Infection of cerebrospinal fluid shunts in infants: a study of etiological factors

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The aim of this study was to find reasons for the high incidence of cerebrospinal fluid shunt infections seen in neonates. Four-hundred sixty-six consecutive shunt operations were analyzed retrospectively in 294 children, and 60 children were studied prospectively by quantitative sampling of skin bacteria before surgery and by sampling open wounds, shunt catheters, surgical gloves, and airborne bacteria. In total, 110 strains of coagulase-negative Staphylococcus isolated from the skin of 53 children before surgery were then tested for bacterial adherence.

Retrospectively, the infection rate for infants younger than 6 months old was 15.7% (28 of 178 procedures), compared with 5.6% (16 of 288 procedures) for older children (p = 0.0005). Of all infections, 67% were due to coagulase-negative Staphylococcus. Age was the only major factor influencing the infection rate. Three of the 60 children studied prospectively developed postoperative shunt infections. All were younger than 6 months and all had high skin bacterial densities before surgery. Contamination during surgery was generally low, but correlated with the preoperative skin bacterial density. Strains of coagulase-negative Staphylococcus with high bacterial adherence were more commonly found in neonates than in older children.

High skin bacterial density in neonates before surgery was a risk factor for infection in this study. These results also suggest that there is selection of more virulent strains of coagulase-negative Staphylococcus on the skin of neonates. Prevention of shunt infections in this high-risk group could be facilitated by the reduction of skin bacterial density before surgery using chlorhexidine shampoos and by the elimination of contamination by skin bacteria during surgery using packs soaked in an antiseptic agent to isolate wound edges and glove-changing before handling the shunt.

KEY WORDS · hydrocephalus · shunt infection · bacterial infection · neonate

POSTOPERATIVE infections of cerebrospinal fluid (CSF) shunts occur with disturbing frequency, with approximately a 10% incidence, in most neurosurgical units throughout the world. A much higher incidence of infection in neonates and young children than in older patients has been reported by several authors. However, no satisfactory explanation for this age effect emerged from these studies because they were all based on retrospective data alone. We postulated a difference in the qualitative or quantitative aspects of the resident skin microbial flora as a possible cause for the observed differences in infection rate and attempted to explore this theory by performing a prospective observational study as well as a retrospective analysis of previous shunt infections at this unit.

Clinical Material and Methods

Retrospective Analysis

A total of 294 children who underwent some form of CSF shunt surgery (466 procedures) at Great Ormond Street Hospital between January, 1987, and January, 1990, were included in the study. The names were obtained from operating theater records, and the patient notes were subsequently examined to determine whether a shunt-associated infection followed the operation and to record the infecting organism. A postoperative CSF shunt infection was defined as an episode of clinical symptoms associated with organisms seen on microscopy or grown from culture of the CSF and presenting within 6 months of surgery. The notes of three children were not found and these were therefore excluded from the analysis.

The following additional information was also recorded: patient age at operation, type of procedure, surgeon performing the operation, type of shunt inserted, etiology of hydrocephalus, and duration and time of operation. No routine system of skin cleansing and isolation of wound edges was employed for these retrospective patients, and the method of skin preparation depended on the surgeon's preference. The mean postoperative follow-up period was 28 months (minimum 7 months).
Prospective Observational Study

Thirty consecutive infants under the age of 6 months who underwent primary insertion of ventriculoperitoneal shunts were studied over an 11-month period. The same type of shunt was inserted in a consistent manner for each patient by one of two senior and two junior surgical staff members. Twenty-five of the 30 patients were operated on at elective surgery and five as emergencies performed outside normal working hours. These patients included 17 girls and 13 boys. The mean age at operation was 2 months (range 5 days to 4 months).

Thirty children over the age of 6 months undergoing shunt insertion or revision were studied in the same way and the results were compared with those of the infant group. There were 18 boys and 12 girls, with a mean age of 50 months (range 6 months to 13 years). The mean age of all 60 children studied prospectively was 2 years.

Before the patients in the prospective group were entered into the study, the reasons underlying the research and the nature of the investigative procedures were fully explained to the parents or guardians. The approval of the Standing Committee on Ethical Practice of The Hospital for Sick Children was obtained for each of the investigative techniques and for the subject and control groups to be studied.

In the anesthetic room, sterile 10-sq cm velvet pads, moistened with saline, were applied to the child’s skin at the operative sites after dry-shaving the scalp. Sterile surgical gloves were used throughout this procedure and the pads were then imprinted onto blood-agar plates without delay. Skin preparation consisted of an approximately 2-minute application of povidine iodine followed by chlorhexidine in spirit, which was left to dry by evaporation. Wound edges were covered by swabs soaked in either chlorhexidine or povidine iodine. No prophylactic antibiotics were used in any of the patients.

Open wounds were sampled for bacteria at defined stages of the operation (after initial skin incision, prior to shunt insertion, and prior to closure) using a similar velvet pad technique. The peritoneal end of the shunt catheter was sampled by drawing a moistened velvet pad along the length of its outside surface just before it was inserted into the peritoneal cavity. This pad was then imprinted onto blood agar. The surgeon’s gloves were sampled at wound closure by direct fingertips imprints onto blood-agar plates. Airborne bacteria were sampled with settle plates placed within 150 cm of the operative sites and left open for the period between skin incision and closure. In 10 cases, 250-ml samples of the irrigation fluid used for flushing the shunt system were taken at the end of the operation. This fluid was then passed through a millipore filter, which was then cultured on blood agar.

All plates were then incubated aerobically at 37°C for 48 hours. The resulting colonies were counted and classified according to their morphological appearance and Gram reaction. Oxidase, catalase, and deoxyribo-

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of Procedures</th>
<th>Shunt Infections No.</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>206</td>
<td>20</td>
<td>9.7</td>
</tr>
<tr>
<td>1988</td>
<td>134</td>
<td>15</td>
<td>11.2</td>
</tr>
<tr>
<td>1989</td>
<td>126</td>
<td>11</td>
<td>8.7</td>
</tr>
<tr>
<td>totals</td>
<td>466</td>
<td>46</td>
<td>10</td>
</tr>
</tbody>
</table>

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Statistical Tests

The Mann-Whitney U-test was used to assess differences between means, and the chi-squared test (with Yates’ correction) for differences in proportions, except for small numbers when Fisher’s exact test was used.

Results

Retrospective Analysis

During the 3-year study period, 46 shunt infections resulted from 466 shunt procedures, giving an overall operative infection rate of 10%. The rates for each year are shown in Table 1. None of the differences between these infection rates achieved statistical significance at the p = 0.05 level. The infection rate according to the age of the patient at the time of operation is shown in Fig. 1; this age effect was consistent during the 3 years. The difference in operative infection rates between patients under 6 months old (28 of 178 procedures, 15.7%) and those over 6 months (16 of 288 procedures, 5.6%) was statistically highly significant (chi-squared test: \( \chi^2 = 12.06, 1 \text{ df, } p = 0.0005 \)). The infection rate was not influenced by the type of shunt implanted, duration of the operation, position on the operation list, which surgeon performed the operation, or the etiology of hydrocephalus. Nor was it influenced by CSF cell or protein concentration (which ranged from < 1 to 30,000 red blood cells (RBC) \( \times 10^9/\text{liter} \) and 0.75 to 7.25 gm/liter, respectively). Primary shunt in-
Prospective Data

The rates of operative contamination observed during this study are summarized in Table 2. Based on a comparison of API biochemical identification numbers and antibiotic sensitivity patterns, among 15 cases of strains of coagulase-negative Staphylococcus isolated from the wound, catheter, or surgeons' gloves, 33% (five cases) were presumed to originate from the patients' skin and 13% (two cases) were presumed to come from the air. Of eight strains isolated from the peritoneal catheter prior to insertion, three had characteristics identical to strains previously isolated from the patient. The other organisms (three Microoccus sp, one Corynebacterium, and one coagulase-negative Staphylococcus) were not matched to any others tested.

The mean skin-surface bacterial density of the 15 cases with wound contamination at any stage of the operation (110 organisms/10 sq cm) was significantly higher than in the 26 cases without contamination (58 organisms/10 sq cm, \( p = 0.012 \)). Overall, there were more highly adherent strains of coagulase-negative Staphylococcus from children under 6 months old (14 of 48 procedures) than from those over 6 months (two of 42 procedures, \( p = 0.018 \) by Fisher's exact test).

The settling rates for airborne bacteria during surgery were higher for patients over 6 months old than for patients under 6 months (mean ± standard deviation: 19 ± 17 and 10 ± 6 colonies/hr, respectively). The mean operating time was 39 ± 15 minutes for the younger group and 42 ± 19 minutes for the older group. The difference between these times was not statistically significant. The timing of surgery in the two groups was different, with four of the older children and only one of the younger group having their operations performed outside normal working hours. The difference in the mean air colony counts between the two age groups was not affected when those cases treated outside normal working hours were excluded. The colonies on settle plates were a mixture of Micrococcus, Corynebacterium, and Staphylococci.

Three of 10 250-ml irrigation fluid specimens used during different operations grew organisms after millipore filtration and culture on blood agar. Only one colony was grown from each of the positive specimens and the organisms were Micrococcus sp, coagulase-negative Staphylococci, and Corynebacterium sp.

Three shunt infections occurred after surgery in the 30 infants under 6 months old, an infection rate of 10%; there were no infections among the older children, so this gave an overall infection rate of 5% in the 60 patients studied. The infecting organisms in the three cases of primary shunt infection were: Enterococcus faecalis type 2, Staphylococcus epidermidis, and Corynebacterium sp. All three patients with shunt infection had a high density of skin bacteria preoperatively.

Despite the small number of infections in this series, the association between shunt infection and skin bacterial density was statistically significant: when compared to the mean for all of the children studied who did not develop infections (75 organisms/10 sq cm), the mean for these three patients (131 organisms/10 sq cm) was significantly higher (Mann-Whitney \( U \)-test, \( p = 0.04 \)). The Enterococcus species causing the first infection had an identical API number and antibiotic sensitivity pattern to an Enterococcus species found on the skin of the affected patient in great quantity before operation. This suggests that the infection resulted from wound contamination by skin bacteria during operation. The S. epidermidis and Corynebacterium sp isolated from the other two infected cases could not be matched with strains from the patient's skin or from any other sample site.
Discussion

Effect of Age

The results from the retrospective analysis of shunt procedures over the past 3 years confirmed an age-dependent effect on the operative shunt infection rate. Children in the 1- to 6-month age range have a significantly higher chance of developing infection/colonization of their shunt than those older than 6 months (p = 0.0005). This period of increased susceptibility to shunt infections has previously been thought to be due to a relative deficiency of the immune response against bacteria.41

The level of maternal immunoglobulin G (IgG) decreases rapidly during the 1st year of life and there is a period (2 to 6 months) when infant IgG levels are less than 50% of normal adult levels. Complement activity in neonates is much lower than in adults and the white blood cell capacity for dealing with infecting organisms is less efficient. Renier, et al.,41 believed that these factors and the period of lowered IgG in children between 2 and 6 months of age were responsible for the high incidence of shunt infection. However, we have seen cases of shunt infection occurring in children who had high titers of antibody specific to the infecting strain of coagulase-negative Staphylococcus, and there seems to be no evidence that such specific or nonspecific immunoglobulins are protective against shunt colonization. Neither can complement activity, opsonization, or neutrophil function be expected to play a protective role, except perhaps in external infections at the incision sites. Once organisms have entered the ventricular system or the shunt system (both immunologically privileged areas), they are safe from antibodies, opsonins, and neutrophils.

The gradual build-up of specific antibodies during the first 3 to 4 years of life does not provide a satisfactory explanation for the rather sudden fall in shunt infection rate 6 to 12 months after birth.6 The relatively low level of serum immunoglobulin M antibodies and complement activity is not a causative factor either, as the incidence of wound infections following general surgical operations in children of this age is similar to or less than that seen in adults.13,33

Skin and Its Resident Bacterial Flora

An alternative explanation for the increased CSF shunt infection rate in young infants comes from the age-related changes in the skin and its resident bacterial flora. Leyden and colleagues12 carried out a quantitative study of the levels of resident aerobic and anaerobic bacteria on the faces of volunteers of different age. They found the density of aerobic cocci and Propionibacterium acnes was higher in infancy than in early childhood. In their study, they also found a higher bacterial density on the head than on the trunk or limbs. Similar results were obtained by Selwyn and Ellis45 in their study of skin bacteria and wound contamination. The bacterial colonization of neonates occurs very rapidly after birth as a result of passage

I. K. Pople, R. Bayston, and R. D. Hayward through the birth canal and subsequent exposure to the local environment.6 Skin Staphylococci are present at birth in small numbers, but their density increases steeply during the first 48 hours to reach a plateau at the end of this period.43 Corynebacteria follow a similar pattern of skin colonization, which may be influenced by environmental factors or antibiotics.

In premature neonates, the pattern of surface colonization with coagulase-negative Staphylococci was studied by D'Angio, et al.19 They sampled the axilla, ear, nasopharynx, and rectum in 18 premature infants in the first 4 weeks of life. During this period, the percentage of infants with S. epidermidis as the only surface coagulase-negative Staphylococcus rose from 11% to 100%. During the 1st week of life, the predominance of a single biotype of S. epidermidis rose from none to 89%, multiple antibiotic resistance rose from 32% to 82% of isolates, and the prevalence of a positive Christensen's test increased from 68% to 95%. Although the number of children studied was small, the authors concluded that premature newborns in the intensive care nursery environment became selectively colonized by a single Christensen-positive, multiresistant strain and that this may have been a risk factor for subsequent infection with this strain. Three of their premature babies suffered septic illnesses as a result of colonization of intravascular catheters by S. epidermidis. The infecting organism was in its characteristics indistinguishable from the resident skin organism in two of the three cases. In addition to age-related changes in the density of surface bacteria reported by previous workers, D'Angio, et al., demonstrated a change in the characteristics of the resident bacterial flora with age. The results of our study confirm that qualitative changes in the resident coagulase-negative Staphylococci do occur over the first few months of life.

There has been much confusion regarding bacterial adhesion and slime production, and many have regarded these terms, and the phenomena they describe, as interchangeable. This situation has not been helped by the promotion of Christensen's test as an indicator of slime production when it is really a test for adhesion. Only recently has a test been devised that makes it possible to separate the two phenomena.11 Data from other sources indicate that colonization of implants takes place in two phases, adhesion being the first and prerequisite event.18 This is dependent on factors such as charge, hydrophobicity, and van der Waals' forces. If adhesion occurs, then some strains go on to produce slime in Phase 2, where microcolonies develop. Colonization is therefore not slime-dependent, but slime production leads to larger aggregates in the shunt and probably greater difficulty in eradication of colonization with antimicrobial agents. We are currently testing the organisms isolated during this study for slime production, and the results will be published elsewhere.

Skin Bacterial Density

There was a statistically significant association between preoperative skin bacterial density and the
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amount of bacterial wound contamination during the operation. Raahave, et al., found a highly significant correlation between the densities of bacteria isolated from open operative wounds and subsequent wound sepsis. Bayston and Lari found that the organisms isolated from the wounds during operation were frequently indistinguishable from the patients' skin organisms and were usually the same ones that caused subsequent shunt infection. In the current study, several infants had high skin bacterial densities before surgery and all three patients with shunt infections were in this group. One of the three had been receiving spiramycin for toxoplasmosis for 3 weeks prior to surgery. Her skin had become selectively colonized with a high density of *E. faecalis*. From this evidence it appears that a high skin bacterial density before surgery was a major etiological factor in at least one of the three cases of postoperative shunt infection in this study.

There are two possible ways for high bacterial skin density to influence the shunt colonization rate: 1) the frequency of wound contamination during insertion of the device may be increased, and 2) the inoculum size may be larger when contamination does occur. In the presence of implanted foreign material, the number of organisms necessary to produce an infection is much reduced. However, the colonizing ability of some organisms, such as *Staphylococcus aureus*, is still partly inoculum-dependent in the presence of foreign material. Early experiments in our laboratories using Bayston's later model for shunt colonization have shown that the colonization dose for some strains of *S. epidermidis* obtained from previous cases of shunt infection is very small and can vary by more than $10^4$ colony-forming units/ml.

**Wound Contamination and Its Prevention**

This study showed that operative contamination during elective shunt surgery in infants still occurs, despite measures to isolate skin and wound edges using swabs soaked with povidone iodine. The origin of the contaminating bacteria from the patients' skin was shown in only a few cases. This is probably due to the nature of the skin sampling, where only the predominant strains, rather than all strains, are selected.

There are several measures that could reduce this amount of wound contamination and thereby possibly reduce the incidence of postoperative shunt infection. The first is to reduce skin bacterial density before the child reaches the anesthetic room by improving antibacterial skin preparation. Chlorhexidine shampooing before surgery has been shown to be effective in reducing skin bacterial density and intraoperative wound contamination from skin organisms during neurosurgical operations. Newsom and Rowland showed that a chlorhexidine scrub of the whole body before cardiothoracic operations had a significant effect on skin bacterial density which lasted at least 3 days after surgery. No effect on the operative infection rate was seen, as was the case with a randomized trial of preoperative chlorhexidine baths in patients undergoing vascular surgery. However, in both of these studies the series was too small to attempt to detect statistically significant, yet clinically important, changes in the infection rate. Unfortunately, in neither case was wound bacterial density studied.

Attempts to sterilize the skin by penetrating the pilosebaceous units have been made using a combination of an anionic detergent with Fabry's tincture (3% salicylic acid and 1% liquefied phenol containing 50% isopropanol) with some success. However, the agents that enhance penetration of pilosebaceous units (salicylic acid and the detergent) are potentially toxic in themselves and may lead to greater systemic absorption of the antiseptic. This happened when hexachlorophene was combined with a detergent and marketed as "Phisohex." When this was used as a scalp preparation prior to shunt surgery, bacteria remained absent from the hair for several hours. However, due to reports of absorption of hexachlorophene into the circulation and consequent toxic effects, its use is no longer recommended. In some premature infants given repeated skin cleansing with iodine-based antiseptic (daily for 2 to 3 weeks), enough iodine may be absorbed to produce clinical hypothyroidism. Currently, chlorhexidine appears to be a better choice than iodine for skin preparation in view of its very low incidence of sensitivity reactions and lack of any important systemic effects.

The surgical technique for CSF shunt insertion varies according to the type of shunt being placed and the routines adopted by the individual surgeon. At Great Ormond Street, there appeared to be little difference between the techniques employed by the two surgeons; this was reflected in a similar infection rate for both surgeons. Less experienced surgeons, such as junior registrars, can achieve equally low infection rates providing they are taught properly. Incorrect surgical technique, failure to appreciate the importance of skin isolation, or lapses in asepsis may be partly responsible for a substantial proportion of CSF shunt infections, and some surgeons have higher shunt infection rates than others. George, et al., found a 25-fold variance in infection rate among surgeons, which related to individual experience or technique, and McCarthy and Wenzel concluded that poor operative technique was a risk factor for CSF shunt infections because one surgeon was responsible for 50% of their infections. However, their conclusions were based on a relatively small number of infections (10 cases), and the observed differences between surgeons failed to achieve statistical significance ($p = 0.07$).

A study by Wooster, et al., of vascular graft contamination during reconstructive vascular surgery in 77 patients found a 56% rate of contamination when standard techniques were used, compared to 35% when the surgeon changed gloves prior to handling the graft. In view of the recovery of organisms from 35% of surgical gloves sampled at the conclusion of the operation in the current study, the application of fresh gloves just before the CSF shunt is inserted is recommended.

The amount of wound contamination during this
study was much lower than that recorded by Bayston and Larj, who were sampling wounds that were not isolated from the skin edges with antiseptic packs. The sampling techniques were similar, yet they isolated much greater numbers of organisms from each contaminated wound. In a study of the effect of using noxifyx-soaked wound-edge packs versus saline-soaked packs on the shunt infection rate, Bayston found no difference between the two. The influence of these packs has also been studied by Tabara and Forrest, who used historical controls to compare the effect of gentamicin-soaked packs with noxifyx-soaked packs and none at all. Only three of 318 shunt procedures resulted in colonization in the gentamicin group, compared with eight of 128 in the noxifyx group and nine of 206 in the group with no wound-edge pack. The authors stressed the importance of isolation of the wound edges and, even though the observed differences in their study do not reach statistical significance, it is possible that the povidine iodine packs currently being used at Great Ormond Street are contributing to the comparatively low rate of wound contamination found in our study. Chlorhexidine-soaked packs may be better, as suggested by Fitzgerald and Connolly, who achieved a low infection rate (2.4%) in 82 shunt operations using these packs. Also, in an animal study, Rodeheaver, et al., have shown that the bactericidal activity of iodine in artificially contaminated wounds is low.

The amount of contamination of irrigation fluid in our study was negligible compared with the results of Strömblad, et al., who found heavy counts in up to 50% of their samples after the fluid had been exposed to theater air during the operation. Considerable importance has previously been given to airborne bacteria as a source of implant infection, particularly in artificial joint surgery. However, Renier, et al., reported an early postoperative CSF shunt infection rate of 8% in their series of 1174 operations, despite the regular use of a surgical isolator. In our study, the airborne bacterial settling rates were higher for children older than 6 months than for babies during their shunt operations, which contrasts with their respective shunt infection rates.

The Role of Antibiotic Prophylaxis in Shunt Surgery

Antibiotic-impregnated silicone has been successfully developed and could provide short-term protection against the colonization of shunt catheters by contaminating bacteria during shunt insertion. It has been suggested that children under the age of 6 months undergoing shunt surgery should be targeted for antibiotic prophylaxis in view of their much higher infection rate. However, the evidence to support the routine use of antibiotics in shunt surgery is weak (Table 3).

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>Antibiotic Employed</th>
<th>No. of Cases</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weiss &amp; Raskind, 1970</td>
<td>oxacillin</td>
<td>30 alt</td>
<td>no benefit</td>
</tr>
<tr>
<td>Bayston, 1975</td>
<td>gentamicin cloxacin</td>
<td>20 rand</td>
<td>no benefit</td>
</tr>
<tr>
<td>Lambert, et al., 1984</td>
<td>gentamicin</td>
<td>68 N/S</td>
<td>20% to 4% NS</td>
</tr>
<tr>
<td>Wang, et al., 1984</td>
<td>trimethoprim &amp; sulfamethoxazole</td>
<td>120 rand</td>
<td>no benefit</td>
</tr>
<tr>
<td>Blomstedt, 1985</td>
<td>trimethoprim &amp; sulfamethoxazole</td>
<td>122 rand</td>
<td>23% to 6% (p &lt; 0.01)</td>
</tr>
<tr>
<td>Schmidt, et al., 1985</td>
<td>methicillin</td>
<td>152 rand</td>
<td>no benefit</td>
</tr>
<tr>
<td>Djindjian, et al., 1986</td>
<td>oxacillin</td>
<td>60 rand</td>
<td>20% to 3% (p &lt; 0.05)</td>
</tr>
<tr>
<td>Blum, et al., 1989</td>
<td>cefazodone</td>
<td>100 rand</td>
<td>14% to 6% NS</td>
</tr>
<tr>
<td>Bayston, et al., 1990</td>
<td>vancomycin</td>
<td>158 rand</td>
<td>6% to 2% NS</td>
</tr>
</tbody>
</table>

*Abbreviations: alt = alternate cases (not randomized); rand = randomized trial; NS = not significant.

The standard of surgical technique is difficult if not impossible to assess accurately. The constant reminder to the surgeon of the problem of CSF shunt infections provided by the researcher taking swabs in the operating theater probably reduces the amount of inadvertent wound contamination by the surgeon and other staff involved in the procedure. By simply looking closely at the problem of shunt infections in children, the frequency of the problem diminishes as a result of greater awareness: a phenomenon labeled the "Hawthorne effect." The etiology of CSF shunt infections in infants is clearly multifactorial and their prevention currently requires a combination of scrupulous surgical technique and measures to reduce the resident skin bacterial population before surgery. Specific recommendations would include the surgeon changing gloves before handling the shunt, the isolation of wound edges with antiseptic-soaked packs during surgery, and the use of two separate chlorhexidine shampoos 2 to 24 hours before operation.

The results of this study support the feeling among many surgeons that some CSF shunt infections in babies younger than 6 months are inevitable unless extra preventive measures are taken, as suggested above. This can be explained by both quantitative and qualitative differences in the skin bacterial flora of these children compared to older patients.

Acknowledgments

We thank Mr. E. Datnow and family for their generous financial support and Messrs. R. Walsh, N. Grant, and W. Harkness for their assistance and encouragement. We would also like to thank the Wade Charitable Trust for their help with some of the incidental laboratory expenses.

References

1. Agarwal DS: Subcutaneous staphylococcal infection in...
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randomized trial in 152 hydrocephalic patients. Neurosurgery 17:1-5, 1985

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