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Optimizing Outcomes in Urologic Surgery: Intraoperative Considerations

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Introduction

Surgical outcomes vary based on patient- and disease-related characteristics as well as institutional, technological, equipment, and human factors. Some factors linked to poor outcomes (e.g., difficult anatomy) cannot be improved prior to surgery. However, there are many factors linked to surgical outcomes that can be modified by either surgeons, surgical teams, or healthcare institutions. This white paper is the second in a three-part series describing such factors and potential intervention strategies that might be useful to optimize the outcomes of surgical patients. It is important to note that this is not a "guideline," as the strength of evidence linking interventions to patient outcome varies widely. Where guidelines on specific topics are available, links have been provided. Since this resource summarizes a large range of topics, additional details can be found in the hyperlinks and references provided. Of note, "intraoperative" is herein arbitrarily defined as the period of time spent in the operating room (OR) rather than just from "cut to closing."

Optimizing Intraoperative Patient Safety

TEAM-BASED TOOLS TO ENSURE BEST PRACTICES IN PATIENT SAFETY

The World Health Organization (WHO) estimates that 234 million surgeries are performed globally each year.[1] Of these, approximately 7 million deaths occur, half of which are believed to be preventable.[2,3] Even greater numbers are impacted by potentially preventable surgical morbidity. ORs are high-risk environments where there is opportunity for great benefit but also potential for significant harm. Physicians, nurses, pharmacists, technicians, and other healthcare professionals must coordinate their activities to ensure patient care is safe and efficient. Communication and teamwork are critical for delivering safe, quality care.

Implementation of surgical safety checklists (SSCs) has been advocated by experts as one strategy to enhance team communication and reduce patient morbidity and mortality.[4,5] The main intent of checklists is to ensure that those "must do" clinical tasks and safety checks are not forgotten and can be embedded into routine workflow patterns. In 2008, the Safe Surgery Saves Lives Group at the WHO launched a perioperative SSC to minimize the risk of wrong site surgery and improve the safety of operative care.[6] SSCs are designed to improve team communication and consistency in care, ultimately avoiding complications.

The WHO SSC was tested in eight diverse settings, including developing countries around the world. When the WHO SSC was used, there was a 50 percent reduction in surgical mortality, from 1.4 to 0.8 percent, and a near 40 percent reduction in inpatient complications, from 11 to 7 percent.[6] Since the publication of that landmark study, several meta-analyses suggest associations between checklist use and reductions in patient mortality, wound infection, pneumonia, blood loss, and postoperative complications.[7-9] In addition, researchers have found that the use of a SSC enhanced communication, teamwork, and a climate of safety, whereas others have shown improvements in cost savings.[10-13] Compliance with SSCs has also been associated with improvements in clinical processes such as antibiotic use, correct site marking, and overall safety processes.[6,7]

Ineffective team communication in the OR is one of the most important causes of medical errors. Communication failures during surgery occur in approximately 30 percent of team exchanges and a third of these jeopardize patient safety by increasing cognitive load, interrupting routine, and increasing tension in the OR.[14] Processes such as huddles, preoperative briefings, and pre-procedural "time-outs" (also known as a "surgical pause" or "call to order") are designed to improve safety and coordination through enhanced communication.[15] These discussions occur at the beginning of the surgical day and prior to the induction of anesthesia, and may include surgical team introductions, articulation of key positioning, surgical steps, and/or gear, medication, or coordination requirements. These formalized discussions often use a checklist or other structured communication tool to confirm clinical task completion and establish a shared mental model among surgical team members. Studies indicate that preoperative huddles reduce disruptions, improve OR flow, and increase surgeon satisfaction.[16]

The challenges of implementation and sustained compliance have become apparent following widespread dissemination of the WHO SSC across diverse countries and healthcare systems. Implementation of checklists does not always lead to compliance. Borchard *et al.* summarized studies evaluating checklist compliance and found that overall compliance rates ranged from 12 to 100 percent.[7] Compliance differs between hospitals and staff members and across specific sections and individual items of the checklist.[7] As team leaders, surgeons must play an important role in implementing, evaluating, and sustaining interventions that improve communication and enhance the culture of safety at their institutions.

Takeaway Points
• Ineffective team communication in the operating room is one of the most common causes of medical errors. • Surgical safety checklists (SSCs) improve team communication and consistency of care and have been associated with reductions in surgical mortality and complications.

PREVENTING SURGICAL SITE INFECTIONS

Surgical site infections (SSI) are among the most common, costly, and debilitating of all hospital-acquired infections. The incidence of SSI is two to five percent in patients undergoing inpatient surgery.[17] SSIs account for 20 percent of all hospital-acquired infections and are associated with an increased length of stay and a two- to 11-fold increased risk of mortality.[18] Numerous risk factors have been associated with the development of SSIs, and can be broadly divided into intrinsic patient factors (modifiable and non-modifiable) and extrinsic factors. A recent overview of Cochrane Reviews suggests there is a lack of high-quality evidence for many strategies that have been proposed for intraoperative SSI prevention.[19] Recommendations for the preparation of the surgical site prior to urologic surgery is mainly extrapolated from research on SSI prevention in other surgical specialties. For example, the American College of Surgeons and Surgical Infection Society: Surgical Site Infection Guidelines, 2016 Update provides a valuable synthesis of current evidence-based recommendations.[20]

Antibiotic Prophylaxis

Antibiotic prophylaxis is an important element of SSI prevention and should be part of the checklist reviewed during "time-out." Inappropriate antibiotic choice, incorrect timing, lack of weight-based dosing, and failed re-dosing have been identified as SSI risk factors.[20] Most antibiotics should be administered within one hour preceding the procedure start; however, some antibiotics, such as vancomycin and fluoroquinolones, need to be infused slowly, and should be initiated up to two hours prior to the procedure.[21-23] This timing is to ensure serum and tissue drug concentration is greater than the minimum inhibitory concentration (MIC) of the likely bacteria for the entire procedure duration.[21] A single antibiotic dose or less than 24 hours of postoperative therapy is recommended for routine prophylaxis.[21,23,24] If a patient is already on scheduled antibiotics, an extra dose of an appropriate agent at the time of surgery is recommended to ensure adequate blood levels at time of incision.[21] Re-dose antibiotics for longer procedures (if greater than two half-lives of the antibiotic) or when there is significant blood loss (>1500mL).[20] It is important to dose by weight, if appropriate, based on the selected antibiotic, to ensure therapeutic but nontoxic dosing. Antibiotic selection and dosing should also be adjusted based on renal or hepatic dysfunction and allergies. Many patients with a reported penicillin allergy can safely receive cephalosporin surgical prophylaxis, as reflected in the recent publication of a clinical practice algorithm.[25] When choosing antibiotic prophylaxis, clinical judgment remains important, and patient-, procedure-, and institution-specific factors and local antibiotic resistance must be considered. Several common prophylaxis guidelines, based on a combination of literature review and expert opinion, are discussed below.

Guidelines for Antibiotic Prophylaxis
The Clinical Practice Guidelines for Antibiotic Prophylaxis in Surgery (2013) were developed jointly by the Infectious Diseases Society of America (IDSA), the American Society of Health-System Pharmacists (ASHP), the Surgical Infection Society (SIS), and the Society for Healthcare Epidemiology of America (SHEA).[21] These guidelines summarize the definitions of wound class criteria and outline antimicrobial recommendations for surgical prophylaxis stratified by type of procedure. Dosing of common antibiotics and re-dosing instructions are reviewed. Alternatives are provided in case of allergy. In addition to the IDSA guidelines, there is also an AUA Best Practice Policy Statement on Urologic Surgery Antimicrobial Prophylaxis.[22] The Statement was written in 2008, reviewed and validated in 2011, and amended in 2012. There are also statements from 2008, 2013, and 2016 regarding the dangers of fluoroquinolone use and the Food and Drug Administration (FDA) Boxed Warning.[26] They ultimately advise against routine fluoroquinolone use if a reasonable alternative is available since potential risk outweighs gain. In 2014 they approved trimethoprim-sulfamethoxazole as an acceptable oral agent for transrectal prostate biopsy prophylaxis. Similar to the IDSA guidelines, this statement provides procedure-specific antibiotic prophylaxis, timing, and duration. Additional factors that influence antibiotic choice are also addressed, including the presence of orthopedic conditions, patient-specific risk factors, placement of a prosthesis, and procedural involvement of vagina, bowel, or entrance into the urinary tract. The Canadian Urological Association guidelines on antibiotic prophylaxis for urologic procedures (2015),[27] provides evidence-based guidelines for antibiotic prophylaxis for transrectal prostate biopsy, shock wave lithotripsy (SWL), non-SWL stone manipulation procedures, endoscopic procedures excluding stone manipulation, and transurethral resection of the prostate. The European Association of Urology (EAU) recently issued updated guidelines on urological infections (2017), which include a section on perioperative antibacterial prophylaxis.[28,29] It is important to keep in mind that guidelines are living documents, and therefore will be periodically amended and updated based on new evidence.

Guidance Specific to Stone Surgery Prophylaxis
The most frequent stone-related procedure complication is urinary tract infection.[30] The AUA and Endourological Society Guideline on the Surgical Management of Stones includes a statement specific to antibiotic prophylaxis: "Antimicrobial prophylaxis should be administered prior to stone intervention and is based primarily on prior urine culture results, the local antibiogram, and in consultation with the current Best Practice Policy Statement on Urologic Surgery Antibiotic Prophylaxis" (Statement 37).[31] The Best Practice Policy Statement does also comment on procedures that involve colonized stones, bacteriuria, or other pre-existing infections. The statement recommends treating these patients with a course of culture-specific antibiotics preoperatively, recognizing that the bacteria may not be eliminated completely, but aiming at least to decrease bacterial colony counts in these high-risk patients. Those with infected stones are at higher risk for infectious complications.[32,33] Therefore, patients may benefit from extended treatment past the standard 24-hour postoperative duration.[22] Preoperative urine or stone cultures with sensitivities and local antibiotic resistance patterns are considered in conjunction with the guidelines to properly select a prophylactic agent in these patients.[30,31,34] Additionally, intraoperative stone cultures can be sent, when applicable, to help guide post-operative therapy or subsequent prophylaxis for staged procedures as they are not always concordant with preoperative mid-stream urine cultures.[35,36] This is best accomplished by manually crushing some of the stone in saline.

Adherence to Guidelines
While guidelines and best practice policy statements exist, prevention still relies on adherence to such recommendations. Additionally, adherence to the guidelines inspires antibiotic stewardship, which is important for the prevention of antimicrobial resistance, treatment-related complications, and cost containment.[37] The Global Prevalence Study of Infections in Urology Investigators reported on practices from 2005-2010 and demonstrated significant variation in antibiotic prophylaxis between countries, regions, and types of hospitals.[38] Furthermore, prophylaxis is not always compliant with guidelines.[38,39] Overall surgeon compliance with the guidelines has been shown to be quite variable and procedure-specific, ranging from 0.6 to 68.3 percent.[40] However, compliance did improve over time and was thought to be due to increasing dissemination of the guidelines. Another study

demonstrated that active teaching of guidelines improved compliance.[41] Lastly, another group showed that a protocol for adherence to EAU Guidelines reduced both antibacterial resistance and decreased antibiotic usage and costs over a two-year period.[42]

In summary, antibiotic prophylaxis is a useful tool in SSI prevention. Guidelines exist to assist clinicians in appropriate antibiotic selection, timing, re-dosing, and duration. Clinical judgment remains important in unique situations and as new literature emerges. Antibiotic stewardship is essential to minimize complications, antibiotic resistance, and cost.

Takeaway Points
• Most antibiotics should be administered within one hour preceding the procedure start. Antibiotics that need to be infused slowly (e.g., vancomycin and fluoroquinolones) should be initiated up to two hours prior to the procedure. • A single dose or less than 24 hours of antibiotics for routine postoperative prophylaxis is recommended. • Guidelines can help guide choice of procedure-specific antibiotics, but surgeons must adjust for local antibiotic resistance as well as patient weight and kidney/liver function.

Hair Removal

Historically, hair at the surgical site was removed prior to incision. However, this practice has been challenged due to lack of evidence that it prevents SSI coupled with concerns regarding increased risk of SSI, especially when razors are used.[43] Microtrauma from shaving is assumed to provide a portal of entry for microbes thus increasing the risk of SSIs. Guidelines from the Centers for Disease Control (CDC), SHEA,[17] the National Institute for Health and Clinical Excellence (NICE), [44] and the Association of PeriOperative Registered Nurses (AORN)[45] recommend not removing hair unless it interferes with surgery. There is high-level evidence that shaving hair with a razor increases SSI risk compared to clipping, although the trials reviewed did not include patients undergoing genital surgery.[43] Multiple clinical practice guidelines recommend that, in cases where hair removal is required, it should be clipped rather than shaved.[17,44-46] However, the SHEA guidelines (2014) state that razors are acceptable for scrotal skin,[17] consistent with a small study of urology patients, which found that clipping can cause greater damage to scrotal skin than razors without improving SSI rates.[47] It is unclear whether hair clipping immediately prior to surgery is associated with fewer SSI than hair removal at home since the available trials are underpowered, according to a recent Cochrane review.[43] AORN guidelines recommend that clipping, if required, should be performed on the day of surgery in the preoperative area (not in the OR) in order to prevent contamination of the sterile field and surgical wound.[45] This recommendation is based on expert opinion rather than trial data.

Takeaway Points
• Leave hair in place if it does not interfere with surgery. • If non-scrotal hair removal is required, clip rather than shave.

Skin Antisepsis

AORN and the CDC[45,48] recommend that patients cleanse their skin the night before and day of surgery with either antiseptic showering [such as with chlorhexidine gluconate (CHG) 4% soap] or direct cleansing of the surgical site (such as with a CHG 2% impregnated cloth).[45] Although chlorhexidine bathing reduces skin colonization,[49] a Cochrane review in 2015 demonstrated a lack of high-level evidence that bathing leads to fewer SSIs.[50] However, in patients colonized with methicillin-resistant Staphylococcus aureus (MRSA), there is evidence supporting a reduction in SSIs after cardiac and joint replacement surgery when using MRSA decolonization protocols (a bundle that includes chlorhexidine bathing).[51]

The FDA standards for preoperative antiseptic preparations are based on a combination of immediate antimicrobial kill and persistent antimicrobial activity.[52] Whatever skin antiseptic is chosen, the manufacturer's instructions for use (IFU) should be followed, including assessment of patient contraindications and allowance for adequate drying time prior to draping.[45] The best active ingredient for skin antisepsis immediately prior to surgery is debated.[53,54] Studies focused on reduction in microbial flora suggest that CHG is superior, but there is not strong evidence that this leads to improved SSI rates.[55] Alcohol-based products seem to exhibit superior efficacy compared to their aqueous counterparts;[55,56] so, the American College of Surgeons (ACS) recommends that alcohol-based preparations be used unless contraindicated.[20] Alcohol-based solutions are designed to dry on the skin; do not blot them. Wait the recommended drying time, usually three minutes on hairless skin, for both maximum efficacy and to decrease the risk of fire.[45] Extra consideration should be given to the pubic area where commonly used alcohol-based antiseptics may take up to an hour to dry if hair is left in place.[57,58] Placement of "drip towels" alongside the patient is also important to prevent pooling of the solution, which can lead to skin irritation, chemical burns, or provide fuel for surgical fires.[45] There is evidence that using chlorhexidine-alcohol skin antisepsis prior to implantation of genitourinary prosthetics is superior to povidone-iodine in decreasing skin colonization,[59] and two consensus documents on penile prosthesis infection prevention recommend use of alcohol-based antiseptics given the available evidence.[60,61]

Takeaway Points
• Use alcohol-based preps unless contraindicated. • Allow prep to dry completely to provide both optimal efficacy and prevent fires (hair slows drying time).

Surgical Hand Scrub

Systematic reviews have concluded that there is low overall quality of evidence to support one type of surgical hand preparation over another.[62] Waterless chlorhexidine scrubs appear to be as effective as water-based scrubs, take less time, and reduce bacterial load compared with povidone iodine scrubs.[20] Alcohol-based hand scrubs also reduce bacterial colony-forming units (CFUs) to a greater degree than aqueous scrubs, but there is no evidence that lower CFUs after surgical hand scrub are associated with lower risk of SSI.[62] Guidelines point out the importance of following each product manufacturer's instructions.

Wound Closure

The CDC defines each of four wound classes: class I – clean, class II – clean-contaminated, class III – contaminated, and class IV – dirty-infected. Primary closure is the standard for clean and clean-contaminated wounds, with delayed primary closure or open wound management for contaminated and dirty-infected wounds. Meticulous closure of fascia and minimization of bacterial contamination appears to have an important role in reducing the risk of SSI. Several prospective randomized trials have demonstrated substantial reductions in SSIs with use of plastic wound protection devices during abdominal surgery.[63,64] Antibiotic impregnated sutures with triclosan also have been shown in a recent meta-analysis to reduce the risk of SSIs.[65] Finally, a urology-specific SSI prevention bundle recommends changing outer gloves prior to closure and using separate sterile closing instruments.[66,67] Many surgeons double glove as a means of personal protection from a patient's body fluids, which is a reasonable practice given the relatively high number of defects in surgical gloves and the risk of puncture to a single glove during surgery.[68] While there is mixed evidence among several randomized trials showing reduction in SSIs with these practices, expert consensus and best practices support their use.

PREVENTING WRONG SITE SURGERY

The prevention of wrong site and wrong procedure surgery has been identified as a priority by numerous organizations including the WHO, Joint Commission, and Agency for Healthcare Research and Quality (AHRQ). Wrong site surgery is rare, with estimates for various procedures ranging from one in 13,000 procedures for wrong site anesthesia blocks to one in 4200 for wrong side ureteral stents.[69] A systematic review estimated that the overall rate was one to five per 10,000 procedures.[70] Given the rarity, demonstrating a statistical reduction would require an unfeasibly large sample size. Therefore, the preventive benefits of a checklist to prevent wrong site surgery are generally assumed based on expert opinion and extrapolation from checklist use in high risk fields such as aviation.

There are several hospital processes designed to ensure that the correct patient is undergoing the correct procedure. In January 2004, the Joint Commission launched the Universal Protocol for Preventing Wrong Site, Wrong Procedure, Wrong Person Surgery.[71] The Universal Protocol is not a checklist per se, but can be implemented using one or more checklists. Preoperative verifications of person, procedure and site should occur in the OR and (if applicable) when the procedure is scheduled, when the patient enters the healthcare facility, and anytime care is transferred between caregivers. Later, the WHO initiated the "High 5s Project" in 2006 to improve the safety of healthcare.[72] The High 5s projects aimed to facilitate the development, implementation, and evaluation of standard operating procedures (SOPs) within hospitals to achieve measurable, significant, and sustainable reductions in a number of challenging patient safety problems with particular focus on the "correct procedure at the correct site." It is imperative that all members of the surgical team are empowered to speak up with concerns about the accuracy of the surgical procedure or site.

Site marking is carried out after all the available information concerning the patient's identity, the procedure, and the surgical site/ intended side (provided by the patient's medical file, notes, imaging, consent, etc.) has been checked and cross-referenced. Surgical site marking should be done by the person who will perform the procedure or by a qualified designee (a physician or nurse participating in the procedure or preparation). Site marking should involve only the operative site and should be visible before the patient is draped. The 'time-out' should occur before incision and involve the entire OR team.

The mark should be made before the patient is moved to the OR. The patient should be aware and involved in site marking, if possible. The mark is made at or near the intended incision site. The mark should be unambiguous (an "X" is not used for site marking), and non-operative sites are not marked. The mark is made using a permanent skin marker sufficient such that the mark is visible after the skin preparation. For midline access to lateral site, the mark indicates correct side. All purely endoscopic procedures without a planned invasive intervention may be exempt from marking or marked at the skin or with a wristband on the side of the intended procedure as per institutional policy. Skin marking may cause a permanent tattoo on premature infants; therefore, an alternative method may be used.

Takeaway Points
• Verbal procedural verification and site marking are designed to prevent wrong site surgery.

PREVENTING VENOUS THROMBOEMBOLISM (VTE)

Urologic surgery often increases the risk of venous thromboembolism (VTE) such as deep venous thrombosis (DVT) and/or pulmonary embolism (PE). Historically, medications that increased the risk of bleeding complications during and after surgery were stopped perioperatively. However, a risk-based approach has now been embraced to balance the risks of bleeding with the benefits of preventing potentially life-threatening VTE. Details of the risk assessment and options for thromboprophylaxis are discussed in detail in the preoperative outcomes paper in this white paper series. It is mentioned here in order to emphasize that the actual application of mechanical thromboprophylaxis (graduated compression stocking and/or intermittent pneumatic compression devices) is often performed in the OR. Contraindication to compression stockings include severe peripheral arterial disease with ischemia, open wounds, or very fragile skin, while intermittent pneumatic compression devices should be avoided in patients with low extremity trauma. American College of Chest Physicians VTE guidelines suggest that intermittent pneumatic compression devices might be preferred over compression stockings given increased skin complications in the latter, but the evidence is indirect and low quality.[73] Institutions vary regarding whether the decision to provide mechanical thromboprophylaxis for surgical patients is based on a local protocol (with the option to "opt out" if contraindicated) or whether the surgeon must request it ("opt in"). The AUA's best practice statement on VTE recommends against mechanical VTE prophylaxis in low-risk ambulatory patients undergoing transurethral surgery.[74]

PREVENTING FALLS/POSITIONING INJURIES

Patient positioning is possibly one of the most critical components of any surgical procedure. While under anesthesia, the patient is completely dependent upon the surgical team to prevent injury while obtaining adequate surgical and anesthetic access. Leading contributors to injury during surgery include falls, points of pressure, moisture, friction or shear energy, heat, and cold. The risk of injury is increased in the setting of poor nutrition, poor circulation due to diabetes or peripheral vascular disease, underlying skin conditions, elevated body mass index (BMI), and decreased range of motion.[75]

Patient transfers must be done in a coordinated fashion with the anesthesia provider and should involve sufficient team members to ensure that the spine remains aligned, the airway is protected, and the limbs are moved in concert with the trunk. Attention to monitors, vascular access lines, drains, and airway support devices during the transfer is critical. When **supine**, the head should remain in a neutral position with appropriate padding. To prevent brachial plexus injuries, arms should not be extended beyond 90 degrees from the torso and should remain parallel with the floor on padding that is level with the table and with the hands supinated. Tucked arms are positioned with the palms facing the thighs and with adequate padding of the ulnar nerves. When moving an anesthetized patient to the **flank** position, the hips and shoulders must be rolled as a unit to avoid spinal torsion.[76] An axillary roll is placed several inches caudal to the axilla to prevent brachial compression injury. With a properly placed axillary roll, a hand can be easily placed in the axilla, which has been lifted off the bed. Lower extremity stretch nerve injuries are prevented by flexing the lower leg at the hip. The upper leg remains straight and is supported by a pillow between the thighs. The **prone** position requires chest bolsters either extending from the clavicle to the iliac crest on each side or extending horizontally across chest and iliac crest to permit normal chest wall movement and minimize abdominal pressure.[77] Attention should be given to breasts and male genitalia to prevent compression or torsion. A specialized headboard will facilitate access to the airway with protective padding to the forehead, eyes, and chin while ensuring the eyes are free from pressure. For the **lithotomy** position, ensure that the stirrups are even. Elevate the legs slowly and simultaneously, limiting external rotation of the hips. Avoid compression injury to the peroneal nerve by preventing pressure to the nerve where it crosses the lateral head of the fibula.[78] To prevent falls, all patients should be secured to the bed with a safety strap or tape that is loose enough to allow one to easily slide their hand underneath. Positioning of the strap over bony prominences without padding should be avoided. Moist epidermis is more prone to injury. Avoid wetting linens with prep solutions or body fluids, and change any linens that are inadvertently soaked prior to the start of surgery.[75] If intraoperative use of an extreme tilted bed position is anticipated, the position should be tested before draping to ensure the patient does not shift.

All pressure points should be padded to prevent compression nerve injury, compromised circulation, pressure ulceration, or rhabdomyolysis. Injuries occur most commonly on the sacrum and heels, and the risk of injury increases with increasing BMI and length of procedure.[79] Padding allows normal capillary interface pressures of 32 mm Hg or less. However, once fully compressed, padding no longer provides protection from pressure injury. Foam pads and mattresses are rated by the amount of weight required to compress them to 25 percent of their original size. Traditionally, 1.25 lbs/in^2 is considered optimal foam density.[80] Convoluted foam (egg crate) compresses easily, making it a poor choice for padding of the torso. In contrast, gel pads serve to distribute pressure evenly over a larger surface area. Blankets and towels provide no padding and will negate the benefits of underlying gel or foam.[81] During prolonged or high-risk cases, the table can be turned periodically from side to side to further reduce periods of extended pressure.

Special consideration must be given to patients placed in lithotomy with steep Trendelenburg (LST) for robotic pelvic surgery. Patients are at high risk of sliding toward the head of the bed, leading to shear and friction injuries to the epidermis, which compound pressure damage. Use of shoulder braces is discouraged because they have been shown to increase brachial plexus injuries.[82] Optimal density foam or memory foam in direct contact with skin helps to prevent the patient from slipping in LST.[76,80] This position can also be associated with facial and airway edema and potential ventilator difficulties in patients with pre-existing pulmonary disease. A rare but potentially devastating complication of LST is increased intraocular pressure leading to blindness, particularly in procedures longer than five hours. Five minute “supine rests” where permitted during long procedures can help to ameliorate these risks.[76]

PREVENTING OPERATING ROOM FIRES AND LASER INJURIES

Healthcare facility policies regarding fire and laser safety are based on Occupational Safety and Health Administration (OSHA) regulations, AORN guidelines, and American National Standards Institute (ANSI) standards. Providers must understand the specific policies of their institution as well as the manufacturer’s instructions for the specific laser and energy devices utilized. General principles of fire and laser safety tailored to urology are presented below.

Over the past four decades, laser and energy devices have become a mainstay of urologic surgery.[83] Multiple laser types have been adopted for various indications, including CO2, KTP, Nd: YAG, Ho: YAG, Tm: YAG, lithium triborate, and diode lasers. These energy sources are used across multiple urologic procedures, including endoscopic treatments for urothelial cancer, endopyelotomy, benign prostatic hyperplasia, urolithiasis, and penile lesions.[83,84] ANSI provides specific guidance around prevention of harm from surgical laser use.[85] A Laser Safety Officer (LSO) and a Laser Safety Committee (LSC) maintain and enforce each institution’s Laser Safety Policy. Laser safety in urologic procedures is based on the type of laser used, mode of operation, power density, tissue response, instrumentation, and risks. ANSI recommends laser-specific protective eyewear for all persons in the nominal hazard zone. Awake patients should wear laser goggles or glasses, while anesthetized patients should be protected (e.g., using wet eye pads, laser-specific eye shields). Similar to ANSI guidelines, AORN has issued guidelines regarding laser safety.[86] They recommend that doors should remain closed and have “laser-in-use” signage and covered windows. Citing evidence that energy-devices carry substantial risk to patients, they advocate for the use of minimal energy settings. They also recommend avoidance of laser or monopolar devices where possible, as these pose the greatest risk of intraoperative fires. To illustrate the potential harms of energy-device use in laparoscopic surgery, AORN guidelines cite an in vitro study demonstrating significant energy leakage in monopolar devices during robotic surgery.[87] Finally, when energy is delivered with a fiber, precautions should be taken to avoid breaking a laser fiber by leaning against, clamping, or bending a fiber beyond the manufacturer’s specifications.[86]

Surgical smoke is the by-product of energy-generating devices (e.g., electrosurgical generators, lasers, powered instruments). Lasers produce an intense, coherent, directional beam of light and also produce heat, which raises the temperature in the cell, vaporizing and releasing steam and cell contents.[83] Surgical smoke might be hazardous to OR staff. In a study of 20 patients undergoing laparoscopic radical nephrectomy, intra-abdominal surgical smoke was collected and analyzed for the presence of carcinogens.[88] Investigators found that five such compounds were detectible at greater than negligible quantities. Other work has shown that infectious agents can also be present in surgical smoke, including human papilloma virus, human immunodeficiency virus, and hepatitis B.[89] Despite a 2013 systematic review showing no immediate adverse effects on OR personnel,[90] the long-term risks have not yet been adequately investigated, and precautions are recommended. These include local exhaust ventilation (LEV), respirator (i.e., N95) mask or laser mask use, and in-line suction with particulate filters.[91,92]

Intraoperative fires are uncommon events in urologic surgery. A closed claims report analysis from the American Society of Anesthesiologists revealed that 90 percent of intraoperative fires are attributable to electrocautery use, with 85 percent of these occurring during head and neck surgery.[93] This is related to the combination of supplemental oxygen administration in close proximity to cautery and laser sources in the setting of combustible material such as drapes or pooling of alcohol-based skin preparations. This illustrates the classic fire triad of oxidizer, fuel, and ignition. Fortunately, in urology, operating near the airway is uncommon, aside from harvesting buccal grafts for reconstruction. Lasers in urology are most commonly used during endourologic procedures that take place in liquid (urine or irrigation), where combustion is unlikely. A recent report of an intra-abdominal fire secondary to cautery use during robotic prostatectomy revealed the cause to be incorrect administration of oxygen for intraperitoneal insufflation.[94] Other reports of intraoperative fires during urologic surgery have been attributed to alcohol-based skin preparation.[95] Simple strategies that surgeons should remember to prevent intraoperative fires include allowing alcohol-based prep to dry completely before beginning the case, re-holstering electrocautery pencils between uses, and placing fiber-optic light sources away from drapes and in standby mode when scopes are not in use.[96] The FDA website provides useful information about surgical fire management and prevention. The FUSE™ (Fundamental Use of Surgical Energy)[97] program provides free access to useful online didactic content. Underlining the importance of fire safety, the FDA advises the team perform a fire risk assessment at the beginning of each procedure; often this is incorporated into the preoperative checklist.[98]

Takeaway Points
Surgeons can help prevent intraoperative fires through the following actions: •allowing alcohol-based prep to dry completely before beginning the case •re-holstering electrocautery pencils between uses •placing fiber-optic light sources in standby mode when not in use

PREVENTING EXCESSIVE RADIATION EXPOSURE

Radiation use within diagnostic medicine has increased over the years as it has become more readily available.[99] Additionally, the incidence of kidney stones, an ailment most commonly diagnosed through medical imaging, continues to rise.[100,101] Many of these patients are exposed to a significant amount of radiation from diagnostic imaging.[102,103] A portion of these patients will also require surgical treatment. These procedures, and a subset of other urologic procedures, are fluoroscopically guided, exposing patients to a significant amount of additional radiation.[104-106] With the rise in radiation-based diagnostic imaging and the increase in the number of kidney stones requiring surgical treatment that entails the use of radiation, increased concerns arise regarding a patient's exposure to radiation.

There are both short- and long-term potential risks of excess radiation exposure.[100,107] Deterministic effects occur over a threshold and include skin injury, hair loss, and cataract development and are not common with urologic intervention.[107,108] Stochastic effects follow a linear-no-threshold model and include risk of malignancy. Risk is believed to rise with increased exposure and is believed to be age-dependent as well.[109-112] Studies have estimated that medical imaging may be responsible for ten percent of all cancers in the United States.[100,113]

Strategies for Minimizing Radiation Exposure

There are some basic safety practices in the OR to follow in order to keep radiation exposure as low as reasonably achievable (ALARA), a concept introduced in 1954.[114] The most important way to minimize radiation is to use the lowest possible settings. The low dose option on the fluoroscope reduces radiation exposure by 60 percent and can be used with both the portable C-arm and fixed cystoscopy tables.[100] Standard fluoroscopy is continuous and administers 30 pulses per second (pps). Various pulsed settings ranging from 1-15 pps can be programmed on the fluoroscope. Lowering the pps reduces fluoroscopy time by 34 percent, 55 percent, and 79 percent at settings of 12, 4, and 1 pps respectively and has been shown to be safe and feasible.[115-119] Radiologists have found pulsed fluoroscopy to be equivalent to continuous fluoroscopy with regard to image quality.[120] The combination of low dose and 1 pps has been shown to reduce radiation exposure by 97 percent with no compromise in outcome.[100,117] The use of 1 pps does create artifact with motion; so, the foot pedal should not be engaged when the fluoroscope is moving to adjust for this. The low-dose settings can be made part of the pre-procedure safety checklist. Using the fluoroscope for as little time as possible during the case is a clear goal. Spot images rather than continuous fluoroscopy are usually adequate, except in rare instances. "Last image hold" technology allows reference images to be saved, stored, and then swapped to a second screen to avoid taking new images.[121] If the entire field does not need to be seen, then the image can be collimated to narrow the area of exposure. This decreases the region of direct exposure, lessening scatter and dose delivered.

In addition to low-dose and other setting adjustments above, there are some additional strategies than can help reduce radiation exposure further. Having a dedicated radiation technologist can potentially reduce time since such individuals are familiar with the case anatomy.[122] Additionally, reducing technologist turnover mid-case, or detailed sign-out if turnover does occur, aids in case familiarity. Standardizing terminology to direct C-arm movement intraoperatively is important to avoid miscommunication and should be discussed pre-procedure. Technologists learn specific language during their training, which they can make available, or the surgeon can present their preferred terminology. Either way, directions should be well defined. Foot pedal control by the surgeon avoids confusion of when fluoroscopy is needed and whether it needs to be continuous or if spot images are adequate. Using the C-arm laser beam to guide the fluoroscope position into the desired location and then marking on the drape the location of the kidney and bladder help the surgeon to direct the technologist between organs.[121,122] The technologist can also mark the floor with tape or erasable marker to seamlessly transition from kidney to bladder; this is particularly helpful when the technologists turnover.

Lastly, and perhaps the most obvious way to decrease radiation exposure, is to avoid its use altogether. Alternative imaging modalities exist that aid in the treatment of kidney stones. There is a body of literature utilizing pure ultrasound guidance for ureteroscopy (URS), SWL, and percutaneous nephrolithotomy (PCNL).[123-128] Limited fluoroscopy can also be used in combination with ultrasound.[129] For PCNL, endoscopic guided access has been shown to decrease puncture attempts, and thus fluoroscopy time.[129-131] Also for PCNL, the use of air pyelogram has been shown to decrease radiation exposure.[132] Lastly, in the case of URS, imaging may not be necessary at all, though this is not always feasible for complex cases.[133-137]

Besides fluoroscopy time, distance and shielding are the other two principles of ALARA. It is important to keep the C-arm position with the patient close to the image intensifier and further away from the energy source. Fixed cystoscopy tables have been associated with higher radiation exposure compared to the portable C-arm.[138] The energy source typically comes from over the patient with fixed tables versus under the table with the portable fluoroscope, which is thought to explain the difference. With regard to patient shielding, radiosensitive organs not within the working field can be covered, such as the thyroid.

Radiation Safety in Pregnant Patients

Pregnant patients are a unique population where radiation safety is particularly important because exposure poses risk to the fetus, with the greatest risk being during the first trimester. The American College of Obstetricians and Gynecologists (ACOG) guidelines state that magnetic resonance imaging and ultrasound are the preferred imaging studies during pregnancy.[139] If taken to the OR for stent placement or URS, ultrasound guidance can typically be used for the duration of the procedure.[140] ACOG states that if a diagnostic imaging technique is necessary or more readily available, it should not be withheld from the pregnant patient.[139] If fluoroscopy is necessary, the lowest possible settings should be used (low dose and 1 pps), spot shots should be taken rather than continuous fluoroscopy, and the pelvis should be covered with lead. If using a fixed table with the energy source over the patient, the lead will drape over the pelvis. If using a portable C-arm, the lead will go under the pelvis, since the energy source comes from below the table. Some report inverting the C-arm to facilitate draping over the pelvis; however, bringing the tube source above the table increases scatter and radiation exposure as mentioned previously.[138]

Radiation Safety in Pediatric Patients

Pediatric patients are another more radiosensitive group, and their exposure during urologic procedures is not inconsequential.[141,142] When using fluoroscopy in this population, guidelines established by the American College of Radiology (ACR) and the Society for Pediatric Radiology (SPR), should be followed.[5] The Alliance for Radiation Safety in Pediatric Imaging initiated the Image Gently campaign and they continue to introduce initiatives such as "Pause and Pulse" intended to educate, and encourage mindfulness when using fluoroscopy in children.[143] In their document, they review ten ways to reduce radiation exposure during these procedures. These include familiarity with the equipment and its low-dose settings, consideration of alternative imaging, proper planning, use of the lowest pulsed setting that is adequate for the procedure, removal of the anti-scatter grid for small patients, avoidance of magnification, collimation to the desired field, proper patient positioning, use of last image hold and image store technology, and inclusion of the physicist for optimization and maintenance.[143] Ultrasound should be preferentially utilized intraoperatively if and when feasible, and radiosensitive organs not in the area of interest can be covered (e.g., thyroid).[123]

Radiation and Occupational Health

While these practices help to minimize radiation exposure to the patient, they also help to minimize radiation exposure to the surgeon and staff in the room. Reducing exposure to the surgeon is also of utmost importance, as high-volume endourologists have the potential for significant exposure over the course of their career.[144-146] While the typical urologist may not be in danger, physicians with routine fluoroscopy exposure have been shown to be at higher risk of multiple malignancies and cataract formation; therefore, limiting exposure is important.[147-151] Occupational exposure is recommended to be less than 20mSv per year averaged over a five-year period (100mSv/5 years) by the International Commission on Radiological Protection (ICRP).[152] Using the lowest settings possible reduces radiation effective dose to the surgeon by 64 percent.[117] In addition to using the lowest possible settings, protective equipment is equally as important. Studies have shown that while endourologists typically wear lead aprons (97 percent), they are less likely to wear thyroid shields (68 percent), leaded glasses/gloves (17 percent/10 percent), or use dosimeter to monitor their exposure (30-34 percent).[118,145,153] Other protective equipment that is available includes lead surgical caps and mobile lead barriers. Lead aprons should be checked annually for cracks. Pregnant surgeons should wear the two-piece design with a lead vest and wrap around skirt apron. They should also declare their pregnancy to the radiation safety officer early so that they can obtain a fetal dosimeter, worn at the pelvis beneath their lead and have it checked monthly. Other strategies to reduce radiation exposure to the surgeon include maximizing the distance of the energy source to the surgeon, placing lead between the energy source and surgeon, and operating in the standing position.[154,155]

Lastly, cognizance is a critical factor. Fluoroscopy time has been shown to decrease if formally measured and reported back to the surgeon quarterly.[156] Similarly, awareness and education via a formal radiation safety curriculum has been shown to significantly decrease fluoroscopy time and exposure.[157-160] Training in radiation safety and knowledge of reduction techniques are often lacking.[118,153] However, there are typically institution-specific radiation safety programs that are required to be completed and repeated every couple of years by those who routinely use radiation-based imaging. The ACR does have guidelines available on the Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures.[161] They outline the qualifications and responsibilities of personnel including maintenance of competence and continuing education. In that document, appendix A reviews quantities and units definitions; appendix B reviews fluoroscopic equipment and machine settings and ways to reduce exposure to the patient, staff and operator; and appendix C reviews detection and management of tissue reactions. While radiation-based procedures will likely never be eliminated from urologic practice, following these principles and continuing medical education (CME) will help keep patients, staff, and the urologic surgeon safe.

Takeaway Points
• The most important way to minimize radiation is to use the lowest possible settings and minimize exposure time. • Protective equipment should be routinely worn by surgical team members.

PREVENTING UNINTENDED CONSEQUENCES OF TEACHING/LIVE SURGERY

Surgical education continues to capitalize on innovations in technology, with examples of improved knowledge dissemination coming from live-streaming of operative cases. However, real-time demonstration of surgical techniques and approaches is not novel. At the beginning of the twentieth century, live surgical demonstrations were a cornerstone of medical education.[162,163] Urologists have been at the forefront of this renewed interest in live surgery, and the literature explores aspects of this topic, from practical implementation methods to ethical considerations. Here the focus is on issues around patient safety as it relates to live surgery, the real-time transmission of surgical video to a remote location for educational purposes.

The evidence generally suggests equivalent outcomes when live surgery cases are compared with controls. In a 2014 systematic review of live surgical demonstrations, the rates of complication in live surgery patients (including a study of robotic partial nephrectomy) were equal or better compared to control procedures or accepted rates reported in the literature, aside from a single study of coronary angioplasty.[164] In a retrospective matched cohort study of 36 robotic-assisted radical prostatectomy (RARP) patients, there were no differences reported in oncological outcomes or complications after a median follow-up of 31 months.[165] There is evidence to support live surgery being safe in endourologic cases as well. Legemate and colleagues describe a study of 151 live surgeries that included 95 ureteroscopic cases and 56 percutaneous cases for nephrolithiasis.[166] They observed no statistically significant differences in intraoperative and postoperative complications, blood transfusions, failed procedures, and length of stay.

While these findings of equivalency are reassuring, there are less encouraging examples reported in the literature. A study of patients abstracted from a large, multinational live surgery database was published in 2017 and included patients undergoing a range of urologic procedures, most commonly RARP.[167] Although the authors conclude that their sample of patients did not experience higher complication rates compared to those reported in the literature, they did report 16 Clavian-Dindo complications grade III or higher, including one death following laparoscopic cystectomy. Finally, evidence from outside urology has demonstrated the potential for increased anesthetic time,[168] and higher complication rates[169] amongst live surgery patients.

Treatment delay has been put forward as a concern in arguments against live surgery. Although there is no evidence to support this in urology, several experts have commented on the potential for delays in surgical treatment for patients selected for live surgery.[170,171] A study of endoscopic retrograde cholangiopancreatography found this to be a significant factor in live surgery cases, with a delay in 87.5 percent compared to 44 percent in controls.[168]

The ethics of performing an operation on a literal stage has been discussed at length in the literature.[172] Concerns center on the consent process, specifically around whether the patient is always adequately informed about what their live operation will entail. With ongoing discussion during the case, is there a possibility for the surgeon to be more distracted? Has the surgeon declared a conflict of interest to the patient as they likely have been compensated for their participation and/or use of specific surgical instruments? Other ethical concerns focus on issues of confidentiality. Although laparoscopic camera views likely prevent the patients face from being exposed during the case, how can one guarantee that this will not happen during a camera cleaning period or if/when the patient is repositioned?

An interesting finding comes from a survey of urologists attending two live surgery sessions.[173] While 78 percent of respondents felt that live surgery is fundamentally ethical, only 58 percent would allow themselves or their family to be a patient for a live operation, calling their earlier response into question. In another survey, this time to members of the EAU Robotic Urology Section with experience performing live surgery,[174] two percent of respondents reported feeling significant anxiety, and 24 percent felt that surgical quality is worse when operating away from their 'home' environment. Other factors such as language barriers, equipment unfamiliarity, and even jet lag were identified by respondents as being negative factors when performing live surgery. Perhaps most worryingly, 42.4 percent of respondents felt that audiences at live surgery events, "…wished the surgeon to struggle or manage a complication during a live surgery broadcast."

It is important to note that often the surgeon is operating on his/her patient in the region or country where the conference is taking place, rather than broadcasting the procedure from his/her 'home' OR.[174] This can lead to language barriers and team communication issues as well as unfamiliar equipment and OR setup.[170]

The literature is mixed as to whether live surgery is superior over recorded cases from an educational stance. A survey of two major urologic conferences in 2014 found that respondents felt that the ability to ask questions in real-time provided by live surgery made it a superior educational tool.[173] Dr. Arthur Smith argues the benefits of video recordings over live surgery in a commentary article to the *British Journal of Urology International*.[170] He highlights, in particular, the ability to stop and rewind recorded video, the use of special 'complications' sessions to provide analysis of retrospectively recorded intraoperative crises or technical events, and an unpublished survey from the World Congress of Endourology that reported 66.4 percent of respondents favored the pre-recorded approach over live surgery.

The only published guidelines concerning live surgery specific to urology comes from the EAU.[175] They advocate for the continued use of an EAU registry of live surgery cases to ensure outcomes remain equivalent compared with non-live cases. They outline a set of organizational requirements that includes surgeon and patient selection, OR team preparation, preoperative planning and checks, and postoperative care in addition to guidance around technical issues with live surgery. Of note, they advocate for the selection of 'standard' cases over complex ones, and for thoughtful selection of surgeons for these events, with adequate case volume in their practice and experience with live surgery events.

Takeaway Points
• Evidence is somewhat mixed regarding the safety and efficacy of live surgery. • Common arguments against live surgery include treatment delay, non-transparent consent practices, and non-familiar operating room teams. • Recorded video with accompanying commentary has been proposed as an alternative method to surgical teaching at urologic conferences.

PREVENTING UNINTENDED CONSEQUENCES OF NEW TECHNOLOGY ADOPTION

As transformative surgical technology continues to innovate the way urological diseases are treated, it is imperative to understand clearly best practice around the safe implementation of these treatments. Regulatory bodies impose strict criteria to prevent patient harm, and it is the responsibility of industry, healthcare organizations, and clinicians to ensure that patient safety is not jeopardized in the name of innovation. Similarly, it is important to understand the current methods and limitations, of credentialing surgeons using new technology. Failure in this process can lead to wasted resources and, most importantly, patient harm.

Although distinctive, many countries use very similar models when considering the implementation of novel technologies in the OR. In the United States, the FDA is responsible for approving medical technology prior to its use in the clinical setting. Surgical devices used in the OR undergo a multistage approval, the complexity of which is dependent on the classification of said device.[176] Many devices must demonstrate feasibility and safety in clinical trials at the bench, animal, and human-levels prior to approval. The approval process ensures that the device in question has a substantial patient benefit that outweighs potential risks, and that the device is not less safe than devices already at market. Failure to demonstrate both efficacy and safety in humans prior to introducing medical or surgical innovation can have disastrous implications, both for patient safety and litigation.[177] The FDA's publically available MAUDE database is a passive surveillance system that contains numerous reports of device associated injury or malfunction.

Despite these regulations, poorly tested technologies may still make it to market and negatively impact patient health. A notable example of this is the ProteGen Sling, a transvaginal mesh implant for female stress urinary incontinence. Rushed to market without adequate evidence from human trials in 1997, this product was recalled two years later following hundreds of devices causing erosion and infection in women.[178] This cautionary tale of surgical innovation highlights the importance of thorough and carefully regulated study of new medical and surgical devices prior to use in the clinical setting.[177]

Health Technology Assessment (HTA) is a widely-used process in many healthcare settings around the world. This process is separate from regulatory proceedings and focuses on the economic impact, cost-effectiveness, and comparisons against alternative solutions or treatments in addition to assessing its risk to patient safety.[179] Although mandatory prior to introducing surgical technology in many countries, this is not the case in the United States. In the United States, these processes are undertaken by a variety of organizations and healthcare providers, including Medicare and Medicaid, AHRQ, and private health care organizations.[180]

Once a new surgical technology or approach has been given FDA approval and undergone any other local checks and balances prior to implementation, the education, accreditation, and monitoring of surgeons conducting these procedures needs to be addressed.[181] In qualified and practicing urologists, this process is often solely under the purview of industry, normally the company manufacturing the new device.[182] It is therefore not surprising that these processes vary widely across devices, procedure types, and state or national borders.[183] In the United States, there is no national program of surgical credentialing for specific procedures. Instead, surgical specialty and subspecialty societies are tasked with providing guidance for hospitals on how best to determine whether a surgeon should be deemed competent to perform a given operation. This has led to the creation of multiple layers of policy statements, recommendations, and guidelines from multiple organizations with different mission statements and objectives.

The American Surgical Association released a set of principles to guide surgeons and hospitals around credentialing and privileging, following a consensus discussion.[184] These eight principles include that surgeons should be board certified, have their outcomes monitored, operate on a minimum number of cases annually for a given procedure, undergo re-credentialing at set intervals, demonstrate technical proficiency in a proctored environment, undertake self-regulation regarding the privileging process, demonstrate professionalism, and participate in retraining and retooling when undertaking new procedures.

The AUA does not provide guidelines for the credentialing of urologists. A policy statement regarding urologists' access to new technology simply states, "The American Urological Association (AUA) recommends that urologists should have access to the technological support necessary to practice the state-of-the-art medicine as defined in the specialty of urology." However, the rapid rise of robotic-assisted surgery compelled the AUA to release a SOP regarding appropriate adoption practices of this technology into practice, with a focus on credentialing procedures, training and assessment recommendations, proctoring, and maintenance of privileges.[185] They include that after receiving unrestricted privileges, urologists should continue to have their outcomes monitored at the institution level and demonstrate an adequate commitment to CME.

The use of a proctor in the early stages of adopting a new surgical technique, procedure, or device has gained wide acceptance in recent times. It is noteworthy that although many credentialing guidelines include the need for proctoring, the definition of what qualifies a surgeon to serve as a proctor, the duties of said proctor, and the amount of time the proctor is required varies across specialties, procedures, and device manufacturers.[186,187] This heterogeneity and lack of standardized definitions, coupled with a lack of formalized assessments of technical and team-based competency reduces the entire proctoring process to simply the observation of novice surgeons for a variable amount of time, leading undoubtedly to wide variations in surgeon performance.[182]

As mentorship and proctorship can often be difficult to facilitate in the context of a busy clinical setting, telemonitoring and telementoring have emerged as potential solutions.[188] This technology allows for the proctoring of surgeons in rural or non-academic institutions where an expert may not be readily available to help and evaluate novice surgeons.[189] While this process may be limited or hindered by latency of communications and information technology concerns, new techniques in telecommunication and cybersecurity may mitigate some of these concerns.[184]

Takeaway Points
• Current credentialing practices for new surgical devices is primarily under the purview of industry, leading to heterogeneous and unstandardized methods of ensuring surgeons are safe to operate using these novel approaches. • Methods of safely introducing and evaluating surgical technology should be designed to limit patient harm. • Proctoring, and more recently telementoring, shows promise as a means of improving the introduction of new surgical technology and techniques that shortens the learning curve of surgeons adopting a novel surgical approach.

Optimizing Intraoperative Patient Physiology

Although, as surgeons, urologists rely on anesthesia providers to manage intraoperative patient physiology, it is important that urologists maintain a working knowledge of contemporary anesthetic and analgesic options as well as intraoperative fluid, temperature, and gastrointestinal management. This can facilitate productive intraoperative communication with anesthesia colleagues.

ANALGESIC CONSIDERATIONS

A cornerstone of perioperative analgesia is the use of a pre-emptive, multimodal analgesic regimen that includes medications from multiple drug classes and a pre-emptive plus intraoperative approach such that patients have optimal pain control and minimal side effects from any single medication. Multimodal regimens may minimize the need for opioid prescriptions at discharge.[190]

Perioperative opioid administration can produce acute opioid tolerance, or tachyphylaxis, as well as opioid-induced hyperalgesia, an increased sensitivity to painful stimuli resulting from opioid use. Multimodal analgesia using non-opioids can reduce the incidence and severity of opioid tolerance and hyperalgesia.[191]

Pre-emptive, multimodal analgesia is often initiated in the preoperative holding area and may include oral acetaminophen, oral non-steroidal anti-inflammatory drugs (NSAIDs), cyclo-oxygenase-2 (COX-2) inhibitors, gabapentin, ketamine and opioids.[192] Oral medications administered within a reasonable time prior to induction of anesthesia are not known to increase aspiration risk, with the exception of specific patient groups at high risk of aspiration such as those with gastric bands, achalasia, or gastric outlet obstruction. The unique benefit of any single agent within a regimen is not always discernable. Important non-opioid components of multimodal analgesics and their optimal application are described below.

Acetaminophen may be administered orally, rectally or intravenously. Evidence from controlled trials and meta-analyses indicates that intraoperative intravenous acetaminophen is a safe and effective analgesic, particularly for elderly patients.[193-195] The analgesic benefits of oral acetaminophen are likely to be comparable to those of intravenous acetaminophen, and oral formulations are less expensive, particularly when given as repetitive doses at regular intervals.[196-198] Intravenous acetaminophen has a greater bioavailabiity than the oral preparation, but a similar effect may be achieved with higher oral doses.

COX-2 inhibitors and **NSAIDs** including celecoxib, ibuprofen, oral naproxen, or intravenous ketorolac contribute to analgesic benefit as part of a pre-emptive or intraoperative, multimodal regimen. Long-term NSAID therapy can be associated with a variety of adverse effects, including gastric mucosal damage, renal toxicity, increased blood pressure, and adverse cardiovascular events, such as myocardial infarction. However, for many patients, NSAIDs can be given safely on a scheduled basis for a short course after surgery. COX-2 inhibitors are considered to be associated with lower risks of upper gastrointestinal adverse events compared to NSAIDs, both of which have analgesic benefits.[199,200] Initiation preoperatively may be opioid-sparing in the early postoperative period compared to postoperative administration.[201] Medications from these classes may increase the risk of perioperative renal injury, particularly in patients with compromised renal function at baseline, and may be omitted from perioperative analgesic regimens for high-risk patients and high-risk procedures.[202,203] In some settings, the analgesic benefit of ketorolac in doses as low as 7.5 mg may be comparable to higher doses of 15 mg or 30 mg but with a theoretically lower risk of renal injury or bleeding.[204-208] Long-term use of NSAIDs is associated with an increased risk of adverse cardiovascular events. Perioperative NSAIDs should be used cautiously in patients with significant coronary artery disease (CAD). Patients with CAD who take aspirin for a cardioprotective effect often should continue aspirin perioperatively. The concomitant administration of another NSAID may inhibit the protective effect of aspirin, and for some NSAIDs, this effect is more pronounced when the NSAID is given before aspirin administration.[209] To avoid interfering with the antiplatelet effect of low-dose aspirin, the FDA recommends giving ibuprofen at least 30 minutes after or more than 8 hours before aspirin ingestion.

The gabapentinoids, **gabapentin** and **pregabalin**, are sometimes employed as part of pre-emptive, multimodal analgesia. However, a unique benefit for acute postoperative pain control with gabapentin is not well-established in the literature, with conflicting data from small trials.[210,211] Fewer data describe the effects of pregabalin as part of a pre-emptive, multimodal analgesic regimen. Gabapentinoids are known to have a sedating effect and, in combination with general anesthesia and postoperative opioids, may not be appropriate for patients at high risk of postoperative pulmonary complications.[212] Gabapentinoids may be most appropriate for patients on such therapy preoperatively and those with existing neuropathic pain.

Ketamine, an antagonist of N-Methyl-D-aspartate (NMDA) receptors, is increasingly used as an opioid-sparing analgesic and provides analgesia with minimal respiratory effects.[213,214] Limited data have evaluated the effects of ketamine in urologic patients. However, anecdotal experience suggests it is most beneficial in patients either at risk of respiratory compromise from opioids or patients who use opioids chronically. A small trial of patients undergoing extracorporeal SWL demonstrated that ketamine infusion initiated prior to the procedure resulted in opioid sparing effects among patients chronically taking opioids.[215] Other perioperative analgesics with NMDA antagonist activity include magnesium and methadone.

Lidocaine infusion can reduce the use of systemic opioids and improve postoperative analgesia.[216] In patients undergoing radical retropubic prostatectomy, lidocaine infusion used intraoperatively and continued for one hour after skin closure resulted in shorter hospital stays, less pain, and faster return of bowel function.[217] Short durations of lidocaine infusion are generally very safe, but in dosing, consideration should be given to the concomitant use of local anesthetics in other routes, such as wound infiltration or nerve block.

Dexamethasone is commonly administered as prophylaxis for postoperative nausea and vomiting (PONV) and occasionally is given perioperatively for its anti-inflammatory effects. Some recent evidence indicates that dexamethasone may confer significant postoperative analgesia, especially at relatively high doses, greater than 0.1 mg/kg intravenous.[218,219]

Takeaway Points
• In appropriate patients, multimodal analgesia should be used in order to minimize side effects.

ANESTHETIC CONSIDERATIONS

For a given procedure, patients may achieve safe and effective surgical anesthesia with various anesthetic techniques. Key sources of variation in management include airway and ventilation management, the use of paralytic agents (neuromuscular blockade), and the choice of general versus regional anesthesia. Absent compelling data from clinical trials, these choices may be guided with respect to optimizing the surgeon's operating conditions, patient safety, analgesia, and patient preference.

There is no evidence that one strategy of airway management, such as laryngeal mask airway or endotracheal intubation, is superior to another. Airway management is guided appropriately by practical considerations that do not require trial-level data. Patients at high risk of aspiration, whether due to a recent meal or pre-existing medical disease, are poor candidates for general anesthesia or deep sedation without endotracheal intubation. In the setting of controlled mechanical ventilation, safety principles are extrapolated largely from the critical care literature and emphasize application of low to moderate positive end expiratory pressure, low tidal volumes of 4-8 mL/kg of predicted body weight, and normoxia, although diverse opinions are held on the latter point.[220-222] Chemical paralysis ("muscle relaxation") may be used to optimize surgical conditions. Residual neuromuscular blockade (i.e., incomplete reversal of the paralyzing agent) is an important safety issue that has been linked to increased postoperative morbidity.[223] It is imperative that the effects of paralysis are absent at the time of extubation. Rates of residual blockade in the recovery room are about 40 percent, but this can be decreased substantially with use of a newer pharmacologic reversal agent. Complete reversal of paralysis decreases the risks of postoperative respiratory complications.[224]

Anesthesia may be performed either as regional anesthesia, general anesthesia, monitored anesthesia care (MAC), or a combination of regional and general anesthesia or regional MAC. The type of anesthesia used is tailored to the surgical procedure and the patient.

Takeaway Points
• The choices of airway management and anesthesia type are guided by aspiration risks, patient preference, and the needs of the particular procedure including exposure and duration.

Regional Anesthesia

Regional anesthesia, such as spinal or epidural anesthesia, is an effective alternative to general anesthesia for many urologic operations, including cystoscopic procedures and transurethral resection of prostate or bladder tumors. For PCNL, epidural anesthesia is considered a safe alternative to general anesthesia for some patients and may result in improved patient satisfaction and decreased early postoperative pain.[225,226]

Epidural analgesia can provide superior pain control for the first three days after major abdominal surgery, and effective analgesia should facilitate early postoperative ambulation.[227] In order to optimize ambulation, epidural catheter placement should be done in a location that avoids effects on lower extremity motor function. Patients should be assessed for hypotension and orthostasis, which can occur with epidural analgesia. Epidural anesthesia and analgesia are commonly used as part of many enhanced recovery pathways for major surgery. Perioperative epidural analgesia can decrease the duration of postoperative ileus after major surgery, including radical cystectomy.[228] Epidural analgesia promotes gastrointestinal motility by minimizing use of systemic opioid but also via a direct of sympathetic blockade: epidural analgesia with local anesthetic increases gastrointestinal blood flow, bowel motility, and splanchnic perfusion.[229,230]

Transversus abdominal plane (TAP) block may be a reasonable alternative to epidural analgesia in radical nephrectomy and other major procedures,[231] either with long-acting local anesthetic preparation or with continuous infusion. TAP block avoids the central neuraxial side effects of epidural analgesia.

Persistent postoperative pain (PPP) may occur in some patients after major surgery. Some evidence exists that epidural anesthesia/analgesia and paravertebral block both may prevent PPP after thoracotomy and breast cancer surgery. However, the evidence for this is somewhat weak.[232] Although no convincing evidence exists that such techniques prevent PPP after major urologic surgery, anxiety before surgery and use of postoperative pain medications may be predictors of chronic pain following radical retropubic prostatectomy.[233]

INTRAOPERATIVE TEMPERATURE MANAGEMENT

The CDC recommends that perioperative teams maintain perioperative normothermia in order to prevent SSI without specifying a lower temperature limit for normothermia, or timing or duration (Category IA – strong recommendation).[48] Clinical evidence regarding an effect of hypothermia on SSI is conflicting.[234] Forced air warming is commonly done for major surgery. During endourologic procedures, warmed irrigation can be helpful. Maintenance of normothermia may have benefits other than prevention of SSI, such as improved cardiac outcomes.[235]

Takeaway Points
• Current recommendations endorse maintenance of normothermia for surgical cases with the intention of preventing surgical site infection and major adverse cardiac outcomes.

INTRAOPERATIVE MANAGEMENT OF GLYCEMIC STATUS, ANTI-EMETICS, GASTROINTESTINAL MOTILITY, AND OPIOIDS

Nausea and vomiting after surgery are a major source of patient distress, delay of discharge, and increased costs of care.[236] Postoperative vomiting additionally risks wound compromise and aspiration. PONV may be caused by medications such as inhaled anesthetics, opioids or surgical manipulation of the bowel. Prophylaxis of PONV is effective and improves patient experience as well as time to discharge.[237] Consistent with ASA performance measurements, patients at high risk for PONV "are likely to benefit from receiving at least two prophylactic pharmacologic anti-emetic agents of different classes." [238] Risk factors for PONV include female gender, history of PONV or motion sickness, nonsmoking status, younger age, laparoscopic surgery, inhalational general anesthesia, and use of postoperative opioids.[239] Anti-emetics include 5-hydroxytryptamine (5-HT3) receptor antagonists (recommended as the first choice for prophylaxis for PONV in children), dexamethasone, antihistamines, butyrophenones, phenothiazines such as perphenazine, propofol infusion, NK-1 receptor antagonists such as aprepitant, and scopolamine (used with caution in the elderly and in men over 60 due to potential for urinary retention and confusion).[238,239] In addition, avoidance of inhalational general anesthetic agents through use of total intravenous anesthesia (TIVA) reduces the risk of PONV. Effective non-opioid analgesia that reduces the need for postoperative opioids also lessens the risk of PONV.

Postoperative hyperglycemia increases the risk of surgical infectious complications.[240] Patients with hyperglycemia, often defined as glucose greater than 180 mg/dL, may benefit from glucose monitoring and control with a goal of euglycemia with insulin therapy, whether subcutaneous or intravenous.[241] With effective perioperative glucose management strategies, the risk of hypoglycemia should be minimal. The CDC recommend perioperative glucose control targeting values <200 mg/dL to prevent SSI (Category 1A – strong recommendation).[48]

Enhanced recovery after surgery (ERAS) pathways that minimize the need for perioperative opioids and selectively employ epidural analgesia to improve gastrointestinal function, as described above, can facilitate early return of bowel motility and reduce length of stay. For radical cystectomy, intraoperative anesthesia management is a major component of effective enhanced recovery pathways. For open surgical procedures, epidural anesthesia with local anesthetics can be combined with TIVA with propofol to minimize intraoperative opioid use. For robotic cases, an intraoperative lidocaine infusion of intravenous lidocaine may be used along with postoperative TAP block.[242]

Takeaway Points
• Intraoperative therapeutics are applied to maintain organ perfusion and euglycemia, minimize ventilator induced lung injury, and prevent postoperative nausea and vomiting.

INTRAOPERATIVE BLOOD PRODUCTS
Practice Guidelines for Perioperative Blood Management have been developed by the ASA.[243] Those recommendations that pertain to urologic surgery are summarized here:

1. Erythropoietin with or without iron may be administered when possible to reduce the need for blood transfusion in selected patients, such as those with renal insufficiency, anemia of chronic disease, or refusal of transfusion.
2. Administer iron to patients with iron-deficiency anemia if time permits. (Oral iron therapy takes longer for effect than intravenous iron.)
3. Determination of whether to transfuse red blood cells for hemoglobin concentrations between 6 and 10g/dL should be based on potential or actual ongoing bleeding, intravascular volume status, signs of organ ischemia, and adequacy of cardiopulmonary reserve.
4. A massive transfusion protocol may be used to optimize delivery of blood products to massively bleeding patients.
5. Consider acute normovolemic hemodilution to reduce allogeneic blood transfusion in patients at high-risk for excessive bleeding.
6. Reinfuse recovered red blood cells as a blood-sparing intervention in the intraoperative period, when appropriate.
7. When feasible, obtain relevant test results before transfusing platelets (platelet count), fresh frozen plasma (PT/INR and aPTT), or cryoprecipitate (fibrinogen levels).[243]

Numerous reports over the past five years have emphasized the acute immunosuppressive effects of blood transfusion, which negatively impact short-term morbidity and mortality as well as recurrence-free survival and cancer-specific mortality for multiple solid organ tumors. The problem is further complicated in cancer patients by the high rate of anemia on presentation. Stored blood cells deteriorate over time at a non-constant rate dictated by donor factors. Loss of cell integrity leads to extracellular accumulation of pro-inflammatory and immunomodulatory cytokines, hemoglobin, and micro-vesicles. This results in an additional inflammatory and immunosuppressive "hit" to the recipient at a time when the body is already under considerable stress. The literature is summarized nicely in two recent comprehensive reviews.[244,245] In short, they recommend aggressive correction of anemia prior to surgery with non-transfusion based strategies, if possible, combined with meticulous control of surgical bleeding to minimize the need for intraoperative blood products.

Takeaway Points
• Avoid intraoperative blood transfusion, if possible.

INTRAOPERATIVE FLUID AND BLOOD PRESSURE MANAGEMENT

General IV Fluid Management
Fluid management in perioperative therapy has been addressed in multiple observational studies. However, few trials, including protocols focused on ERAS, provide convincing and actionable strategies for the diverse range of urologic procedures. Absent this information, fluid management should target adequate global, regional, and local perfusion and be individualized to maintain appropriate intravascular volume.

Intravenous Fluid Management During Post-Bleomycin Retroperitoneal Lymph Node Dissection
Special consideration must be given to patients with prior exposure to bleomycin chemotherapy for testicular cancer, up to 40 percent of whom may harbor subclinical pulmonary fibrosis. Pulmonary failure is the most morbid complication of post-chemotherapy retroperitoneal lymph node dissection and may progress to adult respiratory distress syndrome and death. Any patient with a history of bleomycin exposure should be considered at risk for pulmonary complications, though the risk is greatest in smokers, men over 40 years and those who received more than three cycles of bleomycin. When managing patients with bleomycin exposure, it is critical to avoid excessive fluid administration, which will cause pulmonary edema, decreased diffusion, and requirement for toxic oxygen concentrations.[246] Careful maintenance of fluid balance with judicious use of colloid and crystalloid as needed to maintain hemodynamics appears to be the most important factor for prevention of bleomycin-associated morbidity. Though more controversial, most surgeons recommend that inspired oxygen should be maintained at the lowest fraction of inspired oxygen (FIO2) needed to maintain oxygen saturation above 89 to 90 percent.[247,248]

Intraoperative Blood Pressure Management
Maintenance of appropriate mean arterial pressure is not always achieved with volume and may require vasopressors to offset the decrease in systemic vascular resistance that occurs under anesthesia. In adult inpatients undergoing non-cardiac surgery, intraoperative hypotension is associated with both acute kidney injury and myocardial injury.[249] Recently a large trial of surgical inpatients at increased risk for acute kidney injury demonstrated that management targeting systolic blood pressure within 10 percent of baseline pressure, compared with less conservative management, reduced the risk of postoperative organ dysfunction.[250]

Intraoperative Irrigation Management
Fluid management and monitoring can be more complex in urology than other surgical specialties. Urology is unique

in that in addition to the standard monitored fluids such as intravenous infusions, urine output, and blood loss, there may be additional fluid sources that need to be watched. All endourology cases are performed with fluid irrigation into the urinary tract to aid in visualization. Monitoring the volume of irrigation infused and drained during endourologic procedures, particularly ones that involve high-volume continuous flow such as PCNL, TURP, and transurethral treatment of a large bladder tumor or stone, can identify mismatch.

Intravascular absorption is well known to occur in patients during transurethral resections.[251-253] Absorption is more problematic during cases using monopolar electrocautery, when water or glycine are required. However, bipolar and laser technologies are now widely available, enabling tissue resection and vaporization in saline. For longer procedures, it may be best to utilize such technology to decrease the risks associated with hypotonic solution.

For percutaneous procedures, fluid absorption is also always a concern, though it was previously believed not to be significant in uncomplicated procedures.[254-257] Concerns for absorption have been present for decades, and in the 1990s, multiple research groups established the use of ethanol to monitor fluid absorption during these procedures. Absorption can be intravascular, extravascular, or via pyelovenous backflow. One research group showed that 78 percent of patients absorb some fluid during PCNL, with 28 percent absorbing more than one liter.[258] Another group demonstrated fluid absorption in all 148 patients they studied.[259] Risk increases with longer operative time, more irrigation volume, and higher fluid pressures.[258-260]

Collecting system perforation and venous injury also increase the likelihood of fluid absorption, and if either knowingly occur, the procedure should be terminated. In the setting of unrecognized perforation, substantial irrigation can leak into the retroperitoneum or peritoneum. This can lead to physiological changes, which point to the critical nature of fluid balance monitoring in hopes to identify imbalance early. There have been multiple case reports of massive intra-abdominal collection of extravasated fluid after percutaneous renal surgery. One group aborted their procedure due to intraoperative hypotension, tachycardia, and increased peak inspiratory pressures, and upon rolling the patient back to supine position, discovered that the etiology was abdominal hypertension from intraperitoneal irrigation.[261-263] Patients already at risk for fluid overload, such as those with heart failure or chronic kidney disease, may be at higher clinical risk for absorption.[259] In complex cases, if significant absorption occurs, volume overload can lead to respiratory issues and cardiac failure. Anesthesia staff and nurses should monitor fluid balance closely, but it is ultimately the surgeon's responsibility to verify that this is occurring. Additionally, during percutaneous renal surgery, the urethral catheter drainage bag should be monitored as continuous flow irrigation leads to more rapid filling with subsequent bladder overdistention if not routinely drained.

In addition to fluid status monitoring, it is a strong recommendation in the AUA/Endourological Society Guideline on Surgical Management of Stones that clinicians use normal saline irrigation for these procedures (Evidence Level Grade B).[31] While hypotonic solution and water are likely safe in uncomplicated adults, they should be avoided when possible because of rare but serious complications such as hyponatremia, intravascular hemolysis, mental status changes, seizures, renal or hepatic dysfunction, transurethral resection syndrome, and even death.[264-268] Electrolytes may be checked intraoperatively or postoperatively in the recovery room if there are any concerns.

The risk of hypothermia increases during procedures requiring high volume endoscopic irrigation. Hypothermia is associated with peripheral vasoconstriction, increased cardiac risk, delayed emergence from anesthesia, extended post-anesthesia recovery, slower drug clearance, and hypoxia induced by postoperative shivering.[269,270] Warmed irrigation and intravenous fluids can help prevent this complication.

Takeaway Points
• Intravascular fluid absorption during high volume continuous flow endourologic procedures can be significant; therefore, fluid balance should be monitored for mismatch. • Normal saline irrigation should be used for endourologic procedures whenever possible.

Optimizing Behavior/Performance in the Operating Room

PROMOTING A CULTURE OF SAFETY

It has been almost two decades since the Institute of Medicine (IOM) recommended improving patient safety by addressing organizational cultural issues, especially in the OR.[271] A recent analysis of perception of safety in the OR by OR personnel found that the higher the perception of safety, the lower the 30-day postoperative mortality.[272] Yet, despite improvement efforts, safety culture still varies among hospitals. In institutions where a culture of blame exists, individuals avoid admitting mistakes because they fear punishment. The traditional hierarchical relationships among OR personnel may also inhibit a culture that promotes patient safety and teamwork.

Promoting a culture of safety requires transparency, feedback, and consistent reporting of errors and adverse events, eventually leading to better patient outcomes.[273] Only when errors are reported can systems and processes be assessed and improved.

What commonly is referred to as "just culture" in healthcare refers to an organizational culture that successfully balances the need for transparent non-punitive admission of errors with personal accountability for behaviors and organizational accountability for work systems. Just culture fosters mindfulness in workers, encourages accountability among team members, and engages employees in ongoing learning and system re-design.[274]

Specific elements of a culture of safety include establishing safety as an organizational priority, promoting effective teamwork, encouraging patient engagement, providing organizational openness, promoting transparency, and expecting individual accountability. Shared core values and institutional goals are promoted through education and training.[275] These attributes require strong and committed organizational leadership that promotes engagement and empowerment of all employees.[273]

Strong and dedicated leadership is critical for adopting and maintaining a culture of safety.
The IOM has emphasized that leadership is essential to achieving goals related to quality care and patient safety.[271] Traditionally, surgeons are taught to think and act independently which can result in poor communication.[276] However, successful leaders in the OR value communication and collaboration with their surgical teams.[277] Surgeons must create a psychologically safe environment where staff feel comfortable voicing their concerns. This improves the safe and effective implementation of new technology and maintains team effectiveness.[278] As suggested by Meritt and Helmreich, "a safety culture is more than a group of individuals enacting a set of safety guidelines; it is a group of individuals guided in their behavior by their joint belief in the importance of safety, and their shared understanding that every member willingly upholds the group's safety norms and will support other members to that common end."[279]

Creating a safety culture requires an ongoing multilayer process that is facilitated when the following criteria are met:

1. Leaders act as role models, as the active promoters of the safety culture and its desired outcomes;
2. New members of the organization are integrated into the system by senior members who explain the purpose and importance of the safety culture;
3. Organizations are proactive regarding safety by periodic preventive safety evaluations to identify weaknesses and latent failures in the system before they lead to active failures;
4. Organizations encourage and reward vigilance and inquisitiveness from all members;
5. An integrated approach focusing on system-wide analysis and remediation replaces the philosophy of blame and punishment; and
6. Organizations continually communicate results and celebrate successes to sustain effort and motivation.[280]

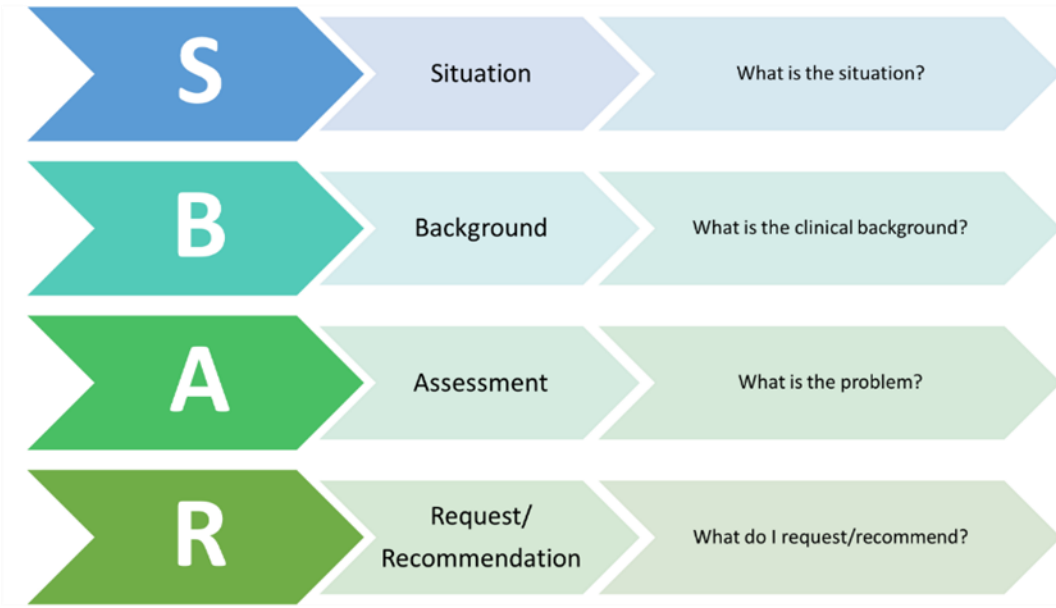
Safety culture can be periodically assessed using organizational surveys alongside relevant safety outcomes to evaluate progress and identify areas that may require additional improvement efforts.

Takeaway Points
• Surgical staffs' ratings of their institution's commitment to a culture of safety are correlated inversely with their 30-day postoperative mortality. • Surgeon leaders are critical in upholding a culture of safety; especially important is maintenance of a psychologically safe environment that encourages team members to speak up with concerns.

TOOLS FOR IMPROVING PATIENT SAFETY

There are many tools that can help providers improve patient safety. Healthcare Failure Mode Effect Analysis (HFMEA) is a method used to prospectively identify potential ways a process might fail and can be used when rolling out new technologies or for proactive assessment of existing high-risk processes.[281] The goal of HFMEA is to find weaknesses and redesign the system to prevent errors before they occur. Six Sigma, LEAN, and other quality improvement methodologies have been adapted for use in healthcare settings to increase efficiency and prevent error. Root Cause Analysis (RCA) is a team-based exercise done retrospectively in response to a near miss or adverse event that generates action items for process redesign and prevention of future harm.[282] To enrich the RCA, the Human Factors Analysis and Classification System (HFACS) can be used to assess the human factors elements contributing to events.[283] The Communication and Optimal Resolution (CANDOR) process is designed to improve the disclosure and investigation of an unexpected adverse event.[284] AHRQ designed TeamSTEPPS® training to focus on teamwork and communication in order to improve patient safety.[285] Specific tools such as SBAR (Situation, Background, Assessment, Recommendation) are used to improve real time communication among healthcare workers, a common cause of medical error (Figure 1).[282] SBAR allows all parties to proactively seek recommendations and necessary information to resolve issues as well as create a shared mental model[286] The Comprehensive Unit-based Safety Program (CUSP) is a method that can help clinical teams make care safer by combining improved teamwork, clinical best practices, and the science of safety. The Core CUSP toolkit gives clinical teams the training resources and tools to apply the CUSP method and build their capacity to address safety issues by building a briefing process and supportive culture.[287] The goal of CUSP is to educate providers on the science of safety and then empower frontline staff to identify and address preventable harm with the support of hospital leadership. Surgical CUSP teams integrate all aspects of patient care by obtaining representation from the preoperative area, postoperative recovery unit, hospital ward, OR, and surgical scheduling staff to identify and correct system defects. Hicks *et al.* demonstrated that clinical staff and technicians can work with hospital executives to implement evidence-based SSI prevention interventions and develop infrastructure for addressing issues that affected patient safety.[288] They identified OR defects and redesigned the briefing and debriefing process in the colorectal ORs, reducing colorectal SSI by 33 percent in one year and improving qualitative reports of OR culture and teamwork.[288] Many hospitals have dedicated Patient Safety Managers with experience using these tools who are willing to partner with clinicians interested in improving surgical patient safety.

Figure 1. Situation, Background, Assessment, Recommendation



IMPROVING INTRAOPERATIVE TEAMWORK (NON-TECHNICAL SKILLS)
Providing consistently safe and successful surgical outcomes is dependent in part on the cooperation and cohesiveness of the surgical team. It is recognized that OR team performance is a key contributor to patient safety, with multiple contributory domains of non-technical skill already identified across the medical and surgical literature.[289-291] These non-technical skills (NTS) are often difficult to quantify, but the introduction of global rating scales (GRS) such as the Non-Technical Skill for Surgeons (NOTSS) has allowed for individual and team ratings in situational awareness, leadership, communication, and decision making. These measurements have been adopted from or inspired by, existing methods developed in other high-reliability industries such as aviation and nuclear energy.[292]

The first and easily most studied instrument for quantifying NTS is the NOTSS tool (Figure 2). It is comprised of four NTS domains, which were determined through cognitive task analyses using Scottish consultant surgeons in general, cardiac, and orthopedic surgery.[293] Situational Awareness, Decision Making, Teamwork and Communication, and Leadership are all captured using the NOTSS instrument.[294] Evidence for the NOTSS tool's ability to discriminate between good and poor NTS performance has subsequently been demonstrated in urology, notably in the context of simulation-based assessment.[295-297] The NOTECHS rubric, an assessment tool adapted from aviation, was originally designed as a means of evaluating the Crew Resource Management (CRM) skills of pilots.[298] Initial studies showed that NOTECHS is a reliable means of assessing NTS in both the simulation[299] and actual OR[290,300,301] settings. Brewin *et al.* found in an immersive, in situ simulation setting that video-assisted rating of team performance with NOTECHS was able to reliably distinguish expert and trainee urologists. Finally, the OTAS (observational teamwork assessment for surgery) tool consists of two components, a checklist and a GRS that assesses team performance over the pre-, intra-, and postoperative periods. After initial construct validation by Undre *et al.*,[302] it was adopted for urologic surgery in 2007.[303] Like other NTS scales, it can be used to score combined team performance or to assess the NTS of a subset of the operative team, such as anesthetists or nurses.

Improvement in NTS metrics serves not only to maximize patient safety by solidifying team performance and communication but also can positively impact individual technical performance. A positive correlation between NTS and technical performance has been demonstrated in simulation studies[304-306] as well as in the OR environment, in both laparoscopic and open surgery.[290,301,307]

The direct relationship between NTS and measures of patient safety has been underexplored to date. However, using principles from human factors research, there is evidence to support the role of teamwork in mitigating latent safety threats in surgery.[308] Of note, research done in cardiac and pediatric orthopedic surgery demonstrated that effective teams, as measured by the NOTECHS tool, had fewer intraoperative safety threats arise.[309] While not directly tested in urologic surgery, it is likely that these findings are translatable as the principle of effective teamwork as a method to detect and prevent latent threats in high-reliability environments has been widely validated.[310,311]

Figure 2. The NOTSS Global Rating Scale

Category	Category rating*	Element	Element rating*	Feedback on performance and debriefing notes
Situation Awareness		Gathering information		
		Understanding information		
		Projecting and anticipating future state		
Decision Making		Considering options		
		Selecting and communicating option		
		Implementing and reviewing decisions		
Communication and Teamwork		Exchanging information		
		Establishing a shared understanding		
		Co-ordinating team activities		
Leadership		Setting and maintaining standards		
		Supporting others		
		Coping with pressure		

* 1 Poor; 2 Marginal; 3 Acceptable; 4 Good; N/A Not Applicable

Adapted from Yule *et al*. 2008[294]

Development and validation of measures of team performance represent only initial steps in improving operative safety. For effective quality improvement, it is imperative that stakeholders can efficiently address gaps in NTS knowledge and ability through targeted educational interventions. Examples of effective, yet separate and complimentary, educational design techniques for NTS training are simulation, coaching, and dedicated OR teams.

In situ simulation, which allows for surgical teams to implement training scenarios in the actual clinical environment in which they work, has been used with good effect for not only enforcing positive NTS within the surgical team, but also for identifying safety threats and human factor issues in the OR. Rao and colleagues showed that non-technical performance of all members of the surgical team improved over two in situ scenarios after a team debriefing.[312] Despite this evidence, in situ simulation has been vastly underutilized in urology, but the evidence from emergency medicine,[310] cardiorespiratory resuscitation,[313] and trauma care[314] supports its ability to improve team performance and enhance patient safety measures.

Immersive simulation situates trainees and surgeons into a high-fidelity simulated OR with 'confederates' representing members of the anesthesia and nursing teams to allow for assessments of teamwork and communication to be completed. Evidence supporting immersive simulation as a means of improving both technical and NTS amongst novice surgeons has been shown specifically in urologic surgery.[297,315] Outside of urology, seminal work by Riley *et al*. showed that perinatal morbidity improved at a hospital randomized to receive simulation-based team training.[316] Team-based simulation interventions focused on urologic surgery could become a useful improvement strategy in the future.

Coaching has been presented as another means of effectively teaching NTS in surgery.[317] This structured approach to training has been extrapolated from athletics,[318] supported by the underlying principle of continuous quality improvement (CQI).[319] This methodology can be applied both in the OR for real time assessment and feedback,[318] or with the use of video-replay at a later time, facilitating discussion and reflection on one's performance.[320,321] Coaching as a means of improving NTS is supported by level-one evidence, with a randomized trial demonstrating trainee improvement in NTS with the application of video-based coaching techniques.[322] Again, while not described in urology, these principles are certainly transferrable to the education and improvement of NTS in the OR amongst urologists and trainees.

Finally, the literature supports the use of dedicated OR teams as a means of standardizing quality of care.[323] Although evidence supporting the use of dedicated, multidisciplinary teams in colorectal[324] and gynecological[325] surgery has been established, evidence from urologic surgery is more sparse. Despite this, work from Sim *et al*. showed that a dedicated robotic surgery team was able to shorten the learning curve for robotic-assisted radical prostatectomy, with significant reductions in blood loss and perioperative pain.[326] Lasser and colleagues found that the use of consistent, non-physician team members was associated with decreased OR time.[327] Jenks *et al*. found that in the sacral neuromodulation cases, a dedicated surgical team led to significantly reduced postoperative infection rates.[328]

Takeaway Points
• Simulation training can improve the non-technical performance of surgical team members and has been linked to improved patient safety metrics. • The use of standardized, dedicated operating room teams may be linked to shorter procedural times and decreased postoperative complication rates in urologic surgery.

MANAGING CONFLICT AND DISRUPTIVE BEHAVIOR

Conflict among team members in the OR has many sources, including equipment needs, scheduling, roles, safety, sterility, and situational control.[329-331] A review of the conflict literature in surgical teams noted mainly negative associations between conflict and team performance.[332] However, there is some evidence that "task-related" (cognitive) conflict can improve innovation, motivation, and team performance, while "relationship" conflict is more often associated with distrust, anger, cynicism, and apathy, negatively impacting team performance and satisfaction.[333,334] Expression of negative emotion as well as misattribution (blaming) and harsh language (profanity, threats, personal attacks) can activate and exacerbate conflict by transforming tasks into relationship conflict.[329,335,336] Surgeons engage in interpersonal conflict more than other physicians and are noted to be particularly stubborn and difficult to deal with once conflict occurs.[330,335] Surgeons under stress justify using forceful communication (e.g., threats) because this expedites achieving their goals.[335] However, this type of communication is also more likely to lead to relationship conflict. The negative effects can unfortunately spread beyond those involved in the conflict.[335] Gawande *et al.* interviewed surgeons and found that poorly managed conflict can be a source of error resulting in patient harm.[318,337] Fortunately, although some conflict is likely unavoidable during surgery, its harmful effects can be mitigated by appropriate management. Successful conflict management strategies reported by OR teams include maintaining calm (emotional control), focusing on problem solving, addressing system issues with administration, respectfully confronting team members, and enhancing communication with expanded explanations.[337] A review of the medical team conflict literature suggests that establishing guidelines for conflict resolution, improving members' skills in conflict management, and fostering a climate of cooperation and trust can all help alleviate the negative impact of conflict on team performance. Historically, few residency programs have offered formal training in conflict resolution. Therefore, for practicing urologists, courses in conflict management can provide a useful forum to learn and practice these skills.

The Joint Commission in 2008 issued a sentinel event alert regarding the negative impact of disruptive behavior on patient care.[338] Intimidating, aggressive, and disruptive behaviors are more commonly noted in individuals in positions of authority and can include verbal outbursts, physical threats, condescending language or more passive resistance, such as impatience or the refusal to answer questions or return pages.[330,339] Such behavior undermines team functioning and impacts patient safety, which relies on quality communication.[338] Ninety-one percent of perioperative nurses surveyed report exposure to verbal abuse in the past year, with abusive anger and condescension noted most commonly.[340] Nurses and other physicians report that attending surgeons display more disruptive behavior than other providers in the hospital setting.[341] The majority of perioperative staff believe that disruptive behavior aggravates stress (93 percent), increases frustration (92 percent), decreases concentration (84 percent), and reduces collaboration/communication (89 percent). Additionally, 46 percent of staff report the association of disruptive behavior with an adverse event.[341] Rudeness has been shown to impact the cognitive skills of other team members and impair performance.[342,343] A recent randomized controlled trial during a neonatal resuscitation simulation provides high-level evidence that rudeness negatively impacts both diagnostic and procedural performance scores as well as measures of teamwork.[344] Unfortunately, physicians justify intimidating behaviors as expressions of frustration or intensity without adverse impacts on communication or patient safety.[339] It is incumbent upon surgeons to recognize that intraoperative reactions can negatively affect the performance of other members on the surgical team.[345] If awareness of this issue alone is not sufficient to change behavior, additional training should be considered to develop healthier coping strategies.[346,347] Hospitals are now required to have both a code of conduct as well as a plan for identifying and addressing disruptive physicians and staff.[348]

Different professions in the OR often attribute motivation (sometimes inaccurately) to other team members. Nurses view surgeons as egotistical and antagonistic, motivated by frustration. Surgeons feel nurses are controlling and rigid about rule-keeping, motivated by fear of management.[349] These inaccurate perceptions coupled with the negative interpersonal interactions previously discussed (e.g., conflict, disruptive behavior) often result in a tense or hostile intraoperative environment. Observational and interview studies note that 100 percent of cases in a large urban hospital and 70 percent of cases in a small institution had "high-tension events," most commonly occurring between surgeons and nurses.[349,350] Tense situations may encourage team members to withhold information or refuse to collaborate.[351] Tension puts performance at risk, as 68 percent of nurses and consultants and 86 percent of trainees surveyed admitted they were more likely to make errors in tense or hostile environments.[352] Improving the understanding of the roles of other team members, developing healthy ways to manage conflict, and avoiding disruptive behavior can improve teamwork communication and maximize patient outcomes.

Takeaway Points
• Conflict in surgical teams can negatively impact team performance, particularly when personal blaming or harsh language is used. • Disruptive behavior among surgeons is common and threatens patient safety by undermining team functioning and adversely impacting communication.

IMPROVING SURGEON AND ASSISTANT ERGONOMICS

Across the spectrum of subspecialty surgery, discomfort and ergonomic issues are becoming more prevalent.[353] In the broadest sense, ergonomics concerns the interaction between the system in which urologists work and the individuals who work within the system.[354] In the context of the surgical environment, ergonomics refers specifically to the manner in which surgeons physically interact with the patient, operating table, surgical equipment, and OR environment and the potential negative sequelae that can arise as a result from poor design or implemention.[355] In urology, the question of surgical ergonomics has been raised since the advent of laparoscopy, where musculoskeletal (MSK) discomfort became a part of the daily experience for many oncologists and endourologists.[355] Survey data supports the notion of ergonomics being an issue in urology, with over 60 percent of respondents attributing MSK pain in the neck, shoulders, and back to work-related incidents.[356,357]

Impact of Surgical Ergonomics

Lack of attention to surgeon ergonomics can adversely impact the healthcare system, increasing cost, decreasing surgeon and surgical assistant efficiency and performance, and potentially affecting patient outcomes.[357-360] A recent systematic review of ergonomic interventions demonstrated a benefit to both patients and healthcare workers, with improved clinician quality of life found in many included studies.[361] Poor ergonomics can increase time away from work,[360] increase use of pharmacological and physical therapy-based interventions,[360] and reduce technical performance.[359] While the impact of surgeon and assistant ergonomics on patient outcomes has not been directly studied, the known influence of technical performance on patient outcomes[362,363] suggests that positioning and other ergonomic factors may contribute to variation in these endpoints.

Risk Factors for Musculoskeletal Strain in the Operating Room

The literature supports the existence of both modifiable and non-modifiable risk factors for surgeon ergonomic-related injury. First, it is accepted that surgeons of different genders face different ergonomic challenges. Although recent evidence suggests female surgeons have superior outcomes in many procedure types,[364] evidence suggests the risk of MSK injury among female surgeons is up to twice that of their male colleagues in laparoscopic surgery.[365,366] However, female surgeons are less likely to seek invasive treatment options for MSK injuries.[367] Smaller hand size has implications for rates of hand injury as well as difficulty with instrument manipulation in laparoscopy.[368,369] Data from the most recent AUA Census (2017) noted that 41 percent of urologists have work-related MSK pain, and rates are even higher in women <45 years of age (65 percent).[370] In contrast, surveys of oncologic surgeons suggest that male sex is an independent predictor of occupational injury.[367,371]

Surgical inexperience has been identified as a risk factor for ergonomic difficulty in the OR. This can manifest as increased eye strain and finger neuropraxia in laparoscopic surgery, as well as MSK injuries to the back, wrists, and hands.[357] Simulation-based studies have shown that resident surgeons showed increased muscle contractility and significantly higher discomfort scores compared to faculty surgeons.[372] A study comparing novice and experienced robotic surgeon performance on the daVinci Surgical Simulator© (Inuitive Surgical, Sunnyvale, CA) found significant differences in elbow and wrist positioning at the robotic console, with novices more frequently positioning their arms in a manner that could lead to MSK strain.[373]

The various surgical approaches also have unique ergonomic sequelae. Although studied much less than minimally invasive approaches,[374,375] open surgery poses its own unique risks to surgeon health. Evidence suggests that compared to minimally invasive surgery, open approaches lead to increased risk of vertebral disc herniation, likely secondary to upper body twisting and suboptimal head positioning.[376,377] The majority of the endourologic literature compares muscle strain when using direct or video/fiber-optic endoscopes, with multiple studies showing the superiority of digital platforms.[378] MSK injury due to ergonomic strain during laparoscopy remains the most well-studied of all the urologic approaches. The combination of static posture and prolonged, isometric muscle contraction serves as the basis for much of the increased pain and fatigue associated with this surgical approach.[372,379,380] Increased effort is required to complete even simple maneuvers, with upwards of five-fold increased force required compared to open surgery.[377,381] Monitor position has also been shown to influence shoulder and neck MSK strain.[382] Additionally, eye strain poses a risk to surgeons performing laparoscopic surgery.[383] Robotic-assisted surgery poses similar challenges with static posture and isometric upper-limb muscle contraction.[353,384] Robotic surgeons attribute between 25 -50 percent of MSK fatigue and discomfort to design of the console,[385,386] with surgeon height playing a role.[387] Similar to laparoscopy, eye strain can pose a risk to surgeons using the robotic console, mitigated by the recent implementation of high-definition video.[384]

Optimizing Ergonomics within the Surgical Environment

The physical setup of the OR has important implications for surgeon ergonomics, including table height, video monitor placement, and pedal placement. Optimal table height adjustment minimizes the strain on the upper limbs and upper back.[361] In open surgery, the recommended height of the table is five centimeters below the level of the tallest surgeon's elbow, with shorter surgeons standing on stools to compensate.[388] In contrast, laparoscopic table height should be lower than open surgery, ideally having the surgeon's elbows flexed between 90 and 120 degrees to avoid shoulder and wrist injury associated with tables at open surgery height.[389] As a guide, the table should be situated at approximately 70-80 percent of elbow height, or roughly the level of the operating surgeon's pubic bone.[390] Monitors should be aligned with the target organ. These principles are illustrated in Figures 3 and 4. Hand-assisted laparoscopic surgeries benefit from having the table much higher, approximately two inches above the elbow height to facilitate non-laparoscopic hand positioning, thereby reducing muscle fatigue.[391] Secondly, poor positioning, especially in the height, of the monitors during minimally invasive surgery may lead to neck and upper back strain[372,392] in addition to issues with asymmetric contraction of spinal muscles.[376,377] Importantly, multiple studies have demonstrated improvements in efficiency,[393] simulation-based technical performance,[394] and reduction in technical errors when a 'gaze-down' display is used.[395] The described optimal height in the literature places the middle of the screen 10-20 degrees below eye level, allowing for neutral cervical spine position, and this typically occurs when the top of the monitor is about eye height.[396] This is illustrated in Figures 3 and 5. In addition to monitor height, recommended viewing distance is three feet away in order to optimize visual acuity and prevent forward protrusion of the neck in order to see clearly.[397] A final cause of MSK strain in the urology OR setup is the placement of foot pedals for the control of fluoroscopy and electrocautery.[398] Improperly placed pedals can lead to physical discomfort in legs or feet caused by prolonged dorsiflexion while hovering one's foot above the pedal so as to not lose contact.[299] Foot pedals should be placed in front of the dominate foot and in line with the target instrument (Figure 3). Alternatives to foot pedals include the use of hand triggers for cautery and fluoroscopy.[398] Even in open surgery where the OR set-up has less influence on surgeon body position, poor surgeon posture can lead to fatigue and MSK strain (Figure 6).

Figure 3. Monitor and Table Placement, Laparoscopic Surgery
The operating surface is at pubic height and the elbows in 90–120 degrees of flexion. The foot pedal is directly in front of the working foot. The monitor is 3–4 feet from the surgeon with the top of the screen at eye level so that the center of the screen is 10–20 degrees below eye level.

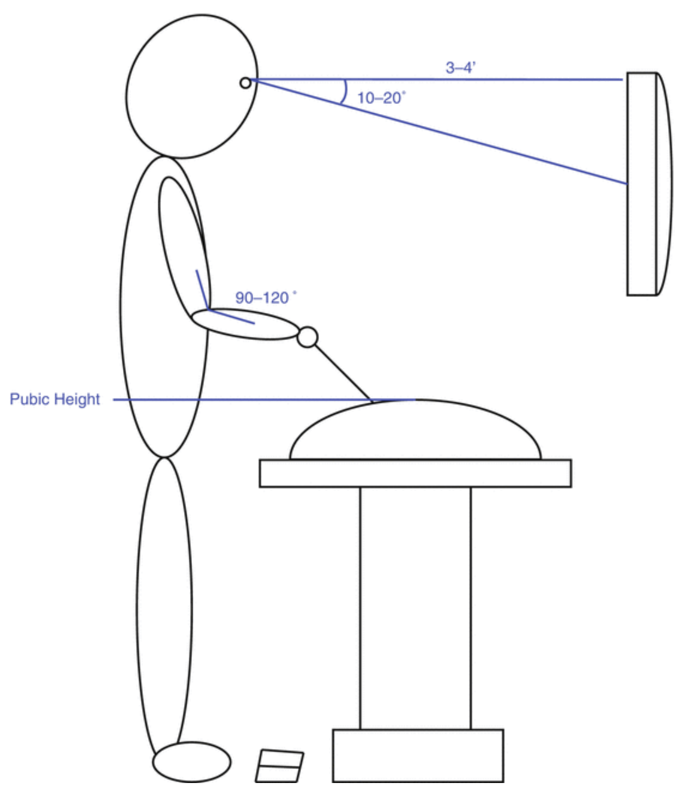


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Figure 4. Monitor and Body Orientation, Laparoscopic Surgery
Proper monitor placement in the OR is shown with a straight line between the surgeon and assistant's body orientation, target organ, and monitor.

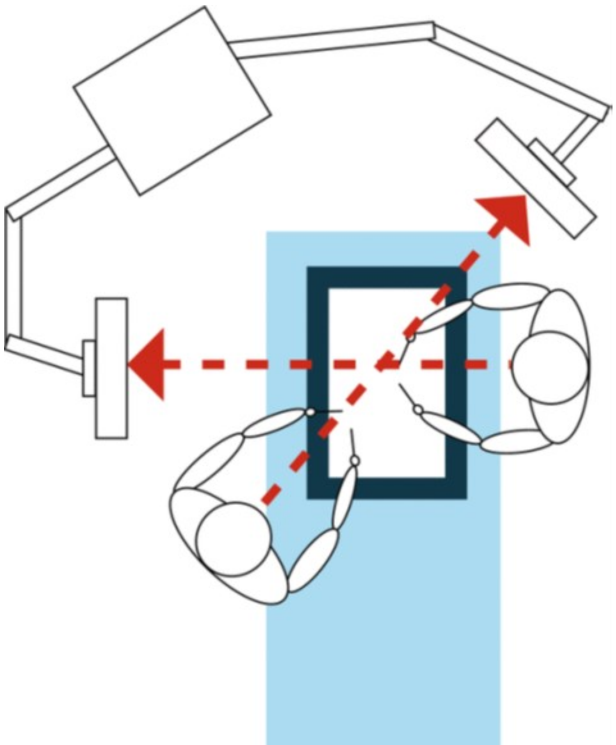

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Figure 5. Monitor Height, Endourologic Surgery

- Correct monitor height is shown in the top image. The top of the monitor is placed at eye level and approximately three feet away from the surgeon.
- Incorrect monitor height, with the monitor above eye level, is shown in the bottom image.

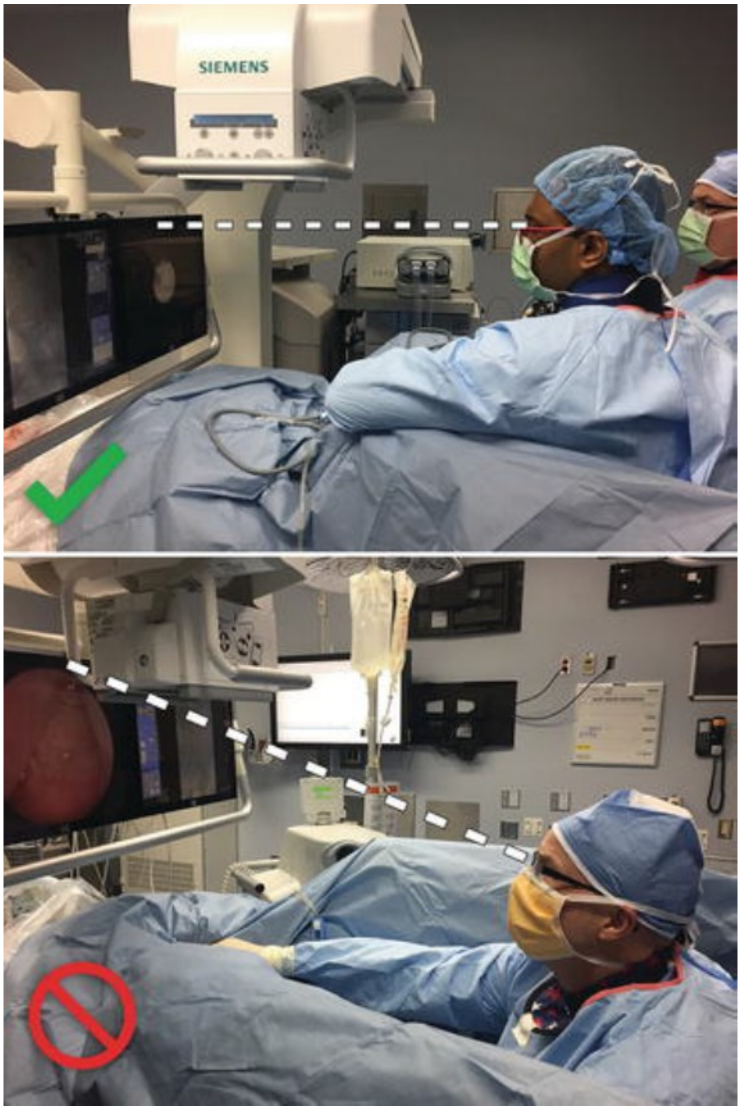

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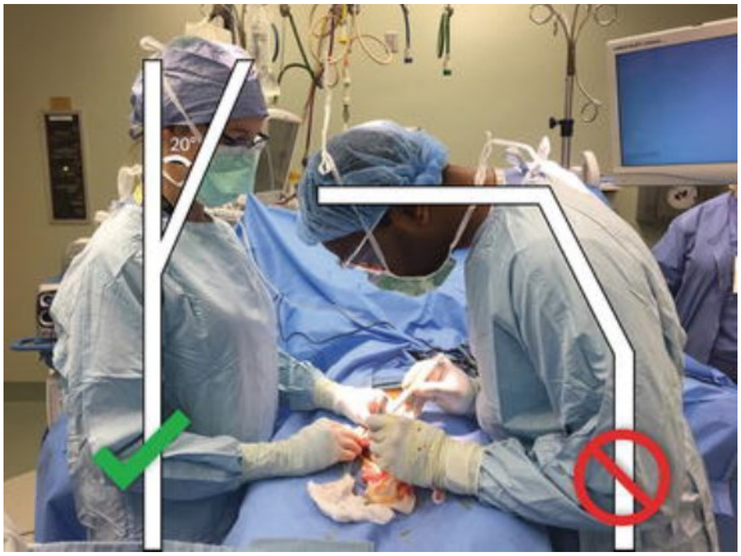
Figure 6. Surgeon Posture
The surgeon on the left is standing with correct posture, head only slightly inclined (approximately 20 degrees). The surgeon on the right has incorrect posture with his back and head overly flexed.



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Strategies to Prevent Intraoperative Musculoskeletal Strain
Simple interventions have been put forward to mitigate ergonomic issues in the OR, including physical warm-ups and micro-breaks.[399-401] Other high-reliability and high-skill industries use physical warm-up as a means of mitigating injury and improving dexterity and circulation. In a systematic review of the surgical literature, preoperative warm-up was found to significantly improve laparoscopic surgical performance, including studies of urology trainees and surgeons completing simulation-based assessments of laparoscopic and robotic skills. [399] Similar evidence exists supporting short intraoperative micro-breaks with stretches to improve surgeon ergonomics, with benefits including improved quality of life, decreased MSK discomfort, and reduced surgeon physiological strain.[401,402] Also, surgeons can use "postural resets" as a habitual way of regularly reassessing and correcting postural quality during intraoperative breaks or during a case natural transitions.[403] These simple, time-efficient interventions can easily be incorporated into a surgeon's daily routine.

Takeaway Points
• Musculoskeletal injury is prevalent amongst surgeons conducting open, laparoscopic, and robotic surgery and is related to isometric muscle contraction, posture, and monitor positioning. • Optimizing ergonomics in the operating room has a direct health benefit to surgeons. • Simple interventions such as warm-up and micro-breaks have supportive but limited evidence demonstrating a reduction in musculoskeletal strain and injury.

MANAGING MUSIC/NOISE/DISTRACTIONS
Intraoperative distractions can negatively affect surgical quality and efficiency. A recent review noted the most common intraoperative distractions were movement (e.g., monitors, doors) and case-irrelevant conversations, while the most disruptive to surgical efficiency and flow were equipment problems, surgical case difficulties, and irrelevant conversations.[404] An observational study of urologic surgeries noted a distraction rate of one every ten minutes, and distractions were associated with deterioration of safety checks.[405] Distractions during general surgery cases were noted to increase both surgeon stress and mental workload as well as decrease measures of teamwork.[406] Cardiac surgical errors and near misses also increased in the presence of distractions and disruptions in surgical flow.[407,408] Several studies suggest that inexperienced trainees are more affected by distractions than experienced surgeons.[404] Therefore, elimination of unnecessary intraoperative distractions and interruptions could help maximize the quality and efficiency of surgical care, especially when trainees are operating. Barriers to the implementation of strategies to reduce distractions and interruptions during surgery include both staff resistance to changing surgical processes as well as providers' poor understanding of the negative performance impact of distractions.[409] For distractions that cannot be eliminated, surgeon education in multitasking and stress management can be helpful, especially for junior staff and trainees.[404,410]

Noise levels during surgery often exceed recommended levels found in occupational safety guidelines, and chronic exposure can induce hearing loss.[411,412] Sources of intraoperative noise include staff conversations, equipment (e.g., lasers, warming units, suction), alarms, air conditioners, and music.[411] Noise can adversely impact cognition, concentration, memory, and performance of surgical team members.[411,413,414] Sound reverberation and poor speech discrimination impair team communication with worrisome patient safety implications.[415] Strategies to better manage intraoperative noise include minimization of irrelevant staff conversation (especially during critical portions of the procedure), use of plastic rather than metal bowls/trays, and designing OR floors/ceilings to absorb rather than reflect sound.[411]

Literature assessing how intraoperative music impacts performance and surgical outcomes has been inconclusive.[416] There is some evidence that music reduces surgeon stress and improves surgical efficiency and performance.[417-419] However, music has also been shown to negatively impact surgeon auditory processing,[420] decrease the accuracy and efficiency of communication among surgical team members, and impair surgical learning.[421] The effect seems modulated by the type of music selected and the volume at which it is played.[411,418] Suggestions to minimize potential negative effects include playing background music at a "reasonable" volume, having team members agree on genre, and stopping music during critical portion of the procedure.[411,415] In addition, "smart" music controllers, such as CanaryBox™, can automatically reduce music volume when patients become hemodynamically unstable, in order to facilitate communication among surgical team members during a crisis.[422,423]

MAXIMIZING TECHNICAL PERFORMANCE

Recent evidence in urology and other surgical specialties has illuminated the significant relationship between intraoperative performance and patient safety.[363] Although the technical skill of a surgeon has always been anecdotally linked to patient outcomes, the literature now supports this in radical prostatectomy,[304] gastrectomy,[424] gastric bypass,[362] and pancreaticoduodenectomy.[425] Innovative approaches to evaluating, improving, and monitoring this measure of surgical quality are emerging in the education and quality improvement literature, using valid assessment instruments and structured training methods.

Simulation has long served as a means of assessing both technical and non-technical skill, primarily for training of surgical residents and fellows. Simulation can be used for assessing surgeon performance in a low-stakes environment, where patient safety is not jeopardized in the name of education. This assessment environment can consist of traditional dry-[240] and wet-lab exercises,[426] in addition to more innovative simulation platforms like virtual reality (VR).[427] Evidence supporting the transferability of VR training to the OR[428] has cemented its use in surgical curriculum, especially robotic surgery.[429] Technical skill assessments can be carried out in the OR, both in real-time[430] and postoperatively using video-capture. Video-capture in the OR, after addressing any patient or hospital ethical concerns, can be particularly advantageous for surgeon learning as it facilitates in-depth analysis of patient safety issues and granular assessment of surgeon performance.[431]

Evaluations of technical skill must be feasible across all OR environments. A lack of video-capture in open surgery can make assessments of technical skill somewhat challenging. The Objective Structured Assessment of Technical Skills (OSATS), although originally developed for dry-lab skills assessment,[432] has since been used in a multitude of surgical settings, including open surgery in the OR.[305]

Laparoscopy continues to be the predominant surgical approach in pediatric urology, endourology, and urologic oncology. It is often taught earlier in residency than other minimally-invasive surgery (MIS) approaches such as robotics. The GOALS (Global Operative Assessment of Laparoscopic Skills) rubric was developed for just this purpose and has been used in urology to assess trainee performance in the simulation setting.[433] However, it has yet to be used in the OR to assess performance, limiting the ability to predict patient outcomes.

Endoscopic surgeries of the urinary tract are commonly performed by trainees and urologists alike. The scope-based skill set is drastically different than abdominopelvic surgical approaches, and this has spurred the creation of assessment tools specific to endourologic operations. The literature in this space supports the transferability of skills from the laboratory to the OR.[434]

Robotic surgery has been a heavily investigated field recently, as this modality has become the gold standard for many urologic surgeries.[429,435] The Global Evaluative Assessment of Robotic Skills (GEARS) tool (Figure 7) remains the most widely useful across the simulation and OR settings.[436] Evidence supporting both its ability to improve OR performance in the simulation laboratory[428] as well as impact patient outcomes following prostatectomy,[304] makes it particularly valuable for evaluating robotic technical performance in trainees and surgeons alike.

Microsurgical approaches are of value to the urologist performing surgery for infertility and other inguinoscrotal pathology. However, little evidence exists in the literature surrounding the evaluation of technical skills in this field. Grober and colleagues used an adaption of the OSATS in microsurgery to assess microsurgical skill in vasovasostomy and found that GRS scores were higher in a simulation-trained cohort, with improved anastomotic patency rates.[437]

Limited evidence has been presented supporting the direct relationship between surgical skill and patient safety. However, new publications across the surgical literature have begun to elucidate the complex way that technical performance of the surgeon contributes to variation in patient outcomes.[304,362,424,425] Studying this topic can be particularly challenging given its controversial nature, but as hospitals and surgeons begin to increase the transparency

Figure 7. Global Evaluative Assessment of Robotic Skills (GEARS) Tool

Depth perception

1	2	3	4	5
Constantly overshoots target, wide swings, slow to correct		Some overshooting or missing of target, but quick to correct		Accurately directs instruments in the correct plane to target

Bimanual dexterity

1	2	3	4	5
Uses only one hand, ignores nondominant hand, poor coordination		Uses both hands, but does not optimize interaction between hands		Expertly uses both hands in a complementary way to provide best exposure

Efficiency

1	2	3	4	5
Inefficient efforts; many uncertain movements; constantly changing focus or persisting without progress		Slow, but planned movements are reasonably organized		Confident, efficient and safe conduct, maintains focus on task, fluid progression

Force sensitivity

1	2	3	4	5
Rough moves, tears tissue, injures nearby structures, poor control, frequent suture breakage		Handles tissues reasonably well, minor trauma to adjacent tissue, rare suture breakage		Applies appropriate tension, negligible injury to adjacent structures, no suture breakage

Autonomy

1	2	3	4	5
Unable to complete entire task, even with verbal guidance		Able to complete task safely with moderate guidance		Able to complete task independently without prompting

Robotic control

1	2	3	4	5
Consistently does not optimize view, hand position, or repeated collisions even with guidance		View is sometimes not optimal. Occasionally needs to relocate arms. Occasional collisions and obstruction of assistant.		Controls camera and hand position optimally and independently. Minimal collisions or obstruction of assistant

GEARS

The GEARS tool adapted from Goh *et al*. 2012 [436]

in which they deliver patient care, the barriers that prevent this type of research may be broken down. New approaches to surgical safety may improve the way trainees and surgeons learn new procedures. One such method adapted from other high-reliability industries is the previously mentioned HFMEA, which breaks down a process to identify the elements that pose the greatest harm to patient safety. In urology, this has been adapted to create modular curricula that introduce surgeons in a stepwise fashion to a new procedure, thereby limiting patient harm.[429] Other examples of this type of approach have been used outside of urology, notably in laparoscopic Nissen fundoplication.[438] This structured, methodical approach could be beneficial in both training and proctoring of new procedures.

Multiple educational intervention strategies have been described that may improve the technical performance of surgeons in training or independent practice. In the preoperative setting, undertaking a surgical “warm-up” has been shown to improve technical performance in the OR.[439] This simple intervention employs simulation platforms that are easy to setup and use, such as VR[440] and box-trainers.[441] In the postoperative space, debriefing with a mentor is perhaps the most widely recognized method of improving performance for trainees, and more recently, practicing surgeons.[442] The adoption of coaching models has enhanced the ability of educator and mentor to provide successful and impactful feedback, incorporating techniques that allow for a non-judgmental and non-paternalistic approach to performance improvement.[443] Coaching can be done immediately following an operative case or simulation, but recent efforts include capturing video from the OR to facilitate in-depth analysis of performance.[321] “Reviewing the game tape” allows surgeons to better study the underlying techniques and maneuvers that led to successful and unsuccessful operative steps or outcomes.[429] Successful models of peer-coaching have been described in multiple contexts, including faculty-trainee[444] and faculty-faculty teaching.[315] In urology, the Michigan Urological Surgery Improvement Collaborative (MUSIC) group at the University of Michigan has begun to use peer-coaching as a method of improving and standardizing state-wide radical prostatectomy outcomes by inviting surgeons from around Michigan to participate in sessions using their own and colleagues’ Improvement Collaborative (MUSIC) group at the University of Michigan has begun to use peer-coaching as a method of improving and standardizing state-wide radical prostatectomy outcomes by inviting surgeons from around Michigan to participate in sessions using their own and colleagues' operative video from robotic-assisted surgeries.[445]

A final method of technical performance improvement utilizes novel approaches in simulation to immerse trainees and surgeons in an environment that closely replicates the OR to recreate rare and often life-threatening intraoperative scenarios.[446] This type of intervention has been tested in urology, with preliminary evidence supporting the use of immersive simulation for training intraoperative crisis management, as well as TURP surgery.[295,447]

Takeaway Points
• Surgeon technical skill is predictive of clinical outcomes in urology and across multiple surgical specialties. • Coaching methods and simulation-based strategies can be used to improve the performance of surgeons in the operating room.

Conclusion

This white paper summarizes a wide variety of intraoperative factors that have been linked (with varying degrees of evidence) either directly or indirectly to the surgical outcomes of patients. The paper addresses intraoperative strategies for prevention of SSIs, wrong site surgery, VTE, positioning injuries, surgical fires, and excessive radiation exposure. The optimization of intraoperative patient physiology is discussed as well as providing helpful tips for both surgeons and anesthesiologists. Potential pitfalls associated with live surgery and new technology adoption are also highlighted. The white paper describes the importance of organizational culture in promoting safety and presents various assessment and improvement tools used in both adverse event investigation and quality improvement projects. Finally, strategies for optimizing intraoperative behavior and performance in the OR are addressed ranging from conflict to ergonomics to technical performance. The white paper is intended to be used as a practical resource for both urologists and institutions to help guide tangible interventions designed to prevent surgical complications and improve patient outcomes.

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