The history of gloves in medicine dates back to more than 250 years. Their first use dates back to 1758, being attributed to the German doctor Johann Walbaum. His gloves were made of sheep cecum and used during the gynecological examination. The above-mentioned facilitated the introduction of the hand into the vagina, protecting from mechanical damage during obstetric procedures (1). At the end of the 17th century the Austrian dermatologist, Joseph Plenk, suggested that midwives use protective gloves when performing vaginal examinations in patients infected with syphilis (2).

A milestone was made in February, 1839. As a popular anecdote says, Charles Goodyear stumbled and poured on the fireplace, a solution of gum with sulfur, accidentally vulcanizing it. The material gained new properties and thus, applications.

It seems to be impossible to determine who was the first to routinely use rubber gloves during surgery, but William Haldsted was considered as their first propagator (Head of the Department of Surgery, John Hopkins Hospital). In 1889, a scrub nurse- Caroline Hampton developed severe eczema of the hands, due to chronic exposure to sublimate (mercuric chloride) and carbolic acid used for the disinfection of the hands. Attempts to apply protective collodium to the hands failed, since every flexion of the fingers tore the cellulose layer. During the visit to the prosectorium, Haldsted noticed that his friend William Welch, an anatomopathologist, wore a pair of clumsy looking rubber gloves. As it turned out the above-mentioned gloves protected his hands from the cadaverous smell, such hated by his wife. After such an observation, Haldsted asked the Goodyear Rubber Company to create a pair of rubber gloves for his nurse. The product proved to be so successful that the eczema healed and all surgeons began to use protective gloves. In June, 1890 roku miss Hampton became Mrs. Haldsted. Furthermore, another surgeon working at the hospital (Joseph Colt Bloodgood MD) noticed that the number of infections after hernia surgery significantly decreased when gloves were used (3, 4).

The first study concerning the use of surgical rubber gloves was published in the Zentralblatt für Chirurgie in 1897, by the Estonian surgeon Werner von Manteuffel. As the Author wrote: „To wear boiled gloves is like to operate with boiled hands” (1).

It is worth mentioning the merits of Jan Mikulicz-Radecki, a Polish surgeon from Wroclaw, who apart from wearing a surgical mask was the first to introduce silk gloves during surgical procedures (5).
However, the ultimate and widespread use of rubber gloves in medical practice, especially interventional procedures, was observed during World War I.

Surgical gloves are assumed to constitute a protective barrier against hematogenous pathogens, such as HIV, and hepatitis type B and C viruses. According to various studies, glove perforation is observed in several to several dozen percent of surgical procedures, although remains undiagnosed, both by the surgeon and nurse. Palmer and Rikett estimated that each operating surgeon during his carrier will at least once have the chance of an HCV infection, and 1 in 1500 cases of HIV, due to a perforated glove (6). Furthermore, based on observations made by Thomas et al. approximately 20% of surgeons beginning surgery have abrasions, which are an invitation for an infection (7).

Latex gloves

Surgical gloves are usually made of natural latex, which is a substance acquired from the milky juice of Brazilian rubber trees (*Hevea brasiliensis*). The microstructure of latex consists of spherical particles having a diameter ranging between 0.1 and 5 micrometers. The space in between the rubber particles are filled with proteins, ammoniac, soaps, water, and numerous other organic and non-organic substances. When the glove is at risk of fluid contact there is gradual dissolution of compounds found between the molecules of rubber with the development of a maze of canals. This process is named hydration (8). The above-mentioned phenomenon is associated with a number of consequences. First of all, gloves become conductive to electricity, which might cause burns during the use of diathermy (9). Additionally, latex swells when absorbing fluids, thereby reducing its stretching ability.

Gloves are more susceptible to damage and moreover, one may observe a deterioration in the sense of touch when wearing them (10, 11). Additionally, they may be less effective as a protective barrier against biological factors, the maze of canals might be responsible for the infiltration of pathogens. Although study results concerning direct transmission of viruses through the gloves subjected to hydration are inconsistent, thus the need for further investigations (12, 13, 14).

As indicated by many investigations, the rate of hydration of various manufacturer gloves is different. This is not surprising considering the fact that natural latex as a biological substance has a high level of differentiation (8). Moreover, the mechanical integrity of gloves is closely related to the degree of porosity of the material. The more the pores, the material is more easily and rapidly subjected to hydration and rupture (14).

Thus far conducted studies have shown that the perforation of latex gloves during surgical procedures is quite a common phenomenon. Based on literature data the incidence of glove perforation amounts to several tens of percent, depending on the type of surgical procedure (15). The highest number of perforated gloves is observed in orthopedics (16), thoracic surgery (17, 18), and maxillo-facial surgery (19), where sharp bone edges and specialistic tools are responsible for high-risk damage. Results in case of laparoscopic procedures are inconclusive. Some Authors report a low damage index (20), while others show a perforation incidence amounting to 20% (15). A surprisingly high incidence is observed in surgical nurses amounting to 40%, according to Hollaus et al. (17).

The index finger of the left operator’s hand is the most common site of perforation. This is probably associated with the fact that the right-handed surgeon holding a needle-holder retains tissues with his left hand (non-dominant), thus, the possibility of accidental pricking. The second most common location of injury is the thumb of the left hand. Both locations account for more than 70% of perforations (6, 20).

Moreover, the number of perforations increases with the duration of the surgical procedure. Laine and Aarnio demonstrated that after two hours the number of perforations increased two-fold (159, while after five hours three-fold (21).

It is worth noting that most authors evaluated the incidence of surgical glove perforation on the basis of the so-called „water leak test”. The method approved by the European Normalization Committee (EN455-1) and Food and Drug Agency (FDA) consists in the visual evaluation of the gloves when fixed to a glass tube and filled with 1000 ml (± 50 ml) of room
temperature water. The observation period was 2 minutes. In the absence of fluid leakage the glove is considered as free of holes (22, 23). However, Sohm et al. demonstrated that the above-mentioned method is very subjective leading to false negative results in case of small diameter holes (24). Therefore, the actual incidence of perforations might be higher, as compared to values presented by the authors.

Dillon and Schroeder confirmed the above-mentioned hypothesis visualizing (optic and electron microscope) numerous micro-defects on the surface of the gloves after their two-hour use (25).

How to minimize the risk?

A cheap and fairly effective method of reducing the risk of blood-borne infections is the use of double gloves (14, 26). Spanish Authors demonstrated that four of five inner gloves maintained protection, in case of exterior glove damage (27). Moreover, in case of damage to both gloves (by a needle) the amount of blood that is in contact with the skin is reduced by 95% (28).

Many authors suggest that the use of double gloves becomes an absolute standard (13, 26, 27, 29, 30, 31). Unfortunately, some of the surgical environment manifests their aversion to such management, arguing about the subjective reduction in dexterity and touch sensitivity (32). Fry et al. showed no such connection in their objective study. Moreover, in order to avoid ischemic numbness in the fingers, due to compression, the authors proposed the use of larger inner gloves, as compared to standard exterior gloves (33). The survey conducted by Paterson showed that the time elapsed after which the surgeon becomes used to double gloves is usually two days, although in selected cases it might amount to as many as 120 days (34).

An interesting solution to help detect hidden damages and perforations of gloves is the so-called Mölnlycke Health Care – The Biogel® Puncture Indication System. The above-mentioned consists of an additional colored pair of gloves, serving as a visible marker of perforation, covered by normal, straw-colored gloves. In case of injury and fluid leakage one may observe the appearance of a colored stain, which is evidence of the need to change gloves. The gloves manufacturer estimated the accuracy index in the identification of small perforations at 97% (35, 36), while that of larger perforations at 100% (37). However, other authors demonstrated the effectiveness of the system in only 44% of cases (21). Korniewicz et al. showed the benefits of double gloving during surgery (30).

Other additional protective measures during surgical procedures might be attributed to knitted gloves. They are usually made of polyethylene or kevlar fibers and used as the second, exterior pair of gloves. The meta-analysis undertaken by Tanner and Parkinson demonstrated that when double latex gloves were used the incidence of inner glove damage amounted to 24%, while in case of knitted exterior gloves the incidence of perforation was reduced to 5% (38). Unfortunately, their main drawback is the significant reduction of manual dexterity and comfort of the surgeon (39).

An innovative idea for the treatment of high-risk procedures is the G-VIR® glove. It consists of three layers: the exterior and interior layers made of synthetic, non-latex rubber, and the central layer consisting of micro-drops of disinfectant. The thickness of such a glove is approximately 500 μm, being comparable to the thickness of double latex gloves. Each glove contains 5 to 8 ml of an aseptic, which is a mixture of chlorhexidine and quaternary ammonium salts (40).

It is worth mentioning that these substances have a high success rate in case of short-lasting contact, they neutralize bacteria and lipid capsule viruses including HIV (41). At the time of perforation the micro-drops gather at the site of the injury. Importantly, the elastomeric structure of the glove and antimicrobial fluid are responsible for the fact that the remaining antiseptic is separated and the protection of the surgeon is maintained (42). Thus far, two experimental studies have been undertaken evaluating their efficacy. The first study showed a 53% to 64% reduction in the number of infections considering laboratory animals subjected to viral contamination (viral diarrhea, herpes simplex) after passing through the G-VIR® glove (43). The second in vivo study showed a 81% reduction in the transmission of the HSV-1 virus, in comparison to the classical latex glove (44). The only completed clinical study showed that elasticity, tactile sensitivity,
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grasping possibilities and degree of sweetening hands are comparable to that of double latex gloves. According to the Authors, greater mechanical durability is observed, as well as difficulties in donning G-VIR® gloves. Another drawback is the ten times higher price.

DPNRL and synthetic material gloves

An interesting alternative for latex gloves are DPNRL gloves (deproteinised natural rubber latex). The main cause of allergic reactions to latex are proteins. The milk of Brazilian rubber trees contains more than 250 proteins of which 56 are related to the development of the IgE dependent response (45). During the production of DPNRL gloves proteins are combined into larger conglomerates, these being eluted from the solution. Thus, nearly 90% of antigens may be removed by means of the above-mentioned method. Although the latex protein concentration is below the detection threshold, gloves are not completely free of these proteins, and thus, should not be used by those allergic to them. They can be routinely used by medical personnel, in order to reduce exposure to latex proteins, and thus, the development of hypersensitivity to these substances (39, 46).

Removal of proteins makes the latex less stable. In order to maintain its properties synthetic stabilizers are added. An additional advantage of this process is that these gloves are 20% thinner, while maintaining the original strength of the latex (46).

In view of the increasing number of allergic reactions, both in case of patients and physicians, extensive use of gloves from the following material were made: polyurethane, nitrile, vinyl, neoprene or polyisoprene. The protection they provide is comparable to latex gloves. The smaller flexibility does not guarantee the same comfort for their users (47). By the significantly reduced tensile strength one may observe an increased probability of perforation.

According to Korniewicz et al. this may be an advantage, since perforations are more rapidly visible to the surgeon, and thus, gloves exchanged (48). It is worth mentioning that studies demonstrated a greater incidence of perforations considering non-latex gloves, as compared to latex gloves. Interestingly, different places were location to injury. In case of latex gloves perforations mostly concerned the fingers, while in case of non-latex gloves the dorsum of the hand (49, 50).

Cause of damage to the surgical gloves

Double gloves provide protection only in case of injuries inflicted by simple geometry sharp objects, such as surgical needles. One should keep in mind that such defects constitute only half of the possible injuries observed in the operating room. The remaining injuries are associated with objects of a more complex geometry (bone elements, injection needles, scalpel), which are not cleansed from blood passing through the glove (wiping effect), and thus, are at increased risk of pathogen transmission (31, 51). As shown, single-layer gloves reduce the amount of blood which passes with the injection by 52%, while no further reduction was observed in case of double gloves (44).

In order to reduce the likelihood of glove damage by surgical needles, it is postulated to use blunt needles. The meta-analysis undertaken by Parantainen et al. demonstrated that the use of blunt needles prevents one perforation every six procedures (52). Mingoli et al. suggested that blunt needles and double gloves be used as the most effective method to prevent hand injuries (53).

Conclusions

Due to the high percentage of surgical glove perforations, it seems necessary to use methods which reduce the risk of pathogen transmission. Of all the discussed solutions double gloves seem to be the simplest, most effective, and cost-beneficial methods. We believe that the habit of using double gloves should be implemented, especially amongst young physicians beginning their specialization, so that the initial period of discomfort and gradual habituation of the hands be associated with the acquisition of surgical skills.
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