Glove Selection and Use in Healthcare Settings

Welcome to the latest edition of BMC Protect's premium article series. In this review article, Dr. Deborah Nelson, PhD, CIH, past president of the American Industrial Hygiene Association (AIHA) and a leading occupational and environmental health and safety expert, summarizes data on glove performance and considerations for glove selection and use in healthcare settings.

Introduction

Just like choosing personal protective equipment (PPE) for any other task, choosing the right gloves for the task at hand requires some knowledge about gloves and about the task to be performed. Did you know that no glove will protect against all hazards, that no glove is perfect, glove thickness doesn't always matter, or that hazard assessment is the first step in choosing gloves? In this article, we'll cover some basic information about glove selection and provide some guidance about use of gloves.

No glove will protect against all hazards.

Gloves worn for heavy manual labor will be thicker and stronger than those chosen for tasks requiring manual dexterity, and gloves to protect against chemicals must meet different specifications than those worn to protect against exposure to microorganisms that might be encountered in healthcare work.

No glove is perfect.

No glove provides a perfect barrier. Liquids can seep through (penetrate) pinholes, seams, tears, punctures. Some liquids can also pass through (permeate) intact barrier materials. Contact with chemicals can damage the glove material, resulting in penetration or permeation. This damage (degradation) might not be visible. If penetration or permeation then occur, the liquid can be held inside the glove, where it could cause skin irritation or in the case of some chemicals, be absorbed through the skin. The length of time required for a chemical to break through intact barrier material of the glove (called "breakthrough time") is available for many combinations of chemicals and materials. Depending on the intended use, it's generally recommended to select a barrier material with a breakthrough time of >8 hours for chemical to be handled. The rate at which chemicals can permeate a barrier material after equilibrium is reached is called the "steady-state permeation rate" (SSPR).

Not all gloves are equal.

As discussed below, even gloves made by the same manufacturer, of the same material, may exhibit different performances.

For chemical exposures, breakthrough time is generally but not always dependent on the thickness of the barrier material (Forsberg et al., 2020, pp. 19-23).

However, as described more fully below, there is no simple relationship between thickness and glove performance, as there is much variation in glove performance, even between gloves made of the same material by the same manufacturer.

Deborah Nelson, PhD, CIH

Conducting job hazard assessments and training workers may be required at your workplace.

Besides being best practices, they're required by the Occupational Safety and Health Administration (OSHA) for all employers that are covered by the OSHA regulations. See our first blog, "How to Conduct a Job Hazard Analysis," for details.

And to repeat what we said in our first blog, if your establishment is covered by OSHA, hazard assessment, training, and record keeping are required for all personal protective equipment PPE), including gloves. OSHA states in 29 CFR 1910.132(f) Training that before performing work which requires PPE, each employee must be trained to know when and what PPE is necessary, how to safely use and care for the PPE, and the limitations of the PPE. Further, the employee must demonstrate understanding of this training and the employer must maintain records of that training (Lies & Morady, 2015). (See 29 CFR 1910.132 General Requirements [Personal Protective Equipment], available at https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.132) for details.)

Establishments covered by OSHA should also be familiar with 29 CFR 1910.138 Hand Protection, available at https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.138. Section 138(a) General Requirements states that employers must select and require employees to wear appropriate hand protection against hazards. And similarly to the requirements in 1910.132, section 1910.138(b) Selection requires employers to consider the task(s) to be performed, conditions, duration of use, and identified or potential hazards.

Multiple factors should be considered in glove selection. Results of the JHA and glove characteristics such as barrier protection, strength and elasticity, comfort, and cost are factors which should be considered.

Factors to Consider when Selecting Gloves

Barrier protection provided by medical gloves has typically been measured using a 1-liter water test, which is described in several standards including ASTM D5151 – 19 Standard Test Method for Detection of Holes in Medical Gloves and BS EN 455-1:2020 Medical Gloves for Single Use. Requirements and Testing for Freedom from Holes (Phalen & Wong, 2012)[1]. The acceptable quality level, or AQL, is a standard set to limit the number of gloves per batch with unacceptable pinhole leaks. The current standard for medical exam gloves is 1.5%, meaning that in a batch of 1000 gloves, less than 15 could fail the leakage tests. Permeation tests for gloves intended for use with chemotherapy drugs are conducted using the ASTM D 6978-05 test.

Strength and flexibility of glove materials can help determine how glove integrity might be affected by extensive hand movements. Tensile strength is a measure of the amount of stress that a material can bear without tearing and is expressed as MPa, or megapascals. (One pascal, 1 kg/(m)(s2), is equal to 0.000145 pounds per square inch.) Elongation measures how far the glove material can be stretched before breaking. Gloves are tested for tensile strength and elongation before and after artificial aging (by heat) of the glove material. The current standards for minimum tensile strength of nitrile medical exam gloves are 14 MPa before and after aging. For latex gloves, the standard is 18 MPa before aging, and 14 MPa after aging. The minimum elongation standard for nitrile gloves is 500% before aging, and 400% after aging. For latex gloves, the standard is 650% before aging, and 500% after.[2]

Comfort is a subjective factor, but must be considered when workers must wear gloves for extended periods. If gloves aren't comfortable, or are too thick and inelastic to allow sensitive touch and dexterity, they won't be worn.

And finally, cost must be considered. Cost per glove is especially important when considering disposable gloves, which are designed to be discarded and replaced when contaminated.

---

[1] However, the standard test may not indicate the presence of pinhole leaks through which virus can pass (Kotilainen et al., 1992). ASTM F 1671 Standard Test Method for Resistance of Materials Used in Protective Clothing to Penetration by Blood-Borne Pathogens Using Phi-X174 Bacteriophage Penetration as a Test System addresses viral penetration but isn't suitable for routine post-manufacturing testing (Phalen & Wong, 2012). These researchers modified the standard water-leak test by restricting the cuffs and providing the potential to add additional water if needed, so that greater pressure would be exerted on the palm, fingers, and thumb of the glove if needed to detect leaks during the test (Phalen & Wong, 2012).

[2] Phalen & Wong (2012) recommended that in addition to tensile strength and elongation, the additional factors of modulus and area density be considered in glove selection.

Performance Differences among Different Nitrile Gloves

Variation among Manufacturers and Brands

Since the move away from latex following increasing concerns and warnings about latex allergies, nitrile has been widely adopted as a glove material in healthcare, food service, retail, beauty salons, retail, automotive, and even home use. The difference in glove performance from one manufacturer to another, and even within one manufacturer's line of seemingly similar nitrile gloves, has been recognized by many researchers (e.g., Korniewicz et al., 2002; Phalen & Wong, 2012; Phalen et al., 2007; Brown et al., 2020; Phalen et al., 2020). These variations in performance have been attributed to differences in formulation, thickness, and other physical characteristics.

Variations in Nitrile Formulations

Many different fillers are added to the basic nitrile to improve glove characteristics. Plasticizers such as waxy hydrocarbons and oils, which can improve the elasticity of the glove material, can increase breakthrough time (BT) and decrease the steady-state permeation rate (SSPR) of aqueous solutions through the glove material. This can help protect users from water-borne solutions and biological fluids (Phalen & Wong, 2012; Phalen et al., 2020).

Physical Characteristics that Can Affect Glove Performance

In addition to variations due to differences in formulations, thickness has been studied as an important factor in influencing glove performance. Studies of glove protection against five chemotherapy drugs showed no leakage through the nitrile gloves (~0.1-mm thick) tested. The latex gloves did exhibit leakage, so were tested at different thicknesses (Oriyama et al., 2017). Similarly, Greenaway et al. (2020) found similar results when they tested nitrile gloves again fentanyl and carfentanil using an adaptation of ASTM D6978-19 for chemotherapy drugs. None of the nine nitrile glove models (with thickness at the palm ranging from 2.5 to 6.6 mil, or 0.0635 mm to 0.1676 mm) that they tested showed measurable permeation of > 0.001 µg/m2/min fentanyl. Similarly, none of the five nitrile glove models (ranging from 2.73 mil – 5.6 mil, or 0.069 – 0.1422 mm) tested for permeation of carfentanil showed rates exceeding 0.001 µg/cm2/min. Due to these very low rates, it thus wasn't possible to test for the effect of glove thickness. They did, however, observe an inverse relationship between the penetration of fentanyl and the thickness of the vinyl and latex gloves they tested; in other words, the thinner the glove, the greater the permeation. The authors supported the use of nitrile gloves for protection against fentanyl and carfentanil, while recommending that end users obtain manufacturers' test data for fentanyl. They also cautioned that while thicker gloves may be more protective, dexterity and function should also be evaluated.

Phalen et al. (2020) examined chemical and physical parameters influencing BT and SSPR. They included area density (AD), which is the mass of the sample per surface area, expressed as g/cm2. Thickness and AD together were "associated with increases in breakthrough time and decreases in the steady-state permeation rate". (Their previous research had indicated that area density was "more closely associated with glove performance when thicknesses are similar".) Glove thickness is usually available, and area density can be measured. Phalen et al. (2020) concluded by suggesting that information on acrylonitrile content and other parameters are harder to obtain but would be valuable to know, and by stating that permeation data for the specific glove product would be preferable. If only general permeation data are available, thickness and area density should be included in glove evaluation.

Recommendations for Glove Selection

The first step is to conduct a Job Hazard Analysis. Will the job task require heavy manual labor, or sensitivity and dexterity? Is the risk primarily physical, chemical, or biological (such as microorganisms)? Are hot, heavy, or abrasive items to be handled? If chemicals are to be handled, are they water-based or organic solvents? Will pharmaceuticals or chemotherapy agents be handled? Acids, bases, pesticides, or other potentially hazardous materials? Will there be exposure to bodily fluids? If so, for short, medium, or long duration? All these factors will affect the selection of glove material, thickness, surface textures, etc. Glove thickness must be balanced against the need for sensitive touch and dexterity. Tensile strength must be balanced against elasticity and comfort.

Selection of gloves for protection against chemicals is often fairly straightforward. For example, the Quick Selection Guide to Chemical Protective Clothing contains clear advice on determining the right barrier materials against the chemical(s) of concern. Unfortunately, this guidebook cautions that its "recommendations are not valid for very thin natural rubber, neoprene, nitrile, and PVC gloves (0.3mm or less)" (Forsberg, et al., 2020, p. 126). The exception is advice on selecting very thin gloves (0.12-0.18 mm) for protection from pharmaceuticals (e.g., nitrile rubber is recommended for protection from methotrexate and several other drugs).

Why are we discussing protection provided by gloves against chemicals, if your main concern is protection against bacteria, viruses, and other microorganisms? It's important for you to know – and to train your employees – about the limitations of all personal protective equipment (PPE). Healthcare workers, including maintenance staff, may be handling chemical cleaning or disinfection products, solvents, or acids. Gloves which are designed to provide a barrier against microorganisms could be permeated or damaged by these chemicals, thereby reducing their effectiveness. Workers may also select the wrong glove for a task and end up with exposure to skin irritants or worse. Job hazard analysis and worker training can minimize these risks.

Recommendations for Glove Use

To get the maximum protection from gloves, the right type and size must first be chosen. The user should wash their hands thoroughly before donning the gloves, pull the gloves up over the cuff if a gown is worn, change gloves if they become damaged or soiled, and avoid touching their face. As a general rule, gloves shouldn't be re-used or washed (see below). Long fingernails and high-profile jewelry should be avoided. In some situations, double-gloving may be recommended.

Some gloves are intended for immersion in liquids, e.g., dishwashing gloves. Others are intended to protect against incidental contact such as splashes, and should be changed if contact occurs. Gloves should also be changed immediately and discarded if any damage such as tears, pinhole leaks, or degradation is apparent. Gloves used for chemotherapy should be replaced every 30 minutes (Oncology Nursing Society et al., n.d.). And as described above, no glove will protect against all hazards, and no glove is perfect. This information should be included in the training required prior to glove use per 29 CFR 1910.132.

If severe shortage of PPE requires that gloves be re-used rather than discarded after a single use, preliminary research indicates that nitrile gloves purchased in the U.S. may be disinfected, with a dilute bleach solution resulting in the least negative impact on glove integrity. Cleaning with alcohol-based hand rub and soap and water resulted in more glove failures due to leakage (Shless et al., 2021).

Conclusion

In conclusion, gloves are an especially important component of worker protection in a wide variety of sectors. Selection of the best gloves for a specific use isn't always simple. If you have questions or concerns, please don't hesitate to reach out to us at 800-977-7888 or info@bmcprotect.com.

References

Brown, C.B., Dubrovskiy, A., Gvetadze, A.R., & Phalen, R.N. (2020). Chemical permeation of similar disposable nitrile gloves exposed to volatile organic compounds with different polarities: Part !: Product variation. Journal of Occupational and Environmental Hygiene 17:4, 165-171. https://doi-org.ezproxy.libproxy.db.erau.edu/10.1080/15459624.2020.1721510

Forsberg, K., Van Den Borre, A., Henry III, N., & Zeigler, J.P. (2020). Quick Selection Guide to Chemical Protective Clothing (7th ed., pp. 19-23). John Wiley & Sons, Inc. ISBN 9781119650553.

Greenawald, L.A., Hofacre, K.C., & Fisher, E.M. (2020). Fentanyl and carfentanil permeation through commercial disposable gloves. Journal of Occupational and Environmental Hygiene, 17:9, 398-407. DOI: 10.1080/15459624.2020.1784426

Korniewicz, D.M., El-Masri, M., Broyles, J.M., Martin, C.D, & O'Connell, K.P. (2002). Performance of latex and nonlatex medical examination gloves during simulated use. American Journal of Infection Control, 30(2), 133-138.

Kotilainen, H.R., Cyr, W.H, Truscott, W., Gantz, N.M., Routson, L.B., & Lytle, C.D. (1992). Ability of 1000 ml water leak test for medical gloves to detect potential for virus penetration. In McBriarty, J.P, & Henry, N.W (Eds.), Performance of Protective Clothing, 4th Vol. ASTM STP 1133. (pp. 38-48) American Society for Testing and Materials, Philadelphia.

Lies, M.A., & Morady, I.R. (July 2015). OSHA-related documents: Creation and retention. Occupational Health & Safety. https://ohsonline.com/Articles/2015/07/01/OSHA-Related-Documents.aspx?Page=2

National Institute for Occupational Safety and Health. (1997). Preventing allergic reactions to natural latex rubber in the workplace (NIOSH Publication No. 97-135). U.S. Department of Health and Human Services, Centers for Disease Control and Prevention. https://www.cdc.gov/niosh/docs/97-135/pdfs/97-135.pdf?id=10.26616/NIOSHPUB97135

Oncology Nursing Society (ONS), American Society of Clinical Oncology, American Society of Health System Pharmacists, Association of Community Cancer Centers, Association of Pediatric Hematology/Oncology Nurses, & Hematology/Oncology Pharmacy Association (n.d.). Personal Protective Equipment for Use With Hazardous Drugs. Retrieved 16 June 2021 from https://www.ons.org/sites/default/files/PPE%20Use%20With%20Hazardous%20Drugs.pdf

Oriyama, T., Yamamoto, T., Yanagihara, Y., Nara, K., Abe, T., Nakajima, K., Aoyama, T., & Suzuki, H. (2017). Evaluation of the permeation of antineoplastic agents through medical gloves of varying materials and thickness and with varying surface treatments. Journal of Pharmaceutical Health Care and Sciences, 3:13, 1-8. DOI 10.1186/s40780-017-0082-y

Phalen, R.N., Dubrovskiy, A.N., Brown, B.C., Gvetadze, A.R. Bustillos, B., & Ogbonmwan, J. (2020) Chemical permeation of similar disposable nitrile gloves exposed to volatile organic compounds with different polarities Part 2. Predictive polymer properties, Journal of Occupational and Environmental Hygiene, 17:4, 172-180, DOI: 10.1080/15459624.2020.1721511

Phalen, R.N., Que Hee, S.S., Xu, W., & Wong, W.K. (2007). Acrylonitrile content as a predictor of the captan permeation resistance for disposable nitrile rubber gloves. Journal of Applied Polymer Science 103:3, 2057-2063. First published as https://doi-org.ezproxy.libproxy.db.erau.edu/10.1002/app.25349

Phalen, P.N., & Wong, W.K. (2012). Tensile properties and integrity of clean room and low-modulus disposable nitrile gloves: A comparison of two dissimilar glove types. Annals of Occupational Hygiene 56(4), 450-457.

Shless, J.S., Crider, Y.S., Pitchik, H.O., Qazi, A.S., Styczynski, A., LeMesurier, R., Haik, D., Kwong, L.H., LeBoa, C., Bhattacharya, A., Hamidi, Y.K., Phalen, R.N. (2021). [Unpublished raw data on physical integrity of medical exam gloves with repeated applications of disinfecting agents: evidence for extended use].