Skin disinfection in preterm infants

I Malathi, M R Millar, J P Leeming, A Hedges, N Marlow

Abstract

Greater care and a more thorough approach to intravenous catheter site disinfection may be important for the prevention of catheter related sepsis, especially with coagulase negative staphylococci in preterm infants. The efficacy of skin disinfection was evaluated in preterm infants using a skin swabbing technique after disinfectant exposure. In the first part of the study, 25 peripheral intravascular catheter sites were quantitatively sampled immediately after routine cannula insertion. Bacterial counts greater than 100 colony forming units/cm² were observed from 10 (40%) sites. In the second part, sampling for bacterial colony counts was done after skin cleansing with various durations of exposure of chlorhexidine/alcohol swabs or povidone iodine. The overall mean reduction in bacterial colony counts after skin cleansing ranged from 90-99%. Skin sterilisation was achieved in 33-92% of cases. The use of two consecutive 10 second exposures resulted in a significantly improved reduction in colony counts compared with a single 10 second wipe. A longer 30 second exposure also resulted in a greater reduction of bacterial numbers compared with a shorter duration of 5 or 10 seconds. Repopulation of disinfected sites occurred within 48 hours. This effect was delayed by occluding the cleansed site with a semi-permeable dressing. There were no significant differences between povidone iodine and the chlorhexidine swabs in reducing bacterial numbers. This study has demonstrated that a brief exposure with a premoistened disinfectant swab is not sufficient for complete elimination of resident skin flora of newborn infants. The use of two consecutive cleanings, or a longer duration of cleansing is recommended for more effective skin sterilisation.

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University Department
of Child Health, St
Michael's Hospital,
Southwell Street,
Bristol BS2 8EG
I Malathi
N Marlow

Department of
Medical Microbiology,
Bristol Royal
Infirmary
M R Millar
J P Leeming
A Hedges

Correspondence to:
Dr Marlow.

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Despite improvements in many aspects of neonatal intensive care, systemic infection remains a major problem among preterm infants. The most common infective agents causing septicaemia after 48 hours of age are the coagulase-negative staphylococci (CNS). In published reviews, CNS infection accounts for a proportion varying between 10 and 90% of all neonatal septicaemias.¹⁻⁴ Among 800 consecutive medical and surgical admissions to our intensive care nursery, between January 1990 and December 1991, 70 infants (9%) had one or more blood cultures positive for

CNS. Of children born before 30 weeks' gestation, 70% had at least one blood culture from which CNS were isolated. There is no evidence to suggest that, in this vulnerable patient group, such findings can be ignored but careful interpretation is needed.

CNS are ubiquitous skin commensals, colonisation of neonatal skin occurring rapidly after birth. During the first week there is a 100-fold increase in the number of skin bacteria per unit area,⁵ which are transferred from the hands of the carers and from the immediate environment. Most studies in adult and paediatric intensive care patients implicate intravascular catheter placement and secondary invasion, initially around the catheter as the source of bacteraemia.^{3 4 6}

Few formal protocols exist for aseptic skin preparation in the infant. Swabs premoistened in alcohol containing chlorhexidine are commonly used for skin disinfection before venepuncture or intravascular catheter placement. In the busy neonatal intensive care situation, where multiple sites of puncture may be required, skin disinfection comprises, in most cases, a brief wipe with these swabs. Recommendations for the duration of exposure and the optimal method of cleansing are not described in most neonatal texts. In preliminary observations, we observed high CNS colony counts on the skin around intravenous sites despite prior cleansing. We therefore studied the efficacy of commonly used methods of skin disinfection in reducing bacterial colony counts in preterm children. The study was divided into two parts, an initial sampling of catheter sites after catheter insertion, followed by an evaluation of disinfection methods.

Population and methods

SAMPLING OF CATHETER INSERTION SITES

Study population

Infants of less than 32 weeks' gestation requiring intravenous catheter insertion between 48 hours and 2 weeks of age were recruited in the initial part of the study. Twenty five catheter insertion sites were studied in 11 infants.

Sampling method

After routine peripheral intravenous catheter insertion, taking no special precautions, and before taping the cannula into place, a 3 cm² area of skin proximal to the insertion site was quantitatively sampled. The area was defined using a flexible polythene template, cut to sit immediately adjacent to the skin puncture site. No attempt had been made to influence the catheter insertion technique and all sites were disinfected with chlorhexidine/alcohol swabs,

the period of exposure being less than 5 seconds in most cases. Twenty five catheter sites were sampled.

Skin bacteria were sampled using a non-traumatic swabbing technique.⁷ This enabled quantitative cutaneous microflora assessment to be performed with minimal disturbance to the child in the clinical setting. The defined areas of skin were rubbed for 20 seconds with a sterile swab that had been immersed in 1 ml of sterile wash fluid (phosphate buffer 0.075 mol/l; pH 7.9 containing 0.1% v/v Triton X-100; and the neutralisers of chlorhexidine (2% Tween 80 and 0.3% lecithin). The tips of the swabs were then broken off into the remaining wash fluid, which was then agitated for 20 seconds. A 0.1 ml aliquot of this solution was then spread onto blood agar plates containing 5% horse blood. Colony forming units (cfu) were enumerated after incubation of agar plates at 37°C for 24 hours.

DISINFECTION STUDY

A rectangular flexible polythene template, in which nine 3 cm² holes had been cut, was applied to the back of each infant, allowing assessment of adjacent areas for comparative purposes. The nine sampling sites were allocated by a 3×3 Latin square distribution to control (no treatment), or to one of two treatments (interventions) for each child.

Interventions

Two common techniques were evaluated: premoistened Steret-H preinjection swab (Setton Prebbles Ltd) containing 70% v/v

isopropyl alcohol and 0.5% w/v chlorhexidine acetate BP; and a cotton wool swab moistened with aqueous 10% povidone iodine (Betadine; Napp Laboratories Ltd). Five protocols were used:

(1) *Duration of exposure* – The effect of disinfection with a chlorhexidine/alcohol swab for 5 or 10 seconds (five infants) and 5 or 30 seconds (five infants) were compared. After exposure for the prescribed duration, the site was allowed to dry for 30 seconds before sampling. Samples were taken using the quantitative swabbing technique described above.

(2) *Double swabbing* – A single 10 second clean with a chlorhexidine/alcohol swab was compared with two 10 second wipes, separated by a 10 second drying time. Again swab washing was performed after a final 30 seconds drying time (10 infants).

(3) *Chlorhexidine versus iodine* – A 10 second swab with a chlorhexidine/alcohol swab was compared with a 10 second swab with aqueous povidone iodine, both with 30 seconds drying time (five infants). The wash fluid used to sample sites treated with povidone iodine contained 0.5% sodium thiosulphate instead of Tween 80 and lecithin.

(4) *The duration of residual effect* – After a 10 second exposure with a chlorhexidine/alcohol swab, sampling from the first square was performed at 24 hours and from the second at 48 hours (five infants).

(5) *The effect of occlusion* – The study sites were prepared and sampled as for (4) above but each site was occluded with Tegaderm (3M Healthcare) after drying until sampling (five infants).

Table 1 Bacterial colony counts at catheter insertion sites

Bacterial cfu/cm ²	No (%) of catheter sites
0	0
<10	7 (28)
10–100	8 (32)
100–1000	5 (20)
>1000	5 (20)

Table 2 Bacterial counts after cleansing using different regimes

	No of babies	Median (range) cfu/cm ²	Mean % reduction in cfu/cm ²	Sterile sites (%)
Duration of cleansing				
(A) chlorhexidine/alcohol 10 v 30 sec				
Control	5	1580 (10–3300)		0/15
10 sec	5	5 (0–1000)	93	5/15 (33)
30 sec	5	3 (0–1000)	96	7/15 (47)
(B) chlorhexidine/alcohol 5 v 30 sec				
Control	5	22 (0–581)		1/12 (8)
5 sec	5	3 (0–23)	96	5/12 (42)
30 sec	5	0 (0–3)	99.7	11/12 (92)
Double swabbing				
Control	10	30 (0–3166)		1/30 (3)
One swab	10	2 (0–22)	98	14/30 (47)
Two swabs	10	0 (0–5)	99.6*	23/30 (77)
Chlorhexidine/alcohol v aqueous iodine				
Control	5	60 (5–608)		0/11
Chlorhexidine/alcohol 10 sec	5	0 (0–23)	96.8	6/11 (55)
Iodine 10 sec	5	0 (0–27)	98.3	9/11 (82)
Duration of effect				
Control	5	477 (0–1826)		1/15 (6)
24 hours	5	68 (3–520)	76.2	0/15
48 hours	5	133 (0–783)	53.9	1/15 (6)
Effect of occlusion				
Control	5	13 (3–3302)		0/15
24 hours	5	5 (0–46)	98	1/14 (7)
48 hours	5	4 (0–130)	72	3/8 (38)

*p=0.01.

STATISTICAL CONSIDERATIONS

The bacterial counts were expressed as mean cfu/cm² for each infant studied. Percentage reduction in cfu based upon controls (untreated areas) were calculated. The Friedman rank sum test was used to test for differences between treatment and controls. Treatments were compared using the Wilcoxon signed rank test based on mean bacterial cfu/cm²/baby.

The study was approved by the local hospital research ethics committee.

Results

Immediately after routine cannula insertion no puncture site was sterile. Seven (28%) had relatively few bacteria present, but 10 (40%) had high densities (>100 cfu/cm²; table 1). These data represent the minimum bacterial counts left at intravenous sites as the site was subsequently disturbed by taping in the cannula.

In the second part of the study, a total of 305 swab washes were made on 35 preterm infants. Of these, 29 swabs were unsuitable for analysis due to contamination. There was great variability in the mean bacterial counts of control areas, most being in the region of 100 cfu/cm², but with some up to 10 times higher (table 2).

Bacterial isolation plates from an infant with high control colony counts. For visual display purposes plates are arranged in rows corresponding to their position in the experimental 'Latin square' but column positions are altered: left column = control (no cleansing), central column = 10 second cleanse, right column = 30 second cleanse.

Generally, the use of a single chlorhexidine/alcohol swab reduced bacterial counts by between 91 and 99%, depending upon the duration of exposure. A long duration of cleansing (30 seconds) was more effective than 5 or 10 second cleansing, producing 96.0–99.7% reductions in cfu, depending on the control count. The figure shows the nine bacterial plates from one infant with very high control counts ($>10^3$ cfu/cm²). The left column comprises plates from the untreated sites, the central column from sites after 10 seconds cleansing, and the right column after 30 seconds cleansing. Despite 30 seconds cleansing, significant numbers of residual bacteria are present.

The use of two consecutive 10 second chlorhexidine/alcohol swabs resulted in a 99.6% reduction in mean bacterial colony counts; a significant improvement compared with use of a single swab for 10 seconds ($p=0.01$).

There was no significant difference in efficacy of reduction of bacterial counts between povidone iodine and chlorhexidine/alcohol.

Table 2 shows the duration of residual effect after cleansing with chlorhexidine/alcohol. Twenty four hours after cleansing, although there were significant reductions in bacterial counts over the control numbers, no site remains sterile and the median bacterial density is 14% of the control bacterial density, and by 48 hours this has doubled to 28% (table 2). The effect of covering the cleansed site with a breathable occlusive dressing would appear to delay this 'repopulation', although the control areas tended to be less densely populated in these children. This effect appears to persist up to 48 hours.

Discussion

Ideally, skin disinfection would achieve the total elimination of vegetative bacteria from the cleansed site. This study shows that by

using a premoistened chlorhexidine/alcohol swab, between 91 and 99.5% of the skin flora can be removed. Depending on the duration of cleansing and the baseline bacterial density, the goal of removal of all detectable bacteria was achieved in between 33% and 92% of cases. While this appears at first sight to be extremely effective in reducing bacterial numbers, the residual bacterial numbers may be of significance, especially in the presence of a foreign body and in the immunocompromised premature infant. There is the potential risk for direct inoculation of bacteria during insertion of the cannula or for contamination of venepuncture or cannula insertion sites if large numbers of bacteria persist after skin cleansing.

Skin disinfectants used in most neonatal intensive care units are chlorhexidine, isopropyl alcohol, povidone iodine, or a combination of these agents. Chlorhexidine is highly active against vegetative Gram positive organisms, and has a relatively long duration of antibacterial activity.^{8,9} Isopropyl alcohol has the advantage of rapid onset of action, although it may be absorbed through neonatal skin. Iodine preparations are as effective as chlorhexidine and demonstrate good sporicidal activity. The efficacy and potency of these agents depend on the manner in which they are applied. One neonatal text recommends that for aseptic skin preparation before minor procedures, such as venesection and intravascular catheter insertion, the alcohol be applied twice in circular motion, away from the procedure site, with some friction, and that the site be allowed to dry.¹⁰ There are few particular suggestions as to the duration of disinfectant exposure in preterm infants. A recommendation for routine venepuncture suggests that alcohol be applied for at least one minute with friction in an adult setting.¹¹ This may pose practical problems, given the fragile nature of the preterm infant's skin.

Commercially available alcohol, chlorhexidine, or iodine pads are commonly used for skin cleansing before venepuncture. In one study, iodine pads produced a significantly higher sterilisation rate (80%) compared with alcohol pads (61%) on adult skin before venesection.¹² Maki *et al* compared the use of all three agents for skin preparation and to treat cannula insertion sites every other day. Chlorhexidine was associated with the lowest incidence of catheter related infections and bacteraemia.¹³ We found no difference between the sterilisation rates or reduction of colony counts between the alcohol based chlorhexidine and aqueous povidone iodine.

In adult studies, the incidence of venous catheter related blood borne infection varies from 0.2 bacteraemias per 100 peripheral catheters to 10 per 100 central catheters.^{14,15} Garland, in a review of 654 peripheral Teflon catheters used during paediatric intensive care, observed phlebitis in 13%, catheter colonisation in 12%, and sepsis directly attributable to a catheter in only one patient.⁶ We suspect that this risk is much higher in preterm infants, in whom the incidence of CNS bacteraemia is

particularly high. Risk factors described for the development of CNS bacteraemia include prematurity, presence of central or peripheral intravascular catheters, and the use of parenteral nutrition.³

Recent clinical evidence suggests that the main source of micro-organisms, which colonise percutaneous intravascular devices and cause local infection and bacteraemia, is from the skin at the catheter entry site. There is the risk of direct inoculation of bacteria during catheter insertion, or from subsequent migration via the transcutaneous insertion wound. In colonised catheters, the proximal and distal catheter tips are colonised with organisms cultured from the skin, while the hubs are sterile,⁶ implying the bacteria are seeded percutaneously, rather than through infected infusate. It has been shown that positive skin swabs from cannula insertion sites have a 61% positive predictive value for cannula colonisation.¹⁶ Similarly, in one unpublished study, a direct correlation was observed between both the level and profile of cutaneous colonisation at catheter insertion sites and the risk of catheter related bloodstream infection.¹⁷ Our findings that 40% of catheter insertion sites are heavily colonised at the time of insertion gives some indication of the inadequacy of current methods of skin disinfection and the potential risk this poses for the preterm infant.

The observed high bacterial counts at cleansed catheter insertion sites could arise either from insufficient eradication of the infant's own bacterial flora or from contamination of the cleansed site by handling. In a study comparing blood cultures with corresponding venepuncture sites, only 31 of 677 cleansed venepuncture sites were positive, and of these, only 7% of positive blood cultures were associated with identical venepuncture site contamination.¹⁸ This lower incidence of venepuncture site contamination is probably because the swabs were taken immediately after cleansing, before any handling. We have shown that the efficacy of skin disinfection may be improved by a longer duration of disinfectant exposure, preferably with the use of two consecutive swabs for cleansing. The problem of subsequent contamination from handling can only be reduced by strict adherence to aseptic technique during catheter insertion, preferably with the use of sterile gloves, especially in the high risk extremely preterm infants. Although this may make cannula insertion more difficult, a longer intravenous site life would be anticipated.

The effect of skin disinfection with a chlorhexidine/alcohol swab as used in this study is transient. Bacterial repopulation occurs steadily over the next 48 hours. In a study of the effects of topical antimicrobial treatment of adult skin, it was found that CNS were eradicated from the surface, but repopulation occurred within 24 hours by organisms that had not been eliminated from the stratum corneum.¹⁹ Unlike mature adult skin, the skin of the preterm infant does not have the morphological structure to support bacteria in the deeper subepidermal layers. Topical

antibiotic ointments applied at catheter insertion sites have shown little benefits in terms of reducing infections in adults,²⁰ but may have a part to play in preterm infants.

The protective effect of a breathable occlusive dressing in delaying repopulation at a cleansed site, might suggest a role for the use of a dressing to be applied at catheter insertion sites. Studies in adult patients in this regard have shown equivocal results. For example, Maki and Ringer showed no reduction of catheter related infections with the use of various types of dressing.²¹ They also observed that both cutaneous colonisation of insertion site and the presence of moisture under the dressing were significant risk factors for infection. Presumably some of this risk is accounted for by the presence of uneradicated bacteria in deeper epidermal layers. The different skin morphology of preterm infants and the use of breathable occlusive dressings may account for our observation that a significant proportion of sites remained sterile under occlusion.

In conclusion this study has demonstrated that a brief exposure with a premoistened disinfectant swab may not be sufficient for total elimination of the resident skin flora. The use of two consecutive cleanings, or a longer period of cleansing (at least 30 seconds), is recommended if more effective skin sterilisation is to be achieved. The careful adherence to stricter aseptic technique would be desirable in order to reduce catheter site contamination. The benefit of different methods of intravenous site care needs to be evaluated in this particularly susceptible patient group.

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