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Hand Assisted Laparoscopic Surgery: An Updated-Overview

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Abstract

Introduction: Hand assisted laparoscopic surgery is an updated highly advanced version of laparoscopic technique. Such technique bridges the gap between traditional surgery and total laparoscopic surgery. Introduction of the hand intracorporeally enhanced the degree of freedom, hence, a remarkable degree of precision and safety in task performance.

Clinical and experimental studies confirmed safe use of the hand with insufflation pressure enhancing dexterity as well as a steep learning curve. Therefore, the author made an overview analysis to the factors related to safety; efficiency; dexterity; instrumentation and cost-effectiveness for the use of hand assisted laparoscopic surgery; with an emphasis on live donor nephrectomy.

Results and discussion: Prospective studies made by Kolvenbach on the use of hand assisted laparoscopic surgery in aortic aneurysm repair proved high degree of safety and efficiency as well as cost effectiveness. Several studies highlighted a multitude of factors significantly contributing into a high degree of precision and task performance; which reflected on uneventful enhanced recovery programme.

The introduction of either hand intracorporeally enhanced the limited degree of freedom for the current laparoscopic tools. There are various hand port devices of which the pros and cons for each port will be discussed in detail. The author's experimental studies confirmed that optimum safe insufflation pressure would be 10 mm Hg with no leak from the hand port and optimum dexterity and task performance.

Conclusion: Hand assisted laparoscopic surgery is a safe and efficient technique. It significantly enhances concept of Enhanced Recovery programme. Raising public awareness can provide a high impact in enhancing live donor nephrectomy; hence reducing the inexorable renal transplant waiting list for patients with end stage renal disease. Such patients are at progressive rise of mortality risk with prolonged waiting list.

Keywords: Hand-assisted, Donor nephrectomy

Introduction

Hand Assisted Laparoscopic Surgery (HALS) is a hybrid approach designed to overcome the mechanical constraints of Total Laparoscopic Surgery (TLS). The Hand considered the best surgical tool to date facilitating exploration, exposure, finger dissection, palpation, and immediate effective haemostasis [1].

However, the use of intracoperal hand may potentially be associated with mechanical constraints due to limitation in intra-abdominal work space as well as for the awkward Surgeons' position [1]. Such constraints may reduce the ultimate task performance. Hence, safety and efficiency for our patients may be compromised.

Upon review of the potential ergonomic limitations in (HALS), the primary outcomes were: Dexterity; Tactile Feedback; and Leakage of insufflation pressure via a Hand port device. The secondary outcomes considered: safety and efficiency; cost-effectiveness and enhanced Recovery Programme.

Literature Review

Search criteria

Search made in March 2017; via my Athens Account for: (http://login.openathens.net); the Core Data Bases (Cochrane Library; Medline and Embase) and Subject-Specific Data Base; using the following

- Key words: hand-assisted, donor nephrectomy,
- Authors showed interest in Hand-assisted Laparoscopic Surgery
- Subject headings

Description

Use of hand and dexterity: In (HALS), either the dominant or non-dominant hand will be introduced intraperitoneal via a hand port device. Such a device will be fixed to anterior abdominal wall through an average 6-7 cm preoperatively planned skin incision. The aim of the hand port device would be to maintain insufflation pressure with minimal effects on dexterity and minimal leakage of intraperitoneal gas [1].

(HALS) introduced in 1995 as a hybrid technique to reduce the high risks imposed by using (TLS) in complex abdominal procedures. Task performance has been significantly reduced in (TLS) by the limited degree of freedom. Permissible movements are only 4 with (TLS). Freedom of movement is the potential for movement in a single independent direction; or rotation around one axis. Laparoscopic instruments can move in / out; rotate or side to side along the z axis; being limited by the narrow ports.

Added to the limitation of movement, would be the loss of tactile feedback in (TLS). Consequently, there will be a significantly high risk

of serious complications associated with postoperative morbidity and mortality [2].

Hence, the use of hand allows a 21 degree of freedom of movements (9 for interphalangeal joints; 10 for metacarpophalangeal joints and 2 for the wrist joint) that by restoration of the direct tactile feedback allowed adequate manoeuvrability for tissue retraction; blunt dissection and secured haemostasis. Task performance has been significantly improved. Safety and efficiency has been confirmed for complex abdominal procedures using (HALS) technique. (9 for i

Some Surgeons' argue that (HALS) would not be cost-effective as the hand port devices remain to be expensive. While other Surgeons question the safe maintenance of gas insufflation [1,2]. The mechanical limitations in (TLS) are due to loss of tactile feedback and reduced degree of freedom have been overpowered by (HALS). (HALS) facilitated retraction; resection; anastomosis; immediate control of bleeding and even major vascular procedures. Therefore, such added benefits would enhance (HALS) cost-effectiveness through a significant reduction in morbidity risk; therefore, reduced hospital stay and ultimately an enhanced recovery.

Several studies evaluated various types of hand port devices. Types of hand port devices are [3]:

• Hand port device (Smith-Nephew PLC, London, UK)

• Single piece devices (Lap disc, Hakko medical, Tokyo, Japan)

• Dexterity device and Intromit

• Extra-corporeal pneumoperitoneum access bubble

• Omni port (Medtech, Ltd, Dublin, Ireland)

An ideal hand-access device should have the following features: single component; ease of insertion with resistance to removal; effective comfortable seal; good internal hand reach; the ability to withdraw and change hands without loss of pneumoperitoneum; hand-forearm comfort; the ability to insert standard laparoscopic instruments/staplers/swabs through access device and maintenance of a uniform tactile feedback sensation and dexterity. The Omni port has been well-studied ensuring maintenance of gas insufflation. 22% of 24 different (HALS) procedures developed gas leak; in a prospective randomized trial [4] (Figures 1-6).

In ergonomic terms, the hand access device replaces the assisting port but is substantially larger to accommodate the intracorporeal hand. However, the ergonomic setup in HALS has two main constraints. First, there is a significant reduction of the internal and external workspace compared with the total laparoscopic approach. Applying the definition of the manipulation angle to HALS, it refers to the angle between the axis of the inserted forearm–hand and the axis of the external instrument. To date, no ergonomic studies on the optimum location of the hand access device in HALS have been reported [5].

Second, there is a discrepancy in the hand-to-target distance between the extracorporeal and intracorporeal limbs in HALS. This results in an awkward posture of the surgeon, who adopts a Lordotic position, resulting in discomfort to the upper limbs.

The problem is heightened by the static posture of the surgeon, with the forearm anchored to the hand port device for long periods during complex procedures. Consequently, many surgeons experience back strain and muscle fatigue of the upper limbs during (HALS) [5]. Furthermore, Hanna et al. [6], investigated the influence of the working surface height on task performance and muscle workload in hand-assisted laparoscopic surgery. The authors concluded that the optimum table height for hand-assisted laparoscopic surgery allows the working surface of the extracorporeal instrument handle to be at or 5 cm above the elbow level.

Clinical Studies

Kolvenbach [7] reported the safety and feasibility for using (HALS) in repair of aortic aneurysm. (TLS) in aortic repair did not gain much support because of significant constraint of obesity and in severe calcifications. Furthermore, aortic cross-clamping extending well beyond 2 hours; increasing the risk for distal embolization. Hence, the long operating times in (TLS) would raise the morbidity & mortality
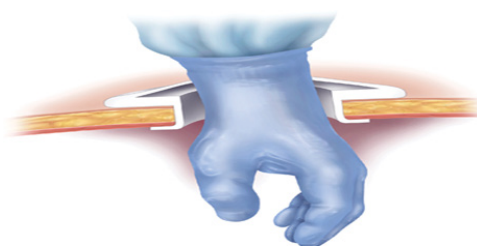

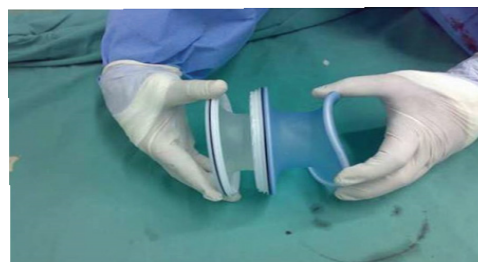**Figure 1:** Zinner MJ, Ashlay SW Maingot's abdominal operations 12th edition www.accesssurgery.com.
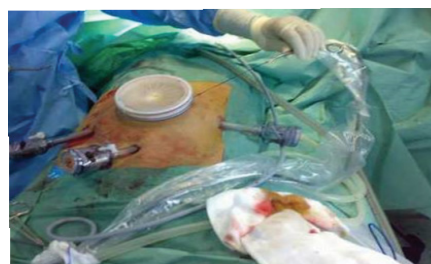

Figure 2: Lap disc.

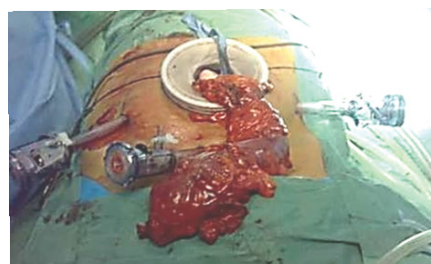**Figure 3:** Ergonomic hand port location.

Figure 4: Colon exteriorized via the hand port.

Figure 5: Complete healing of scars post-hand assisted laparoscopic sigmoid colectomy.

Figure 6: Omni port hand-access device.

Variables	N=29	N=19
Mortality (%)	1 (3.4)	1 (5.2)
Complications		
Pneumonia	-	2
Atelectasis	-	1
Sigmoid ischemia leus	1	-
Distal embolisation	1	-
Incisional hernia	-	1
Lymphatic fistula	1	1
Colitis	1	-
Total (%)	5 (17.2)	5 (26.3)

Table 1: Distribution of complications in 29 laparoscopic and 19 conventional procedures.

Open	Mean	Maximum	Minimum
Time in ICU (d)	2.11	6.00*	1
EBL (mL)	813.68	1900.00	100
Operative time (min)	135.79	240.00*	75.00
XClamp (min)	49.16	75.00*	32.00
Laparoscopic			
Time in ICU	1.30	7.00	1.00
EBL	711.00	2000.00	250.00
Operative time (min)	180.67	345.00	130.00
XClamp (min)	56.67	90.00	44.00

Abbreviations: ICU: Intensive Care Unit; EBL: Estimated Blood Loss; XClamp: Aortic Cross Clamp Time; *P<0.05.

Table 2: Mean; maximum and minimum perioperative data between open and laparoscopic (HALS) surgery.

Variables	Conventional surgery			Laparoscopic (HALS) surgery		
	Food	Length of Stay (d)	Temperature	Food	Length of Stay (d)	Temperature
Mean	3.32*	9.37*	34.34*	1.57	5.93	35.07
Maximum	7	18	35.7	6	21	35.9
Minimum	1	5	33.2	1	4	33.4

Note: Food, day when solid food was given temperature (C), postoperative temperature; *P<0.05

Table 3: Postoperative data.

Variables	HALS			EVAR		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
LOS (d)	7.43	4.00	15.00	6.46	3.00	12.00
ICU (h)	27.37	0.00	67.00	13.7308	0.00	38.00
NACL (mL)	4,700.00	3,000.00	7,500.00	3,515.38	2,700	4,500.00

Abbreviations: LOS: Length of Stay; ICU: Intensive Care Unit; NACL: Sodium Chloride.

Table 4: Clinical Data comparing HALS AAA Repair and EVAR.

The median and interquartile ranges of the degree of discomfort incurred during the use of hand access device Cuff pressure	10 mmHg	20 mmHg	30 mmHg	P value
Leakage	0 (0)	0 (0)	0 (0.25)	p=0.126
Texture feedback	0 (0)	0 (1)	0.5 (1)	p=0.155
Vibration feedback	0 (0)	0 (1)	0 (1)	P=0.101
Dexterity	0 (0)	1 (1.25)	1(0.50)	P=0.002

Table 5: The median and interquartile ranges of the degree of discomfort incurred during the use of hand access device Cuff pressure.

Median and interquartile ranges of the leakage rate (L/sec) with different Omni-port cuff pressures Cuff pressure Insufflation pressure	10 mmHg	20 mmHg	30 mmHg
10 mmHg	0.01 L/sec (0.0103)	0.005 L/sec (0.006)	0.003 L/sec (0.003)
15 mmHg	0.0176 L/sec (0.03)	0.0065 L/sec (0.0088)	0.003 L/sec (0.01)
20 mmHg	0.0176 L/sec (0.0162)	0.0105 L/sec (0.013)	0.0055 L/sec (0.0124)
30 mmHg	0.035 L/sec (0.3)	0.01 L/sec (0.0207)	0.005 L/sec (0.0116)

Table 6: Median and interquartile ranges of the leakage rate (L/sec) with different Omni-port cuff pressures Cuff Pressure Insufflation pressure.

Cuff pressure Indentation diameter	10 mmHg	20 mmHg	30 mmHg
2.8 mm	2 (1.75)	2 (2)	2.50 (2)
3.6 mm	1.50 (1.50)	2 (2.25)	2.50 (2.25)
4 mm	2 (1.50)	1 (2)	2 (1.50)
4.6 mm	2 (3)	1.50 (2)	2 (1.25)
3.8 mm	2 (0.75)	2 (2)	2 (1.50)
4.4 mm	2 (1.25)	2 (2)	1 (1.25)
3.2 mm	2 (1.25)	2 (3)	2 (2.5)
4.2 mm	1 (3)	1.50 (3)	2 (3)
3.4 mm	2.50 (2)	2 (2.50)	1.50 (2.25)
3 mm	2 (3.50)	1 (3)	2 (2)

Table 7: Median (interquartile range) of error distance (mm) for different Omni-port cuff pressures.

risks; hence procedure considered not cost-effective. The following tables considered (Tables 1-7) self-explanatory for the significant benefit in using (HALS) in aortic repair when compared to (TLS) and (EVAR): -assisted laparoscopic

Initial enthusiasm of EVAR to exclude AAA is currently vanishing due to significant late failure rate, aneurysm ruptures after exclusion and high costs. Kolvenbach indicated in a randomised trial that (HALS) aortic surgical surgery reduced hospital stay; reduced need for ventilator support, early resumption of diet; and earlier return to normal activities [7].

A group of surgeons from China University 2017 [8] demonstrated the safety and feasibility of (HALS) in complete Mesocolic excision (CME); in right hemicolectomy. CME is the counterpart of standard TME in colorectal surgery. Several perioperative variables have been evaluated between (78 HALS) and (72 Open) methods.

Statistical significant difference has been observed in: Reduced skin incision (5.8 cm vs. 16.3 cm);

• Operative time (156 min versus 130 min);

• Blood loss (120 ml vs 127 ml);

• Postoperative pain score (Score of 3 vs 5.1);

• First bowel movement (50.9 hour vs 77.6 hours);

• Duration of hospital stay (7.2 days vs 9.6 days) as well as

• Postoperative complications namely anastomotic leak (0 for both).

However, short time survival time has not been statistically significant (79.5% in HALS vs 77.8% in Open); after a follow-up of 19.8-20 months.

Meshikhes [9] described the feasibility and safety for (HALS) sigmoidectomy. Author's indication was sigmoid tumours. He used the Lap disc port: The author demonstrated that HAL sigmoid colectomy combines the advantages of laparoscopic (minimally invasive) as well as that of conventional open surgery with restoration of tactile feedback sensation, safe finger dissection and rapid control of bleeding accidents. As an abdominal wound is needed at the end of totally laparoscopic colectomy procedure for specimen retrieval, this access may well be made and utilized early during the procedure thereby facilitating dissection and reducing the operating time. With this hybrid procedure, the learning curve is relatively short as most of the technical problems-such as handling the long colon and multiple large vessels ligation-that are associated with laparoscopic colectomy is overcome. Hand assisted laparoscopic surgery is recommended as an adjunct to and a 'bridge' towards totally laparoscopic procedures.

Several clinical studies (HALS)– Live Donor nephrectomy [10] proved the following beneficial clinical outcomes: Warm ischemia time; enhanced dexterity; optimum safe pressure; and proficiency-gain curve. Such a hybrid technique gained a pronounced Donors' acceptance; hence it would contribute significantly in reducing the current inexorable waiting list.

In another relatively recent review analysis [10], HALS proved safety and feasibility when selecting the right kidney or kidneys with multiple principle or polar arteries and/or multiple veins. 165 cases underwent HALS: Left kidney retrieved in 96.9%; Multiple arteries identified in 18.7%; Multiple principle arteries in 8 out of 18.7%; Superior Polar artery in 9 out of 18.7%; Inferior Polar artery in 14 out of 18.7%; More than 1 principle vein in 17.57%.

Despite a longer warm ischemia time, there has been NO significant difference in recipient kidney function; time of surgery; bleeding and discharge of donor.

Hence, the current trend is to preserve the inferior polar artery and to use either right or left kidney stressing the recommendation for full dissection of the renal vein to its origin with IVC and the use of Hem-olok (instead of staples) for kidney retrieval.

Furthermore, Kolvenbach demonstrated a potentially enhanced significant benefit in reduced need for postoperative analgesia particularly for the epidural and morphine based injections; early bowel functioning; early introduction of oral nutrition as well as early hospital discharge and return to normal daily activities. Such factors matched the principles of the current trend for Enhanced Recovery (ERAS) of patients.

After surgery (ERAS) has been incorporated into mainstream clinical practice. The key principles of perioperative nutrition management include: minimization of the catabolic response to surgery, avoidance of long periods of starvation with reinstitution of feeding as soon as possible after surgery. It is now common practice to permit patients to drink clear fluids until 2 hours before surgery and the avoidance of solids is limited to 6 hours preoperatively.

Experimental Studies

Elenin et al [3] made several experimental observations. Experiments were mainly based on evaluation of the leakage of insufflation pressure through hand port; and degree of loss of tactile feedback/dexterity. Omni port device has been used in all experiments. The Omni port was positioned at the level of the styloid process in all participants. The circumference of the wrist was measured at the level of the styloid process. 10 Surgeons randomly selected: at various surgical expertise level and after a thourough clinical history to ensure being generally well.

Hanna et al. [11] tested the effects on microcirculation of the hand using laser Doppler imaging and Iontophoresis, with acetylcholine as an endothelial-dependent vasodilator and sodium nitroprusside as an endothelial-independent vasodilator. Maintenance of pneumoperitoneum during surgery using a hand access device depends on sealing pressure equal to or slightly exceeding the insufflation pressure. Such pressure setup may potentially result in hand ache; which may impair tactile feedback and dexterity of the surgeons. Hence, optimum task performance will be compromised.

Consequently, several studies implemented to identify the cause for such hand ache. The aim would be to assist in developing better tolerated hand access devices. Nerve pressure has been ruled out as nerves could tolerate pressures up to 500 mmHg. As the seal pressure is far less than the systolic blood pressure, hence such a sealing pressure would not have any detrimental effect on major arterial vessels [8].

The endothelium plays a crucial function in the vascular tone. Endothelial changes observed as earliest effects to systemic insults by releasing potent vasodilators and vasoconstrictors. The endothelium normally responds to acetylcholine by releasing nitric oxide, which in turn causes relaxation of the smooth muscle in the vessel wall and therefore vasodilation. The dysfunctional endothelium paradoxically responds to acetylcholine by vasoconstriction due to a direct smooth muscle constrictor effect. Several reports have documented the effect and mechanisms of gradually increased pressure on skin blood flow [8].

Hanna et al. [2] demonstrated that changes in hand microcirculation would not be the cause of hand ache; the cause of which remains unknown. Changes in body posture incurred during HALS may play an important role in the discomfort experienced by the surgeon as he or she adopts a Lordotic stance because the hands are in different planes. The restricted mobility of the forearm through the access port limits adjustment of the hand relative to the trunk. Such outcome has been similarly achieved by the author's experimental work [3]. However, the study made by Manasnayakorn et al. was based on acute changes that did not investigate the influence of more prolonged and repeated exposures to the pressures on hand microcirculation.

Equally important, this study did now test the hand while performing any tasks before or during the measurement of hand microcirculation, which differs from the clinical setting during HALS when the surgeon's intracorporeally hand executes surgical tasks at various directions. The role of these factors in the aetiology of hand aches warrants further investigation.

Discussion

In all experiments, the three main variables (leakage of gas; tactile feedback and dexterity) were evaluated at three main pressures: 10,20 and 30 mm Hg. Pressure inflation time was 2 minutes with deflation intervals of 10 minutes to ensure complete hand rest before testing the next cuff pressure. Safe optimum insufflation pressure associated with minimum leakage and optimum dexterity as well as least loss of tactile feedback was 10 mmHg [3].

Tactile feedback has been evaluated for its two main constituents: sense of vibration and Texture recognition. Tactile feedback has been assessed at different vibration frequencies; all of which should be less than 20 HZ (The non-audible range). All participants instructed to place only their tip of the index finger at the testing device and for 1 min. Each test will be followed by a 10-min rest interval. Texture recognition has been tested by a special device that harboured 10 holes of graded sizes. All participants were asked to sense the 10 holes at the 3 main testing pressures. Error distance recognition was the end-point in texture recognition. In sense of vibration, the frequency at which each subject felt the vibration at each pressure recorded [3].

Dexterity assessed using the Crawford's small part dexterity test (Psychological Corporation Limited, London, UK). The device placed inside a Laparoscopic simulator. 30° Camera used by all participants; which has been attached to a 2-dimentional Sony monitor (Model No PVM-14043 MD, Sony, Tokyo, Japan). Each subject has been asked to place the pins and collars laparoscopically; at the three different insufflation pressures. Each test was for 3 min; with a 10-minute rest interval. The end was the number of successful holes completed at each pressure [3].

Results tabulated and analysed. Data was not normally distributed. Therefore, non-parametric tests such as Kruskall-Wallis and Mann-Whitney were used as appropriate. At pressure 10 mmHg, no wrist discomfort experienced by all subjects; using a visual analogue scale. There has been a significant rise in discomfort while approaching pressure of 30 mmHg [3].

There was a degree of air leakage on using different cuff pressures with any of the insufflation pressures. The leakage rate has significantly increased with the increase in the insufflation pressure (p<0.0001) and the decrease of the Omni-port cuff pressure (p=0.008). [3]

The median (interquartile range) vibration frequency felt by subjects was 4.7 (10.22), 7.36 (7.37) and 11.85 (7.57) Hz for the Omni-port cuff pressure of 10, 20 and 30 respectively (p=0.04). There was also significant difference between subjects in the threshold of vibration felt (P<0.001). [3]

The increase of Omni-port cuff pressures did not have significant effect of the recognition of exact location of different size indentations (p=0.1).

The median (interquartile range) of successful targets was 5.5 (3.5), 7.5 (4.25) and 6.5 (3.25) with the use of Omni-port cuff pressure of 10, 20 and 30 mmHg respectively (p=0.45). Also, there was a significant difference between subjects in dexterity at different Omni-port cuff pressures (P<0.001) [3].

Such experiments confirmed the clinical impression that there has been an existing discomfort at the wrist joint with the hand access device on increasing the insufflation pressure. However, (HALS) proved safe maintenance of insufflation pressure throughout the procedure and without a compromise of the image displayed.

This study has demonstrated that there has been a distortion in tactile feedback on increasing the insufflation pressure. Such observation highly suggested a pathological impact on the digital microcirculation of the fingers.

Dexterity has also been optimum at 10 mmHg. Participants experienced increasing difficulty on increasing the pressure. Their main suffering was at the wrist joint as well as from the distorted position of the Surgeons' body relative to the monitor position. Monitor position maintained constant for all subjects and at all tested pressures [3].

Conclusion

Hand assisted laparoscopic surgery considered safe; reliable; feasible; enhanced dexterity; cost effective and therefore, clinically applicable.

Consequently, enhancing live kidney donation can significantly be enhanced in reducing the waiting list for chronic kidney disease patients.

Further experimental and technological studies would be required to evaluate the current hand access devices in relation to the current monitors to improve the surgeons' discomfort.

It is strongly recommended to use insufflation pressure of 10 mmHg which proved to be optimum in maintaining tactile feedback and dexterity as well as patients' safety.

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