RESEARCH ARTICLE

# Technical Improvement Using a Three-Dimensional Video System for Laparoscopic Partial Nephrectomy

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## Abstract

**Background: Laparoscopic partial nephrectomy is one of the major surgical techniques for small renal masses. However, it is difficult to manage cutting and suturing procedures within acceptable time periods. To overcome this difficulty, we applied a three-dimensional (3D) video system with laparoscopic partial nephrectomy, and evaluated its utility. Materials and Methods: We retrospectively enrolled 31 patients who underwent laparoscopic partial nephrectomy between November 2009 and June 2014. A conventional two-dimensional (2D) video system was used in 20 patients, and a 3D video system in 11. Patient characteristics and video system type (2D or 3D) were recorded, and correlations with perioperative outcomes were analyzed. Results: Mean age of the patients was 55.8±12.4, mean body mass index was 25.7±3.9 kg/m$^2$, mean tumor size was 2.0±0.8 cm, mean R.E.N.A.L nephrometry score was 6.9±1.9, and clinical stage was T1a in all patients. There were no significant differences in operative time (p=0.348), pneumoperitoneum time (p=0.322), cutting time (p=0.493), estimated blood loss (p=0.335), and Clavien grade of >II complication rate (p=0.719) between the two groups. However, warm ischemic time was significantly shorter in the 3D group than the 2D group (16.1 min vs. 21.2min, p=0.021), which resulted from short suturing time (9.1 min vs. 15.2 min, p=0.008). No open conversion occurred in either group. Conclusions: A 3D video system allows the shortening of warm ischemic time in laparoscopic partial nephrectomy and thus may be useful in improving the procedure.**

**Keywords:** Three-dimensional - laparoscopic partial nephrectomy - warm ischemic time - suturing time - video system

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## Introduction

The development of new and improved abdominal imaging techniques has made it easy to diagnose incidental small renal masses (Kane et al., 2008). Radical nephrectomy has traditionally been the sole treatment of choice for renal tumors, but small asymptomatic renal tumors can now be feasibly treated by nephron-sparing surgery, also known as partial nephrectomy (PN) (Miller et al., 2006; Zini et al., 2009; MacLennan et al., 2012). PN is now the gold standard surgical technique for small renal cell carcinoma (RCC). According to the RCC guidelines, PN is the standard treatment for patients with clinically localized RCC <4 cm T1a tumors (Ljungberg et al., 2014).

Laparoscopic partial nephrectomy (LPN) was first described in 1993 (Winfield et al., 1993) and has since become a recognized procedure (Eisenberg et al., 2010). Some studies have compared the operative outcomes or oncological outcomes between open partial nephrectomy (OPN) and LPN (Gill et al., 2007; Marszalek et al., 2009; Van Poppel, 2010; Minervini et al., 2014; Fardoun et al., 2014). In these series of studies, the surgical and oncological outcomes of LPN proved to be comparable to those of OPN, but it is believed LPN should be performed by experts in laparoscopy because of its technical difficulty and a lack of tactility. The most challenging point of LPN is to resect the tumor and to close the renal parenchyma within a limited warm ischemia time (WIT) (Minervini et al., 2014). Moreover, a two-dimensional (2D) monitor cannot provide perspective sensation, which makes these procedures more difficult.

Three-dimensional (3D) video systems have been developed to overcome these problems of conventional 2D video systems. These new video systems consist of a 3D monitor, 3D laparoscope, and 3D vision glasses that all staff members (operator, scopist, assistants, and nurses) can wear. Some previous studies have evaluated 3D laparoscopic systems in comparison with 2D systems (Patel et al., 2007; Wagner et al., 2012; Smith, 2014; Aykan et al., 2014; Kinoshita et al., 2015). Most of these studies were conducted using a dry-box system and showed that 3D systems increased the accuracy of laparoscopic performance and reduced surgeon fatigue.

Since 2013, our institute has adopted a 3D video system in laparoscopic urological surgeries, particularly LPN. Few studies have compared the surgical outcomes

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of 2D and 3D systems. The present study was undertaken to investigate the benefit of a 3D video system in LPN.

## Materials and Methods

This retrospective study was conducted in 31 patients who underwent LPN between November 2009 and June 2014 by a single surgeon (A.M.). We implemented this 3D video system in LPN in June 2013. Prior to this, LPN was performed with a 2D video system. In this study, 20 patients underwent 2D-LPN between November 2009 and June 2013, while 3D-LPN was performed in 11 patients between June 2013 and June 2014. The indication for LPN was clinical T1a RCC, and the decision as to whether clinical T1a RCC was suitable for OPN, LPN, or laparoscopic radical nephrectomy (LRN) was made by the surgeon, considering his laparoscopic skill, the characteristics of the patient's body habitus, comorbidities, tumor size, and location.

All patients received general anesthesia during surgery, and epithermal anesthesia was continued for 2 days. Both 2D-LPN and 3D-LPN were performed by a transperitoneal approach. Patients were situated in the flank position, and four ports were placed (scope, right hand, left hand, and assistance for traction or suction). For a right side RCC, an additional port was required to retract the liver. Energy devices (En Seal, Ethicon®, and Argon Beam Coagulation, Bard Medical system®) were used as needed. We confirmed the location and depth of the tumor using ultrasonography during surgery (Wang et al., 2014). The renal artery was intercepted with a bulldog clamp in all cases, and endoscopic cold scissors were used to cut the renal parenchyma. The resection margin was assessed macroscopically, and a 4-0-Maxon (Covidien®) running suture was placed in the resection bed to ensure hemostasis and closure of the collecting system as needed. Renal reconstruction was achieved with 2-0-Vicryl (Ethicon®) interrupted sutures. At both ends of the suture thread, Hemo-O-lock (Tereflex®) or LAPRA-TY (Ethicon®) was used instead of manual ligation. Measurable bleeding after declamping the renal artery was treated with an additional suture. For all surgeries, hemostatic agents (TachoSil, CSL Behring®, BeriPrast P, CSL Behring®, and SurgiCel, Ethicon®) were attached to the resection bed or bleeding point.

In the surgeries with a 3D system, we used Olympus 3D laparo-thoraco videoscope systems, which were supplied by the vendor (Olympus Medical Systems Corp., Tokyo). These systems included a 3D laparo-thoraco videoscope (LTF-Y0009), a video processor (OTV-Y0018), a xenon light source (CLV-Y0013), a 3D mixer (MAJ-Y0041), and a 24-inch polarized monitor (LMD-2451MT) (Sony Corp., Tokyo). The videoscope was a 10-mm diameter deflectable scope. Two HD-CCD (charge-coupled device) chips were placed on the tip of the endoscope. Polarized glasses were used to see the 3D images (Figure 1).

After receiving institutional review board approval, we re-evaluated all recorded videos retrospectively, and measured perioperative outcomes: operative time (OT), pneumoperitoneum time (PT), WIT, cutting time, and suturing time. Cutting time was defined as the time of cutting the renal parenchyma, and we regarded suturing time as the time from the first grasp of the needle to the completion of parenchymal suturing. The number of parenchymal sutures and the number of times in which the needle was switched to obtain an adequate angle were also counted. Estimated blood loss (EBL), complications, and patient characteristics (age, body mass index (BMI), tumor side, RENAL nephrometry score, blood laboratory data, and comorbidity) were cited from medical records. Tumors were pathologically staged according to the TNM classification. The severity of any surgical complication was graded according to the modified Clavien system. Renal function was measured by estimated glomerular filtration rate (eGFR) calculated by the Cockloft-Gault formula, at admission and 3-month follow-up.

Student's t-test and chi-square test were used to test for differences between the 2D-LPN group and 3D-LPN group. A p value less than 0.05 was considered to be significant. These analyses were performed with the SPSS v. 22.0 statistical software package (IBM Corp., Somers, NY).

## Results

There were no statistically significant differences in the patient background characteristics of age, BMI, tumor size, tumor laterality, RENAL nephrometry score, and baseline eGFR between the 2D-LPN and 3D-LPN groups as shown in Table 1. The perioperative data are

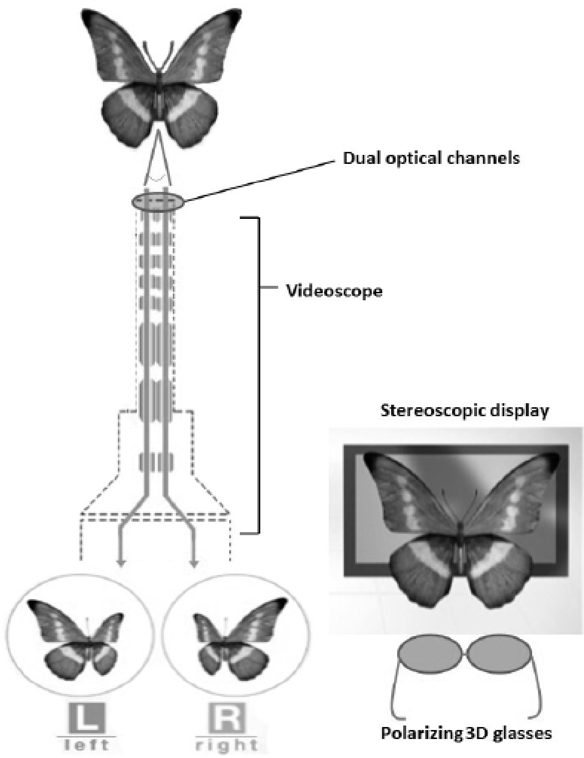


**Figure 1. A 3D Laparo-Thoraco Videoscope with Dual Optical Channels Captures Two Phase-Shifting Images for Each Eye.** Two images are projected superimposed onto the same screen with polarized filters. The viewer wears 3D glasses which contain a pair of opposite polarizing filters, and each eye only sees one of the images. Therefore, the surgical movements on the stereoscopic display can be observed as 3D images

**Table 1. Patient Characteristics**

| | | Total n=31 | 2D n=20 | 3D n=11 | p value |
|---|---|---|---|---|---|
| Age | years | 55.8±12.4 | 57.3±13.0 | 53.0±11.4 | 0.366 |
| Gender | male | 27 | 18 | 9 | 0.447 |
| | female | 4 | 2 | 2 | |
| Body mass index | kg/m$^2$ | 25.7±3.9 | 24.8±0.8 | 27.1±0.7 | 0.114 |
| Laterality | left | 16 | 8 | 8 | 0.085 |
| | right | 15 | 12 | 3 | |
| Tumor size | cm | 2.03±0.75 | 2.02±0.81 | 2.05±0.66 | 0.937 |
| RENAL nephrometry Score | | 6.87±1.89 | 6.75±2.20 | 7.09±1.22 | 0.583 |
| Preoperative eGFR | ml/min/kg | 71.2±13.0 | 72.3±12.4 | 69.2±14.4 | 0.533 |

**Table 2. Surgical Outcomes**

| | | Total n=31 | 2D n=20 | 3D n=11 | p value |
|---|---|---|---|---|---|
| Operative time | min | 169.0±48.4 | 175.2±55.6 | 157.8±44.2 | 0.348 |
| Pneumoperitoneum time | min | 129.7±44.4 | 135.5±45.9 | 118.2±41.2 | 0.322 |
| Warm ischemic time | min | 19.4±6.0 | 21.2±5.8 | 16.1±5.2 | 0.021 |
| Cutting time | min | 6.0±2.6 | 6.3±2.7 | 5.6±2.5 | 0.493 |
| Parenchymal sutures | times | 6.6±2.2 | 6.7±2.4 | 6.5±2.0 | 0.658 |
| Switching the needle | times | 6.4±3.8 | 7.8±4.0 | 3.9±1.8 | 0.006 |
| Estimated blood loss | ml | 27.9±39.5 | 22.8±36.8 | 37.3±44.2 | 0.335 |
| Complication rate | % | 13 | 10 | 9.1 | 0.719 |
| eGFR change at 3POM | ml/min/kg | -7.2±8.5 | -8.0±10.0 | -5.7±4.4 | 0.492 |

summarized in Table 2. Between 2D-LPN and 3D-LPN, there were no significant differences in OT (175 min vs. 158 min, p=0.348), PT (136 min vs. 118 min, p=0.322), cutting time (6.3 min *vs*. 5.6 min, p=0.493), or EBL (23 mL vs. 37 mL, p=0.335). However, WIT in 3D-LPN (16.1 min) was significantly shorter than in 2D-LPN (21.2 min, p=0.021). In addition, suturing time in 3D-LPN was significantly shorter than in 2D-LPN (9.1 min vs. 15.2 min, p=0.008). There was no significant difference in the number of parenchymal sutures between the 2D (6.7 times) and 3D (6.4 times, p=0.658) groups, but the frequency of switching the needle was significantly lower in 3D-LPN than in 2D-LPN (3.9 times *vs*. 7.8 times, p<0.01). In all cases, surgical margin proved to be pathologically negative.

Overall, six complications occurred: two cases with Clavien grade I back pain and four cases with Clavien grade IIIa complications (false aneurysm needed interventional radiology). No grade IV or V complications were observed. There was no statistically significant difference in the Clavien >II complication rate between 2D-LPN and 3D-LPN (3/20 *vs* 1/11, p=0.719). No open conversion occurred in either group. At 3-month follow-up, no difference in eGFR decrement from baseline was observed between the 2D (-8 ml/min/1.73m$^2$) and 3D (-6 ml/min/1.73m$^2$, p=0.497) groups.

## Discussion

The role of PN as a surgical technique for small renal tumors has been expanding (Miller et al., 2006; Zini et al., 2009; MacLennan et al., 2012). Today, it has become the gold standard for clinical T1a RCC (Ljungberg et al., 2014). OPN was the conventional strategy for nephron-sparing surgery, followed in steps by LPN (Winfield et al., 1993; Eisenberg et al., 2010). Previous studies have reported there are no significant differences in the perioperative and long-term outcomes in cancer control and preserved renal function between OPN and LPN (Gill et al., 2007; Marszalek et al., 2009; Van Poppel, 2010; Minervini et al., 2014; Fardoun et al., 2014). Additionally, LPN is considered to be less invasive with lower postoperative pain and better cosmesis than OPN. However, LPN is still performed almost exclusively at a limited number of facilities because it requires expert experience and skill in laparoscopy due to the difficult procedures and the following challenges: 1) holding or applying the needle is quite difficult because the operative field of LPN is not symmetrical, like in laparoscopic radical prostatectomy, 2) the exact horizontal plane is hard to identify by the surgeon and scopist, 3) the kidney is quite mobile with instability since it is often resected from the surrounding tissue in order to find the renal mass, and 4) bleeding and false aneurysms are important complications of LPN, and to prevent them the parenchymal suturing should be exact and fine. A 3D video system provides a stereoscopic view for the operator, assistants, and scopist. Accordingly, a 3D video system is thought to be suitable for LPN since it can clear some of above-mentioned hurdles.

The present study assessed our LPN technique, and investigated the utility of a 3D video system. We compared the perioperative outcomes of 2D-LPN and 3D-LPN, and found that we could achieve short WIT using a 3D video system. There were no differences in cutting time, but our results indicated that short suturing time with less re-grasping of the needle by the 3D video system might have contributed to the improvement of WIT. Therefore, this is the first report to examine the benefit of a 3D video system in LPN. Our 3D-LPN series included 11 cases, all of which were performed continuously after our 2D-LPN series, and it could be one of limitations because the surgeon's experience might have been responsible for the shortening of WIT. However, we excluded 28 cases of 2D-LPN during the first three years, which were thought to be cases in the learning period, and we only collected cases in which the operative time reached the plateau. Therefore, bias due to learning effect in our results is thought to be limited.

Previous studies have compared perioperative data between robot-assisted partial nephrectomy (RAPN) and LPN (Benway et al., 2009; Pierorazio et al., 2011; Zhang et al., 2013). In these studies, OT, WIT, and EBL in LPN were reported to be inferior to those in RAPN. However, these LPN procedures were not performed with a 3D video system but with a 2D video system. Our mean OT, WIT, and EBL in LPN with a 3D video system were comparable with those reported RAPN cases. RAPN is known to require much higher facility costs than LPN (Ferguson et al., 2012; Elsamra et al., 2013), and many of the surgical instruments for LPN can be used in gastroenterological and gynecological surgeries in common, making the cost per case of LPN considerably less than that of RAPN.

In conclusion, A 3D video system can provide good surgical outcomes comparable to those of RAPN, and also has a definite cost advantage. We believe 3D video systems would contribute to the prevalence of safe and minimally invasive surgery for RCC.

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