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Brief Technical Report

Comparison of Efficiencies of Three Techniques for Colon Surgery

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ABSTRACT

Purpose: **To determine the most efficient technique for performing a colectomy, we used the methodology of time–motion analysis.**

Methods: **The efficiency of five hand-assisted and six regular laparoscopic colectomies and one open colectomy, performed by four surgeons in three different hospitals, was measured. The open colectomy was analyzed as a reference procedure.**

Results and Conclusions: **The hand-assisted laparoscopic technique was the most efficient. Hand-assisted laparoscopy was therefore less time consuming than laparoscopic surgery. Open surgery was the fastest technique, because the time for every surgical motion is a factor of three shorter than for the two laparoscopic techniques.**

INTRODUCTION

SINCE 1994, THREE TECHNIQUES have existed for colon resections. The conventional open procedure is a well-established technique with a long history. The laparoscopic approach has been used since 1991.[1,2] The hand-assisted laparoscopic technique was developed in 1994.[3-6] In the latter procedure, the surgeon is able to introduce the nondominant hand into the abdominal cavity (Fig. 1).

Since the latter technique became feasible, it has afforded the opportunity to compare the features of open and laparoscopic surgery. The hand-assisted method restores an important feature of open surgery, namely direct contact between tissue and the human hand. By means of a plastic airtight sleeve, the surgeon introduces a hand into the abdomen while maintaining the pneumoperitoneum.[6] In this way, the mini-laparotomy, an approximately 8-cm muscle-splitting incision, which is usually made during the later stages of a laparoscopy-assisted colectomy in order to withdraw the resected specimen, is applied at an early stage during the operation. A wound protector is inserted to allow the removal of the resected part of the colon without contamination of the wound.

The three operative techniques can be distinguished according to direct or indirect manual and visual access (Table 1). The small-incision technique—the open surgical approach through a reduced incision—is not applied to colon surgery, because the operation area inside the abdomen is too large to reach all structures of interest via this limited-access technique.

Comparison of operative techniques in the literature has been directed mainly toward the medical outcome and the total operation time. The influence of the access

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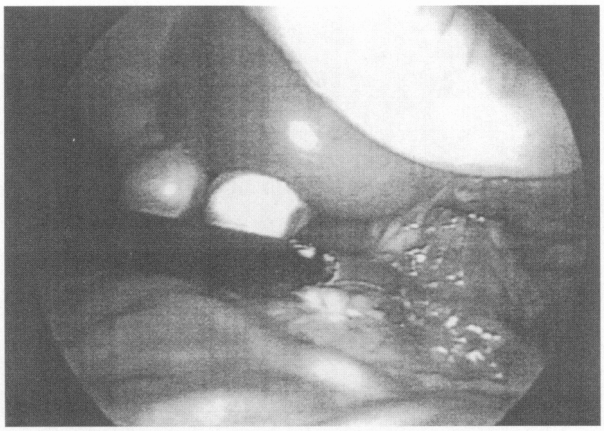

FIG. 1. Laparoscopic image of surgeon's hand inside abdominal cavity during hand-assisted laparoscopic operation. Thumb and two fingertips are visible.

techniques on the operation process itself has seldom been reported.

In order to determine the most efficient technique for performing a colectomy, the efficiency of the hand-assisted laparoscopic technique and the laparoscopic technique without hand assistance was measured. Conventional open colon surgery, a well-established technique with a minimum of technical limitations, was used as reference.

PATIENTS AND METHODS

Patients

This study is part of a randomized multicenter controlled trial carried out in Europe and the United States and has been approved by the Medical Ethical Committee with informed consent of the patients. Eighty patients with colon disease were assigned to undergo either laparoscopic or hand-assisted laparoscopic colon surgery in conjunction with the Dexterity PneumoSleeve and Protector Retractor. Inclusion criteria are a minimum of 18 years of age, ASA class I or II, and an indication for laparoscopic colectomy. The exclusion criteria are previous major abdominal surgery, ASA class III or IV, other intended surgical interventions, and factors making follow-up difficult. Time and motion analysis was performed on a subset of procedures in both groups. The subset cases were selected at random from the operations performed in The Netherlands. One open colectomy was analyzed as a reference procedure.

Surgeons

Surgeons with laparoscopic colorectal surgery experience of more than 20 interventions were allowed to participate.

Time and motion analysis

The operations were recorded with the split-screen video recording unit.[7] The laparoscopic image, an overview of the operating team, a colonoscopic image, and sound were recorded to allow off-line evaluation. The hand-assisted laparoscopic operations were recorded in the same way as the laparoscopic operations, as the surgeon works in both cases from the guidance of the video images. The open operation was recorded with a head-mounted camera, depicting all activities inside and outside the abdominal cavity with one image.

For the evaluation, the *dissection phase* of the proce-

TABLE 1. OPERATIVE TECHNIQUES FOR COLON SURGERY, CLASSIFIED ACCORDING TO METHOD OF ACCESS

Manipulation	*Direct vision*	*Indirect (laparoscope)*
Direct	Open surgery	Hand-assisted laparoscopy
Indirect (instruments only)	Small-incision surgery[a]	Laparoscopy

[a]Not applicable for colon surgery.

TABLE 2. TAXONOMY OF SURGICAL ACTIONS FOR DISSECTION PHASE, PRESENTED ACCORDING TO CRITERIA OF EFFICIENCY[a]

Actions	*Definition*
Cut/separate tissue	Dissect tissue with a pair of scissors, a dissector, or a coagulator
Stretch tissue	Stretch tissue with forceps or by hand
Observe by laparoscope	Observation by the surgeon with the laparoscope
Palpate tissue	Palpate tissue by instrument or hand
Exchange instrument	Take out one instrument and insert another
Retract tissue	Retract tissue with a bowel clamp or by hand
Ligate vessels	Ligate vessels by clip or suture
Clean laparoscope	Clean a dirty or foggy laparoscope
Unclassified actions	Activity that is not categorized by the other terms

dures was analyzed, as this phase is performed in the laparoscopic set-up both for the hand-assisted and the standard laparoscopic operations.

The categories of the taxonomy (Table 2) determine the conversion of the operation into a sequence of surgical actions. Beyond studying the operative techniques, one purpose of the analysis is to give feedback to the surgeons on their operative work. The taxonomy serves as the vocabulary by which the surgeon and the engineer communicate, so the terms have to be distinguishable, comprehensive, meaningful, and well defined.

It is useful to distinguish the actions to emphasize the difference between those that are goal oriented and those that do not contribute directly to the advancement of the operation. This distinction provides a description of the surgical performance that focuses on the efficiency of the process. For example, during the dissection phase, the goal-oriented actions are *stretch tissue* and *cut/separate tissue,* which contribute directly to the treatment of the patient's tissues.

The parameter *surgical actions efficiency* (SAE) is defined as the ratio of the goal-oriented actions to the total number of actions. The parameter *time per action* (TPA) is determined as a measure of the manipulating and observing speed of the different operating methods. In addition, the categories of actions and the total dissection time are presented.

Process chart presentation

To convert the images into a series of surgical actions and to present this series, a new method was developed based on process-charting techniques.[8,9] A process chart is a graphical way of presenting the sequence of actions in order to improve the understanding of the process. Figure 2 gives a part of the flow chart of a laparoscopic dissection. The goal-oriented actions *stretch tissue* and *cut/separate tissue* are in the left column. For the dissection phase, the actions that contribute directly to the main goal of this phase, the dissection of tissue, are called goal oriented. The additional actions are displayed in the middle column. The vertical axis represents time. Comments in the right column elucidate the nonefficient actions.

The first actions show few irregularities. After a certain time, the sequence looks like a zigzag pattern of stretching and cutting tissue. Gradually, however, the surgeon is confronted with deteriorating laparoscopic images as a result of blood on the tissues. Additional actions have to be applied before the cutting actions can continue. In a process flow chart, a regular pattern of actions shows visually at which stage the surgeon is working efficiently.

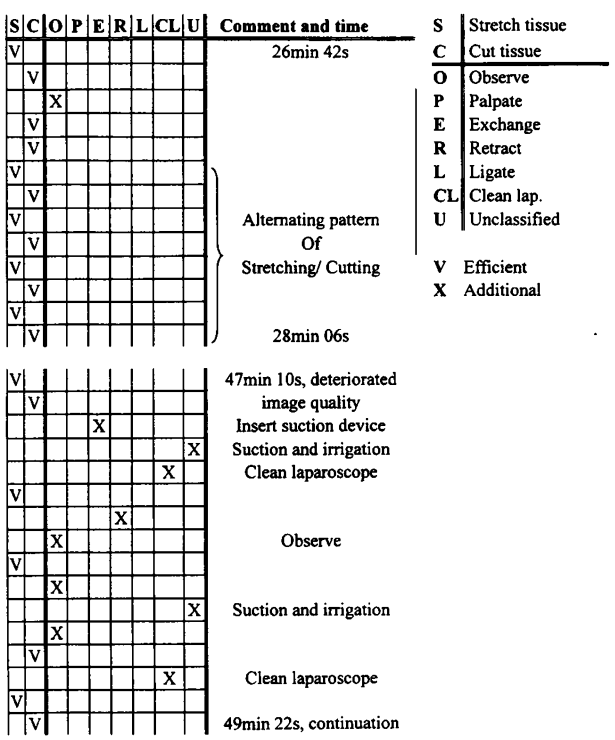

FIG. 2. Process flow chart of part of laparoscopic dissection. Vertical axis represents time. At top, actions are regular and efficient (goal directed). At bottom, the sequence shows less progress.

TABLE 3. RECORDED LAPAROSCOPIC AND HAND-ASSISTED OPERATIONS PERFORMED BY FOUR SURGEONS

	Surgeon No.				
Operation	*I*	*II*	*III*	*IV*	*Total*
Lap. sigmoid resection	3	1	0	1	5
Lap. right hemicolectomy	1	0	0	0	1
Hand-assisted sigmoid resection	2	1	1	0	4
Hand-assisted ilioceacal resection	1	0	0	0	1
Total	7	2	1	1	11

Data analysis

To compare the efficiency of the laparoscopic and hand-assisted laparoscopic technique, the non-parametric Mann-Whitney test was applied. A two-tailed P value of <0.05 is considered significant.

RESULTS

Between December 1995 and April 1996, five hand-assisted and six regular laparoscopic colectomies and one open colectomy, performed by four surgeons in three hospitals, were video recorded (Table 3). The open colectomy was recorded as a reference procedure, without technical limitation, logistic hindrance, or any inexperienced team member.

The SAE of the hand-assisted technique was 29% higher than that of the laparoscopic technique ($P < 0.05$) and open technique (Table 4). The TPA for the open technique was a factor of three shorter than for the laparoscopic and hand-assisted technique, indicating that direct manipulation and vision allow fast movements of the surgeon.

The dissection time of the open technique was almost a factor of five shorter than for the laparoscopic technique and almost a factor of three shorter than for the hand-assisted approach, resulting from the short time per action and the small number of actions (Fig. 3). The hand-assisted technique required fewer actions than the laparoscopic and the open techniques.

Compared with the laparoscopic technique, the hand-assisted technique showed fewer camera observations but more palpations, indicating a shift from visual to manual information, as the hand directly touches the tissues (Table 4). The hand-assisted technique needs less tissue retraction, as the back of the hand removes bowel from the operating area during the dissection task.

DISCUSSION

Time–motion analysis enables a quantitative analysis of the per-operative process on the basis of a small number of operations.[7,10] The complete dataset from the clinical trial showed no differences in terms of total operation time among the countries involved. We proposed SAE as a parameter for the evaluation of surgical tech-

TABLE 4. AVERAGE (± SD) OF TIME AND ACTIONS PARAMETERS OF LAPAROSCOPIC AND HAND-ASSISTED TECHNIQUE AND OPEN REFERENCE

	Technique		
Parameters/Actions	*Laparoscopic (N = 6)*	*Hand-assisted (N = 5)*	*Open*
SAE (%)	55 ± 6	71 ± 14	55
TPA (sec)	12.8 ± 1.9	13.5 ± 3.0	4.3
Dissection time (min)	61 ± 34	36 ± 8	13
Total number of actions	278 ± 158	169 ± 68	185
Stretch tissue	74	61	45
Cut/separate tissue	80	59	56
Observe with laparoscope	26	9	0
Palpate tissue	6	13	19
Exchange instrument	34	12	36
Retract tissue	33	1	23
Clean laparoscope	10	7	0
Close vessels	7	4	2
Unclassified actions	9	3	4

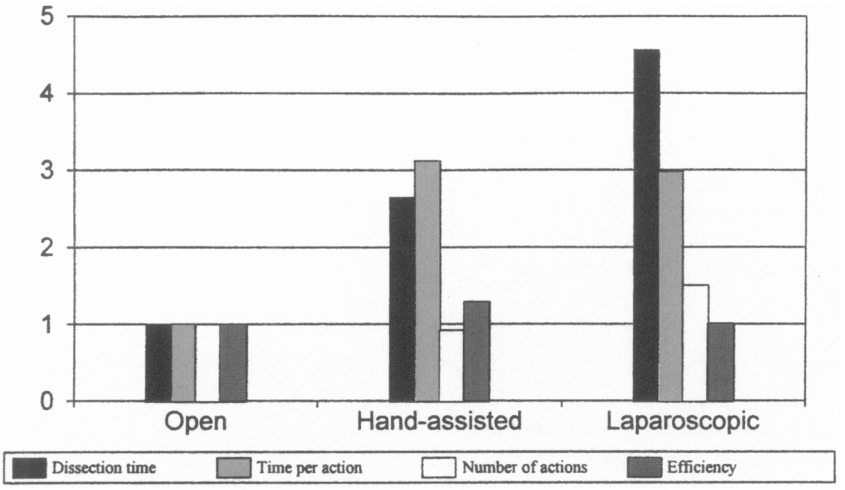

FIG. 3. Time and actions parameters of dissection phase (see Table 4) of three techniques in relation to open (reference) procedure.

niques. The value of this parameter is illustrated by the fastest dissection phase that we observed. This phase accounted for 88% of the goal-oriented actions, indicating that these actions are the core actions of this operation phase.

The time–motion analysis method has recently been validated by den Boer and associates.[10] Accuracy and reproducibility was proven, based on an interobserver agreement of 0.98. In our study, the agreement among the four observers was 0.85. The observers had either a medical or a technical background, showing that observers from different disciplines analyzed the operations similarly.

Even compared with the reference open operation, the hand-assisted laparoscopic technique appeared to be the most efficient. During open surgery, the surgeon changes an instrument and retracts tissue more often from the operative field.

The SAE is not the only parameter which determines the operation time. However, SAE provides a good measure of whether the separate actions of the surgeon contribute directly to the process of the operation. This way, a useful measure is created to analyze irregularities in the process and the underlying technical limitations.

The parameter TPA explained the much shorter dissection time of the open operation. The values that we measured for the TPA were in good accordance with previous results from laboratory research.[11,12] Tendick and associates[11] reported on a paperclip positioning task in an environment with minimal depth cues. The task completion time under the condition of direct binocular view and hand instruments (open surgery) was 5 seconds per task. The same task under the condition of two-dimensional video and laparoscopic instruments (laparoscopy) took 17 seconds. In a similar study, Rau and colleagues[12] showed for a manipulation task could be completed in one third the time under open surgical conditions (direct binocular view and direct manual manipulation). Hand-assisted laparoscopic surgery was not included in this study.

It may be questioned whether efficiency is compatible with being careful. For example, extra observations with the laparoscope decrease the efficiency. However, these observations might be useful, for instance, to avoid blood vessels. In this example, a lot of extra actions to correct the bleeding would be spared, which would increase the efficiency. Moreover, activities of observation indicate that the surgeon lacks information about the anatomic structures or the orientation inside the abdomen. So it is relevant to investigate the reasons for performing the actions. Efficiency, as illustrated by the flow chart, describes a goal-oriented procedure clearly in terms of actions. A pattern of stretching and cutting the tissue could be recognized.

The flow chart is a powerful instrument for the analysis of irregularities during the operation. The underlying reasons for irregularities can be complex. For example, in case of bleeding, the tissue becomes covered with blood, increasing the absorption of light. Subsequently, a cascade of events may occur. Suction and irrigation needs to be applied to create a clear view to search for the source of the bleeding. Also, the laparoscope is likely to become dirty or foggy, obscuring the view even more.

It takes at least a few minutes before the surgeon is able to proceed with the operation. This is relatively long in comparison with open surgery, where a small amount of bleeding can be taken care of easily.

Efficiency is important for other reasons. Assuming that every action carries a certain risk and consumes a certain time, reducing the number of actions might improve the safety of the operation. An additional positive effect may be that the anesthesia time is reduced.[13] However, the importance of these aspects will need to be assessed by physicians in the future, as the medical outcome of these operations is outside the scope of this study.

The TPA is an important parameter for the level of concentration of the team members during the operation. As the pace of the actions during open surgery is high, on average 14 per minute, a kind of rhythm arises. This fast flow of actions is appreciated by both the surgeon and the assistants. With a good operative assistant, the surgeon's eyes are directed continuously toward the abdomen, and the instruments are handed directly to him or her without the need to look aside. In laparoscopy, the operation pace is slow, an average of 4 per minute. The operative assistant has only a few things to do, mainly exchanging instruments. As the dissection phase usually takes more than 1 hour, the attention of the assistant diminishes. So it is understandable that the laparoscopic approach does not find favor in the eyes of the operative team. It is plain that a high pace of operating is important not only for the patient, but also for the motivation of the operative team. The work of the assistants is important for the logistic organization and has a tremendous influence on the operation time. Therefore, the motivation of the team members needs to be taken into account as a factor of considerable importance.

CONCLUSIONS

A method to analyze the efficiency of surgical techniques has been developed. According to the SAE, the hand-assisted laparoscopic technique is the most efficient. Hand-assisted laparoscopy is less time consuming than laparoscopic surgery but still features an equal TPA, indicating that a combination of an insufflated abdomen, a laparoscopic camera system, and laparoscopic instruments reduces the manipulation speed of the surgeon. The TPA of the open technique is a factor of three shorter than for the other two techniques. With the current instrumentation, the dissection during open colon surgery is therefore one third or less that during the two minimally invasive techniques. The laparoscopic technique features a limited efficiency and a TPA comparable to that of the hand-assisted technique and is therefore the slowest.

The flow chart is a powerful tool to present the sequence of surgical activities. The action pattern of an individual surgeon, a kind of fingerprint, is recognized at a glance. Irregularities during the process become directly visible by the appearance of less efficient patterns. This way, the underlying limitations of operation techniques can be analyzed, discussed, and improved.

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