A Collaborative Study of Infective Endocarditis in the 1970s

Emphasis on Infections in Patients Who Have Undergone Cardiovascular Surgery

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SUMMARY Twenty-six major cardiovascular centers participated in a cooperative study of all cases of infective endocarditis occurring during a single calendar year to obtain an overview of infective endocarditis. The study was designed to learn which patients appear to be at highest risk to develop this infection after palliative or reparative cardiovascular surgery.

Of 278 patients developing infective endocarditis during the year at these medical centers, 63 (23%) had had previous cardiovascular surgery and 215 had not. Seventy percent of the 278 patients had recognized congenital or acquired heart disease before developing the infection. Rheumatic heart disease accounted for over half of the patients with underlying structural heart disease.

A majority (55%) of the 63 patients who had been operated on before developing endocarditis had prosthetic valves inserted. Of those who did not require prosthetic valves, the majority had congenital heart disease with systemic artery-to-pulmonary artery shunts.

Although these data were obtained from a selected group of patients, they confirm a significant risk of endocarditis in patients with prosthetic valves and suggest that in postoperative patients with non-valvular congenital heart disease, the highest risk appears to be in cyanotic patients with palliative pulmonary artery-to-systemic artery shunts.

ALTHOUGH CERTAIN TRENDS are evident, some features of the epidemiology and the prevention of infective endocarditis are unexplained, especially in patients who have undergone cardiovascular surgery. Patients with prosthetic heart valves appear to be at increased risk of developing infective endocarditis in the months and years after cardiac surgery. However, less is known about the risk of developing endocarditis for other patients who have undergone cardiac surgery, such as those with congenital heart disease who have had reparative or palliative surgery not requiring a prosthetic valve. For example, infective endocarditis in patients who have undergone successful closure of a ventricular septal defect appears to be uncommon. In other patients, such as those who have required redirection of systemic and pulmonary venous return because of transposition of the great vessels, the risk of developing infective endocarditis is not known.

Because of the sporadic occurrence of infective endocarditis in postoperative patients in individual medical centers and because of ethical constraints, carefully controlled clinical trials to justify the need for antibiotic prophylaxis to prevent infective endocarditis in postoperative cardiac patients after dental and certain surgical procedures have not been carried out. Medical and dental practitioners caring for these patients depend primarily on clinical observations on studies with induced infective endocarditis in experimental animal models and empiricism.

The primary purpose of this collaborative effort was to determine, if possible, which postoperative patients, including not only those requiring prosthetic heart valves, but also those with repaired or palliated congenital heart disease, remain at risk to develop infective endocarditis after cardiovascular surgery. In addition, the study provides an overview of the spectrum of infective endocarditis in patients with and without underlying heart disease seen in large North American medical centers in the 1970s. We undertook this retrospective pilot study realizing that it could not replace a carefully designed prospective study, since the factors necessary for calculation of the actual risk of developing endocarditis in specific groups of patients would not be available. Nonetheless, a collaborative survey could provide otherwise unobtainable information which could be useful not only in guiding physicians and dentists, but especially by providing a basis for a more definitive prospective study.

This paper describes the findings from these analyses, emphasizing data from patients who had previously undergone a cardiovascular surgical procedure — either reparative or palliative — before they developed infective endocarditis.
Materials and Methods

In 1974 an ad hoc committee of the Council on Cardiovascular Disease in the Young of the American Heart Association designed this cooperative study. Thirty major North American cardiovascular centers caring for a wide variety of cardiac patients were asked to participate. The cooperation of a specific collaborating physician at each institution was sought and this physician was asked to review carefully the medical records of all patients cared for during the year 1972 and coded out as having had infective endocarditis. Records were requested and reviewed regardless of the age of the patient, whether the patient had had cardiovascular surgery or whether underlying heart disease was present before the infection. This provided in the absence of the number of patients operated on for any specific cardiac lesion—a definition of the patient population with infective endocarditis, especially those who had developed the infection at some time after cardiovascular surgery. The medical record of each patient with endocarditis was reviewed and a questionnaire was completed by the cooperating physician at each center.

Confirmation of the diagnosis of infective endocarditis was based on the review of the hospital record and upon the answers to several questions on the original questionnaire, including: Was the patient initially referred to your institution because of bacterial endocarditis? (i.e., was the diagnosis made or suspected before referral?) Did endocarditis cause detectable cardiac damage? If yes, specify. Did endocarditis necessitate cardiovascular surgery? How was the diagnosis of bacterial endocarditis made for this episode (clinical diagnosis, positive blood culture or autopsy)? If diagnosis was culture proven, list organism(s) recovered from: blood, valve or endocardium.

List site(s) of vegetations: suspected, proven, site unknown.

The physician reviewing the hospital chart was also given the option to question the diagnosis and eliminate the record. When the completed questionnaires were returned from each participating center, we carefully reviewed each questionnaire. Cases for which the diagnosis seemed unlikely were eliminated from further evaluation. The data were subsequently programmed for computer analysis.

Results

Questionnaires were returned from 26* of the 30 medical centers. Most of these cardiovascular centers care for both adult and pediatric patients; nine care only for children. Data from 278 patients diagnosed with endocarditis after primary chart review at each institution and after review of the data submitted by each participating physician are included in this analysis. There were a total of 174 (63%) males and 104 (37%) females. One hundred fifty-six (56%) of the

*University of Alabama Hospital; University of California Medical Center, Los Angeles; University of California Medical Center, San Francisco; Case-Western Reserve University Hospital; Children’s Hospital of Los Angeles; Children’s Hospital Medical Center (Boston); Children’s Memorial Hospital (Chicago); Children’s Hospital (Philadelphia); Cincinnati Children’s Hospital; Columbia-Presbyterian Medical Center (New York); Duke University Medical Center; University of Florida Hospital; University of Indiana Hospital; University of Kansas Hospital; Mayo Clinic; University of Miami Hospital; University of Minnesota Hospitals; New York Hospital (Cornell); University of Rochester (NY) Hospitals; Hospital for Sick Children (Toronto); Stanford University Medical Center; St. Louis Children’s Hospital; Texas Children’s Hospital; Vanderbilt University Hospital; University of Washington Hospital; Washington (D.C.) Children’s Hospital.
278 patients had been followed at the reporting medical center before the onset of infective endocarditis.

Sixty-three (23%) of the 278 patients had previously undergone cardiovascular surgery before developing infective endocarditis (fig. 1). Thirty-four (54%) of these 63 required placement of prosthetic heart valves before onset of the infection. The remaining 215 (77%) of the 278 patients had not been operated on because of heart disease. Of these 215 unoperated patients, 129 (60%) were recognized by their physicians as having underlying structural heart disease before developing endocarditis; 86 were not thought to have preexisting heart disease. Thus, 192 (69%) of the patients in this report had recognized congenital or acquired heart disease before they developed endocarditis.

The mean age of the 63 postoperative patients was 38.4 years (range 6 months–83 years) (fig. 1). For the 129 patients with underlying heart disease who had not undergone cardiovascular surgery the mean age was 44.5 years (range 1–87 years), and for the 86 unoperated patients without underlying heart disease the mean age was 43.3 years (range 2–86 years).

The distribution of the 271 patients for whom the ages at the onset of infective endocarditis were known is shown in figure 2. There appear to be two age-related peaks for both the total number of patients (total height of each bar) and for the 63 patients who had had cardiac surgery before developing endocarditis.

The diagnosis of infective endocarditis was a clinical diagnosis for nine (14%) of the 63 previously operated on and for 21 (10%) of the 215 patients who did not have surgery before developing endocarditis. Positive blood cultures were obtained from 86% and 88%, respectively, of the patients in the two groups. Endocarditis was an unexpected autopsy finding in less than 3% of the 278 cases.

Forty-one percent (79) of the 192 patients (63 operated and 129 unoperated) with underlying heart disease were thought to have had rheumatic valvular heart disease; 26% (50 patients) had congenital valve deformities, primarily of the aortic valve (fig. 3). The three other common congenital defects in these 192 patients were ventricular septal defect (6%), tetralogy of Fallot (6%) and transposition of the great vessels (5%).

Figure 4 shows the distribution of the original underlying heart disease in only those 63 patients who had undergone cardiovascular surgery before developing infective endocarditis. Thirty-nine of the patients (63%) had either congenital or acquired valvular heart disease. Of those patients with other forms (excluding those who had required prosthetic valves) of congenital heart disease, the majority (15 of 23) were patients with systemic artery-to-pulmonary artery...
shunts (table 1). Other congenital lesions were found only infrequently in the group with postoperative infective endocarditis. In the patients reported by this retrospective study there were few with cyanotic lesions who had undergone reparative rather than palliative surgery. None developed infective endocarditis after coronary artery bypass surgery.

Of the 278 patients, information was available from 276 hospital records defining the ordinal position of the reported episode of infective endocarditis. The attack reported in this analysis represented the initial attack of infective endocarditis in over 90% of the patients (table 2). Of the 63 postoperative patients 90% (57) of the infections were initial attacks and six represented repeat attacks. Three of the six postoperative patients with recurrent attacks were patients with rheumatic heart disease and three were patients with congenital heart disease (tetralogy of Fallot, transposition of the great vessels and tricuspid atresia). The distribution of patients in each category (i.e., first, second and third attack) was similar regardless of whether they had previous cardiac surgery.

Data were available from the records of 267 patients regarding the interval from the onset of symptoms to establishment of the diagnosis (fig. 5). For 200 of the 267 patients (75%), the diagnosis was made within 1 month after the onset of symptoms. As shown in the hatched areas of figure 5, this was also true for the 63 postoperative cases.

Approximately one-third of the 63 cases of infective endocarditis in the postoperative patients occurred more than 5 years after cardiovascular surgery, 37% occurred within 1–5 years after surgery and the remaining patients developed the infection within 1 year of the procedure. Of the 63 patients developing infective endocarditis after cardiovascular surgery, most attacks occurred late (table 3), which we have defined as endocarditis occurring more than 3 months after cardiovascular surgery. Twenty-seven (79%) of the 34 patients who developed prosthetic valve endocarditis (PVE) were late cases; none of the 23 postoperative patients who did not require a prosthetic valve developed the infection earlier than 3 months after surgery. Late endocarditis occurred in four of the six patients who had cardiac surgery for other indications (e.g., placement of transvenous cardiac pacemakers or repair of atrial perforation at catheterization). Nine (seven with prosthetic valves and two requiring surgery for other indications) of the 63 cases of postoperative infective endocarditis occurred in the first 3 months after surgery.

The microorganisms recovered from those patients

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**Table 1. Patients with Congenital Heart Disease Who Developed Infective Endocarditis After Cardiovascular Surgery**

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tetralogy of Fallot with shunt</td>
<td>6</td>
</tr>
<tr>
<td>Transposition of great vessels, pulmonary stenosis with shunt</td>
<td>6 (65%)</td>
</tr>
<tr>
<td>Tricuspid atresia with shunt</td>
<td>2</td>
</tr>
<tr>
<td>Hypoplastic right heart with shunt</td>
<td>1</td>
</tr>
<tr>
<td>Tetralogy of Fallot repaired</td>
<td>1</td>
</tr>
<tr>
<td>Transposition of great vessels with ventricular septal defect, repaired</td>
<td>1</td>
</tr>
<tr>
<td>Ventricular septal defect, repaired</td>
<td>1</td>
</tr>
<tr>
<td>Aortic valvotomy</td>
<td>2</td>
</tr>
<tr>
<td>Subaortic stenosis, relieved</td>
<td>2</td>
</tr>
<tr>
<td>Coarctation of aorta, repaired</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>23</td>
</tr>
</tbody>
</table>

*Excluding patients with prosthetic valves.
with infective endocarditis who had not previously undergone cardiac surgery are shown in table 4. Organisms recovered from that subgroup with underlying heart disease who had not had surgery are compared with the unoperated patients who did not have underlying heart disease before developing the infection. Streptococci were commonly recovered from both groups of patients, accounting for two-thirds of the organisms in the former group and one-third in the latter (in each group α-hemolytic organisms, not group D — were most frequently recovered). In both groups of patients Staphylococcus aureus was the most common species of staphylococci recovered, accounting for 63% of the staphylococci from those with underlying heart disease and 85% of the staphylococci from those without underlying heart disease. Various gram-negative organisms (e.g., E. Coli, Klebsiella, several species of Hemophilus) were recovered with almost equal frequency from both groups. An equal percentage of patients in each group had sterile blood cultures, 17 of 129 (13%) and nine of 86 (10%), respectively.

Figure 6 compares the bacteriologic data from the 34 patients with PVE with the 23 postoperative patients with congenital heart disease not requiring prosthetic valves. The six patients (table 3) who had other cardiac surgical procedures are not included in this figure. As in the unoperated patients, staphylococci and streptococci were the most commonly recovered microorganisms. Although streptococcal strains were recovered from three of the early cases of PVE, the significance is difficult to determine, since only seven patients were involved. There were twice as many recoveries of Staphylococcus epidermidis (six) as Staphylococcus aureus (three) in the late cases of PVE. Only Staphylococcus aureus (three patients) was isolated from the late cases of endocarditis in postoperative patients with congenital heart disease without prosthetic valves. Two (approximately 7%) of the late cases of prosthetic valve endocarditis had no bacteria recovered from blood cultures, compared with about one-fourth (six patients) of the late cases of postoperative patients with other forms of congenital heart disease not requiring a prosthetic valve.

The mortality data from the patients reported in this study are shown in table 5. The overall mortality for the entire group was 26% (73 deaths occurring from 1972 to the completion of the questionnaires in 1974). The status of eight patients was unknown. Fifty (68%) of these 73 deaths were felt to be related to infective endocarditis. The highest mortality rate was in

| Table 2. Ordinal Position of Current Episode of Infective Endocarditis |
|------------------|------------------|------------------|
| Number of previous episodes | 276 Patients | Patients with previous cardiac surgery (63) | No previous cardiac surgery (213) |
| Number | % of 276 | Number | % of 63 | Number | % of 213 |
| No previous episodes | 250 | 90.6 | 57 | 90.5 | 193 | 90.6 |
| One previous episode | 12 | 4.3 | 3 | 4.7 | 9 | 4.2 |
| Two previous episodes | 12 | 4.3 | 2 | 3.2 | 10 | 4.7 |
| Three or more previous episodes | 2 | 0.8 | 1 | 1.6 | 1 | 0.5 |
| Totals | 276 | 100 | 63 | 100 | 213 | 100 |

*Data available for 276 of the 278 patients.

| Table 3. Patients Who Developed Endocarditis After Cardiovascular Surgery (n = 63) |
|------------------|------------------|------------------|
| Type of cardiac surgery | Early* | Late† |
| Prosthetic valve | (34) | 7 | 27 |
| Congenital heart disease | (23) | 0 | 23 |
| Other (e.g., transvenous pacemakers) | (6) | 2 | 4 |
| Totals | 63 | 9 (14%) | 54 (86%) |

*Endocarditis within 90 days of cardiovascular surgery.
†Endocarditis later than 90 days after cardiovascular surgery.

| Table 4. Microorganisms Recovered from Blood Cultures of 215 Unoperated Patients with Infective Endocarditis* |
|------------------|------------------|------------------|
| Underlying heart disease (129†) | No underlying heart disease (86‡) |
| Staphylococci | | |
| S. aureus | 12 | 29 |
| S. epidermidis | 5 | 4 |
| Not specified | 2 | 1 |
| Streptococci | 80 | 26 |
| Alpha streptococci | 69 | 14 |
| Enterococci | 6 | 8 |
| Gamma streptococci | 3 | 1 |
| β-hemolytic Streptococci | 2 | 3 |
| Streptococcus pneumoniae | 3 | 3 |
| Gram negative bacteria | 14 | 10 |
| Fungi | | |
| Candida species | 5 | 4 |
| Aspergillus | — | 1 |
| Total | 121 | 78 |

*Includes only those patients who did not undergo cardiovascular surgery before developing endocarditis.
†Two organisms recovered from nine patients.
‡Two organisms recovered from one patient.
patients without underlying heart disease before developing infective endocarditis; 31 of these patients (36%) were known to be dead 2 years after their infection and 81% (25) of the deaths in this group of patients were related to infective endocarditis. Both overall mortality (21%) and percent of deaths related to endocarditis (55%) were lowest for these 129 patients who had recognized heart disease before developing the infection, but had not undergone cardiovascular surgery. Of the 10 deaths related to infective endocarditis in the operated group, eight were patients with prosthetic valve endocarditis and only one was a patient who had been operated on for cyanotic congenital heart disease; the remaining patient required placement of a transvenous pacemaker.

We attempted to identify events such as dental or surgical procedures that might have been related to the onset of infective endocarditis in the 63 patients who had undergone cardiovascular surgery. The original questionnaire requested information regarding dental or surgical procedures temporally related to the onset of the infection, as well as whether antibiotic prophylaxis had been given. If antibiotic prophylaxis had been given, a judgment was requested as to whether the dose was adequate, based upon available recommendations during 1972–1974.\textsuperscript{12} Evaluation of the questionnaires suggested possible associated or predisposing events for 23 (36.5%) of the 63 postoperative patients (table 6); approximately half of these were thought to be dental-related.

In about one-fourth of these 23 instances the reviewing physician evaluated the event as a true prophylaxis failure (i.e., from the hospital chart it was thought that adequate antibiotic prophylaxis had been given before and after the procedure, but infective endocarditis developed anyway). Most of these were also patients requiring dental procedures.

Twenty-three patients (8%) of the 278 patients reported were identified as narcotic addicts. Their mean age was 28.8 years (range 15–56 years). Only one of these 23 was identified as having underlying heart disease before developing endocarditis. \textit{Staphylococcus aureus} was recovered from approximately half of the narcotics addicts who developed endocarditis. Candida species comprised

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure6.png}
\caption{Microorganisms recovered from early- and late-occurring cases of prosthetic valve endocarditis compared with those recovered from postoperative patients with other forms of congenital heart disease who did not require a prosthetic valve (see text).}
\end{figure}

\begin{table}
\centering
\caption{Mortality Data of 278 Patients with Infective Endocarditis (IE)}
\begin{tabular}{|c|c|c|c|c|}
\hline
 & Recognized heart disease before endocarditis (129) & Cardiac surgery before endocarditis (63) & No heart disease recognized before endocarditis (86) \\
& Number & (\% of 129) & Number & (\% of 63) & Number & (\% of 86) \\
\hline
Status unknown & 4 & (3\%) & - & - & 4 & (5\%) \\
Alive & 98 & (76\%) & 48 & (76\%) & 51 & (59\%) \\
Dead & 27 & (21\%) & 15 & (24\%) & 31 & (36\%) \\
(Death related to IE) & 15 & (15/27 = 55\%) & 10 & (10/15 = 66\%) & 25 & (25/31 = 81\%) \\
Totals & 129 & (100\%) & 63 & (100\%) & 86 & (100\%) \\
\hline
\end{tabular}
\end{table}
slightly less than 25% of the responsible microorganisms recovered from this group of patients; enterococci also accounted for less than 25% of the recovered organisms.

**Discussion**

This collaborative study was stimulated by discussions of the 1972 American Heart Association recommendations for antibiotic prophylaxis for prevention of bacterial endocarditis. It became clear that little is known about the risk of developing infective endocarditis in the months and years after reparative or palliative surgery for many of the more common forms of congenital heart disease, especially those which have been approached by innovative surgical techniques in the past 10–15 years. One recent evaluation of specific congenital cardiac defects indicated that the risk of infective endocarditis is reduced after repair of a ventricular septal defect, but is increased after valvotomy for congenital aortic stenosis, emphasizing the need for additional data. The American Heart Association recommendations have indicated that, with few exceptions, patients remain at risk to develop infective endocarditis in the years after cardiovascular surgery, just as they did before surgery. Few data justify this approach, although most clinicians follow this practice.

Although limitations of a retrospective multicenter study were recognized, this pilot study was chosen as an initial approach for two reasons: First, no single medical center would be likely to see a sufficient number of cases of infective endocarditis in each category to draw conclusions. Second, even if a single center was able to gather a large group of patients with infective endocarditis, the cases would probably span several decades and might not accurately reflect current trends.

The primary purpose of this study was to collect data about postoperative endocarditis. Because the protocol allowed collection of information about endocarditis in noncardiac and nonsurgical patients, we have included some of these findings, as they provide data about the spectrum of patients developing endocarditis in North America in the 1970s.

Because of the methods used to collect information and the selection of medical centers that participated, there may be limitations in our conclusions. The selection of several children’s hospitals obviously influenced the age sample as well as the spectrum of cardiovascular disease reported. Also, the exact risk of developing endocarditis after surgery for any one cardiac lesion cannot be calculated from our data because the denominators (e.g., the number of specific cardiovascular surgical procedures performed, or the total number of both operated and unoperated at-risk patients) are not available. Since the patients at risk to develop endocarditis in any single year are drawn from the population of patients operated on yearly for all previous years, to be meaningful the correct denominator would have to be the sum of cases over 10–15 years. One-third of the cases reported here occurred 5 or more years after cardiac surgery. The fact that these cases were collected for only 1 calendar year also may have influenced the conclusions by restricting the sample which was analyzed. In spite of these limitations, our analyses provide insight into this clinical problem. In addition, these data indicate the need for specifically directed prospective studies.

The data collected from records of 278 patients (from 26 centers) were analyzed, an average of about 11 cases/center/year. In general, the number of cases reported was smaller for the centers which cared only for children than for those which cared for both children and adults.

Although influenced by the participating centers selected for this multicenter study, the age distribution of the cases of infective endocarditis is interesting (fig. 2). Of the two age-related peaks, the early age-related peak appears to be related to a younger group of patients with non-valvular congenital heart disease, and the second peak to an older group with either acquired or congenital valvar heart disease. This suggests that the advancing mean age of patients with endocarditis reported by some centers might be influenced by the selection of cases at that hospital. This study confirms that infective endocarditis remains a problem in the pediatric age group.

Rheumatic heart disease was the most common category of underlying heart disease both in the total group of patients with endocarditis as well as in the subgroup which underwent cardiovascular surgery before the infection. Of those patients with other forms of valvular heart disease, most were thought to represent congenital aortic valve deformities, primarily bicuspid aortic valves, which are more common than once thought. Although the mitral valve click or prolapse syndrome was seldom specifically implicated, this could have been due to a lessened awareness of this entity in 1972. Infective endocarditis certainly occurs in these patients.

The majority of the postoperative cases of infective endocarditis (34 of 63, 54%) occurred in patients with prosthetic heart valves. Of the 23 postoperative patients with congenital heart disease who did not require prosthetic valves, almost two-thirds were cyanotic patients requiring palliative systemic artery-
to-pulmonary artery shunts. This was especially interesting, since only two postoperative patients (9%) had undergone reoperative surgery for similar lesions (tetralogy of Fallot and transposition of the great vessels with ventricular septal defect) before developing endocarditis. The lack of cases of infective endocarditis in postoperative patients with other forms of congenital heart disease may only be a reflection of the sample analyzed. Assignment of a low risk for developing endocarditis for these other categories of repaired or palliative congenital heart disease may be premature and must await prospectively collected data.

Scattered reports in the literature agree with our findings of the risk of endocarditis in cyanotic patients with systemic-to-pulmonary artery shunts. In a review of 115 patients with tetralogy of Fallot, Kaplan and colleagues reported an 8% incidence of infective endocarditis after palliative shunts; all were patients who had had the Pott’s procedure. Infective endocarditis was also a relatively common complication in a 20-year surgical follow-up of shunts in patients with tetralogy of Fallot reported from Guy’s Hospital. Similar findings were reported by Taussig et al. in patients with tricuspid atresia and in patients with dextrocardia requiring Blalock-Taussig anastomoses. Based on these data and information from this study, cyanotic patients with palliative shunts might be considered in a relatively high risk group.

The finding that this was the initial attack (table 2) in approximately 90% of both the operated and unoperated patients reported here is not surprising. However, we could find no similar study for comparison.

We chose 90 days to divide early from late postoperative endocarditis because, in this retrospective study, we felt this might more clearly separate these two groups of patients. Eighty percent (27 of 34) of the cases of PVE reported here were late cases (table 3). This is a somewhat higher percentage than that reported in other series of PVE, perhaps related to the difference in defining early and late disease.

It is difficult to locate data to compare with our findings that all patients operated on for other forms of “congenital” heart disease developed endocarditis which occurred more than 3 months after cardiac surgery. However, in one series of postoperative patients who had undergone systemic artery-to-pulmonary artery shunts, Taussig et al. reported a majority of infections occurred in the first 2 months after the shunt was constructed. We do not know whether this difference is real and, if so, whether it is due to more effective aseptic techniques in the operating room and/or more effective antibiotic prophylaxis in the 1970s, or to a difference based on the sampling techniques chosen for this study. The fact that only 15% of all the cases of infective endocarditis in the 63 postoperative cases developed early endocarditis does suggest that techniques used in the operating room and during the perioperative period may be more effective in preventing intraoperative infection.

**Staphylococcus aureus** was the most common staphylococcus recovered. The fact that 85% of the staphylococci isolated from patients without underlying heart disease were *Staphylococcus aureus* may be explained by the fact that this organism was recovered from over 50% of the narcotics addicts. As reported by others, streptococci were very frequently recovered; *Streptococcus viridans* was most often responsible. Gram-negative organisms are unusual causes of infective endocarditis, but have been recovered in several patients after cardiovascular surgery. However, in the patients reported here they were most often recovered from debilitated patients without heart disease.

Several studies have reported that approximately 10% of patients with clinical manifestations of infective endocarditis have sterile blood cultures, which is similar to our findings (about 12%). The relatively high incidence (26%) of sterile blood cultures in postoperative patients with clinical endocarditis without prosthetic valves is puzzling, but is quite similar to the greater than 30% incidence in patients with congenital heart disease recently reported.

Since this was a retrospective study which evaluated mortality a maximum of 2 years after the occurrence of infective endocarditis, these mortality data (table 5) may not reflect the long-term risk of any specific group of patients. Both the percentage of deaths from any cause and the percentage of deaths related to infective endocarditis were greatest in unoperated patients without evidence of underlying heart disease might be explained by the fact that many of these patients had debilitating chronic diseases (e.g., malignancies).

The 23 cases of infective endocarditis in narcotic addicts are noteworthy for two reasons: First, almost all of them were reported from medical centers on the east or west coasts of the United States. Second, as has been reported by others, the most common organism recovered from narcotic addicts was *Staphylococcus aureus*. The enterococcus also was frequently isolated from narcotic addicts, as has been reported.

The efficacy of antibiotic prophylaxis in preventing bacterial endocarditis associated with dental and surgical procedures has been questioned. Antibiotic prophylaxis failures have been reported after dental work, cardiac catheterization and vaginal delivery. Although evaluation of antibiotic prophylaxis was not a primary purpose of this study, we attempted this based upon American Heart Association recommendations available in 1972–1974, not current American Heart Association recommendations. Our findings confirm the suspicion that antibiotic prophylaxis failure may occur more frequently than has been suspected.

The goal of this collaborative pilot study was to learn which categories of patients remain at risk to develop infective endocarditis after reoperative or palliative cardiovascular surgery. The results raise important questions and provide justification for a
collaborative prospective study, especially since it is unlikely that well-controlled single-center studies can provide the required data.

Acknowledgments

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