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Evaluation of the effect of medical gloves on dexterity and tactile sensibility using simulated clinical practice tests

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ABSTRACT

Understanding the effect of medical gloves on manual performance is critical for improving glove design and mitigating the impediment to surgical performance caused by gloves. Existing test methods do not correspond well with clinical and surgical tasks. Based on interviews with clinicians, two new tests were proposed: locating a pulse in a simulated blood vessel, and placing and tying sutures in simulated tissue. A pilot study was carried out using 19 clinicians employed at Sheffield Teaching Hospitals. Subjects performed each test three times, with latex and nitrile examination gloves, and without gloves, the order being randomised. In addition to objective test scores, subjects' perception of their relative performance in each condition was recorded. In the Pulse Location Test, performance was found to be significantly better without gloves, while differences between gloves were not statistically significant. Perceived performance correlated well with measured performance. In the Suturing Test, no statistically significant performance differences were found between the three hand conditions, although subjects perceived ungloved performance to be significantly better than with either the latex or nitrile gloves. The Pulse Location Test showed promise as a clinical performance evaluation tool, and could be used to improve medical glove design for better tactile performance. The discrepancy between subjects' perceived and measured performance in the Suturing Test needs further investigation to determine whether the perceived differences translate into genuine clinical performance differences that were not able to be measured using the current method, or whether the difference is purely psychological.

Relevance to industry: The test methods outlined will allow manufacturers to understand the effect of gloves and glove properties on manual performance in medical tasks and improve the design accordingly. Reducing the inhibiting effect of gloves will improve safety and reduce the need to remove gloves for clinical tasks.

1. Introduction

The primary function of medical gloves is to prevent the transmission of pathogens between clinicians and patients. Therefore, the main consideration in glove design and evaluation has rightly been barrier integrity – the ability of the glove to remain intact during use (BSi, 2000) – as well as the obvious need to minimise cost. More recently, the allergenic properties of the glove have also been a significant consideration and have led to major changes in glove properties (NHS Plus, 2008). However, the effect of the gloves on manual performance, i.e. dexterity and cutaneous sensibility, has only recently begun to be explored. Outside of the medical field, glove effects on performance have been studied for a number of years, since it is recognised that manual performance has an impact on both safety and efficiency. Early studies focused on thick gloves for cold weather (Griffin, 1944) or chemical protection (Robinette et al., 1986), which tend to cause substantial reductions in manual performance. However, in clinical situations, where manual errors could lead to injury or increased time in surgery, for example, small differences in manual performance may be significant in terms of safety and efficiency.

A number of recent studies (Johnson et al., 2013; Shih et al., 2001) have attempted to quantify the finer effects of medical gloves on clinical performance. However, these studies have generally been limited to test methods such as the Purdue Pegboard

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Test and the Semmes-Weinstein Monofilaments that assess general manual ability (of industrial job applicants or those with sensorimotor deficiencies, for example) rather than performance in a clinical context.

In order to understand and quantify the effect of gloves on clinical performance, it is necessary either to evaluate the gloves within a clinical environment, or to establish that performance measures used in the laboratory adequately replicate the requirements of clinical practice. The difficulty with evaluating gloves in clinical practice is in creating a repeatable, objective measure of performance, since every case varies, even when performing a routine task. It also introduces a number of ethical issues that would make large-scale evaluation of glove properties and performance very difficult. For this reason, clinical studies of manual performance have generally been restricted to subjective assessments (e.g., Chua et al., 1996), which are limited in their ability to inform design for better performance.

If laboratory tests can be shown to reproduce the manual performance requirements of clinical practice, they offer a more practical solution in which glove properties could quickly and safely be varied and the effects on performance usefully assessed. In order to determine the elements of manual performance most relevant to clinical practice, a study of clinicians (Mylon et al., 2014) was conducted, in which they were asked to identify the clinical tasks they performed that required most dexterity and tactile sensibility, and those that were most adversely affected by gloves.

An evaluation of existing tests (Mylon et al., 2011) relevant to medical glove design found that the manual performance required for some of the tasks mentioned (particularly a number of orthopaedic tasks that involve inserting or removing pins and screws) is adequately simulated by tests such as the Bennett Hand-Tool Test (Bennett, 1965) and the Crawford Small-Parts Dexterity Test (Crawford and Crawford, 1956). However, two of the tasks most commonly perceived as being adversely affected by gloves in the study of clinicians (Mylon et al., 2014) were: location and palpation of blood vessels for the purpose of cannulating, taking blood or measuring a pulse; and suturing, including knot-tying. Neither of these are well simulated by existing tests.

Two new test methods were therefore proposed for evaluating the effect of gloves on manual performance in clinical practice. The first was to be based around the location of a pulse in a simulated blood vessel, while the second would involve placing and tying sutures in simulated tissue.

2. Simulated pulse location test development

Cannulating involves palpating vessels to determine the quality of the vein (does it bounce, does it drain normally?) and whether it pulsates (i.e., is it a vein or an artery?), and inserting a needle into the vessel. The task involves tactility (both through the fingers and through the needle), dexterity, and active haptic sensing (the use of sensors in muscles, tendons and joints). Official teaching (e.g., Ronis, 2008) tells medical students to don gloves after initial palpation of the vessel, but many practitioners perform the whole procedure without gloves because they cannot feel the vessel or the pulse (Mylon et al., 2014), thus increasing the risk of bloodborne infections being transmitted. Reducing the impact of gloves on the performance of such tasks, particularly on cutaneous sensibility, is therefore critical to improving compliance with universal precautions.

Any test to assess the effect of gloves on location and palpation of blood vessels would need to involve hidden pressurised vessels, preferably with the ability to pulsate the fluid. Such an apparatus has been designed for training purposes and initial examination suggested that the concept could be replicated in the lab using a simplified rig.

2.1. Study of existing technology

The heart pumps blood around the body by peristalsis – the contraction of the muscles in a wave that forces the blood around the system. The pressure in the system increases when the left ventricle contracts to pump blood out (this higher pressure is known as the 'systolic pressure') and decreases when the right ventricle relaxes to allow blood back in (this lower pressure is known as the 'diastolic pressure'). The difference between these two pressures is known as the 'pulse pressure'. Because of the elastic nature of blood vessels, this variation in pressure results in a variation in diameter of the vessels, which is what is felt as a pulse in the arm.

Training equipment has been designed to allow medical trainees to practise palpating the pulse and drawing blood samples. A Life/form Arterial Puncture Arm (Nasco, Fort Atkinson, WI) was examined to determine how the pulse was created. The pulse simulation equipment consists of latex tubes which are filled with liquid. At each end is a reservoir. After the tubes are filled, one end is clamped off, and a squeeze bulb is used to create a pressure pulse. The tubes sit in grooves in the polymeric core of the arm which means the pulse cannot be felt except for at two designated locations where the firm polymer is replaced with low density foam that squashes on palpation, allowing the pulse to be felt.

While this is an effective training tool, it has some limitations as far as testing is concerned. Since the location of the pulse cannot be varied, the participant will know after the first attempt where to expect the pulse. This makes it much easier to detect, and makes verification of detection harder. Furthermore, the squeeze bulb does not allow accurate, controlled variation of the pulse pressure, which is necessary to find the threshold of detection for a given hand condition.

To overcome these problems, a new design was proposed in which the pulse could be sent through any one of a number of 'vessels', and in which the pulse pressure and rate could be controlled. For consistency of flow, it was proposed to use a peristaltic pump (EYELA Micro-Tube Pump MP3) to create the pulse.

2.2. Final apparatus

The final test apparatus can be seen in Fig. 1. The artificial vessels are made from latex tubing, which is flexible enough to cause palpable changes in diameter with pressure changes. The diameter was chosen to match the existing Arterial Puncture Arm, but is also close to the diameter and thickness of the radial artery (Adbdulahad, 2006). The tubes sit in v-section grooves cut into a block of low-density rigid polystyrene foam, so that they just protrude above the surface. The tubes are then covered in a 1.5 mm sheet of neoprene sponge, which was chosen for its low stiffness that gives more of a flesh-like feel than stiffer rubbers such as silicone or vinyl (used in the Arterial Puncture Arm) and allows enough compression to feel the vessels beneath it.

A case was constructed from medium-density fibreboard (MDF) through which the latex tubes are fed from the peristaltic pump via a five-way ball valve switch, which allows the pulse to be directed down any of the five vessels individually. After passing through the foam, the tubes are clamped through a flexible plate which is bolted to the casing and allows each tube to be opened and closed individually (Fig. 1). An aluminium lid was manufactured to hide the workings (where fluid flow could be seen) from the subject, and to improve the aesthetics. The five-way switch was connected to the peristaltic pump via a stiffer plastic tube. To set up the apparatus, the cover and rubber sponge sheet were removed, all five valves