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SURGICAL ENDOSCOPY
and Other Interventional Techniques

Optimum view distance for laparoscopic surgery

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Abstract
Background: Proper visualization of the surgical field without fatigue is essential in laparoscopic surgery and reduces the risk of iatrogenic injuries. One of the important factors influencing visualization is the viewing distance between the surgeon and the monitor. This was the subject of the current investigation.
Methods: For this study, 14 surgeons participated in experiments designed to determine two working distances from a standard 34-cm (14 in. diagonal) cathode ray tube (CRT) monitor: (a) the maximum view distance permitting small prints of a near vision chart to be identified clearly by sight, (b) and the minimum view distance (of a standard resolution chart) just short of flicker, image degradation, or both. The range of the monitor optimal working distance for laparoscopic surgery was extrapolated from these data sets.
Results: The maximum view distance allowing identification of detail averaged 221 cm (range, 166–302 cm). The mean minimal view distance short of flicker/image degradation was 136 cm (range, 102–168 cm). The coefficient of variation for the two view distances was almost identical (18% vs 17%, respectively), and a frequency histogram confirmed the normality of the two data sets. Thus, for most surgeons, the extrapolated monitor view distances for laparoscopic surgery using a 14-in. diagonal (34-cm) monitor range from 139 to 303 cm (57–121 in.) for maximal distance viewing and from 90 to 182 cm (36–73 in.) for close-up viewing (i.e., a monitor optimal working distance ranging from 90 to 303 cm (36–121 in.).
Conclusions: For most surgeons operating from a 14-in. diagonal CRT monitor, both the maximal and minimal (close-up) view distances are individually variable, but the surgeon should never be farther than 3 m (10 ft) or less than 0.9 m (3 ft) from the monitor. However, within limits, the maximal view distance increases with increasing monitor size. The limit for close-up distance is 0.9 m, irrespective of monitor size.

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Key words: Laparoscopic surgery — Monitor maximal and minimal view distances — Optimal working distance range — Resting point of accommodation — Resting point of vergence

The endoscopic surgeon, even in the most modern and well-equipped operating room, often operates at an ergonomic disadvantage. As a result, the surgeon frequently is forced to adopt uncomfortable body positions that contribute significantly to fatigue and discomfort, which may lead to musculoskeletal disorders. The image display of the operative field on a high-resolution cathode ray tube (CRT) monitor contributes to this problem. Yet its crucial importance lies in the fact that in laparoscopic surgery, the monitor provides the only visual link between the internal anatomy and the surgeon [1].

The position and inclination of the monitor with respect to the surgeon's head and view angle (eye stance) is an ergonomic consideration of great importance for two reasons. First, it is essential for optimal viewing, and hence correct interpretation of the anatomy displayed on the monitor. Second, a suboptimal monitor location causes eyestrain with irritation, blurred vision, and headaches.

Several considerations govern the optimal viewing distance between the surgeon's eyes and the monitor: near (close-up) and maximum viewing distances, eye viewing angle or stance, tilt of the monitor, etc. All these have been studied in relation to the use of computer screens by office workers [2–10], but there has been little published human-factors work in this field that relates directly to laparoscopic surgery.

At rest, for the normal line of sight, the eyes are parallel to each other and tilted downward by about 15° to 30° below the horizontal line of sight. Viewing problems and eyestrain become an issue with near viewing of the monitor because of the eyes' need to accommodate (change focus) and converge to avoid diplopia. As the viewing distance gets shorter, more contraction of the ciliary (accommodation) and orbital (convergence)

N5

An oculist and surgeon should
be descended from religious parents
be religious himself, and should have studied Latin,
anatomy, and the science of medicine

N8

Be a surgeon, having learned the barber trade from
youth on; not suitable are those that come to it
from the plough, manure waggon, or late in life
Have studied with an accomplished oculist and surgeon

N12

Have healthy and young eyes
Have fine, subtle, healthy hands and fingers, and
be nimble with both hands
Be able to draw and design in order to obtain
instruments

N18

Be married

Fig. 1. Reading chart test for near vision.

muscles is needed, hence the increased propensity for eyestrain [11]. The human eyes have default distances for accommodation (resting point of accommodation [RPA]) and convergence (resting point of vergence [RPV]) [8, 12]. Both are individually variable, and although similar, are not identical: RPA is 30 to 34 in. (75–85 cm), and RPV is 32 to 40 in. (80–100 cm). Obviously, accommodation and vergence are not needed beyond 100 cm, and individuals with perfect (20/20) or corrected vision should not experience eyestrain at these viewing distances provided they take strategic "rest breaks" from focusing on the screen [13]. These strategic rest breaks are important because of the phosphor pulsations known to degrade eye muscular movements responsible for fixation and refixation [14, 15].

There is a finite distance away from the monitor at which the details of an image still are adequately perceived by the observer. The monitor optimal working distance (MOWD) for laparoscopic surgery is the distance that enables the individual surgeon to resolve all the finer details of the displayed anatomy without experiencing eyestrain. Studies to establish the normal range of MOWD for laparoscopic surgery must therefore obtain information on both minimum (near) and maximum distance viewing. This was the objective of the current investigation.

Materials and methods

For this study, 14 surgeons with experience in laparoscopic surgery from the specialist registrar level (resident) to the consultant (attending) level participated in experiments designed to establish (a) the maximal (longest) viewing distance at which the finest details of an image can be clearly seen, and (b) the minimum viewing distance below which flicker and/or image degradation from visible scan lines is experienced. All the participating surgeons had corrected eyesight.

The image used for the experiments was the "reading type" chart for testing near vision [16]. The chart presents a series of Times Roman font passages in sizes (points) ranging from 5 to 48 (Fig. 1). The chart was displayed on a standard 34-cm (14-in. diagonal) Sony CRT laparoscopic monitor (resolution, 600 lines). To achieve this, the chart was placed inside a closed box with a black neoprene floor to abolish glare. A zero-degree Hopkins II laparoscope was introduced inside a box, and positioned perpendicularly on the smallest print section (size 5) of the chart, selected as the viewing target. The laparoscope-to-target distance was fixed at 100 mm [17].

The viewing by the participating surgeons was undertaken under strictly controlled conditions. The lights in the laboratory were switched off for all the experiments, resulting in a low ambient light intensity of 2 Lux, as measured by a photometer. In each case, the monitor position was such that each surgeon viewed it at eye level. All the participating surgeons had corrected eyesight.

Each surgeon began viewing at a distance of 500 cm. At this distance, none of the participants were able to read the 5-point print. Thereafter, each was asked to advance slowly toward the monitor to establish the optimal distance for easy reading of the 5-point print. This distance was interpreted as the maximum view distance at which a laparoscopic surgeon should be able to scan visually (with smooth-pursuit eye movements) and perceive all the pictorial details of a 5-point image generated electronically on a CRT monitor.

After the maximum viewing distance had been established, the reading type chart was replaced by a standard resolution card inside the viewing box without a change in the experimental conditions (Fig. 2). Starting at the maximum view distance, each observer then advanced slowly toward the monitor until he began to notice flickering, image degradation, or both. This distance is important not only because of image degradation, but also because it causes eyestrain. In the context of the study, the distance at which each participating surgeon observed screen flicker/image degradation was regarded as the minimum view distance for laparoscopic surgery.

Results

The results of the minimum and maximum view distances for the 14 surgeons are shown in Table 1. The maximum distance that allowed identification of detail averaged 221 cm (range, 166–302 cm). The minimal view distance (at which flicker/image degradation was observed) ranged between 102 and 168 cm (mean, 136 cm). The coefficient of variation for the two view distances was almost identical (18% and 17%, respectively), and a frequency histogram established the normality for the two data populations. Hence, for most of the surgeons (85%) the two monitor view distances for laparoscopic surgery using a 14-in. (34-cm) monitor are outlined in Table 2. In other words, the absolute range of MOWD (from minimum to maximum viewing) for laparoscopic surgery using a 14-in. monitor varies considerably between individuals and ranges from 90 (36 in.) to 303 cm (121 in.).

Within limits, other attributes being equal (e.g., resolution, color balance, aspect ratio), the maximum view distance increases with monitor size as the displayed anatomic components of the operative field get larger. Thus, for example, the maximum view distance for a 21-in. monitor using the same camera system increases by up to 50%, but the amount varies from individual to individual. However, monitor size does not alter near viewing significantly because for the vast majority of surgeons, near viewing at less than 36 in. (90 cm) induces eyestrain from overactivity of the ciliary (image focus) and ocular muscles involved in convergence (prevention of diplopia). Hence, for most lapa-

Fig. 2. Resolution card placed on black neoprene to reduce glare. The distance between the telescope and the paper was 100 mm.

Table 1. Monitor view distances of 14 surgeons

	Mean (cm)	SD.	Coefficient of variation (%)	Lowest value (cm)	Highest value (cm)
Maximal view distance	221	41.3	18	166	302
Minimum view distance	136	23.2	17	102	168

SD, standard deviation

Table 2. Estimated normal monitor view distances for the general population of surgeons with corrected eyesight (mean ± 2 SD)

	Metric range (cm)	Imperial range (in.)
Maximal view distance	139–303	57–121
Minimum view distance	90–182	36–73
Monitor optimal view distance range	90–303	36–121

roscopic surgeons, operating at a minimum view distance much less than this is inadvisable.

Discussion

To our knowledge, there have been no published data on the optimal view distance for minimal access surgery that maximizes perception of anatomic detail and avoids eyestrain and misinterpretation of images of the operative field displayed on the television monitor. The latter is recognized as a major cause of iatrogenic injuries [18].

The results of the current study investigating near and maximal view distances to obtain the MOVD for laparoscopic surgery has, to a large extent, confirmed data obtained from studies on computer monitor work. As expected, the minimal view distance was found to be close to both RPA and RPV. One practical recommendation of the current study relating to the design of future operating rooms dedicated to endoscopic surgery is shown in Fig. 3. This concerns the use of concentric perimeter rings on the floor that indicate to the surgeon his or her distance from the operating room isocenter/monitor.

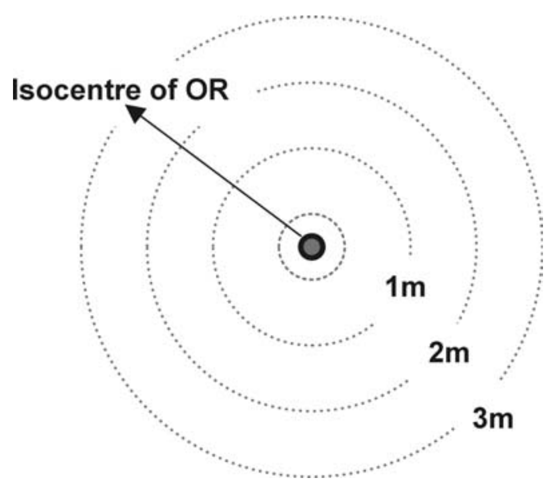

Fig. 3. Suggested floor markings for endoscopic surgery operating room to indicate viewing distances.

Some other important human factors were not investigated in the current study. Several of these, such as view angle (eye stance), are insufficiently appreciated. Previous viewing guidelines recommended that the center of the monitor screen should be at the same level as the geometric eye point of the viewer to ensure the most comfortable gaze corresponding to the resting position of the eyeballs (i.e., 15° below the horizontal line of sight). Subsequent studies have shown that this applies only to distance viewing. For near viewing, there is now evidence that the ideal view angle is 20° to 50° below the horizontal line of sight [19], and this is now recommended by the International Standards Organization [20]. For most subjects, the downward gaze increases the ability to accommodate and converge for near vision [21] and reportedly reduces the incidence of headaches and eyestrain substantially [22]. The ability to accommodate improves by as much as 25% to 30% with an increase in the downward viewing angle to the "reading position" [20]. In laparoscopic surgery, there is good evidence that gaze-down viewing increases both the efficiency and quality of the task [23].

Another human factor overlooked in the ergonomics of image displays for laparoscopic surgery is the monitor tilt. In endoscopic surgery, the monitor currently is placed upright on a solid platform without any tilt. For computer work, the monitor is tilted such that its upper margin is further back than the lower margin. This recommendation is based on the physiology of normal sight whereby objects in the upper part of the peripheral visual field usually constitute the background to the objects being viewed by the observer. It is not known whether this applies to laparoscopic surgery, and if so, the ideal extent of the inclination.

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