Surg Endosc (2004) 18: 1597–1600
DOI: 10.1007/s00464-003-8210-1

SURGICAL ENDOSCOPY
and Other Interventional Techniques

Time–motion analysis of operation theater time use during laparoscopic cholecystectomy by surgical specialist residents

M. H. Geryane,[1] G. B. Hanna,[1] A. Cuschieri[2]

[1] Department of Surgery and Technology, St. Mary's Hospital, Imperial College, London, United Kingdom
[2] Surgical Skills Unit, Ninewells Hospital and Medical School, University of Dundee, Dundee DD1 9SY, Scotland, United Kingdom

Received: 12 April 2003/Accepted: 12 May 2004/Online publication: 11 October 2004

Abstract
Background: Data on man–machine interfaces in the operation theater are essential to the improvement of surgical efficiency. This study analyzed the activity of the operating team during laparoscopic cholecystectomy by surgical trainees.
Methods: The endoscopic image and overview of the operating room were recorded during 20 laparoscopic cholecystectomies performed by specialist residents. Time–motion analysis of the recorded tapes was performed.
Results: The median (interquartile range [IQR]) for theater time was 134 ± min (IQR, 52 min). The components of operative time for the surgeon were 26% for insertion of access ports and wound closure, 57% for intracorporeal endoscopic work, and 17% for instrument change. Only 52% of the scrub nurse time was related to the operation. Machine and video setup, adjustment of ancillary equipment together, and delivery of instruments and items requested by the surgeon and scrub nurse accounted for 13% of the circulating nurse time.
Conclusions: With the current nonergonomic theater design and structure, a significant proportion of theater time during routine uncomplicated laparoscopic surgery is used for nonoperative functions. The study highlights the need for improved ergonomic design, integrated bus operating systems under the control of the surgeon, and multifunctional laparoscopic instruments.

Key words: Time–motion analysis — Laparoscopic cholecystectomy — Theater time — Specialist surgical residents

Optimum management of operation theater time has become a key concern of the National Health Service because of lengthy waiting lists and financial constraints. Objective information on theater time use is necessary for efficient surgical performance, increased safety, and accommodation of supervised surgical operative training.

Efficiency entails appropriate use of manpower, facilities, and equipment to achieve the ideal operative care because operating room time constitutes a significant part of the cost for surgical treatment. This applies especially to short-stay laparoscopic surgery, (e.g., laparoscopic cholecystectomy [LC]), for which 60% of hospital costs are incurred while the patient is in the operating room [14]. In addition, complications often can be traced to errors that occur in the operating room. Besides increased suffering, complications add considerably to treatment costs.

Time–motion studies examine the actions of the operating team to identify the ideal motion patterns conducive to optimal task execution. The use of motion and time study has brought many benefits to a range of industries, hence its appeal especially to the manufacturing sector of the economy. Although less often used in health care services, it can confer similar benefits for such services, especially operative surgery, in which time–motion studies may identify unproductive activities and inefficient communication between theater staff and provide information for improving operating room layout and equipment design [9]. The objectives of the current descriptive study were to analyze the use of theater time, the activity of the operating team, and the nature of instrument use during a common laparoscopic operation.

Materials and methods

Patients

For this study, 20 consecutive patients with symptomatic gallstone disease were consented to participate. All the operations were performed in the main theater suite at Ninewells Hospital.

Correspondence to: A. Cuschieri

Operation

Laparoscopic cholecystectomy was selected for this study because it is a common operation worldwide [13], it incorporates standard laparoscopic techniques, and it exemplifies the complex interaction between conventional operating room design and evolving surgical operative technology. Therefore, LC can be regarded as a marker laparoscopic operation such that the results of the study can be applied to a wide range of routine laparoscopic operations. A standard technique for LC was used [10].

Procedure

External video recording of the operating room and a video record of the endoscopic image were obtained for each operation. The audio and video records of the operating team (surgeons, scrub and circulating nurses) activity and the layout of theater equipment were obtained with external video camera (Sony CCD-TR427E,Tokyo, Japan, autofocus with a 0.5× super wide-angle lens). The camera was mounted at a height of 192 cm and at a distance of 306 cm from the foot of the operating table. This position was selected because it allowed the camera to capture most of the movements around the operating table. Activities at the time of surgery, which were outside the field of the video camera, were recorded directly by the clinical research fellow.

The external video recording started when the anesthetized patient was brought into the operating room and ended when the patient was transferred out of the operating room. The internal video recording was obtained using an SVHS videocassette recorder (Matsushita Electric Industry Company, Osaka, Japan) for the entire operation from the first insertion of the laparoscope. A record also was kept of the operative team (surgeon, camera operator, assistant, scrub nurse, and circulating nurse) for each operation included in the study. The members of the theater staff were not informed about the objectives and end points of the study.

Data analysis

The external video recordings were analyzed to determine the time that the patients spent in the operating room for the activity of the operative team (activity by the surgeon, scrub nurse, and circulating nurse during the operation). The internal video recording was analyzed to identify the pattern of instrument use by the surgeon (type of instrument, duration of use, frequency of exchange). Each operation was graded for the degree of difficulty according to preset criteria [5]. The theater time, from induction of anesthesia to cleaning of the instruments after the operative procedure, was divided into six periods. The surgeon's work time was analyzed in terms of three components: intracorporeal and extracorporeal execution time and instrument exchange time (Table 1). The latter included the type of instruments, duration of use, and frequency of instrument exchange. A complete record of the surgeon's verbal instructions for adjustments to ancillary equipment and requests for instruments was obtained.

The motion and time analysis for the scrub nurse included preparing instruments, handing instruments to the surgeon, and following the progress of the operation on the monitor. The motion and time analysis for the circulating nurse included the adjustment of video imaging and ancillary equipment and the supply of instruments as requested by the surgeon or scrub nurse.

Because the data obtained by the study were not normally distributed, they have been expressed as medians and interquartile range (IQR), and nonparametric tests (Kruskal–Wallis one-way analysis of variance and Mann–Whitney U test) were used in the analysis.The significance level was set at 5%.

Results

This study involved 4 consultants, 4 specialist residents, 1 senior house officer, 11 scrub nurses, and 13 circulating nurses. The principal surgeon was a specialist resident in 19 cases and a consultant in 1 case. The camera operator was a consultant in 8 cases, a specialist resident in 7 cases, and a senior house officer in 5 cases. In terms of difficulty, four operations were classified as grade 1, nine as grade 2, and seven as grade 3.

Table 1. Definitions of operating theater time

Anesthetic induction time	Period spent in the anesthesia room
Surgical preparation time	Period between arrival of patient in operating room and start of skin preparation
Operative setup time	Interval between skin preparation and first skin incision
Operative time	Time from first incision to last skin suture
Recovery time	Interval between end of operative time and exit of patient from theater
Instrument cleaning time	Time spent by nurse cleaning instruments before sterilization
Intracorporeal surgical time	Time that the surgeon performed tasks inside the abdominal cavity
Extracorporeal surgical time	Time that the surgeon performed tasks outside the laparoscopic field such as trocar insertion and closing of incisions
Instrument exchange time	Time from when the tip of the instrument entered the cannula until the tip of the other or the same instrument protruded from the cannula

Theater time

All the operations were completed laparoscopically, and an intraoperative cholangiogram was performed in 13 cases. The various times obtained from the activity–time analysis are shown in Table 2. Thus, even with the operations performed by surgical trainees assisted by consultants, the actual operating time was only 62% of the total time the patient spent in the operating theater.

Activity of the operative team

Surgeon

The medians for the frequency of the surgeon's instructions were 7 (IQR, 3) for adjusting machine and equipment setups and 29 (IQR, 15) for obtaining instruments, and with no significant difference between surgeons for either machine and equipment adjustment requests (p = 0.29) or instrument requests (p = 0.4). The surgeons' intracorporeal and extracorporeal execution times were 46 min (IQR, 28.81 min) and 21 min (IQR, 14.7 min), respectively, whereas the time for instrument change by surgeons was 11 min (IQR, 8.11 min). The proportions of time spent were 55% for intracorporeal work, 23% for extracorporeal functions, 13% for instrument exchange, 8% for intraoperative cholangiogram, and 1% for camera cleaning.

Scrub nurse

The medians for the frequency of preparing and handing instruments by the scrub nurse was 28 min (IQR, 21)

Table 2. Analysis of operating theater time

	Median (min)	Interquartile range
Total theater time	134	52
Anesthesia time	15	8
Surgical preparation time	7	5.5
Surgical setup time	5	2
Operative time	83	51
Instrument cleaning time	11.5	3

and 33 min (IQR, 14), respectively. Most of the scrub nurse activity during the operation was spent preparing instruments, which required a median time of 18 min (IQR, 19.25 min), whereas 3 min (IQR, 2.75 min) was spent in handing instruments to the surgeon and 16 min (IQR, 28.5 min) was spent following the procedure on the monitor respectively. The number of scrub nurse posture changes between the surgeon, monitor, and trolley was 84.

Circulating nurse

The circulating nurse was asked to adjust the machine setup 18 (IQR, 3) times, which represented an activity time of 5.6 min (IQR, 1.8 min) (Table 3). He or she was requested to bring instruments or items to the scrub nurse 5 (IQR, 6) times in an activity time of 3.68 min (IQR, 4.2 min).

Pattern of instrument use

The median frequency of instrument change by the surgeon was 28 (IQR, 27) times. Table 4 shows instrument usage at the main (epigastric) port. The diathermy hook knife was the main instrument used. The assisting port at the right upper quadrant was used mainly to introduce the assisting grasper held in the operator's non dominant hand for retraction of the gallbladder for a median time of 57 min (IQR, 43.5 min). Instrument change through the assisting port was observed 4 (IQR, 1.25) times for the grasper and once for the cholangiogram catheter.

Discussion

It is important to stress that this time–motion analysis study investigated LC performed by surgical trainees. However in relative terms, the components of operative time, pattern of instrument use, and interaction with the nursing staff are unlikely to be materially different from those experienced by the fully trained consultant and attending surgeons. The main message of the study is that the current layout of the operating room, including the operating table, designed for open surgery and essentially unchanged for centuries, is insufficiently *patient–endoscopic operator* centered. Largely for this reason, the current operating room layout imposes ergonomic restrictions that impede efficient execution of endoscopic operations, with an undue increase in operating time and possible lowering of the safety threshold.

Table 3. Pattern for the adjustment of the video endoscopic equipment setup

Machine	Frequency n (IQR)	Time (min) n (IQR)
Monitor	3 (4.75)	1.025 (0.96)
Gas insufflator	4 (1.75)	0.64 (0.43)
Electrosurgical device	3 (1.00)	0.6 (0.42)
Suction-irrigation device	3 (2.75)	1.23 (1.49)
Camera box	2 (2.00)	0.74 (0.41)
Light source	4 (1.50)	0.56 (0.43)

IQR, interquartile range

Table 4. Instrument usage via the main (epigastric) port

Instrument	Duration of use (minutes) n (IQR)	Frequency of exchange n (IQR)
Diathermy hook knife	21.75 (11.68)	6 (7.75)
Pledget	1.5 (4.96)	2 (5.50)
Clip applicator	1.62 (1.15)	5 (2.25)
Hook scissors	0.75 (0.64)	2 (2)
Dissecting scissors	1.45 (3.41)	1 (2.25)
Crocodile forceps	0 (0.88)	0 (3.25)
Grasping forceps	1.2 (3.46)	1 (2.25)
Ligature loop	3.13 (2.14)	1 (0.25)
Suction/irrigation	6.08 (13.78)	3.50 (6.50)
Bag	4.13 (3.23)	0

IQR, interquartite range

There is a real need to address the ideal requirements in terms of space, layout, fixtures, and key equipment (including the operating table and image display) for endoscopic surgery, with the focus firmly centered on the needs of the patient and surgeon as the main protagonists of the interventions. This need was underscored by the current study, which showed that the productive operative time accounted for only 62% of the total theater time. This extent of inefficient execution imposed by the environment and system is likely to be greater for more complex and advanced laparoscopic operations, especially those requiring extraspecialized equipment. Obviously, further studies are needed and information from these used to design future operating rooms dedicated to endoscopic surgery.

The extent of the time spent by patients in essential routine but nonoperative activities should be considered when operative work is organized, and theater lists are planned, although it should be stressed that the cited percentage relates to a major training hospital where this level of elective surgery is performed predominantly by specialist residents supervised by their consultants.

During LC, the surgeon spends only 55% of the operative time in intracorporeal laparoscopic work, whereas a significant proportion of time is incurred in the placement of access ports and wound closure (23%). Port location is important because it affects the ergonomics of the laparoscopic procedures and consequently the time and quality of intracorporeal task performance [4]. A small but important immediate morbidity may result from iatrogenic injury to bowel, solid organs, and blood vessels during port insertion, and in the longer term, incisional hernia may follow inadequate closure of these wounds [11, 12].

The current study documented that instrument exchange is responsible for 13% of operative time. Analysis of the instrument exchange pattern showed that the use of dissection instruments and the suction irrigation device accounted for most of the instrument exchange. This highlights the importance of multifunctional laparoscopic instruments because instrument exchange during laparoscopic procedures consumes time [2], besides enhancing the risk of instrument stab injury, especially to solid organs, and disrupting the choreography of the operation [3].

The scrub nurse spent 48% of the operative time in actions directly related to the operation such as preparing the instruments (23% of operative time) and following the operative steps on the monitor (21% of the operative time). The surgeon requested additional instruments 29 times per procedure. Because the scrub nurse spent a significant time in preparing instruments, she was not able to follow the procedure on the monitor. Consequently, she relied on clear instructions from the surgeon for instrument exchange. Instrument handing time accounted for 4% of the operative time. This short instrument handing time is explained by the experience level of the nursing staff working in a dedicated laparoscopic operating room and concurs with other reports on the effect of nursing experience in reducing operative time [7]. The scrub nurse had to change her position and posture to follow the operation on the monitor often and for a significant time because the setup did not include a monitor dedicated to the scrub nurse. This is an important practical consideration because human factors research has indicated that fatigue and impaired performance result from awkward and strained postures in task performance [1, 6, 8]. In this study, the scrub nurse had to change position approximately 84 times between the surgeon, monitor, and instrument trolley.

Most of the circulating nurse actions involved adjusting the setup of video laparoscopic equipment and bringing instruments to the scrub nurse, with a median frequency of 18 and 5 times per procedure, respectively. The video laparoscopic equipment used in the current study consisted of a stand-alone stack, the components of which required individual adjustment before and during the operation by the circulating nurse. This observation highlights the need for integrated bus systems under the direct but remote control of the surgeon with software that stores the settings for the various ancillary equipment preferred by individual surgeons.

Acknowledgments. The authors thank David Smith, consultant surgeon for recruiting his patients in the study, and the nursing staff in theater 6 for their cooperation.

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