Surg Endosc (2001) 15: 497–503
DOI: 10.1007/s004640090002

Surgical Endoscopy
Ultrasound and
Interventional Techniques

Analysis of the quality and efficiency in learning laparoscopic skills

K. T. den Boer,[1,2] L. Th. de Wit,[2] P. H. P. Davids,[2] J. Dankelman,[1] D. J. Gouma[2]

[1] Delft University of Technology, Faculty of Design, Engineering and Production, Man-Machine Systems Group, Mekelweg 2, 2628 CD Delft, The Netherlands
[2] Academic Medical Center, University of Amsterdam, Department of Surgery, P.O. Box 22700, 1100 DE Amsterdam, The Netherlands

Received: 6 August 2000/Accepted in final form: 12 October 2000/Online publication: 3 April 2001

Abstract.
Objectives: This study demonstrates the application of time-action analysis to the evaluation of task performance of diagnostic laparoscopy with laparoscopic ultrasonography.
Methods: The first 25 diagnostic laparoscopies with laparoscopic ultrasonography performed by a surgical resident were analyzed and compared with the outcomes of these procedures performed by an experienced surgeon. The time, actions, and correctness of task performance were evaluated. Furthermore, outcome correctness and postoperative complications were assessed.
Results: No postoperative complications occurred. The resident made one wrong diagnosis, for which the cause was detected by peroperative analysis. Additionally, 1% of the subtasks were performed only partially, 4% not at all, and 2% using the wrong technique. The efficiency for most diagnostic tasks remained significantly lower than that of the experienced surgeon ($p < 0.001$).
Conclusions: Time-action analysis can be used to provide detailed insight into the quality and efficiency of learning surgical skills. It enables objective measurement of correctness in task performance as well as time and action efficiency.

Key words: Laparoscopy — Learning curve — Quality assessment — Surgical task analysis — Time-action analysis

Laparoscopic surgery demands detailed analysis and support of learning surgical skills because it has introduced numerous new techniques and skills the surgeon needs to acquire [16]. Several suggestions have been made for standardizing skill training programs and assessing guidelines for resident education [6, 16]. However, no standardized method exists for assessing the quality of education and controlling the actual efficiency level or correctness of task performance [1, 2, 5, 6, 17]. In surgery, the importance of quality assessment studies is increasingly recognized. However, the surgeon–resident relationship of most education programs makes objective task analysis difficult [11].

The literature assumes that a surgeon is experienced if the total operation times and complication rates are stabilized at a certain minimum level after a number of procedures, which varies from 5 to more than 25 procedures [8]. Several studies stress the importance of expertise in reducing mortality rates, hospital stay, and costs [12]. However, operative time reduction and hospital mortality rates do not provide insight into the actual peroperative complications or risks nor the expertise of each single surgeon. Therefore, analysis of the learning process should address not only the outcome in terms of morbidity, mortality, and overall operative time reduction, but it should also analyze task performance. Laparoscopic training uses both simulated and actual surgery, and time-action analysis could be used to evaluate either approach. In this article we analyze actual operative training.

This article provides an example of time-action analysis used to analyze the learning of new tasks (the first 25 procedures) of a surgical resident being introduced to diagnostic laparoscopy with laparoscopic ultrasonography (DLLU). This basic laparoscopic procedure was selected to demonstrate how the learning of diagnostic laparoscopic skills is evaluated with respect to time and action efficiency and correctness of task performance by comparing a resident with an experienced surgeon. Actions within each phase are identified using a reference table of 35 basic actions and their corresponding recorded action times.

Patients and methods

Patients

Patients with a suspected periampullary tumor were selected after standard noninvasive staging (e.g., ultrasonography combined with color Doppler and spiral computed tomography [CT] scan) showed that the tumor was

Correspondence to: K. T. den Boer

Table 1. Specific US phase action thesaurus

Main task	Definition
Searching a structure	Search, find, and recognize a structure on the US image.
Scanning the liver for suspect lesions	Scan the liver superficially and deep for suspect lesions (metastasis) using the US probe.
Locating the place of the suspect lesion	Locate and name the 3D position of the suspect lesion.
Following a structure	Follow the path of a structure (e.g., vessel, bile duct) in the US image.
Examining a suspect lesion in detail	Examine the lesion's characteristics (e.g., diameter, regularity, growth, consistency) and relation to surrounding tissue (e.g., ingrowth) in detail.
Freezing the US image	Freeze the US image to measure the lesion's size.
Waiting	Wait for personnel to hand over instrumentation or execute an order.

Table 2. Correctness of diagnostic laparoscopy with laparoscopic ultra sonography (DLLU) subtasks performed according to the standard protocol

No.	Task	No.	Subtasks	C[a]	P	N	W	N.A.
1	Create carbon dioxide pneumoperitoneum	1.1	Insert Veress needle				18	
		1.2	Insufflate the abdomen with carbon dioxide	18				
		1.3	Remove Veress needle	18				
2	Insert access ports	2.1	Insert first (optical) port	18				
		2.2	Insert laparoscope	18				
		2.3	Inspect abdomen	18				
		2.4	Insert second port under direct sight	18				
		2.5	Insert third port under direct sight	18				
		2.6	Inspect possible bleeding site	18				
3	Inspect using laparoscope	3.1	Insert first forceps	17			1	
		3.2	Insert second forceps	18				
		3.3	Inspect Treitz ligament	13	2	3		
		3.4	Inspect mesocolon	15	2	1		
		3.5	Inspect hepatoduodenal ligament	17	1			
		3.6	Inspect omentum	18				
		3.7	Remove first forceps	18				
		3.8	Remove second forceps	18				
		3.9	Insert irrigation equipment	18				
		3.10	Insert lavage fluid	18				
		3.11	Suck off 200 ml lavage fluid	18				
		3.12	Inspect liver (all segments)	16	2			
		3.13	Inspect lymph nodes	18				
		3.14	Inspect peritoneum	18				
		3.15	Examine each suspect lesion in detail (seize, consistency, aspect, ingrowth)	12				6
		3.16	Remove irrigation equipment	18				
4	Inspect using US probe	4.1	Insert US probe	18				
		4.2	Inspect liver (all segments)	18				
		4.3	Inspect pancreatic duct	18				
		4.4	Inspect common bile duct	18				
		4.5	Inspect superior mesenteric vein	16		2		
		4.6	Inspect portal vein	18				
		4.7	Inspect confluens	16		2		
		4.8	Inspect celiac trunk	17		1		
		4.9	Inspect lymph nodes	18				
		4.10	Inspect common hepatic artery	18				
		4.11	Inspect superior mesenteric artery	17		1		
		4.12	Examine vessel ingrowth and tumor extension	15	2	1		
		4.13	Examine a suspect lesion in detail (seize, consistency, aspect, ingrowth)	16				2
		4.14	Freeze, measure, and save the US image	18				
5	Take a biopsy	5.1	Insert biopsy forceps or needle	4		1		13
		5.2	Position the instrument in the suspect lesion	4		1		13
		5.3	Take a biopsy from the suspect lesion	4		1		13
		5.4	Hand over the specimen	4		1		13
		5.5	Check possible bleeding site	4		1		13
		5.6	Control hemostasis	3		1	1	13
6	Close up patient	6.1	Remove irrigation fluid	18				
		6.2	Remove instruments	18				
		6.3	Remove operating ports	18				
		6.4	Check access wounds	4		14		
		6.5	Release carbon dioxide from abdomen	18				
		6.6	Remove laparoscope	18				
		6.7	Remove optical port	18				
		6.8	Suture the port wounds	18				
	Total			807	10	33	20	84

[a] C, correctly; P, partially; N, not at all; W, using the wrong technique; NA, not applicable

locally resectable and did not show signs of distant metastases. Patients were excluded if they were not fit for an extensive surgical procedure. No patient-specific data were recorded except for the diagnosis and outcome of operation, and the recordings were labeled by a specific number. The study protocol was approved by the Ethics Committee of the Academic Medical Center (AMC) of Amsterdam.

Procedure

The DLLU procedure was selected for study, first, because it is a basic laparoscopic procedure, and second, because this standardized procedure has been performed on a regular basis in more than 500 patients at AMC since 1992, in accordance with a strictly defined standard protocol [7, 10, 13].

Briefly, the protocol was divided into five phases. The first phase, the opening phase, started with the first incision. It was followed by the inspection phase, in which metastases of the peritoneum, liver, mesentery, and hepatoduodenal ligament were sought. The third phase, the ultrasonography phase, assessed tumor ingrowth into the vessels and surrounding tissue as well as metastases in the liver and lymph nodes of the celiac vessels using a 7.5-MHz linear array ultrasonography (US) probe (UST-5522-7.5, Aloka Co., Tokyo, Japan). In addition, the abdominal cavity was irrigated with 500 ml of isotonic saline, which was sampled for cytologic examination. In the fourth phase, the biopsy phase, biopsies of suspect metastatic lesions were taken under direct laparoscopic or ultrasonographic guidance using biopsy forceps or core-biopsy needles. The last phase was the closing phase.

Diagnostic laparoscopy was always performed in combination with laparoscopic ultrasonography for tumor staging as a separate procedure before surgical exploration and resection. During the procedure, an experienced radiologist interpreted the US image together with the surgeon or resident performing the US or biopsy phase. The DLLUs for periampullary tumor staging were carried out by one surgical resident, starting with his first performed DLLU (under the supervision of an experienced surgeon) and continuing until the 25th DLLU. The surgical resident had never performed a DLLU before the start of this study, but had performed 100 other basic laparoscopic procedures.

This article is closely related to an existing report [3] in which an experienced surgeon was analyzed and average values obtained for 18 patients. These reported results were treated as a reference for the current study.

Recording instrumentation

During the surgical procedure, an overview image of the operating theater was recorded simultaneously with the image from the laparoscope and laparoscopic ultrasonograph through the use of a four-channel video mixing device. Sound also was recorded. All the actions performed by the operating team were recorded with a video camera placed next to the operating lights to guarantee a central overview. The instrumentation for recording the procedures was mounted in a portable cabinet, thus allowing instant use of any of the operating theatres and placement outside the operating team's range of action. The analysis of the recorded procedures took place outside the operating theater, so it would not interfere with the operative process.

Data processing method

The correctness of task performance was studied in the DLLUs with respect to correctness of the technique applied, failure of DLLU, postoperative complications, and outcome correctness. The outcomes of DLLUs were divided into four groups, with the tumors diagnosed (a) as resectable after DLLU; (b) as possibly irresectable, which could however not be proven by pathology; (c) as proved irresectable by pathology of the biopsy specimen; or as not present. The DLLU outcome of resectability or irresectability was compared with the outcome at laparotomy, which was considered the gold standard, proving whether the outcome of DLLU was correct or not. The correctness of the resident's performance was evaluated by an experienced surgeon after all 25 DLLUs were recorded. For each subsequent task of the standard DLLU protocol, the experienced surgeon verified whether the task was performed correctly (C), incorrectly, that is, partially, (P), not at all (N), or using the wrong technique (W). If no suspect lesions were detected, some subtasks were considered not applicable (NA), for example, taking a biopsy when no lesion was suspected.

A quantitative time-action analysis was performed to evaluate the speed of task performance and the number of basic actions. The time-action results of the surgical resident were compared with those of a standard DLLU based on the results of 18 DLLUs by an experienced laparoscopic surgeon, who had performed 800 basic and advanced laparoscopic procedures, 300 of which were DLLUs) [3]. First, for each phase, the time and actions were analyzed using a general thesaurus of 35 actions strictly defined previously and validated quantitatively [3]. Second, for the learning of specific diagnostic skills, the US-phase tasks were studied in detail because the resident had no former experience in performing US tasks. Table 1 shows the specific US-phase action thesaurus used to analyze the efficiency of the resident as compared with the standard, which was based on the results of US phases performed by the experienced surgeon. Table 2 shows the specific protocol subtasks used to analyze the correctness of task performance

The data were processed using a spreadsheet program and analyzed using SPSS, the statistical program for Windows. The differences between the times and actions of the resident compared with the mean time and actions of the experienced surgeon were analyzed by calculating a difference score (DS) for time and actions: $DS_{time} = time_{resident} - time_{standard}$. The time-action results of the resident were log-normally distributed, so the data were normalized by a log transformation. The differences in log-transformed times and actions were tested using a one-sample *t*-test and the differences in variances using an *F*-test (24, 17 *df*). A *p* value less than 0.05 was considered significant.

Table 3. Failure of laparaorscopy, complications, and outcome diagnostic laparoscopy with laparoscopic ultrasonography (DLLU)

	Residents ($n = 18$)[a]	Experienced surgeons ($n = 18$) [3]
Failure of laparoscopy[b]	0	0
Complications[c]	0	0
Outcome correctness[d]	correct/incorrect	correct/incorrect
Resectable	14/1	8/0
Possibly irresectable	0/0	5/0
Proven irresectable	1	5
No malignancy	2	

[a] 18 DLLUs performed without a supervisor
[b] A laparoscopic procedure that had to be converted to an open procedure because of major complications
[c] All complications registered in the patient file (per i- and postoperative).
[d] The number of times a diagnosis made during DLLU was proved to be (in-)correct during laparotomy

Results

This study analyzed 43 DLLUs performed for periampullary tumor staging: 18 performed by an experienced surgeon and 25 by a surgical resident. A supervisor actively participated in the first seven DLLUs performed by the resident, controlling the correctness of subtasks performed. These first seven DLLUs were therefore included only for the time-action analysis and thus excluded from the correctness evaluation. The biopsy phase was evaluated only for correctness of task performance and not for efficiency because such a small number of biopsies (4) was taken in the 25 DLLUs performed by the resident.

Correctness

Table 3 shows the clinical outcomes of the procedures performed by the resident without a supervisor ($n = 18$) and

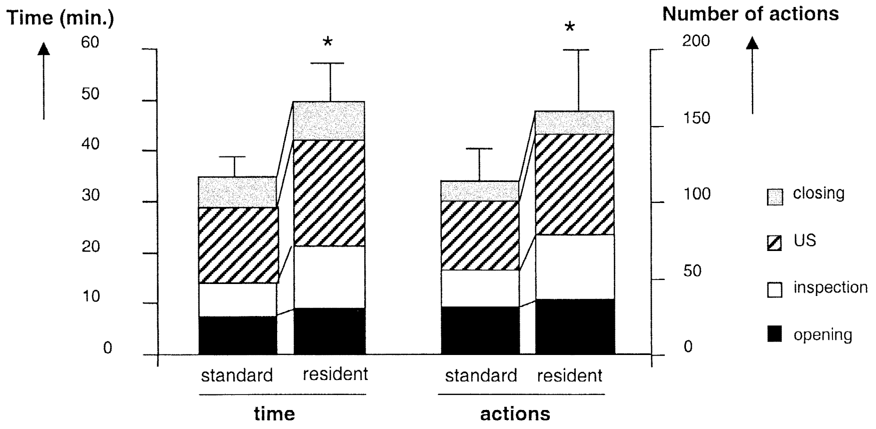

Fig. 1. The mean operation time (min) and mean number of actions of the standard as compared with the resident. The first two bars show the total operation time for the standard and the resident, with each color representing the contribution per phase. The last two bars show the total number of actions, also divided into phases. *A p value less than 0.001, based on the two-sided t-test comparing the log-normalized values of the total times and the number of actions of the standard versus the resident.

those performed by the experienced surgeon ($n = 18$). No failures of DLLU or complications occurred in either group. The outcome of DLLU was correctly diagnosed in 17 of 18 procedures performed by the resident. The resident misdiagnosed one tumor as resectable, which was proved incorrect during laparotomy because metastases were detected in the omentum and mesocolon of the patient. The cause of the resident's misdiagnosis could not be traced by the postoperative outcomes. The experienced surgeon diagnosed all 18 procedures correctly, even in the five cases for which the irresectability could not be proved by pathology during the DLLUs.

Table 2 shows that the resident technically performed most of the subtasks correctly (93%; C = 807 + NA = 84). The resident performed 33 subtasks incorrectly. He performed the insertion of the Veress needle incorrectly in 18 cases, blocking the safety mechanism by a slightly incorrect positioning of the hand. Once, the first forceps was not inserted under direct sight, and in the closing phase, the resident failed in 14 cases to double-check the insertion wounds of the trocars for bleeding vessels.

Table 2 also shows that the resident performed diagnostic subtasks not at all or only partially. The inspection for tumor ingrowth into the ligaments or vessels was not performed in 11 cases and partially performed in 9 cases. In one DLLU, the resident wrongly omitted taking a biopsy of a suspect intrahepatic lesion and thus failed to perform all the subtasks of the biopsy phase. He once controlled the hemostasis wrongly, resulting in slight coagulation damage to the liver. Furthermore, the subtask analysis showed that the misdiagnosis occurred because the resident only partially performed a crucial diagnostic subtask, thereby missing the metastasis. The recorded comments of the surgeon during the operation showed clearly that the resident was convinced that he had performed all the diagnostic subtasks correctly and completely. In 84 cases, the resident correctly considered a subtask as not applicable because no suspect lesions were observed.

Time-action analysis

Figure 1 shows that the total operation time and the number of actions of the resident were significantly higher as compared with the standard based on the mean times and actions of the experienced surgeon ($p < 0.001$). The inspection and US phases especially differed significantly between the resident and the surgeon (Figs. 1 and 2).

Figure 2 shows the DS for the times and number of actions for each consecutive DLLU performed by the resident relative to the standard for the opening, inspection, ultrasonography, and closing phases, including linear trend lines. As shown, the DS_{time} for the opening and closing phases did not differ from the standard. The inspection and US phases show a significant difference for the DS_{time} and $DS_{actions}$ ($p < 0.01$), and a larger variance than the standard ($p < 0.05$).

Figure 3 shows the three different time and action distributions encountered in the tasks of the US phase. Figure 3a shows the distribution of the DS for the task of scanning of the liver. The distribution remained significantly above the reference line and showed no significant decrease in the linear trend lines for the DS_{time} and $DS_{actions}$ (no increase in efficiency). Figure 3b shows the DS for the search to find a structure in the US image, with decreasing trend lines (increasing efficiency), and Fig. 3c shows the DS for waiting on personnel, which is distributed randomly around the reference line without any correlation, and varied widely among the procedures. Accordingly, the DS_{time} and $DS_{actions}$ for waiting on personnel is not significantly different between the resident and the standard, showing that the task is dependent on the operating team and independent of the operating surgeon. The distribution of the diagnostic US tasks: (i.e., following and locating an anatomic structure or lesion) is similar to that seen in Fig. 3a. The examination of a suspect lesion in detail is similar to that observed in Fig. 3b, which also shows decreasing trend lines, and the freezing of the US image (performed by the radiologist) is similar to that in Fig. 3c. The standard variations of the US tasks do not differ from the standard, except for the time required to examine the lesion in detail ($F = 3.4$; 24, 17 df).

Discussion

Time-action analysis, recently developed to evaluate the peroperative surgical procedure, proved capable of detecting and quantifying the efficient actions, the limiting factors, and the time spent on different phases of surgical procedures, accurately and reproducibly [3, 5]. The current

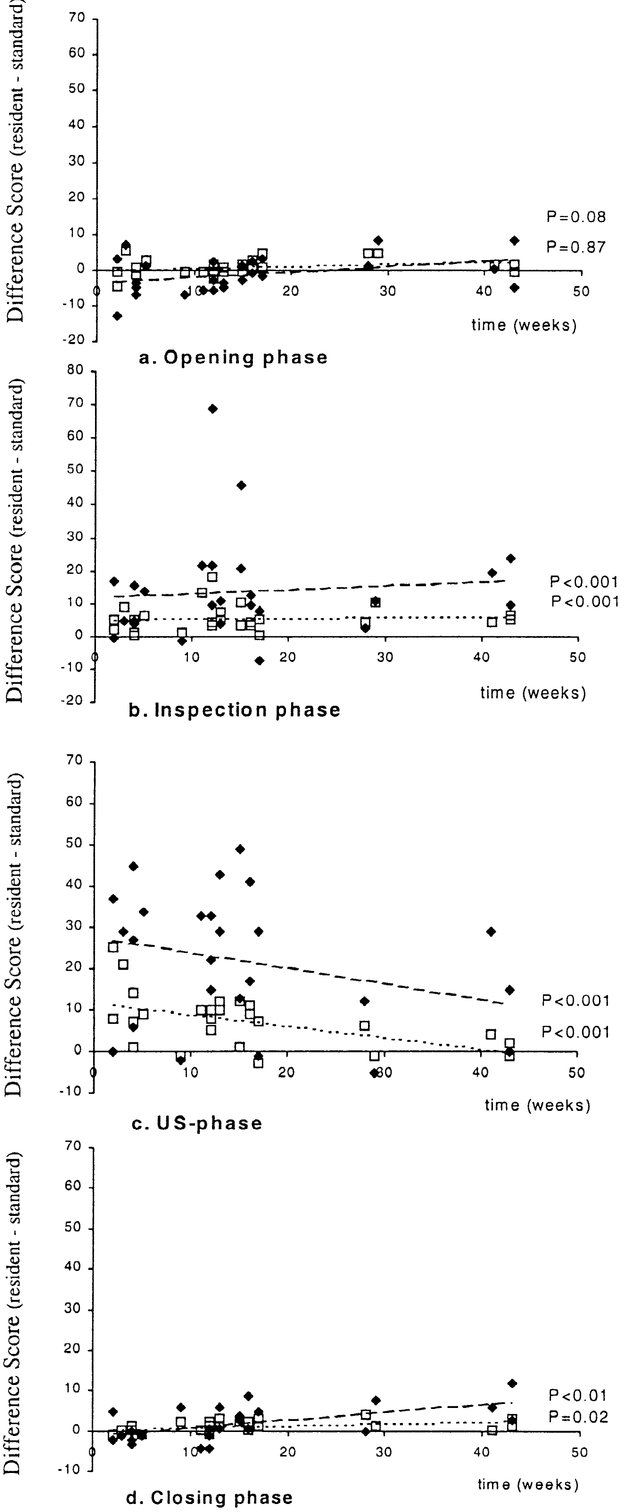

Fig. 2. The difference scores (DS) for the time in min (□) and the number of actions (◆) between the resident and the standard are shown for the opening **(a),** inspection **(b),** ultrasonography **(c),** and closing phase **(d).** Linear trend lines are included for the DS_{time} (dotted line) and DS_{action} (dashed lines). The *p* values shown are based on the one-sample *t*-test of the log-normalized values.

study demonstrated that time-action analysis also could be used to evaluate learning of skills with respect to efficiency and correctness of task performance, providing insight into

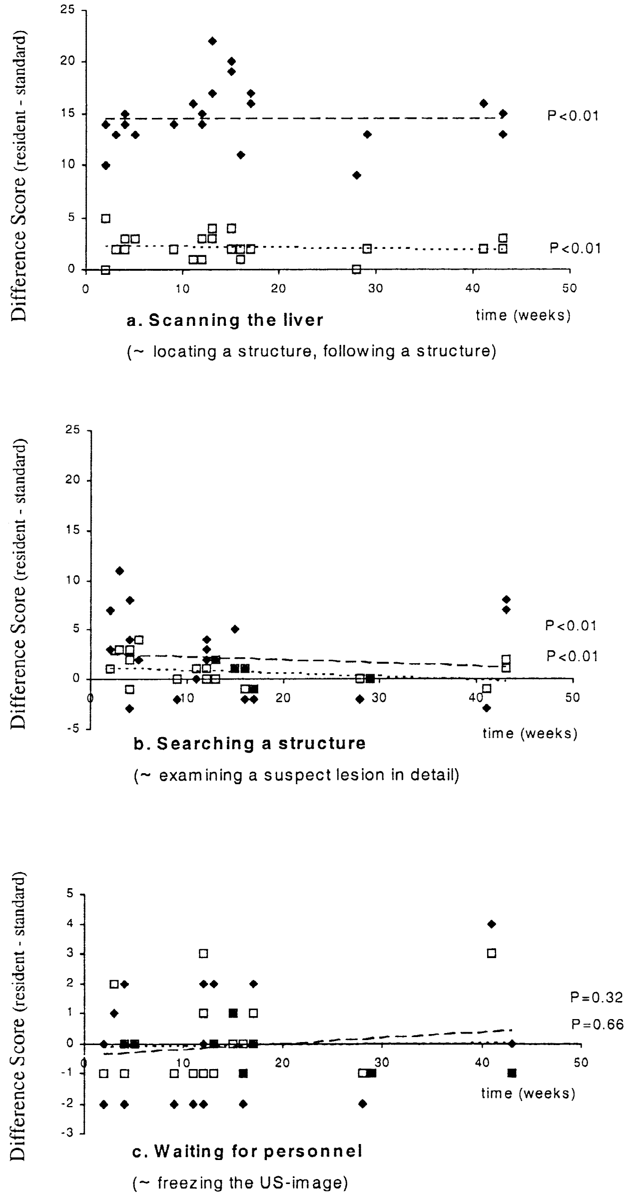

Fig. 3. The difference scores (DS) for the time in min (□) and the number of actions (◆) between the resident and the standard are shown for the ultrasonography (US) tasks. **a** Scanning of the liver. **b** Searching a structure in the US image. **c** Waiting for personnel to hand over instrumentation or execute an order. The distribution of the actions: Locating and following a structure are similar to **a.** Examining a suspect lesion in detail is similar to **b.** Freezing of the US image by the radiologist is similar to **c,** as indicated in brackets. Linear trend lines are included for the DS_{time} (dotted line) and DS_{action} (dashed lines). The *p* values shown are based on the one-sample *t*-test of the log-normalized values.

the learning of skills, in addition to total operation times and postoperative outcomes [8]. It applied the method to a relatively simple laparoscopic procedure (DLLU) with many new laparoscopic tasks to illustrate the application. However, time-action analysis can be applied to all types of procedures, including open and laparoscopic procedures.

Caution should be taken not to generalize the conclusions of this study to other surgical tasks. This study demonstrated the applicability of a method to DLLUs. For other surgical tasks, the method should be used to analyze other types of operations. A database of quality and efficiency reference parameters should be determined for each specific procedure. These data could be used to control the quality of surgical courses, and to assess the expertise of residents in both laparoscopic and open surgery. Caution also should be taken not to answer the question of clinical benefit from DLLUs on the basis of the postoperative outcomes for the 43 patients studied, because that was not the aim of this study, and a reliable answer is described in the literature [13].

The literature describes the quality of performance mostly in terms of mortality rates, number of postoperative complications, or local recurrences in cancer surgery [9]. However, these studies do not provide insight into the underlying causes of these complications or incorrect outcomes. The subtask analysis of this study detected that the misdiagnosis resulted from an incorrectly performed subtask, showing additional incorrectly performed subtasks, which fortunately did not cause more incorrect diagnoses in these cases. Nevertheless, every incorrect task performance increases the risk of complications, and thus should be reduced. The first step in reducing incorrect tasks is to detect them.

To residents, incorrectly performed tasks are usually pointed out by the supervisor. However, experienced surgeons supervise only the first procedures and, as this study shows, even supervision does not reveal all incorrect task performance. The incorrect insertion technique of the Veress needle was detected only by the detailed correctness analysis and not during the first seven supervised DLLUs or other laparoscopic procedures the resident performed under the supervision of an experienced surgeon. This highlights the importance and additional benefit of detailed peroperative correctness and efficiency analysis.

The method described in this study is detailed and therefore relatively time consuming. The analysis of one procedure generally takes as long as the total operation time of the analyzed procedure. However, the level of detail can be reduced, depending on the objectives of each study. Furthermore, software is becoming available to facilitate and quicken the data collection and evaluation (e.g., The Observer; Noldus information technology, Wageningen, the Netherlands).

The US phase comprised the highest component of new tasks for the resident. Accordingly, this study showed that US tasks were the most difficult to learn. Most incorrect task performance stemmed from the interpretation of the US image, and the efficiency difference between the resident and the standard was highest for the US phase ($p < 0.001$). Learning to increase efficiency appeared to be a slow process. Most diagnostic tasks performed by the resident did not increase in 25 DLLUs, except for two specific US tasks. Task efficiency strongly depends on the type of task, and probably is influenced also by the personal technique, the routines transferred from other procedures, and the supervisors training the resident.

Because laparoscopic operations have become a primary component of general surgery, curriculum guidelines for resident education are important [6, 16]. These guidelines should contain an outline of knowledge and tasks to be mastered in basic and advanced laparoscopy. Time-action analysis proves to be accurate in clarifying specific learning difficulties, providing valuable feedback information that can support the generation of guidelines for efficient training [4, 14, 15]. Specific skill training could be started in laboratory settings, without the need for an extra supervisor. For example, in DLLUs, the interpretation of the ultrasonographic image could well be trained in skills laboratories involving surgical trainers, computer simulations, or animal models [4]. This would enhance the quality of the surgical technique before the procedure is performed in the operating room, thereby reducing the risk of complications and wrong diagnosis in a human patient. In addition, time-action analysis could help the supervisor to focus his or her instructions on the difficult tasks required for a particular procedure, and it could support transfer of training and individual feedback [18]. Time-action analysis also could assess the quality of courses, simulation programs, or conventional education by a supervising surgeon, and therefore could be very well applicable for evaluating the learning of standard surgical skills in both laparoscopic and open surgery.

Conclusions

This study shows that peroperative analysis can evaluate the efficiency and quality of task performance, objectively and accurately. In the future, time-action analysis could become implemented routinely to control the quality of surgical courses and the task performance of surgeons in both laparoscopic and open surgery. The learning of diagnostic laparoscopic skills was analyzed to exemplify the use of time-action analysis. The example shows that the resident's efficiency for each specific diagnostic task remained significantly lower than that of the experienced surgeon ($p < 0.001$), except for two US tasks. The subtasks were performed correctly in 93% of the cases, partially in 1%, not at all in 4%, and by use of the wrong technique in 2%. The postoperative analysis did not show these incorrect subtasks performance, nor did the supervisor correct all the technically wrong task performance.

Acknowledgments. This research is part of the Minimally Invasive Surgery and Interventional Techniques (MISIT) program of the Delft Interfaculty Research Center on Medical Engineering (DIOC-9).

References

1. Barnes RM (1980) Motion and time study: design and measurement of work. John Wiley & Sons, New York, pp
2. Bessell JR, Baxter P, Riddell P, Watkin S, Maddern GJ (1996) A randomized controlled trial of laparoscopic extraperitoneal hernia repair as a day surgical procedure. Surg Endosc 10: 495–500
3. Boer den KT, Wit de LT, Gouma DJ, Dankelman J (1999) Perioperative time-motion analysis of diagnostic laparoscopy with laparoscopic ultrasonography. Br J Surg 86: 951–955
4. Chew FS, Smirniotopoulos JG (1993) Educational efficacy of computer-assisted instruction with interactive videodisc in radiology. Invest Radiol 28: 1052–1058
5. Claus GP, Sjoerdsma W, Jansen A, Grimbergen CA (1995) Quantitative standardised analysis of advanced laparoscopic surgical procedures. Endosc Surg Allied Technol 3: 210–213
6. Cuschieri A, Wilson RG, Sunderland G, McIntyre IM, Youngson GG, Cash JD, Mackay N, Shields SR (1997) Training initiative list scheme (TILS) for minimal access therapy: the MATTUS experience. J R Coll Surg Edinb 42: 295–302

7. Delden van OM, Wit de LT, Nieveen van Dijkum EJM, Smits NJ, Gouma DJ, Reeders JWAJ (1997) Value of laparoscopic ultrasonography in staging of proximal bile duct tumors. J Ultrasound Med 17: 7–12
8. Deschamps C, Allen MS, Trastek VF, Johnson JO, Pairolero PC (1998) Early experience and learning curve associated with laparoscopic Nissen fundoplication. J Thorac Cardiovasc Surg 115: 281–284
9. Gordon TA, Bowman HM, Tielsch JM, Bass EB, Burleyson GP, Cameron JL (1998) Statewide regionalization of pancreaticoduodenectomy and its effect on in-hospital mortality. Ann Surg 228: 71–78
10. Gouma DJ, deWit LT, Nieveen van Dijkum EJM, VanDelden OM, Bemelman WA, Rauws EAJ, VanLanschot JJB, Obertop H (1996) Laparoscopic ultrasonography for staging of gastrointestinal malignancy. Scand J Gastroenterology 218: 43–49
11. Leval de MR (1997) Human factors and surgical outcomes: a Cartesian dream. Lancet 349: 723–725
12. Lieberman MD, Kilburn H, Lindsey MBMF (1995) Relation of perioperative deaths to hospital volume among patients undergoing pancreatic resection for malignancy. Ann Surg 222: 638–645
13. Nieveen van Dijkum EJM, DeWit LT, VanDelden OM, Rauws EAJ, VanLanshot JJB, Obertop H, Gouma DJ (1997) The efficacy of laparoscopic staging in patients with upper gastrointestinal tumors. Cancer 79: 1315–1319
14. Rosser JC, Rosser LE, Savalgi RS (1997) Skill acquisition and assessment for laparoscopic surgery. Arch Surg 132: 200–204
15. Shapiro SJ, Paz-Partlow M, Daykhovsky L, Gordon LA (1996) The use of a modular skills center for the maintenance of laparoscopic skills. Surg Endosc 10: 816–819
16. Society of American Endoscopic Surgeons (SAGES) Integrating advanced laparoscopy into surgical residency training. Surg Endosc 12: 374–376
17. Traverso LW, Koo KP, Hargrave K (1997) Standardizing laparoscopic procedure time and determining the effect of patient age/gender and presence or absence of surgical residents during operation: a prospective multicenter trial. Surg Endosc 11: 226–229
18. Wickens CD (1992) Memory, learning, and training. In: Pearson L, Caterer MC (eds) Engineering psychology and human performance. HarperCollins, New York, pp 211–257