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KR Crosse

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REVIEW ARTICLE

Pre-surgical hand preparation in veterinary practice

KR Crosse

School of Veterinary Science, Massey University, Palmerston North, New Zealand

ABSTRACT
The objective of this paper is to review the evidence for different methods of surgical hand preparation applicable to veterinary practice. Surgical hand preparation is an essential step in performing surgery as a veterinarian. Recommended protocols and products for surgical hand preparation have varied since its inception in the late 1800s. Many factors must be considered when assessing the efficacy, safety, and users' compliance with any available product. Traditional scrub methods employing chlorhexidine gluconate or povidone-iodine have been compared to alcohol-based rub protocols with respect to immediate and prolonged efficacy, safety, compliance, requirements for theatre furniture, cost and water usage. Although much of the comparative data has been generated in human medical facilities, extrapolation of the data to veterinary surgery is appropriate. Considerations for veterinary practice are specifically discussed. Overall, the benefits of alcohol-based rubs indicate that this should be the preferred method of pre-surgical hand preparation for veterinarians in all types of practice.

Abbreviations: ABR: Alcohol-based rub; CHG: Chlorhexidine gluconate; PI: Povidone-iodine; SSI: Surgical site infections

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Introduction

An end measure of the success of aseptic technique in veterinary surgery is timely wound healing and an absence of surgical site infections (SSI) without the need for antimicrobial treatment. SSI cause patient morbidity, prolonged hospital stays, increased use of antimicrobials and increased costs to the client. *Staphylococcus pseudintermedius* is now identified in recent studies as the most common isolate from canine SSI (Nazarali *et al.* 2015; Windahl *et al.* 2015). Alarmingly, in one prospective study from a Canadian veterinary hospital, the most common bacterial species cultured from canine SSI was methicillin-resistant *S. pseudintermedius* which was isolated from 47% of culture-confirmed SSI compared to 10% for methicillin-susceptible *S. pseudintermedius* (Turk *et al.* 2015). There is also increasing evidence that *S. pseudintermedius* can be isolated from veterinarians themselves via nasal swabs and hand and animal-contact surfaces in companion animal hospitals (Hanselman *et al.* 2009; Paul *et al.* 2011; Perkins *et al.* 2020). Often, the veterinarian performing the surgical procedure will be the clinician with overall responsibility for the case, overseeing the care from I/V catheter placement, through surgery, post-operative care and discharge to the client. This suggests that while there are numerous routes by which a surgical wound can be contaminated from an exogenous source pre-, intra- or post-operatively, the surgeon is a risk factor for introducing potentially pathogenic bacterial species during surgery.

Many aspects of current aseptic technique are historical but due to the ethical cost of conducting a prospective study comparing SSI rates with and without aseptic technique, it is likely this will never be undertaken. Each step of the aseptic technique including preparation of the patient, ensuring sterility of the environment and equipment, and the preparation of operative personnel, all contribute to reducing the probability of contamination. It is the surgeon's responsibility to mitigate, as much as possible, the risks of SSI that relate to their own action and the advice they give to other members of the veterinary team. The risks of multi-drug resistant SSI and the prevalence of methicillin-resistant *S. pseudintermedius* and other resistant bacterial species, intensify the need to prevent bacterial colonisation of wounds. Pre-operative hand preparation is a small act within the global treatment of patients; however, its importance is great and ensuring veterinarians' compliance with good hand hygiene practices in order to uphold clients' expectations and optimise patient care is essential. Therefore, the means for hand asepsis should ideally be widely available, cheap, not reliant on other expensive fittings or furniture, non-harmful to the operator, easy to use, effective and compatible with frequent use without detrimental effect to skin health and normal flora.

CONTACT KR Crosse k.crosse@massey.ac.nz

The objective of this article is to review different methods of surgical hand preparation applicable to veterinary practice to reach a recommendation that is suitable across the spectrum of clinics in New Zealand and worldwide. Despite there being many occasions where hand hygiene is essential in veterinary practice, the scope of this review is limited to pre-surgical preparation.

History

Our understanding of the need for hand asepsis for medical or veterinary procedures precedes our understanding of germ theory. Ignaz Semmelweis faced much criticism in the 1840s when he proposed the link between doctors performing post-mortem examinations and subsequent fevers in post-partum mothers in a womens' hospital (Semmelweis 1861; Best and Neuhauser 2004). He had noticed women treated by female midwives had a much lower rate of post-partum disease and recommended doctors wash their hands between performing autopsies and treating the women. Sadly, this was met with great derision and Semmelweis ended his career without any recognition of this most essential piece of medical knowledge.

Despite the early work of Ibn Sina (b. 980 AD) in Persia demonstrating "germs" as a cause of disease, it took a further 800 years for the European scientific community to be persuaded that the evidence for germ theory was sound, with the work of Louis Pasteur (Gaynes 2011). Much more quickly the work of Snow, Koch and Lister accumulated to develop germ theory and the first use of antiseptics (Tulchinsky and Varavikova 2000). Lister's seminal series of articles in 1867, introducing carbolic acid, should have resulted in great and rapid change, however, scepticism was still rife (Lister 1867). It was only after his move to London in 1877, where he successfully performed a variety of invasive surgical procedures without the consequence of post-operative fevers, that the tide began to turn (Keen 1915). Finally, in 1879, agreement of Lister's theory and method within the medical profession was made at the International Medical Congress in Amsterdam.

Meleney (1941) described five sources of bacterial contamination of surgical wounds: the patient's skin, the nose and throat of the operating room personnel, bacteria in the air of the operating room, the hands of the doctors and nurses, and the instruments and materials used during the operative procedure. This was incorporated into the veterinary literature by Singleton (1968) two decades later. This included a 28-step method for the preparation of the theatre, patient and surgeon with an emphasis on the contribution of each individual step to the overall success of aseptic technique. The recommended method for hand preparation was washing and scrubbing with hexachloraphene or zalpon. The following year a more thorough review of disinfection in veterinary practice was published, with the recommendation of polyvinyl-pyrrolidone with iodine for surgical hand preparation (Graham-Marr and Spreull 1969). It was not until the late 1990s that a controlled veterinary study comparing surgical scrubbing with chlorhexidine gluconate (CHG) and povidone-iodine (PI) demonstrated that either was suitable and effective at significantly reducing the bacterial load (Wan *et al.* 1997).

Microbial flora

There are two populations of bacteria that are important in the context of healthcare workers' hands: resident flora and transient flora. The latter may include potentially pathogenic bacteria (Price 1938). The resident flora consists of bacteria found under the superficial cells of the stratum corneum and on the surface of the skin. When culture methods were used to determine the bacterial species present, the resident flora was found to be dominated by *Staphylococcus epidermidis* with other staphylococcal and corynebacterial species also found (Evans *et al.* 1950; Rayan and Flournoy 1987). Newer genomic approaches, however, have revealed a much greater diversity of organisms (Grice and Segre 2011). Using 16S ribosomal RNA metagenomic sequencing, the most common species of resident bacterial flora fall under four phyla: Actinobacteria, Firmicutes, Bacteroidetes and Proteobacteria. Whilst *Staphylococcus* and *Corynebacterium* spp. are still the most common resident species in moist skin zones (e.g. axillae and skin folds) when using genomic methods, the populations of dry skin areas (including the hands) are incredibly diverse (Grice *et al.* 2009). There is even a high proportion of Gram-negative bacteria, which previously had always been considered simple contaminants of skin from the gastrointestinal tract (Roth and James 1988). Host and environmental factors also play roles in the specific constituents of each individual's skin microbiome (Grice and Segre 2011). Resident flora is important to skin health, and some species appear to have a role in host defence against pathogenic bacterial activity (Roth and James 1989; Cogen *et al.* 2008). Generally, microbes of the surgeon's resident flora less commonly contribute to SSI in human surgery compared to the patient's bacterial flora (Anonymous 2009). There is currently no evidence in the veterinary literature demonstrating SSI caused specifically by either the transient or resident flora of the surgeon. *S. pseudintermedius* is the most common isolate from canine SSI, but this would be considered a very rare contributor to human resident skin flora (Hanselman *et al.* 2009). Changes to the local environment through host behaviour may lead to increasing load, reduction in diversity and colonisation with pathogenic species (Roth and James 1988). The acts of hand washing and particularly scrubbing may play a role in altering the resident flora population.

The transient flora colonises the superficial layers of the skin and is much more likely to be removed by good hand hygiene. These transient bacteria do not multiply on the skin but can survive for extended time periods (Aly and Maibach 1981). They are transferred to the hands when touching patients, equipment or furniture and are frequently associated with hospital-acquired infections (Anonymous 2009). Unfortunately, it has been shown that the hands of surgical staff (compared to their internal medicine colleagues) have higher total bacterial counts and a greater proportion of pathogenic bacteria (Coelho *et al.* 1984). It was suggested in this study that frequent contact of infected wounds and regularly scrubbing hands for 10 minutes both contributed to this increased pathogenic load by altering the local environment of the surgeons' skin.

Hand health

It is important to consider that any practices that affect the types and numbers of pathogens on a healthcare worker's hands, may have an effect on the likelihood of SSI. One of the interesting factors in good hand hygiene practise is the poor general compliance by healthcare workers. Most commonly dryness and itchiness are cited as the reasons that proper hand hygiene is avoided (Boyce *et al.* 2000). An increase in skin dryness between scrubbing episodes is more prevalent when a scrub brush is used (*vs.* washing hand with PI) especially in the winter months (Kikuchi-Numagami *et al.* 1999). Furthermore, a study comparing soap-and-water hand washing to asepsis with alcohol gel showed epidermal water loss to be significantly greater with soap-and-water washing (Winnefeld *et al.* 2000). In a large cohort study of healthcare workers using alcohol-based rubs (ABR) alone in a teaching hospital, an extraordinary low rate (0.45%) of cutaneous adverse reactions was reported (Graham *et al.* 2005). This is compared to a reported 2% rate of allergic contact dermatitis caused by CHG in healthcare workers (Toholka and Nixon 2013).

Facilities

When using soap with or without brush protocols, there is a necessity for good hospital furniture to ensure the practise of hand preparation is reliable. A deep sink that reduces splashing, hands-free tap systems and generous space outside a thoroughfare, are all required to reduce self-contamination during the scrub process. *Pseudomonas aeruginosa* has previously been isolated from taps in hospitals (Blanc *et al.* 2004), and therefore the removal of tap aerators is recommended (Cross *et al.* 1966). There are no specific studies investigating the incidence of contamination of surgeons preparing for surgery in an area specific to that purpose compared to those using a multipurpose sink and bench in a general area of a clinic. It would be assumed though, that a lack of space and increase in the number of surrounding non-sterile objects would make successful preparation more difficult.

Fingernails and jewellery

The influence of nail polish on bacterial load on hands has been studied with regard to traditional scrub protocols, but not with ABR. Where traditionally it was always recommended that nail polish should not be worn, there is conflicting evidence in the literature. One study has shown that there was no difference in microbial culture after surgical hand preparation with or without nail varnish using 10% PI in a 2-minute immersion bag technique (Kulkarni *et al.* 2018). In contrast, Edel *et al.* (1998) found significantly greater cfu following a 5-minute scrub with antimicrobial soap in participants wearing nail varnish compared to natural nails. There is further evidence, however, that more cfu are present after a CHG scrub on hands with old polish (worn longer than 4 days) or chipped varnish than on hands with non-polished or newly applied polish (Wynd *et al.* 1994). Artificial nails were shown to have a greater number of pathogenic bacterial species present both before and after surgical hand preparation and are therefore not recommended (Edel *et al.* 1998; McNeil *et al.* 2001). Despite there being no clear evidence in the literature that wearing simple jewellery (a wedding band), leads to the transmission of pathogenic bacteria, it is widely accepted across reviews that all hand jewellery should be avoided in any healthcare job and especially when preparing for surgery (Anonymous 2009; Cimon and Featherstone 2017). None of the above studies have used the endpoint of SSI, rather they have used various culture methods immediately before and after hand preparation. Despite there being some conflicting evidence across the literature, the overall current recommendation would be to avoid hand and wrist jewellery, nail polish and artificial nails in all personnel preparing to perform surgery. The other consideration regarding nail polish and jewellery is the inherent variability between individual cases. It would be very difficult to ensure that staff members wearing nail polish had it recently applied, that it wasn't chipped, that acrylic nails weren't being worn and the nail itself is clean, without additional set point checks being done pre-operatively. Instead, it is much easier to achieve compliance by making a blanket recommendation that nail polish, artificial nails and hand jewellery should not be worn when working in an operating theatre environment and then verify nails are visibly clean without nail polish.

Surgical gloves

In 1893 Bloodgood demonstrated lower infection rates in hernia surgeries where surgeons wore gloves compared to those that did not (Geelhoed 1988). In veterinary surgery, the use of sterile gloves as part of the aseptic technique is widely accepted, though not always used (Demetriou *et al.* 2009; Anderson *et al.* 2013). Whilst sterile surgical gloves are clearly an ideal barrier to protect patients from the bacteria on the surgeons' hands, gloves are not perfect. In three recent studies within the veterinary literature the incidence of glove perforation by the end of surgery was reported to be 23.3% (Character *et al.* 2003), 26.2% (Hayes *et al.* 2014) and 17.9% (Biermann *et al.* 2018). In addition to glove perforation, contamination of gloves has been shown to occur in around 30% of small animal surgical procedures (Walker *et al.* 2014). Although there was an instance of one glove perforation in this study, the other sources of contamination were not found. Contamination was not associated with length of procedure, left vs. right hand, category of wound, or type of procedure. There are known risk factors for glove perforation: increased duration of procedure, orthopaedic procedures, use of powered instruments or surgical wire and being the primary surgeon. The reported detection rate of glove punctures by veterinary surgeons is poor at 30.8% (Hayes *et al.* 2014). Interestingly a study of human dentists showed that increased glove perforations were noted if an ABR was used immediately before glove application. It was recommended in this study, therefore, that allowing hands to completely dry before gloving is an important step (Pitten *et al.* 2000). It cannot always be assumed either, that veterinarians will choose to wear sterile surgical gloves to perform surgery. In a survey of New Zealand veterinarians, it was reported that only 68.4% and 67.9% of veterinarians wore surgical gloves to perform an ovariohysterectomy in a dog and cat respectively (Gates *et al.* 2020). With the protective layer of surgical gloves less than perfect, or not being worn at all, good hand asepsis is essential to reducing the risk of bacterial contamination of the surgical wound.

Client expectations

Since the inception of hand washing and the understanding of aseptic technique, standard practices in modern human medicine follow strict guidelines, especially within operating theatres. It is therefore not surprising that veterinary clients may expect similar standards of care within veterinary hospitals. Results of a survey of pet owners in the United Kingdom suggested that >90% of clients assumed veterinarians wore gloves and gowns when performing surgery (Demetriou *et al.* 2009). The lowest expectation was for theatre shoes or covers at 62.2%. These figures contrasted starkly with frequencies reported by veterinary practices for use of gloves (37.5%) gowns (14.3%) and theatre shoes or covers (7.1%). Although not included in the survey questionnaire, it is reasonable to assume that clients would also expect veterinarians to execute proper hand asepsis prior to operating on their pets. The results of a recent New Zealand survey of veterinarians showed similar results with only 19.1% and 11.9% reported to use gloves, gowns, cap and mask when performing an ovariohysterectomy in a dog or cat respectively (Gates *et al.* 2020). We do not have any current data, however, on the expectation of clients in New Zealand to compare this to. It is likely that the societal expectation for improvements in the environmental impact of our practices is increasing, however, this has not been studied.

Methods of hand preparation

Broadly there are two approaches to surgical hand preparation: a traditional scrub with either CHG or iodine-based (PI) soaps or an ABR. The goal, however, with either approach is the same: to eliminate transient flora, reduce the resident flora at the start of each procedure and prevent bacterial growth on the hands for the timespan of the procedure. With these targets in mind, most testing of products regarding their efficacy examines the ability for immediate bacterial reduction, persistent action (for a number of hours) and the effect of use, multiple times over a number of days.

Pre-scrub preparation

It is recommended by the World Health Organisation that as part of surgical hand preparation, hands should be washed in soap and the subungual area cleaned with a nail pick to remove gross contaminants and debris prior to hand asepsis (Anonymous 2009). This is despite there being little clear evidence that nail cleaning with a pick or brush has any effect on cfu present on hands after either preparation method (Tanner *et al.* 2009).

Traditional scrub protocols

There are many studies comparing the relative efficacy of CHG and PI for the reduction of bacterial numbers on healthcare workers' hands when used as a surgical scrub. When used as a 3–5-minute scrub CHG was shown to be more effective at reducing cfu on hands immediately after scrubbing and at a delayed time point (Pereira *et al.* 1990; Herruzo-Cabrera *et al.* 2000; Furukawa *et al.* 2005). In the one veterinary study comparing CHG, PI and ABR, data from the preliminary phase of the study showed PI to be significantly less effective at reducing cfu on hands than CHG (Verwilghen *et al.* 2011b). All these studies used bacterial culture to quantify cfu on participants' hands as a proxy for the actual outcome measure of effectiveness, namely SSI. Therefore, these studies demonstrate effectiveness in reducing a risk factor for infection, rather than reducing infection rates. It is likely the lack of this specific data regarding the effect of choice of pre-surgical scrub product on SSI means definitive conclusions are yet to be drawn in the literature.

As well as choice of the substance for the scrub protocol, the time taken in preparation has also been studied. Regarding CHG, a study comparing 2-, 4- and 6-minute protocols showed that 4-and 6-minute scrubs had no advantage over the 2-minute scrub (O'Shaughnessy *et al.* 1991). Despite this finding, the authors still recommended a 4-minute scrub at the start of the day, and use of the 2-minute protocol only for subsequent procedures. Interestingly 10% PI has been tested over a much wider time period, from a 30-second wash to 20-minute contact. In this study (Poon *et al.* 1998), the authors showed neither vigorous scrubbing nor contact time greater than 30 seconds provided any extra benefit.

Despite the common parlance of "scrubbing" to infer surgical preparation, the use of a scrub brush is widely discouraged in the literature. An early crossover experimental study showed that although there was no statistical difference in the number of cfu isolated from participants' hands after scrubbing with a brush or without, twice the number of subjects had a greater reduction in bacterial counts when they washed with soap alone (Loeb *et al.* 1997). There is also concern that abrasion of the skin will alter resident microbial flora (Coelho *et al.* 1984).

Alcohol-based rub protocols

When formulating a rub solution, the variables considered are the type of alcohol, concentration of alcohol, addition of long-acting compounds (e.g. CHG) and the addition of emollients. The goal is to ensure the ideal balance of immediate bactericidal activity, persistent activity once the alcohol has evaporated and the rate of that evaporation. The presence of water is a crucial factor in destroying or inhibiting the growth of pathogenic microorganisms with alcohol, as it acts as a catalyst for the denaturation of proteins (Morton 1971). Isopropyl alcohol concentrations >91% coagulate proteins instantly (Morton 1950). This creates a protective layer that shields other proteins from further coagulation and therefore reduces overall bacterial cell death (Morton 1971; Ali *et al.* 2001; Yosef *et al.* 2001). Seventy per cent alcohol solutions penetrate the cell wall more completely. They therefore permeate the entire cell and coagulate all proteins. They also evaporate more slowly than 90–100% solutions (Yosef *et al.* 2001). The antibacterial efficacy of different ethanol concentrations is compared to the European standard solution of 60% propanol (prEN12791; Anonymous 2016). One study demonstrated equivalent efficacy of only the 85% ethanol concentration and recommended that ethanol-based rubs have a good chance of equivalence to 60% propanol (European standard solution) if the concentration is >75% but <95% (Suchomel and Rotter 2011). Some reports have suggested that additional active ingredients provide improvements over pure alcohol products, but this finding has not been consistently reported (Suchomel *et al.* 2009; Olson *et al.* 2012; Hennig *et al.* 2017).

As for traditional scrub techniques, it is recommended that a simple hand wash (including cleaning of nails) is performed prior to the use of ABR (Anonymous 2009). There is some evidence, however, that dryness of hands is critical to the efficacy of the alcohol rub (Hübner *et al.* 2006) and therefore a delay between the wash and alcohol rub or thorough drying of the hands in a non-damaging and sterile manner is advised. There has been some concern that other skin products used by surgical staff may neutralise the active ingredients in ABR. Although no compounds inactivate the alcohol portion if the concentration is within the recommended boundaries, there is some evidence the CHG component may be inactivated by emollients or thickeners (Kaiser *et al.* 2009).

Comparison of products

In one study the efficacy of non-abrasive hand scrub method with 4% CHG; hand rub with a mixture of 30% 1-propanol and 45% 2-propanol solution, 70% 2-propanol solution, or 61% ethanol solution with 1% CHG were compared. The 61% ethanol solution with CHG showed similar immediate efficacy to 4% CHG, but improved reduction in bacterial counts at the end of surgery (Chou *et al.* 2016). Another study compared the efficacy of 61% ethanol with 1% CHG, zinc pyrithione in 70% ethanol and 7.5% PI scrub used by healthy volunteers. Over a 5-day period with participants preparing for surgical procedures daily, only the 61% ethanol with 1% CHG met efficacy criteria set out by the Food and Drug Administration of the USA at days 2 and 5, showing prolonged use to be safe and efficacious (Gupta *et al.* 2007). There was no comparison to an alcohol-only group in this study, however. Traditional scrub techniques with CHG or PI were compared to a hand rub with 45% 2-propanol, 30% 1-propanol and 0.2% mecetronium ethylsulfate in a veterinary setting (Verwilghen *et al*. 2011b). The ABR and CHG had a similar immediate effect, although the sustained effect was significantly better for the ABR. Both were superior to the PI scrub in this study. Although demonstration of reduction in cfu is often used as a measure for efficacy, the effect on the incidence of SSI is likely more critical. This is difficult to demonstrate as SSI is a result of many factors. A significant study of over 4,000 consecutive human patients demonstrated nearly identical rates of SSI for the scrub (2.48%) and ABR (2.44%) groups (Parienti *et al*. 2002). A recent meta-analysis of human studies that compared scrubbing with CHG or PI *vs*. using an ABR has broadly concluded that residual cfu counts were lower in the CHG and alcohol groups compared to the PI group. However, SSI rates were not different between the groups. Furthermore, alcohol rubs were favoured by the participants and had higher compliance rates (Ho *et al.* 2019). Again, within these studies use of neutralisers prior to culture was not homogenous, which may significantly increase the apparent efficacy of CHG and PI (Kampf *et al*. 2005).

There is emerging evidence that resistance to CHG is developing in bacterial populations and, potentially even more concerning, that co-resistance towards antimicrobials is a feature of this resistance pattern (Kampf 2018).

Residual activity

While the immediate bacterial reduction is similar for CHG and PI-containing soaps, regrowth is more rapid after hand antisepsis with PI-containing soaps (Tanner *et al*. 2016). An ABR (61% ethyl alcohol with 1% CHG) showed an immediate reduction in cfu that was not different compared to that of a CHG scrub, but after 2 hours significantly less cfu were present in the ABR group (Edwards *et al*. 2017). As a comparison, a similar study in another equine hospital did not find a difference at either immediate or post-surgical time points when comparing a traditional CHG scrub to the same ABR (da Silveira *et al.* 2016).

Across a wide range of products, there are conflicting results in the literature, with studies showing significant residual effects of mecetronium ethylsulphate in alcohol (Verwilghen *et al.* 2011b) or no residual effect (López-Gigosos *et al.* 2017). Similarly, conflicting results are also reported for CHG in alcohol with either residual effects demonstrated (López-Gigosos *et al.* 2017) or not (Hennig *et al.* 2017). Alcohol-only products have been reported to have either increased residual activity (Hennig *et al.* 2017) or reduced residual activity with the addition of a neutraliser when compared to CHG-alcohol products (Biermann *et al.* 2019). It is plausible however that the apparent residual effect of alcohol is due to the continued death of damaged organisms rather than potential activity on new contaminants (Lilly *et al.* 1979). Although there are significant contributions to both the human and veterinary literature with studies comparing the efficacy of different products, there is variation of study design and use or not of neutralisers which makes direct comparisons difficult. There is no direct comparison of the same alcohol in the same concentration with the addition of CHG or mecetronium ethylsulphate or no additive, including the use of neutralisers, to truly compare the effectiveness of each of these compounds. As studies use previously manufactured products, the application of these parameters to a study would be very difficult.

Gross contamination of hands

In comparison to human healthcare workers, it could be assumed that veterinarians are more likely to have gross contamination of their hands. Most human surgeons would enter the surgical suite at the start of a day and stay within this controlled area away from the rest of the hospital for the remainder of the day. Veterinary work tends to be more varied and often personnel are required to move back and forth between clean and dirty procedures throughout a shift. One study carried out in an equine hospital has examined the effect of gross contamination on the efficacy of ABR in reducing bacterial load on the hands in pre-surgical hand preparation (Edwards *et al.* 2017). They demonstrated that although both CHG scrub and ABR preparations reduced bacterial load significantly in the presence of gross faecal contamination, positive cultures were obtained from the hands of all participants immediately after preparation and after 2 hours. The recommendation from this evidence also aligns with the World Health Organisation guidelines which states "If hands are visibly soiled, wash hands with plain soap before surgical hand preparation" (Anonymous 2009).

Compliance and training

The importance of training in the success of hand preparation has been illustrated in comparative studies. Widmer *et al*. (2007) demonstrated that prior to training only 31% of healthcare workers were compliant in hand hygiene practises, but after training this increased to 74%, importantly also reducing bacterial counts isolated from hands. In another study medical students in Years 1 and 2 of training were compared to those in Years 3 and 4 (Sutter *et al.* 2010). It was hypothesised that during clinical rotations the students in the later years would be exposed to training in the use of ABR and would therefore have better outcomes in bacterial reduction. The hypothesis was confirmed, demonstrating that regular clinical practice achieved improvement in the same manner as an experimental training session. An observational study of pre-surgical hand preparation used in companion animal hospitals in Canada found that contact times for either CHG scrub or ABR varied widely and practices that did not conform to guidelines in current textbooks were common (Anderson *et al.* 2013). This demonstrates the need for good communication of the expected practice, and the reduction of obstacles to ensure that compliance is achievable. It is not unexpected that training improves performance in what is in essence a physical skill. The ongoing compliance in following the practice guidelines, however, is potentially more important.

Tangentially, there is evidence in veterinary surgery that use of a pre-operative checklist reduces SSI in companion animal patients (Bergström *et al.* 2016; Launcelott *et al.* 2019). These studies demonstrate that increasing compliance to actions that are within the normal expectations of good clinical practice reduces rates of SSI. It is therefore important that initial education regarding hand preparation should be followed by assessment of compliance with the regimen to ensure continued efficacy.

Cost

In a large human teaching hospital, the costs of hand scrubbing and hand rubbing were compared and this demonstrated that a change to hand rubbing would reduce the costs of this task by 67% (Tavolacci *et al.* 2006). Although monetary costs are important to business, water as a resource and cost is also a consideration. It is estimated the average (3-minute) scrub protocol uses 18.5 L of water which can then be multiplied to estimate the water saving over a set time period (Jehle *et al.* 2008). For example, at Massey University's Veterinary Teaching Hospital (Palmerston North, NZ) an average of three personnel prepare for each procedure, with 15 procedures per week for 50 weeks per year. Therefore, changing to waterless hand preparation could save >41,000 L of water per year. Changing from a scrub to ABR protocol (4.8 vs. 2.7 minutes) may also lead to time savings (Gaspar *et al.* 2018), though this difference may not be significant when taking into account the whole time period of a case.

Conclusion

Compliance with evidence-based hand preparation prior to performing surgery is an important step in reducing the morbidity of SSI. This is especially important with current increases in microbial resistance to antimicrobials which may have been used as a substitute for compliance with aseptic technique in clean or clean-contaminated surgeries. Surgical hand preparation as part of aseptic technique is important for reducing use of antimicrobials and rates of antimicrobial resistance in the future and also because we may struggle to treat a resistant infection in that particular patient. It is clear from veterinary studies in the United Kingdom and New Zealand that practices for surgical preparation vary widely among veterinarians in first opinion practices. Furthermore, surgical hand preparation outside the clinic is necessary in large animal and equine practice and is also likely to vary in standard. It is assumed, however, that independent of the location or wearing of surgical gloves, gowns, hats and masks, that prior to every surgery the minimum preparation involves direct hand preparation. The two broad options for hand preparation are the traditional scrub with either CHG or PI, and ABR. In a global survey of specialist surgeons (Diplomates of the American and European Colleges of Veterinary Surgeons) the majority of respondents were using soap-based scrub protocols (79.9%) and rates among equine and large animal surgeons were higher (84.5%) (Verwilghen *et al.* 2011a). This preference split may have changed over the last 9 years as anecdotally the use and knowledge of ABR does seem to be increasing. Nearly all comparisons of these methods have been made in the setting of either human hospitals or veterinary teaching hospitals where there is more likely to be a controlled scrub environment in a clean area with hands-free tapware and purpose-built scrub sinks, compared to what may be available in many veterinary practices. There is no current comparison in the scientific literature of these methods for example in the setting of field surgery or at a multipurpose sink as may commonly occur in many veterinary surgical settings. What can be learnt from the published data is that commercial ABR are well tolerated and as effective as a CHG scrub regarding both immediate reduction of bacterial numbers, and persistent effects. It can be argued therefore, that in the absence of purpose-built scrub facilities that ensure water-based protocols are effective, the benefits of ABR may be greater. Where full theatre apparel is not being worn, the most reliable and effective means of hand preparation is of even more importance.

As we enter times when antimicrobial use is under scrutiny, it is important for veterinary surgeons to apply practices that reduce our need for their use. The safety net of perioperative prophylactic antimicrobial treatment may not always be available and therefore improving our standards of aseptic technique will be critical to maintaining patient health. On the basis of this review, it can be concluded that across the span of veterinary surgical practice, the use of ABR should be promoted. It is possible that in the setting of general veterinary practice, the benefits of ABR over traditional scrubs are even more marked than reported in the literature due to the varying availability of designated scrub sinks in clinics and even more limited facilities for field surgery. Training would be necessary and could easily be disseminated via video tutorials to ensure the use of ABR is effective.

It is likely that as a consequence of the current global pandemic of COVID-19 the understanding and use of alcohol gels and rubs to clean our hands will vastly change. For all healthcare workers, we find no surprise in the importance of hand washing, and yet it is rarely so clearly demonstrated on a global scale in such a disarming way. As veterinarians we often shrug off the easy steps: more keen to learn advanced surgical procedures than to be excellent in aseptic technique and masters of Halstead's principles. Minimising SSI is an attainable goal with the simple act of cleaning our hands. Alcohol-based rubs are effective in eliminating transient flora, reducing resident flora, safe for repeated use, have high compliance with appropriate training, can be used in or out of clinic facilities, are cost effective and water saving. Even if ABR is only as effective as traditional scrubbing in terms of bacterial load reduction, the other benefits should be enough to sway our practice in favour of their preferred use.

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ORCID

KR Crosse http://orcid.org/0000-0001-7089-9785

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