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Single-Site Laparoscopic Nephrectomy: Is It Cost-Effective?

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Abstract

Background: With the emergence of Laparoendoscopic Single-Site Surgery (LESS) and its potential patient benefits, a cost comparison was conducted to enable informed decision-making for the selection of minimally invasive surgical approach type for nephrectomy.

Methods: A literature-based cost comparison of Hand-Assisted Laparoscopic (HAL), Conventional Laparoscopic (LAP), and LESS nephrectomies was conducted to determine whether the benefits of LESS offset the expense of this new technique and its expensive technologies. Using institutional rates the total cost of each approach was determined by summing the costs of instrumentation unique to each approach, Operative Time (OT) and patient length of stay (LOS). One-way and two-way sensitivity analyses were performed varying each of the costs to determine cost-equivalence thresholds across the approaches.

Results: Based on the literature review (n=557), LESS was the most cost effective due to short OT and LOS. OT would have to be less than 121 and 145 minutes or LOS would have to be less than 1.5 and 2.86 days for HAL and LAP to be more cost-effective than LESS, respectively.

Conclusion: The cost difference between LAP and LESS was minimal and small decreases in OT, LOS or both would result in a cost-advantage for LAP. Although LESS was the most economical approach, this preliminary cost analysis was based on the procedural outcomes of expert surgeons that were early-adopters of LESS. Prospective, controlled trials comparing HAL, LAP and LESS are critical for procedural optimization and cost control.

Keywords: Laparoscopic nephrectomy; HAL; LAP

Introduction

Since the first laparoscopy nephrectomy performed by Clayman et al. [1], Laparoscopy has become the gold standard for the management of both benign and malignant renal diseases. With the evolution of minimally-invasive urologic surgery the impetus has been to reduce the invasiveness by decreasing the number and size of abdominal incisions. For each incision the surgeon must be concerned about the risks of pain, bleeding, injury to intra abdominal organs, hernias and cosmesis (scar formation). As minimally invasive surgery technologies advance there is the potential for increased costs of the supplies and equipment that may be offset by reductions in operative time, hospital length of stay, and/or time to convalescence. However, the first step towards cost control is the identification and understanding of the factors that contribute to the overall cost.

The two most commonly performed minimally invasive techniques for nephrectomy are Hand-Assisted Laparoscopic (HAL) and Conventional Laparoscopic (LAP). Laparoendoscopic Single-Site Surgery (LESS) is the natural progression beyond HAL and LAP and is increasingly being used in the urologic community worldwide for both benign and malignant conditions of the kidney [2,3]. Raman et al. showed that LESS nephrectomy is feasible with comparable perioperative outcomes and less blood loss compared to LAP [4]. Other small case series have shown LESS nephrectomy patients have decreased postoperative pain and narcotic use, shorter hospital stay, and improved cosmesis compared to LAP [2,5]. A recent large, multi-institutional study of LESS urological procedures revealed that complications of LESS are also similar to those of LAP with reasonable conversion rates in experienced hands [6]. Notably, time to return to normal activities and return to work has been noted to be significantly shorter for simple and donor nephrectomies performed via LESS compared with standard laparoscopic approach [3,5]. Conversely, some studies have shown no difference in LESS postoperative pain control, operative time, or length of hospital stay compared with LAP [4,7]. With this conflicting data, it is not yet known whether LESS is a reasonable alternative financially compared with LAP and HAL.

According to the Centers for Medicare and Medicaid Services, national healthcare expenditures approached $2.7 trillion in 2011 and will most certainly continue to increase [8]. Cost control measures and judicious economical choices are crucial to increasing the access to healthcare while maintaining a high quality of care. In the context of surgical patients, it can be presumed that to minimize costs the most minimally invasive approach should be performed in order to decrease hospital length of stay and time to convalescence. However, newer technologies and techniques, such as LESS, that may provide these benefits are often scrutinized for their higher cost. Accordingly, cost analyses remain vital to objectively assess new technologies and techniques to determine if in addition to their potential clinical benefits they are likewise economical. Even with the increasing popularity of LESS, at present there are no cost analysis studies comparing LESS, HAL and LAP nephrectomy to determine whether the benefits of LESS compensate for its expense. Thus, the aim of this study was to determine whether LESS was a more costly alternative compared to standard laparoscopic and hand-assisted laparoscopic nephrectomy taking into consideration operative time, hospital length of stay, and operating room instrument costs. It was hypothesized that LESS would

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be more expensive due to the higher costs of the novel equipment and longer operative times.

Materials and Methods

Institutional cost comparison

Institutional Review Board (IRB) approval was obtained to perform a retrospective chart review of all nephrectomies performed by a single expert surgeon (CL) at the University of Nebraska Medical Center (UNMC) from 2008 to 2012. Operative technique was not randomized across the included patient population. All open, partial, and bilateral nephrectomies were excluded. HAL, LAP and LESS simple and radical nephrectomies and nephroureterectomies were included in the study. All included cases were approached transperitoneally. HAL cases were performed with the GelPort Laparoscopic System (Applied Medical, Rancho Santa Margarita, CA and USA) and two disposable 12-mm trocars. LAP cases were performed using two disposable 12-mm trocars and two 5-mm trocars. All other instruments used for HAL and LAP were reusable. LESS nephrectomy was performed using the GelPOINT Advanced Access Platform (Applied Medical, Rancho Santa Margarita, CA, USA) through a periumbilical incision. Disposable 5-mm Roticulator Endo Dissect and Endo Grasp instruments (Covidien, Mansfield, MA, USA) were also used for LESS. The total costs of disposable instruments (INST) unique to HAL, LAP, and LESS from our institution were $596.21, $197.74 and $741.38, respectively (Table 1).

Standard demographic data were collected as well as past surgical history, comorbidities, indication for surgery, Operative Time (OT), Length of Stay (LOS), conversion rate and postoperative complications within 30 days. Cost estimates were supplied by the institutional operating room administration at UNMC. For every procedure, anesthesia charged a base rate of $35.64 plus an additional $4.05 per minute. For the operating room there was a base rate of $399 (includes non-chargeable supplies used during a case e.g. gowns, gloves, etc.) plus an additional $14.96 per minute depending on patient acuity, number of staff needed to run the room, etc. To standardize included cases, costs were calculated using the highest end of the spectrum for all patients regardless of acuity or level of care. Instrument (INST) costs of disposables used for each technique were obtained from our institution's operating room administration. Instrument cost was calculated using the costs of disposables unique only to each modality. Sutures, cautery, reusable instruments, laparoscopes, cameras, laparoscopic suction/irrigation system, Harmonic ACE Curved Shears (Ethicon Endo-Surgery, Cincinnati, OH, USA), clip applier, Endo GIA stapler (Covidien, Mansfield, MA, USA), and Endo Catch specimen bag (Covidien, Mansfield, MA, USA) were used for all procedures and for simplicity were excluded from the instrument cost estimates. Anesthesia and surgeon professional fees were also not included. Cost of a standard non-Intensive Care Unit (ICU) day for a typical urologic patient was obtained from the director of critical care and calculated to be approximately $1,051 per day. This included room, board and ancillaries such as nursing care, blood products, IV fluids, medications, laboratory and other diagnostics.

Literature-based cost comparison

In order to compare our institution's experiences with published reports, a literature search was performed using MEDLINE to examine contemporary series of HAL, LAP, and LESS nephrectomies. Only peer-reviewed Randomized Control Trials (RCTs) or case-control studies in which the authors directly compared LESS and LAP were included. Also, the studies must have been published in English within the last five years. A large contemporary review of HAL studies was included for comparison to avoid bias against this technique. In this study Lotan et al. computed the weighted mean OT and LOS using nine peer-reviewed reports of HAL radical and simple nephrectomies [9]. The weighted means for LAP and LESS OT and LOS were then calculated from the combined series. Next, the weighted means of OT and LOS were converted into costs using our institutional rates and combined with INST cost to calculate the overall costs of each of the three techniques. One-way and two-way sensitivity analyses were performed varying OT and/or LOS to determine cost-equivalence thresholds between the approaches. Data analyses were completed using Excel (Microsoft Corporation, Redmond, WA, USA) and Minitab (Version 14, Minitab Inc., State College, PA, USA). Statistical analyses were purposefully not performed given the small sample sizes.

Results

Institutional cost comparison

The retrospective chart review identified 42 patients who underwent nephrectomies performed by a single endourologist at UNMC. Twenty-nine patients underwent HAL, 9 patients underwent LAP, and 4 patients underwent LESS nephrectomies (Table 2). Mean OT was shortest for HAL at 129.7 minutes, whereas mean LOS was shortest for LAP at 2.22 days. The overall cost of LESS was $738.46 less expensive than HAL due to a shorter LOS (3.34 vs. 2.25 days) (Table 3). However, LAP was the most cost effective at $816.98 primarily due to the increased INST costs of LESS.

Literature-based cost comparison

At present, there are no published RCTs or case-control studies that compare all three approaches (HAL, LAP and LESS) for nephrectomy. The literature search yielded only four studies that met the inclusion criteria and directly compared LAP and LESS (Table 4). HAL has been extensively studied and a large, contemporary cost comparison study's weighted average for OT and LOS were used [9]. The weighted means for OT were 204, 149.8, and 150.4 minutes and the weighted means for LOS were 3.0, 2.95, and 2.34 days for HAL, LAP, and LESS, respectively (Table 5). Using the institutional cost model, LESS was $1,567.43 less expensive than HAL due to a shorter OT (204 vs. 150.4 minutes) and LOS (3 vs. 2.34 days) (Table 6). LESS was also $86.06 less expensive than LAP due to a shorter LOS (2.95 vs. 2.34 days).

One-way sensitivity analyses were performed by varying a single parameter (i.e., OT or LOS) at a time to determine points of cost equivalence for HAL and LAP compared to LESS (Table 6). The one-way sensitivity analyses showed that OT would have to be less than 121 and 145 minutes or LOS would have to be less than 1.5 and 2.86 days for HAL and LAP to be more cost-effective than LESS, respectively.

Approach	Instruments	Cost /Procedure (U.S. Dollars)
HAL	GelPORT[a] 12-mm VersaStep[b] ports x 2	$488.75 $107.46 $596.21 Total
LAP	12-mm VersaStep[b] ports x 2 5-mm VersaStep[b] ports x 2	$107.46 $90.28 $197.74 Total
LESS	GelPOINT[a] 5-mm Roticulator Endo Dissect[b] 5-mm Roticulator Endo Grasp[b]	$573.00 $84.19 $84.19 $741.38 Total

[a]Applied Medical, Rancho Santa Margarita, CA, USA, [b]Covidien, Mansfield, MA, USA

Table 1: HAL, LAP and LESS nephrectomy disposable instrument costs.

	HAL	LAP	LESS
Number of cases, *n*	29	9	4
Gender (%)			
Male	65.5	77.8	50
Female	34.5	22.2	50
Age (years)[c]	61.7 (16.75)	55.6 (12.45)	32.8 (13.67)
Weight (kg)[c]	90.3 (25.7)	93.3 (20.2)	88.0(29.5)
BMI (kg/m^2)[c]	30.5 (7.88)	29.9 (4.28)	28.5 (5.94)
Smoking History (%)			
Current smoker	10.3	33.3	50
Former smoker	34.5	22.2	0
Nonsmoker	55.2	44.5	50
Indication (%)			
Oncologic	89.7	100	25
Non-oncologic	10.3	0	75
Pathology (%)			
Oncologic	86.2	66.7	0
Non-oncologic	13.8	33.3	100
Operative side (%)			
Right	34.5	55.6	25
Left	65.5	44.4	75
Comorbidities (%)			
Yes	13.8	100	50
No	86.2	0	50
Previous abdominal surgery (%)	65.5	55.6	50
American Society of Anesthesiologists (ASA) Score[c]	2.93 (0.53)	2.67 (0.50)	2.50 (0.58)
Operative Time (OT)[c]	129.7 (28.16)	130.8 (32.02)	143.5 (35.71)
Estimated Blood Loss (mL)[c]	124.3 (105.4)	70.6 (60.9)	37.5 (14.4)
Converted (%)	0	0	0
Length of Stay (LOS)[c]	3.34 (0.90)	2.22 (1.20)	2.25 (2.50)
Postoperative Complication (%)	11.5	0	25

[c]Mean (Standard Deviation)

Table 2: Institutional cases.

Approach	*n*	OT (min)[c]	OT Cost[d]	LOS (days)[c]	LOS Cost[e]	INST Cost	Total Cost	Cost Difference
HAL	29	129.7 (28.16)	$2,900.62	3.34 (0.90)	$3,510.34	$596.21	$7,007.17	$738.46
LAP	9	130.8 (32.02)	$2,920.77	2.22 (1.20)	$2,333.22	$197.74	$5,451.73	($816.98)
LESS	4	143.5 (35.71)	$3,162.58	2.25 (2.50)	$2,364.75	$741.38	$6,268.71	-

[c]Mean(Standard Deviation), [d]OT Cost=$434.64 + $19.01 per minute (includes anesthesia and surgery), [e]LOS Cost=$1,051 per non-ICU day

Table 3: Institutional operative outcomes and estimated costs.

Study	Approach	Procedure	*n*	OT (min)[f,g]	LOS (days)[f,g]	EBL (cc)[f,g]
Raman et al. [4]	LAP	10 Simple and 12 Radical	22	125 (90-240)	2.21 (1.2-4.4)	100 (20-520)
	LESS	5 Simple and 6 Radical	11	122 (90-210)	2.04 (1.3-3.1)	20 (10-600)
Park et al. [2]	LAP	38 Radical	38	172 (110-250)	3.9 (3-7)	199.5 (50-500)
	LESS	19 Radical	19	191 (125-335)	2.7 (2-4)	143.2 (100-300)
Raybourn et al. [7]	LAP	10 Simple	10	165 (90-220)	2.1 (1-6)	68 (30-150)
	LESS	10 Simple and 1 Radical	11	151 (45-290)	2.36 (1-4)	51 (20-100)
Tugcu et al. [3]	LAP	13 Simple	13	114 ± 15	2.11 ± 0.37	47.15 ± 6.4
	LESS	14 Simple	14	117.5 ± 13.12	2.07 ± 0.26	50.71 ± 8.69

[f]Mean (Range), [g]Mean ± Standard Deviation

Table 4: OT and LOS and EBL results from four contemporary LAP and LESS nephrectomy comparison studies.

Instrumentation costs for LESS far exceeded HAL and LAP, yet LESS was the least expensive overall. Although the instrument costs of LAP could theoretically be decreased by $86.06 to achieve an overall cost-equivalence with LESS, one-way sensitivity analyses were not performed using instrumentation costs. Moreover, it was not possible to decrease the instrumentation costs of HAL by $1567.43 since the INST cost of HAL was already less expensive than LESS at $596.21.

Two-way sensitivity analyses were also performed to determine cost thresholds for each treatment option. A longer OT for HAL required a shorter LOS and vice versa to be cost equivalent to LESS (Figure 1 left). If OT for HAL was shortened to be equivalent with LESS at 150 minutes, then the LOS for HAL would also have to decrease to less than 2.5 days to be cost-equivalent compared to LESS. The cost difference between LAP and LESS was minimal and the two-way

Approach	*n*	OT (min)	LOS (days)
HAL			
Lotan et al. [9]	419	204	3
Weighted Mean[h]	419	204	3
LAP			
Raman et al. [4]	22	125	2.21
Park et al. [2]	38	172.4	3.9
Raybourn et al. [7]	10	165	2.1
Tugcu et al. [3]	13	114	2.11
Weighted Mean	83	149.8	2.95
LESS			
Raman et al. [4]	11	122	2.04
Park et al. [2]	19	190.8	2.7
Raybourn et al. [7]	11	151	2.36
Tugcu et al. [3]	14	117.5	2.07
Weighted Mean	55	150.4	2.34

[h]Weighted mean from 9 studies compiled in Lotan et al. [9]

Table 5: HAL, LAP, and LESS contemporary studies used to generate weighted means of OT and LOS.

	Approach	*n*	OT (min)	OT Cost[d]	LOS (days)	LOS Cost[e]	INST Cost	Total Cost	Cost Difference
Unadjusted Cost Estimates	**HAL**	419	204	$4,312.68	3	$3,153.00	$596.21	$8,061.89	$1,567.43
	LAP	83	149.8	$3,282.34	2.95	$3,100.45	$197.74	$6,580.53	$86.06
	LESS	55	150.4	$3,293.74	2.34	$2,459.34	$741.38	$6,494.46	-
OT Sensitivity Analysis	**HAL**	419	121	$2,734.85	3	$3,153.00	$596.21	$6,484.06	($10.40)
	LAP	83	145	$3,191.09	2.95	$3,100.45	$197.74	$6,489.28	($5.18)
	LESS	55	150.4	$3,293.74	2.34	$2,459.34	$741.38	$6,494.46	-
LOS Sensitivity Analysis	**HAL**	419	204	$4,312.68	1.5	$1,576.50	$596.21	$6,485.39	($9.07)
	LAP	83	149.8	$3,282.34	2.86	$3,005.86	$197.74	$6,485.94	($8.53)
	LESS	55	150.4	$3,293.74	2.34	$2,459.34	$741.38	$6,494.46	-

[d]OT Cost=$434.64 + $19.01 per minute (includes anesthesia and surgery), [e]LOS Cost=$1,051 per non-ICU day

Table 6: Estimated costs of HAL, LAP and LESS nephrectomies and one-way sensitivity analysis for cost equivalence for OT and LOS.

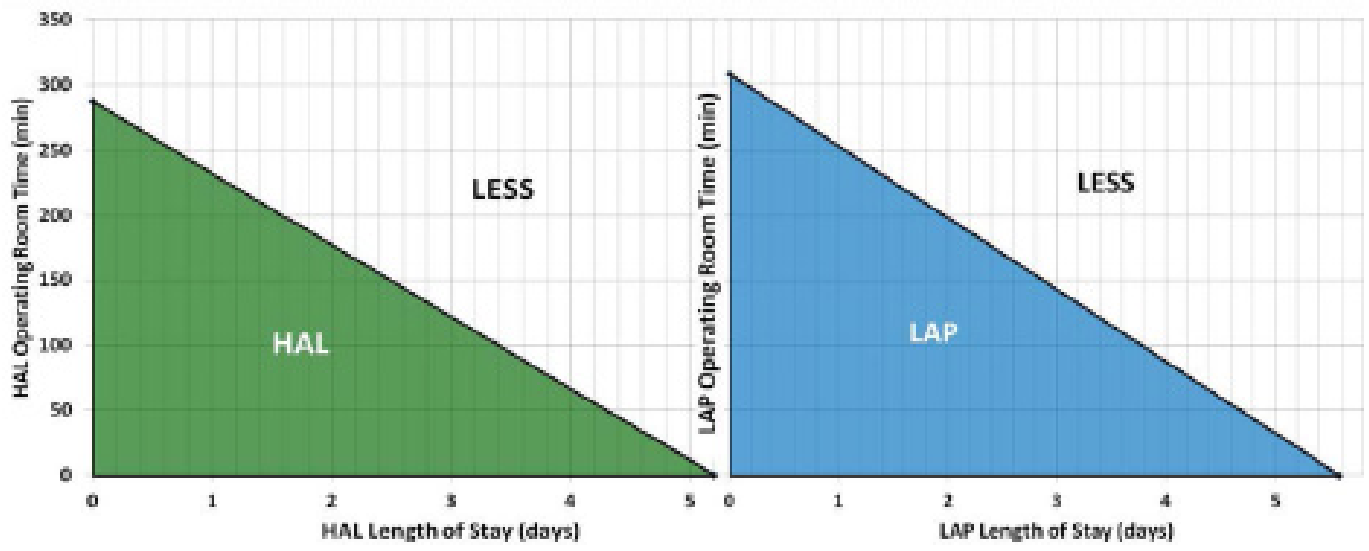

Figure 1: Two-way sensitivity analysis varying OT and LOS for HAL (left) and LAP (right).

sensitivity analyses showed that small decreases in OT or LOS or both would result in a cost-advantage for LAP compared to LESS (Figure 1 right).

Discussion

With the introduction of LESS, minimally-invasive surgery has taken one more step towards decreasing the number and size of incisions which may reduce perioperative pain and bleeding and improve cosmesis and time to convalescence. However, new operative techniques must be applied conservatively until the safety, efficacy and cost effectiveness of such techniques have been proven to be superior compared to the standard of practice. Although LESS nephrectomy has had comparable or improved outcomes relative to LAP in regards to operative time, length of hospitalization, analgesic use, and complications without compromising surgical outcomes [3,4,7] there will continue to be pressure to also demonstrate cost effectiveness compared to HAL and LAP nephrectomies. Similar to LESS nephrectomy, cost comparisons of radical prostatectomy techniques led

to the identification and understanding of the factors that contributed to the global costs and ultimately procedure standardization [10].

The cost model identifies three factors that have traditionally had a great financial impact on the adoption of new techniques: instrumentation cost, operative time and hospital length of stay. The cost of disposable instruments for LESS was much more costly than HAL and LAP nephrectomies, yet LESS resulted in the lowest overall cost based on cases from the literature review. The one and two-way sensitivity analyses showed that the decreased length of hospital stay of LESS was the leading factor for LESS to be less costly than LAP and HAL. In addition to a decreased length of stay, LESS also had a decreased operative time compared to HAL, and both factors combined enabled LESS to have a large cost advantage over HAL. Similarly, the institutional case review also demonstrated a cost advantage for LESS over HAL despite a 74 minute decrease in the operative time for HAL compared to the weighted mean operating time in the literature review (130 vs. 204 minutes).

Overall, LESS was more cost-effective compared to LAP and HAL nephrectomies. Based on this initial analysis and the literature, LESS can be more cost effective, less invasive, and decrease time to convalescence while maintaining procedural efficacy. However, LESS is a difficult technique to learn and master. The procedural outcomes (operative time and length of stay) are based on expert surgeons and may not be generalizable to other surgeons and institutions. As early adopters, these pioneering surgeons are critical to the standardization of this ground-breaking approach by not only developing best practices but also through the creation of enabling technologies that allow all minimally invasive surgeons to transition to LESS. This initial cost-comparison model highlights the critical need for prospective, controlled trials comparing hand-assisted laparoscopic, conventional laparoscopic and laparoendoscopic single-site nephrectomies. It also provides the framework towards cost optimization by identifying the factors that can be improved upon in order to make these approaches more economical and thus accessible. Specifically, even with an increased operative time and instrumentation costs, LESS can be cost effective through a reduction in length of stay and time to convalescence.

As a preliminary cost analysis there were several limitations of our study. The institutional and literature-based results were taken from expert surgeons who are familiar with these advanced laparoscopic techniques. It can be assumed that other surgeons less familiar with these techniques will incur higher costs until they are proficient. Furthermore, neither the institutional or literature cases investigated time to convalescence, which has shown favorable patient outcomes for LESS [3,5]. Longitudinal follow-up should be an important consideration in future studies as it may widen the economic gap between the approaches in favor of LESS. Institutionally, there was a small sample size of LESS case due to the conservative application of this novel approach. For this highly screened population, three of the four LESS patients were in their 20's and only one of the LESS patients had a preoperative diagnosis of cancer while a majority of the HAL and LAP patients had preoperative diagnosis of cancer. Similarly, only four literature-based studies directly compared LAP and LESS, and there we no studies comparing all three approaches. Although Kaouk et al. [11] published a large, multi-institutional retrospective series of LESS in urology, large, prospective, randomized controlled trials comparing HAL, LAP and LESS are critically needed for procedural optimization and cost control.

Even though the institutional review included a selective group of patients for LESS, based on the cost model it can be anticipated that future patients with worse pathology and more comorbidities that require longer operations will likely benefit from LESS. Evidence supporting or negating this preliminary cost comparison can and should be evaluated in the near-term after multi-centered studies of LESS are conducted. Continued utilization and advancement of LESS-technologies will undoubtedly result in lower instrument costs over time. Cooperatively medical device manufacturers and surgeons can reduce the cost of LESS instruments and learning curve by creating functional yet intuitive instruments that mitigate the inherent difficulties of LESS. Making the advanced technologies of LESS user friendly and enabling for surgeons of all skill levels will also decrease the workload of this technique making it accessible to a wider range of patients and procedures.

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