Review

A Review of Single-Use and Reusable Gowns and Drapes in Health Care

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ABSTRACT

Gowns and drapes are used widely in healthcare facilities. Gowns have been used to minimize the risk of disease acquisition by healthcare providers, to reduce the risk of patient-to-patient transmission, and during invasive procedures to aid in maintaining a sterile field. Drapes have been used during invasive procedures to maintain the sterility of environmental surfaces, equipment, and patients. This article reviews the use of gowns and drapes in healthcare facilities, including the characteristics, costs, benefits, and barrier effectiveness of single-use and reusable products.

Currently, gowns protect healthcare personnel performing invasive procedures from contact with bloodborne pathogens. Although gowns have been recommended to prevent patient-to-patient transmission in certain settings (eg, neonatal intensive care unit) and for certain patients (eg, those infected with vancomycin-

resistant enterococci), scientific studies have produced mixed results of their efficacy. While appropriate use of drapes during invasive procedures is recommended widely as an aid in minimizing contamination of the operative field, the efficacy of this practice in reducing surgical-site infections has not been assessed by scientific studies.

Based on an evaluation of the functional requirements, environmental impact, and economics of gowns and drapes, clear superiority of either reusable or single-use gowns and drapes cannot be demonstrated. The selection of particular gowns and drapes by individual healthcare facilities requires an assessment of the facility's requirements, available products, and costs and should be based on the desired characteristics of an ideal gown or drape as defined in this paper (*Infect Control Hosp Epidemiol* 2001;22:248-257).

Gowns and drapes have been used for more than a century by healthcare professionals. Gowns have been used to minimize the risk of disease acquisition by healthcare providers, to reduce the risk of patient-to-patient transmission, and during invasive procedures to aid in maintaining a sterile surgical or procedure field. Drapes have been used during invasive procedures to maintain sterility of environmental surfaces, equipment, and patients. Modern technology allows gowns and drapes to be constructed of many materials. Healthcare facilities should understand the characteristics of the ideal gown or drape and base their purchase decisions by balancing health and safety concerns with economic, environmental, and comfort issues.¹

This article addresses important issues regarding gowns and drapes, including a consideration of their uses, characteristics of an ideal gown and drape, benefits, cost, environmental impact, and barrier effectiveness.

USES OF GOWNS AND DRAPES IN HEALTH CARE

Gowns are used widely in healthcare facilities as part of personal protective equipment to minimize the passage of microbes to surgical patients and to minimize exposure of healthcare providers to infectious agents, especially bloodborne pathogens such as human immunodeficiency virus (HIV), hepatitis B virus, and hepatitis C virus. Drapes are used on patients during invasive procedures to eliminate or minimize the passage of microorganisms from non-sterile to sterile areas, thereby reducing the risk of nosocomial infection.

Healthcare providers are at risk for acquiring infection during patient-care activities, especially bloodborne pathogens during invasive procedures. The risks of acquisition of hepatitis B,^{2,3} hepatitis C,⁴ and HIV^{5,6} have been well documented. All three pathogens can be acquired via contact of contaminated body fluids with nonintact skin or

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mucous membranes. Because of these risks, the Occupational Safety and Health Administration (OSHA) promulgated a rule in 1991 to minimize healthcare workers' risks of acquiring bloodborne pathogens.⁷ This rule required that employers provide healthcare workers with appropriate personal protective equipment (PPE). PPE is defined as specialized clothing or equipment for protection against pathogens. The rule lists examples such as gowns, laboratory coats, eye protection, masks, face shields, and gloves. The OSHA rule allows the employer and employee to select the PPE based on the type of exposure and the quantity or amount of body fluids that may be encountered during the performance of the task or procedure. The rule directs that blood or other potentially contaminated body fluids must not reach the employee's work clothes or street clothes, undergarments, skin, eyes, mouth, or other mucous membranes. This protection must last for the expected duration of the task or procedure. The type of PPE required depends on the following three factors: (1) the condition of exposure, which includes the part at risk (eg, face, legs, hands) and the type of the exposure (eg, pressure, fluids, droplets, aerosols); (2) the amount of blood or body fluid exposure (ie, a few drops to large volumes of liquid); and (3) the duration of likely exposure (ie, short exposure, such as starting an intravenous line, or long exposure, such as cardiathoracic surgery).

Nosocomial infections result in substantial morbidity and mortality. The Centers for Disease Control and Prevention (CDC) has estimated that nosocomial infections cause 19,027 deaths and contribute to an additional 58,092 deaths per year. Surgical-site infections (SSIs) have been estimated to cause 3,251 deaths directly and to contribute to 9,726 deaths.⁸ Since the incidence of SSIs in the lowest-risk category of procedures is approximately 1% and an estimated 27 million surgical procedures are performed each year, more than 270,000 SSIs are likely to occur each year. Multiple strategies have been recommended to reduce the incidence of SSIs, including the proper use of drapes to cover tables, equipment, and the patient, so as to create a sterile field during an invasive procedure.¹ Drapes most commonly are used during surgery, but they also are used for a variety of other invasive procedures, including cardiac catheterization, lumbar puncture, and placement of arterial or central venous access devices. Drapes are recommended by the CDC to reduce SSIs.⁹ Drapes also are recommended to prevent bloodstream infections during intravascular line insertion.¹⁰

More recently, gowns have been evaluated as a means to reduce patient-to-patient transmission of resistant pathogens such as methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant *Enterococcus* (VRE; see "Benefits" below).

CHARACTERISTICS OF THE IDEAL GOWN OR DRAPE

The characteristics of an ideal gown or drape have been well defined in the literature but not previously summarized (Table 1).^{1,11-15} Each of these characteristics may be measured by one or more "standardized" tests.¹¹ These

standardized tests have been developed by several organizations, including the American Society for Testing and Materials (ASTM; eg, ASTM F-1670, ASTM F-1671), the American Association of Textile Colorists and Chemists, the Health Industry Manufacturers Association, and the National Fire Prevention Association. Although a variety of tests have been used to compare barrier qualities of fabrics, there is controversy^{16,17} about which test procedure most closely mimics actual conditions found in the surgical environment. Current tests allow a broad categorization of gowns, based on increasing protection from liquid penetration: resistant (ie, resists penetration of liquids but will allow penetration with pressure), repellent (ie, resistance to wetting by a liquid), or impervious (ie, liquid-proof, prevents the penetration of liquids and microorganisms).

For reusable products, one must consider not only the characteristics of the purchased items but also the characteristics of the laundered products. Maintaining manufacturers' specifications is easier for single-use items compared with reusable products.

AVAILABLE GOWNS AND DRAPES

Surgical gowns and drapes are fabricated from either multiple- or single-use materials. These two basic types of products each have advantages and disadvantages. In addition, within each of these two broad categories, there is considerable variation in design and performance characteristics which reflects the necessary trade-offs in economy, comfort, and degree of protection required for particular surgical procedures.¹²

Traditional Reusable Materials

From the late 19th century to the 1970s, hospital sheeting used cotton muslin as the primary fabric. During this era, three fabrics were commonly used. All-cotton muslin (140-thread-count muslin) is a loosely woven fabric that is soft, absorbent, drapeable, and extremely porous. Since it is readily permeable, this material does not possess any liquid-resistance capability. Furthermore, it tends to abrade easily and generate lint. Blended sheeting (180-thread-count percale) consists of a polyester and cotton blended sheeting that has permanent press qualities but otherwise exhibits performance similar to muslin. Finally, T280 barrier (175- to 280-thread-count), a tightly woven cotton or polyester-and-cotton blended fabric, was the first reusable fabric with a water-repellent chemical finish. However, resistance to liquid penetration diminishes with repeated wash cycles.¹²

In the 1980s, new surgical textiles with improved, multiple-use protective qualities were developed. Advances in these materials included more consistent barrier properties, reduced flammability, low lint generation, and extended durability. Two broad groups of products encompass all the known varieties currently available. The first is polyester sheeting, which consists of a tightly woven fabric made of continuous-filament synthetic yarn that is chemically finished. The second includes composite materials, combinations of woven or knitted fabrics engineered to obtain enhanced performance characteristics by laminating or coating them with various

TABLE 1
CHARACTERISTICS OF AN IDEAL GOWN OR DRAPE

Characteristic	Gown or Drape	Goal
Barrier effectiveness	Both	Ability to prevent penetration of contaminated liquids (ie, act as a repellent) and microorganisms. For reusable products, ability to maintain complete barrier effectiveness despite multiple washings.
Infection benefit	Both	Prevent the greatest number of nosocomial infections.
Quality maintenance	Both	Consistent barrier effectiveness and reliability among all new products and, if used, among all reused products.
Functionality	Both	Ability to allow wearer to perform activities without hindrance.
Comfort	Gown	Absence of heat fatigue in wearer, which may increase mistakes, impair performance, make the worker less efficient, and increase the employee's stress; allows moisture to evaporate quickly; nonallergenic.
Cost	Both	Low total cost, including acquisition cost per unit, storage cost, waste handling, laundry charges (reusable only), waste-disposal cost, potential liability (cost of gown failure), loss, and damage (reusable only).
Tear strength	Drape	Ability to resist tears, which compromises the sterile field and allows penetration of microorganisms or liquids.
Strength	Both	Ability to resist punctures.
Available sizes	Both	Multiple sizes available (eg, small through extra large).
Sterilizability	Both	Item must be capable of being sterilized, using standard methods (eg, ethylene oxide).
Public image	Both	Must consider local concerns regarding single-use versus reusable products (eg, landfill problems, water supply, stained reusable products).
Drapeability	Drape	Ability to conform to patient or equipment contours smoothly and closely.
Linting	Both	Minimize linting. If linting occurs during a surgical procedure, lint may enter the wound increasing the risks for nosocomial infection and foreign-body reactions.
Biocompatibility	Both	Does not chemically irritate skin.
Toxicity	Both	Does not contain toxic materials.
Flammability	Drape>gown	Flame-resistant fabrics preferred, especially for surgical drapes (ignition devices present in the OR include lasers, electro-surgical units, and hot-wire cauteries). However, all fabrics, including fire-resistant fabrics, will burn in an oxygen-enriched environment.
Abrasiveness	Both	Does not physically damage skin.
Odor	Both	Odor free.
Storage requirement	Both	Minimize storage requirement.
Procedure sets or surgical packs	Both	Self-contained procedure sets or surgical packs available, which decrease set-up time (single-use only).
Environmental impact	Both	Reusable: production, water, electricity to heat water, sewer, waste disposal. Single-use: production, waste disposal (landfill).
Waste disposal	Both	Adheres to local and state solid-waste rules. Minimize total waste disposal.
Laundry risk	Both	Contaminated drapes and gowns, if not properly managed, may represent a risk to persons transporting or cleaning the contaminated item (reusable only).

Abbreviation: OR, operating room.

types of films that provide increased protection against strike-through of liquids and microorganisms.¹²

Single-Use Materials

Single-use surgical gowns and drapes are most commonly constructed of nonwoven materials, alone or in combination with materials that offer increased protection from liquid penetration (eg, plastic films). Nonwoven fabrics are derived from various forms of natural (eg, wood pulp, cotton) and synthetic fibers (eg, polyester, polyolefin) that can be engineered to achieve desired properties by the use of special fiber types, bonding processes, and fabric finishes.

The three most commonly used nonwoven fabrics for surgical gowns and drapes are spunlace, a hydroentangled material often consisting of wood pulp and polyester fibers; spunbond/meltblown/spunbond, a fabric consisting of three thermally or adhesively bonded layers (spunbond provides the strength, meltblown the barrier); and wet-laid, a nonwoven fabric consisting of wood pulp or a blend of polyester and wood-pulp fibers. The fibers are suspended in water to obtain a uniform dispersion and then are separated from the slurry by draining the water through a fine mesh screen.^{12,13} Chemical treatments can be used to improve liquid penetration resistance.

Reinforcement of Reusable and Single-Use Products

Both reusable and single-use products are commonly reinforced to enhance or improve their properties and performance. For some surgical gowns and drapes, the barrier properties of one ply (ie, single sheet or layer of fabric) of a material may not be adequate for the particular application; in these cases, additional materials are often added in the form of additional layers of material, coating, reinforcements, or laminates. In addition, reinforcement may be added to improve absorbency and nonslippage or to produce other desirable characteristics.¹² The following materials are being used in reusable and single-use products: standard (one layer) fabric; reinforced fabric (second layer of fabric used to reinforce base material); zone-impervious fabric; and impervious fabric.

For many years, gowns made from woven 140-count cotton muslin were the standard fabric. However, liquids and skin-cell fragments that ranged from 5 to 60 μm could penetrate the threads of 140-count muslin easily, allowing contaminants to reach the patient. The barrier effectiveness of woven materials has been improved by the development of tighter weaves, liquid-repellent finishes, and new fabrics (100% polyester fiber).

Another improvement in the reusable fabric area has been the development of layered fabric with a highly resistant membrane between two layers of fabric. These new reusable materials provide good barrier protection on first use, but maintenance of these barrier properties is dependent on controlling all variables during the reprocessing. Some studies have shown that the barrier capabilities of laundered reusable fabrics are diminished.¹⁸

Liquid-proof protection is available with poly-reinforced, nonwoven, single-use products and with some reusable products that incorporate membranes. For situations when resistant or repellent fabric is appropriate, unreinforced nonwoven and reusable gowns and drapes may be chosen. Highly resistant barriers are available with single-use products made from nonwoven fabrics reinforced with polyethylene and layered reusables with membranes. Gowns must be selected to provide protection against liquid strike-through for the anticipated pressures and blood loss. Some researchers suggest that, with the exception of head and neck surgery, plastic-film reinforced gowns are recommended for all surgical cases when the anticipated blood loss is >100 mL and the duration exceeds 2 hours. For most procedures with less than 100 mL of blood loss or duration less than 2 hours, reinforced gowns are recommended. Plastic-reinforced gowns are suggested for use during procedures conducted in the abdominal area.¹⁹

BENEFITS

Gowns are used widely in the hospital in an attempt to reduce the risk of acquiring or transmitting nosocomial infections. The major uses of gowns are twofold. First, gowns are used in surgery and while performing invasive procedures, both to decrease the transmission of skin flora from the healthcare staff and to protect the staff against

contact with potentially infective material, such as blood. Second, gowns are used when caring for patients with certain infectious disease (eg, MRSA, respiratory syncytial virus, and VRE) to aid in preventing cross-transmission. The usefulness of barrier precautions has been reviewed.²⁰

Role of Gowns During Surgery in Preventing Nosocomial Wound Infections

The surgical site is the third most common site of nosocomial infections and accounts for approximately 15% of all nosocomial infections. The CDC estimated that in 1992 SSIs resulted in a mean additional hospital stay of 7.3 days at a mean cost of \$3,152.⁸ The use of highly resistant gowns and drapes in the operating room has been a standard infection control practice to prevent SSIs, because they act as barriers to bacteria that are shed by the patient or the surgical team members into the open wound during the operation.²¹ The CDC recently published a guideline providing science-based recommendations for prevention strategies to reduce the incidence of SSIs.⁹ This guideline made the following recommendation regarding surgical attire and drapes: "use sterile surgical gowns and drapes that are effective barriers when wet (ie, materials that resist liquid penetration)." This recommendation was ranked as a *category 1B*, strongly recommended for implementation and supported by some experimental, clinical, or epidemiological studies and strong theoretical rationale.

Six prospective studies (Table 2), all but one conducted prior to 1990, have compared the use of nonwoven and woven cotton gown and drape fabric to prevent intraoperative wound infections.²¹⁻²⁶ All studies were conducted in a prospective fashion. Assignment to reusable versus single-use gowns and drapes differed among the studies and included random assignment, crossover design, and pre- and post-initiation of a disposable draping system. Some, but not all, studies used personnel who were masked as to the type of gown used for assessing the outcome variable (ie, wound infection). The study by Dr. Garibaldi was relatively small, but the authors used intraoperative wound contamination as their primary outcome measure, which effectively increased the power of the study.²¹ They reported that there was only a 10% probability that they would have missed a significant difference between single-use and reusable gowns, if such a difference truly existed. Several large studies have reported higher infection rates (relative risk >2.0) associated with reusable fabrics.^{22,24,25} Dr. Moylan and colleagues reported a logistic model using postoperative infection as the dependent variable and five predictors: type of gown (single-use vs reusable), wound category, length of operation, gender, and antibiotics.²⁴ In both this model and the model including interaction terms, use of reusable gowns and drapes was associated with a significantly higher rate of SSIs. These studies stand in contrast to the prospective, randomized, masked study of Dr. Garibaldi and colleagues, which was unable to demonstrate a difference in either SSIs or wound contamination between reusable and single-use gowns and drapes.²¹ Methodological flaws potentially present in these earlier studies included lack of true randomization, inadequate descrip-

TABLE 2
REVIEW OF STUDIES COMPARING INFECTION RATES FOR SINGLE-USE VERSUS REUSABLE GOWNS AND DRAPES

Study	Moylan ²²	Garibaldi ²¹	Balkin ²³	Moylan ²⁴	Baldwin ²⁵	Bell-chambers ²⁶
Study years	Prior to 1980	1984	1981-1983	Prior to 1987	1979-1980	1995-1996
Design	Prospective, crossover	Prospective, randomized	Prospective, crossover	Prospective, crossover	Prospective, pre- and post-initiation of disposable draping	Prospective, randomized
Outcome by masked observers	No (independent observer)	Yes	Not specified	No (independent observer)	Not specified	Yes
Results	Single-use Spunbonded olefin	Single-use Spunlaced fiber and polyester blend	Single-use Spunlaced fabric	Single-use Spunlaced	Single-use 40% polyester and 60% wood pulp	Single-use Paper drape
Type of gown	Reusable Cotton, 140 or 180 threads/sq in	Reusable Polyester and cotton poplin (180 threads/sq in), reinforced	Reusable Polyester and cotton (128 threads/sq in), reinforced	Reusable Cotton, 280 threads/sq in	Reusable Cotton, 140 threads/sq in	Reusable Fabric drape
No. of operations	1,100	226	2,139	1,060	3,236	250
Intraoperative contamination	NS	69 (30.5%)	NS	NS	NS	NS
Low level	NS	35 (15.5%)	NS	NS	NS	NS
High level	NS	5 (2.2%)	108 (5.0%)	73 (6.51%)	15 (0.46%)	13 (5.2%)
Infection rate	25 (2.27%)	NS	77/1,655 (4.7%)	30 (2.83%)	35 (1.11%)	12 (5.08%)
Clean procedures	(1.98%)	NS	31/484 (6.4%)	(1.8%)	NS	NS
Clean-contaminated procedures	(2.09%)	NS	33/517 (7.4%)	(4.8%)	NS	NS

Abbreviation: NS, not specified.

tion of the products tested, failure to account for all patients enrolled, failure to assure that reusable products were used within their life-expectancy, assessment of the primary outcome (ie, SSI) by personnel aware of the subject's intervention, and improper statistical tests.

Recently, Bellchambers and coworkers reported a prospective, randomized, masked study that compared reusable gowns and drapes to single-use items in patients undergoing coronary artery bypass surgery.²⁶ No difference in the rates of sternal or leg-wound infections between the groups was noted. A logistic regression of risk factors for sternal wound infection revealed that body mass index ($P=.004$) and duration of surgery ($P=.02$), but not type of gown or drape used ($P=.73$), was associated with sternal wound infections.

Additional studies using currently available single-use gowns and drapes versus reusable gowns are required to assess the clinical impact of single-use versus reusable gowns. Such studies should be prospective and randomized, with independent assessment of outcomes. In addition, other variables such as antimicrobial prophylaxis, surgical scrubs, preoperative showers, and hair-removal methods must be standardized. Such studies should assess other factors, such as healthcare provider comfort, relative costs, other economic measures, and environmental impact.

Role of Gowns in Preventing Cross-Transmission of Nosocomial Pathogens

The CDC has provided recommendations for the proper isolation of patients with infectious diseases.²⁷ This guideline states that "gowns are worn by personnel during the care of patients infected with epidemiologically important microorganisms to reduce the opportunity for transmission of pathogens from patients or items in their environment to other patients or environments." Gowns should be worn for specified patients known or suspected to be infected or colonized with epidemiologically important microorganisms that can be transmitted by direct contact with the patient (hand or skin-to-skin contact that occurs while performing patient-care activities that require touching the patient's dry skin) or indirect contact (touching) with environmental surfaces or patient-care items in the patient's environment. The guideline states that the gown (a clean, non-sterile gown is adequate) should be worn when entering the room if one anticipates that clothing will have substantial contact with the patient, environmental surfaces, or items in the patient's room, or if the patient is incontinent or has diarrhea, an ileostomy, a colostomy, or wound drainage not contained by a dressing. The gown should be removed prior to leaving the patient's environment. After gown removal, one should ensure that clothing does not contact potentially contaminated environmental surfaces to avoid transfer of microorganisms to other patients or environments. Infections for which gowns are recommended include draining abscesses, adenovirus infection in children, varicella, zoster, congenital rubella, cutaneous diphtheria, certain viral hemorrhagic fevers, *Clostridium difficile* colitis, multidrug-resistant pathogens (eg, VRE, MRSA), pediculosis and other

ectoparasites, respiratory syncytial virus (RSV) in children or immunocompromised adults, and major *S aureus* or streptococcal skin or wound infections. The guideline does not specify what types of gowns should be worn. It also notes that adequate data regarding the efficacy of gowns to prevent cross-transmission are not available.

Gowns or cover gowns have been used for years in hospital newborn units in the belief that they reduce cross-transmission. Studies, including those that have used a randomized design, have demonstrated no benefit to the routine use of cover gowns on postpartum units for healthy full-term infants.²⁸⁻³¹ Specifically, the incidence of nasal and umbilical colonization with *S aureus* is not altered by the use of cover gowns.^{30,31}

As in newborn units, cover gowns have been widely used in neonatal intensive care units.³² Multiple prospective studies have failed to demonstrate that the routine use of cover gowns in this setting decreased bacterial colonization of the infants, overall nosocomial infection rates, or the incidence of intravenous catheter colonization.³³⁻³⁵ However, Agbayani and colleagues reported a randomized trial that found that necrotizing enterocolitis occurred more frequently during a modified gowning period than in the gowning period, but were unable to show any consistent difference in colonization, mortality, or infection rates.³⁶ Klein and coworkers also reported a reduction in nosocomial infections during pediatric intensive care when protective isolation (which included protective, high-barrier gowns and gloves) was used.³⁷

Respiratory syncytial virus represents a serious nosocomial hazard, especially for infants with cardiorespiratory diseases or immunodeficiency states. The virus is spread by close contact with infected secretions, by large-particle aerosols, and by fomites. Small-particle aerosols do not seem to be a major route of transmission. Hospital personnel are thought to be the main vector, transmitting the virus on contaminated hands and even becoming infected themselves by self-inoculation of mucous membranes. Control measures have included hand washing, gloves, gowns, cohorting RSV-infected patients, face masks, and eye-nose goggles. Compliance with both glove and gown use has been demonstrated to reduce the rate of nosocomial RSV infection among children.³⁸ A later prospective study demonstrated that the combination of cohort nursing and glove and gown use decreased the risk of RSV transmission but that the use of gowns and gloves alone or cohort nursing alone failed to produce a significant reduction in cross-transmission.³⁹

The incidence of nosocomial infections due to MRSA and VRE has dramatically increased in recent years. Control of VRE outbreaks has been achieved by instituting multiple infection control interventions, including the use of disposable gowns when entering the rooms of patients with known or suspected colonization.^{40,41} However, a controlled clinical trial failed to demonstrate that the universal use of gloves and gowns was superior to the universal use of gloves alone in preventing rectal colonization by VRE patients in a medical intensive care unit.⁴² It has been suggested that the failure to demonstrate that gown use

reduced VRE cross-transmission in this study may have been due to the lack of heavy environmental contamination.⁴³ Further studies are needed to determine when the routine use of gowns by personnel provides added protection against the spread of VRE.

ENVIRONMENTAL IMPACT OF GOWNS AND DRAPES

Both single-use and reusable gowns and drapes have an environmental impact. The environmental impact has been evaluated in an independent report prepared by Arthur D. Little and commissioned by Johnson & Johnson.⁴⁴ The Little report developed a product life-cycle inventory that allowed comparison of the environmental impact of single-use versus reusable gowns and drapes. The life cycle included resource inputs (energy, water, raw materials); life-cycle stages (raw material acquisition, manufacturing, transportation, use/reuse/maintenance, and waste management); and environmental outputs (water pollutants, air pollutants, solid and hazardous wastes). An analysis of the inventory results showed that neither the single-use nor the reusable products studied were clearly superior from an environmental standpoint. The single-use products consume more raw materials and energy and generate more solid waste than the reusable products. Most of the air emissions (nitrogen oxides, sulfur oxides, and particulates) from manufacture and transport of both types of products result from energy production; hence, the single-use products produce more energy-related air emissions. These types of air emissions are associated with the air pollution resulting in acid rain. The reusable products consume substantially more water and produce more water pollution. They also generate more volatile organic compounds as air emissions. Volatile organic compound emissions generally are associated with smog levels in the atmosphere. As the Little report notes, it is difficult to place judgment on which types of environmental burdens are more important or damaging to the ecology.⁴⁴

Currently, approximately 80% of hospitals in the United States have chosen to use single-use gowns. The cost of disposal will be determined, in part, by whether blood-contaminated gowns and drapes constitute "regulated medical wastes" that would require additional and more costly methods of disposal. Whether blood-contaminated gowns and drapes are considered regulated medical waste varies among the different states. In states that do not classify blood-contaminated gowns or drapes as regulated medical waste (eg, North Carolina), it is crucial for healthcare facilities to segregate these items separately from regulated medical wastes to achieve cost savings. However, neither the CDC nor the Environmental Protection Agency provide detailed guidance on whether blood-contaminated gowns and drapes should be considered regulated medical waste.

Overall, hospital waste accounts for 2% of national municipal wastes. Gowns and drapes contribute approximately 2% of all hospital waste. Thus, gowns and drapes constitute approximately 0.04% of all municipal wastes.⁴⁴

COSTS ASSOCIATED WITH REUSE

The Little report commissioned by Johnson & Johnson also addressed the economic impact of reusable versus single-use gowns and drapes. This economic analysis considered five cost components: direct costs, drape set-up and changing costs, laundering and reprocessing costs, storage and inventory costs, and disposal costs. For single-use items, direct purchase cost was the most important factor (approximately 90% of total costs); factors that had an impact on costs of reusable items included the number of reuses, laundering and reprocessing costs (75%-95% of total cost), and number of drapes used per procedure. Interestingly, disposal costs for single-use items averaged only 4% to 5% of the total costs. Applying this analysis (1991 dollars) to an average single abdominal operation revealed that the total cost for drapes was \$18 and for gowns was \$10, with similar cost whether single-use or reusable items were used.⁴⁴

An important factor to consider in cost estimates of reusable gowns is the standard allowance for loss and damage, which often runs approximately 2%. Reusable gowns and drapes may be discarded improperly. Operating room gowns may be removed from the healthcare facility for personal use. The approximate cost of a single-use gown is \$3 to \$7, whereas the approximate cost of a reusable reinforced gown is ≤\$60.⁴⁵ While some manufacturers predict 75 uses, a hospital's loss, damage (tears, holes), and resistance to blood and viral penetration for 75 launderings or sterilizations may drastically reduce the garment's life span and increase the cost per procedure. A loss rate of 2% may not seem important, but it will have a substantial impact on the life of the product. For example, a reusable gown with an engineered life of 80 uses in an environment with a 2% loss or damage rate will have an actual life of only 41 uses (ie, about a 50% shortened life expectancy).

The actual costs associated with disposable versus reusable scrub suits and gowns in the operating room have been evaluated. Comparing two hospitals, DiGiacomo and colleagues concluded that reusable scrub suits and gowns would result in cost savings in excess of \$100,000 (1990 dollars) compared to using disposables.⁴⁶ However, single-use scrub suits have not been proposed, and the inclusion of scrub suits skews the data in favor of reusables. In contrast, Moylan²⁴ (Table 3) and Murphy⁴⁷ showed lower costs with the use of disposable gowns and drape systems. A cost-effectiveness analysis of current reusable versus disposable products should be undertaken using accepted cost-effectiveness analysis methodologies.

BARRIER EFFECTIVENESS OF GOWNS AND DRAPES

Multiple difficulties have been described in the literature regarding the evaluation of the barrier effectiveness of surgical gowns. First, surgical gowns are used for two main purposes: to minimize contamination of the operating room environment by microbial skin flora of participating healthcare workers and to prevent skin or clothing contact by the healthcare team with potentially infective patient material, especially bloodborne pathogens (eg, HIV, hepati-

TABLE 3

COMPARATIVE ANNUAL COSTS FOR DISPOSABLE VERSUS REUSABLE GOWNS AND DRAPES

	Community Hospital	University Hospital	Metropolitan Hospital
Annual no. of procedures	13,100	10,924	7,334
Cotton gowns and drapes, \$			
Laundry costs	234,400	150,120	73,162
Direct	154,100	142,000	17,532
Indirect	80,300	8,120	55,630
Handling costs	94,100	126,896	4,550
Purchase costs	23,000	239,320	6,913
Other costs	17,200	14,062	52,038
Total	368,700	530,398	136,663
Cost/procedure	28.14	48.56	18.63
Disposable gowns and drapes, \$			
Laundry costs	80,300	0	0
Direct	0	0	0
Indirect	80,300	0	0
Handling costs	7,500	0	0
Purchase costs	243,400	332,273	112,283
Other costs	6,500	0	0
Total	337,700	332,273	112,283
Cost/procedure	25.78	30.41	15.30

Adapted from Moylan JA, et al.²⁴

tis B virus). Hence, multiple tests to evaluate barrier effectiveness are required. Second, despite the publication of standardized methods for determining the barrier effectiveness of gowns, universal acceptance of these standardized tests does not exist. Most methods rely on a soak-through of liquids. Third, viral penetration of gowns may occur in the absence of obvious soak-through. Fourth, laboratory testing may not mimic actual in-use testing. Specifically, certain areas of the body are subject to stress and pressure, resulting in increased permeability. Finally, the multitude of products and changes in product design makes generalizations regarding comparative effectiveness difficult.

Multiple test methodologies for assessing the barrier effectiveness of gowns and drapes have been described. These can be divided into tests of fabric characteristics (eg, composition, thickness, air permeability, and water-vapor transmission rate); liquid-barrier properties (eg, mason jar test, penetration of liquids upon impact, hydrostatic pressure tests); and penetration by microorganisms, which may be aerosolized or contained in liquid. Tests of liquid penetration may use a variety of liquids, including water, synthetic blood, or human blood. Some tests are qualitative, providing only a positive or negative result, whereas others provide quantitative results.

The viral penetration of surgical gowns by HIV has been compared to the soak-through point by multiple investigators.^{48,49} Both studies reported that HIV could penetrate some surgical-gown materials in common use at the time of the studies. Further, HIV penetration was sometimes noted in the absence of visible soak-through.

Because certain areas of the body are subject to stress and pressure resulting in increased permeability, Beck and Collette⁵⁰ and Bernard and Beck⁵¹ have suggested that gowns should be tested both in the laboratory setting and under conditions of use. Simulated surgical movements (ie, leaning, reaching, arm resting) have been found to develop less than 2 psi pressure.⁴⁵ Using a 32-sensor mat placed in the abdominal area of a surgeon during operative procedures, Smith and colleagues demonstrated that pressure contacts were frequent, generally less than 2.9 psi, and lasted less than 15 seconds.⁵² Liquid strike-through has been demonstrated in laboratory tests to be both pressure- and time-dependent.^{45,53} The importance of pressure in leading to strike-through has been demonstrated by evaluating gowns after clinical use in surgical procedures. An evaluation of blood strike-through during 234 surgical procedures revealed that strike-through was related to the extent of contamination on the outside of the gown and was heavy in areas of the gown subjected to stress or pressure (ie, chest, forearm, abdomen).⁵⁴ Pissiotis and coworkers observed the following rates of strike-through: reusable gowns, 90%; disposable single-layer gowns, 11%; and disposable reinforced gowns, 3%.⁵⁵ The areas most vulnerable to strike-through were the cuff, forearm, thigh, chest, and abdomen. Ahmad and colleagues demonstrated the following failure rates of gowns to prevent blood strike-through in obstetrical procedures: single-layer nonwoven fabric, 55.8%; reinforced fabric, 26.7%; reinforced fabric with highly resistant fabric in chest and forearms, 21.1%; and full length with impervious front panel and forearms and ther-

mally sealed side seams, 16.7%.⁵⁶ Prolonged contact of gowns with blood may result in increased permeability when external pressure is applied.⁵⁷ A recent study of multiple hospitals in Germany demonstrated that deficiencies could be observed in the processed items (eg, 58% had holes in one or more individual items).⁵⁸

Bearing in mind the above-mentioned difficulties in assessing the comparative barrier effectiveness of gowns, recent studies allow the following generalizations.^{45,49,53,59-62} Fabric characteristics, such as construction, repellency, and pore size, contribute to gown performance. Laminates or polypropylene-treated gowns (eg, 97%-100% polypropylene, spunbond/meltblown/spunbond laminates) provide the greatest protection against blood strike-through and bacterial penetration. Gowns composed of a single layer of non-woven fabric provide the next greatest effectiveness. Gowns composed of 100% woven cotton, used on reusable products, provided the least protection. Individual products may vary greatly, and these conclusions are only generalizations.

The cumulative effect of laundering on the barrier efficacy of reusable cotton gowns has been studied by several investigators.^{18,53} In general, reusable gowns provided less protection than new gowns.^{18,45,61} Leonas reported that reusable gowns with a single layer of fabric demonstrated an increased amount of bacteria transmitted through the fabric after laundering, whereas those reinforced with a second fabric layer did not.¹⁸ Granzow reported that washed reusable gowns composed of 100% woven cotton were somewhat more effective in preventing blood strike-through and passage of *S aureus* than new reusable gowns.⁵³ However, Belkin noted that this finding is likely attributable to the apparently loosely woven, readily permeable, 100% cotton fabric shrinking during the laundry process(es), and the tightening up of the (warp and fill) yarns.⁶³

CONCLUSION

Appropriate gowns are useful to prevent exposure to bloodborne pathogens by healthcare workers. The use of gowns to prevent patient-to-patient transmission of nosocomial pathogens remains controversial, because studies assessing the efficacy of gowns have produced mixed results. The use of drapes in invasive procedures is widely recommended, for theoretical reasons, to minimize microbial contamination of the surgical site, although modern scientific studies have not assessed the efficacy of barrier protection in this setting.

Older studies suggested that single-use gowns and drapes used during surgical procedures were superior to reusable products in preventing SSIs. These studies have limited relevance because of methodological flaws and product improvements. Only limited data are available regarding currently available products. In conclusion, a clear superiority of currently available single-use gowns and drapes versus reusable products has not been demonstrated based on efficacy to prevent infections, environmental impact, or economics. The selection of particular gowns and drapes by individual healthcare facilities requires an assessment of the facility's requirements, avail-

able products, and costs, and should be based on the desired characteristics of an ideal gown or drape.

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Vancomycin Use and VRE Colonization in Dialysis Patients

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Vancomycin is widely used with hemodialysis patients as empirical therapy for dialysis-associated infections. To determine the relation of this practice to the generation of vancomycin-resistant enterococcal (VRE) colonization, Atta and coinvestigators from Johns Hopkins in Baltimore, Maryland, conducted a 2-year prospective cohort study. Cultures for VRE were taken from rectal swabs obtained from patients at the start and finish of the study period and during interim hospitalizations.

The results showed that 10 of 124 patients initially grew VRE. Twenty-four of the remaining patients had no follow-up cultures because of patient death (62%), transfer to another dialysis facility

(17%), patient's refusal (7%), and transplantation (4%), and thus were excluded. The remaining patients (n=90) had a median age of 54.3 years and were 92% African American and 50% male. Fifty-eight percent were treated by hemodialysis. They received 403 g of intravenous vancomycin over 157.2 patient-years of follow-up, 73% as outpatients.

Sixteen (17.8%) of 90 patients became colonized with VRE, an incidence rate of one case per 9.8 patient-years of follow-up. None of the 29 patients who did not receive vancomycin developed VRE, compared with 26% of those treated with vancomycin ($P=.001$). The odds ratio (95% confidence interval) for the association of outpatient vancomycin (g/y) with VRE colonization was 1.23 (1.05, 1.44, $P=.008$). The association remained significant following adjustment in separate logistic regression analyses for relevant demographic, clinical,

antimicrobial (inpatient vancomycin, oral or intravenous cephalosporins, aminoglycosides, quinolones, or anti-anaerobics), and hospitalization exposures. The unadjusted relative risk of death in patients growing VRE was significantly higher than in those not colonized with VRE ($P=.005$).

The authors concluded that VRE colonization is a relatively common and underrecognized problem among chronic dialysis patients and is strongly and independently associated with the outpatient use of vancomycin, which should be avoided whenever possible.

FROM: Atta MG, Eustace JA, Song X, Perl TM, Scheel PJ. Outpatient vancomycin use and vancomycin-resistant enterococcal colonization in maintenance dialysis patients. *Kidney Int* 2001;59:718-724.