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Update on medical and surgical gloves

Occupational dermatitis to personal protective equipment (PPE), particularly to gloves, mainly occurs in healthcare workers. They are all irritant and/or allergic contact dermatitis (eczema and contact urticaria). Prolonged glove wearing by healthcare workers favours skin irritation of the hands and wrists. It is very important to consider characteristics and materials of gloves used in the medical field. Rubber additives are the main allergens in gloves. Latex or natural rubber remains by far the most frequent cause for occupational contact urticaria from gloves. The problem of prevention of infections risks in the health environment and the choice of medico-surgical gloves is described. In a surgical environment (in ORS), double gloving is recommended. Today, it appears as the best protection, even if in France it is far from being systematically used. Choosing the appropriate medical or surgical gloves requires having sufficient preliminary information on the assets, drawbacks and use limits of each of them. In cases of known contact allergic dermatitis, advice from dermatologists or allergologists is essential when it comes to suggesting substitution gloves.

Key words: medical gloves, surgical gloves

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The role of medical gloves is to protect patients from a potential infection transmitted by a member of the medical staff. They are considered as medical devices. The recommendation for the wearing of gloves as an individual skin protection dates back to 1987 and was part of the “universal precautions” whose aim was to protect healthcare workers from the risk of transmission of infectious agents when in contact with the blood, secretions or body fluids of a patient [1, 2]. This protection measure is to be enforced particularly in cases of direct contact with skin lesions or mucous membranes [2]. The barrier effect of gloves is what the enforcement of these recommendations first seeks [2]. Gloves also reduce microbial contamination and make efficacious handwashing easier once removed. They reduce the risk of transmitting infectious agents to patients. Thus, proper use of gloves in hospitals is essential [3].

The advent of surgical gloves is the result of the application of the concept of “glove” to surgery [4]. In a surgical environment (in ORs), double gloving is recommended. Today, it appears as the best protection, even if in France it is far from being systematically used [5].

Occupational dermatoses to personal protective equipment (PPE), particularly to gloves, mainly occur in healthcare workers [6, 7]. They are above all irritant and/or allergic contact dermatitis (eczema and contact urticaria) [8]. Prolonged glove wearing by healthcare workers favours skin irritation of the hands and wrists [9]. Rubber additives are the main allergens in gloves. Latex or natural rubber remains by far the most frequent cause for occupational contact urticaria from gloves.

There is a wide variety of updates on medical and surgical gloves, particularly in the field of contact dermatology-allergology. Some of them are detailed below.

Regulations

Two European directives regulate the placing on the market of two categories of gloves with two different purposes. The intended purpose of the gloves determines the class they fall in [10].

Medical gloves, designed to protect patients, are medical devices and therefore fall under directive 93/42/CEE [10]. Gloves for the protection of staff against biological agents, chemicals or ionising radiation are considered as personal protective equipment (PPE) and fall under directive 89/686/CEE [10]. Conformity to European directives is testified by the CE marking.

Concerning the procedures for placing on the market, examination gloves are in class I, i.e they only require the manufacturer to draw up a declaration of conformity (no intervention of a notified body). Surgical gloves are class II. The intervention of a notified body, chosen by the manufacturer, verifies the conformity of the product or approves and assesses the manufacturer's quality assurance system. Both categories of gloves are subject to standards.

Concerning medical gloves, the trials for the verification of conformity to the 93/42/CEE directive they fall under are carried out following the EN 455 European standard, which has three parts:

– For single-use medical gloves, *part 1* concerns watertightness (freedom from holes). The latest French standard

NF EN 455-1 dates from February 2001. Its aim is to set requirements applying to freedom from holes in this category of gloves and to the corresponding test methods (quality control trials on manufactured gloves). The studied glove is filled with 1,000 mL of water and then its external side is visually examined to check the presence or absence of droplets, after a 2-to-3-minute delay. A watertight, leak-free glove has no defects or pinholes. It is thus considered as a barrier to the transmission of infectious agents. Gloves intended for use in the medical field are used for the patient's and the user's protection against any form of cross-contamination.

– *Part 2* describes the norm that specifies the requirements and test methods regarding the physical properties of single-use medical gloves (examination/procedure gloves and surgical gloves). The latest update for French standard NF EN 455-2 dates from February 2001. Part 2 thus describes the sizes of gloves and their break strength, before and after accelerated ageing, and makes a distinction between surgical and examination gloves as well as between latex and synthetic materials.

– *Part 3* specifies the requirements and tests for biological evaluation of single-use medical gloves. The latest update of French standard NF EN 455-3 dates from February 2007. It describes labelling requirements for gloves and the display of information about the test methods used. It assesses the biocompatibility of the gloves, particularly the extractable protein content of natural rubber gloves [10]. It should be pointed out that the EN 455 standard does not assess the level of protection against various chemicals used in the medical field (cytotoxic drugs, disinfectants, bone cement, dental resin...) [10]. Some products might diffuse through the glove and reach the tegument or damage the material and make it permeable to infectious agents. The EN 374 standard "Protective Gloves against Chemicals and Micro-organisms" suggests a test method to assess resistance to chemicals [11].

The NF-medical label, which is not compulsory, guarantees that the product was controlled according to the principles of quality assurance. Additional characteristics such as aspect, minimal elongation at break, tear resistance of the cuff (examination gloves), powder (surgical gloves) and sterility (NF EN 500 or NF EN 552 standards) are provided, thanks to controls from French National Laboratory of tests [10].

Epidemiological data

Gloves are the main etiology for occupational contact skin allergy to rubber additives (40 to 70% of cases) [12]. Healthcare workers are the occupational group particularly exposed, as rubber gloves are worn for long periods [12]. In a study of the German Network of Departments of Dermatology (IVDK), Geier *et al.* reported many cases of allergic contact dermatitis from rubber gloves worn at work [13]. The most frequent occupations where it was seen were: healthcare workers (44.9%) followed by cleaners (8%) and hairdressers (3.9%) [13]. Among patients suspected of contact skin sensitisation to gloves, all professional sectors taken into account, thiurams represent 16.2% of positive epicutaneous tests and tetraethylthiuram disulfide represents 10.3% of positive tests. As regards other rubber

allergens, positivity rates are lower: zinc diethyldithiocarbamate (3.3%), zinc dibutyldithiocarbamate (0.4%), mercaptobenzothiazole and mercapto-mix (2.9%), thiouraeas (0.4%), 1,3-diphenyl-guanidine (1.9%) [12]. Thiuram still remains the main marker for allergy to rubber gloves [12].

In a recent study carried out by Foo *et al.*, during the SARS epidemic in Singapore in 2006, the answers to questionnaires (94.7% of respondents) on skin reactions to PPE among healthcare workers were analysed. Clinical symptoms from gloves (xerosis, itch, various lesions) were reported by 21.4% of healthcare workers wearing rubber medical gloves. No skin reaction to plastic gloves was otherwise reported [14].

An evaluation of the prevalence and incidence of sensitisation to latex was carried out by Larese Filon *et al.* in a group of 1040 healthcare workers in Trieste hospital. These Italian authors then carried out a second evaluation of this allergy to latex, from 2000 to 2002, subsequent to a changeover to a latex powder-free environment. Glove-related symptoms were seen in 21.8% of nurses (227), mainly dermatitis: 38 (3.6%) complaining of contact urticaria and 24 (2.3%) of asthma and/or rhinitis. Those clinical manifestations were significantly related to positive latex prick tests and to a personal history of atopy [15]. Simple measures such as avoiding unnecessary glove use, use of non-powdered latex gloves by all workers, and use of non-latex gloves by sensitised subjects proved effective in stopping the progression of latex-related clinical symptoms and avoiding new cases of allergy [15].

In a study carried out between 2001 and 2002, Valks *et al.* underlined that sensitisation to natural rubber or latex (positivity of prick tests and increase in specific IgE levels) is far more frequent in healthcare workers than in other workers (16.7% *versus* 2.3%), particularly cases of contact urticaria from latex (71.4% *versus* 28.6%) [16]. In 2006, Bousquet *et al.* reviewed all the epidemiological studies regarding immediate latex allergy in the general population and healthcare workers. [17]. This meta-analysis, carried out under the auspices of the French National Regulatory Authority, underlines the marked prevalence of latex allergy (clinical and prick tests): 3 to 3.5 times as high in healthcare workers as in the general population. According to those studies, the prevalence of latex IgE-mediated sensitisation ranges from 1.4 to 1.65% in the general population *versus* 4.1 to 5% in healthcare professionals [17]. Healthcare workers are the professional category with the highest prevalence of latex allergy [9]. For Tennstedt *et al.*, occupational allergy to latex proteins affects about 7 to 15% of healthcare workers: nurses, doctors, dentists, surgeons... (frequency in the general population being 1.5%) [18]. Repeated hand washing and scrubbing as well as the use of antiseptics by healthcare workers may weaken the skin barrier and thus favour antigen penetration. Variations in the allergenic composition of the internal and external surfaces of latex gloves have been noticed [18]. Besides, detailed analyses show a protein concentration markedly higher on the inner surface (0.40 mg/g) compared to the outer surface (0.13 mg/g) of gloves [19], which also accounts for the very high prevalence of latex allergy in healthcare workers [18].

Characteristics and materials of gloves used in the medical field

These gloves are for single use only (except for protective gloves against ionising radiation). Their thickness is low: from a few tens of μm to a few tenths of a millimeter, according to their use. The cuff protecting the forearm is of variable length [10]. Examination gloves can be made of natural rubber or latex, synthetic rubber or nitrile, thermoplastic polymers such as PVC or polyvinyl chloride or polyethylene (PE). Surgical gloves are most usually made from latex or natural rubber, but they can also be made of synthetic rubber (nitrile, neoprene or others: styrene butadiene rubber [Elastyren[®]] or styrene-ethylene-butadiene rubber [Tactylon[®]]) [10]: the various previously-mentioned materials provide protection against microbiological hazards.

Gloves are often made by soaking a mould. Polyethylene gloves are made by the sealing of two films (their weak point due to the sealing is their lack of elasticity) [10]. Thin latex or natural rubber or cis-isoprene gloves contain several potentially allergenic components: water soluble proteins responsible for type I immediate skin reactions (contact urticaria), but also vulcanisation accelerators, antioxidants and pigments that may be responsible for cutaneous type IV or delayed hypersensitivity reactions (contact dermatitis). Thin synthetic rubber gloves do not contain latex proteins. They can be made of nitrile (acrylonitrile-butadiene copolymers or NBR), chloroprene (neoprene or polychloroprene), styrene-butadiene (styrene-butadiene copolymers or SBR or SBS), or styrene-ethylene-butadiene rubber (styrene-ethylene-butadiene copolymer or SEBS). Apart from styrene-type synthetic rubber gloves, their main allergenic components are vulcanisation accelerators [9, 20]. In addition, they may contain antioxidants and pigments that potentially cause allergic contact dermatitis. Thin PVC or vinyl thermoplastic polymer gloves (vinyl chloride-based polymers) or polyethylene (PE) gloves contain pigments and antioxidants that may cause contact dermatitis [10].

Contact dermatitis from medical and surgical gloves

Irritant contact dermatitis [9, 20]

Due to occlusion, sweating and maceration in gloves, wearing gloves for long periods is equivalent to wet work. Glove powder can be considered as a non-negligible parameter of skin irritation as can some agents – such as ethylene oxide – used for their sterilisation [9].

Type IV or delayed contact dermatitis [9, 20]

When confronted with hand allergic dermatitis, occupational dermatosis from gloves should come to mind. Skin lesions on the wrists, at the cuff line, are very evocative [9]. Allergens vary according to the materials (rubber or thermoplastic polymers) of the glove.

Rubber gloves

Vulcanisation accelerators, particularly thiurams but also dithiocarbamates, benzothiazoles, thioureas and guanidines

are the most frequent allergens involved. Antioxidants (paraphenylenediamine derivatives PPD, IPPD...) are usually found in black or dark rubber gloves, which are generally not used in the medical field.

Thiurams have gradually been replaced by dithiocarbamates and/or mercaptobenzothiazoles derivatives [13, 21]. According to the manufacturers, the use of thiurams in the production of gloves has been decreasing over the past few years. In 1992, Knudsen *et al.* revealed the presence of thiurams in 4 types of sterile natural rubber surgical gloves [22]. In 2000, the same author found thiurams in only one type of single-use medical gloves in 19 brands analysed. Among 11 natural latex surgical glove brands analysed by Brehler *et al.* in 2002, none of them contained thiurams [24]. Even if thiurams still represent the main cause for allergy to rubber gloves [13], recent studies seem to show a decrease in frequency of positive patch test reactions to thiuram-mix, particularly in healthcare workers [21, 25]. Tetramethylthiuram disulfide (TMTD), tetramethylthiuram monosulfide (TMTM), tetraethylthiuram disulfide (TETD), tetrabutylthiuram disulfide (TBTD), bispentamethylenethiuram disulfide (PTD) and pentamethylenethiuram tetrasulfide (PTT) are the main allergens to bear in mind [9]. Thiurams, which represent the most frequently reported cause for allergic contact dermatitis to latex, are no longer detected in recently manufactured gloves [26].

Dithiocarbamates, such as zinc diethyldithiocarbamate (ZDEC), zinc dibutyldithiocarbamate (ZDBC), zinc dimethyldithiocarbamate (ZDMC), zinc pentamethylenedithiocarbamate (ZPC) and zinc dibenzylthiocarbamate (ZBEC) are frequently used. Zinc diethyldithiocarbamate (ZDEC) and zinc dibutyldithiocarbamate (ZDBC) are the two most frequent rubber vulcanisation accelerators, according to the works of Knudsen *et al.* [23]. Brehler *et al.* noticed that they are also present in variable concentrations in most of the 11 types of gloves they studied [24]. Accelerator concentrations are not lower in powdered gloves than in powder-free gloves [24]. Those chemical components have little water solubility. Washing procedures seem to have little or no effect on the concentration of accelerators in rubber gloves [24]. According to the data gathered by Geier *et al.*, zinc dibenzylthiocarbamate is more often used as a vulcanisation accelerator in rubber gloves than ZDEC or ZDBC [27]. Analysis of the presence of zinc dithiocarbamates in 19 disposable medical gloves used in southern Sweden was carried out using the high-performance liquid chromatography (HPLC) method developed by Mathieu *et al.* [28]. Among the 19 gloves analysed, 10 contained zinc diethyldithiocarbamate (0.070-3.5 mg/g), 3 contained zinc pentamethylenedithiocarbamate (1.0-4.3 mg/g), 4 contained zinc dibutyldithiocarbamate (0.9-1.1 mg/g), and 2 contained 2-mercaptobenzothiazole (0.005-0.008 mg/g). None of them contained thiurams, according to Bergendorff *et al.* [29]. There are high chemical similarities between thiurams and dithiocarbamates, which accounts for patients reacting both to thiuram-mix and carba-mix [20, 30]. Currently, thiuram-mix is tested in the standard series when looking for allergy to thiurams and dithiocarbamates [20].

Benzothiazoles, particularly 2-mercaptobenzothiazol (MBT), zinc mercaptobenzothiazole (ZMBT), N-cyclohexyl-2-benzothiazylsulfenamide (CBS), morpholinylmercaptobenzothiazole (MOR), dibenzothiazyl disulfide (MBTS) and mercaptobenzimidazole (MBI) are also widely used as

vulcanisation accelerators in glove manufacturing. Using different methods for analysis, including HPLC, Depree *et al.* thus screened and quantified the sulfur rubber vulcanisation accelerator content (2-mercaptobenzothiazole and zinc dialkyldithiocarbamates) from 38 brands of “off-the-shelf” latex and nitrile gloves. It was found that accelerator levels ranged from not detectable to 7.35 mg/g in the gloves analysed. Some types of gloves contain one or more accelerators. ZDEC, ZDBC and mercaptobenzothiazole are found alone or in multiple combinations in nitrile, medical latex exam and non-medical latex gloves [26]. Powdered gloves had significantly higher accelerator levels than powder-free gloves from the same manufacturer. As regards powder-free gloves, halogenation processes for the surface of the glove are frequently used. Gloves are treated in chlorination baths or others, followed by neutralisation with aqueous ammonia or aqueous solutions of sodium thiosulfate. Such processes can theoretically eliminate and/or oxidize accelerators [26].

Thioureas are more rarely responsible for allergic contact dermatitis when wearing gloves. The main allergens are: dibutylthiourea (DBTU), diethylthiourea (DETU), diphenylthiourea (DPTU) and ethylenethiourea (ETU). Thioureas are mainly used in neoprene rubber [9, 20].

Among **guanidines**, 1,3-diphenylguanidine is the main allergen to remember [31].

Miscellaneous other components: all latex or natural rubber gloves as well as rubber or synthetic elastomer gloves contain vulcanisation additives. However, Crepy specifies that there is a particular family of synthetic rubbers: styrenic thermoplastic elastomers (TPE-S or thermoplastic elastomer styrene). This family represents an intermediate between rubber and resin and has elastomer properties with no vulcanisation stage [9, 20]. As opposed to the chemical reticulation of vulcanisable rubbers, this sort of styrene thermoplastic elastomers is obtained following physical reticulation by heating. Potential additives are thus pigments, anti-UV protective agents, antioxidants... [9]. Concerning the latter, it should be noted that amines can migrate to the surface of rubber objects [32].

Other allergens such as latex, hexamethylenetetramine [33] and diaminodiphenylmethane used in neoprene rubber... are less frequently responsible for contact dermatitis from rubber gloves. N-(cyclohexylthio)phtalimide is a vulcanisation retarder whose role in allergy to rubber gloves remains unknown [12, 34]. This compound is believed not to be used in medical items [12]. Cetylpyridinium chloride is a quaternary ammonium widely used as a slip agent and as an antiseptic compound in many medical gloves. It is rarely incriminated in allergic contact dermatitis due to latex surgical gloves [35, 36]. Isothiazolinones in the powder of latex gloves [12] as well as formaldehyde [37, 38] may be allergens occasionally found in gloves, particularly rubber gloves.

Plastic gloves

Allergic contact dermatitis from plastic gloves is far less frequent than from rubber gloves.

1,2-benzisothiazolinone-3-one, used as a slimicide in disposable PVC powder-free gloves for medical use, was recently responsible for a small epidemic of allergic contact dermatitis in dental personnel and healthcare workers in Finland. Aalto-Korte *et al.* reported at least 6 cases of allergic contact dermatitis to this variety of isothiazolinone. 31 brands of disposable PVC gloves were analysed.

A third of them contained benzisothiazolinone. A concentration of 20 p.p.m. benzisothiazolinone in a glove seems to be enough for sensitisation in patients with a history of hand dermatosis [39].

Ponten investigated the presence of formaldehyde in 9 types of reusable protective gloves made of PVC but also of latex and nitrile with a textile internal lining. Formaldehyde was found in 6 gloves out of 9. However, reusable gloves are not used in the medico-surgical field [37]. Plastifying agents for PVC, such as adipic polyesters [40, 41] or other components such as bisphenol A [42, 43], pigments (irgalite orange F₂G) [44] and others [45]... have exceptionally been reported as responsible for allergic contact dermatitis from plastic gloves.

Type I or immediate contact dermatitis: contact urticaria

Latex still remains the main cause for contact urticaria from rubber gloves, particularly medico-surgical gloves. Healthcare workers (surgeons, anesthetists, gynecologists, nurses, dentists... [46]) represent a risk group for developing immediate type I hypersensitivity to latex proteins [18, 46]. Atopic patients or patients allergic to certain fruits or multioperated patients are also a risk group [47]. The most commonly incriminated *Hevea brasiliensis* (Hev b) allergens in latex or natural rubber allergy in healthcare personnel are Hev b₂, Hev b₅, Hev b₆, Hev b₇ and Hev b₁₃ [20].

Urticaria from latex proteins may occur after direct contact with gloves but it can also be airborne. Tennstedt reports that these types of airborne urticaria mostly appear in operating areas (poorly ventilated operating rooms for minor surgery or rooms with closed-circuit ventilation) where many operations follow one another [18]. They occur within a few minutes after unpacking pairs of latex gloves [18]. The aerodispersible corn starch powder contained in some types of gloves that is projected into the work atmosphere when the gloves are unpacked is thought to act as a vehicle for many latex sensitising proteins [47, 48]. The overall number of pairs of gloves used by surgeons and/or anesthetists is thought to play a major part in the risk for the occurrence of airborne contact urticaria [47, 48].

Latex proteins are not the only causes of contact urticaria. However, the other components of natural rubber or synthetic gloves are much more rarely responsible for type I allergic contact dermatitis. Isolated cases of contact urticaria from corn starch powder itself are sometimes reported [12, 49]. Liu *et al.* reported a recent case in a nurse [50].

Vulcanisation additives in natural rubber or synthetic (dithiocarbamates, 2-mercaptobenzothiazole, phenol derivatives, IPPD derivatives and thiurams) gloves are exceptionally involved [20, 51]. Horn *et al.* recently reported a case of contact urticaria to an antioxidant in nitrile gloves worn by a nurse at work. The product involved was 2,2'-methylene-bis-(4-methyl-6-tert-butylphenol) (Ralox LC®) [52]. Ethylene oxide, formerly used to sterilise medical gloves, was reported to be responsible for contact urticaria [12]. Cases of contact urticaria from plastic gloves (phtalates...) are extremely rare [20]. Sugiura *et al.* reported a case of contact urticaria due to polyethylene gloves [53].

Leukoderma

The very few cases of chemical leukoderma due to the wearing of rubber gloves are mainly due to monobenzyl ether of hydroquinone (MBEH) [12].

Biological hazards and medico-surgical gloves

There is a risk of transmission of various infectious agents (bacteria, viruses and others) via blood and biological fluids. The specific risks of occupational virus contamination by HIV and hepatitis B and C viruses (VHB, VHC) in healthcare workers must be underlined. They depend on the circumstances of exposure: skin splashes, cut or puncture injuries, deep stings with a hollow needle that had been placed in a source patient's vessel or containing blood are mainly involved in the transmission of HIV virus in healthcare workers [2]. Gloves reduce the blood inoculum transmitted to healthcare workers. For Zbitnew *et al.*, in specific experimental conditions, intact (vinyl or latex) gloves act as effective barriers to the transmission of various viral particles (HSV-1; type 9 echovirus... and even HIV-1) in healthcare settings [54]. However, Balty reminds us that "the barrier provided by gloves is not absolute" (due to intrinsic porosity of latex materials or others...) [10]. Whatever the type of gloves, be they examination or surgical gloves, the material they are made of has microscopic holes, depressions, tortuous channels penetrating the entire thickness of the glove. These holes, non-detectable during the water retention test (NF EN 455-1 standard), can be seen in electron microscopy even in brand new gloves. Gloves can be permeable to small particles such as viruses. This permeability to micro-organisms increases with time and use [10]. However, several elements counterbalance these risks, such as healthy skin with an intact epidermal barrier and frequent changing of gloves. A small quantity of infectious particles can permeate through the material of the gloves [10].

In Europe, there is no regulation regarding viral penetration through medical gloves. Thus, there is no standardised method that directly tests the ability of gloves to prevent the penetration of micro-organisms. There is currently no standardised test method to assess the resistance of a glove material to the passage of micro-organisms [10]. Nonetheless, methods using viruses and bacteria to test gloves have been developed. Prior classical culturing of these micro-organisms is required to be able to detect them. Broyles *et al.* presented a PCR (*polymerase chain reaction*) method that can be used on natural latex and synthetic gloves and allows the rapid detection of penetration of gloves by viruses [55].

Studies on the resistance of surgical and examination gloves to dynamic penetration by bloodborne pathogens were carried out thanks to collaboration between the department of toxicology, the Université Catholique de Louvain's virology laboratory and Ansell Europe's medical business group. They used Phi-X₁₇₄ bacteriophage as a surrogate non-pathogenic micro-organism. Its diameter is much smaller than HIV or hepatitis viruses. The twenty medical (examination and surgical) glove brands that were tested

show neither viral nor bacterial penetration (as viruses are smaller than bacteria). The gloves they tested were latex gloves (for example: Gammex[®] PF gloves, Sensiclean[®]...), neoprene gloves (for example: Dermaprene[®] Ultra gloves; Micro-Touch Dermaprene[®] gloves) and nitrile gloves (for example: Nitratex[®] gloves; Micro-Touch nitrile gloves...) [56].

Currently, there are no international standards based on microbiological methodology for testing the ability of medical examination or surgical gloves to prevent the passage of viruses.

In the USA, three protocols for direct examination of the viral barrier properties of non-latex gloves were compared with 1,080 gloves: 270 gloves from each of two surgical brands and two medical examination brands. In this study bacteriophage phiX174 was placed inside and outside the gloves tested. Further research is needed to provide quality control settings [57].

Double gloving (*i.e.* wearing two pairs of gloves) is usually recommended for surgical or medical procedures with a high risk of exposure to blood or other biological products. It is indeed very unlikely that the pinholes in the material of the protective gloves in contact with the skin should coincide exactly with those in the external gloves [10]. Both superimposed gloves must be changed frequently and systematically after a tear or perforation. External gloves must be changed regularly during surgical procedures (duration of use for surgical gloves should be between half an hour and two hours according to guidelines) [10]. In 2007, studies showed that single-gloving reduces the volume of blood transmitted by 52% compared to a naked hand but that double gloving provides no further protection regarding stings with hollow needles [58].

The G-VIR[®] glove was built around the dynamic protective barrier concept. The glove contains a disinfectant agent which diminishes the transmitted viral load in case of blood exposure accident, particularly due to stings with hollow needles. The glove has a composite, triple-layer structure: two mechanical layers in latex-free thermoplastic elastomer with no vulcanising agent, and an inner "biological" layer encased between the mechanical layers containing a disinfectant agent that is a mixture of quaternary ammoniums and chlorhexidine digluconate [59]. This type of glove should not be worn by people allergic to the previously-mentioned antiseptics [60]. The materials are less resistant to certain aggressive solvents and compounds, due to the absence of vulcanising agents [61]. Bricout *et al.* developed specific *in vivo* and *in vitro* test methods which enabled them to specify the reduction factor of the viral load in surgeons and other healthcare workers during simulations of percutaneous injuries with hollow needles or simulations of prolonged cutaneous or mucous membrane exposure to blood from patients infected by hepatitis C or HIV viruses [58]. For Krikorian *et al.*, in "standardised" puncture conditions, the surgical glove G-VIR[®] elicited an 81% reduction in the amount of HSV1 transmitted, as compared with single or double latex glove systems [62]. In 2008, Caillot *et al.* specified that G-VIR[®] gloves offer excellent mechanical protection, are suitable for daily surgical practice and may be recommended in high risk surgical procedures [63].

Choosing medical and surgical gloves

The manufacturing quality of brand new gloves – be it of latex, nitrile or vinyl – seems essential when choosing protective gloves against micro-organisms [64]. The quality of the barrier evolves differently according to the material of the gloves and their use [10]. Though latex seems to provide better protection than vinyl, there are differences between brands and between batches of the same brand [65-67].

Korniewicz JM *et al.* underlined that stress levels also play a part. At low stress levels, latex and vinyl gloves have similar performances; at high stress levels, vinyl gloves are an almost ineffective barrier [68, 69]. As Balty reports, barrier integrity lasts longer in rubber gloves [10]. Thanks to their great elasticity, latex rubber gloves or nitrile gloves have higher resistance to in-use mechanical strains than vinyl gloves. Their elasticity enables rubber glove wearers to make precise gestures by combining tactile sensitivity and deftness [20]. Latex offers the best resistance to punctures and tears [20]. Vinyl gloves are not made for high stress levels and prolonged use. Glove porosity and perforations increase with the duration of wear, its low thickness, temperature and how much the user sweats [2, 65, 65, 70]. Perforation of surgical gloves during surgery is a real threat. 12 to 18% of gloves are perforated by the end of a surgery. Over half of the perforations go unnoticed by users [70, 71]. The importance of double gloving during surgical procedures, as well as changing outer gloves regularly, should be underlined, particularly in cases of stings. Concerning double gloving, if the outer glove is changed regularly, perforation rate at the end of surgery drops to 5% for the inner glove [70, 18]. According to various guidelines, duration of use for surgical gloves should be between half an hour and two hours [10]. As no gloves are completely puncture-proof, resorting to fine under-gloves resistant to cuts (high-resistant fibers such as Kevlar, Spectra, Dyneema... or stainless steel knitted thread) might be contemplated for high risk procedures [10].

After a certain length of wear, examination gloves may also have holes [68, 72]. Electron microscopic study of the surface of so-called hypoallergenic surgical gloves shows a large number of easily rubbed-off latex microparticles [73]. In many hospitals, the majority of sterile surgical gloves are “powder-free”. The internal surface of the gloves is often chlorinated, which makes slipping gloves on easier (despite the absence of powder). This process makes this surface completely smooth while reducing its hydrosoluble-protein content [18]. To reduce the risks of latex allergy, it is advisable to avoid choosing that type of gloves when not strictly necessary.

Balty suggests using vinyl gloves for short-time examinations with no excessive stress. As regards surgical gestures and long procedures requiring good dexterity, this author also suggests resorting to synthetic rubber (neoprene, nitrile) gloves, whose flexibility and elasticity are close to those of natural rubber [10]. The use of powder-free latex gloves with a low protein content reduces the risks of allergy, particularly in healthcare workers. Schmid *et al.* noticed fewer cases of glove intolerance in dental students who wore powder-free, low-protein gloves. However, this

does not prevent potential sensitisation [74]. This preventive measure should also prevent latex particles adsorbed by powder from being sprayed into the air. Regarding powdered gloves, their powder content should preferably be inferior to 2 mg per glove [10]. Protection creams must not be used under gloves as they can cause latex deterioration [75].

Concerning protection gloves against chemicals used in the medical field, their choice depends on the preliminary evaluation of the specific resistance of the materials they are made of (EN 374 standard). Shaffer *et al.* specify that, for instance, nitrile rubber or butyl gloves offer impervious protection from glutaraldehyde. Thus, they ought to minimise hand exposure to glutaraldehyde [76].

For highly toxic medicines (cytotoxics, anti-cancer medicines), double gloving is usually recommended. Though data are available in the scientific literature as to the resistance of materials to various products, resorting to double gloving made of different materials is advised for want of enough information on the subject. Changing gloves frequently, even immediately in case of any accidental projection, is recommended [10].

Choosing substitution gloves for healthcare workers

In the case of immediate latex allergy

Latex-free gloves ought to be chosen. Nitrile or neoprene gloves have barrier functions close to those of latex. PVC or vinyl medical gloves are less resistant to high stretching forces and will have to be changed more often. In the case of regular stress, their barrier quality will decrease. Thus the protection they offer is not as good during prolonged use [77].

In cases of immediate skin sensitisation to natural latex gloves, Tennstedt *et al.* recommended the following gloves:

- neoprene gloves: Dermaprene® (Ansell), Duraprene® (Cardinal), Néolon® (Becton-Dickinson);
- styrene-type synthetic rubber gloves: polystyrene-polybutadiene-polystyrene gloves: Elastyren® (Danpren) or polystyrene-polyethylene-butylene-polystyrene gloves: Tactylon® (Smart Practice) [18].

If the properties and qualities usually provided by latex are not essential to the task, resorting to vinyl gloves, with the previously-mentioned limits of use, might be a possibility: for example: Triflex® gloves (Cardinal) or True Touch® gloves (Becton-Dickinson) [18].

In the case of allergic contact dermatitis to additives in rubber gloves

The majority of natural rubber or synthetic gloves contain vulcanisation accelerators. To recommend appropriate substitution gloves, it is important to know their chemical composition exactly. In this respect, companies will have to be asked for information so as to choose gloves that do not contain the causal allergen.

European information sites on gloves may provide invaluable help:

- French site: www.inrs.fr (provides a list of gloves with the various vulcanisation accelerators used, published by INRS in 1996) [78];

– German site: www.gisbau.de rubric: Aktuelles (information on glove composition) [79].

In the case of allergy to thiurams, nitrile or neoprene gloves should not be chosen without gathering further information as to the additives used, insofar as nitrile and neoprene rubbers may contain similar allergens [9, 20]. It should also be borne in mind that cross-allergies between thiurams and dithiocarbamates may occur. Glove manufacturing processes and glove material composition may evolve over time (for instance: fewer thiurams...) [9, 20].

Styrenic thermoplastic elastomer type synthetic rubber gloves (SBS and SEBS) do not contain vulcanisation additives since they are not vulcanised [9, 20]. Crépy reports that styrenic thermoplastic elastomer type sterile medical gloves can also be used as substitution gloves for people sensitised to vulcanisation accelerators. Insofar as their reticulation is chemical and not physical, their resistance to chemicals is even lower. Tactilon® type gloves thus prove to be incompatible with the bone cements used in orthopedic surgery [9, 20].

Plastic (PVC or polyethylene) gloves do not contain vulcanisation accelerators either.

Compensation

Dermatoses due to medical or surgical gloves may appear in different tables of occupational diseases of the French Social Security general scheme (*tables N°43, 49, 51, 65, 95...*). The two main tables are:

– table N°65: “allergic eczema-like lesions” the listed substances for compensation are: mercaptobenzothiazole, tetramethylthiuram sulfide, IPDD and its derivatives, dithiocarbamates, thiourea derivatives, cobalt, benzi-sothiazoline-3-one...;

– table N°95: “allergic occupational diseases caused by latex (or natural rubber) proteins.”

Conclusion

In healthcare jobs, wearing medical or surgical gloves as a means of skin protection for both patients and healthcare workers is essential while performing medical gestures, particularly “high-risk” gestures.

Choosing appropriate gloves is in line with a skin prevention strategy. Agner and Held proposed educational programmes for the prevention of contact dermatitis [80]. The recent results of several German studies regarding the implementation of primary and secondary prevention measures in healthcare workers show how important such actions are in professions with an increased risk of suffering from occupational skin diseases [81-83].

However, occupational allergic contact dermatitis to glove materials (eczema or contact urticaria on hands) are frequent. Rubber additives as well as latex proteins are the main allergens to remember.

Choosing the appropriate medical or surgical gloves requires having sufficient preliminary information on the assets, drawbacks and use limits of each of them. Occupational physicians play a major role in the prevention of contact dermatoses and infectious risks in a healthcare environment. The advice provided by dermatologists or

allergologists is essential when it comes to suggesting substitution gloves in the case of known contact allergic dermatitis. The changes in manufacturing processes and the composition of medical and surgical gloves suggest that we should remain vigilant and follow, in the future, the latest updates in this domain. ■

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