

Monitor height ergonomics: A comparison of operating room video display terminals

Gregory I. Kelts, M.D.,¹ Kevin C. McMains, M.D.,¹ Phillip G. Chen, M.D.,² and Erik K. Weitzel, M.D.¹

ABSTRACT

A surgeon's eyes should be positioned 1 meter (m) distant and no more than 15° below the top of an operating monitor (0.27 m). We sought to determine which operating room video display terminal can best accommodate ergonomically optimized gaze during surgery. Floor to eye height was measured for surgeons in seated, perched, and standing positions. These ranges were then compared to vertical displacement ranges for monitors measured from floor to top of the screen. Eye height was measured for standing (1.56–1.80 m), perched (1.40–1.65 m), and seated (1.10–1.32 m) positions. The minimum distance (min) between the floor and the top of the monitor and the vertical mobility range (VR) of the monitor were measured throughout a tertiary medical center including towers with boom arms (TcB) (min: 1.58 m, VR: 0.37 m), towers without booms (TsB) (min: 1.82 m, VR: 0.025 m), ceiling mounted booms (CMB) (min: 1.34 m, VR: 1.04 m), and portable monitors (PM) (min: 1.73 m, VR: 0.04 m). The tangent of 15° declination was used to calculate a correction factor to determine the minimum optimal ergonomic display height. The correction factor was subtracted from the eye height at each position to determine the lowest target height and the highest target floor to eye distance for each position. Analysis of variance with least significant difference post hoc testing identified all minimum distances and vertical ranges to be statistically different ($p < 0.001$). Monitor vertical displacement varied between styles of carts. CMB video display terminal systems can accommodate standing, perched and the tallest seated surgeons. TcB, TsB and PM systems cannot adequately accommodate all standing, perched or seated surgeons.

(Allergy Rhinol 6:e28–e32, 2015; doi: 10.2500/ar.2015.6.0119)

The first documented use of endoscopy to examine the paranasal sinuses occurred in 1901.¹ Over the course of the 20th century, surgeons refined endoscopic techniques, which culminated in the work of Messerklinger and Stammberger in the 1970s and 1980s.^{1–4} After this seminal work, practitioners published multiple technologic and procedural modifications.^{1–4} Presently, sinus surgeons use digital cameras to project images onto digital video display terminals (VDT). VDT can display standard or enhanced images, depending on the surgeon's preference. However, the understanding of surgical ergonomics has not kept pace with the steady enhancements in optics and operating room technology.⁵

In response to these ergonomic challenges, several investigators evaluated the different operating room configurations to decrease fatigue and reduce eye-strain.^{2,5} In an effort to determine the optimal ergonomics for laparoscopic surgical procedures, the general surgery community has produced the bulk of this

research.² The consensus from these data is that the optimal monitor position is at least 1 m from the surgeon's eyes and at a declination that ranges from 0° to –15° from the surgeon's neutral gaze.^{6–8} Monitor positioning is highly applicable to the endoscopic sinus surgeon as well, who may use standing, perched, or seated operating postures. Standard operating room configurations of VDT towers, including those that are on ceiling mounted booms (CMB), easily accommodate optimal positioning for the standing surgeon. However, when seated or perched, the eye-to-floor distance is decreased, which requires a greater range of motion for the VDT to be situated low enough to conform to ergonomic ideals. Thus, some configurations can prove challenging for the seated surgeon.

The purpose of this study was to evaluate the physical limits of four standard operating room VDT configurations: VDT towers without booms (TsB), VDT towers with booms (TcB), CMBs, and portable monitors (PM). VDT systems were compared to assess which system allowed a monitor position that met the ergonomic requirements of the perched or seated ESS surgeon.

METHODS

This study was assessed as minimal risk and, as such, was exempt from institutional review board review. The study was conducted in San Antonio Military Medical Center, a tertiary care center. There are 28 operating rooms in this facility, and all are equipped

From the ¹San Antonio Uniformed Services Health Education Consortium, Department of Otolaryngology, San Antonio, Texas, and ²University of Texas Health Science Center at San Antonio, San Antonio, Texas

Presented at the American Rhinologic Society Annual Meeting, September 20, 2014, Orlando, Florida

The authors have no conflicts of interest to declare pertaining to this article

Address correspondence to Gregory Kelts, M.D., 3551 Roger Brooke Dr, San Antonio, TX 78234

E-mail address: gregory.i.kelts.mil@mail.mil

Copyright © 2015, OceanSide Publications, Inc., U.S.A.



Figure 1. From left to right TcB, CMB, TsB, PM.

with two to three CMB arms with VDT monitors attached. In addition, the otolaryngology service uses two portable endoscopy towers with boom arms for the VDT monitor, several endoscopy towers with fixed screens, and portable “slave” monitors (Fig. 1).

Surgeon Measurements

The study investigators obtained three measurements that were representative of common surgical positions from eight different members of the otolaryngology residency program. The first measurement was floor-to-eye distance while standing (FTED). The second was FTED while “perched” comfortably on the edge of the chair. The “perched” position was a near standing position with the feet flat on the floor but with the majority of the surgeon’s weight supported by the chair (Fig. 2). The third position was the FTED with the surgeon seated comfortably in a surgical chair (Fig. 3). In addition, each surgeon’s height was measured.

Gaze Height Calculations

The optimal gaze height, based on previously available data, is 1 m from the surgeon’s eyes and at a declination of 0° to 15°. To calculate the range of optimal gaze heights for each position, the tangent of 15° was calculated for a distance of 1 m. This calculation resulted in a correction factor of 10.5 inches. Subtracting this from the average eye height for each position resulted in the lowest ergonomically optimized eye target height. The highest ergonomically optimized eye height for each position was the average eye height for each respective position.

Equipment Measurements

Measurements were obtained for four separate types of VDT equipment in the operating rooms at San Antonio Military Medical Center. These VDT systems included TcBs, TsBs, CMBs, and PMs. The distance from

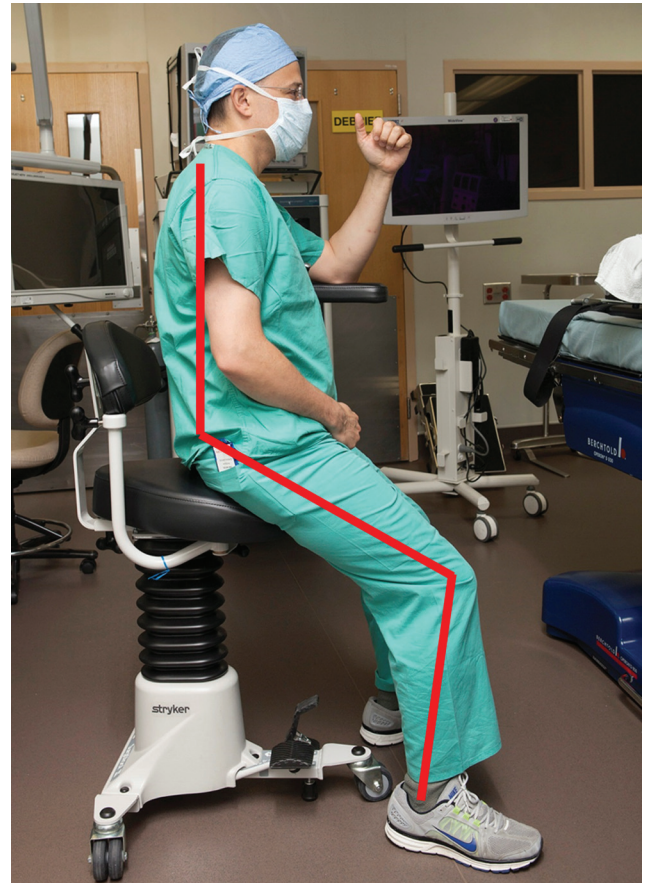


Figure 2. Perched position.

the floor to the top of the VDT was measured with the VDT in its lowest position and then the measurement was taken with the VDT in its highest position. The difference between these measurements represented the vertical range for each piece of equipment.

Data Analysis

Analysis of variance was used to analyze the variance of the data among the different surgeons’ eye heights and heights of the monitor positions. After analysis of variance, least significant difference *post hoc* analysis was used to compare the differences among the groups.

RESULTS

Surgeon Measurements

We measured eight members of the San Antonio Military Medical Center Otolaryngology residency program in the three positions described above. The study group consisted of five males and three females. The mean height for the three females was 1.71 m, and the mean height for males was 1.81 m. The mean height of all study participants was 1.68 m (Table 1). FTED measurements were obtained from each of the study participants in the positions listed in Table 1. The mean FTED in all participants were 1.68 m, 1.51 m, and



Figure 3. Seated position.

1.23 m for the standing, perched and seated positions, respectively (for the males, 1.71, 1.53, and 1.26 m, respectively; for the females, 1.63, 1.46, and 1.17 m, respectively).

The minimum ergonomically optimized target positions were calculated by subtracting the correction factor of 0.27 m from the mean floor-to-eye distances. The lowest target positions for the standing, perched, and seated positions were 1.41 m, 1.24 m and 0.96 m, respectively. The maximum ergonomically optimized target position was at 0° declination from the resting gaze. As such, the maximum target height was equal to the mean FTED for each position. These heights are listed in Table 1.

We measured 44 VDT systems throughout the operative suite. Data were obtained for 17 VDT TcBs, 8 VDT TsBs, 10 CMBs, and 10 PMs. The maximum and minimum floor-to-VDT distance, and the ranges for the four VDT systems are presented in Table 2. The TsB VDT display had a mean range vertical height of 0.025 m, which was the lowest range measured. The CMB VDT displays had the greatest mean range of vertical height at 1.04 m when compared to all other VDT systems. The CMB systems also had the largest maximum vertical range of all the systems with one system measured at

1.12 m. The CMB VDT systems also had the lowest mean vertical height, of 1.34 m. The shortest FTED able to be accommodated by each system was 1.35 m for TcB, 1.74 m for TsB, 1.31 m for CMB, and 1.57 m for PM. These results were found to be statistically different, with $p < 0.001$.

DISCUSSION

Research into the effects of VDT position originated in the occupational health literature. Specifically, addressing the effects on employees who work on monitors for a large portion of their day. Pickett and Lees⁹ examined the complaints of data entry workers who use VDT displays. Eighty-nine percent had eyestrain, and 79% had neck pain.⁹ They also noted a trend toward higher levels of complaints by workers without an adjustable height work stations. Sauter *et al.*¹⁰ noted that neck and shoulder discomfort was the second most frequently reported complaint among workers who use VDT displays in their daily work. In particular, standing for extended periods of time during the course of one's occupation has been significantly associated with complaints of low back pain and can exacerbate preexisting complaints of low back pain.¹¹⁻¹³ These studies demonstrate the deleterious effects of suboptimal ergonomics for standing workers and workers who use VDT systems.

Several investigators studied factors that led to fatigue among VDT workers and identified potential solutions to these problems. Jaschinski-Kruza⁷ noted increased eyestrain in subjects when observing VDT monitors at 50 cm when compared with monitors placed at 100 cm. When these subjects were allowed to determine their own VDT distance, they selected a mean distance of 74 cm.⁷ Jaschinski *et al.*⁸ identified increased eyestrain of workers when the monitor distance was moved from 92 cm to 63 cm. This group also noted decreased strain when the monitor was positioned 18 cm below the horizontal compared with monitors placed in the horizontal plane of the eye. Coincidentally, when subjects were allowed to position their monitors to their own preference they placed the monitors 60-100 cm from their eyes, declined from 0-160°.⁸ Marmaras *et al.*¹⁴ examined the effect of digital liquid crystal displays and the effect on monitor positioning and found that, when compared with older cathode ray tube systems, workers had a tendency to place monitors closer to 1 m from their eyes. El Shallaly and Cuschieri¹⁵ noted that, because digital and liquid crystal display technologies allow the production of larger VDT terminals, the minimum viewing distance remains ~1 m from the eyes. As VDT size increases, surgeons can place monitors at distances farther than 1 m and still have proper ocular accommodation.¹⁵ Menozzie *et al.*¹⁶ noted that, when subjects were pre-

Table 1. Participant heights

Subject No.	Sex	Height, meters	Eye Height Standing, meters	Eye Height Perched, meters	Eye Height Seated, meters
1	Male	1.75	1.63	1.49	1.27
2	Male	1.90	1.80	1.65	1.28
3	Male	1.85	1.77	1.61	1.32
4	Female	1.73	1.64	1.47	1.17
5	Male	1.73	1.63	1.40	1.17
6	Male	1.83	1.74	1.52	1.24
7	Female	1.68	1.56	1.42	1.10
8	Female	1.73	1.68	1.49	1.24
Mean		1.77	1.68	1.51	1.23

Table 2. VDT system data

	Mean Maximum Vertical Height, meters	Mean Minimum Vertical Height, meters	Mean Range, meters	Maximum Height of all VDT Systems, meters	Minimum Height of all VDT Systems, meters	Maximum Vertical Range of all VDT Systems, meters
TcB	1.96	1.58	0.37	2.13	1.35	0.51
TsB	1.85	1.82	0.03	1.91	1.74	0.05
CMB	2.38	1.34	1.04	2.51	1.31	1.12
PM	1.77	1.73	0.04	1.89	1.57	0.08

TcB = tower with boom arm; TsB = tower without boom arm; CMB = ceiling mounted boom; PM = portable monitor.

sented with VDT images at varying angles in relationship to their Frankfort horizontal (line drawn from the porion to the inferior orbital rim), they experienced the least discomfort when their visual target was 12.4° below the Frankfort horizontal. Turville *et al.*⁶ noted a preference among their subject group for monitors placed a 15° decline from horizontal. Overall, these studies demonstrate that the ideal monitor position among VDT workers is close to 1 m from the eyes at a declination of ~15° below horizontal.

Several authors validated data obtained from the occupational health literature for the laparoscopic surgery community.¹⁷⁻²¹ Brown *et al.*¹⁷ compared task performances for laparoscopic surgeons who used conventional up-gaze with task performance who used down-gaze imaging systems and found a 50% increase in neck and shoulder discomfort within the up-gaze group. Omar *et al.*¹⁸ also compared a traditional gaze-up image display during complex task with performance with the image display at hand level. Subjects in this study accomplished their assigned tasks in less time when compared with performing the same task at a traditional display height.¹⁸ Haveran *et al.*¹⁹ and Erfanian *et al.*²⁰ further noted improved performance with the monitor position aligned directly in front of the surgeon's working field. Matern *et al.*²¹

performed electromyography monitoring of surgeons who were performing endoscopic tasks. Improved performance was noted when VDT displays were in line with their hand-eye working axis and positioned at or below eye level.²¹ They also observed the lowest electromyographic activity in C2-C4 musculature when the monitor was in line with the surgeon's gaze and at eye level.²¹

Based on these data, two groups produced recommendations for optimizing operating room setup for endoscopic surgeons.^{2,5} First, monitors should be placed directly in front of the surgeon, between 80 and 120 cm from the surgeon's eyes.^{2,5} Furthermore, monitors should be low enough to allow for 15–45° of neck flexion.^{2,5} These findings are in accord with the laparoscopic literature.²² In order to accomplish these ergonomic parameters for endoscopic surgeons, both authors recommend utilizing adjustable VDT displays to accommodate the surgeons' differing heights. They specifically recommended VDT displays that hang from CMBs.^{2,5,22}

The results of the current study demonstrated that CMBs provide the widest vertical range of motion for the VDT display. The optimum target height for the display for standing surgeons ranges from 1.41–1.68 m. Based on our measurements, CMB and TcB provided an adequate range to support the standing position,

with a mean minimum height of 1.34 and 1.58 m, respectively. The optimum target height for the seated and for the perched positions among our cohort ranged from 0.96–1.23 m and 1.24–1.51 m, respectively. The only VDT display that provided proper ergonomic positioning for perched surgeons was the CMB system. The CMB system provided proper ergonomic positioning for the tallest seated surgeons in this cohort; however, the lowest height for the CMB system did not support the FTED of shorter, seated surgeons. Sitting during long endoscopic sinus surgeries may help prevent the development or exacerbation of low back pain; however, depending on the operating room setup, surgeons may sacrifice optimum ergonomics with respect to the position of their VDT.

There were several limitations of this study. This study examined the VDT systems at a single institution. Variables, such as ceiling height, VDT mounts, and operating room arrangement, may differ at other institutions. The results of this study still demonstrated that systems with minimal vertical displacement may not conform to the ergonomic requirements of surgeons in all operating positions. Another weakness of this study was that we recorded only ergonomic data and did not record any other objective variables, such as electromyography or measurements of ocular strain. This study was designed as a process improvement study to examine limitations in the operating room setup. We plan to conduct future research in these areas.

CONCLUSION

Proper ergonomic positioning is critical for endoscopic sinus surgeries. It is shown in the ergonomic literature that proper VDT orientation can significantly affect task performance, eyestrain, and musculoskeletal fatigue. VDT monitors should be placed ~1 m directly in front of and 0–15° declined from the surgeon's eyes. Fixed height towers do not provide an adequate range of heights to allow ergonomic positioning during endoscopic sinus surgery. CMBs provided the most flexible range of heights. Only CMB systems were able to accommodate the ergonomic requirements of the standing, perched, and tallest seated endoscopic sinus surgeon. Seated surgeons, to prevent the onset or exacerbation of musculoskeletal complaints, may be making ergonomic compromises, depending on their particular operating room configuration and equipment.

REFERENCES

- Kennedy DW, Zinreich SJ, Rosenbaum AE, and Johns ME. Functional endoscopic sinus surgery. Theory and diagnostic evaluation. *Arch Otolaryngol* 111:576–582, 1985
- Ayad T, Péloquin L, and Prince F. Ergonomics in endoscopic sinus surgery: Systematic review of the literature. *J Otolaryngol* 34:333–340, 2005.
- Husain Q, Patel SK, Soni RS, et al. Celebrating the golden anniversary of anterior skull base surgery: Reflections on the past 50 years and its historical evolution. *Laryngoscope* 123:64–72, 2013.
- Stammberger H, and Posawetz W. Functional endoscopic sinus surgery. Concept, indications and results of the Messerklinger technique. *Eur Arch Otorhinolaryngol* 247:63–76, 1990.
- Ramakrishnan VR, and Montero PN. Ergonomic considerations in endoscopic sinus surgery: Lessons learned from laparoscopic surgeons. *Am J Rhinol Allergy* 27:245–250, 2013.
- Turville KL, Psihogios JP, Ulmer TR, and Mirka GA. The effects of video display terminal height on the operator: A comparison of the 15 degree and 40 degree recommendations. *Appl Ergon* 29:239–246, 1998.
- Jaschinski-Kruza W. Eyestrain in VDU users: Viewing distance and the resting position of ocular muscles. *Hum Factors* 33:69–83, 1991.
- Jaschinski W, Heuer H, and Kylian H. Preferred position of visual displays relative to the eyes: A field study of visual strain and individual differences. *Ergonomics* 41:1034–1049, 1998.
- Pickett CW, and Lees RE. A cross-sectional study of health complaints among 79 data entry operators using video display terminals. *J Soc Occup Med* 41:113–116, 1991.
- Sauter SL, Schleifer LM, and Knutson SJ. Work posture, workstation design, and musculoskeletal discomfort in a VDT data entry task. *Hum Factors* 33:151–167, 1991.
- Biering-Sørensen F, Thomsen CE, and Hilden J. Risk indicators for low back trouble. *Scand J Rehabil Med* 21:151–157, 1989.
- Macfarlane GJ, Thomas E, Papageorgiou AC, et al. Employment and physical work activities as predictors of future low back pain. *Spine (Phila Pa 1976)* 22:1143–1149, 1997.
- Xu Y, Bach E, and Orhede E. Work environment and low back pain: The influence of occupational activities. *Occup Environ Med* 54:741–745, 1997.
- Marmaras N, Nathanael D, and Zarboutis N. The transition from CRT to LCD monitors: Effects on monitor placement and possible consequences in viewing distance and body postures. *Int J Ind Ergon* 38:584–592, 2008.
- El Shallaly G, and Cuschieri A. Optimum view distance for laparoscopic surgery. *Surg Endosc* 20:1879–1882, 2006.
- Menozi M, von Buol A, Krueger H, and Miège C. Direction of gaze and comfort: Discovering the relation for the ergonomic optimization of visual tasks. *Ophthalmic Physiol Opt* 14:393–399, 1994.
- Brown SI, Frank TG, El Shallaly G, and Cuschieri A. Comparison of conventional and gaze-down imaging in laparoscopic task performance. *Surg Endosc* 17:586–590, 2003.
- Omar AM, Wade NJ, Brown SI, and Cuschieri A. Assessing the benefits of “gaze-down” display location in complex tasks. *Surg Endosc* 19:105–108, 2005.
- Haveran LA, Novitsky YW, Czerniach DR, et al. Optimizing laparoscopic task efficiency: The role of camera and monitor positions. *Surg Endosc* 21:980–984, 2007.
- Erfanian K, Luks FI, Kurkchubasche AG, et al. In-line image projection accelerates task performance in laparoscopic appendectomy. *J Pediatr Surg* 38:1059–1062, 2003.
- Matern U, Faist M, Kehl K, et al. Monitor position in laparoscopic surgery. *Surg Endosc* 19:436–440, 2005.
- van Det MJ, Meijerink WJ, Hoff C, et al. Optimal ergonomics for laparoscopic surgery in minimally invasive surgery suites: A review and guidelines. *Surg Endosc* 23:1279–1285, 2009. □