JOURNAL OF NEUROLOGICAL SURGERY – PART B
Skull Base

Ergonomics in Endoscopic Trans-Sphenoidal Surgery: a Survey of the North American Skull Base Society

Journal:	*JNLS-B*
Manuscript ID	21-Jan-0010.R1
Manuscript Type:	Original Article
Date Submitted by the Author:	24-Jan-2021
Complete List of Authors:	Mattogno, Pier Paolo; Fondazione Policlinico Gemelli IRCCS, Neurosurgery Marciano, Filippo; University of Brescia, Department of Mechanical and Industrial Engineering Catalino, Michael; Brigham and Women's Hospital, Pituitary and Neuroendocrine Center, Department of Neurosurgery Mattavelli, Davide; University of Brescia, Department of Medical and Surgical Specialties, Radiological Sciences and Public Health Cocca, Paola; University of Brescia, Department of Mechanical and Industrial Engineering Lopomo, Nicola; University of Brescia, Department of Information Engineering Nicolai, Piero; Padua University Hospital, Department of Otolaryngology-Head and Neck Surgery Laws, Jr., Edward; Brigham and Women's Hospital, Harvard Medical School, Neurosurgery Witterick, Ian J.; University of Toronto Raza, Shaan; University of Texas MD Anderson Cancer Center, Neurosurgery Devaiah, Anand; Boston University, Otolaryngology Lauretti, Liverana; Fondazione Policlinico Gemelli IRCCS, Neurosurgery Olivi, Alessandro; Policlinico Universitario Agostino Gemelli, Neurosurgery Fontanella, Marco; Azienda Socio Sanitaria Territoriale degli Spedali Civili di Brescia, Clinic of Neurosurgery Gentili, Fred; University Health Network, Department of Neurosurgery Doglietto, Francesco; University of Brescia, Department of Medical and Surgical Specialties, Radiological Sciences and Public Health
Keywords:	Endoscopic Transsphenoidal Surgery, Ergonomics, Operating room set-up, Patient’s positioning, Surgeons’ position, Survey

Manuscript: "Ergonomics in Endoscopic Trans-Sphenoidal Surgery: a Survey of the North American Skull Base Society"

Reviewer 2

1. *Although 116 surgeons returned the survey only 107 reported actually being involved in ETS? Therefore the denominator should be 107 as the other 9 really don't have a practice that contributes to the purpose of the survey? Please verify that you used 107 for your denominator when calculating your percentages?*

We have verified the reported percentages; unless otherwise stated, we confirm that 107 is their denominator.

2. *I think you certainly have to recognize that you basically have surveyed primarily, very experienced, academic surgeons. Therefore, this is more of an analysis of how "recognized experts" do it rather than how the average surgeon in the U.S. (or elsewhere) actually does ETS. I think you should more specifically acknowledge this in your limitations.*

We have added the following sentence in the "Limits of the study" paragraph of the Discussion section: "the population involved in the study is mainly composed of academic surgeons experienced in ETS; the survey, therefore, expresses the preferences of a selected group of experts."

3. *Your bar graph says, "Helbow" instead of "elbow."*

We thank you also for noticing this misspelling, which has been corrected.

Ergonomics in Endoscopic Trans-Sphenoidal Surgery: a Survey of the North American Skull Base Society

Pier Paolo Mattogno, MD[1,2], Filippo Marciano, PhD[3], Michael P. Catalino, MD, MSc[4], Davide Mattavelli, MD, PhD[5], Paola Cocca, PhD[3], Nicola Lopomo, PhD,[6] Piero Nicolai, MD[7], Edward R. Laws Jr., MD[4], Ian Witterick, MD, MSc, FRCSC[8], Shaan M. Raza, MD[9], Anand K. Devaiah, MD[10], Liverana Lauretti, MD[2], Alessandro Olivi, MD[2], Marco M. Fontanella, MD[1], Fred Gentili, MD, MSc, FRCSC[11], Francesco Doglietto, MD, PhD[1]

[1]Neurosurgery, Department of Medical and Surgical Specialties, Radiological Sciences and Public Health, University of Brescia, Brescia, Italy.

[2]Department of Neurosurgery, Fondazione Policlinico Agostino Gemelli IRCCS, Rome, Italy.

[3]Department of Mechanical and Industrial Engineering, University of Brescia, Brescia, Italy.

[4]Pituitary and Neuroendocrine Center, Department of Neurosurgery, Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts, USA.

[5]Otorhinolaryngology, Department of Medical and Surgical Specialties, Radiological Sciences and Public Health, University of Brescia, Brescia, Italy.

[6]Department of Information Engineering, University of Brescia, Brescia, Italy.

[7]Department of Otolaryngology-Head and Neck Surgery, University of Padua, Padua, Italy.

[8]Department of Otolaryngology-Head and Neck Surgery, University of Toronto, Toronto, Ontario, Canada.

[9]Department of Neurosurgery, The University of Texas MD Anderson Cancer Center, Houston, Texas, USA.

[10]Department of Otolaryngology-Head and Neck Surgery, Boston University School of Medicine, Boston Medical Center, Boston, Massachusetts, USA.

[11]Department of Neurosurgery, Toronto Western Hospital, University of Toronto, Toronto, Ontario, Canada.

Corresponding author:

Francesco Doglietto, MD, PhD

Associate Professor

Neurosurgery, Department of Medical and Surgical Specialties, Radiological Sciences and Public Health, University of Brescia

Largo Spedali Civili, 1

25123 Brescia, Italy

Phone: +39 030 3995587

Fax: +39 030 3995008

Email: francesco.doglietto@unibs.it

Abstract

Background and objective: Different surgical set-ups for endoscopic transsphenoidal surgery (ETS) have been described, but studies on their ergonomics are limited. The aim of this paper is to describe present trends in the ergonomics of ETS.

Design and participants: A 33-question, web-based survey was sent to North American Skull Base Society members in 2018 and 116 responded to it (16% of all members). Most respondents were from North America (76%), in academic practice (87%), and neurosurgeons (65%); they had more than 5 years of experience in ETS (73%), had received specific training (66%), and performed at least 5 procedures/month (55%).

Results: Mean reported time for standard and complex procedures were 3.7 and 6.3 hours, respectively. The patient's body is usually positioned in a straight, supine position (84%); the head is in a neutral position (46%) or rotated to the side (38%). Most surgeons perform a binostril technique, work with a partner (95%), and operate standing (94%), holding suction (89%) and dissector (83%); sometimes the endoscope is held by the primary surgeon (22-24%). The second surgeon usually holds the endoscope (72%) and irrigation (42%). During tumor removal most surgeons stand on the same side (65-66%). Many respondents report strain at the dorso-lumbar (50%) or cervical (26%) level. Almost one-third of surgeons incorporate a pause during surgery to stretch, and approximately half exercise in order to be fit for surgery; 16% had sought medical attention for ergonomic related symptoms.

Conclusions: Most respondents value ergonomics in ETS. The variability in surgical set-ups and the relatively high report of complaints underline the need for further studies to optimize ergonomics in ETS.

Keywords: Endoscopic Transsphenoidal Surgery; Ergonomics; Operating room set-up; Patient's positioning; Surgeons' position; Survey

Introduction

The advent of endoscopic transsphenoidal surgery (ETS) in the last 20 years has resulted in a revolution in skull base surgery.[1] The expanding indications have led to progressively more complex and longer operations. Different operating room set-ups, as well as positions of the surgeons and patient, have been described, with only a few studies focusing on ergonomics and ETS.[2–4] On the other hand, the importance of ergonomics is increasingly recognized in other surgical specialties that are endoscopy based[2,5–7] and characterized by a small access site (i.e., "minimally invasive surgery").[8,9] This study investigated current surgical practices among endoscopic skull base surgeons, as well as possible issues related to ergonomics in ETS.

Materials and Methods

Study design and group of respondents

A 33-question, web-based survey was administered to members of the North American Skull Base Society (NASBS) from January to April 2018 (Supplementary Material 1). The questions were divided into three subgroups: 1. personal data and training; 2. personal experience and practice in ETS; 3. ergonomic considerations related to ETS, including positioning of the patient and surgeons in the operating room (OR), surgeons' set-up during bimanual dissection, important factors considered for ergonomics, and physical complaints and their prevention (Supplementary Material 1).

Data collection and statistical analyses

Data were elaborated using Survey Monkey® software online.

Results

Of 795 NASBS members, 116 responded to the survey (response rate: 16%); 107 reported being involved in ETS and 93 completed the survey (12%) (Supplementary Material 2).

Personal data and training

Most respondents (76%) were from North America, in academic practice (87%), not in training (91%), and neurosurgeons (65%). Most (73%) had more than 5 years of experience in ETS, had received specific training (66%), and performed at least 5 procedures/month (55%).

Practice in ETS

Mean reported time for standard and complex procedures were 3.7 and 6.3 hours, respectively. Most surgeons use image guidance (84%), a binostril technique, and work with a partner (95%).

OR set-up: surgeons' and patient's positions

The most frequent position of the first surgeon during tumor removal is: standing (94%), holding suction (89%) and dissector (83%), or grasping forceps (38%). In some cases, the endoscope is held by the primary surgeon (22-24%). The second surgeon usually holds the endoscope (72%) and irrigation (42%) or suction (37%). Most respondents position the patient supine, with the head in neutral position (46%) or rotated to the side (38%); less frequently (14%) the torso and head are tilted (Figure 1A). During tumor removal surgeons usually stand on the same side (65-66%) (Figure 1A), and monitors are positioned accordingly (Figure 1B).

Ergonomics in ETS

Most responders (81%) tailor surgery for ergonomic considerations and select instruments accordingly (92%). Surgical factors considered important to maximize ergonomics in addition to surgical access and visualization include: sphenoidotomy (71%), septectomy (69%), removal of sphenoid septa and sellar opening (67%), dural opening (51%). Patient-specific factors include: conformation of middle turbinate (53%) and need for septoplasty (31%). The most cited ergonomic considerations were: height of table/bed head (86%), monitor placement (80%), attention to posture (60%), and adjustments of patient position during surgery (50%) (Figure 2). Many surgeons report

strain at the dorso-lumbar (50%) or cervical (26%) level (Figure 3). Almost one-third incorporate a pause during surgery to stretch and move. Half of respondents engage in physical activity in order to be fit for surgery and 16% had sought medical attention for ergonomic related symptoms.

Discussion

In recent years, minimally invasive surgery (MIS) has been developed and is increasingly used in different surgical specialties thanks to the introduction of the endoscope and other technological advancements. The analysis of ergonomics related to MIS has been extensively performed in General Surgery, Gynecology and Urology,[10–14] in order to make interventions more comfortable and effective for both surgeons and patients and improve outcomes in terms of reduced surgical times and complications.[8,9]

The prevalence of work-related musculoskeletal disorders is significantly higher among endoscopists and minimally-invasive surgeons compared to other surgical and medical specialties, but data on the prevalence of disorders among surgeons dedicated to ETS is limited.[4] In particular, in a survey including 62 otolaryngologists performing ETS, 74% of respondents considered it more ergonomically taxing than functional endoscopic endonasal surgery, and received medical care in 23%.[2] On the other hand, some studies have attempted to provide ergonomic guidelines related to instruments and tools to prevent work-related musculoskeletal disorders, OR setup, and patient position, while others have analyzed the potential advantages of robotic surgery applied to EES and ESBS in terms of ergonomics.[3,5,15]

In this context, the present survey has been elaborated in collaboration with the North American Skull Base Society (NASBS) in order to define the most widely adopted scenarios in surgical set-up in ETS and to investigate opinions and possible issues related to ergonomics of surgeons who perform ETS.

Survey respondents

The response rate to the survey appears low (116/795; 16% of the total membership), but is certainly underestimated: the total membership in 2018 was used as a denominator, but the real number of NASBS members who perform ETS is certainly lower; as this number is not available, the total membership has been used as a denominator. Furthermore, it has been reported that surveys with lower response rates are not necessarily less accurate than the ones with higher rates.[16,17]

Certainly, the responders who completed the survey are members of NASBS and significantly involved in ETS: most work in North America (76%) and in academic practice (87%); 65% are neurosurgeons, with at least 5 years of experience in ETS (73%), and perform at least 5 procedures/month (55%).

Surgical set-up

The mean reported operative time is 3.4 h (2.4-3.7) for standard ETS and 5.3 h (3.9-6.3) for ESBS; these data, especially for ETS, appear to be slightly higher than the average reported in the literature.[18]

The relatively long duration of all endoscopic transnasal approaches underlines the importance of addressing potential ergonomic issues, such as maintaining awkward postures and developing muscular fatigue, which in general can lead to physical discomfort and strain, to reduce potentially negative effects on surgeons and patients.

More than 90% of respondents work with a partner and use a binostril technique, while only a small minority work on their own (5%). The available literature has reported similar results with both techniques.[19]

Only a minority use the endoscope holder (10%), while most use the so-called “four-hands technique” with two operators working together. During tumor removal the assistant surgeon usually holds the endoscope (72%), which is held in some teams by the primary surgeon. ENT surgeons report the latter set-up more frequently compared to neurosurgeons, but with no significant difference (28% vs 18%). The team approach has theoretically many different advantages including: sharing knowledge, increased comfort with complex nasal and intracranial anatomy, and the possibility of interchanging

roles during surgery to mitigate the effects of fixed positions. Furthermore, the four-hand technique might theoretically be more efficient if the primary surgeon is holding the suction, rather than the endoscope in the non-dominant hand, especially in case of bleeding since coordination between suction and bipolar might be easier if the same person is holding them. Nonetheless, all these aspects need to be investigated with quantitative and objective research methods.

Positioning of surgeons and patient

The vast majority of responders operate in a standing position (>90%), with two surgeons on the same side (64%) during tumor removal. Concerning the patient's position, 83% use the supine neutral position with an extended or/and slightly rotated head (Figure 1); this set-up derives from the one used by ENT surgeons in functional endoscopic sinus surgery[20] and was applied to endoscopic pituitary surgery by its pioneers.[21] Even if it is the most widely used set-up, some potential ergonomic issues can be identified. The main one is represented by the primary surgeon's position: if the primary surgeon is not holding the endoscope during tumor removal, the cervico-dorsal spine is rotated and/or flexed to achieve a relatively specular position to the patient's head and therefore a symmetric use of the arms. A minority of respondents who use this set-up (29% of all responders) place the two surgeons on opposite sides: this position in theory implies an adjunctive physical stress on both upper arms, cervical and lumbar spine for both surgeons, who are forced to work obliquely with respect to the surgical field. Nonetheless, all these aspects merit quantitative and objective comparative data.

Only a small percentage of respondents (8%) choose the patient position that derives from a traditional microsurgical transsphenoidal approach, with the patient in supine position, the head slightly flexed and turned to the right (to face the primary surgeon), right arm flexed over the torso, and head and chest elevated 20° (Figure 1). Neurosurgeons are still familiar with this position and are indeed the only ones that apply it to ETS, as compared to ENT surgeons (12% vs. 0, respectively). This position permits good surgical maneuverability, consenting the first surgeon to face the patient and comfortably use a binostril corridor.[15,22] However, considering the ergonomic balance, the

asymmetric weight distribution due to oblique position of the first surgeon cannot be considered optimal. Furthermore, the surgeons position is only part of intraoperative positioning, which has many variables that were not investigated in detail by the survey: as an example, the venous drainage of the patient's head and neck should be taken into account as a crucial element for having a bloodless surgical field.

Finally, the surgeon's sitting position can be considered advantageous from an ergonomic point of view, but its use in ETS is not straightforward;[23,24] it is, indeed, used only by a minority of respondents (6%).

Ergonomics: perception and complaints

Most respondents (80%) value ergonomics for surgical set-up and (91%) consider it essential in the evaluation of surgical instruments. The constant development of new and performing surgical tools dedicated to ETS with ergonomic handles might have reduced the sense of fatigue in the upper limbs and in particular in the hands, wrists and elbows, justifying a lower rate of discomfort expressed by responders compared to other districts such as the spine. Table height and monitor position are considered highly and have been reported as significant issues related to ergonomics (Figure 2).[11,12,25–35]

Most surgeons report performing the following procedures during ETS to optimize exposure and maneuverability in the surgical corridor: sphenoidotomy, posterior septostomy, and removal of the sphenoid septa; these data are consistent with the literature and have become common surgical practice.

Only 30% of respondents report taking a break during surgery and half are engaged in physical activity in order to be fit for surgery. A significant number of responders (16% have sought medical advice for ergonomic-related symptoms. Surgical fatigue, mainly related to prolonged incorrect position of the surgeon during procedures, as already highlighted by previous studies,[36] is concentrated in specific musculoskeletal districts: in particular the cervical and lumbar spine,

shoulders, elbows, and hands are involved in prolonged holding of the surgical instruments and the endoscope during lengthy procedures.

Limits of the present study

It is impossible to quantify the bias caused by the relatively low response rate. Furthermore, the population involved in the study is mainly composed of academic surgeons experienced in ETS; the survey, therefore, expresses the preferences of a selected group of experts. Moreover, the survey was not designed to allow for subgroup analyses, which should be the object of future studies. Despite these limitations, we believe that the survey well depicts present trends in ETS thanks to the participation of expert and dedicated skull base surgeons.

Conclusions

Ergonomics represent a fundamental and innovative field of research in the context of endoscopic skull base surgery, as it is capable of optimizing surgical performance, allowing surgeons to be more effective and resistant, especially in complex and long procedures. The present survey documents that ergonomics is perceived to be important by the skull base surgery community, but there is also relatively wide variability in surgical set-ups for ETS and a significant number of physical complaints related to surgery. A systematic study, which can keep into account the multifactorial characteristics (i.e. postures, kinematics and muscular fatigue) of the tasks involved in ETS and that can be based on the integration of the most recent posture and movement analysis, wearable technologies[37] and biomechanical modelling, is advocated to investigate the optimal solutions for ETS from an ergonomics point of view in a multiparametric perspective.

References

1. Doglietto F, Prevedello DM, Jane JA, Han J, Laws ER. Brief history of endoscopic transsphenoidal surgery--from Philipp Bozzini to the First World Congress of Endoscopic Skull Base Surgery. *Neurosurg Focus*. 2005;19(6):E3.

2. Little RM, Deal AM, Zanation AM, McKinney K, Senior BA, Ebert CS. Occupational hazards of endoscopic surgery. *Int Forum Allergy Rhinol*. 2012;2(3):212-216. doi:10.1002/alr.20108

3. Ramakrishnan VR, Montero PN. Ergonomic considerations in endoscopic sinus surgery: lessons learned from laparoscopic surgeons. *Am J Rhinol Allergy*. 2013;27(3):245-250. doi:10.2500/ajra.2013.27.3872

4. Marciano F, Mattogno PP, Codenotti A, Cocca P, Fontanella MM, Doglietto F. Work-related musculoskeletal disorders among endoscopic transsphenoidal surgeons: a systematic review of prevalence and ergonomic interventions. *Int J Occup Saf Ergon*. Published online July 1, 2020:1-10. doi:10.1080/10803548.2020.1774160

5. ASGE Technology Committee, Pedrosa MC, Farraye FA, et al. Minimizing occupational hazards in endoscopy: personal protective equipment, radiation safety, and ergonomics. *Gastrointest Endosc*. 2010;72(2):227-235. doi:10.1016/j.gie.2010.01.071

6. Hirschowitz BI. The cost of doing business: occupational hazards for endoscopists. *Endoscopy*. 1994;26(6):559-561. doi:10.1055/s-2007-1009034

7. Lobo D, Anuarbe P, López-Higuera JM, Viera J, Castillo N, Megía R. Estimation of surgeons' ergonomic dynamics with a structured light system during endoscopic surgery. *Int Forum Allergy Rhinol*. 2019;9(8):857-864. doi:10.1002/alr.22353

8. Alleblas CCJ, de Man AM, van den Haak L, Vierhout ME, Jansen FW, Nieboer TE. Prevalence of Musculoskeletal Disorders Among Surgeons Performing Minimally Invasive Surgery: A Systematic Review. *Ann Surg*. 2017;266(6):905-920. doi:10.1097/SLA.0000000000002223

9. Dalager T, Søgaard K, Bech KT, Mogensen O, Jensen PT. Musculoskeletal pain among surgeons performing minimally invasive surgery: a systematic review. *Surg Endosc*. 2017;31(2):516-

526. doi:10.1007/s00464-016-5020-9

10. van Det MJ, Meijerink WJHJ, Hoff C, van Veelen MA, Pierie JPEN. Ergonomic assessment of neck posture in the minimally invasive surgery suite during laparoscopic cholecystectomy. *Surg Endosc*. 2008;22(11):2421-2427. doi:10.1007/s00464-008-0042-6

11. Rosenblatt PL, McKinney J, Adams SR. Ergonomics in the operating room: protecting the surgeon. *J Minim Invasive Gynecol*. 2013;20(6):744. doi:10.1016/j.jmig.2013.07.006

12. Matern U. Ergonomic deficiencies in the operating room: examples from minimally invasive surgery. *Work*. 2009;33(2):165-168. doi:10.3233/WOR-2009-0862

13. Reddy PP, Reddy TP, Roig-Francoli J, et al. The impact of the alexander technique on improving posture and surgical ergonomics during minimally invasive surgery: pilot study. *J Urol*. 2011;186(4 Suppl):1658-1662. doi:10.1016/j.juro.2011.04.013

14. Esposito C, Najmaldin A, Schier F, et al. Work-related upper limb musculoskeletal disorders in pediatric minimally invasive surgery: a multicentric survey comparing laparoscopic and sils ergonomy. *Pediatr Surg Int*. 2014;30(4):395-399. doi:10.1007/s00383-013-3437-y

15. Ekanayake J, Baudracco I, Quereshi A, Vercauteren T, Dorward NL. The conversational position in endoscopic pituitary surgery. *Br J Neurosurg*. 2018;32(1):44-46. doi:10.1080/02688697.2017.1406058

16. Visser PS, Krosnick JA, Marquette J, Curtin M. Mail Surveys for Election Forecasting? An Evaluation of the Colombia Dispatch Poll. *Public Opinion Quarterly*. 1996;60(2):181-227. doi:10.1086/297748

17. Keeter S, Kennedy C, Dimock M, Best J, Craighill P. Gauging the Impact of Growing Nonresponse on Estimates from a National RDD Telephone Survey. *Public Opinion Quarterly*. 2006;70(5):759-779. doi:10.1093/poq/nfl035

18. Qureshi T, Chaus F, Fogg L, Dasgupta M, Straus D, Byrne RW. Learning curve for the transsphenoidal endoscopic endonasal approach to pituitary tumors. *Br J Neurosurg*. 2016;30(6):637-642. doi:10.1080/02688697.2016.1199786

19. Mamelak AN, Carmichael J, Bonert VH, Cooper O, Melmed S. Single-surgeon fully endoscopic endonasal transsphenoidal surgery: outcomes in three-hundred consecutive cases. *Pituitary*. 2013;16(3):393-401. doi:10.1007/s11102-012-0437-1

20. Stammberger H. Nasal and paranasal sinus endoscopy. A diagnostic and surgical approach to recurrent sinusitis. *Endoscopy*. 1986;18(6):213-218. doi:10.1055/s-2007-1018382

21. Jho HD, Carrau RL, Ko Y, Daly MA. Endoscopic pituitary surgery: an early experience. *Surg Neurol*. 1997;47(3):213-222; discussion 222-223. doi:10.1016/s0090-3019(96)00452-1

22. Jane JA, Thapar K, Kaptain GJ, Maartens N, Laws ER. Pituitary surgery: transsphenoidal approach. *Neurosurgery*. 2002;51(2):435-442; discussion 442-444.

23. Ayad T, Péloquin L, Prince F. Ergonomics in endoscopic sinus surgery: systematic review of the literature. *J Otolaryngol*. 2005;34(5):333-340. doi:10.2310/7070.2005.34507

24. Bolduc-Bégin J, Prince F, Christopoulos A, Ayad T. Work-related musculoskeletal symptoms amongst Otolaryngologists and Head and Neck surgeons in Canada. *Eur Arch Otorhinolaryngol*. 2018;275(1):261-267. doi:10.1007/s00405-017-4787-1

25. Sari V, Nieboer TE, Vierhout ME, Stegeman DF, Kluivers KB. The operation room as a hostile environment for surgeons: physical complaints during and after laparoscopy. *Minim Invasive Ther Allied Technol*. 2010;19(2):105-109. doi:10.3109/13645701003643972

26. Manasnayakorn S, Cuschieri A, Hanna GB. Ergonomic assessment of optimum operating table height for hand-assisted laparoscopic surgery. *Surg Endosc*. 2009;23(4):783-789. doi:10.1007/s00464-008-0068-9

27. Berquer R, Smith WD, Davis S. An ergonomic study of the optimum operating table height for laparoscopic surgery. *Surg Endosc*. 2002;16(3):416-421. doi:10.1007/s00464-001-8190-y

28. van Veelen MA, Kazemier G, Koopman J, Goossens RHM, Meijer DW. Assessment of the ergonomically optimal operating surface height for laparoscopic surgery. *J Laparoendosc Adv Surg Tech A*. 2002;12(1):47-52. doi:10.1089/109264202753486920

29. Matern U, Waller P, Giebmeyer C, Rückauer KD, Farthmann EH. Ergonomics: requirements

for adjusting the height of laparoscopic operating tables. *JSLS*. 2001;5(1):7-12.

30. van Det MJ, Meijerink WJHJ, Hoff C, Totté ER, Pierie JPEN. Optimal ergonomics for laparoscopic surgery in minimally invasive surgery suites: a review and guidelines. *Surg Endosc*. 2009;23(6):1279-1285. doi:10.1007/s00464-008-0148-x

31. Haveran LA, Novitsky YW, Czerniach DR, et al. Optimizing laparoscopic task efficiency: the role of camera and monitor positions. *Surg Endosc*. 2007;21(6):980-984. doi:10.1007/s00464-007-9360-3

32. Zehetner J, Kaltenbacher A, Wayand W, Shamiyeh A. Screen height as an ergonomic factor in laparoscopic surgery. *Surg Endosc*. 2006;20(1):139-141. doi:10.1007/s00464-005-0251-1

33. Smith WD, Berguer R, Nguyen NT. Monitor height affects surgeons' stress level and performance on minimally invasive surgery tasks. *Stud Health Technol Inform*. 2005;111:498-501.

34. Matern U, Faist M, Kehl K, Giebmeyer C, Buess G. Monitor position in laparoscopic surgery. *Surg Endosc*. 2005;19(3):436-440. doi:10.1007/s00464-004-9030-7

35. Lee SR, Shim S, Yu T, Jeong K, Chung HW. Sources of pain in laparoendoscopic gynecological surgeons: An analysis of ergonomic factors and proposal of an aid to improve comfort. *PLoS One*. 2017;12(9):e0184400. doi:10.1371/journal.pone.0184400

36. Rimmer J, Amin M, Fokkens WJ, Lund VJ. Endoscopic sinus surgery and musculoskeletal symptoms. *Rhinology*. 2016;54(2):105-110. doi:10.4193/Rhin15.217

37. Meltzer AJ, Hallbeck MS, Morrow MM, et al. Measuring Ergonomic Risk in Operating Surgeons by Using Wearable Technology. *JAMA Surg*. 2020;155(5):444-446. doi:10.1001/jamasurg.2019.6384

Figures captions

Figure 1. (A) Positions of the patient and surgeons and (B) monitors during ETS.

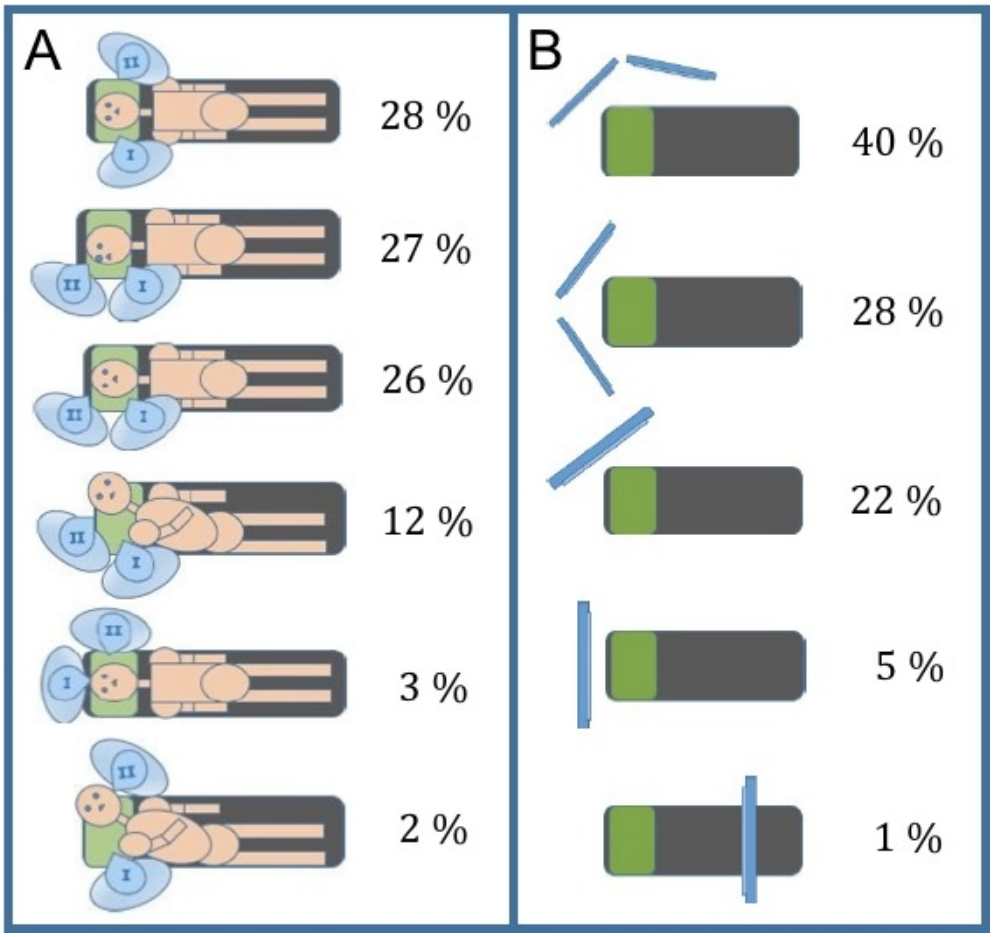
A. Patient in the supine position with head extended or slightly turned is preferred to "conversational" position with face and torsum facing the surgeon (84% vs 14%); same-side position of surgeons is more common than an opposite-side one (65 % vs 30%).
B. Position of monitors during tumor removal is mainly preferred at the head of surgical bed, for both single or double monitor setup (99% vs 1%).

Figure 2. Prevalence of work-related musculoskeletal disorders among responders.

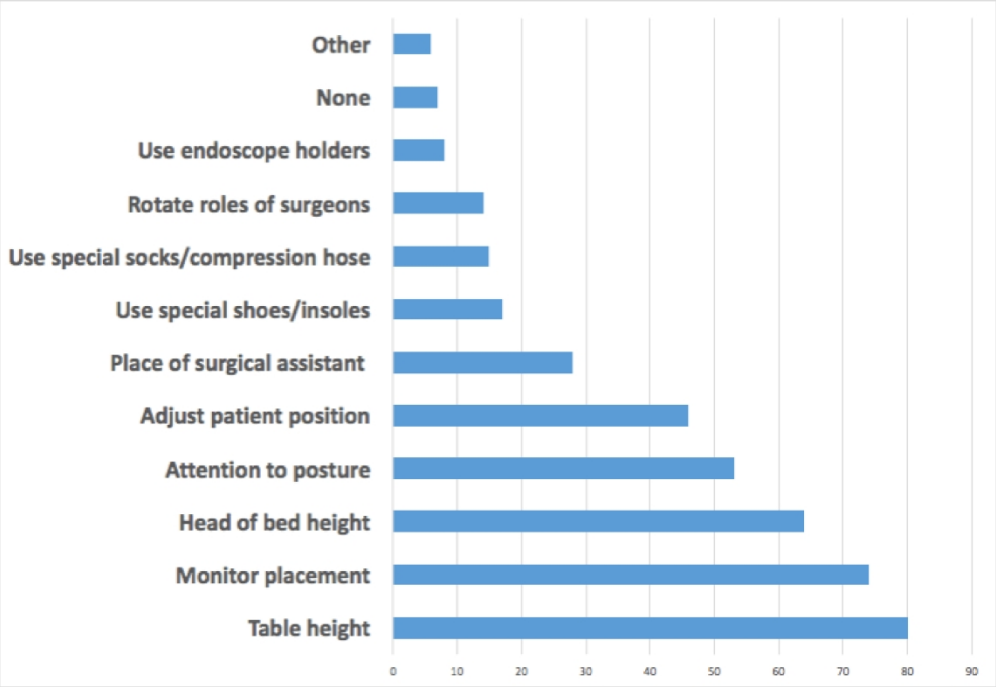
The spine (dorso-lumbar and cervical) is the most affected district followed by upper limb (shoulder, wrist, hand), and lower limb (knee, leg, hips).

Figure 3. Ergonomic considerations used to optimize OR setup during ETS.

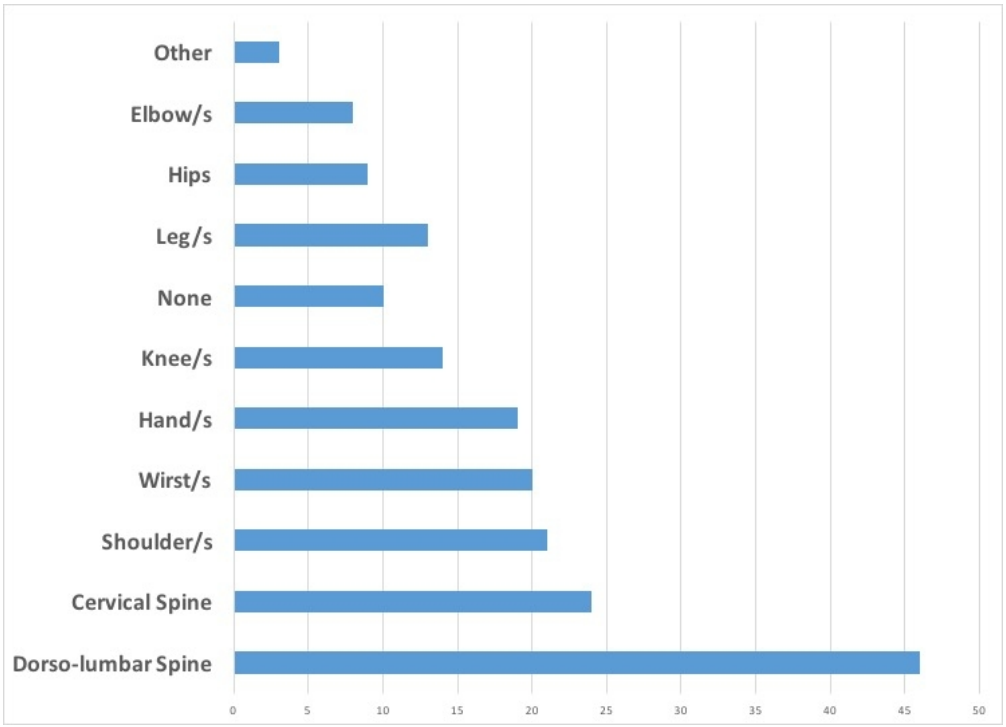
Heights of table and head of bed, monitor placement, and positions of the patient and surgeons are considered to be the most significant elements for ergonomic improvement during ETS.



201x188mm (72 x 72 DPI)



261x179mm (300 x 300 DPI)



263x189mm (72 x 72 DPI)