assess tumor complexity and plan the LPN, as described by Kutikov [7]. Procedural volume has served as a surrogate measure of the surgeon's expertise; for this study, we divided the surgical team into surgeons with more than and fewer than 100 LPN procedures. PSM that could be caused by an inappropriate excision technique was registered by a pathologist using microscopic examination, and perioperative complications, such as bleeding or urinary fistula, which could be caused by an inappropriate suturing technique, were recorded in the patient's journal according to the Clavien-Dindo classification [8].

The demographic (including age, sex, tumor type and side, tumor size at CT scan, RENAL score and grade, surgeon's expertise, bleeding amount, surgical margins and postoperative complications) and clinical outcomes (WIT, ResT, Rect and IntT), collected from patients' health records, were analyzed using descriptive statistics. Student's t-test and Pearson's χ^2 test were used to compare the means and proportions, respectively. Stepwise multivariable regression models were used to assess predictors for all surgical times. Statistical significance was set at $p < 0.05$. All data were analyzed using the SPSS statistical software (version 26.0; IBM Corp., Armonk, NY, USA).

3. Results

3.1. Demographics

The population and tumor characteristics are summarized in **Table 1**. The cohort comprised 75% males with a mean age of 65. Most of the tumors were solid

(83.3%) with a mean tumor diameter of 2.8 cm and a mean RENAL score of 7 points, with 44.4% of the tumors being low complexity, 52.8% medium complexity and 2.8% high complexity. Of the surgeries, 58.3% (21) were performed by a surgeon with a learning curve of fewer than 100 procedures and the remainder by the other two surgeons, both with learning curves of over 100 procedures. All three surgeons operated on similar low and medium-complexity tumors, and only two more experienced surgeons operated on high-complexity tumors. Three (8.3%) positive margins were recorded and Clavien-Dindo ≥ 2 complications occurred in four patients (11.1%) with bleeding and A-V fistulae. No patient registered an urinary fistulae.

Table 1. Population demographics.

Variable	**Overall (n = 36)**	Variable	**Overall (n = 36)**
Age (years)		**Surgery time** (minutes)	
Mean (SD)	65.8 (10.5)	Mean (SD)	155.61 (31.56)
Sex		**WIT registered (seconds)**	
Man	27 (75%)	Mean (SD)	870 (255.9)
Woman	9 (25%)		
Tumor type		**WIT measured by SVR (seconds)**	
Solid	30 (83.3%)	Mean (SD)	887.2 (267.9)
Cystic	6 (16.7%)		
Side		**Resection Time (seconds)**	
Right	15 (41.7%)	Mean (SD)	240.2 (87.6)
Left	21 (58.3%)	Percent of WIT	27.2%
CT diameter (cm)		**Reconstruction Time (seconds)**	
Mean (SD)	2.86 (1.16)	Mean (SD)	473.6 (175.9)
		Percent of WIT	52.6%
RENAL score		**Intermediate Time (seconds)**	
Mean (SD)	7.00 (1.79)	Mean (SD)	173.1 (55.8)
		Percent of WIT	20.2%
RENAL score grade			
Low (4 - 6)	16 (44.4%)		
Medium (7 - 9)	19 (52.8%)		
High (10 - 12)	1 (2.8%)		
Surgeon's expertise			
<100 procedures	21 (58.3%)		
>100 procedures	15 (41.7%)		
Bleeding (ml)			
Mean (SD)	143 (114)		
Surgical margins			
Negative	33 (91.7%)		
Positive	3 (8.3%)		
Postoperative complications			
<Clavien Dindo grade 2	32 (88.9%)		
≥Clavien Dindo grade 2	4 (11.1%)		

The surgical features included a mean WIT of 887 seconds. The ResT used to resect the tumor was measured with a mean of 240 seconds (122 - 475) being 27.2% (17.6% - 38.9%) of all the WIT. The mean RecT was 473 seconds (154 - 870), representing 52.6% (30.9% - 65.4%) of the WIT. The mean IntT was 173 s (66 - 310), representing 20.2% (10.6% - 37.4%) of the WIT.

3.2. Predictor Factors for WIT, ResT, RecT and IntT (Table 2)

We found a moderate (r = 0.362) correlation between the WIT and RENAL score ($p = 0.030$), with a longer WIT for a higher RENAL score. Nevertheless, no significant difference was found between the WIT values for low and medium-complexity tumors ($p = 0.078$), although the mean ischemia time was higher in medium-complexity cases. The surgeon with fewer than 100 LPN had a significantly longer WIT with a mean of 977 s ($p = 0.015$).

No correlation was found between the ResT and RENAL score ($p = 0.120$) or other factors except the surgeon's experience, with a significantly longer ResT (mean 268 s, p = 0.019) for the surgeon with fewer than 100 LPN. Similarly, no correlation was found between the RecT and RENAL score ($p = 0.078$) or other factors except the surgeon's experience, with a significantly longer RecT (mean 530 s, $p = 0.015$) for the surgeon with fewer than 100 procedures.

Table 2. Factors correlated with total ischemia time, resection time, reconstruction time and intermediate.

Variable	N	Total ischemia time		Resection time		Reconstruction time		Intermediate time	
		Mean*/ Pearson corr. **	*p*	Mean*/ Pearson corr. **	*p*	Mean*/ Pearson corr. **	*p*	Mean*/ Pearson corr. **	*p*
Sex* Man	27	891.07	*0.883*	237.19	*0.724*	472.41	*0.945*	181.19	*0.137*
Woman	9	875.56		249.33		477.22		149.00	
Tumor* Solid	30	897.33	*0.619*	243.90	*0.581*	473.70	*0.995*	179.47	*0.130*
Cyst	6	836.50		221.83		473.17		141.50	
Side* Right	15	901.40	*0.792*	260.27	*0.252*	483.27	*0.785*	157.19	*0.169*
Left	21	877.05		225.90		466.71		190.32	
RENAL Grade* Low	16	789.50		217.19		419.50		152.19	
Medium	19	950.37	*0.078*	252.53	*0.147*	507.63	*0.152*	190.32	*0.152*
High	1	1250.00		375.00		693.00		182.00	
>100 surgeries	15	761.13	***0.015***	200.40	***0.019***	394.47	***0.015***	166.40	*0.548*
Operator * < <100 surgeries	21	977.24		268.67		530.14		177.95	
Age**	36	0.004	*0.979*	−0.073	*0.674*	0.054	*0.756*	−0.025	*0.886*
Tumor size**	36	0.221	*0.195*	0.043	*0.803*	0.302	*0.074*	0.045	*0.793*
RENAL score**	36	0.362	***0.030***	0.264	*0.120*	0.298	*0.078*	0.388	***0.019***

* Student t-tests ** Pearson χ^2 tests.

We found a moderate (r = 0.388) correlation between IntT and RENAL score (p = 0.019), with a longer IntT for a higher RENAL score. However, no significant difference was found between the IntT values for low and medium-complexity tumors (p = 0.152), although the mean IntT was higher in medium-complexity cases.

After stepwise regression, two models were found to predict the WIT, as presented in Table 3, the model including operator and the RENAL score with better accuracy (R = 0.523). Only one model could predict the ResT and RecT, depending on the operator variable (R square = 0.152 and 0.149 respectively) as 15% of the ResT and RecT were determined by which surgeon performed the LPN. The model that could predict the IntT depended only on the RENAL score variable (R square = 0.151) as 15% of the IntT was determined by tumor complexity.

3.3. Correlation between ResT with PSM and RecT with Complications' Rate

No correlation was found between ResT, either as a continuous variable (p = 0.418) or as a percentage of the WIT (p = 0.670), and the probability of PSM. We tested a cut-off of 180 s (3 min) to determine whether a low ResT below 3 min correlated with positive margins without statistical significance (p = 0.156). A strong correlation was found between RecT and the probability of developing complications with a p value of 0.012 and an odds ratio of 1.008.

4. Discussion

To the best of our knowledge, no data are available regarding intraoperative video documentation review for LPN. Radical prostatectomy surgeons have accepted SVR as a form of quality assurance to reduce complications and improve outcomes [9]. Touijer *et al.* conducted such a video review methodology to understand the mechanism of PSM for laparoscopic radical prostatectomy showing that it could help decrease PSM, particularly in organ-confined disease [10].

For LPN, efforts should be made to reduce the WIT without compromising precise excision of the tumor and optimal reconstruction of the resection surface. Thus, we aimed to determine how much time surgeons took to resect the tumor, and to reconstruct the kidney and how much of the WIT was used for other maneuvers, such as instrument transfer from nurse to surgeon or any other "dead" time.

Table 3. Stepwise regression analyze for warm ischemia time, resection time, reconstruction time and intermediate time.

	Total ischemia time			Resection time			Reconstruction time			Intermediate time		
Model	R	R Square	*Sig. F Change*	R	R Square	*Sig. F Change*	R	R Square	*Sig. F Change*	R	R Square	*Sig. F Change*
1	0.403[a]	0.163	*0.015*	0.389[a]	**0.152**	*0.019*	0.385[a]	**0.149**	*0.020*	0.388[a]	**0.151**	*0.019*
2	**0.523[b]**	0.273	*0.032*									
Predictors	a. Operator **b. Operator, RENAL score**			a. Operator			a. Operator			a. RENAL score		

The time taken to resect the tumor, time to reconstruct the kidney and intermediate time represented 27%, 53% and 20%, respectively, of the total WIT. For our population with a mean WIT of almost 15 min, 4 min were used to resect the tumor, twice as long to reconstruct the kidney (8 min), and 3 min for other maneuvers. It is also noteworthy that more than half of the total WIT was used to reconstruct the kidney.

In most studies, procedural volume has served as a surrogate measure of the surgeon's expertise as an objective assessment of operative proficiency, technique and skills, especially in complex procedures, such as LPN. Porpiglia *et al.* [11] evaluated the impact of the learning curve and tumor anatomical characteristics on margins, ischemia and complication rate and found that WIT < 20 min increased with the surgeon's experience and decreased when complex lesions were treated with LPN. In our study, the surgeon's experience and tumor anatomical aspects evaluated using the RENAL score were the factors influencing the WIT, ResT, RecT and IntT, although both factors determined in a low percentage of 15% these surgical times.

Ficarra *et al.* [12] found that anatomical tumor characteristics were an independent predictor of WIT, adjusted for the effects of surgeon experience and clinical tumor size. We found that only ResT and Rect as part of the WIT depended on surgical experience, in contrast with IntT which depended on tumor morphology. We believe that our standardized routine of taking a time-out before clamping the artery and an experienced kidney surgeon-nurse team can explain why the surgeon's experience was not a predictor for IntT.

Ko *et al.* [13] found the surgeon's experience, tumor morphology as the PAUDA score, and tumor size to be predictors of WIT. Among these factors, accumulating surgical experience was the most important and only modifiable factor for reducing the WIT. Our study found no significantly longer IntT for the surgeon with fewer than 100 LPN in contrast with the WIT, ResT and RecT. IntT depended more on tumor morphology, which is not a modifiable factor, but reducing IntT by improving teamwork and surgical planning could reduce the WIT independently of the surgeon's experience.

To best of our knowledge, no data are available to evaluate the time used to resect the tumor or to reconstruct the kidney, as separate parts of the WIT, neither studies assessing their separate impact on PSM nor those evaluating that on postoperative complications. Our study found no correlation between ResT and PSM, even with a subgroup analysis of times less than 3 min, as we expected that an accelerated resection could lead to PSM. The small sample size and low PSM rate of this study could have biased our findings. Conversely, the RecT significantly correlated with the postoperative complication rate as the longer the time taken to reconstruct the resection surface, the higher the probability of developing a complication. A longer time to reconstruct the kidney in our study was needed mainly to achieve hemostasis, as we did not separately repair the urinary collecting system. We recorded no urinary leakage, postoperative bleeding or

development of an A-V fistula as the only Clavien-Dindo grade >2 postoperative complications. Interestingly, Ficarra *et al.* [12] also found that urinary collecting system repair was not associated with an increased risk of postoperative complications such as urine leakage.

The main limitation of this study is the small sample size, and the tumors were relatively small and of low to intermediate complexity, which we believe represents patients we typically treat in our daily practice in this era of incidentally finding early kidney cancer on CT scans. The study was not blinded because SVR requires a trained kidney surgeon to identify the specific steps of the procedure. Some patient characteristics and comorbidities were not recorded owing to the retrospective design of this study. We believe that this study offers several opportunities for future research using SVR analysis to assess WIT for robot-assisted PN.

5. Conclusions

We divided WIT into ResT, RectT and IntT using SVR. ResT represents more than a quarter of WIT without necessarily affecting PSM. Conversely, RecT represents more than half of the WIT and affects the probability of developing postoperative complications. The surgeon's experience influences the WIT, ResT and RecT but not the IntT, which depends more on the tumor morphology.

As time is not used to resect or reconstruct, IntT represents a fifth of the WIT. We believe that, in addition to improving the surgical experience, efforts to reduce the WIT should also focus on reducing IntT, especially for more complex tumors, by improving surgical planning and teamwork, without compromising surgical margins and complication rate.

Acknowledgements

This study was approved by the Institutional Review Board of our institution. The use of surgical video content for extracting quality improvement and educational material was subject to written approval by the patient and all the patients in our study signed an informed consent form.

Author Contributions

Ovidiu Barnoiu: conceived and designed the study, collected the data and wrote the paper. Ole Tysland: contributed data and analysis tools. Aage Andersen: contributed data and analysis tools.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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