Infective endocarditis in congenital heart disease: Japanese national collaboration study

K Niwa, M Nakazawa, S Tateno, M Yoshinaga, M Terai

Objective: To provide pure cohorts of paediatric and adult patients with congenital heart disease (CHD) and infective endocarditis (IE) for making future guidelines.

Design: Japanese nationwide survey.

Setting: 66 Japanese institutions.

Patients: 170 children, mean (SD) age 7.4 (5.7) years (range 14 days to 17 years), and 69 adults, age 32.5 (14.1) years (range 18–69) who developed IE between 1997 and 2001 (one in 240 admissions with CHD).

Main outcome measures: Clinical presentation of IE.

Results: 119 patients including 88 with cyanotic CHD had previous cardiac surgery. Procedures preceding IE were dental (12%) followed by cardiovascular surgery (8%). Sites of infection were left sided in 46% and right sided in 51%. Vegetation with diameter of 11 mm was documented in 151 (63%). Frequent complications were embolic events (stroke 11%, other emboli 20%) and cardiac failure (23%). The most common microorganisms were streptococci (50%) and staphylococci (37%) with methicillin resistant Staphylococcus aureus in 7.5%. Empirical treatments were penicillins (alone or with other antibiotics 57%) followed by cephems (22%) and vancomycin (11%). Surgery during active IE was common (26%), with vegetation (45%) and heart failure (29%) as the most frequent indications. Mortality was 8.8%: 8.0% among patients who received medical treatment alone and 11.1% among those with active IE who underwent surgery. The causes of death (n = 21) were surgery (7), infection (7), cardiac failure (6), and renal failure (1).

Conclusions: Because of a recent increase in the incidence of IE and high mortality and complication rate, it is mandatory to establish well formulated recommendations for management of IE in paediatric and adult patients with CHD based on a large cohort. Results of this nationwide multicentre database should be helpful in establishing guidelines.
Continuous data were compared between subgroups by two
www.heartjnl.com
Staphylococcus aureus
of 14 patients with intravenous prophylaxis, methicillin
intravenously (14 patients) or orally (eight patients). In nine
associated with IE were identified (table 2). In 22 of 78
times in two. In 28 of 119 (23.5%) patients with previous
CHD. A residual defect after repair was observed in 55 of 75
patients who died, whether they were treated with drugs alone, underwent surgery during active
IE (before a full course of antibiotics had been completed),
or underwent surgery with healed IE (after a full course of
antibiotics had been completed).

Statistical analysis
Data were expressed as mean (SD) with range, the number and
percentage, or the number of answers as a percentage of
total number of answers. When a question had no response
or when an answer was unclear, those data were not counted.
Available data from participating hospitals were analysed
with StatView J-5.0 PPC (SAS Institute Inc, Cary, North
Carolina, USA). Discrete variables were analysed by χ²
test. Continuous data were compared between subgroups by two
sample t test or the Wilcoxon rank sum test wherever
appropriate. When p < 0.05, the data were defined as
significant.

RESULTS
Demographic data
The male to female ratio was 143:96. Of the population of
239, 20 (8.4%) were infants aged 5.1 (3.3) months (range 14
to 10 months). Table 1 lists the diagnoses of CHD. No
patients had rheumatic heart disease. Previous reparative or
palliative cardiac surgery was undertaken in 119 patients
with CHD (119 of 216 (55.1%), 75 with reparative surgery
and 44 with palliative surgery) including 88 with cyanotic
CHD. A residual defect after repair was observed in 55 of 75
(73.3%) patients. IE reoccurred in 21 of 229 (9.2%) patients:
one in 10, twice in two, three times in two, and four or more
times in two. In 28 of 119 (23.5%) patients with previous
cardiac surgery, IE developed perioperatively.

Prophylaxis
In 78 of 234 (33.3%) patients, conditions and procedures
associated with IE were identified (table 2). In 22 of 78
(28.2%), prophylactic antibiotic regimens were administered
intravenously (14 patients) or orally (eight patients). In nine
of 14 patients with intravenous prophylaxis, methicillin
resistant *Staphylococcus aureus* (MRSA) (*n* = 7) or *Candida
albicans* (*n* = 2) was the causative microorganism. In eight
patients with oral prophylaxis, streptococci were found in
three and staphylococci in four. No patients used injected
drugs.

Site of infection
The site of infection was identified (175 of 239 of patients
(73.2%)) more often in paediatric patients (127 of 170
(74.7%)) than in adults (48 of 69 (69.6%), *p* = 0.1). Left
sided IE was observed in 81 of 175 (46.3%) patients: mitral
valve, 44 (25.1%); aortic valve, 26 (14.9%); both the mitral
and aortic valves, five (2.9%); left atrium, two (1.1%); left
ventricular outflow tract, two (1.1%); and ascending aorta,
arch, or both, six (3.4%). Right sided IE was observed in 89 of
175 (50.9%) patients: tricuspid valve, 37 (21.1%); ventricular
septal defect, 19 (10.8%); right ventricle, 12 (6.9%); right
ventricular outflow tract conduit, 10 (5.7%); pulmonary
valve, nine (5.1%); pulmonary artery, four (2.2%); left carotid
vein, one (0.5%); and atrial septal closure suture, one (0.5%).
IE in both right and left ventricles was observed in four
(2.3%) and Blalock-Taussig shunt in two (1.1%). In adults,
the prevalence of left sided IE (29 of 48 (60.4%)) was higher
than that of right sided IE (21 of 52 (40.4%). In 23 children
without underlying structural heart disease, sites of infection
were mitral valve, 15; aortic valve, five; both mitral and aortic
valve, two; and tricuspid valve, one (IE due to central venous
catheter insertion).

Bacteriology
Causative microorganism were identified in 201 of 239
(84.1%) patients (table 3).

Diagnosis of IE
Blood samples were cultured 3.5 (range 1–18) times for each
patient. The mean (SD) interval between initial blood
culturing and initiation of antibiotics was 90.8 (150) hours
(range 0–720 hours).

Transoesophageal echocardiography (TOE) was performed
in 30 of 228 (13.2%) patients and 23 of them were adults. IE
findings were positive in 167 of 235 (71.1%) patients: vegetations, 145 (61.7%); enhanced intensity of endocardium,
127 (54.0%); perforations of valve leaflet, 17 (7.2%); and
periannular extension of abscess, 14 (6.0%). Mean (SD)
vegetation size was 11.1 (6.7) mm (range 1–39 mm). Vegetation
size in patients with systemic embolisation (*n* = 26) was
11.5 (6.5) mm (range 1–27 mm), which was
similar to the size in patients without systemic embolisation
(10.9 (6.3) mm (range 1–39 mm)). In six patients, vegetations
of 6 mm were identified by pathological examinations
but were not found by echocardiographic study. Vegetation
was detected in 39 of 67 (58.2%) patients with a size of
11.1 mm in adults, which was similar to the size in paediatric
patients (106 of 170 (62.4%), 11.1 mm, *p* = 0.2).

Prosthetic material infection
Prosthetic material was infected in 26 of 136 (19.1%) patients:
prosthetic valve, four; right ventricular outflow conduit, 10;
right ventricular outflow patch, two; ventricular septal defect
defect patch, six; Blalock-Taussig shunt, two; pulmonary
artery banding, one; and ventriculoatrial shunt, one.

Complications
Complications were observed in 116 of 239 (48.5%) patients
after a mean (SD) of 29 (42) days (range 0–180 days) of
illness (table 4). In 19 of 25 of patients with cerebral emboli,
IE was associated with 37.5% (11 of 29). In 23 children
with IE (before a full course of antibiotics had been completed),
or underwent surgery with healed IE (after a full course of
antibiotics had been completed).
Table 1. Diagnoses of underlying congenital heart disease

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Total (n = 216)</th>
<th>Non-operated (n = 97)</th>
<th>Repaired (n = 75)</th>
<th>Palliated (n = 44)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VSD, VSD + ASD or PDA</td>
<td>81 (37.5%)</td>
<td>65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tetralogy of Fallot with/without pulmonary atresia</td>
<td>39 (18.1%)</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single ventricle (heterotaxia)</td>
<td>19 (8.8%)</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double outlet right ventricle</td>
<td>16 (7.4%)</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mitral stenosis/regurgitation</td>
<td>15 (6.9%)</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aortic stenosis/regurgitation</td>
<td>11 (5.1%)</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[bicuspid aortic valve]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complete TGA</td>
<td>8 (3.7%)</td>
<td>0</td>
<td>Rastelli: 5, Jatene: 1</td>
<td>AP shunt: 2</td>
</tr>
<tr>
<td>COA, COA VSD</td>
<td>6 (2.8%)</td>
<td>0</td>
<td>VSD closure: 4</td>
<td>SCLF: 2</td>
</tr>
<tr>
<td>AVSD</td>
<td>6 (2.8%)</td>
<td>2</td>
<td>AVSD closure, MVP: 3</td>
<td>AP shunt: 1</td>
</tr>
<tr>
<td>Corrected TGA</td>
<td>5 (2.3%)</td>
<td>0</td>
<td>Rastelli: 2, TVR: 1, VSD closure: 1</td>
<td>AP shunt: 1</td>
</tr>
<tr>
<td>ASD</td>
<td>2 (0.9%)</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PDA</td>
<td>2 (0.9%)</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Truncus arteriosus communis</td>
<td>2 (0.9%)</td>
<td>0</td>
<td>Rastelli: 2</td>
<td></td>
</tr>
<tr>
<td>Valvular aneurysm</td>
<td>2 (0.9%)</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ebstein’s disease</td>
<td>1 (0.5%)</td>
<td>0</td>
<td>TVP: 1</td>
<td>Norwood: 1</td>
</tr>
<tr>
<td>HLHS</td>
<td>1 (0.5%)</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Tetralogy of Fallot and pulmonary atresia: 22.
AP, aortopulmonary; ASD, atrial septal defect; AVP, aortic valvoplasty; AVR, aortic valve replacement; AVSD, atrioventricular septal defect; COA, coarctation of the aorta; HLHS, hypoplastic left heart syndrome; ICR, intracardiac repair; MVP, mitral valvoplasty; MVR, mitral valve replacement; PAB, pulmonary artery banding; PDA, patent ductus arteriosus; SCLF, subclavian flap; TVC, total cavopulmonary connection; TGA, transposition of the great arteries; TVR, tricuspid valve repair; VSD, ventricular septal defect.

Antimicrobial treatment

Table 5 shows empirical antimicrobial treatment (n = 235). Antibiotics were started at 18.5 (33.3) days (range 0–240 days) of illness, which was within seven days in 104 of 203 (51.2%) patients. The duration of antibiotics administration was 29.7 (16) days (range 1–70 days). Antibiotics and antifungal agents were (n = 420 in 235 patients) penicillins in 147 (63%), cephems in 81 (35%), aminoglycosides in 84 (36%), carbapenems in 43 (18%), vancomycin in 29 (12%), clindamycin in four (2%), and chloramphenicol in one (0.4%).

Cardiac surgery

Cardiovascular surgery for IE was performed in 103 of 239 (43.1%) patients. This was during active IE (full course of antibiotics had not been completed) in 63 of 239 (26.4%) at 37.2 (34.8) days (range 0–180 days) of illness and in healed IE (full course of antibiotics had been completed) in 40 of 239 (16.7%) at 301 (456) days (range 30 days to 49 months) of illness. In 12 of 26 patients with prosthetic material infection, cardiac surgery was undertaken during active IE. Table 6 lists indications for cardiac surgery.

Mortality

Total mortality was 21 of 239 (8.8%). Fourteen of 176 (8.0%) patients who received medical treatment alone (n = 176) died. None of 40 (0%) patients who had surgery (n = 40) after IE had healed died. Seven of 63 (11.1%) patients who had surgery (n = 63) during active IE died, which was similar to mortality with medical treatment alone (p = 0.2).

The mortality among paediatric patients (16 of 170 (9.4%)) was similar to that of adults (five of 69 (7.2%), p = 0.6). Three of the 12 patients with prosthetic material infection died: one with medical treatment alone and two others who underwent surgery during acute IE.

Causes of death

The causes of death in 21 patients were surgery in seven, cardiac failure in six (including two with cerebral embolisation), IE unresponsive to antimicrobials in six, pneumonia in one, and renal failure in one.

DISCUSSION

Clinical features of IE in 239 patients—170 paediatric and 69 adults—with CHD are established. The incidence of IE in adults—with CHD are established. The incidence of IE in

Table 2. Conditions and procedures associated with infective endocarditis

<table>
<thead>
<tr>
<th>Conditions and procedures</th>
<th>Number (n = 78)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invasive dental procedures</td>
<td>29 (37.2%)</td>
</tr>
<tr>
<td>Cardiovascular surgery</td>
<td>20 (25.6%)</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>11 (14.1%)</td>
</tr>
<tr>
<td>Invasive dilatational procedures</td>
<td>5 (6.4%)</td>
</tr>
<tr>
<td>Unexpected trauma</td>
<td>4 (5.1%)</td>
</tr>
<tr>
<td>Atopic dermatitis</td>
<td>4 (5.1%)</td>
</tr>
<tr>
<td>Central venous catheter</td>
<td>2 (2.6%)</td>
</tr>
<tr>
<td>Catheter intervention</td>
<td>1 (1.3%)</td>
</tr>
<tr>
<td>Meningitis</td>
<td>1 (1.3%)</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>1 (1.3%)</td>
</tr>
</tbody>
</table>

Table 3. Causative microorganisms

<table>
<thead>
<tr>
<th>Organism</th>
<th>Number (n = 201)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staphylococcus species</td>
<td>100 (49.8%)</td>
</tr>
<tr>
<td>Streptococcus species</td>
<td>87 (43.3%)</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>11 (5.5%)</td>
</tr>
<tr>
<td>β Streptococcus</td>
<td>2 (1.0%)</td>
</tr>
<tr>
<td>Staphylococcus species</td>
<td>74 (36.8%)</td>
</tr>
<tr>
<td>S aureus</td>
<td>64 (31.8%)</td>
</tr>
<tr>
<td>MRESA</td>
<td>15 (7.5%)</td>
</tr>
<tr>
<td>S epidermidis</td>
<td>10 (5.0%)</td>
</tr>
<tr>
<td>MRSE</td>
<td>4 (2.0%)</td>
</tr>
<tr>
<td>Haemophilus species</td>
<td>9 (4.5%)</td>
</tr>
<tr>
<td>Candida species</td>
<td>5 (2.5%)</td>
</tr>
<tr>
<td>Pseudomonas</td>
<td>4 (2.0%)</td>
</tr>
<tr>
<td>Others†</td>
<td>9 (4.5%)</td>
</tr>
</tbody>
</table>

*Unknown causative microorganism: 38; †Granulicatella species 3, Micrococcus species 1, Moraxella species 1, Gemella species 1, enterococci 1, bocillus 1.
patients with CHD is increasing, especially in infants and adults with previous cardiac surgery. Despite recent developments in prevention and diagnosis of IE and medical and surgical management of acute IE, complication rates and mortality are still too high. Because of the high mortality caused by IE among patients with CHD (8.8%) it is mandatory to establish formulated recommendations for the medical and surgical management of paediatric patients and adults with IE and CHD based on a large database. Results of this nationwide multicentre database should be helpful in achieving this goal.

Demographic data
The prevalence of IE in patients with CHD has been increasing. It is reported that drug misuse is often associated with IE in adults in the USA and Europe, but there were no patients associated with drug abuse in this study or in a recent nationwide survey of IE in adults in Japan.11

Diagnosis of CHD and cardiac conditions associated with IE
Ventricular septal defect, patent ductus arteriosus, aortic valve abnormalities, and tetralogy of Fallot are reported to be common underlying conditions for IE.2 9 10 15 In this study, ventricular septal defect was the most frequent underlying condition with patent ductus arteriosus and aortic abnormalities lower than in previous reports.5 10 Instead, cyanotic CHD, such as tetralogy of Fallot, single ventricle with or without heterotaxia, double outlet right ventricle, and transposition of the great arteries (38%) were more frequent. The most common lesion to develop IE after surgery is reportedly tetralogy of Fallot or an aortopulmonary shunt.3 4 In this study, aortopulmonary shunt, extracardiac repair, and prosthetic material were frequent lesions.

Prophylaxis
Significant bacteraemia is defined by the American Heart Association as organisms commonly associated with IE and attributable to identifiable procedures such as dental, oral, and respiratory tract procedures. In our study, the most frequent procedure associated with IE was dental followed by cardiac surgery. Otolaryngeal procedures, pneumonia, and atopic dermatitis were also important predisposing causes or conditions for IE in patients with CHD.13

Site of IE
In children with CHD, right sided IE is reported to be more frequent than left sided, but in adults mainly with acquired heart disease, left sided IE is more prevalent.16 In adults with CHD in this study, left sided IE was more frequent than right

<table>
<thead>
<tr>
<th>Complications</th>
<th>Number (n = 116, multiple answers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased valvar regurgitation</td>
<td>73 (30.0%)</td>
</tr>
<tr>
<td>Cardiac failure</td>
<td>56 (23.4)</td>
</tr>
<tr>
<td>Systemic emboli</td>
<td>48 (20.1)</td>
</tr>
<tr>
<td>Stroke</td>
<td>25 (10.9)</td>
</tr>
<tr>
<td>Systemic abscess formation</td>
<td>12 (5%)</td>
</tr>
<tr>
<td>Arrhythmia development</td>
<td>13 (5.4%)</td>
</tr>
<tr>
<td>Periannular extension of abscess</td>
<td>11 (4.6%)</td>
</tr>
<tr>
<td>Intracranial haemorrhage</td>
<td>7 (2.9%)</td>
</tr>
<tr>
<td>Prosthetic valve dysfunction</td>
<td>4 (1.7%)</td>
</tr>
<tr>
<td>Glomerulonephritis/renal failure</td>
<td>4 (1.7%)</td>
</tr>
<tr>
<td>Mycotic aneurysm</td>
<td>3 (1.3%)</td>
</tr>
</tbody>
</table>

Table 4 Complications

<table>
<thead>
<tr>
<th>Antibiotics</th>
<th>Number (n = 235)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penicillins alone</td>
<td>54 (23%)</td>
</tr>
<tr>
<td>Penicillins plus aminoglycosides</td>
<td>50 (21%)</td>
</tr>
<tr>
<td>Penicillins plus others*</td>
<td>30 (13%)</td>
</tr>
<tr>
<td>Cephems alone</td>
<td>29 (12%)</td>
</tr>
<tr>
<td>Cephems plus aminoglycosides</td>
<td>8 (3.4%)</td>
</tr>
<tr>
<td>Cephems plus others†</td>
<td>15 (6%)</td>
</tr>
<tr>
<td>Carbapenems alone</td>
<td>9 (4%)</td>
</tr>
<tr>
<td>Carbapenems plus others‡</td>
<td>7 (3%)</td>
</tr>
<tr>
<td>Vancomycin alone</td>
<td>4 (1.7%)</td>
</tr>
<tr>
<td>Vancomycin plus carbapenems</td>
<td>6 (2.6%)</td>
</tr>
<tr>
<td>Vancomycin plus others‡</td>
<td>17 (7%)</td>
</tr>
<tr>
<td>Oxacephems</td>
<td>4 (1.7%)</td>
</tr>
<tr>
<td>Antifungal agents (fluconazole)</td>
<td>2 (0.8%)</td>
</tr>
</tbody>
</table>

Table 5 Empirical antimicrobial treatment

<table>
<thead>
<tr>
<th>Indication</th>
<th>Number (n = 63, multiple answers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation: possible future development of systemic embolisation/status after systemic embolisation</td>
<td>37 (52.4%)</td>
</tr>
<tr>
<td>Cardiac failure unresponsive to medical treatment</td>
<td>20 (31.7%)</td>
</tr>
<tr>
<td>Prosthetic material infection</td>
<td>14 (20.3%)</td>
</tr>
<tr>
<td>Periannular extension of abscess</td>
<td>11 (17.5%)</td>
</tr>
<tr>
<td>Persistent bacteraemia despite appropriate medical treatment</td>
<td>5 (7.9%)</td>
</tr>
<tr>
<td>Arrhythmia</td>
<td>2 (2.9%)</td>
</tr>
<tr>
<td>Others</td>
<td>4 (5.8%)</td>
</tr>
</tbody>
</table>

Table 6 Indications of surgery in active infective endocarditis
sided IE. Right sided lesions susceptible to IE were common in CHD. About 10% of reported paediatric patients and IE have no underlying structural heart disease and the site of IE was usually the aortic or mitral valve associated with *S aureus* bacteraemia. In this study, 23 children (13.8% of the paediatric patients) developed IE without structural heart disease and the site of IE was a left sided cardiac lesion in all except one. The results were similar to previous reports, but about half of the cases were associated with streptococcal bacteraemia.

**Microorganism**

The organisms that cause IE in children most often are Gram positive cocci (32–43%). With the increasing frequency of cardiac surgery in patients with complex CHD in which prosthetic materials are used, the incidence of infection with staphylococci, Gram negative bacilli, and fungi has been increasing. In this study, Gram positive cocci, especially *Streptococcus* species (50%) and *Staphylococcus* species (37%), were the most frequent microorganism followed by *Haemophilus* (4.5%) and *Candida* species (2.5%). In *Staphylococcus* species, *S aureus* (with 24% MRSA) was the most frequent microorganism.

**Echocardiography**

Transthoracic echocardiography is more likely to identify vegetations in patients with normal anatomy or isolated valvar pathology than in complex cyanotic CHD as a result of interference in complex cyanotic CHD by arterial grafts, conduits, and valves. The low detection rate (62%) of vegetation by echocardiography in both paediatric and adult patients in this study may be attributable to our higher prevalence of post-surgical patients with complex CHD with prosthetic materials.

In this study, TOE was used in only a small number of patients, especially in adults. TOE is superior to transthoracic echocardiography in detecting vegetations in the adult cohort. However, this was not a study of the usefulness of TOE in paediatric cohorts. Paediatric patients usually have a much better echo window than do adults.

**Blood culture**

Two to three sets of blood cultures over a 24 hour period is thought to be adequate in most cases in children with IE and blood samples were cultured 3.5 times for each patient in this study. The positive rate of pathogens grown in blood culture was reported to be 68–98% and the rate dropped to 60% when antibiotics were used before blood culturing. In this study, blood cultures were positive for pathogens in 86% of the patients despite the high incidence of prior administration of antibiotics (69% of the patients; most of these were administered orally) before blood culturing.

**Complications**

Cardiac failure, usually accompanied by valve regurgitation, is one of the most important predictive factors for mortality of IE. Prosthetic valve IE is common and usually results in valve replacement in adults. Extension of IE beyond the valve annulus predicts higher mortality with more frequent development of cardiac failure and the need for cardiac surgery. In this study, cardiac failure worsened because of IE in 21% of patients. Periannular extension of the abscess was observed in only 5% and prosthetic valve IE was observed in 1.7%, which is consistent with previous reports on paediatric patients with IE. Neurological signs and symptoms are often associated with *S aureus* infection and are reported in 20% of children with IE. In this study, cerebral emboli were observed in 11% of the patients and 76% were associated with *S aureus* infection.

Because the likelihood of cure with antibiotics alone is decreased, surgical intervention is often required. A potentially life threatening complication is the development of IE in a surgically created shunt or conduit in patients with complex CHD. In this study, prosthetic material was infected in 26 of 120 patients with previous surgery (22%) and 12 required urgent cardiac surgery that resulted in three deaths.

Vegetation of 10 mm or greater is a predictive sign of embolisation, especially a mitral valve vegetation. In this study, the size of vegetation was 11 mm and systemic embolisation was observed in 20% of the patients: 53% of the embolisations were cerebral. Vegetation size in patients with embolisation (n = 26) in this study was 11.5 (6.5) mm; a similar number of patients did not have embolisation. The most frequent site of vegetation that resulted in embolisation is reported to be the mitral valve but in this study in patients with CHD, the aortic and tricuspid valves were also frequent foci for embolisation. Mycotic aneurysms are uncommon complications of IE and are very rare, especially in children. In this study, mycotic aneurysm was observed in two adults, and one child required neurosurgery. The development of new atrioventricular or bundle branch block is a frequent sequela of periannular extension of the abscess in adults. In this study, no patients with conduction defects had periannular extension of the abscess.

**Medical management of IE**

For empirical infection, penicillins alone or penicillins combined with aminoglycosides are widely recommended. In this study, penicillins (alone or combined with aminoglycosides) were most often used antibiotics for this purpose (57%), but about 20% of the physicians preferred cephalosporins and 12% preferred vancomycin (or a combination of others).

**Mortality and cardiac surgery in patients with active IE**

The prognosis of children with IE depends on many factors, such as severity of underlying cardiac lesion, presence of prosthetic materials, type of infecting organism, and duration of illness before diagnosis. Mortality among paediatric patients with CHD and IE is reported to be lower than among adults with acquired heart disease. The recently reported mortality among paediatric patients with IE is about 10%, which is similar to our mortality (9.4%) and higher than that of adults with CHD (7.2%).

The incidence of reinfection of newly implanted valves in patients with active IE has been estimated at 2–3% in adult patients, and surgery as an adjunct to medical treatment was recognised as more effective than medical treatment alone. In this study, 26% of the patients underwent cardiac surgery during active IE with no recurrence but with higher mortality than with medical treatment alone. The risk factors for death were not measured in this study; however, this relatively higher mortality among patients with surgery in the acute phase may be attributable to differences in factors such as the timing of the operation, severity of cardiac disease, rate of complication, or differences in microorganisms between these two subgroups.

Indications for surgery in active IE are uncontrollable cardiac failure or infection, an episode of embolisation, fungal IE, periavalvar abscess, and prosthetic materials, such as prosthetic valve, conduit, aortopulmonary bypass graft, or patch infection. The most frequent indication for surgery in this study was a vegetation likely to develop systemic embolisation or the status after systemic embolisation and heart failure. The current practice of cardiac surgery for CHD is the frequent use of prosthetic material in a variety of cardiac locations. A high mortality has been reported among
patients with IE with infected prosthetic materials requiring replacement. In this study, infected prosthetic material was surgically removed from 17 patients with a resultant mortality of 12%.

Because of the recent increase in the incidence and the high mortality from IE (8.8%), it is mandatory to establish formulated recommendations for the medical and surgical management of IE in paediatric and adult patients with CHD based on a large database.

Limitations

Most cardiologists in Japan use the Duke criteria for diagnosing IE, but some in the participating institutions had no uniform criteria and the diagnosis of IE in the reported cases was not validated. Our patients had a large age range from infants and children to adults with CHD. Many cardiologists participated in this study; therefore, these factors may cause a bias in the analysis of the clinical profile of IE in Japanese patients with CHD.

Conclusions

Precise features of IE in 239 paediatric and adult patients with CHD are clarified. An increasing number of patients, especially infants and adults with cyanotic CHD and previous surgery, are developing IE. Despite recent advances in diagnosis and treatment, mortality and the rate of complications, such as cardiac failure and systemic embolisation, are high. To reduce mortality and morbidity in patients with CHD and IE, it is necessary to establish guidelines for IE prevention and management based on a large cohort of patients. The nationwide multicentre database was designed to meet this need, and the results should be helpful in establishing guidelines for IE in CHD.

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Authors’ affiliations

K Niwa, S Tateno, Chiba Cardiovascular Centre, Chiba, Japan
M Nakazawa, Tokyo Women’s Medical University, Tokyo, Japan
M Yoshimura, Kagoshima University, Kagoshima, Japan
M Terai, Chiba University, Chiba, Japan

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K Niwa, M Nakazawa, S Tateno, M Yoshinaga and M Terai

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