The Effects of Laparoscopic Surgery on the Operating Room Environment

RAMON BERGUER, M.D.
ASSISTANT PROFESSOR OF SURGERY, UNIVERSITY OF CALIFORNIA, DAVIS, CALIFORNIA
ASSISTANT CHIEF OF SURGERY, VA NORTHERN CALIFORNIA HEALTH CARE SYSTEM
MARTINEZ, CALIFORNIA

ANGEL ALARCON, M.D.
ASSISTANT PROFESSOR OF SURGERY
CENTRAL UNIVERSITY OF ECUADOR
QUITO, ECUADOR

The clutter of equipment and lines in today's operating room (OR) is increasing. This problem may present unnecessary hazards to traffic and adversely affect the performance of the surgical team. Endoscopic surgery is particularly affected by this problem because it requires additional equipment. This study offers surgeons' views about OR crowding and provides a detailed summary of the distribution of furniture, equipment, cables, and tubes during open and laparoscopic operations. We prospectively studied an unselected series of general surgical open (OP, n=10) and laparoscopic (LAP, n=10) operations performed at a major university teaching hospital.

We recorded the location of all furniture and equipment as well as the source, course, and destination of all cables and tubes in the OR. Cables and tubes touching the surgeon or assistant were noted. Results are expressed as median values for each group. Surgeons enjoyed laparoscopic operations less and felt they were more complex and time-consuming to set up and complete. A majority of surgeons believed that their work was more hampered by cables and tubes during laparoscopic surgery than during open surgery. We observed that a total of 39% of the OR space is occupied (LAP 41% vs. OP 36%, $p<0.002$) by furniture (23%), equipment (7%), and persons (8%). There was a median of 31.5 cables and tubes present during each operation (LAP 34 vs. OP 27, $p<0.0002$) with a median of 4.5 of these lines (LAP 6 vs. OP 2, $p<0.0003$) touching a member of the surgical team. We conclude that today's OR is characterized by significant crowding from furniture, equipment, and a multitude of cables and tubes. This problem is worse during laparoscopic operations due to the increase in equipment. Innovative designs will be needed to reduce clutter in the OR of the future.

INTRODUCTION

The advent of endoscopic surgery has brought with it an increased amount of equipment in the operating room.[1] This equipment–video cameras, light

Figure 1. Intraoperative photograph of a laparoscopic operation demonstrating the accessory equipment needed for this type of surgery.

Table 1. Types of operations observed

Laparoscopic	n	Open	n
Cholecystectomy	5	Resect mesenteric tumor	1
Fundoplication	4	Colostomy closure	1
Lymphadenectomy	1	Hepatic resection	2
		Colectomy	1
		Exploratory laparotomy	1
		Cystgastrostomy	1
		Ileostomy closure	1
		Pancreaticoduodenectomy	1
		Resection abdominal mass	1
Total	**10**		**10**

sources, insufflators, suction/irrigation devices, and other instruments needed to perform minimally invasive procedures–takes up additional space in an already crowded OR environment (Fig. 1).[2] Laparoscopic operations are also afflicted with an increased number of tubes and cables connecting the equipment to power and vacuum sources as well as to the operating field. The hazards of a multitude of cables in crowded ORs have been discussed by other authors.[3,4] Thus during laparoscopic surgery, surgeons and other members of the operating team find themselves working in an increasingly cramped space with a limited ability to arrange the OR layout to their needs. In summary, laparoscopic operations highlight the need to eliminate today's clutter of equipment and lines in future OR designs.

One of the important concepts underlying OR layouts over the last 50 years has been the need for each OR to be used for different types of operations.[5,6] Thus the ability to move equipment in and out of the room has been important since different surgical specialties require substantially different equipment and instruments. The result is that today's OR is basically a rectangular "shell" with sources of medical gasses, electrical power, and suction.[7] Universally used equipment such as ceiling lights have been incorporated in all rooms, but all other equipment items remain moveable. While this OR arrangement does yield flexibility in room use, it results in the constant need to move equipment in and out of rooms between operations. A second disadvantage of this "universal" OR layout is the need to maintain a number of frequently used items (electrocautery, suctions, canisters, intravenous poles, patient warmers) in the workspace of the team, instead of in a constant and out-of-the-way locations. Every piece of equipment in the OR requires at least one input and output line (and frequently more than one) for its use; hence its presence in the middle of the OR adds to the number of cables and tubes carried across the OR floor to the surgical field.

The advent of minimally invasive surgery has resulted in different surgical specialties now having many *similar* equipment needs. Many different surgical procedures are now carried out with similar video-endoscopic imaging techniques and halogen light sources.

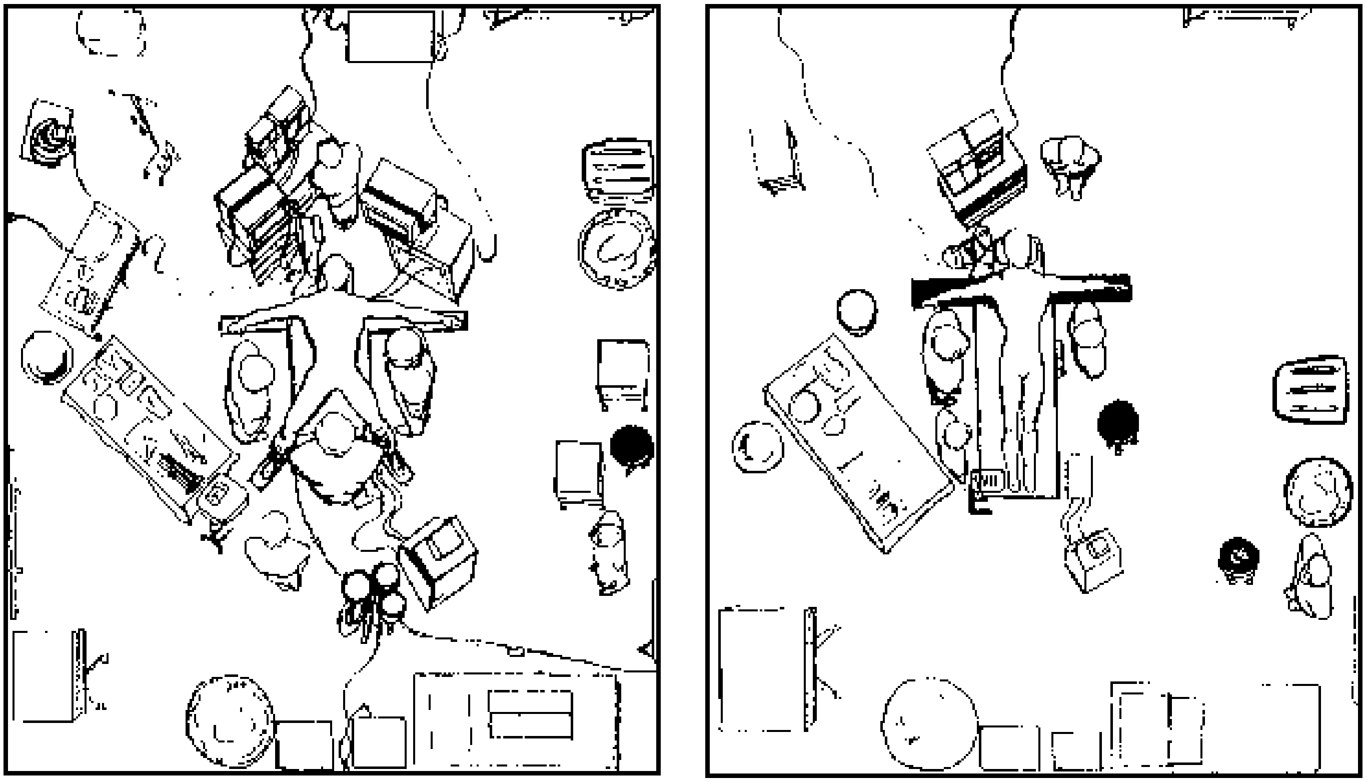

Figure 2. Sample drawings from two observed operations (a: Laparoscopic; b: Open) Individual items are accurately located in the operating room, although the drawings are not made to scale. Note the visibly increased crowding and number of cables and tubes in the laparoscopic operation.

Surgical exposure is now universally obtained with gas or liquid insufflation. This means that this equipment can be considered standard for minimally invasive surgery in different specialties. Thus tomorrow's minimally invasive OR could accommodate orthopaedic, general surgical, urologic, gynecological, and other endoscopic surgical procedures by using much of the same equipment. This concept forms the basis for an "endosuite"[8] which incorporates this standard endoscopic support equipment in the OR in such a way as not to increase the crowding and line tangling about the surgical team.

OR design has traditionally been carried out by a team of architects, engineers, hospital administrators, and microbiologists.[9,10] Adaptation of OR design to the rapid technological changes in the field of surgery and their impact on the patient, operating team, and hospital costs can best be carried out with direct involvement by surgeons in the design process. By focusing the OR layout and equipment design on the surgical task, the surgeon can provide critical input to allow engineers, architects, and administrators to tailor OR design for the most efficient use and best patient care.[11] Without this involvement, we run the risk of simply adding technology to an unplanned surgical theater with resultant overcrowding, personnel hazards, and difficulty incorporating useful new equipment into the practice of surgery.[12]

The present article presents surgeons' perceptions of the OR environment during laparoscopic surgery as well as an objective assessment of the state of crowding in today's OR.

Table 2. Questionnaire response comparing laparoscopic to open operations

	Greater than open
Overall enjoyment	39%
Overall complexity of setting up and completing	75%
Amount of work and effort in setting up and completing	71%
Time to set up and complete	57%
Number of cables and tubes	100%
Number of pieces of equipment	100%
Degree of restriction on your performance by cables and tubes	57%
Degree of restriction on your performance by equipment	64%

HISTORICAL BACKGROUND

While the history of surgery is as old as the human race, the development of a specific place for the performance of operations is relatively new.[13] For most of surgical history, operations were performed in the nearest available and convenient space, frequently the battlefield or peoples' homes.[13] In the 19th century, operating theaters were first designed in the pattern of the classical Greek theater with rising tiers of curved seating. In the 20th century, for reasons of hygiene and construction efficiency, the theater design gradually gave way to the square or rectangular OR we know today.[6] Alternative designs of nearly every imaginable shape have been used to improve OR function, but none appears to hold any real advantage over the square or rectangle.[11] The modern OR in the United

States consists of a square or rectangle of at least 400 sq ft with wall or ceiling sources of medial gasses, electrical power, and suction.[10,14] However, the limitation of current OR design is that it is an expression of traditional thinking rather than the result of a study of function.[6] Where the designs incorporate ideas ahead of current practice, the advance is at best piecemeal leading to a lack of uniformity in projected design requirements for the future and ultimately a financial hesitancy to seek out and incorporate needed improvements.[6,11]

METHODS

Questionnaire

A questionnaire was handed out to 28 general surgeons and residents asking them to compare the impact of laparoscopic operations on the OR environment to open operations. Responses were graded on an ordinal scale of 1, 2, 3, 4, or 5 and divided into two groups for each question: (A) "greater than" (4 and 5) and (B) "equal or less than" (1, 2, and 3). The percentage of responses falling into groups A or B for each question was tallied.

Study of OR Space Occupancy

Ten laparoscopic and 10 open general surgical operations (Table 1) were recorded by a single observer (AA) over a six-month period at the University of California Davis Medical Center to analyze the impact of newer equipment-intensive laparoscopic operations on OR crowding. A specially designed data sheet was used to record the location and size of all furniture and equipment items as well as the number, source, course, and destination of all cables and tubes in the OR. A drawing of the OR layout was used to correlate numerical data with the actual OR layout (Fig. 2).

Group data is reported as the median and inter-quartile range (IQR) to provide a measure of central tendency in the absence of a Gaussian distribution. Statistical comparison of laparoscopic and open operation subgroups was performed using the Mann–Whitney U-test with significance defined at the $p<0.01$ level using an Apple Macintosh IIs with Stat-View software (version 4.1).

RESULTS

Questionnaire

The results of the questionnaire are summarized in Table 2. Only 39% of surgeons enjoyed laparoscopic operations more than open surgery. All respondents felt laparoscopic surgery was attended by more tubes, cables, and equipment than open surgery, although they could not quantify the increase. Three-fourths of the respondents believed that laparoscopic operations were more complex to set up and required more effort to complete. More than half of the respondents also considered that there is a greater degree of restriction on the surgeon's performance placed by cables, tubes, and equipment (17% stipulated that this was caused in part by a lack of standardization).

OR Space Occupancy

The relationship between OR size and the percent of OR area occupied by persons, furniture, and equipment for the 10 laparoscopic and 10 open operations is depicted in Figure 3. Laparoscopic and open operations were carried out in operating rooms of similar square footage (398 vs. 416 sq ft, p=NS, Table 3) and were attended by a similar number of OR personnel (8 vs. 9 people, p=NS). During laparoscopic operations, the percentage of the OR occupied by furniture, equipment, and persons increased significantly from 36% to 41% ($p<0.002$). Laparoscopic operations also resulted in an increase in the total number of cables and tubes in the OR from 27 to 34 ($p<0.0002$). There was a threefold increase in the number of cables and tubes that touched a member of the operative team during laparoscopic surgery (6 vs. 2, $p<0.0003$).

Table 3. Operating room clutter in laparoscopic and open operations

	Laparoscopy (n=10) Median	IQR*	Open (n=10) Median	IQR*	p
Area (sq ft)	398	41	416	82	NS
Persons	8	1	8.5	3	NS
Total % area occupied	41	4.6	35.7	6.7	.002
Total cables and tubes	34	3	27	2	.0002
Cables and tubes touching surgeon or assistant	6	2	2	2	.0003

**IQR= Inter-quartile range*

DISCUSSION

The generally enthusiastic press reports about laparoscopic surgery create the impression that problems of OR layout and equipment design are not a significant concern to surgeons. The results of our questionnaire challenge this notion and undoubtedly demonstrate that surgeons consider laparoscopic operations to be more difficult to set up for and more complex to perform than open operations. We also found that the majority of surgeons questioned felt that the increased amount of equipment and the attendant cables and tubes *do* limit their performance during laparoscopic surgery. Thus it is not surprising that only 39% of respondents enjoy laparoscopic surgery more than open surgery. We consider these findings to have significant implications for those involved with OR and equipment design. Surgeons need to be more vocal about problems in the OR environment that affect their work and demand that architects and engineers respond to their needs.

Although much has been written about proper OR design[4,11,14,15] there is little or no objective information about the degree of crowding or line tangling in today's surgical suite. Our study provides the first measure of these problems and the degree to which laparoscopic operations have increased them. This information is important as a baseline for comparison with future OR layouts. Our objective results are consistent with the responses to the questionnaire. Today's OR has approximately 40% of the floor space occupied and the remaining free space is

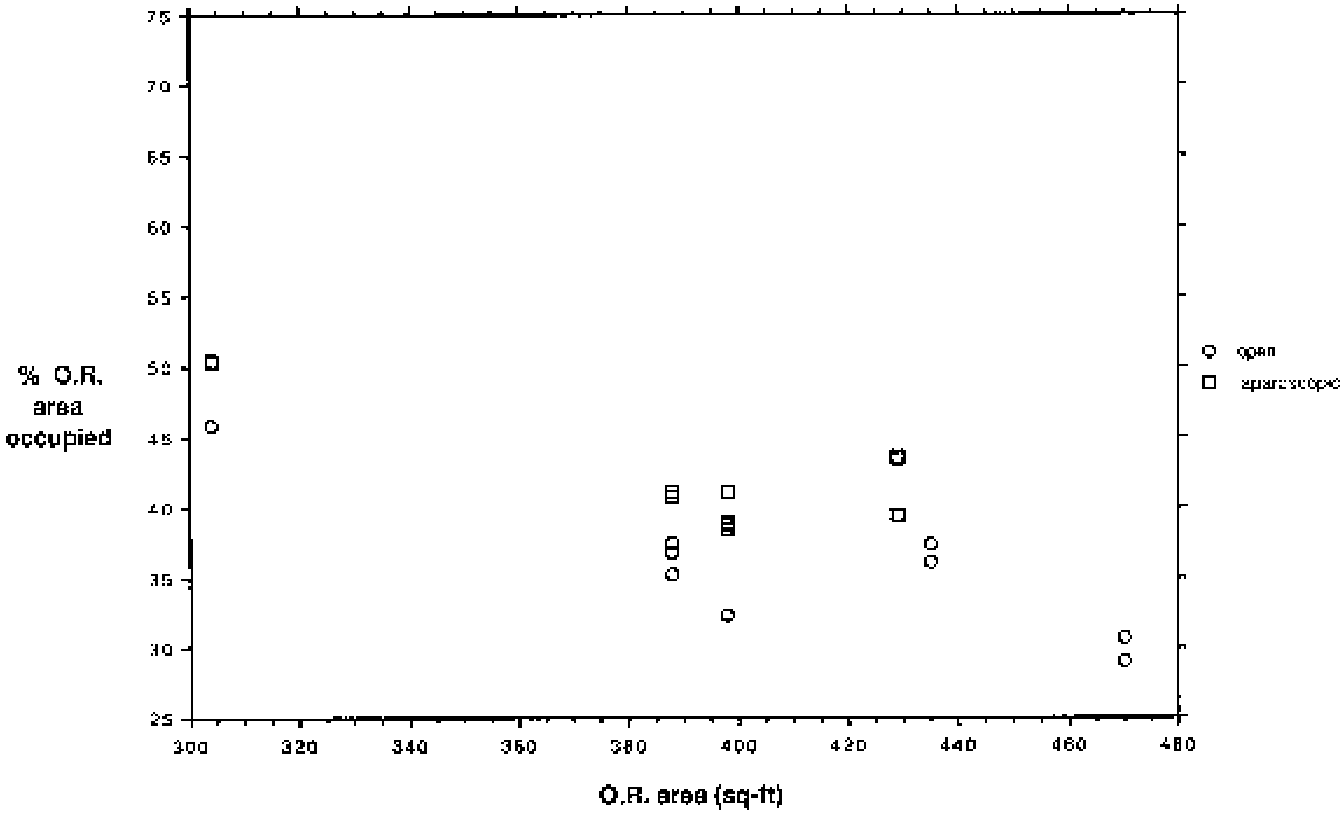

Figure 3. Graph depicting the relationship between operating room size (x-axis) and the total floor space occupied by people, furniture, and equipment (y-axis) for 20 general surgical operations. Note that laparoscopic operations are always more crowded than open operations.

crisscrossed by over 30 cables and tubes coursing from the wall, ceiling, and equipment towards the operative field. Laparoscopic operations have significantly increased the number of equipment items, cables, and tubes surrounding the surgeon, including those that actually touch a member of the operating team. These findings explain why the surgeons surveyed in our study considered that their movement was more restricted by these items during laparoscopic operations. We did not assess the effect of the OR layouts on the performance of the surgeon or the surgical team in this study. It seems clear, however, that the crowding and number of lines present in the immediate vicinity of the operating table presents an obstruction to equipment movement, a potential hazard to personnel, and an increasing impediment to the surgeon's work. If the current situation is not addressed, the crowding and inefficient use of space in the OR may hamper the future incorporation of new technology into surgical procedures.

The problems of inefficient OR layouts have been addressed by a number of authors.[6,7,11,16] Several solutions have been proposed to reduce equipment crowding and lines crossing the floor in the OR.[17] Tubing and cables can originate from the ceiling or a ceiling-mounted column; they can be carried to the operating field by a wall-mounted boom; they can traverse the floor in a single path; or they can originate from a central location (floor or plinth). Ceiling-mounted columns have become the most popular method of providing the above needs in the OR and in some emergency rooms[18] because they allow the unobstructed movement of personnel around the patient. However, ceiling-mounted columns offer only a partial solution to the problem of obstructing cables and tubes in the OR because these devices mainly provide connections to the anesthesia machine leaving the electrical and suction lines to the surgical field coursing through the air and across the floor.

One of the most innovative solutions to the problem of equipment crowding and line tangling in laparoscopic operations is to mount all major equipment components on ceiling mounted moveable arms or tracks so that they can be conveniently positioned near the patient but remain off the floor. This arrangement would free the floor space around the operating table, allow integrated power and data connections to the equipment through the ceiling mounts, and would provide a direct route for output cables and tubes to the surgical field that would not hamper traffic around the OR. Such an OR design has been promoted by Stryker Corporation[8] but has not been widely adopted. We must begin to understand that endoscopic operations in different surgical specialties are becoming *increasingly similar* and encourage OR design teams to incorporate these and other innovative ideas into an integrated endoscopic surgical suite. More recent design projects using virtual reality design tools may prove to be of value by allowing designers and surgeons to test OR layouts in advance.[19]

In conclusion, our results demonstrate that surgeons are acutely aware of the increased crowding in the OR environment brought about by laparoscopic operations. We have also documented a significant increase in equipment crowding and lines in the OR during laparoscopic operations. We hope that the results of this study will encourage surgeons, architects, and engineers to question the traditional tenets of OR design and to redouble their efforts to design the OR of the future based upon the efficiency and safety needs of the surgical team. STI

ACKNOWLEDGEMENTS

Universal Medical Press expresses its appreciation to Piero B. Isola for drawing the illustrations.

REFERENCES

1. Green FL, Taylor NC. Operating room configuration. In: Ballantyne G, Leahy PF, Modlin IR, eds. Laparoscopic surgery. Philadelphia: W.B. Sauders; 1994. p 34-41.
2. Kernaghan SG. Technology and the surgical suite: forest of instrumentation improves, but complicates, surgical practice. Hospitals 1982;56:101-5.
3. LoCicero J, Nichols RL. Environmental health hazards in the operating room. Bulletin of the American College of Surgeons 1982;67:2-5.
4. Putsep E. Planning of surgical centres; London: Lloyd-Luke; 1973. p 249.
5. Rosenkoetter MM, Price DL. OR of the future: implications for design. Aorn J 1976;24:241-248.
6. Smith W. Planning the surgical suite. New York: F. W. Dodge; 1960. p 459.
7. Bevan PG. Efficiency in the operating suite. In: Johnston I, Hunter AR, eds. The design and ultilization of operating theatres. London: Edward Arnold; 1984. p 93-103.
8. Endosuite [videocassette]. Stryker Endoscopy; 1994.
9. Slaney G. Foreword. In: Johnston I, Hunter AR, eds. The design and utilization of operating theatres. London: Edward Arnold; 1984.
10. Laufman H. Architectural and engineering aspects of the operating room environment. Bull Soc Int Chir 1974;33:1-10.
11. Laufman H. What's wrong with our operating rooms? Am J Surg 1971;122:332-343.
12. Klebanoff G. Operating-room design: an introduction. Bull Am Coll Surg 1979;64:6-10.
13. Faircliff R. The objectives in planning operating theatre suites. In: Johnston I, Hunter AR, eds. The design and utilization of operating theatres. London: Edward Arnold; 1984. p 1-3.
14. Quebbeman EJ. Preparing the operating room. In: Wilmore DW et al, eds. Care of the surgical patient: a publication of the committee on pre- and postoperative care. Sci Am 1993;(5)1-13. Vol. 2(VI).
15. Nora PF. OR environment: a surgeon's view. Am Operating Room Nurse J 1976; 24:266-267.
16. Boyers SP. Operating room setup and instrumentation. Clin Obstet Gynecol 1991;34:373-386.
17. Smith H, McIntosh P, Sverisdottir A, et al. Improved coordination makes for faster work. Ergonomic analysis of a trauma resuscitation room. Prof Nurse 1993;8:711-5.
18. Wilder RJ, Williams GR. The ceiling-retractable service column [letter]. JAMA 1981;246:1403-4.
19. Kaplan K, Hunter I, Durlach NI, et al. A virtual environment for a surgical room of the future. In: Satava RM, Morgan K, Sieburg HB, et al., eds. Interactive technology and the new paradigm for healthcare. 1st ed. San Diego: IOS; 1995. Vol. 18; p 161-167.