Laparoscopic Doppler Technology in Laparoscopic Renal Surgery

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ABSTRACT

Background and Objectives: Laparoscopic Doppler technology has previously been reported to help identify vasculature during laparoscopy. Recently, we published our initial experience with this technology during laparoscopic radical nephrectomy, laparoscopic nephroureterectomy, laparoscopic partial nephrectomy, and robotic-assisted laparoscopic pyeloplasty. We now present a prospective, pilot evaluation of the Doppler probe for these procedures.

Methods: A laparoscopic Doppler probe was used in the above laparoscopic renal surgeries in 50 patients. Anatomic findings, Doppler survey time, dissection time, operative time, estimated blood loss, changes in management, subjective time saved/utility, technical difficulties, clinical complications, and ease of use were prospectively recorded.

Results: Mean Doppler survey time was 1.77 minutes. Mean hilar dissection time was 9.25 minutes. Eight accessory vessels were not seen on preoperative imaging in 7 patients (17%). In 3 cases of RALP, Doppler rectified preoperative imaging in detecting a crossing vessel. The probe altered management in 16% of patients, subjectively saved time in 78% of patients, and had 100% concordance with dissection. There were no complications but 2 technical failures.

Conclusion: The probe is quick, safe, easy to use, and has perfect concordance with surgical dissection. Randomized comparison with and without Doppler assistance is necessary to confirm the utility of this technology.

Key Words: Laparoscopy, Technology, Ultrasonography, Urologic surgical procedures.

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INTRODUCTION

Identification and isolation of vascular structures are crucial and technically demanding aspects of laparoscopic renal surgery. Specifically, dissection of the renal hilum often poses a challenge due to the variable number of hilar vessels.[1] Preoperative imaging often helps to determine hilar anatomy, but it is not always accurate.[2–4] Congenital anomalies, surgical history, body habitus, and tumor location can also complicate intraoperative dissection and result in vascular injury.[4–6]

Ultrasound technology has been used to minimize intraoperative challenges and complications in laparoscopic surgery since 1982, when Fukuda and colleagues[7] used ultrasound imaging to laparoscopically evaluate hepatic tumors. Since then, laparoscopic ultrasound has been further refined to include Doppler capabilities. The use of laparoscopic Doppler technology has been described in treatment of mesenteric ischemia, cholecystectomy, and varicocelectomy.[8–10] In laparoscopic renal surgery, there have been case reports of renal cryoablation and partial nephrectomy using laparoscopic ultrasound with color Doppler capabilities.[11,12] The transducer of these probes are bulky, measuring approximately 1cm in width and 5cm to 7cm in length. All must be inserted through a 12-mm trocar.

We recently reported our surgical technique and initial experience using a laparoscopic Doppler probe during laparoscopic radical nephrectomy (RNx), laparoscopic nephroureterectomy (NU), laparoscopic partial nephrectomy (PNx), and robotic-assisted laparoscopic pyeloplasty (RALP).[13] This current article reports on a study that prospectively evaluated the efficacy of the laparoscopic Doppler probe used during 50 cases of laparoscopic renal surgery.

MATERIALS AND METHODS

After obtaining IRB approval for this prospective study, all operations were performed by a single surgeon (MDS). An IRB-approved data sheet was used to collect data by an alternate member of the surgical team. All patients underwent preoperative CT or MRI, and the number of accessory vessels (AV) or crossing vessels (CV) was recorded

based on written findings or surgeon review for RNx/NU/ PNx or RALP, respectively. Any patient with more than a single renal artery or vein was considered to have an AV. If no imaging report was available, then imaging was reviewed by the operating surgeon (MDS) and findings were recorded in the patient's chart preoperatively. The operative techniques for laparoscopic RNx, NU, PNx, and RALP have each been previously described.[14–17] Details of the Doppler probe (Vascular Technology Inc, Nashua, NH) and its use during each of the aforementioned operations have also been previously described.[13] Briefly, the laparoscopic Doppler system consists of a 5-mm sterile, disposable end-firing probe that is plugged into a non-sterile 8MHz transceiver, powered by AA alkaline batteries.[13] Little-to-no specific training in the Doppler's use is needed by the surgeon or operating room staff. The probe is placed through any pre-existing 5-mm port and used to guide dissection and isolation of both the renal hilum and aberrant vasculature in the previously mentioned operations. The probe also confirms parenchymal ischemia prior to tumor resection in partial nephrectomy, and helps identify crossing vessels during robotic-assisted pyeloplasty.

Recorded operative data included time to complete Doppler survey, number of AV or CV found during Doppler survey, time to complete hilar dissection, number of AV or CV found during dissection, operative time, estimated blood loss (EBL), changes in surgical management based on Doppler findings, and intraoperative complications and/or technical failures associated with Doppler use. Subjective measures included an assessment of the effect on operative time due to Doppler use as well as an evaluation of the ease of use of the device. The Doppler survey time was defined as the amount of time the Doppler probe was in the trocar scanning the renal hilum; the hilum was systematically scanned from the upper pole to lower pole and the number of renal arteries and veins present was recorded. The hilar dissection time was defined as the time elapsed after the lower pole of the kidney had been cleared of all attachments until the point at which all arteries and veins had been isolated for either clamping or transection. Changes in operative management were defined as a change in clamp position or additional clamping due to the discovery of AV or early branching arteries, or altered pyeloplasty technique due to incorrect CV status on preoperative imaging. The operating surgeon subjectively determined whether overall operative time was saved with the use of the Doppler according to the following criteria: if radiographically unrecognized vessels were discovered on Doppler survey, if

reclamping was indicated based on postclamp Doppler, or if vessel dissection was expedited by Doppler based on surgeon experience. The ease of use score for the Doppler probe ranged from 1 to 5 ("very easy" to "very difficult" to use) as reported previously.[13] A surgical assistant recorded all objectively measured operative data.

RESULTS

Fifty patients underwent laparoscopic renal surgery using the Doppler probe. Eleven patients underwent RNx, 5 patients underwent NU, 26 patients underwent PNx, and 8 patients underwent RALP. The results of these procedures are summarized in **Table 1**. Among the patients who underwent RNx/NU/PNx, Doppler survey identified 16 AV in 14 patients (33%; 14/42). This included 11 accessory arteries and 5 accessory veins. Of these, 5 accessory arteries and 3 accessory veins were not seen on preoperative imaging in 7 patients (17%; 7/42).

Overall, the probe altered management in 8/50 (16%) patients. In 2 PNx patients, early branching arteries that required reclamping were detected. In these cases, a persistent arterial Doppler signal occurred after clamping, indicating the need to reposition the clamp more proximally. Proper clamping was verified by loss of Doppler signal within the renal parenchyma and was further confirmed by minimal bleeding during excision. Three partial nephrectomy patients underwent attempted selective arterial clamping after accessory arteries were discovered by the Doppler. In 2 patients, the Doppler probe confirmed that selective clamping was adequate, and in one patient the Doppler signal persisted and clamping of a second artery was performed. Of the RALP patients, Doppler corrected preoperative imaging in detecting the presence (2 cases) or absence (1 case) of a crossing vessel in 3 patients. Of note, all 3 of these patients had a previously failed repair.

It was subjectively felt that dissection was easier and operative time was saved in 78% of patients with the use of the Doppler probe. The probe had 100% concordance with findings on hilar dissection, and its use was rated as "very easy" in every case. The probe also identified a significant lumbar vein in 3 patients. Use of the probe caused no clinical complications, and 2 technical failures occurred. In each instance, the probe lost signal output during the Doppler survey and had to be replaced. The replacement probe worked well both times, and minimal operative time was lost.

Table 1.
Doppler Probe Results

	RNx/NU*	PNx*	RALP*	Overall
Patients	16	26	8	50
Mean Doppler time (minutes)	1.82	1.48	2.62	1.77
Mean hilar dissection time (minutes)	10.38	7.93	N/A	9.25
Mean operating time (minutes)	119.8†	192.9	171.0	N/A
Mean estimated blood loss (mL)	104.2†	200.0	52.0	N/A
Total accessory vessels on CT	1	7	N/A	8
Patients with accessory vessels on CT	1	6	N/A	7
Total accessory vessels on Doppler	5	11	N/A	16
Patients with accessory vessels on Doppler	5	9	N/A	14
Patients with crossing vessel	N/A	N/A	7	7
Patients with altered management	0	5 (19.2%)	3 (37.5%)	8 (16%)
Patients where Doppler saved time	12 (75%)	21 (80.8%)	6 (75%)	39 (78%)
Ease of use score rating: "very easy"	16 (100%)	26 (100%)	8 (100%)	50 (100%)
Complications	0	0	0	0
Technical failure	1 (6.3%)	1 (3.8%)	0	2 (4%)

* RNx = laparoscopic radical nephrectomy; NU = laparoscopic nephroureterectomy; PNx = laparoscopic partial nephrectomy; RALP = robotic-assisted laparoscopic pyeloplasty.

†Values for RNx patients only. NU patients not included.

DISCUSSION

Laparoscopic Doppler technology has previously been shown to be beneficial in nonrenal laparoscopic surgery,[8–10] and we recently reported on the feasibility of its use in laparoscopic renal surgery.[13] This current study confirms that the technology provides significant assistance during laparoscopic renal surgery. The laparoscopic Doppler provided a real-time map of the renal vasculature that was precisely concordant with surgical dissection and correctly altered surgical management in 16% of patients. The system was found to be very easy to use, and on average, the Doppler survey was completed in less than 2 minutes. Furthermore, use of the Doppler was subjectively thought to have saved operative time in 78% of patients and its use caused no clinical complications.

The ability of preoperative imaging to determine accessory vessels has previously been studied. In 2007, Schlunt and colleagues[18] reported that before laparoscopic donor nephrectomy, the sensitivity of imaging to determine the number of renal arteries and veins was 97% and 100%, respectively, when read by a single radiologist. The sensitivity and specificity for accessory or early branched

arteries was 89% and 100%, respectively. The imaging protocol used in Schlunt's study entailed a multi-detector CT angiography in 4 phases with 3D reconstruction at 1-mm intervals and maximum intensity projections.[18] By comparison, we were quite surprised to learn that in half of the patients with accessory vessels the vessels had not been seen on preoperative imaging. One possible explanation is that the majority of our imaging studies did not use specific angiographic protocols to maximize delineation of renal vascular anatomy. In addition, only 59% of preoperative imaging reports in our study commented on the number of renal vessels. For the remainder of the cases, the number of renal vessels was solely determined by the operating surgeon. As a secondary endpoint, this study suggests that the Doppler probe achieves 100% predissection localization of renal vasculature. The Doppler probe provides a real time "vascular map" just prior to and during dissection. This avoids potential bleeding complications that can not be predicted based on preoperative imaging alone and expedites dissection, potentially decreasing operative time. Furthermore, it may reduce patient time in CT or MR scanners, the volume of contrast load, and radiation exposure in patients undergoing CT angiogram.

The Doppler probe also appeared advantageous in its effect on operative management. In addition to identifying accessory vessels, it helped confirm proper arterial clamping in patients undergoing PNx. Use of the Doppler altered clamping technique in 5 PNx patients, obviating the need for reclamping after incision into the parenchyma, which can be quite difficult due to bleeding. Furthermore, selective arterial clamping could not have been safely attempted in the 3 patients as previously mentioned. The Doppler probe was necessary to ensure ischemia around the tumor while allowing other portions of the kidney to remain well perfused. We have also found the probe to be especially useful after previous endopyelotomy or other renal surgery. In these cases, the anatomy is often obscured by scar tissue, making dissection without the Doppler probe laborious and potentially dangerous. As such, injury to the crossing vessel could have easily occurred during the 2 RALP cases where preoperative imaging did not identify it. This is similarly true in other patients with chronic inflammation or congenital abnormalities. Overall, we believe the Doppler probe had significant benefits in these cases with altered management.

While many studies have previously reported mean total operative times for the above procedures, to our knowledge no report has formally analyzed the mean time required for hilar dissection. With the laparoscopic Doppler probe, the mean time averaged 9.25 minutes, which we believe to be more rapid than dissection without the probe. The operating surgeon felt that time was saved in 78% of patients. This study did not directly compare cohorts of patients undergoing these operations with or without the laparoscopic Doppler probe. However, an ad hoc retrospective analysis compared the mean operative time and EBL for RNx, PNx, and RALP in this study to recent studies of the same procedures without the laparoscopic Doppler probe by the same surgeon. The recently published studies documented mean operative times of 187.6 minutes, 248.4 minutes, and 217 minutes and mean EBLs of 192cc, 222cc, and 59cc for RNx, PNx and RALP, respectively.[19–21] In this current study, mean operative times were 119.8 minutes, 192.9 minutes, and 171 minutes, and mean EBLs were 104.2cc, 200cc, and 52cc for RNx, PNx, and RALP, respectively **(Table 1)**. In the current study, an average of 67.8 minutes shorter operative time and 87.8cc less blood loss was documented for RNx. For PNx, an average of 55.5 minutes shorter operative time and 22cc less blood loss was documented. For RALP, an average of 46 minutes shorter operative time and 7cc less blood loss was documented. Clearly, the significantly less operative time recorded in the current study is not solely due to the laparoscopic Doppler probe. The previous studies were performed earlier in the surgeon's career, and surgeon experience likely played a significant factor. Furthermore, there is a learning curve for operative staff that leads to overall efficiency within the operating room. As a conservative estimate, we believe the Doppler probe attributed to approximately 15 minutes of time saved in the operating room.

Overall, the Doppler survey took less than 2 minutes to complete, enabled the surgeon to avoid all unknown aberrant vessels, and allowed for reclamping prior to transecting only partially controlled vasculature or incising well-perfused parenchyma. Given the prevalence of aberrant renal hilar anatomy[1] and the imperfect sensitivity of imaging renal vasculature, we believe that the laparoscopic Doppler probe significantly facilitates dissection around the renal hilum. Compared with laparoscopic ultrasound, the laparoscopic Doppler probe has a much smaller profile, approximately 5mm in diameter, provides audio feedback, and is much easier to use. The current study greatly expands on our initially reported experience with this technology[13] by documenting its perfect concordance with operative dissection, improved operative time, safety, and ease of use. A multi-institutional prospective, randomized trial is currently being performed to more formally analyze the findings of this study.

Disadvantages of the Doppler probe should be mentioned. Use of the probe adds an additional step to the operation, and the probe replaces another working instrument in the operative field. In our hands, the probe had a 4% technical failure rate, though a replacement probe functioned normally in all cases. Finally, the probe currently costs about $130; however, this may be justified with expedited dissection, avoidance of complications, and/or decreased OR time. Our institution charges $1,100 for every 15 minutes additional OR time. As previously described, 15 minutes of OR time saved by the lap Doppler is a conservative estimate. Accounting only for OR time, use of the lap Doppler probe saved an average of $970 per patient. The current prospective randomized comparison with and without Doppler assistance will help delineate these benefits. Lastly, the Doppler may mitigate the need for a CT angiogram or MR angiogram prior to certain laparoscopic renal surgeries, further reducing cost, time, and morbidity associated these studies.

CONCLUSION

This article reports on the first formal, prospective study evaluating a laparoscopic Doppler probe for renal surgery. We report objective and subjective data that support the utility of this technology for assessment of vasculature during laparoscopic partial and radical nephrectomy, nephroureterectomy, and minimally invasive pyeloplasty. Our data demonstrate rapid and easy use, perfect concordance with findings on surgical dissection, and numerous instances where use of this technology altered surgical management. The laparoscopic Doppler is now an integral component of our laparoscopic renal surgeries, and we are currently further investigating its objective benefits in a prospective, randomized multi-institutional study.

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