

Minimizing occupational hazards in endoscopy: personal protective equipment, radiation safety, and ergonomics

The ASGE Technology Committee provides reviews of existing, new, or emerging endoscopic technologies that have an impact on the practice of GI endoscopy. Evidence-based methodology is used, by using a MEDLINE literature search to identify pertinent clinical studies on the topic and a MAUDE (U.S. Food and Drug Administration Center for Devices and Radiological Health) database search to identify the reported complications of a given technology. Both are supplemented by accessing the “related articles” feature of PubMed and by scrutinizing pertinent references cited by the identified studies. Controlled clinical trials are emphasized, but in many cases, data from randomized, controlled trials are lacking. In such cases, large case series, preliminary clinical studies, and expert opinions are used. Technical data are gathered from traditional and Web-based publications, proprietary publications, and informal communications with pertinent vendors.

Technology Status Evaluation Reports are drafted by 1 or 2 members of the ASGE Technology Committee, reviewed and edited by the committee as a whole, and approved by the Governing Board of the ASGE. When financial guidance is indicated, the most recent coding data and list prices at the time of publication are provided. For this review, the MEDLINE database was searched through August 2009 for articles related to personal protection equipment by using the key words “personal protection equipment” (exp Protective Clothing/ or exp Protective Devices/ or exp Masks/ or exp Occupational Exposure/”) “infection control” paired with “Endoscopy.” For the radiation section, the following key words were used: “radiation and endoscopy,” “radiation and ERCP,” and “radiation safety.” For the ergonomics section, the following key words were used: “ergonomics of endoscopy,” “endoscopist injury,” “medical ergonomics,” “endoscopy and musculoskeletal strain,” “musculoskeletal injury and endoscopists,” “occupational diseases and endoscopy,” “cumulative trauma disorder and endoscopy,” “repetitive strain injury and endoscopy.”

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BACKGROUND

Personnel performing or present during GI endoscopy and individuals handling endoscopy equipment are exposed to many potential hazards. These include body fluid and chemical exposures, laser and radiation exposure, and musculoskeletal injuries. Protection for the endoscopic staff exposed to these hazards can best be accomplished by consistent application of safety practices. Regulatory guidelines established by Occupational Safety Health Administration (OSHA) requires employers to evaluate the risk potential of each task, provide training and the necessary protective equipment and apparel, and ensure their appropriate use to protect employees from exposure to harmful substances and potentially infectious materials.¹ There are no endoscopy-specific requirements that have been published. The Centers for Disease Control and Prevention (CDC) provides guidance for the selection and use of personal protective equipment (PPE) (Table 1).² The Joint Commission on Accreditation of Healthcare Organizations does not have endoscopy-specific requirements but bases its standards on CDC guidance requiring a facility to have written infection prevention and control goals. The facility must implement these prevention measures and use standard precautions, including the use of personal protective equipment, to reduce the risk of infection.³

Infection control during GI endoscopy including the reprocessing of endoscopes and transmission of microorganisms by endoscopy has been reviewed in a separate American Society for Gastrointestinal Endoscopy practice guideline.⁴ Another recent joint society guideline reviews radiation safety concerns for patients.⁵

TECHNICAL CONSIDERATIONS

PPE

PPE refers to a variety of barriers used alone or in combination to protect the skin, mucous membranes, airways, and clothing from contact with blood-borne pathogens and other potentially infectious materials (OPIMs).²

TABLE 1. Safety measures for endoscopists and assistants

Safety feature	Level of recommendation
PPE	OSHA required*/CDC recommended†
Gowns	
Gloves	
Eye protection/face shields	
Masks/face shields	
Radiation safety	
Lead aprons	Required‡
Thyroid shields/leaded eyeglasses	Optional‡
Ergonomics	
Adjustable monitor height	Optional
Adjustable procedure table height	Optional
Two-piece lead aprons	Optional

CDC, Centers for Disease Control and Prevention; OSHA, Occupational and Safety Health Administration; PPE, personal protective equipment.

*OSHA regulation 1910.1030(d)(3)if potential for exposure to blood-borne pathogen or OPIM from splashes, spray, spatter, or droplets.¹

†CDC recommends features of PPE and process for use in care settings with blood borne pathogen or OPIM exposure anticipated.²

‡Regulated by individual state agencies.

OPIM relevant to GI procedures include saliva, gastric and pancreaticobiliary secretions, feces/colonic effluents, and ascitic fluid. PPE includes specialized gowns or aprons, gloves, masks, respirators, goggles, and face shields. It is important to note that general work clothes (uniforms, pants, shirts, surgical scrubs, lab coats) or personal clothing not intended to function as protection against a hazard are not considered PPE.

Universal precaution recommendations are now encompassed within and redefined as standard precautions that assume that every patient is potentially infected with an organism that could be transmitted in the health care setting. Consequently, infection control practices are necessary during the delivery of health care to all individuals.²

Gowns are recommended to protect the skin and clothing from contamination with blood and OPIMs during procedures. Recent testing standards (Association for the Advancement of Medical Instrumentation PB70) provide an objective measure of liquid barrier performance of gowns and their level of protection.⁶ Adopted by the U.S. Food and Drug Administration (FDA) as a standard for product testing, this classification system determines 4 levels of fluid resistance from level 1 (least protective) to

level 4 (most protective, fully impervious surgical gown). Any gown not classified at least as level 1 is deemed nonprotective. For most surgical procedures, at least an Association for the Advancement of Medical Instrumentation level 3 has been recommended by several manufacturers. As a consequence of possible heavy exposure to fluid in endoscopic procedures and a significant potential for fluid penetration of the gown, a higher level of protection (level 3 or higher) against moderate to heavy fluid contact is advisable. Both disposable and reusable gowns are available (Table 2). Disposable gowns may be made of plastic, paper, or a composite. Reusable gowns are usually made of fabric that is laundered between uses, although they are limited by a finite number of washings before the barrier is no longer effective.

Gloves should be worn during all procedures, handling patient care equipment, or touching contaminated environmental surfaces.⁷ Among the factors in selecting gloves are barrier properties, patient allergies, staff allergies/sensitivities, comfort, and tactile sensitivity. Prolonged use of latex gloves may cause skin sensitivity, contact dermatitis, or de novo latex allergy.⁸ Synthetic nonsterile disposable gloves are available in materials such as nitrile (Table 2). Vinyl gloves have a higher failure rate in clinical settings so they are not recommended by the CDC.² Because gloves may leak even without obvious damage, hand hygiene should always be performed immediately after removing PPE. The FDA provides guidance on minimum safety requirements for medical gloves.⁹ This includes instructions for 510k specifications and the distinctions required for medical examination gloves, chemotherapy gloves, and surgeon's gloves. Because sterility is not required, most gloves used for PPE in endoscopy are medical examination or chemotherapy gloves.

In addition to the risk of direct splash to the eye, both conjunctivitis and systemic infection can also occur from touching the eyes with contaminated fingers or other objects.^{10,11} Protective eyewear must meet certain minimum requirements under the OSHA standard. They should be designed to provide adequate protection against the particular hazards to which the employee is exposed. Eye protection must be comfortable, allow for sufficient peripheral vision, and must be adjustable to ensure a secure fit. It may be necessary to provide several different types, styles, and sizes to properly fit all endoscopy staff. Appropriately fitted, indirectly vented goggles or face shields with antifog coating provide the most reliable practical eye protection from splashes, sprays, and respiratory droplets likely to be encountered in GI endoscopy (Tables 1 and 2). An antifog feature improves the visual clarity. Personal eyeglasses and contact lenses are not considered adequate protection.

The mucous membranes of the mouth, nose, and eyes may act as portals of entry to infectious agents. The skin may also act as a portal when its integrity is compromised by trauma or disease (eg, acne, dermatitis). Masks should

TABLE 2. Representative PPE products

PPE	Manufacturer	Features*	Price range per unit (\$)†
Gowns	Busse (Hauppauge, NY)	Spunbonded polypropylene gown, repellent fluids, full or open back	0.90-1.20
	Cardinal Health (Dublin, Ohio)	SMS isolation gowns, fluid resistant	2.30-3.20
	Kimberly-Clark (Dallas, Texas)	Impervious gowns, universal size, plastic film, open back with thumb hooks,	1.60-4.40
	McKesson (San Francisco, Calif)	Impervious gown, blue, universal, performance backless, splash resistant, slips over head	0.89-1.86
	Medline (Mundelein, Ill)	Coated polypropylene or SMS material, nonsterile, open- or closed-back gowns, thumb loop or elastic wrists	1.20-1.30
	Owens & Minor (Richmond, Va)	Fluid-resistant gowns, heavier weight SMS gown	0.92
	Regional vendors	Reusable composite fabric procedure gown	1.20-2.20‡
Eye protection	DeRoyal (Rose Hill, Va)	Protective glasses, wraparound, antifog and static, replacement lenses	1.16
	Fisher (Pittsburgh, Pa)	Protective glasses, lightweight, disposable	1.52
	Kimberly-Clark	Protective eyewear, disposable or reusable, frames, shields, replacement lenses	1.70-21.20
	Uvex (Fuerth, Germany)	Goggles, clear lens polycarbonate, disposable or reusable	2.04-29.00
Face shield	DeRoyal	Antifog face shield, antiglare, vented foam, Velcro strap	3.28
	Kimberly-Clark	Fog-free face shield, wraparound design, full facial coverage	2.40-2.70
	Medline	Disposable face shield, band and contoured foam	1.63-1.85
Masks	Cardinal Health	Splash-resistant procedure mask, ear loops, fog free	0.30-1.00
	Kimberly-Clark	Tie-on mask, pleated with ear loops, with and without shield, fog-free with visor	0.19-1.19
	McKesson	Yellow procedure mask, ear loops	0.30-1.02
	Molnycke (Norcross, Ga)	Filtered mask, ear loop	0.26-1.58
Gloves	Cardinal Health	Nitrile or latex examination gloves, powder or powder free, microtextured, emollient coating	0.08-0.30
	Kimberly-Clark	Purple nitrile examination gloves or latex, extra-long 12-inch length, sterile and nonsterile	0.09-2.62
	Medline	Synthetic, nitrile examination gloves	0.06-0.09
	McKesson	Latex or nitrile, powder-free examination gloves, texture	0.06-0.12
	Microflex (Reno, Nev)	Supersoft nitrile formulation, extended cuff	0.09-0.27
	Molnycke	Sterile, nonlatex or latex, powder free	2.63

PPE, personal protective equipment; SMS, Spunbond-Meltblown-Spunbond nonwoven material.

*Because of the extensive number of products in the market, prices and features available in some products are for general reference only.

†Prices obtained from a survey of vendors (August to October 2009). Pricing may vary based on local contracts.

‡Rent per gown per week.

fully cover the nose and mouth to prevent fluid penetration and need to be used in combination with goggles. There are 2 types of masks available: surgical masks and procedure (isolation) masks. Only surgical masks are regulated by the FDA and are required to have fluid-resistant properties. Because procedure masks are not evaluated by the FDA, there may be significant variability in their protective performance. Masks are available in a variety of materials and shapes (molded and nonmolded) (Table 2). A fluid shield layer may be present to improve fluid resistance. Masks may be secured in different ways such as head ties, elastic head bands, and ear loops. Some masks may still contain latex. Face shields (disposable or nondisposable) that attach to the forehead and extend down to cover the eyes, face, nose, and mouth are an alternative to goggles and masks. However, masks with attached small eye shields extending upward should not be relied on as optimal eye protection.¹²

The CDC recommends that the provider remove PPE and perform hand hygiene before leaving the procedure room.² Keeping in mind that the outside of gloves, goggles, face shields, and gowns are contaminated, the CDC has a recommended sequence for removing PPE.¹³ First, remove the gloves and discard. Second, remove the goggles by the ear pieces (or face shields by head band). Third, unfasten the gown ties and pull it away from neck and shoulders and discard. Last, remove the mask by unfastening the bottom and then the top ties or elastics and discard. Gowns should be removed after each procedure and not reused. Furthermore, the CDC provides instructional material such as posters and videos that demonstrate the sequences for donning and removing dirty gowns and other PPE.¹³

This PPE should also be worn by personnel responsible for endoscope and device disinfection. Individual high-level disinfection agents are associated with a different potential for toxicity, and personnel should be provided manufacturer's handling instructions. During the early phases of equipment reprocessing, care should be taken to avoid aerosolization of these agents, some of which can cause skin and mucous membrane irritation or allergic reactions in staff and patients.

Radiation Safety

The use of fluoroscopy to aid endoscopic procedures, including ERCP and other interventional procedures, places both the patient and the endoscopy staff at risk of radiation-induced injury.^{14,15} A person's biological risk (ie, the risk that a person will experience adverse health effects from an exposure to radiation) is measured by using the conventional unit rem (radiation equivalents in man) or the SI unit equivalent called the sievert, where 1 Sv = 100 rem. Estimates of radiation exposure to endoscopy staff vary, but it should be noted that radiation exposure is cumulative over time. In a recent small study of 66 procedures, the estimated annual whole-body effective dose

equivalent received by the endoscopists ranged between 3.35 and 5.87 mSv.¹⁶ This dose is thought to be within safety limits for radiation exposure to personnel. The International Commission on Radiologic Protection has classified radiation exposure as low (≤ 3 mSv per year, which is the background level of radiation from natural sources in the United States), moderate (3–20 mSv per year, which is the upper annual limit for occupational exposure for at-risk workers averaged over 5 years), or high (>20 –50 mSv per year, the upper annual limit for occupational exposure for at-risk workers in any given year).¹⁷ For diagnostic x-ray use in the United States, regulations related to monitoring annual exposure limits of health care personnel are established by state agencies.

Exposure of endoscopy staff to radiation can be limited by using several techniques. The first and most obvious step is to limit the time of application of radiation to the patient. Others include appropriate shielding and increasing the distance of the staff from the radiation beam. Hospital credentialing programs with periodic updates for medical staff using fluoroscopy are important to educate the clinician on the appropriate and safe use of fluoroscopy for the patient and endoscopy unit personnel.

The overriding principle for the use of fluoroscopy in the endoscopy suite is guided by the concept of ALARA or to use radiation doses "as low as reasonably achievable." Preset audible alarms at fixed intervals can be used as a reminder of total fluoroscopic time. Fluoroscopy units are generally stationary dedicated units or mobile C-arm units, and the latter have been associated with higher radiation exposures. All modern fluoroscopy equipment comes with a last image hold feature. This feature retains the last fluoroscopy frame on the monitor and therefore lessens the need for continued fluoroscopy. The use of pulsed fluoroscopy with the pulse rate set as low as practical provides a significant reduction in the absorbed dose.¹⁸ Endoscopists should minimize use of the boost and magnification modes during fluoroscopy and should collimate down to the anatomic region of interest. In addition, determining the areas to be imaged before irradiation can reduce unnecessary panning. Advances in imaging such as EUS and MRCP have reduced the need for diagnostic ERCP studies and may be alternatives to help reduce the exposure of both patients and endoscopy staff to radiation.

The primary source of radiation to endoscopy personnel is from radiation scattered from the patient. Positioning one as far away from the patient as possible is essential in limiting exposure. If an endoscopy staff member is standing 1 m from the patient, the radiation exposure for that individual is 1/1000 the patient's exposure. For radiation from a point source, exposure of an individual decreases by the inverse square of the distance from the source. If the endoscopist moves twice as far away from the radiation source, the radiation exposure will approximately drop by a factor of 4. When fluoroscopy is in use, a warning light outside the fluoroscopy room should come

on to alert individuals not to enter the room. There are no specific design specification recommendations for endoscopic fluoroscopy rooms as opposed to other x-ray rooms.

Shielding is required for all staff in the fluoroscopy unit (Table 1). Aprons containing lead shielding 0.5 mm thick are standard in most fluoroscopy units and block more than 90% of scattered radiation. When procedures are performed that require individuals to turn away from the radiation source, wraparound lead aprons should be used. Lightweight 2-piece aprons transfer half to the weight to the user's hips, decreasing the strain on shoulders and back. Newer lead aprons include thyroid protection as part of the apron. Lead aprons should be hung vertically to prevent cracks and tested radiographically for defects on an annual basis.^{19,20} Optically clear lead glasses can reduce the operator's eye exposure by 85% to 90%. There are no mandatory requirements for either thyroid shields or leaded glasses, although many recommend the thyroid shield routinely and leaded glasses for individuals with high case loads.¹⁴ Lead skirts covering the operator side of the fluoroscopy unit may provide added protection. Stand-alone mobile shields have been introduced in some endoscopy units to further reduce exposure.

Exposure detection programs are an important component of radiation safety. Although there may be institutional variation, a radiation-exposure dosimeter (ie, badge) should be worn exterior to lead shielding at collar level.¹⁴ If a second badge is worn, it should be worn at waist level underneath the lead apron. The collar dosimeter gives a good estimate of neck and head exposure but overestimates whole-body dose. Similarly, the dosimeter under the apron at waist level underestimates the whole-body dose. Each staff member should receive a regular report of radiation exposure. An unexpected increase in exposure should prompt an investigation to determine the cause of the aberrant values.

There are unique aspects in the radiation safety for pregnant personnel. There are no mandatory requirements for pregnant individuals to avoid fluoroscopy, and reporting pregnancy to a radiation safety officer is voluntary. State regulations generally recommend limiting the dose to the fetus to 500 mrem over the entire gestation. A second dosimeter is often worn under the lead apron in pregnant personnel to help monitor fetal exposure, and film badges should be monitored monthly. Maternity-style lead aprons are commercially available.

Ergonomics

Ergonomics is the study of workplace design. The goal of ergonomics is to optimize the interaction of the operator with his or her tools, work tasks, and workplace to minimize injury and maximize efficiency.²¹ Risk factors for work-related strain injury include repetition, prolonged awkward postures, high forces, contact stress, and vibration.²² Importantly, GI endoscopy involves many of these

risk factors, with repeated pinching or gripping of the endoscope and pushing, pulling, and torquing of the insertion tube in potentially awkward postures.

Gastroenterologists spend 43% of their time performing endoscopic procedures and perform an average of 12 EGDs and 22 colonoscopies per week.^{23,24} The need for ergonomic evaluation is paramount, considering studies highlighting overuse injuries in endoscopists. Survey-based studies have estimated a prevalence of musculoskeletal symptoms ranging from 37% to 89%.²⁵⁻³² Pain in the thumb, hands, neck, and back were most commonly reported,^{25,27-31} and, not surprisingly, the risk of injury seems to be related to procedure volume.^{25,29,30,32} Potential mechanisms of injury include the repetition, potentially high forces, and sustained awkward postures associated with GI endoscopy. Studies measuring forces during colonoscopy have demonstrated high peak forces, especially during colonoscope insertion, which may reach levels associated with an increased risk of injury to the thumb and wrist.³³⁻³⁶ A quantitative analysis of these risk factors and the potential for upper extremity biomechanical overload was recently conducted by using the Occupational Repetitive Actions (OCRA) index in 6 Italian endoscopists.³⁷ The OCRA index is an ergonomic risk-assessment tool that considers all repetitive tasks in a work cycle and stratifies the risk of injury into 3 levels: green (no risk), yellow (low risk), and red (risk).³⁸ The 6 endoscopists were evaluated during 2 different insertion methods: 1-person versus 2-person endoscopy. For all procedures, the endoscope was held by the subject's left hand, and the right hand was used to turn the dials. This study found slight exposure levels (OCRA scale = green-yellow, no or low risk) for the left upper limb and medium to high exposure levels (OCRA scale = red, risk) for the right upper extremity, with no difference in risk between 1-person and 2-person endoscopy. A concomitant survey assessing the prevalence of diagnosed upper extremity disorders found that 40% of 88 surveyed endoscopists had already had a diagnosis of an upper extremity disorder, mostly in the hand-wrist area. Used as a prediction tool, the OCRA index estimates that after 10 years of exposure, approximately 10% of endoscopists would be expected to have an upper extremity musculoskeletal disorder.³⁷

Clearly, basic ergonomic principles should be incorporated into the practice of endoscopy. One important ergonomic principle is the maintenance of neutral postures, which allows for maximal force production with minimal energy expenditure.²¹ To achieve neutral postures, the workplace should be designed with enough flexibility to fit the majority of the demographically diverse population of gastroenterologists. One route to this goal would be through the application of anthropometry, which is the study of human dimensions, to the design of the endoscopy suite. In general, the workplace should accommodate the fifth percentile female to the 95th percentile male²¹ (Table 1).

The first step is assessment of the changeable elements in the workplace environment. The main determinants of upper body posture in the endoscopy suite are the locations of the monitor and the patient in relation to the endoscopist. To neutralize neck and back postures, the monitor should be located directly in front of the endoscopist. The monitor height should be adjustable to accommodate the height of the endoscopist and his or her preferred viewing distance. The optimal viewing angle is 15 to 25 degrees below the horizon of the eyes,²¹ and thus the monitors should be placed with the middle of the screen at or below eye level. The optimal monitor distance has not been formally studied in GI endoscopy, but will depend on monitor size, image clarity, and endoscopist preference³⁹ and has been estimated to be between 52 and 182 cm (20.5-63.8 inches).⁴⁰ Monitor booms and mobile stands facilitate flexible positioning. To accommodate the optimal viewing angle and the range of monitor distances for the fifth percentile female and the 95th percentile male eye height, the center of the monitor should be adjustable between 93 and 162 cm (36.6-63.8 inches) above the floor.⁴⁰ The procedure table should also be adjustable to allow for neutral elbow, shoulder, and back postures. Optimally, the endoscope insertion tube should be held by the right hand between elbow height and 10 cm below elbow height.⁴⁰ This will minimize forward flexion of the trunk and abduction of the right shoulder. To accommodate the fifth percentile female to the 95th percentile male elbow height, the procedure table should be adjustable between 85 and 120 cm (33.5-47.2 inches).⁴⁰

Equally important to thoughtful workplace design is optimizing the interaction between the gastroenterologist and the endoscope. EGD is inherently shorter in duration relative to other endoscopic procedures.⁴¹ The short duration of EGDs minimizes the exposure of the endoscopists to significant loads. Colonoscopy with or without biopsy is typically longer in duration and requires more time to advance and withdraw the instrument compared with EGD.⁴¹ The repetition and potential for high forces while maneuvering the colonoscope tip can lead to overuse injury. The left hand is active in gripping the control section of the colonoscope, the left thumb is active in turning the dials of the colonoscope, and the left wrist is important in stabilizing the control section. The right hand pinches or grips the insertion tube, and the right arm is active in pushing, pulling, and torquing the colonoscope. Previous studies have demonstrated the potential for injury to the left thumb, right thumb, and left wrist during colonoscopy.^{35,42} Currently, there are limited options to reduce hand or wrist loads during endoscopy. A technique called the "left hand shaft grip" has been described to provide assistance to the left thumb during sharp turns or difficult polypectomies.⁴³ Recognizing muscle fatigue and allowing for adequate break times are important to allow the muscles to rest.²¹ Changes in endoscope design offer theoretical advantages, and new ergonomically favorable

endoscopic devices are currently under development.⁴⁴ Many of these new technologies would eliminate the need for an endoscopist to maneuver the colonoscope through the colon because it is self-propelled and either self-navigating or guided by a joystick.⁴⁴⁻⁴⁷ However, most are not yet commercially available.

More advanced endoscopic procedures also confer risk to the operator. For example, ERCP, which already involves the risk factors associated with upper and lower endoscopy, contains an additional load on the left thumb because of the elevator. Furthermore, the ERCP operator is burdened with an increase in static load on the neck, shoulders, and back because of the use of lead aprons, which can weigh as much as 9.1 kg and can apply a load of approximately 2068 kPa (300 lb per square inch) in the intervertebral disc space.³¹ The use of lead aprons has not been systematically studied in ERCP, but a 2-piece lead apron offers a theoretical advantage because the load can be more evenly distributed between the spine and pelvis.⁴⁰ Similarly, echoendoscopes may be associated with increased rates of overuse injury. The older mechanical echoendoscopes have their motor mounted on the control handle. These models are therefore significantly heavier than electronic echoendoscopes (weight of control section approximately 0.9 vs 0.5 kg, respectively) and will expectedly produce an increased static load on the left hand and wrist.⁴⁰ Static loading will lead to decreased muscle perfusion and accumulation of lactic acid, which can lead to muscle fatigue and pain.⁴⁸ Thus, whenever possible, electronic echoendoscopes should be favored over the older mechanical echoendoscopes. Balloon-assisted enteroscopy is also associated with prolonged procedure times and extensive right arm repetitive maneuvers and may predispose the endoscopist to injury.

Even with optimal monitor and bed heights, the static standing posture during endoscopy can be problematic. Survey-based studies have reported discomfort in the feet, legs, and back that respondents have attributed to prolonged standing.^{28,30} Cushioned mats are thought to decrease standing fatigue by causing minor postural instability, leading to subtle movements of the muscles that can increase blood flow to the legs, and are often recommended in standing workplaces, especially for jobs requiring prolonged standing on hard surfaces.^{49,50} Mats need to be easily cleaned or disposable given the types of procedures frequently performed in GI endoscopy and should be slip resistant to minimize risk of falls.⁴⁹ Cushioned insoles provide another option to improve comfort from prolonged standing.

INDICATIONS AND EFFICACY

The intent of OSHA is to guide the correct use of PPE for each anticipated exposure. CDC documents provide guidance on the selection, use, and removal of PPE.^{2,13} Currently, there are no guidelines for PPE use specific for

GI endoscopy, but given the inherent risk of splashes or spattering of OPIM or blood during endoscopy, PPE should be used based on OSHA and CDC standards (Table 1). It is up to individual institutions to assess the risk of exposure, select appropriate PPE, provide appropriate training, and monitor compliance in their use.

As noted previously, standard precautions assume that blood and body fluid of any patient could be infectious, and PPE is indicated whenever there is a potential for exposure. The CDC recommends that under Standard Precautions: "Gloves should be used when touching blood, body fluids, secretions, excretions, or contaminated items and for touching mucous membranes and non-intact skin. A gown should be used during procedures and patient care activities when contact of clothing and/or exposed skin with blood, body fluids, secretions, or excretions is anticipated. Mask and goggles or a face shield should be used during patient care activities that are likely to generate splashes and sprays of blood, body fluids, secretions, or excretions."² Based on these principles, it is recommended to use appropriately fitted gloves, gowns, masks, and goggles or a face shield when performing GI endoscopy. Surveys among endoscopy personnel suggest low use of these important safety measures. Less than half of gastroenterologists reported that they always complied with universal precautions.⁵¹ However, mucocutaneous exposures occur more frequently during endoscopy than is usually appreciated by the endoscopist. In 1 study, there was a reported 9.5% splash rate to the skin of the face, forearms, and feet and 4.1% to the eyes.¹¹

Lead aprons are indicated for all individuals in the procedure room when fluoroscopy is performed. There are few studies examining specific measures to reduce radiation exposure during GI endoscopy. Studies have demonstrated that recording total procedure radiation exposure times is associated with a reduction in fluoroscopy time.⁵² In another study of 199 ERCPs, limiting x-ray exposure to 3-second intervals compared with continuous exposure was associated with a 16.4% decrease in fluoroscopy time.⁵³ Although not required in most states, the added protection of a thyroid guard has been shown to reduce the total body effective dose by 46% per year.⁵⁴ In addition, free-standing mobile radiation shields have also been shown to reduce radiation exposure by more than 90%.^{55,56}

The ergonomic measures to reduce injury are based on mechanical principles of musculoskeletal strain, and studies examining the outcome of select measures are limited. No studies have evaluated interventions to reduce the risk factors associated with repetitive strain injury in GI endoscopy. However, general workplace interventions have been evaluated in the ergonomics literature. For instance, during ERCP, 2-piece lead aprons offer a theoretical advantage. In a pilot study with a crossover design, 5 radiographers compared 2-piece, 1-piece, and 1-piece lead aprons with a waist belt. The 1-piece lead apron was

associated with significantly more discomfort in the neck and low back compared with the 2 other lead aprons.⁵⁷ A biomechanical analysis of a radiologist wearing a 15-lb 1-piece lead apron demonstrated a force of 300 lb per square inch on the low back, which was reduced by 80% with the use of a 2-piece lead apron.⁵⁸ For floor antifatigue mats, previous studies have demonstrated that subjective ratings of fatigue and discomfort in the lower extremities and back are improved with the use of softer flooring.⁵⁹ However, there is no objective evidence of the benefit of softer flooring as measured by changes in electromyographic muscle tone, leg volume, and postural movements.⁵⁹ Similarly, insoles have been associated with subjective improvements in comfort and fatigue, suggesting a possible benefit, but no objective benefit has been consistently demonstrated.^{50,59} In fact, antifatigue mats and insoles have not been evaluated in endoscopy, and several factors need to be considered that are specific to the endoscopy suite. Compression stockings, which have been shown to reduce edema and improve subjective symptoms of discomfort in subjects with chronic venous insufficiency and in healthy females, can be considered during prolonged standing.^{60,61}

FINANCIAL CONSIDERATIONS

It is the health care facility's responsibility to provide PPE and to ensure its appropriate use at no cost to the employee. Failure to comply with these OSHA regulations may expose the health care worker to risk of infections and the facility to penalties for noncompliance. With the development of newer, single-use and more efficacious PPE, the cost may be significant. Costs do vary markedly based on product specifications and contractually established pricing, but for the most commonly used disposable gowns, masks, eyewear, and nonsterile gloves, an average cost of PPE per case is estimated at \$5.20 (Table 2). This estimated cost is based on the assumption that none of the PPE is reused. Also the cost of PPE per procedure is a function of the number of wearers and the amount and type of PPE used per person. The use of these items is an inherent expense of the safe performance of endoscopy.

A lead apron costs approximately \$150.00 to \$300.00 and thyroid shields approximately \$50.00. Leaded glasses cost as much as \$300.00 depending on the style. There may also be a finite cost to enhancing the ergonomic flexibility of the endoscopy lab, particularly with respect to video monitor positioning and procedure table features. Ideally, these considerations should be included in design and construction plans. Proper functioning of endoscope tip deflection controls is also an important means of avoiding excessive strain and maintenance, and repair costs should consider this safety measure. From a personnel standpoint, musculoskeletal injuries can lead to lost time from work and lost productivity.

SUMMARY

PPE, when used properly, can protect health care personnel from harmful exposure. Attention to special needs such as natural rubber latex allergies of both staff and patients, the liquid barrier performance of gowns, proper fitting, training, and supervision are necessary for proper use. The selection of appropriate PPE should be individualized to the type and degree of exposure anticipated. The appropriate use of fluoroscopy in GI endoscopy and the application of methods to limit both patient and staff exposure are paramount to maintaining a safe work environment. Basic ergonomic principles should also be incorporated into the practice of endoscopy in an attempt to minimize the risk of musculoskeletal injury. Ergonomics in GI endoscopy, specifically endoscopic design, is an area in need of further study.

Abbreviations: CDC, Centers for Disease Control and Prevention; FDA, U.S. Food and Drug Administration; OCRA, Occupational Repetitive Actions; OPLM, other potentially infectious material; OSHA, Occupational Safety and Health Administration; PPE, personal protective equipment.

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