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Comparison of Four Antiseptic Preparations for Skin in the Prevention of Contamination of Percutaneously Drawn Blood Cultures: a Randomized Trial

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A number of skin antiseptics have been used to prevent the contamination of blood cultures, but the comparative efficacies of these agents have not been extensively evaluated. We therefore sought to compare the efficacy of four skin antiseptics in preventing blood culture contamination in a randomized, crossover, investigator-blinded study conducted in an emergency department and the inpatient wards of a university hospital. The patient group included all patients from whom blood samples were obtained percutaneously for culture. Skin antisepsis was performed with 10% povidone-iodine, 70% isopropyl alcohol, tincture of iodine, or povidone-iodine with 70% ethyl alcohol (i.e., Persist). The blood culture contamination rate associated with each antiseptic was then determined. A total of 333 (2.62%) of 12,692 blood cultures were contaminated during the study period compared to 413 (3.21%) of 12,859 blood cultures obtained during the previous 12-month period (relative risk = 0.82; 95% confidence interval, 0.71 to 0.94; $P = 0.006$). During the study, the contamination rates were determined to be 2.93% with povidone-iodine, 2.58% with tincture of iodine, 2.50% with isopropyl alcohol, and 2.46% with Persist ($P = 0.62$). We detected no significant differences in the blood culture contamination rates among these four antiseptics, although there was some evidence suggesting greater efficacy among the alcohol-containing antiseptics. Among the evaluated antiseptics, isopropyl alcohol may be the optimal antiseptic for use prior to obtaining blood for culture, given its convenience, low cost, and tolerability.

Blood cultures are important for the diagnosis and management of bloodstream infections. Because of the low threshold that many clinicians maintain for obtaining blood cultures, the number of cultures obtained far exceeds the number of bloodstream infections diagnosed. As with any screening or diagnostic test performed in a population with a low prevalence of disease, many blood cultures are found to be falsely positive. False positives result from the introduction of organisms from a site outside of the bloodstream into the sample of blood obtained for culture. This is referred to as contamination of the culture.

The problem of blood culture contamination is widespread. Up to 50% of all positive cultures may be positive due to the presence of contaminants (2, 8, 22). Recent studies have reported that 0.6 to 6.25% of percutaneously drawn cultures are contaminated (6, 10, 15, 19, 20). Coagulase-negative staphylococci and other skin flora are the most common contaminants. Unfortunately, these organisms can also be significant pathogens. One study found that 25 to 37% of cultures yielding coagulase-negative staphylococci represented significant bacteremia (19). Thus, difficult diagnostic and therapeutic dilemmas arise when these organisms are isolated. For example, although physicians were found to be quite accurate in determining the significance of cultures growing coagulase-negative staphylococci, nearly half of the patients with false-positive cultures still received antibiotics (19).

The consequences arising from contaminated cultures are not trivial. In a prospective observational study, Bates and colleagues examined the costs and length of stay for hospitalized adults from whom blood cultures were obtained (3). Based on multivariable analyses, charges for patients with contaminated cultures were found to be significantly higher for intravenous antibiotics (median, $874 versus $492), total laboratory costs (median, $2,056 versus $1,426), and microbiology costs (median, $460 versus $219) than for patients with negative cultures. The total excess cost associated with contamination was $4,385 per patient. There was also a trend toward longer hospitalization (median, 12.5 versus 8 days). In another study, the mean total costs were $4,100 higher for patients with contaminated cultures compared to those with negative cultures (7). In addition to financial excesses, one must also consider issues such as the development of antimicrobial resistance due to unnecessary antibiotic exposure and the individual patient's physical and psychological reactions to additional testing and prolonged hospitalization.

Antisepsis of the skin at the venipuncture site is used to prevent contamination by decreasing the bacterial counts of the resident flora. This practice cannot completely prevent contamination, however, because ca. 20% of skin bacteria are located in deep layers of the skin or in other structures into which antiseptics cannot penetrate (17). A number of antiseptics have been used for this purpose, including alcohol, povidone-iodine, tincture of iodine, and chlorhexidine. Povidone-iodine is probably most commonly used, although three studies have found tincture of iodine to be more effective (7, 16, 20). The present study was designed to compare four commercially available skin antiseptics: povidone-iodine, tincture of iodine, isopropyl alcohol, and povidone-iodine with alcohol (Persist).

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tific Meeting of the Society for Healthcare Epidemiology of America, Toronto, Canada, 1 to 3 April 2001 [abstr. 268].)

MATERIALS AND METHODS

Study design. A randomized, crossover, investigator-blinded design was selected. This was selected to maximize the number of cultures included and to permit both concurrent controls for each group and historical comparisons within each group. Blood cultures drawn percutaneously in the emergency department and on all inpatient care units, except the neonatal intensive care unit, were included. Informed consent was considered unnecessary by the Human Investigation Committee of the University of Virginia Health System. Patients were divided into four intervention groups based on the hospital unit on which they were located. Groups were determined based on the geographic location and subspecialty of the hospital units. Units located close to one another and units that shared staff were included in the same group. This method of group assignment was selected in order to decrease the incidence of the use of an antiseptic other than the one randomized to each group due to any sharing of supplies across related units. At the beginning of the study, one of the four antiseptics was assigned to each study group for use with all cultures drawn over the following 12-week period. Packages of the assigned antiseptic were located adjacent to the blood culture vials in the supply room of each unit. Povidone-iodine-saturated pads were relocated to a more distant site to discourage their use for blood cultures and to promote use of the assigned antiseptic. At the end of this period, the antiseptics were rotated among the study groups and a second 12-week study period followed a 2-week washout period.

At the end of each study period, the antiseptic was removed from each unit and replaced with the antiseptic to be used during the following period. A 2-week washout period during which no data were collected separated each study period so that any antiseptic remaining from the previous study period could be used or removed from the unit prior to beginning evaluation of a different antiseptic. This rotation occurred three times so that all study groups could use all four antiseptics.

Materials. Tincture of iodine (2% iodine and 2% potassium iodide in 47% ethyl alcohol [TI]), 70% isopropyl alcohol (IPA), 10% povidone-iodine (PI), and Persist (povidone-iodine and 70% ethyl alcohol) were packaged in identical envelopes distinguishable only by a label with the letter A, B, C, or D, which was assigned to each antiseptic by the sponsor. Each package contained three swabs. Persist was produced by Becton Dickinson, in Sandy, Utah. The IPA, PI, and TI were obtained from Aplicare (Branford, Conn.). Aplicare packaged all four products.

Phlebotomy technique. Before the first study period, an educational program regarding the phlebotomy technique was presented to all healthcare workers responsible for obtaining blood culture specimens. A pocket-sized copy of a detailed description of the preferred technique was distributed during the oral presentation and was also mailed to resident physicians with their paychecks (Table 1).

Equipment was assembled prior to beginning the procedure. Exam gloves were worn during the procedure. The site was scrubbed firmly but gently with a swab beginning directly over the site of venipuncture and continuing in an outward direction by using circular strokes. This was repeated with the remaining two swabs. The area was allowed to dry completely after the third swab with a minimum delay of 1 min. While the site was drying, culture bottles were prepared. The tops were wiped with an alcohol pad that was then placed over the septum until the time of inoculation. A tourniquet was applied proximal to the venipuncture site, and the blood sample was obtained with a butterfly needle and syringe, with care taken not to touch the prepped area. Culture bottles were inoculated by using the same needle used to perform the phlebotomy. The tourniquet was removed, and the venipuncture site was wiped with alcohol-saturated pads until any and all traces of color from the antiseptic had been removed.

Standard aerobic and anaerobic bottles were processed by the microbiology laboratory according to standard protocols by using BacT Alert, a continuously monitored, carbon dioxide detection system (Organon Teknika Corporation, Durham, N.C.). Specimens were incubated for 7 days unless the ordering physician requested a longer incubation. All positive vials were inoculated onto appropriate media and further processed by conventional techniques.

Data collection. The number of percutaneously drawn cultures performed in each unit was obtained weekly from the laboratory's computerized database. Each culture was classified as either negative (i.e., no growth) or positive. A blinded physician investigator (D. P. Calfee), who had no blood collection responsibilities, reviewed the positive cultures and further classified them, based on a previously described method, as true positive or as contaminated (10, 15). A culture was classified as contaminated if a common skin organism (i.e., coagulase-negative staphylococci, *Micrococcus* species, *Propionibacterium acnes*, viridans streptococci, *Corynebacterium* species other than group JK, or *Bacillus* species) was isolated from only one of two or more blood samples obtained from different sites. Published national guidelines have considered such cultures to be false positive and have recommended against antimicrobial therapy (1, 9). Cultures yielding such an organism for which there was no companion culture for comparison were excluded from the analysis. The contamination rate was calculated by dividing the number of cultures classified as contaminated by the total number of cultures included in the analysis. This was done for each patient care unit during each study period. After the randomization code was broken after completion of the study, the overall contamination rate and individual contamination rates for each antiseptic were calculated. This method was also used by the same blinded investigator to calculate the baseline rate of contamination during a 12-month period prior to initiation of the study protocol, during which time PI was used for skin antisepsis. Blood samples for culture were obtained by a similar range of personnel (physicians, nurses, and phlebotomists) during the study and baseline periods.

TABLE 1. Recommended phlebotomy protocol

Step	Blood culture study protocol[a]
1	Obtain one envelope from the "antiseptic skin prep for blood culture" box. Each of these packages will contain three swabsticks soaked in an antiseptic agent. Blood culture bottles, tourniquet, syringe(s), butterfly needles, alcohol pads, gauze pads, and bandage(s) should also be obtained.
2	Select the site of venipuncture. (If the patient is unusually dirty, wash the intended site with soap and water prior to venipuncture.)
3	Put on exam gloves.
4	Open the package and remove one swabstick.
5	Scrub the venipuncture site gently but firmly with the swabstick beginning in the center and continuing in an outward direction using circular strokes for an area 2 to 3 in. in diameter.
6	Repeat this procedure for the two remaining swabsticks.
7	After the third swab, allow the area to dry completely. (Even if the area appears to be dry sooner, wait at least one full minute before venipuncture is performed.)
8	Prepare the culture bottles for inoculation and wipe the tops with a sterile alcohol pad.
9	Apply a tourniquet, being careful not to touch the prepped area with gloves or tourniquet.
10	Perform phlebotomy by using the needle and syringe. (A 20-ml portion of blood per set of cultures is recommended for adult patients.)
11	Directly inoculate the blood culture bottles by using the same needle used to perform the phlebotomy (i.e., do not change needles). Note: if a blood sample is drawn at the time of placement of a new intravascular catheter or at the initiation of hemodialysis through a graft or fistula, prepare the skin as described above and draw the sample through the catheter into a syringe. Using aseptic technique, place a sterile needle on the syringe and inoculate the culture bottles.
12	Dispose of the needle and syringe in the appropriate sharps container.
13	Send the blood samples to the lab by the standard protocol. No special handling or labeling is required for this study.
14	Use an alcohol pad (or pads) to wipe the prepped area until none of the color from the skin prep remains (i.e., the white alcohol pad should remain white after rubbing). (Note: not all of the skin preparations will discolor the skin, but wipe the area with an alcohol pad anyway.)

[a] When a blood culture is ordered, this procedure should be followed. It is generally recommended that two sets of blood cultures be obtained from two different sites in the evaluation of any new fever.

Each week, the blinded physician investigator visited all of the study units. The number of remaining antiseptic packages was counted, and additional packages were provided to replace those used during the previous week. Compliance with the study (i.e., use of the assigned antiseptic) was estimated on a weekly basis by comparing the number of cultures drawn on each unit to the number of antiseptic packages used on that unit. Personnel working on units with low weekly compliance rates were reminded of the protocol. Study personnel did not directly observe phlebotomy procedures.

Statistical analysis. A sample size of 1,775 per study arm was calculated to be necessary to achieve 80% power in detecting a 2% difference in contamination rates (assuming contamination rates of 4% with one antiseptic and 2% with another). This calculation was based on a Bonferroni multiple comparison procedure to allow comparison of each study arm to all other study arms, if such comparisons were indicated by the detection of a significant difference among the four antiseptics. In that case, plans were made to divide the usual alpha of 0.05 by the number of potential intergroup comparisons (i.e., six) to produce a new alpha level of 0.008 for each intergroup comparison. Contamination rates were compared by using the chi-square test.

Cost analysis. The total cost associated with the use of each antiseptic was calculated. This estimate included the annual cost of the antiseptic (as calculated by multiplying the cost of antiseptic for one blood culture by the number of blood cultures performed during the 12-month study period) and the excess cost attributable to blood culture contamination. The cost of each antiseptic for one blood culture was obtained from the Materiel Support Services of the University of Virginia Health System. The excess cost of contamination was calculated by multiplying the estimated number of contaminated cultures occurring over a period of 1 year (using the contamination rates observed during the study) by the excess cost attributed to a contaminated blood culture at one institution ($4,100) (7). This was seen as an appropriate estimate due to the calculation of a similar excess cost in a separate study at a different institution (3). The calculated total costs were compared to determine the savings or excesses associated with the use of each antiseptic.

RESULTS

The period of 1 October 1998 through 30 September 1999 served as the baseline period. During this interval, 413 (3.21%) of 12,859 percutaneously drawn cultures were contaminated. During the study, 12,806 blood cultures were obtained percutaneously. A total of 12,692 (99.1%) of these cultures met the criteria for inclusion in the analysis; 333 (2.62%) were found to be contaminated. This represented a significant reduction in contamination (relative risk [RR] = 0.82, 95% confidence interval [CI] = 0.71 to 0.94, $P = 0.006$). Individual contamination rates for the four antiseptics were 2.93% (99 of 3,378) for PI, 2.58% (81 of 3,138) for TI, 2.50% (78 of 3,125) for IPA, and 2.46% (75 of 3,051) for Persist ($P = 0.62$). The relative risks of contamination with PI, TI, Persist, and IPA during the study were 0.91 (95% CI = 0.74 to 1.14, $P = 0.44$), 0.80 (95% CI = 0.62 to 1.02, $P = 0.067$), 0.77 (95% CI = 0.59 to 0.98, $P = 0.03$), and 0.78 (95% CI = 0.6 to 0.99, $P = 0.038$), respectively, compared with the use of PI during the baseline period.

The results of the study did not appear to have been influenced by any one particular study group. While there was variability in the contamination rate associated with each antiseptic among the four groups, the relative efficacies of the antiseptics within each group were similar (Table 2). There were no statistically significant intragroup differences among contamination rates between any of the four antiseptics. PI had the highest rate of contamination in all four groups. Group 1, the emergency department, consistently demonstrated the highest contamination rates. General medical and oncology wards and the medical intensive care unit (group 2) and the cardiac, pediatric, and obstetrics-gynecology wards and cardiac and pediatric intensive care units (group 3) had the lowest contamination rates. Surgical wards and surgical intensive care units (group 4) had intermediate contamination rates. The overall risk of blood culture contamination was greater in group 1 than in groups 2 (odds ratio [OR] = 1.48, 95% CI = 1.09 to 2.01, $P < 0.01$) and 3 (OR = 1.81, 95% CI = 1.26 to 2.61, $P < 0.001$). The risk of contamination was also greater in group 4 than in groups 2 (OR = 1.3, 95% CI = 0.96 to 1.77, $P = 0.08$) and 3 (OR = 1.60, 95% CI = 1.11 to 2.30, $P < 0.01$). There was no apparent association between blood culture contamination and season or the order in which the antiseptics were used, as evidenced by the lack of significant differences in contamination within groups during the four study periods, whose dates roughly approximated those of the four seasons (Fig. 1).

TABLE 2. Blood culture contamination rates among individual study groups

Group[a]	Contamination rate (%)[b]				
	TI	PI	IPA	Persist	Overall
1	3.32	3.47	3.23	3.13	3.30
2	1.76	2.69	2.32	2.21	2.26*
3	2.02	2.07	1.56	1.79	1.85*†
4	2.89	3.29	2.87	2.67	2.92
Overall	2.58	2.93	2.50	2.46	2.62

[a] Group 1, emergency department; group 2, medical and oncology wards and medical intensive care unit; group 3, cardiac, pediatric, obstetrics-gynecology wards and cardiac and pediatric intensive care units; group 4, surgical wards and intensive care units. $P \geq 0.1$ for all intragroup comparisons of contamination rates associated with each antiseptic.

[b] *, $P < 0.01$ compared to group 1; †, $P < 0.01$ compared to group 4.

Overall, coagulase-negative staphylococci accounted for 76.8% of all blood culture isolates classified as contaminants. Other contaminating organisms included *Propionibacterium* species (7%), viridans streptococci (4.7%), *Bacillus* species (4.7%), *Corynebacterium* species (3.8%), and *Micrococcus* species (2.9%). The frequency distribution of contaminating organisms was similar among the four antiseptics (data not shown).

Overall, compliance was good. Estimated compliance exceeded 100% on 20 units, indicating the use of more than one packet per culture drawn. This was likely due to failed venipuncture attempts, necessitating skin prepping at multiple sites. Three units had overall compliance rates of 93 to 97%. The six remaining units had overall compliance rates ranging from 15% to 60%. These six units performed 220 (1.7%) of the cultures included in the analysis. Examination of the results from these six units yielded a contamination rate of 1.36%, with rates of 0, 0, 3.28, and 2.0% for PI, TI, IPA, and Persist, respectively. To further assess the effect of noncompliance, contamination rates were recalculated by using data only from units with an estimated compliance rate in excess of 100%. These adjusted rates were very similar to those calculated by using data from all 29 units.

An estimate of the savings associated with the use of each of the three alcohol-containing antiseptics compared with the use of PI was calculated. The cost associated with PI was calculated by using the overall contamination rate observed with PI (including the baseline period and the PI arm of the study) and an antiseptic cost of $0.108 per culture. For the alcohol-containing products, the contamination rate was calculated by combining the results of the three study arms that used these

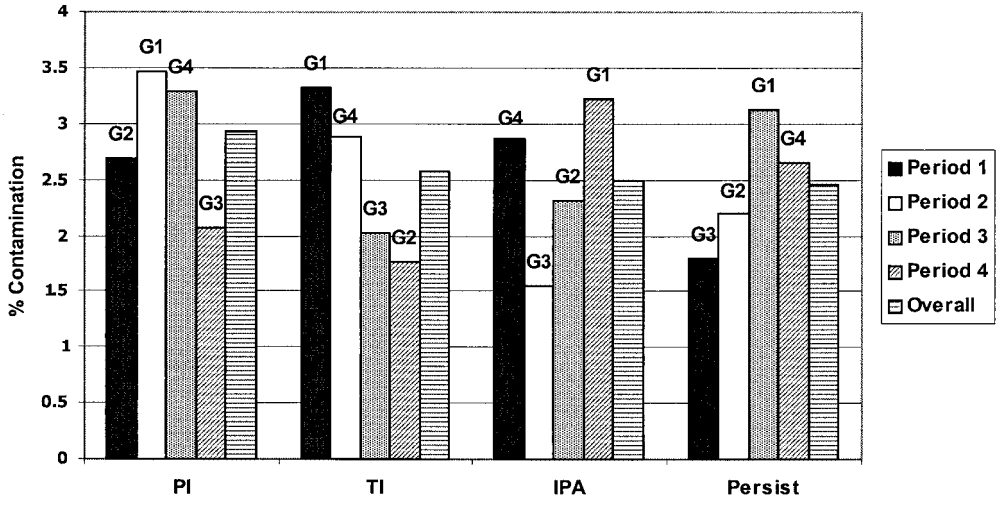

FIG. 1. Contamination rates for each antiseptic during each of the four study periods. The label above each bar indicates the study group with the antiseptic during each period (e.g., "G1" indicates group 1).

products. The calculated contamination rates were 3.15 and 2.51% for PI and the alcohol-containing antiseptics, respectively ($P = 0.006$). The average costs of each alcohol-containing antiseptic per culture were \$0.0492, \$0.525, and \$0.58 for IPA, TI, and Persist, respectively. This analysis determined that the use of an alcohol-containing antiseptic would save this institution \$326,109 (using Persist) to \$332,846 (using IPA) per year even if the magnitude of difference in contamination rates was only 0.64%, as seen in the present study. Looking only at the cost of the antiseptic, the use of IPA would save between \$746.29 and \$6,736.91 per year compared to the use of PI and Persist, respectively.

DISCUSSION

The excess costs and diagnostic difficulties associated with contaminated blood cultures, as well as the personal costs experienced by patients, make efforts to reduce contamination important. Cutaneous antiseptics are a major focus of these efforts. Several antiseptics have been used for this purpose, but relatively few comparisons of the efficacy of these products have been reported. Three studies have directly compared the commercially available prepping agents (10, 18, 20), and four others have compared prepping agents by different methods of application (7, 15) or by unspecified methods of application (6, 16).

Three previous studies (7, 16, 20) found significantly lower rates of contamination with TI than with PI. The results of the present study supported these findings by showing a relative reduction in blood culture contamination of 20% when TI was used during the study compared to the use of PI during the baseline period (RR = 0.80, 95% CI = 0.62 to 1.02, $P = 0.067$). The contamination rate with TI was also lower than that observed with PI during the study (12% relative reduction), but the sample size of this study was not planned to detect a difference this small as statistically significant.

This lack of sufficient power was due to lower-than-expected contamination rates. The rate of contamination with PI in the current study (2.93%) was substantially lower than in two earlier prospective studies, in which PI contamination rates ranged from 3.8 to 6.25% (7, 20). The TI-associated rate of contamination in the current study was about the same or even lower than in the other studies (2.58% compared to 2.4 and 3.74%). This suggests that the similar contamination rates of PI and TI in the current study were largely due to the lower contamination rate with PI, possibly due to improved technique as a result of increased awareness of the importance of minimizing contamination in the setting of a study and implementation of a specific phlebotomy protocol. In two of the three prior studies reporting the superiority of TI (16, 20), there was no standardized phlebotomy technique and no specified minimum interval between the application of antiseptic and performance of the phlebotomy. Without a specific protocol, it is unlikely that sufficient time was always allowed for PI to have maximal activity, thus maximizing any differences between PI and a more rapidly acting antiseptic, such as TI.

Despite the unexpected limitation in statistical power, there was evidence to suggest less contamination with alcohol-based antiseptics. This evidence included the significant decrease in overall contamination rates during the study compared to the baseline period, the significantly lower contamination rate for the combined alcohol-containing antiseptic groups compared to the combined PI groups (baseline period and PI study arm), and the absence of a significant difference between contamination rates when PI was used during the study and baseline periods despite significant differences between the baseline PI contamination rate and the rates observed for IPA and Persist. The apparent benefit of alcohol-containing antiseptics was likely due to their more rapid antimicrobial activity compared to iodophors (4, 5, 13; L. L. Fauerbach, M. J. Schoppman, V. R. Singh, L. S. Netardus, D. L. Pickett, and J. W. Shands, Program Abstr. 31st Intersci. Conf. Antimicrob. Agents Chemother., abstr. 1269, 1991).

The results of the present study are consistent with those of two earlier studies that demonstrated the equivalence of alcohol to iodine-containing antiseptics in preventing contamina-

tion of blood cultures. Lee et al. reported the equivalence of IPA and 2% tincture of iodine in 1967 (6). Subsequently, Shahar et al. (18) documented contamination rates of 4.4 and 3.3% with PI and alcohol, respectively ($P = 0.39$). The ability of that study to detect a significant difference between the two antiseptics was limited by a small sample size.

Recently, a solution of 0.5% chlorhexidine gluconate in 67% isopropyl alcohol was demonstrated to be superior to PI in preventing blood culture contamination (1.4% versus 3.3% contamination, respectively) (7). It is possible that this was due to the alcohol component of the chlorhexidine solution rather than to the chlorhexidine itself since chlorhexidine has not been credited as being a rapidly acting antiseptic in most studies (11, 12). Thus, comparison of the efficacy and cost-effectiveness of this product to other alcohol-containing antiseptic preparations is warranted.

There are several other possible explanations, in addition to insufficient power, for the lack of a significant difference among the four antiseptics noted during the present study. This study was designed to minimize additional responsibilities or activities (such as documentation or labeling) required of healthcare workers in an attempt to maximize participation. Thus, an intent-to-treat analysis was selected such that documentation of the antiseptic used for individual patients was not required. With this type of analysis, noncompliance with use of the study materials would result in a bias toward a lack of difference between PI and the other antiseptics. However, the likelihood of such noncompliance was reduced by moving nonstudy antiseptics to another location and by the grouping strategy. In addition, the estimated compliance with the use of study materials was high. The six units with poor compliance were among those where the smallest number of cultures were obtained and accounted for only 1.7% of cultures included in the analysis. When noncompliant units were excluded from the analysis, there was no change in the results. Thus, noncompliance was unlikely to be responsible for the findings of this study.

The definition of contamination used in two earlier studies was also different from that used in the current study. Unlike the Strand study, the present study required a companion set of cultures that yielded no growth in order to include a culture growing common skin flora as a contaminant in the analysis. Thus, a number of potentially contaminated cultures were excluded. If companion cultures had not been required, a total of 233 (5.96%) of 2,909 emergency department cultures obtained during the baseline period would have been considered contaminated compared to 4.50% for PI and 4.14% for TI during the study ($P = 0.79$). Again, no difference was detected between PI and TI during the study based on this definition.

A potential confounding factor in the current study was the introduction of a 24-hour phlebotomy team into the inpatient non-critical care units at the beginning of the second study period (21). Prior to this, most of the cultures performed in these units had been obtained by resident physicians. The new phlebotomy team performed approximately four to eight sets per day, representing 10.5 to 21% of daily cultures. However, the lack of difference between the results of the first study period and the later periods suggests that any confounding effect that occurred was minimal.

Application of the findings of this study on a national scale could result in a substantial savings for the U.S. healthcare system. An estimate of potential savings was calculated by using data from the Q-Probes program of the College of American Pathologists (14). In 1989, ca. 800 participating healthcare facilities performed nearly 170,000 blood cultures during a 30-day period. If we assume that this period was representative of usual practices at these facilities, roughly two million blood cultures would be performed annually at these facilities. If we assume that these facilities are a representative sample of the ca. 6,000 hospitals in the United States, an estimated 15 million blood cultures would have been performed in the country in that year. If similar trends continue at the present time and the same cost analysis method used in the present study is applied to these data, the use of IPA rather than PI (which is the most commonly used antiseptic for this purpose nationwide) prior to phlebotomy for blood cultures would prevent ca. 96,000 contaminated blood cultures per year, with a resulting savings of $400 million annually. If baseline contamination rates in many of these hospitals are actually higher than the estimates used in this analysis, then even greater cost savings could be achieved.

In conclusion, blood culture contamination rates ranged from 2.46 to 2.93% during this study when povidone-iodine with alcohol (Persist), isopropyl alcohol, tincture of iodine, or povidone-iodine ($P = 0.62$) was used. There was, however, evidence to suggest less contamination with the alcohol-based antiseptics. Given the demonstrated efficacies of these four antiseptics, their relative costs, the greater risk of cutaneous reactions with TI, and the potential to decrease costs by producing more accurate results, IPA may be the optimal antiseptic for percutaneous blood cultures. Future investigations will be needed to directly compare isopropyl alcohol and other alcohol-containing antiseptics with chlorhexidine gluconate in the prevention of blood culture contamination.

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