INCIDENCE AND RISK FACTORS FOR SURGICAL GLOVE PERFORATION IN SMALL ANIMAL OPHTHALMIC SURGERY

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ABSTRACT

Objective: To determine the incidence of perforation of surgical gloves and identify associated risk factors that contribute to glove perforation in small animal ophthalmic surgery.

Study design: Observational cohort study.

Sample population: Surgical gloves (n=2000) collected following 765 small animal ophthalmic procedures.

Methods: All the gloves were tested for perforation at the end of the procedure using a water leak test. The potential risk factors for glove perforation were recorded, and associations between these risk factors and perforation were explored using univariable (Fisher's exact test) and mixed effect logistic regression analysis. Results were considered significant if $P < 0.05$.

Results: Glove perforation was detected in 6% of procedures. Glove perforation was 1.97 (95% CI 0.98-4.22) times more likely in extraocular than in intraocular surgeries (7.3% vs. 3.9%; p=0.0462). The incidence of perforations was not statistically different between main and assistant surgeon (p=0.86). No significant association was found between the risk of glove perforation and duration of the procedure (p=0.13). Perforation of the non-dominant hand was 2.6 (95% CI 1.38-4.98) times more likely than the dominant hand (74% vs. 26%; p=0.0028). Only 22% of the perforations were detected intraoperatively. Multivariable analysis identified only extraocular surgery as a risk factor for perforations.

Conclusions: There is a low incidence of glove perforation in small animal ophthalmic surgery, but extra care of the non-dominant hand is required, especially during extraocular procedures.

KEYWORDS: extra ocular, non-dominant, fore finger, thumb, needle, water leak test

INTRODUCTION

Surgical gloves are a protective barrier worn during surgical procedures to reduce the risk of pathogen dissemination that can cause infections in the surgeon and the patient.[1]

Their integrity is therefore important in maintaining a sterile environment and reducing the possibility of surgical site infections (SSI) that are a considerable concern in veterinary medicine, having been described as a complication in 2.5% to 30% of small animal surgical procedures.[2-6] Although a search of the veterinary and human ophthalmic literature via Pubmed® resulted in no studies that specifically link glove perforation with infection of ocular tissues, the integrity of surgical gloves is cited as a critical factor to prevent infections in surgery.[7] Two large scale studies explored the correlation between glove perforation and SSI and showed that, in the absence of antimicrobial prophylaxis, glove perforation is a risk factor for SSI.[8,9] Furthermore, there are case studies in the literature that have implicated surgical glove perforation with outbreaks of Staphylococcal infection in operated patients.[10,11]

The incidence and risk factors contributing to surgical glove perforation have been largely investigated in many human medicine subspecialties and in a number of veterinary studies. In small animal surgery performed at veterinary teaching hospitals, glove perforations were found following 22 and 26% of procedures.[12,13] Amongst the risk factors described in veterinary studies as contributing to surgical glove perforation, the type and the duration of the procedure were the two most commonly identified.[12-16] In ophthalmic surgery in humans the reported rate of glove perforation ranged from 0.3% to 21%.[17-19] A recent study amongst nurses scrubbed as assistant for the surgeon during ophthalmic surgery in humans, reported a rate of glove perforation of 4%.[20] To date, the occurrence of glove perforation in veterinary ophthalmic surgeries has not been reported. Several methods have been described in the published literature to test the integrity of surgical gloves, including: observation of skin wetness after submersing a gloved hand under water;[11,21] water inflation of the glove (water leak test) with[16-18] or without[12-15] external compression; air inflation-water submersion with[19] or without[22,23] external compression; use of water soluble dyes to allow easier identification of perforations such as fluorescein[23, 24] or methylene blue;[25] and electrical conductance methods.[14, 26, 27]

The aim of this study was to elucidate the incidence of glove perforation in small animal ophthalmic surgery using a water leak test (WLT) modified by previous authors,[13,18] and to explore potential risk factors. In addition, the ability of the wearer to detect glove perforation intraoperatively was investigated.

MATERIALS AND METHODS

The study was performed as an observational cohort study.

A total of 2000 gloves (1000 pairs) were collected between June 2017 and November 2018 following 765 ophthalmic procedures performed at three referral hospitals in the UK (Eye Vet Clinic, Leominster; The Royal Veterinary College, London; Dick White Referrals, Six Mile Bottom). The standard WLT described by the American Society of Testing and Materials[28] is the test most widely reported in the literature[12-14,16,18-20] to estimate the incidence of perforation in surgical gloves and relies on the pressure applied by 1000mL of water inside the glove to detect perforations. The standard WLT was modified by Prendiville *et al*. and Hayes *et al.*[13,18] (500mL of water) and this was the method used for the current study.

The gloves were tested for perforations immediately after the end of the surgical procedures by the glove wearers (37 different glove wearers across the 3 hospitals participated in this study). Each glove was filled with 500mL of tap water and the cuff was occluded at its wrist section with one hand, whilst the other hand squeezed the water filled glove; the body and the fingers of the glove were visually inspected for leaks. Glove test results and potential risk factors were recorded after each procedure. The potential risk factors included the type of surgery (extra vs intra ocular), the role of the surgeon (main vs assistant) and the duration of surgery. The hand that was perforated (dominant vs non-dominant), along with the number and location of perforations was recorded. The authors recorded the location of the perforations within each hand as follows: thumb, fore finger, middle finger, ring finger, little finger, palm or dorsum as previously described by Miller *et al.*[19] In case of observed intraoperative perforation, the glove was removed and tested to confirm perforation. All gloves worn were made of latex. Three different types of gloves from 2 manufacturers were used: Biogel (powder-free, straight finger design, natural rubber latex surgical glove with Biogel hydrogel polymer coating), Biogel Tech (powder-free, curved finger design, natural rubber latex medical glove with Biogel hydrogel polymer coating) and Gammex (PF Micro-thin powder-free latex surgical glove).

Normality distribution of duration of surgery was evaluated using the Shapiro-Wilk test. Outcome was defined as any glove perforation in either the dominant or the non-dominant glove in each pair. The relationship between the perforations and the risk factors was explored using a Fisher's exact test for 2 by 2 tables and then calculating odds ratios (ORs) and 95% confidence intervals (CI). A multivariable logistic regression was used to calculate ORs and their CI for the predictor variables of perforation. The Hosmer-Lemeshow test was used to assess the goodness of fit of the model. Statistical analysis was performed using R 3.6 for MacOS (R Core Team (2013). R: A language and environment for statistical computing.

R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org). Results were considered significant if P<0.05.

RESULTS

Overall, a glove perforation occurred during 46 of 765 procedures (6%), or in 2.3% of gloves. Of the 765 procedures in our study, 60% were extraocular and 40% were intraocular. The univariable analysis showed that glove perforation was 1.97 times more common in extraocular procedures (CI 0.98-4.22) compared to intraocular procedures (7.3% vs 3.9%, p= 0.0462). There was not a significant difference in perforation rate between the main surgeon and the assistant (4.7% and 4.3% respectively, p= 0.86). (**Table 1)** Perforation rate was not significantly different when considering procedure duration (p=0.13): 0% for procedures lasting less than 15 minutes (n=69); 5.4% for procedures lasting 16 to 30 minutes (n=260); 6.3% for procedures lasting 31 to 45 minutes (n=218); 4.9% for procedures lasting 46 to 60 minutes (n=121); 2.5% for procedures lasting 61 to 75 minutes (n= 40); 13.7% for procedures lasting 76 to 90 minutes (n= 29) and 7.1% for procedures lasting longer than 91 minutes (n=28).

Multivariable analysis identified only extraocular surgery as a risk factor for perforations (OR 1.98; CI 1.04-4.03; p= 0.0459). There was not a significant difference in perforation rate between the main surgeon and the assistant (OR 1.15; CI 0.57-2.52; p= 0.71). (**Table 2)** The Hosmer-Lemeshow test suggested the goodness of fit of the model (p= 0.67) and the model correctly predicted glove perforation in 95.4% of cases. All the surgeons in this study were right-handed. The frequency of glove perforation was significantly different between the dominant and the non-dominant hand: perforation on the non-dominant hand was 2.6 times (CI 1.38-4.98) more common than the dominant hand

(72% of the perforated gloves were non-dominant gloves, p=0.0028). Of the 46 gloves that were found to be perforated, 42 (91.3%) had a single perforation, whilst 4 gloves had multiple perforations (giving a total of 50 perforations). Multiple perforation was not associated with any variable and was not more likely to be noticed by the surgeon compared to single perforation. The thumb and the fore finger were more commonly involved in perforation (13 for the thumb and 14 for the fore finger; representing 26% and 28% of total perforations respectively). The middle finger was involved in 9 perforations (18%), the palm was involved in 6 perforations (12%), the ring finger in 5 perforations (10%) and the little finger in 3 perforations (6%). No perforations were observed in the dorsum**. (Fig 1)** Perforations were noticed intraoperatively in 10 cases (22%).

DISCUSSION

This study reports the incidence and risk factors for surgical glove perforation during small animal ophthalmic surgery. Ophthalmic procedures involve the utilisation of sharp instruments in a dim light environment, those being factors that could potentially increase the risk of glove perforation. On the other hand, ophthalmic procedures are often elective procedures, less invasive and of a shorter duration compared to other surgeries and given the results of previous ophthalmic studies in humans, the authors expected the perforation incidence to be low. The present study found that the overall incidence of glove perforation was relatively low, with 6% of procedures exposed to at least one glove perforation. This result was lower compared to those observed in previous studies in veterinary medicine,[12-14,16] but within the range reported in the ophthalmic literature in humans.[17-19] The only significant risk factor for glove perforation identified in this study was the type of surgery, with extraocular procedures being more at risk for glove perforation. This finding was similar to that documented in a previous ophthalmic study in humans.[19] The authors hypothesise that the nature of extraocular surgery, and the behaviour of surgeons performing extraocular surgery could explain the higher incidence of glove perforations. Intraocular surgery is generally more delicate, more precise and carries higher risks of serious complications. As a result it seems logical that surgeons and assistants are more focused and attentive during such procedures. Most intraocular surgery is performed via an operating microscope – the hands are supported and steady, with small finger movements controlling instuments in a small and well illuminated surgical field. In contrast, during extraocular surgery, the surgical field may be larger which results in greater hand, arm and body movements, and along with the use of larger instruments and needles, the opportunity for glove perforation may be higher. It is possible that the surgeon and assistant may be less focused during extraocular procedures, as absolute precision in surgical technique is less critical to achieve a successful surgery. In addition, during extraocular procedures the fingers are more likely to be used to load suture needles into the needle holders, increasing the risk of injuries. Conversely, in intraocular surgery specialised instruments (suture forceps with tying platform) to handle the sutures and load the small gauge needles into the needle holders are routinely used, therefore the manual handling of suture needles is minimal. Further studies would be required to confirm this hypothesis, for example by studying video recordings of all surgeries and trying to pinpoint the moment any glove perforation occurs.

The present study found that the non-dominant hand was more likely to suffer perforations and the thumb and fore finger were the fingers more commonly involved. Several researchers have reported that gloves worn on non-dominant hands are more likely to sustain perforations,[12,14,16,19,29] and furthermore these are usually found in the thumb and the fore finger, [12,14,16,19,29,30] most likely due to handling of suture needles by the non-dominant hand during surgical procedures.[29,30] A study in soft tissue surgery in humans about the influence of suture technique on surgical glove perforation reported that avoiding manual handling of needles by using a meticulous ‘no touch’ technique would much reduce the risk of surgical glove perforation.[21] In another study, Corlett *et al.* compared a standard suturing technique with a ‘no touch’ technique and reported that the latter minimise the risk of surgical glove perforation during wound closure.[31] The ‘no touch’ technique described by Orengo *et al* requires the consistent use of mechanical assistance in the loading or adjustment of a suture needle into the needle holder.[32] Orengo *et al* emphasise that at no time the surgeon should use hands to place or adjust the needle into the needle holder.[32] In light of the previous studies[21,31,32] and the current study, it would be sensible to always use an instrument to handle the needles to minimise the risk of glove perforation, regardless the type of surgery (extra or intraocular).

There was not a significant difference between the main and assistant surgeon’s frequency of glove perforation in the present study, while other veterinary medicine studies found the primary surgeon more likely to have glove perforations.[12-14] One explanation for this could be that the previous studies[12-14] involved more invasive procedures, where the gloves of the primary surgeon may experience more stress, caused by increased tissue and instrument handling, than the gloves of other team members. Ophthalmic procedures, on the other hand, involve minimal tissue handling and this could explain why no significant difference between the main and assistant surgeon’s frequency of glove perforation was found in the present study.

Interestingly, unlike previous studies, no significant association was found between glove perforation and duration of surgery in the current study.[12-16,19] This could possibly be explained by the relatively low number of surgeries lasting over 46 minutes included in this study.

The present study found that the ability of the glove wearer to detect perforations intra operatively was quite poor with 78% of perforations unnoticed. This data was similar to the low detection rates documented in previous studies.[12-14,16,27] Burrows *et al* suggested that this might be due to the lack of awareness within the surgeons of how frequently surgical gloves may be damaged during operations.[12] It has also been suggested that the focus of the operator on the procedure precludes awareness of glove perforation.[27] To address this problem, double gloving puncture indicator systems that include differently coloured under and over gloves have been developed to facilitate detection for glove perforation intraoperatively.[15,33,34]

There were several limitations to the present study. Previous studies suggested that the WLT might not be as sensitive as an alternative method, the electroconductivity test (ECT), in detecting micro perforations.[14,26,27] The ECT relies on a decrease of electrical resistance of the glove barrier to detect micro perforations, however, despite being more sensitive than the WLT, this method may produce false positive results due to the hydration of the latex.[14,35] Although the WLT has a low sensitivity for micro perforations detection and could underestimate the true incidence of glove perforation, it was selected by the authors over the ECT because it has been widely validated and is the most commonly used test to estimate the incidence of surgical glove perforation.[12-14,16,18-20] In addition, given the multicenter nature of the study, the time, the costs and the additional equipment required, performing ECT would not have been feasible.

Another possible limitation could be that the gloves were tested by the main surgeon or the assistant, rather than an independent assessor, and this may have resulted in a bias toward under detecting perforations because the WLT might not have been performed in the standardised way by all the glove wearers (i.e. differences in the pressures applied on gloves by different surgeons). Furthermore, the temperature of the water and the duration of the WLT (i.e. the amount of time the glove was filled with water) were not recorded, and these could be additional limitations of the study.

A further limitation could be that the amount of water used to fill the gloves in this study (500mL) might generate insufficient pressure to provoke leakage and confirm perforation from a very small hole. The authors decided to use the WLT modified by Prendiville *et al.* and Hayes *et al.*[13,18] because the amount of water used by the standard WLT described by the American Society of Testing and Materials (1000mL)[28] would not fit the surgical gloves without the use of special equipment.

During the data collection in this study one of the surgeons suffered an intraoperative needle stick injury of the finger with a 30-gauge insulin needle, which resulted in a small amount of haemorrhage within the glove. The glove was changed and submitted for the WLT, but no leakage was observed. This incident appeared to confirm the limitations of the WLT as described above.

The association between glove perforation and SSI in veterinary medicine has not yet been investigated. On the other hand, in the human surgical literature there is evidence of strong statistical association between glove perforation and SSI (in the absence of antimicrobial prophylaxis)[8,9] and glove perforation is considered a potential source of infection in surgery.[7] The association between glove perforation and SSI was not investigated by the present authors and additional studies to assess the influence of glove perforation on SSI in small animal ophthalmic surgery is warranted.

CONCLUSIONS

This study concluded that the incidence of glove perforation in small animal ophthalmic surgery was low. When perforation was detected, it most commonly affected the thumb and fore finger of the non-dominant hand during extra-ocular procedures.

Extra care of the non-dominant hand while handling sharp instruments and avoiding handling the needles with fingers could help minimise the risk of glove perforation.

CONFLICT OF INTEREST

The authors declare no conflicts of interest and they are the only responsible for the content and writing of this manuscript.

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