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Interoperative efficiency in minimally invasive surgery suites

M. J. van Det · W. J. H. J. Meijerink ·
C. Hoff · J. P. E. N. Pierie

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Abstract
Background Performing minimally invasive surgery (MIS) in a conventional operating room (OR) requires additional specialized equipment otherwise stored outside the OR. Before the procedure, the OR team must collect, prepare, and connect the equipment, then take it away afterward. These extra tasks pose a thread to OR efficiency and may lengthen turnover times. The dedicated MIS suite has permanently installed laparoscopic equipment that is operational on demand. This study presents two experiments that quantify the superior efficiency of the MIS suite in the interoperative period.
Methods Preoperative setup and postoperative breakdown times in the conventional OR and the MIS suite in an experimental setting and in daily practice were analyzed. In the experimental setting, randomly chosen OR teams simulated the setup and breakdown for a standard laparoscopic cholecystectomy (LC) and a complex laparoscopic sigmoid resection (LS). In the clinical setting, the interoperative period for 66 LCs randomly assigned to the conventional OR or the MIS suite were analyzed.
Results In the experimental setting, the setup and breakdown times were significantly shorter in the MIS suite. The difference between the two types of OR increased for the complex procedure: 2:41 min for the LC ($p < 0.001$) and 10:47 min for the LS ($p < 0.001$). In the clinical setting, the setup and breakdown times as a whole were not reduced in the MIS suite. Laparoscopic setup and breakdown times were significantly shorter in the MIS suite (mean difference, 5:39 min; $p < 0.001$).
Conclusion Efficiency during the interoperative period is significantly improved in the MIS suite. The OR nurses' tasks are relieved, which may reduce mental and physical workload and improve job satisfaction and patient safety. Due to simultaneous tasks of other disciplines, an overall turnover time reduction could not be achieved.

Keywords Efficiency · Interoperative · Minimally invasive surgery · Minimally invasive surgery suite · Operating rooms · Turnover time

Laparoscopic procedures require specialized equipment that usually is not permanently present in a conventional operating room (OR). Before laparoscopic procedures, OR personnel must collect the laparoscopic equipment, stationed on large trolleys, from its storage facility and install it in the OR. This can be a time-consuming task. The average general surgery OR is not designed to house this equipment, leading to crowded workplaces, floors cluttered with tubing and wiring, operative inefficiencies, and safety problems for patients and staff [1].

In the early 1990s, the concept of the dedicated minimally invasive surgery (MIS) suite was first introduced as a means to solve these problems and others associated with MIS. The modern MIS suite is a fully integrated OR in which the laparoscopic equipment and multiple flat-screen monitors are permanently installed to be operational on demand inside the OR. The equipment is installed in columns attached to a ceiling-mounted suspension system that facilitates versatile positioning apart from the monitors. All

M. J. van Det (✉) · C. Hoff · J. P. E. N. Pierie
Department of Surgery, Leeuwarden Medical Center,
P.O. Box 888, 8901 BR Leeuwarden, The Netherlands
e-mail: marc.van.det@znb.nl

W. J. H. J. Meijerink
Department of Gastro Intestinal Surgery, Free University
Medical Center, Amsterdam, The Netherlands

the tubing and wiring are concealed inside the suspension system and led out of the OR through the ceiling. The laparoscopic equipment can be remotely controlled by the operating surgeon using voice control or by the circulating nurse using a touch panel at a control station away from the sterile field.

A MIS suite is designed to reduce OR clutter and staff workload; increase comfort, safety, and OR efficiency; and enhance ergonomics and OR team performance [2–4]. Many hospitals around the world have already invested, or are investing, in one or multiple MIS suites, but to date, no evidence has been provided to show the actual effect this type of OR has on efficiency in everyday practice.

We therefore conducted a study comparing setup and breakdown times of the MIS suite and the standard OR for both complex and standard laparoscopic procedures. We performed these measurements in an experimental setting and in daily practice.

Materials and methods

Study design

This study aimed to determine the turnover time reduction in the MIS suite compared with the conventional OR for complex and standard laparoscopic procedures. The time span between two operations is dependant on many factors and disciplines. For an accurate estimation of the exclusive contribution the MIS suite makes to interoperative efficiency, we decided first to perform measurements in an experimental setting. Second, we analyzed interoperative periods in a clinical setting to evaluate whether the actual interoperative periods, including nonsurgical activities, also were reduced with the improved efficiency in the MIS suite.

In the experimental situation, a crossover design was used. The times required to set up and to break down an operative setting for a standard laparoscopic cholecystectomy (LC) and a complex laparoscopic sigmoid resection (LS) were recorded. The setup time was defined as the time required to prepare an empty OR for a procedure up until all laparoscopic and video equipment was installed and operational. The breakdown time was defined as the time required to dismantle the laparoscopic and video equipment and clean up the OR up until the OR was empty and ready for the next procedure.

The clinical part of this study measured the turnover times in daily practice for LCs. The pre- and postoperative periods were divided into the same identifiable stages as in the experimental setting. After data collection, the clinical results were compared between the different types of OR and with the experimental results.

Operating room setup

Both types of OR are situated in the same complex, have the same size, and meet the latest standards. The storage room for the laparoscopic trolleys used in the conventional OR is centrally located in the operating complex. For both the experimental and the clinical measurements we used ORs adjacent to the storage room.

In the experimental situation, three randomly chosen teams of two OR nurses had to set up and break down the operative setting. The one OR nurse performed the tasks of the sterile scrub nurse, whereas the other performed the tasks of the circulating nurse. In random order, each OR nurse performed each task in both types of OR, so we had six measurements per type of procedure per type of OR in which each nurse was her own matched control.

All the participants were highly qualified laparoscopic OR nurses especially trained by "the endoscopic team." This group of nurses routinely perform a wide variety of laparoscopic procedures in both the MIS suite and the conventional OR.

Table 1 shows the equipment necessary to perform the procedures. The setup for the standard LC required less equipment than the setup for the more complex LS.

In the clinical part of the study, 66 consecutive LCs were analyzed. In randomized order, 36 were assigned to the MIS suite and 30 to the conventional OR on the day before the procedure. Standard equipment, as shown in Table 1, was used for each procedure. In the MIS suite, two flat-screen displays were used compared with one cathode ray tube (CRT) monitor on top of the single laparoscopic trolley in the conventional OR. Figure 1A and B delineates the floor plan of the operative setup inside the OR.

Table 1 Equipment needed and its location to perform a laparoscopic cholecystectomy (LC) and a laparoscopic sigmoid resection (LS) in the minimally invasive surgery suite (MISS) and the conventional operating room (Conv)

Equipment	LC MISS	LC Conv	LS MISS	LS Conv
Insufflation	Boom 1	Trolley[a]	Boom 1	Trolley 1[a]
Camera	Boom 1	Trolley[a]	Boom 1	Trolley 1[a]
Light source	Boom 1	Trolley[a]	Boom 1	Trolley 1[a]
Documentation	Control station	Trolley[a]	Control station	Trolley 1[a]
Electrocautery	Boom 2	Boom	Boom 2	Boom
Monitor 1	Suspended	Trolley[a]	Suspended	Trolley 1[a]
Monitor 2	Suspended		Suspended	Trolley 2[a]
Ultracision			Boom 2	Cart 1[a]
Suction/ irrigation			Cart	Cart 2

[a] Items not permanently present in the OR

Data collection

Within one complete time cycle of a laparoscopic procedure from empty OR before the procedure to empty OR after the procedure, we identified three interoperative phases (Fig. 2). Two phases were identified in the preoperative period. Phase 1 comprised preparation of the OR, the monitors, and the laparoscopic equipment up until the patient could enter the room. After the patient was asleep and draped, phase 2 comprised the installation and connection of the camera, light source, insufflator, and electrocautery devices as well as switching on the monitors. This phase was completed when the equipment was fully operational and the camera image was visible on the monitors.

After completion of the laparoscopic procedure, which we did not analyze, the postoperative period, phase 3, consisted of breaking down the laparoscopic instruments and equipment and returning them to the storage facility. Phase 3 was completed when the OR was empty and ready for the next procedure.

In the experimental situation, the OR nurses were carefully instructed not to rush and to perform their tasks in a usual pace and fashion. Phases 1, 2, and 3 were

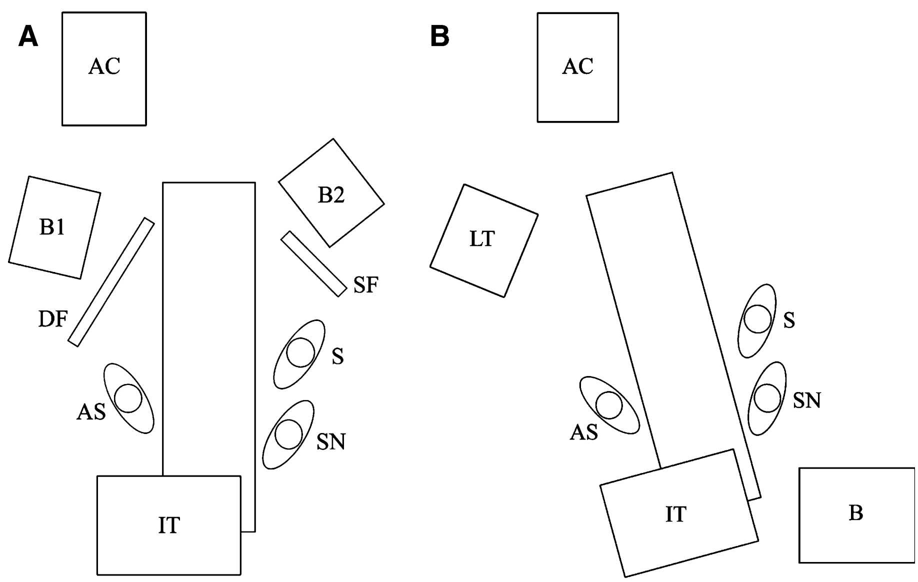

Fig. 1 (**A**) Setup for a laparoscopic cholecystectomy in the minimally invasive surgery (MIS) suite. S, surgeon; SN, scrub nurse; AS, assisting surgeon; IT, instrument table; DF, double flat screen; SF, single flat screen; AC, anesthesia console; B1, boom 1; B2, boom 2. (**B**) Setup for a laparoscopic cholecystectomy in the conventional operating room. S, surgeon; SN, scrub nurse; AS, assisting surgeon; IT, instrument table; LT, laparoscopic trolley; AC, anesthesia console; B, boom

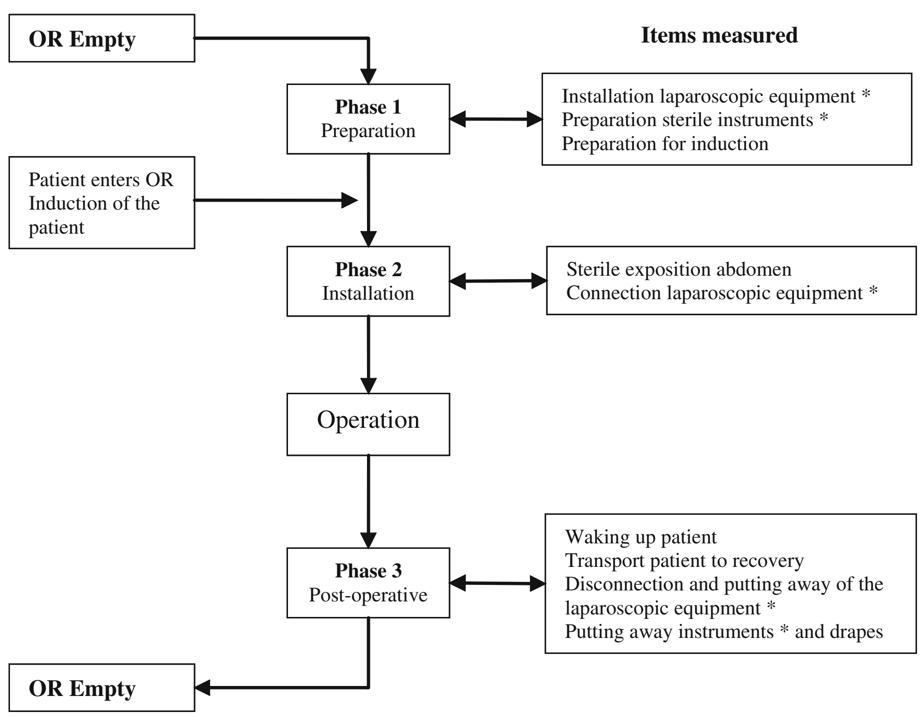

Fig. 2 The different phases of a laparoscopic procedure with the tasks performed during these phases. The items marked with an asterisk (*) were measured in the experimental setting. All items were measured in the clinical setting

simulated. All the measurements were performed by one observer, who used a stopwatch to time the phases. After each phase, the time measurements were instantly processed on a laptop computer.

The clinical measurements were performed without instruction of the OR personnel. The same phases were identified and recorded. In addition to the laparoscopic work performed by the OR team in each phase, there also were other tasks to be done for the OR team and the anesthesia team. These other tasks were not influenced by the type of OR but did require a certain amount of time. The duration of each complete phase was measured by recording the start and completion times. To appreciate the amount of time required to perform only the separate laparoscopic tasks within each phase, the timer function of a stopwatch was used for this more specific measurement.

Two observers collected the data. The first observer measured 45 consecutive procedures randomly assigned to the different types of OR (25 in the MIS suite and 20 in the conventional OR) and also conducted the measurements in the experimental setup. The second observer performed the last 21 consecutive procedures (11 in the MIS suite and 10 in the conventional OR). Although the observers measured two different samples, we compared the laparoscopic setup and breakdown times of the two observers per type of OR to estimate the reproducibility and observer bias of the data.

Statistical analysis

For the experimental setting, mean outcomes and their standard deviations were compared per OR nurse between the MIS suite and the conventional OR using the *t*-test for paired observations. For the clinical setting, mean outcomes were compared using the independent samples *t*-test. The samples for each type of OR measured by the two observers also were compared using the independent samples *t*-test.

All statistical tests were two-tailed. A *p* value less than 0.05 was used for all tests to indicate statistical significance. All statistical analyses were performed using SPSS 14.0.1 for Windows (SPSS, Chicago, IL, USA).

Results

In the experimental setting, the three teams of OR nurses performed their tasks in at normal pace and provided six paired data sets per type of procedure per type of OR.

Table 2a shows the results for the LC in the experimental setting. The execution times for setup (phase 1) and breakdown (phase 3) were significantly shorter in the MIS suite than in the conventional OR. After the equipment was set up, the connection time (phase 2) did not differ between the two types of OR. The execution times of the complete preoperative setup (phases 1 and 2) and the overall execution time (phases 1, 2, and 3) also were significantly shorter in the MIS suite. The mean difference in the overall execution time was 2:41 min (standard error (SE), 15.7s; $p < 0.001$).

Table 2b shows the results for the LS in the experimental setting. All the execution times were significantly shorter in the MIS suite. The mean difference in the overall execution time was 10:47 min (SE, 26.1 s; $p < 0.001$).

In the clinical setting, 66 LCs were analyzed. All 66 LCs were performed for uncomplicated symptomatic gallbladder stones. There were no major intraoperative complications or conversions to open cholecystectomy.

Table 2 Mean execution times in the minimally invasive surgery suite (MISS) and the conventional operating room (Conv) in the experimental setting for the different interoperative phases as indicated in Fig. 2

LC	MISS	Conv	Mean diff	SE	*p* Value
(a) Laparoscopic cholecystectomy (LC)					
Setup phase 1	1:01.1 ± 21.0	2:28.2 ± 11.4	1:27.1	10.9	<0.001
Setup phase 2	1:35.6 ± 11.9	1:40.6 ± 24.5	5.0	9.4	0.621
Setup (phases 1 & 2)	2:36.7 ± 22.4	4:08.8 ± 32.0	1:32.1	11.7	0.001
Breakdown (phase 3)	1:37.2 ± 23.9	2:46.2 ± 9.2	1:09.0	10.7	0.001
Total (phases 1, 2, & 3)	4:13.8 ± 39.8	6:55.0 ± 35.7	2:41.2	15.7	<0.001
(b) Laparoscopic sigmoid resection (LS)					
Setup phase 1	1:14.0 ± 18.9	6:21.0 ± 40.1	5:07.0	18.1	<0.001
Setup phase 2	1:54.6 ± 38.3	2:54.0 ± 41.4	59.4	7.2	<0.001
Setup (phases 1 & 2)	3:08.6 ± 39.3	9:14.9 ± 57.2	6:06.3	22.9	<0.001
Breakdown (phase 3)	2:06.7 ± 26.6	6:47.7 ± 19.1	4:41.0	12.7	<0.001
Total (phases 1, 2, & 3)	5:15.3 ± 62.2	16:02.6 ± 58.3	10:47.3	26.1	<0.001

diff difference; *SE* standard error of the mean

Table 3 Mean execution times (± SD)) in the minimally invasive surgery suite (MISS) and the conventional operating room (Conv) in the clinical setting

Daily practice	MISS	Conv	Mean diff	SE	p Value
Phase 1[a]	39.9 ± 17.4	2:40.4 ± 33.4	2:00.5	6.4	<0.001
Phase 2[a]	56.5 ± 17.1	1:56.7 ± 20.8	1:00.2	4.7	<0.001
Preop (phases 1 & 2)[a]	1:36.4 ± 19.9	4:37.1 ± 33.8	3:00.7	6.7	<0.001
Preop (phases 1 & 2)	14:27.8 ± 3:33.8	16:20.8 ± 3:38.5	1:53.0	1:04.8	0.089
Procedure	1:05:53.8 ± 25:39.6	1:04:01.7 ± 20:19.4	1:52.1	5:47.0	0.748
Phase 3[a]	59.1 ± 15.8	3:37.0 ± 52.8	2:37.9	9.3	<0.001
Phase 3	6:19.1 ± 2:28.9	7:01.8 ± 2:53.5	42.7	39.7	0.293
Total (phases 1, 2, & 3)[a]	2:35.6 ± 26.6	8:14.1 ± 54.0	5:38.5	10.2	<0.001
Total (phases 1, 2, & 3)	20:46.9 ± 4:41.6	23:22.6 ± 5:18.6	2:35.7	1:29.6	0.146

diff difference; *SE* standard error of the mean; *Preop* preoperative

[a] Execution times for laparoscopic tasks only as indicated in Fig. 2

Table 4 Comparison of the measurements by the observers in the minimally invasive surgery suite (MISS) and the conventional operating room (Conv)[a]

Observers	Observer 1	Observer 2	Mean diff	SE	p Value
Lap setup (phases 1 & 2)[a] MISS	1:34.7	1:40.4	5.7	7.2	0.440
Lap setup (phases 1 & 2)[a] Conv	4:35.2	4:40.9	5.7	13.3	0.671
Phase 3[a] MISS	58.6	1:00.2	1.6	5.8	0.792
Phase 3[a] Conv	3:47.3	3:16.3	31.0	20.0	0.132
Total (phases 1, 2, & 3)[a] MISS	2:33.4	2:40.6	7.2	9.7	0.462
Total (phases 1, 2, & 3)[a] Conv	8:22.5	7:57.2	25.3	20.7	0.232

Lap laparoscopic

[a] Phases comply with the tasks as indicated in Fig. 2

Table 3 shows the execution times for the different phases as a whole and for the laparoscopic tasks only. The execution times for the entire preoperative phases were not significantly different between the two types of OR. Also, the execution times for the procedure and the postoperative stage were not significantly different. The laparoscopic execution times, unlike the entire phase, were significantly shorter in the MIS suite during each phase. The mean difference in the overall interoperative laparoscopic execution time was 5:39 min (SE, 10.2 s; $p < 0.001$).

The interobserver reproducibility was evaluated for the laparoscopic setup (phases 1 and 2) and for the postoperative laparoscopic phase (phase 3) in the different types of OR (Table 4). The execution times for the different samples from the two observers showed no significant differences.

Conclusions and discussion

Performing MIS procedures in a conventional OR requires the application of equipment not commonly present in the OR. Before the start of the laparoscopic procedure, OR personnel must collect the equipment, stationed on large trolleys, from its storage facility. Electricity, video cables, and carbon dioxide supply must be connected and inspected before usage. These tasks are physically burdensome and time demanding, and they are prone to connection errors and malfunctioning of the equipment that do occur in the majority of laparoscopic cases [5].

This study demonstrates that the time necessary to install, set up, and break down laparoscopic equipment for MIS interventions can be significantly reduced in a dedicated MIS suite. The time reduction increases with the complexity of the procedure because complex procedures require the setup of additional monitors and other equipment already present and ready for use in the MIS suite.

The experimental data suggest that an average time reduction of 2:41 min for a standard procedure and 10:47 min for a more complex procedure can be achieved per procedure in the MIS suite.

The results of the clinical measurements, however, could not translate the experimental results into a significant time reduction for the interoperative period. Our clinical data suggest a mean difference in the entire interoperative period of 2:36 min in favor of the MIS suite

(Table 3). Due to the relatively long phases compared with the laparoscopic tasks alone, which required only a fraction of the recorded time, the standard deviations and standard errors were too large for statistical significance to be reached. A look at the execution times for the laparoscopic tasks alone shows a significant time reduction for each interoperative phase, resulting in a potential overall time reduction of 5:39 min for the surgical OR team during the interoperative period.

Obviously, in our hospital, the duration of the interoperative period depends not only on the tasks and pace of the surgical OR team but also on the pace of the anesthesia team. Only when they also can streamline their workflow inside the OR by means of protocolling their work or performing certain tasks before the patient enters the OR can the full efficiency profit of the MIS suite be achieved.

The results of the two observers who performed the measurements in daily practice were very similar, suggesting that this is a reliable and replicable way of recording interoperative execution times. Because the observers measured different samples, a true interobserver reliability could not be calculated.

In the clinical setting, we did not measure the possible turnover time reduction for complex laparoscopic procedures. Because the variance in the complete preoperative preparation times and the postoperative breakdown times was already very large for LCs, we realized that this variance would only increase during the more complex procedures, mostly due to all the additional nonsurgical tasks.

Also, we did not examine the effect of the MIS suite on intraoperative efficiency. Luketich et al. [6] performed a study to evaluate the workload reduction for the circulating OR nurse by the use of voice control, a feature of the MIS suite. Their results demonstrate that during laparoscopic fundoplication, the intraoperative workload of the OR nurse can be reduced by 4.35 min and that satisfaction scores for both the surgeon and the nurse are significantly improved when voice control is used. However, in their article, they did not mention the effect of voice control on their procedure time.

Features other than voice control also are likely to contribute to improved efficiency during the procedures. Monitors installed on ceiling-suspended beams facilitate an ergonomic viewing direction [4, 7]. When viewing direction is optimized, it is possible to perform laparoscopic tasks more efficiently and effectively [8, 9].

The MIS suite concept with its permanently installed laparoscopic equipment available on demand allows a more efficient workflow during the interoperative period for the OR team. Although to date this has not led to a significant time reduction for the overall interoperative period, we did demonstrate that the workload of the OR nurses is significantly reduced. A reduced workload may contribute to job satisfaction and reduce mental and physical stress. Also, safety and ergonomics may be improved for both the OR team and the patients. Because OR nurses no longer need to transport the heavy equipment through the OR complex, they have more time available to prepare the patient and the OR for the upcoming procedure.

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