Ergonomics and GI endoscopy

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Gastroenterologists are at risk for overuse injuries, such as carpal tunnel syndrome (CTS), DeQuervain's tenosynovitis, and lateral epicondylitis due to the repetition and prolonged awkward postures associated with endoscopy. Much attention has been paid to the safety of patients during endoscopic procedures, but the safety of the physician is often forgotten. Indeed, the rigorous training and increasing demand for colonoscopy have made the gastroenterologist a commodity in today's workplace. Survey-based studies estimate a 37% to 89%[1-7] prevalence of musculoskeletal pain among gastroenterologists, although the proportion of occupation-related injuries is unknown. According to a recent American Society for Gastrointestinal Endoscopy (ASGE) survey, gastroenterologists spend 43% of their time performing endoscopy,[8] and increased endoscopy volume is associated with an increased risk of musculoskeletal complaints.[1,5,6]

Ergonomics is the study of the physical and cognitive demands of a task in relation to an individual's capacity. In effect, ergonomics evaluates how a job can best be fit to an individual, instead of forcing an individual to fit into a job. Because work-related injuries can be devastating to a physician's livelihood, it is important for physicians to be educated on ergonomic principles to minimize the risk for endoscopy-related injury. We herein review the available literature on the prevalence, risk factors, and potential mechanisms for upper extremity and neck injuries in endoscopists and propose general ergonomic guidelines to reduce these risks.

Abbreviations: ACGIH, American Conference of Industrial Hygienists; ASGE, American Society for Gastrointestinal Endoscopy; CTS, carpal tunnel syndrome; EMG, electromyography; PAL, progressive addition lenses.

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METHODS

A systematic review was performed of published studies that evaluated the ergonomics of endoscopy and focused on current video endoscopy technology. Thus, 1990 was chosen as the first year of literature review, because this is when videoendoscopy became widely available. MEDLINE (1990 to October 2008) was searched for English language publications by using the following MeSH terms and search strategy: (''human engineering'' or ''cumulative trauma disorders'' or ''musculoskeletal disease'' or ''occupational disease'' or ''equipment design'') and (''gastroenterology'' or ''endoscopy, digestive system'' or ''endoscopy, gastrointestinal'' or ''colonoscopy''), and the following key words: ''ergonomics of endoscopy,'' ''endoscopist injury,'' ''medical ergonomics,'' ''endoscopy and musculoskeletal strain,'' ''musculoskeletal injury and endoscopists,'' ''occupational diseases and endoscopy,'' ''cumulative trauma disorder and endoscopy,'' and ''repetitive strain injury and endoscopy.'' A total of 9279 articles were retrieved. To broaden the results and to allow for inclusion of abstracts, further searches were performed on Google Scholar by using the key words listed above. References from all relevant articles were also reviewed to identify additional articles. The principle investigator (A.S.) searched all titles and reviewed abstracts to determine eligibility. Full articles were retrieved for all relevant titles for which an abstract was not available and for all abstracts that appeared to meet inclusion criteria. Articles were included if they were determined to be related to the ergonomic evaluation of GI endoscopy. More specifically, articles were included if they addressed the prevalence, risk factors, or mechanism of injury in endoscopists; if they measured posture or forces during endoscopy; or if they provided recommendations on tactics to reduce injury in endoscopists. Studies that addressed ergonomic issues associated with fiberoptic endoscopy were excluded from review.

After review of all titles and abstracts by the primary investigator, only 12 articles initially were identified through MEDLINE that fulfilled these criteria.[1,6,7,9-17] After review of Google Scholar results and the references from relevant articles, an additional 9 articles were identified.[2-5,18-22] One article, previously published in abstract form, was

TABLE 1. Summary of endoscopist surveys

Study	Type of study	Response rate (%)	Number of endoscopists	Age (y)	Sex (% men)
Buschbacher,[1] 1994	Survey of ASGE members	72	265	Mean (SD) 47.8 ± 8.6	95.1
O'Sullivan et al,[7] 2002	Survey of Canadian ERCP endoscopists	74	114	–	–
Liberman et al,[6] 2005	Survey of worldwide members of American Society for Colon and Rectal Surgery	28	608	Mean (SD) 48 ± 9.5	89.3
Keate,[4] 2006	Online survey of ASGE members	N/A	237	–	–
Hansel et al,[3] 2007	E-mail survey, case-control study of Mayo Clinic gastroenterologists (GI group) and nonprocedure-oriented internists and subspecialists (non-GI group)	GI-group, 63 non-GI group, 45	72 10	–	–
Lee and Valiozis,[5] 2007	Survey of members of Gastroenterological Society of Australia	12.4	94	88% between ages 31 and 60	84
Byun et al,[2] 2008	Endoscopists practicing in general hospitals or health promotion centers in Korea willing to participate	N/A	55	Median age 39	67

ASGE, American Society for Gastrointestinal Endoscopy; *N/A*, not applicable; CTS, carpal tunnel syndrome.
*The total of 12% reported missing work because of injury and/or requiring surgery for injury; surgery rate not specifically defined.

included in this review, and has subsequently been published.[21] One abstract was provided by one of the investigators in this study (K.M.).[23]

The full texts of all selected articles were reviewed by the primary investigator (A.S.) for extraction of data. Seven articles[1-7] addressed the prevalence of endoscopist injury. Five articles[9,11,17,18,22] evaluated or discussed possible risk factors and mechanisms of injury. One online study[19] evaluated postures during endoscopy, whereas 4 articles[10,12,20,21] evaluated the forces applied during endoscopy, and 6 articles[13-16,22,23] provided recommendations to reduce injury during endoscopy.

RESULTS

Prevalence of endoscopist injury

A total of 7 articles[1-7] were included (Table 1). These studies differed in the population being studied, the survey instruments, and the types of procedures performed, which precluded pooling of data. Therefore, a descriptive analysis is provided. In total, these studies demonstrate a prevalence of musculoskeletal complaints among endoscopists ranging from 37% to 89%.[1-7] Common regions of pain are the left thumb, right wrist, neck, and back, and these injuries are more common among gastroenterologists than among other internal medicine specialists.[3] The risk of injury appears to be related to endoscopy volume.[1,5,6]

A survey of 400 randomly selected gastroenterologists from the ASGE in 1994 reported 57% of respondents had a main musculoskeletal complaint, with many having more than one complaint.[1] Of those with pain, 85% reported that their condition bothered them at work, and 44% had suffered from the pain for more than 6 months. Physicians who performed more endoscopies (measured in terms of hours per week, number of procedures per week, or percentage of work time devoted to endoscopy) were more likely to complain of thumb, hand, elbow, or low back pain. Thumb, wrist, and hand pain more commonly occurred on the left and elbow pain on the right. Physicians who complained of thumb, hand, and neck pain tended to attribute their symptoms to performing endoscopy.[1]

A study of surgeons who performed colonoscopy reported that 39% of surgical endoscopists had at least one injury or pain related to colonoscopy, whereas the risk increased to 47% among surgeons who performed more than 30 colonoscopies per week.[6] Most of the right upper-extremity injuries were attributed to torquing of the

TABLE 1 (*Continued*)

Years in practice	Mean (SD) time spent in endoscopy	% Reporting injury	Type of injury (%)	% Requiring surgery	% Time off work
All >0.5 y	12.4 h/wk	57	Low back (13), thumb (10), neck (10), elbow (8), CTS (4), shoulder (3), hand numbness (3), other (6)	3.2	–
Mean (SD): injured, 14.7 (7) y; noninjured, 11.6 (5.9) y	–	67	Back (57), neck (46), hand pain (36), shoulder (16), elbow (8), other (5)	8	–
Mean (SD): 14.8 (8.6) y	2.4 (1.9) d/wk	39	Right foot (12.5), neck (10.7), right hand (8.7), back (8.6), right fingers (7.2), left fingers (6.4), left-hand pain (6.3), left thumb (5.3), right thumb (3.3), CTS (2)	2.7	1.3
–	–	78	Hand or CTS (43), back (29), neck (28), other (16)	(<12%)*	12
–	–	74 35	GI group: thumb (19), hand (17), back (12), neck (10)	–	13.2
–	–	37	Thumb (70)	–	9
Median duration 3.25 y	19.5 (7.7) h/wk	89	Right shoulder (31), left shoulder (29), left finger (29), right wrist (26), neck (18), left wrist (18), right finger (16)	0	2

colonoscope, and the left thumb, finger, and hand injuries were attributed to turning the control dials and gripping the colonoscope handle.[6]

In an online survey of 237 ASGE members, 78% of respondents reported one or more injury.[4] Most respondents (85%) reported pain when performing endoscopy. The endoscopic activities associated with pain included applying torque to the colonoscope (29%) and manipulating the colonoscope head (17%) (left thumb pain).[4]

A case-control study compared gastroenterologists at the Mayo Clinic with nonprocedure-oriented internal medicine specialists and subspecialists.[3] The incidence of any musculoskeletal injury was higher in the GI group (74%) compared with the non-GI group (35%). In this study, there was no significant association between endoscopy volume or years performing endoscopy and injury.[3] This is in contrast to the 1994 ASGE survey,[1] the survey of surgical endoscopists,[6] and a recent study of members of the Gastroenterological Society of Australia, in which volume of endoscopy was a significant predictor of injury.[5]

Recently, 55 Korean endoscopists participated in a survey in which 89% of respondents reported at least one musculoskeletal complaint, and 73% reported more than one injury.[2] These endoscopists devoted substantial time to endoscopy, with a mean (SD) procedure time of 19.5 ± 7.7 hours per week and a mean (SD) number of 270.2 ± 153 endoscopies per month. This survey also included the largest percentage of women endoscopists (33%). Severe pain (pain greater than 55 mm on a 100-mm visual analog scale) was reported by 47.3% of endoscopists (26/55), with more women than men reporting severe pain (61% vs 40%, respectively; $P = .15$).[2]

The type of injury is an important factor in determining the duration of disability. A retrospective cohort study of disability claims in Washington State determined that a diagnosis of CTS and back-neck sprain predicted a longer duration of disability. For instance, fewer than 50% of workers diagnosed with CTS returned to work within 1 month of their injury.[24] This is in contrast to disability from more acute injuries, such as fractures and non-back–related sprains and strains, in which up to 70% of workers had returned within 1 month and 80% to 95% by 2 months.[24] Disability data were not consistently provided in the various studies. Surgery was required in 0% to 8%[1,2,4,6,7] of respondents who reported injury in the various studies, and 2% to 13%[2-6] required time off work.

Despite the differences in survey methods, these studies document an association between endoscopy and musculoskeletal complaints, and they show a consistently high prevalence of musculoskeletal complaints among endoscopists. Surgery and time off work was required in a minority of respondents, although it is still a concerning finding. Men predominate in these surveys; therefore, the prevalence and site of injury in women is not as clear.

Applying ergonomics to gastroenterology: risk factors and potential mechanisms of injury

Ergonomic evaluations involve understanding how a job affects people, both physically and emotionally, with the goal of increasing worker safety, productivity, and job satisfaction.[25] It is thought that overuse injuries occur from repeated microtrauma to a tendon, ligament, or joint, or repeated ischemia to peripheral nerves. The repeated loading, injury, and repair may lead to degenerative changes over time.[26-28] These degenerative changes are in contrast to acute injuries from tripping, falling, or other sudden high loads.

The risk factors associated with overuse injuries of the upper extremities include high pinch force, repetitive hand activities, awkward postures, vibration, and contact stress.[27,28] GI endoscopy involves several of these factors.[22] Gastroenterologists perform an average of 12 EGDs and 22 colonoscopies per week,[29] resulting in frequent hand-intensive activities throughout the day. The few studies that directly evaluated hand forces during endoscopy demonstrated high forces because of gripping or pinching the endoscope, and pushing-pulling and torquing of the insertion tube.[10,12,21] There may also be sustained awkward postures during endoscopy, including extension or rotation of the spine if the video monitor is placed too high or to the side of the endoscopist.[14,19] In a survey of endoscopists who perform ERCP, 67% of rooms reviewed by a study kinesiologist and occupational therapist were thought to be poorly designed because of awkward placement of the monitor or use of nonadjustable patient beds, and ergonomic room design was significantly associated with no complaint of injury.[7] Awkward postures may also be related to endoscope manipulation. During endoscopy, the left hand grips and stabilizes the control section, the left thumb manipulates the control dials, the right hand pinches or grips the insertion tube, and the right arm pushes, pulls, and applies torque to the endoscope. These activities may require extreme or prolonged wrist flexion or extension and/or radial or ulnar deviation during endoscopy that can decrease pinch and grip strength.[30,31] High finger forces in association with awkward wrist postures can further increase the risk of overuse injury.

Human engineering is another important aspect of ergonomics.[25] The interaction between the operator and their tools, workstation, and tasks should be optimized to reduce overuse injury. Although the optics of endoscopes continue to improve, the basic shape and design of the instrument have not changed for over 20 years. Current endoscope design requires mechanical application of force to the control dials to deflect the insertion-tube tip during examination. A recent case report describes "colonoscopist's thumb," a tenosynovitis of the left thumb attributed to the repeated application of force by the left thumb during colonoscopy,[11] previously described as "endoscopists' thumb."[9,17] Although the majority of the force is applied by the left thumb, the digits of the left hand may provide additional force if the endoscopist has a large enough hand. Coupled with up-down tip deflection by the left hand, movement of the endoscope tip also can be achieved by application of torque to the insertion tube by the right hand and arm. In addition to the torque and push-pull forces applied by the right hand, the right hand is also important for threading tools through the biopsy channel. One prior report describes "biliary endoscopist's knuckle," a traumatic arthritis of the metacarpophalangeal joint attributed to repeated high-force gripping to push large-caliber prostheses through biliary and pancreatic strictures.[17]

A survey of U.S. gastroenterology fellows asked respondents their impression of how their hand size (median surgical glove size 7.5) affected their capacity to learn endoscopy.[18] The response rate was 17.5% (227 fellows). Forty-one percent considered their hand too small for a standard endoscope's control section and 62% thought their hand size impaired their ability to perform endoscopy. Sixty-three percent of respondents with a surgical glove size <6.5 (mostly women) would opt for an endoscope with a smaller handle if available compared with 28.3% of fellows with a larger glove size ($P \leq .001$).[18] No consideration to date has been given in endoscope design to accommodate variability in hand size or the difference in hand sizes between men and women. A pilot study evaluated the use of an angulation dial adapter (Olympus America, Center Valley, Pa) for hand spans (defined as the thumb to the fifth digit) <19 cm.[23] Although no significant difference was found in procedure time or ease of procedure, retroflexion was rated significantly easier with the adapter by all endoscopists. The investigators concluded that further evaluation of endoscope design may reduce hand fatigue and injury, given the angulation dial showed a trend toward decreased procedure time in physicians with small hands.[23]

The application of basic ergonomic principals, such as maintaining neutral wrist, neck, and shoulder postures during endoscopy, keeping hand forces low, and optimizing endoscope design, may reduce the risk of injury and make endoscopy more comfortable for the gastroenterologist, meriting further investigation.

Measurement of forces during endoscopy

Limited data are available on the forces exerted during endoscopy. Four articles, describing 3 studies, were included for review.[10,12,20,21] All articles specifically evaluated colonoscopy. However, these studies differed in their measurement tools, types of forces being evaluated, and use of in vivo versus in vitro colonoscopy, precluding pooling of data.

One study assessed forces applied by the right hand during tube insertion as a proxy for forces applied to the colon wall and the risk of bowel perforation.[10,20] Perforation occurs at direct colonic-wall forces greater than 53.9 N. The investigators designed a tubular hand grip that wrapped around the insertion tube, which contained strain gauges to measure force and torque. The mean peak pushing force was 17.9 N when the tip was in the sigmoid colon and at the hepatic and splenic flexures; however, forces greater than 10 N occurred only 5% of the total time.[10] The peak torque forces occurred when the tip was in the sigmoid colon and during shortening of the instrument.[10]

A second study evaluated the forces applied during colonoscopy in an in vitro model by using a transducer sheath that was integrated into 50 cm of a colonoscope insertion tube, proximal to the distal 11-cm flexible tip.[12] A 3-dimensional electromagnetic image-sensing catheter was placed into the biopsy channel to evaluate looping during the experiment. The outfitted colonoscope was used by an experienced endoscopist during a series of colonoscopies limited to the left side of the colon in a model that this team of researchers previously used and validated for measuring torque forces of the right hand.[32] Right-hand grip forces were also recorded. Grip forces steadily increased as the colonoscope was inserted into the model's sigmoid colon (maximum 9.3 N). The maximum force measured along sensors in the insertion tube was 12.7 N, with an average force of 0.28 N. Forces on the colonoscope appeared greatest during looping in the sigmoid colon. The forces measured on the colonoscope insertion tube were less than the grip forces applied externally by the right hand.[12]

A recently completed study addressed more directly whether the musculoskeletal load during colonoscopy approached levels associated with risk of overuse injuries.[21] Right-thumb pinch forces and right and left forearm muscle electromyography (EMG) activity was evaluated in 3 male endoscopists during 9 colonoscopies. Peak pinch forces of the right hand during insertion into the left and right colon exceeded 10 N, a level that is associated with increased risk of musculoskeletal injury of the thumb and wrist.[33,34] Peak muscle activity in the forearm muscles also exceeded safety thresholds established by the American Conference of Industrial Hygienists (ACGIH).[35] The ACGIH hand activity level is an ergonomic risk-assessment tool that compares hand activity and applied force, as a percentage of the maximal strength of the individual subject, to established thresholds above which a risk of injury exists. Activity of the left-wrist extensors (active in holding the control section of the colonoscope), the right-wrist extensors (active in torquing the insertion tube), and the left-thumb extensors (active in manipulating the colonoscope dials), exceeded the ACGIH hand activity level action limit, ie, a level at which general controls or surveillance are warranted according to the ACGIH. Peak muscle activity in the left-wrist extensors, which stabilize the instrument-control section, approached the ACGIH hand-activity–level threshold limit, a level at which redesign of the task is recommended by the ACGIH to reduce hand force and the risk of overuse injury.[21] Further study is needed to confirm these findings in a larger cohort of endoscopists.

In summary, the studies evaluating the forces exerted during colonoscopy vary in the measurement tool used and the types of forces recorded. However, these studies document potentially high peak forces during colonoscopy that may reach levels associated with an increased risk of musculoskeletal injury of the thumb and wrist. Mean forces throughout colonoscopy appear low. The greatest loads occur during insertion, especially into the sigmoid colon, presumably because of looping. Only one study evaluated EMG activity of the distal upper extremity during colonoscopy, and loads of the left-wrist extensors, the right-wrist extensors, and the left-thumb extensors approached levels at which general controls or surveillance was warranted.

Optimizing the ergonomics of endoscopy

No guidelines or published endoscopic studies were identified that evaluated optimal room setup, monitor height, or bed height during endoscopy. Therefore, the following recommendations for endoscopy are generally extrapolated from the laparoscopic surgery and general ergonomics literature.

Monitor location and height. The main determinants of upper-body postures are the location of the patient, placement of the endoscopy equipment, and location of the monitor. The monitor placement is an especially important determinant of torso and head posture. Optimal monitor position was studied in the surgical laparoscopy literature. Monitors should be placed directly in front of the endoscopist while in the position of "work," to avoid rotation and flexion of the cervical spine and should be adjustable to eye level, as has been anecdotally recommended.[16,22] One study of simulated laparoscopic suturing evaluated subjective and EMG measurements in 3 different monitor positions: in front at eye level, in front at the height of the operating field, and 45 degrees to the right at eye level. The neck and shoulder muscle activity was significantly lower when the monitor was positioned in front at eye level,[36] a position in which the cervical spine is in a neutral posture, with little lateral spine rotation. The findings were confirmed in a second laparoscopy study.[37] An unpublished study of gastroenterologists in Lisbon, Portugal[19] evaluated endoscopists' postures and perceived level of discomfort while performing EGD and colonoscopy within different room configurations. During EGD, when the monitor was at the head of the patient's bed, endoscopists were in cervical right rotation 77% of the time and cervical extension 29% of time. When the monitor was placed directly in front of the endoscopist at a fixed height during colonoscopy, neutral cervical posture was achieved 93% and cervical extension 25% of the time. Overall, perceived discomfort during both procedures was low.[19] Extrapolating from these studies, it appears that placement of the monitor directly in front of the endoscopist achieves a neutral neck posture and minimizes right and left cervical rotation. This position is likely associated with less discomfort and with optimal performance, although this has not been systematically studied among endoscopists.

Several studies evaluated optimal monitor height. A study of 8 laparoscopic surgeons found that the favored monitor position, when fixed at a distance of 120 cm, was achieved by placing the middle of the screen at approximately 20 cm lower than the height of the surgeon.[38] A randomized study of endoscopists, which compared a video headset versus a conventional video monitor, provides additional insight into optimal monitor height.[14] Image quality and comfort level were assessed with the 2 image display systems in 5 endoscopists during 96 colonoscopies. The video monitor was mounted from the ceiling at a fixed height, with its center 200 cm above the floor. The mean height of the endoscopists was 173 ± 5 cm. The headset was associated with reduced neck strain, although the video monitor had superior video image quality and was associated with improved comfort for all other parameters measured, including blurry vision and eye strain.[14] The laparoscopy study cited above[38] suggests that the optimal viewing height would be at eye level or lower (ie, <173 cm), indicating that the monitor was mounted too high for the endoscopists in this study. High monitor placement likely led to excessive cervical extension and neck strain.[38,39]

Optimal monitor height also depends on the distance of the monitor from the endoscopist. The optimal monitor distance can be extrapolated from the computer and laparoscopic literature. The optimal viewing angle for computer monitor use is 15 to 25 degrees below the horizon of the eyes.[25] In a study of the effects of visual display distance on eye accommodation, head posture, and vision and neck symptoms in computer users, the optimal distance was between near (52 cm) and middle (73 cm) distance from the eyes (taking into account screen-font size and the subject visual acuity).[40] A study of optimal viewing distance among 14 surgeons during simulated laparoscopic surgery that used a 34-cm cathode-ray–tube monitor (14-inch diagonal) concluded that the optimal distance was between 90 and 182 cm for close-up viewing (defined as the minimum view distance below which image degradation was experienced) and 139 to 303 cm for maximal distance viewing (defined as the maximal distance at which the finest details of an image could still be seen).[41] Taken together, we estimate that the optimal viewing distance of video monitors during endoscopy is between 52 and 182 cm. This is a broad range, which will depend on monitor size, image clarity, and endoscopist's preference.[42] Larger monitors can be placed at even longer viewing distances.

Overall, these findings suggest that monitor height should be adjustable so that it can accommodate the height of the endoscopist and the preferred viewing distance. Anthropometric data[25] can be applied to determine what degree of adjustability is required of a monitor in a typical endoscopy suite within the constraints of these viewing angles and monitor distances. To accommodate the 5th percentile female to the 95th percentile male eye height, the monitor should be adjustable such that the center of the monitor can be adjusted between 93 to 162 cm above the floor.

Optimal bed height. In a study of surgeons simulating laparoscopic tasks, the optimal operating table height was a compromise between spine and arm position.[43] The optimal height was between elbow height and 10 cm below elbow height. If physicians had to flex their trunks during a task to accommodate a lower table height, then there was an increase in discomfort with higher difficulty ratings. At higher bed heights, increased deltoid and trapezius EMG muscle activity was seen because of shoulder abduction.[43] Another study, of laparoscopic surgeons, found that optimal table height was 70% to 80% of elbow height, which allowed the joints to stay in a neutral posture over 90% of the procedure time.[44] By extrapolating from laparoscopy to endoscopy, we believe that the endoscopy gurney should be adjusted to allow holding of the endoscope between elbow height and 10 cm below elbow height to minimize forward flexion of the back and shoulder abduction. To accommodate the elbow height of the 5th percentile female to the 95th percentile male,[25] the examination bed should be adjustable between 85 and 120 cm.

Procedural specific recommendations

EGD. EGDs generally are short procedures, with a mean (SD) procedure time of 14 ± 6 minutes.[45] In this short time frame, it is unlikely that there will be significant prolonged loads on the endoscopist. Thus, the most important factor is maintenance of neutral body postures.

Colonoscopy. The mean (SD) times for a diagnostic colonoscopy without or with biopsy are 23.4 ± 11.1 minutes and 26.4 ± 12.5 minutes, respectively.[45] Colonoscopy can lead to overuse injury because of repetition, high forces while maneuvering the colonoscope tip, and prolonged awkward postures. The left-wrist extensors (which stabilize the instrument control section) appear to be at greatest risk for injury.[21] In a case study, ''colonoscopist's thumb'' or DeQuervain's tenosynovitis (wrist tendonitis at the first extensor compartment) was attributed to left-thumb strain because of repeated turning of the dials of the control section of the colonoscope.[11] At this time, there are limited options to reduce hand or wrist loads during endoscopy. If a procedure requires additional use of the right-left dial to negotiate a turn, then a technique called the ''left hand shaft grip'' has been proposed.[15] This technique consists of holding the control section with the left thumb, index finger, and middle finger while simultaneously supporting the insertion tube with the left-hand fourth and fifth fingers, so that the right hand is free to assist in turning the right-left dials during sharp turns or for added precision during endoscopic therapy. A variation of this technique, the ''pinkie maneuver,''[13] also has been described. A 2-handed technique has been postulated to reduce the risk of left-thumb injury but has not been formally studied and, in general, is not thought to be as efficient as the one-handed technique to control the dials.[22] In an attempt to minimize the risk associated with the repetition of colonoscopy, it is important to be aware of hand and wrist postures during endoscopy and to recognize the potential for fatigue in the hand and forearm muscles. Recovery time is important. A break from endoscopy allows the heavily used muscle groups to recover.[25] This ''break'' can be the time used to complete an endoscopy report. Neither 2-person colonoscopy nor seated colonoscopy has been studied. Changes in colonoscope design, such as the use of a joystick, trackballs, or pushbutton devices, offer theoretical ergonomic advantages. New endoscopic devices are under development,[46] although their ergonomic impact has not been formally studied.

ERCP. In addition to the factors discussed above pertaining to upper endoscopy and colonoscopy, ERCP uses an elevator, which increases the left-thumb load. In addition, ERCP involves the static load of the lead apron. Lead aprons can weigh up to 6.8 to 9.1 kg (15-20 pounds) but can apply a load of approximately 2068 kPa (300 pounds per square inch) on the intervertebral disk spaces.[7] Eleven percent of 237 endoscopists who participated in an online ASGE survey reported problems with lead aprons.[4] In a survey of interventional cardiologists, approximately 42% of 424 respondents reported spinal problems.[47] In a case-control study of interventional cardiologists (n = 385), orthopedic surgeons (n = 131), and rheumatologists (n = 198), significantly more interventional cardiologists (7%) reported cervical disk disease than orthopedists (0.3%) or rheumatologists (0%).[48] Prior studies documented an increased risk of acute prolapsed cervical intervertebral disk associated with frequent lifting of 11.3 kg (25 pounds),[48] and it can be argued that the weight of a lead apron coupled with cervical disk extension caused by improper monitor placement can increase cervical intradisc pressure[39] and risk of injury.[48] Although this issue has not been systematically studied in ERCP, 2-piece lead shields may more evenly distribute the load across the spine and pelvis. As noted, it is important to place the endoscopic and fluoroscopic monitors in front of the endoscopist and at the proper height to avoid neck extension or lateral rotation.[7]

EUS. Mechanical echoendoscopes are much heavier (the weight of the control section is approximately

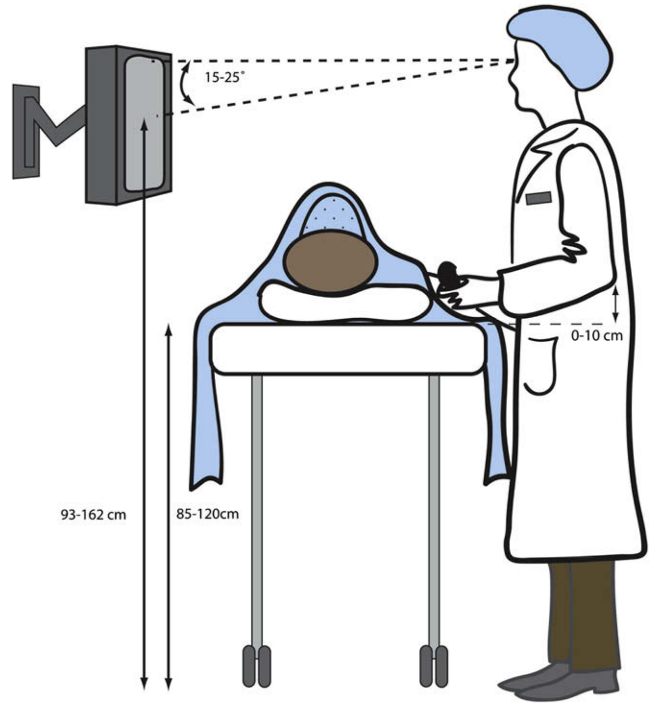

Figure 1. Recommended endoscopy suite layout with adjustable height patient bed and adjustable monitor. The monitor should be positioned directly in front of the endoscopist while endoscopy is performed. Monitor height should be just below eye level, with an optimal viewing angle of 15-25 degrees below the horizon from the eyes to the center of the monitor and an optimal viewing distance between 52 and 182 cm. To accommodate the 5th percentile female to the 95th percentile male height, the monitor height should be adjustable from 93 to 162 cm. The examination table should be at or below elbow height (0-10 cm below the elbow). To accommodate the 5th percentile female to the 95th percentile male elbow height, the examination table height should be adjustable from 85 to 120 cm.

0.9 kg), and produce increased static loads on the left hand and wrist compared with electronic echoendoscopes (weight of control section approximately 0.5 kg). Endoscopists should preferentially use the electronic echoendoscopes whenever possible.

Personal factors

Use of corrective lenses. Our visual ability to accommodate decreases as we age, resulting in presbyopia. This leads to the use of bifocal or progressive addition lenses (PAL) that allow the user to correct both near and far visual acuity with one pair of eyeglasses. Endoscopists who wear bifocal or PAL lenses during endoscopy may need to extend their neck to see through the bottom of the lenses, depending upon their distance from the monitor. If the monitor is positioned too high, this can lead to prolonged and excessive neck extension. To prevent this, endoscopists should consider the use of dedicated monofocal lenses or so-called ''endoscopy lenses,'' which function much like ''computer glasses'' to provide the needed correction for monitor viewing at a comfortable distance in order to maintain a neutral neck and resting-eye position. For endoscopists who wish to use bifocals or PAL lenses, the height of the monitor should be lowered to prevent neck extension.

Summary

In summary, the prevalence of musculoskeletal complaints has been shown to be higher for endoscopists than for other medical specialties, with a range of 37% to 89%. GI endoscopy is associated with several risk factors for overuse injury: repetitive hand motion, high hand forces, and awkward wrist, shoulder, and neck postures. Further study is needed to determine how workstation design and tool design changes can reduce these injuries. To optimize the ergonomics of endoscopy, we recommend the following:

- The endoscopy suite should be set up with the monitor positioned directly in front of the endoscopist while endoscopy is performed (Fig. 1).
- Monitor height should be just below eye level, with an optimal viewing angle of 15 to 25 degrees below the horizon from the eyes, with a viewing distance of 52 to 182 cm, depending on monitor size and endoscopist preference. To accommodate the 5th percentile female to the 95th percentile male eye height, the monitor height should be adjustable from 93 to 162 cm.
- The examination table should be at or below elbow height (0-10 cm below the elbow). To accommodate the 5th percentile female to the 95th percentile male elbow height, the examination table height should be adjustable from 85 to 120 cm.
- During ERCP, a 2-piece apron should be used to reduce loads on the upper back and cervical spine.
- Electronic EUS scopes should be used in favor of the mechanical EUS scopes whenever possible.
- Recovery time between endoscopies is important. A break from endoscopy allows the muscle groups to rest and ''pay back'' some of the lactic-acid debt that was incurred during a work cycle of endoscopy.

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