bol. Accordingly, the exercise data points have the smallest numeric coordinates on both the ordinate and the abcissa.

Discussion

The results demonstrate that the carotid upstroke closely tracks the pre-ejection period and that the carotid incisura closely tracks the aortic component of the second heart sound. The tracking relationships show slopes and correlation coefficients close to 1.00. Figures 2 and 3 show that the data at all points have very little scatter from the regression line. The most scatter was during IHG. This is reflected in its relatively low coefficients. Thus, measurements of CARu and CARIN can be used, respectively, in place of PEP and EMS (IIₐ) in certain stress tests, with the exception of IHG during which CARu varies with PEP but predicts it to a too limited (64%) extent. Indeed, if the combined series is recalculated without IHG, the overall values improve as shown in the last line of table 1. (The near-perfect correlations for EMS in table 2 make recalulation redundant.) Conversion to PEP and EMS is readily performed by using the data in tables 1 and 2 as regression equations for the appropriate control or challenge state. For PEP, the general formula for this is:

\[
PEP = \frac{CARu - a}{b}
\]

and for EMS:

\[
EMS = \frac{CARIN - a}{b}
\]

References

5. Quarry VM, Spodick DH: Cardiac responses to isometric exercise: Comparative effects with different postures and levels of exertion. Circulation 49: 905, 1974

The Incidence of Bacteremia in Pediatric Patients Following Tooth Extraction

LARRY J. PETERSON, D.D.S., M.S., AND RONALD PEACOCK, D.D.S.

SUMMARY Procedures which produce bacteremias may lead to bacterial endocarditis in the susceptible patient. Recent work has suggested that bacteremia does not occur in children following extraction of teeth as it does in adults. One hundred and seven children were divided into four groups. Group I, which consisted of children who had nondiseased primary teeth extracted, had 35% positive blood cultures. Group II consisted of children who had diseased primary and permanent teeth removed. The incidence of positive blood cultures was 53%. Group III, which consisted of patients who had extractions of nondiseased permanent teeth, had a 61% incidence of positive blood cultures. Group IV served as a negative control. Bacteremias do occur in children following the extraction of normal and diseased primary and permanent teeth. Therefore, the susceptible pediatric patient who is to undergo a dental extraction procedure must be given prophylactic antibiotics.

THE ASSOCIATION of the bacteremia which follows tooth extraction with subsequent subacute bacterial endocarditis (SBE) was recognized forty-five years ago.1 However, evidence from experimental work which firmly established the causal relationship between the bacteremia and the onset of SBE has only recently been reported.2-4 Although direct evidence in man is lacking, the fact that the bacteremia following dental extraction may result in SBE in the susceptible patient must be seriously considered.

The patient most susceptible to SBE following a bacteremia is the one with underlying valvular heart disease. Congenital and rheumatic heart diseases are the most common predisposing factors, but other types of heart disease which result in turbulent blood flow in the heart may also predispose a patient to the disease.5,6 The administration of prophylactic antibiotics to reduce the probability of the occurrence of SBE in the susceptible patient who is to undergo

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a procedure which will cause a bacteremia, has been recommended. 7

Recently, a number of studies which have investigated the incidence of bacteremia following dental procedures in children have been reported. 8–13 Some of these reports indicate that no bacteremia could be demonstrated following dental prophylaxis and extractions. 8–10 Conversely, other studies have presented evidence that bacteremia does indeed occur following these types of procedures. 11–14 At least one of the former investigators has recommended that since their study did not demonstrate a bacteremia, antibiotic prophylaxis prior to certain types of dental procedures was not necessary and, in fact, was unwarranted. 8 However, if that study is in error, if bacteremias do occur, then the recommendation to avoid antibiotic prophylaxis must not be accepted.

The purpose of this study was to determine the incidence of bacteremia, if any, in pediatric patients following the removal of normal and diseased primary and permanent teeth using local anesthesia in the awake patient.

Materials and Methods

Patient Population

Each of one hundred and seven healthy pediatric patient volunteers between the ages of 5 and 13 was placed into one of four groups depending upon the reason for the dental extractions. All teeth were removed using local anesthesia and forceps extraction techniques. Group I was composed of 28 patients who required extraction of healthy primary teeth for space management and interceptive orthodontic purposes; that is, they were removed for reasons other than disease. Group II consisted of 34 patients who required removal of primary or permanent teeth which had diseased or necrotic pulps and associated abscesses. The diagnosis was based on radiographic and/or clinical findings. These patients almost universally complained of previous or present pain in the affected tooth. Group III consisted of 18 patients who presented for removal of permanent teeth for orthodontic reasons. As in Group I, these teeth were removed for reasons other than disease. Group IV was composed of 27 patients who presented for restorative dental treatment. This group served as a negative control.

Blood Culture Technique

The patients in Groups I, II and III had blood for culture drawn within two minutes following removal of the tooth (teeth), while Group IV patients had blood for cultures taken prior to their dental treatment.

Before the extraction, the antecubital fossa was prepared with a two minute scrub with providone-iodine solution. The arm was wiped dry with a sterile gauze, and a final layer of the iodine solution applied. This last layer of solution was left in place, allowed to dry, and the arm covered with a sterile gauze pad. After the extraction, the antecubital fossa was thoroughly wiped with 70% ethanol, and the venipuncture performed. The preparation of the puncture site in the patients in Group IV was the same. The last layer of providone-iodine was allowed to dry for three minutes, then the site was wiped with alcohol.

Two 2 ml blood samples were drawn into Becton-

<table>
<thead>
<tr>
<th>Group</th>
<th>Average age (yr)</th>
<th>Average number of teeth extracted</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>10.4 (6–12)*</td>
<td>1.4 (1–3)</td>
</tr>
<tr>
<td>II</td>
<td>9.8 (5–12)</td>
<td>1.2 (1–3)</td>
</tr>
<tr>
<td>III</td>
<td>12.1 (10–13)</td>
<td>3.4 (2–4)</td>
</tr>
<tr>
<td>IV</td>
<td>10.1 (7–12)</td>
<td>0.0</td>
</tr>
</tbody>
</table>

*Range in parenthesis.

Dickinson Vacutainer culture tubes from each patient, using a single venipuncture. This procedure gave approximately 10% (V/V) blood in the culture medium. The first tube was grown aerobically, the second anaerobically. The culture medium was a peptone broth supplemented with yeast extract, vitamins, and amino acids to increase microorganism growth. Sodium polyanethol sulfonate in a concentration of 0.025% was used as an anticoagulant and to neutralize the bactericidal activity of the blood.

A fifth group of cultures was taken from serial dilutions of Streptococcus sanguis in brain heart infusion to serve as a positive control. Ten cultures each were taken from samples of 1,000 bacteria per milliliter, 100/ml, 50/ml, 10/ml, 5/ml, and 1/ml using the vacuum tube system employed with the patients.

The cultures were incubated at 35° C. Tubes with growth were subcultured at 24 and 48 hours. The original culture tubes were incubated and observed for 16 days before being reported as negative. Recovered organisms were identified as to genus. All culture work was done in the Clinical Microbiology Laboratory at the Eugene Talmadge Memorial Hospital.

Results

The ages of the patients (table 1) show little variation among the four groups. There were several younger patients in Group II, while essentially all of the patients in Group III were older. The number of teeth extracted in each patient (table 1) was small in both Groups I and II. The number of teeth removed per patient was higher in Group III.

The incidence of positive blood cultures is presented in table 2. In the groups of patients which underwent extractions, there was a substantial number of positive cultures. The extraction of nondiseased primary teeth resulted in positive blood cultures in 35.7% of the patients, while removal of nondiseased permanent teeth resulted in a 61.1% positive culture rate. Extraction of diseased teeth had an intermediate incidence of 52.9%. The patients in Group IV,

<table>
<thead>
<tr>
<th>Group</th>
<th>Positive cultures</th>
<th>Negative cultures</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>10 (35.7%)</td>
<td>18</td>
<td>28</td>
</tr>
<tr>
<td>II</td>
<td>18 (52.9%)</td>
<td>16</td>
<td>34</td>
</tr>
<tr>
<td>III</td>
<td>11 (61.1%)</td>
<td>7</td>
<td>18</td>
</tr>
<tr>
<td>IV</td>
<td>0</td>
<td>27</td>
<td>27</td>
</tr>
<tr>
<td>Total</td>
<td>39 (48.8%)</td>
<td>68</td>
<td>107</td>
</tr>
</tbody>
</table>

Among Groups I, II and III, the X² (2 df) = 3.24, P > 0.10.

Between Groups I, II and III considered as a single group, and Group IV, X² (1 df) = 18.66, P < 0.001.
the negative control patients, had no positive blood cultures. The influence of the number of teeth extracted on the incidence of positive blood cultures was subjected to statistical analysis by the product moment correlation between the number of teeth extracted and the resultant condition of the culture. The corresponding $P$ value was greater than 0.1, indicating no statistical significance.

The microorganisms removed from culture and their incidence is presented in table 3. Of the 39 positive cultures, 23 grew two or more organisms.

The seventy cultures grown from the serial dilutions of Streptococcus sanguis were uniformly positive.

Discussion

Although the mortality rate of patients with SBE has decreased in the antibiotic era, the morbidity associated with this disease remains substantial. Thus, the prevention of SBE must be of primary concern. Since it is well established that a bacteremia may cause SBE in the susceptible animal, and since that SBE may be prevented with appropriate antibiotic therapy, it follows that the accurate delineation of those procedures which cause bacteremia is essential.

It has been suggested that pediatric patients, unlike adult patients, may not have a bacteremia following dental treatment. If, in fact, this is true, the use of antibiotics for the prophylaxis of SBE is inappropriate and should be discontinued.

In order to confirm the findings presented by Speck and his colleagues, a similar study was designed by which bacteremia, if present, could be detected. Extractions were performed using only standard local anesthesia techniques with 2% lidocaine with 1:100,000 epinephrine. In a previous study, the patients were placed under general anesthesia with the placement of a nasal endotracheal tube. The placement of the tube caused sufficient trauma to the nasal mucosa to cause a bacteremia in 12% of the patients. Therefore, it was impossible to determine the exact cause of positive blood cultures following both the intubation and the dental manipulation.

Because of the age of the patients and their almost universal aversion to venipuncture, pre-extraction blood cultures were not drawn for humanitarian reasons. Previous investigations have shown that the incidence of pre-treatment positive blood cultures in asymptomatic healthy subjects was quite low. Lineberger and DeMarco found 50 of 50 pre-treatment cultures were negative, and Khairat found only one of 242 pre-extraction cultures to be positive. In the current study, pre-treatment blood cultures were drawn from 27 asymptomatic, healthy children who presented for dental treatment other than extraction. Each of these pre-treatment cultures was negative for bacterial growth. It was felt therefore that pre-existing bacteremias were absent and that the cultures which were positive in Groups I, II and III following extraction were due to the extraction and not to other causes. None of the patients in the control group (Group IV) had dental disease sufficient to warrant extraction, as was also the situation with the patients in Groups I and III. The patients in Group II did have local abscesses which may have caused occasional transient bacteremias. However, as the incidence of bacteremias in Group II was intermediate between Group I and Group III, we feel that the local disease had little or no effect on the incidence of the bacteremias in Group II.

In order to test the sensitivity of the culture technique, serial dilutions of Streptococcus sanguis ranging from 1,000 bacteria per milliliter to 1 bacterium per milliliter, using brain heart infusion as the diluent, were cultured using the same technique as used for the blood cultures. Two milliliters of each of the concentrations were drawn into the vacuum culture tubes and incubated aerobically. Each of the cultures was positive within 24 hours. Thus, the system of culture and subculture being employed was of adequate sensitivity for this study.

The average age of the patients varied only slightly among the four groups. The patients in Group III tended to be slightly older as they were of the age at which orthodontics is performed. Fewer teeth were extracted from each patient in Groups I and II, while the average number of teeth removed per patient in Group III was 3.4. This reflects a general trend to remove four first premolar teeth for orthodontic reasons. The larger average number of teeth removed in Group III and the high incidence of positive blood cultures in that group did not have a statistical relationship.

Previous investigators have claimed that the state of gingival health may influence the incidence of bacteremia following dental therapy. If that were true, and since children tend not to have significant periodontal disease, then bacteremia would be rarely, if in fact ever, present following dental treatment. The periodontal conditions of the patients treated in this study were within the normal range of health for children, with several exceptions. These were in patients with periapical abscesses which caused significant periodontal defects. Those patients with a chance of periodontal involvement, i.e., the patients in Group II, had fewer positive cultures (53%) than Group III (61%), who had normal gingival health. Thus, it would appear that the statement that the generally good state of periodontal health found in children is such that bacteremias do not occur, is an invalid one.

The percentage of bacteremias found in children in this study was quite similar to the percentage of bacteremias found in studies of adult patients. There is an apparent difference in the incidence of positive cultures among Groups I, II, and III. When subjected to the chi square test, however, there is no significant statistical difference among them. When Groups I, II and III are combined into a single

<table>
<thead>
<tr>
<th>Organisms</th>
<th>Aerobic</th>
<th>Anaerobic</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Streptococcus</td>
<td>16</td>
<td>4</td>
<td>20 (29%)</td>
</tr>
<tr>
<td>(alpha hemolytic)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peptostreptococcus</td>
<td>7</td>
<td>7</td>
<td>14 (10%)</td>
</tr>
<tr>
<td>Diphtheroids</td>
<td>10</td>
<td>6</td>
<td>16 (33%)</td>
</tr>
<tr>
<td>Staphylococcus</td>
<td>6</td>
<td>2</td>
<td>8 (12%)</td>
</tr>
<tr>
<td>(coagulase negative)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bacteroides</td>
<td>8</td>
<td>3</td>
<td>11 (12%)</td>
</tr>
<tr>
<td>Veillonella</td>
<td>4</td>
<td>2</td>
<td>6 (9%)</td>
</tr>
<tr>
<td>Neisseria</td>
<td>1</td>
<td>1</td>
<td>2 (1%)</td>
</tr>
<tr>
<td>Vibrio</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>37 (54%)</td>
<td>32 (46%)</td>
<td>69 (100%)</td>
</tr>
</tbody>
</table>
group and compared to the control group, Group IV, 
$P < 0.001$.

Identification of the bacteria isolated as to genus was performed by routine laboratory methods. The bacteria recovered from the positive cultures were similar to those present in the normal gingival crevice.$^{18}$ This finding supports the fact that the bacteria recovered by culture came from the oral cavity, and were not contaminants from such sources as the skin.

Streptococcus and Staphylococcus organisms seen in 30% of the positive cultures are among the most commonly seen in SBE, especially when dental treatment has been suspected as the etiological factor.$^{5,6}$ In a recent report,$^{14}$ five of 11 pediatric patients admitted to the hospital with a diagnosis of SBE had their disease caused by an organism commonly found in the gingival crevice. Of these five, one had a history of previous tooth extraction. In another study,$^6$ of 32 episodes of endocarditis in children in which prior etiological events were identified, eight cases were thought to result from dental extractions. The organisms isolated from the eight patients were normal inhabitants of the mouth.

Although aerobic organisms are usually recovered from patients with SBE, evidence does exist that anaerobic bacteria can be cultured from the blood of patients with bacterial endocarditis, and may, in fact, be found in pediatric patients with SBE who have dental problems.$^{19}$ In a previous study, 46% of the organisms isolated from pediatric patients with SBE were anaerobic.$^{18}$ While the role of anaerobes in the etiology of SBE is not as yet resolved, their presence in the blood following dental extraction must be viewed with concern.

Based on the results of the study, it appears quite clear that the extraction of abscessed deciduous and permanent teeth as well as normal deciduous and permanent teeth causes a clinically significant incidence of bacteremia. This study confirms the work of Elliott and Dunbar.$^{11}$ However, this study does demonstrate bacteremias following extraction of sound permanent teeth for orthodontic purposes which they did not observe in their small sample of four patients. This study also indicates that the type of dental manipulation may play a role in the production of bacteremia. Speck$^8$ did not observe bacteremias following vigorous prophylaxis while the current study demonstrated bacteremias following extraction of normal and diseased teeth.

In view of the high percentage of patients in all three test groups who had positive blood cultures following extraction procedures, it is our strong recommendation that antibiotic prophylaxis as recommended by the American Heart Association$^7$ be instituted whenever extractions are planned in pediatric patients who have significant pre-existing valvular heart disease.

References

The incidence of bacteremia in pediatric patients following tooth extraction.
L J Peterson and R Peacock

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