**Perioperative infection in children with heart disease in high-income countries**

**Supplementary Material Table 1:**

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| Authors | Country | Design | Population and number of subjects | Classification of infection | Type and definition of infections | Frequency of infection | Type of organism |
| Wessel et al., 1987[16](#_ENREF_16) | Germany | Retrospective cohort | Children,  n = 245 | Post operative infection | Fungal and bacterial infection | In 1983-1984, bacterial and fungal infections occurred in 3.6% of 245 compared to 17.8% of 469 in 1968-1972 | Staphylococcal infections decreased from 3.4% to 0.8%  Gram-negative bacteria decreased from 6.9% to 0%  *Candida albicans* infections increased from 0% to 1.2% |
| Pollock et al., 1990[38](#_ENREF_38) | Canada | Prospective cohort | Children,  n = 310 | Post operative infection | Bacteremia was positive culture, but no contamination  Superficial sternal wound infection limited to skin and soft tissue overlying the sternum with or without bacteremia  Deep sternal wound infection (mediastinitis) was infection extending to sternum and/or mediastinum contents with or without bacteremia | 40/310 (12.9%) patients developed nosocomial infections and had 78 episodes of infection, of which 28% (22) were surgical site  Incidence of bacteremia and other central and arterial line-related infections were 6.8/100 | *Staphylococcus aureus* was 70%, coagulase negative staphylococci was 30%, *Pseudomonas aeruginosa* (27%), Candida spp. (27%) |
| Valera et al., 2001[15](#_ENREF_15) | Italy | Prospective cohort study | Children aged ranging from 0 to 441 months,  n = 104 | Post operative infection | Nosocomial infections were diagnosed according to National Nosocomial Infections Surveillance System criteria | Nosocomial infection was 30.8% (32/104): 23.1% developed one infection, 7.7% two or more  Rate of nosocomial infection was 2.17/100 hospitalization-days (50/2304)  Rate of sepsis was 19/1000 catheter-days (16/852)  Risk factors of nosocomial infection: length of preoperative admission >5 days, length of admission >10 days, delayed chest closure, and cyanotic heart disease | The most common pathogen was *Pseudomonas aeruginosa* |
| Allpress et al., 2004[17](#_ENREF_17) | USA | Prospective cohort | Children aged <18 years,  n = 826 | Post operative infection | Surgical site infections was defined using National Nosocomial Infections Surveillance System criteria | Surgical site infection developed in 19/826 (2.3%): limited to soft tissue was 12 and deeper infection was 7  Risk factors of surgical site infection: duration of surgery (OR 1.4; 95%CI 1.2-1.8) and age <1 month (OR 14; 95%CI 3.3-58.4) | *Staphylococcus aureus* yielded in 11, coagulase- negative *Staphylococcus* in 5 and *Escherichia coli* in 2  One patient did not have pathogen isolated |
| Costello et al., 2008[22](#_ENREF_22) | USA | Interrupted time-series design  Intervention included a comprehensive central line–associated bloodstream infection prevention initiative including establishment of a unit-based infection control nurse position, education for physicians and nurses, real-time feedback on central line–associated bloodstream infection data, implementation of central venous line insertion, access, and maintenance bundles, and introduction of daily goal sheets on rounds | Children aged 0.1 to 18 years,  n = 3319 | Post operative infection | Laboratory-Confirmed bloodstream infection was defined using National Healthcare Safety Network Criteria | Preintervention: central line–associated bloodstream infection rate was 7.8/1000 catheter-days  Intervention period: central line–associated bloodstream infection rate was 2.3/1000 catheter-days |  |
| Sarvikivi et al., 2008[13](#_ENREF_13) | Finland | Retrospective cohort | Children aged ranging from 8.7 ± 30.5 months,  n = 511 | Post operative infection | Surgical site infection occurred within 30 days after surgery | Nosocomial infection rate was 6.3/1000 patient-days including 21 superficial and 6 deep surgical site infections |  |
| O’Brien et al., 2010[28](#_ENREF_28) | USA | Retrospective cohort | Children aged <18 years,  n = 992 | Post operative infection | Bacteremia: a positive blood culture (including positive bacterial, fungal, or yeast culture) during the first 14 days after a surgical procedure and experienced signs or symptoms of infection or the infection was treated by the physician | 15/992 (1.5%) patients developed bacteremia  Glucose level associated with postoperative bacteremia (OR 3.3, 95%CI 1.04-10.39) |  |
| Lomtadze et al., 2010[9](#_ENREF_9) | Georgia | Retrospective cohort | Children aged 1 day to 15 years,  n = 387 | Post operative infection | Nosocomial infection was defined based on the National Infections Surveillance System criteria | Nosocomial infection was 62/387 (16%): 55 had one infection and 7 had two different infections  Sepsis was diagnosed in 24 (34,8%), primary bloodstream infection with positive blood cultures were 3 (4,3%), severe sepsis occurred in 1 patient, septic shock – in 2 patients (2,9%)  Nosocomial pneumonia was in 27 (39,1%), surgical site infecion in 8 (11,6%), urinary tract infections in 3 (4,3%), endocarditis in 1 (1,4%) patients | The main most causative Gram-negative agents: Klebsiella spp., *Pseudomonas aeruginosa* and Acinetobacter spp.  The commonest Gram-positive pathogens were *Staphylococcus epidermidis* and *Staphylococcus aureus* |
| Barker et al., 2010[19](#_ENREF_19) | USA | Retrospective cohort,  Multicenter study (48 centers) | Children aged <18 years,  n = 30078 | Post operative infection | Major infection was defined as septicemia, mediastinitis, or endocarditis before hospital discharge, or after discharge if it was attributed to the operation | Of 30078 children, 2.8% had major infection (2.6% septicemia, 0.3% mediastinitis, and 0.09% endocarditis)  Mortality and postoperative length of stay were greater in those with major infection (mortality, 22.2% versus 3%; length of stay >21 days, 69.9% versus 10.7%)  Predictors of major infections: young age, high complexity, previous cardiothoracic operation, preoperative length of stay more than 1 day, preoperative ventilator support, and presence of a genetic abnormality (p<0.001) |  |
| Medrano Lopez et al., 2010[10](#_ENREF_10) | Spain | Prospective cohort | Children aged <24 months,  n = 2613 | Pre operative infection | Acute respiratory infections | Bronchiolitis occurred in 54.1%, upper respiratory tract infection (21%), pneumonia (19.9%), and others (17.4%)  Risk factors for admission: malnourishment, infant age, male gender, chromosome alterations, wheezing, inadequate respiratory syncytial virus prophylaxis fulfillment, and siblings <11 years of age | In one-thirds of the patients no etiologic agent was identified  Respiratory syncytial virus was common in 3.8% specific hospitalization rate |
| Prasad et al., 2010[30](#_ENREF_30) | USA | Retrospective, nested case-control study | Children,  n = 59 | Post operative infection | Definitions of catheter-associated bloodstream infection was based on National Nosocomial Infection Surveillance system criteria | 59 children developed a catheter-associated bloodstream infection  The median time from catheter insertion to onset of infection was 9 days  Catheter was an independent risk factor for infection | Gram positive yielded in 73%, coagulase-negative *Staphylococci* (49%), Gram-negative bacilli (19%), *Staphylococcus aureus* (12%), and other organisms (20%) |
| Costello et al., 2010[21](#_ENREF_21) | USA | A matched case-control study | Children,  n = 216 (72 case of surgical site infection and 144 controls) | Post operative infection | Superficial incisional, deep incisional, or organ space surgical site infection was defined using National Healthcare Safety Network criteria | Independent risk factors for surgical site infection: age <1 year (aOR 2.28; 95%CI 1.18-4.39) and cardiopulmonary bypass time >105 minutes (aOR 1.92; 95%CI 1.02-3.62)  Independent risk factors for organ space surgical site infection: aortic cross-clamp time >85 minutes (aOR 5.61; 95%CI 1.06-29.67) and postoperative exposure to at least three separate red blood cell transfusions (aOR 7.87; 95%CI 1.63-37.92) |  |
| Sohn et al., 2010[32](#_ENREF_32) | USA | Retrospective cohort | Children aged <18 years,  n = 626 | Post operative infection | Definitions for surgical site infection and other ICU-acquired infections were applied | Procedures performed in 46/626 patients (6.3%)  Infections were superficial (n=22; 47.8%), deep tissue (n=7; 15.2%), or organ space (n=17; 37%), including 5 episodes of mediastinitis  Risk factors for surgical site infection: aged <30 days old (OR, 2.9; 95%CI 1.2-70, perioperative medical device, and parenteral nutrition (OR, 3.3; 95%CI, 1.4-7.9) |  |
| Woodward et al., 2011[35](#_ENREF_35) | USA | Cross sectional study,  Multicenter study | Children,  n = 8774 | Post operative infection | Definition of surgical site infection used National Healthcare Safety Network criteria | Of 8774 procedures, mean sternal wound infection rate was 1.53% (range 0 to 9.09)  Variations in preoperative measures, antibiotic regimens, and wound care did not statistically associated with sternal wound infection |  |
| Glass et al., 2011[37](#_ENREF_37) | Canada | Prospective cohort | Infants >36 weeks’ gestation  n = 127 infants | Post operative infection | Bloodstream, pneumonia, or surgical site infection | Infection was in 23/127 infants (18%) consisted of bloodstream infection (13 (10%)), pneumonia (8(6%)), or surgical site infection (7(6%)) | *Staphylococcus epidermidis* – 4 cases – *Escherichia coli, Enterobacter cloacae*, and Bacillus spp – 2 cases each – *Staphylococcus aureus,* Enterococcus spp, and Klebsiellae spp – 1 case each |
| Shin et al., 2011[42](#_ENREF_42) | Korea | Retrospective cohort | Children and adults aged ranging from 2 days to 20 years,  n = 154 | Post operative infection | Wound problems were categorized according to the consensus-based definitions  Sterile wound dehiscence was defined as separation of the layers of the surgical wound with no growth of bacteria on culture and without the signs and symptoms of infection, such as redness, tenderness, or swelling of the surgical wound | Mortality was 28/154 (18.2%)  Sternal wound infection or systemic infection was in 17/154 (11%) patients  Sterile wound dehiscence occurred in 14/154 (9%) patients |  |
| Roeleveld et al., 2011[12](#_ENREF_12) | Netherlands | Retrospective cohort | Children,  n = 125 | Post operative infection | Nosocomial infection was defined using National Nosocomial Infections Surveillance criteria | The rate of ventilator-associated pneumonia was 17.1/1000 mechanical ventilation-days  Patients with pneumonia had longer duration of ventilation and longer ICU stay  Risk factors of ventilator-associated pneumonia: Pediatric Risk of Mortality III score of ≥10 and transfusion of fresh frozen plasma | *Haemophilus influenzae, Moraxella catarrhalis, Staphylococcus aureus* and *Pseudomonas aeruginosa* |
| Marom et al., 2011[41](#_ENREF_41) | Israel | Retrospective cohort | Children aged <18 years,  n = 50 | Pre-operative infection | Infective endocarditis was defined using  Duke’s criteria | Of 51 infective endocarditis episodes, incidence density was 0.32/1000 hospitalizations  20/50 (41%) had an isolated CHD, 13/50 (25%) had an underlying chronic disease, 9/50 (18%) were previously healthy, and 8/50 (16%) were preterm  Mortality rate was 12% (6/51) | Healthcare-associated endocarditis agents were Candida spp(8/30, 27%), coagulase-negative staphylococci (6/30, 20%), and Gram-negative bacilli (5/30, 16%)  Community-associated endocarditis agents were viridans streptococci (8/21, 38%) and *Staphylococcus aureus* (4/21, 19%) |
| Ascher et al., 2012[18](#_ENREF_18) | USA | Retrospective cohort | Infants aged from 4 to 120 days,  n = 11638 | Pre operative sepsis | Sepsis was defined as a positive blood culture  Multiple positive blood cultures for the same organism within a 21-day period were considered a single sepsis episode | Incidence of sepsis was 656/11638 (6%)  Incidence density was 71/1000 admission-day  Predictors of mortality: sepsis (OR 1.53, 95%CI 1.09-2.13), Gram-negative bacteremia (OR 2.01, 95%CI 1.20-3.37), and candidemia (OR 3.18, 95%CI 1.60-6.34) | Gram-positive organisms (64%) and coagulase-negative Staphylococcus and *Staphylococcus aureus* |
| Algra et al., 2012[2](#_ENREF_2) | Netherlands | Retrospective cohort | Children aged <18 years,  n = 102 | Post operative infection | Surgical site infection and bloodstream infection were defined using National Healthcare Safety Network criteria | 25% of 102 had infection: surgical site infection (26% of all infections) and bloodstream infection (25%) |  |
| Harder et al., 2013[25](#_ENREF_25) | USA | A nested case–control study | Children aged <18 years,  n = 375 | Post operative infection | Surgical site infection was defined using National Healthcare Safety Network criteria | 43/375 (11%) developed surgical site infection |  |
| Kansy et al., 2012[8](#_ENREF_8) | Poland | Retrospective cohort | Children aged <18 years,  n = 6314 | Post operative infection | Major infection (septicemia, mediastinitis, or endocarditis) was defined using the same definitions as in the Society of Thoracic Surgery study | 197/6314 (3.1%) had major infections (septicemia 3%, endocarditis 0.015%, mediastinitis 0.09%)  Patients with major infections had greater mortality, ventilation time, and length of stay |  |
| Forstner et al. 2013[3](#_ENREF_3) | Austria | Retrospective cohort study | Children and adults aged ranging from 7 to 88 years,  n = 169 | Post operative infection | Proven invasive candidiasis was defined using standardized invasive fungal disease criteria | 10/169 (5.9%) had proven invasive candidemia |  |
| Pasquali et al., 2013[29](#_ENREF_29) | USA | Prospective cohort,  Multicenter study (28 centers) | Children aged <18 years,  n = 32856 | Post operative infection | Nosocomial infection included sepsis, wound infection, mediastinitis, endocarditis, pneumonia | 3.7% of 32856 had a postoperative infection  Hospitals with the highest infection rates had longer length of stay (13.2 versus 11.7 days, p<0.001) and increased hospital costs ($71,100 versus $65,100, p<0.001), but similar mortality rates (OR 0.99, 95%CI 0.80 -1.21, p=0.9) |  |
| Rushani et al., 2013[39](#_ENREF_39) | Canada | Cross sectional study,  Population-based multicenter study using Quebec CHD Database | Children aged <18 years,  n = 47518 | Pre operative infection | Infective endocarditis on the first hospitalization | Incidence density of infective endocarditis 6.1/1000 hospitalization-day (95%CI 5.0–7.5)  Predictors of endocarditis: cyanotic CHD (aOR 6.44, 95%CI 3.95–10.50), endocardial cushion defects (aOR 5.47, 95%CI 2.89–10.36), left-sided lesions (aOR 1.88, 95%CI 1.01–3.49), cardiac surgery within 6 months (aOR 5.34, 95%CI 2.49–11.43) and aged <3 years (aOR 3.53, 95%CI 2.51–4.96; reference, ages 6–18) |  |
| McNeil et al., 2013[26](#_ENREF_26) | USA | Prospective cohort | Children aged <19 years,  n = 216 | Post operative infection | Nosocomial isolates were defined as those that were isolated > 48 hours of hospitalization  Surgical site infections were regarded as those in which a positive culture for *Staphylococcus aureus* was obtained from a surgical site along with signs and symptoms of infection and the absence of an alternative diagnosis | 248 *Staphylococcus aureus* infections developed in 216 patients  Surgical site infection was 28.2%  Bacteremia was 20.4%  Bacteremia associated with infective endocarditis was 29.5% |  |
| Toth et al., 2013[14](#_ENREF_14) | Hungary | Prospective cohort | Children aged <18 years,  n = 1796 (129 Down syndrome and 1667 non-Down syndrome) | Post operative infection | Infections, catheter-related and deep sternal wound infection, positive blood culture or sepsis | Severe infection was seen in 22.5% of Down’s group versus 11.9% in the non-Down’s syndrome group, p=0.001 |  |
| Fortun et al., 2013[4](#_ENREF_4) | Spain | Prospective cohort | Children and adults aged 8 to 35 years,  n = 821 | Pre operative infection | Infective endocarditis was defined using the Duke’s criteria | Infective endocarditis was in 45/821 (5.5%) involved patients with CHD  In 24/45 cases (53 %), endocarditis involved a prosthetic valve  In 20/45 (44 %) a non-corrected native-valve  Global mortality was 24%  Predictor of mortality: bacteremia confirmed nosocomial endocarditis (OR 23.7, 95%CI 2.3–239.9) |  |
| Murray et al., 2014[27](#_ENREF_27) | USA | Retrospective cohort | Children aged <1 year,  n = 552 | Post operative infection | Surgical site infection, primary and secondary bloodstream infection, and central line–associated bloodstream infections was defined using National Healthcare Safety Network criteria | 19/552 (3.4%) developed surgical site infection and 29/552 (5.2%) developed bloodstream infection  Predictors for surgical site infection: aged <30 days, incorrect timing of preoperative antibiotics, and excessive bleeding within 24 hours of surgery  Predictors for bloodstream infection: duration of use of arterial lines | Gram-positive bacteria caused 75% of surgical site infections and bloodstream infection and methicillin-susceptible *Staphylococcus aureus* caused 63% of surgical site infection |
| Turcotte et al., 2014[33](#_ENREF_33) | USA | Retrospective cohort | Children aged <18 years,  n = 634 | Post operative infection | Definition of nosocomial infection was based on National Healthcare Safety Network criteria | 38/634 (6%) had nosocomial infection including 7 (1%) central line–associated bloodstream infections, 12 (1.9%) non-central line–associated bacteremias, 6 (0.8%) early postoperative endocarditis, 9 (1.3%) surgical site infection, and 4 (0.5%) ventilator-associated pneumonia  Risk factors for nosocomial infection: mechanical ventilation (RR 1.07 per day, 95%CI 1.03–1.11, p=0.0002), postoperative transfusion of blood products (RR 3.12, 95%CI 1.38–7.06, p=0.0062), postoperative steroid use (RR 3.32, 95%CI 1.56–7.02, p=0.0018), and antibiotic prophylaxis >48 h after surgery (RR 2.56, 95%CI 1.31–5.03, p=0.0062) | 66.7 % of the pathogens associated with surgical site infection were susceptible to cefazolin |
| Wei et al., 2015[34](#_ENREF_34) | USA | Retrospective cohort | Small gestational age and non-small gestational age infants weighed <2500 g,  n = 136 | Post operative infection | Postoperative infection was defined as a positive culture or a treatment with antibiotics or antifungal agents for a minimum of 7 days | Older postnatal age at surgery and greater duration of time between birth and surgery was associated with an increased risk of preoperative infection (p<0.0001)  Lower weight at surgery was associated with an increased risk of postoperative infection  A weight of ≥ 2400 g at the time of surgery was associated with lower rates of postoperative infections |  |
| Izquierdo-Blasco et al., 2015[6](#_ENREF_6) | Spain | Before and after study  Intervention: an interdisciplinary infection control program including preoperative, intraoperative, and postoperative measures | Children aged 1 month to 16 years,  n = 64 | Post operative infection | Deep and superficial surgical site infection was defined according to National Healthcare Safety Network criteria | Preintervention: surgical site infection was 10.9% (95%CI 4.7–18.8)  Postintervention: surgical site infection was 1.92% (95%CI 0.4–5.52)  Risk factors for surgical site infection: median age (14 days in infected versus 2.3 years in non-infected patients; p<0.01), hospitalization unit (10.3% surgical site infection cumulative incidence in the Neonatal ICU versus 0 cases in the Pediatric ICU; p<0.01), and median preoperative hospital stay (14 days in infected versus 1 day in non-infected patients; p=0.03) |  |
| Chiu et al., 2016[40](#_ENREF_40) | Taiwan | Retrospective cohort | Children aged <2 years,  n = 8127 (1050 cyanotic CHD and 7077 acyanotic CHD patients) | Pre operative infection | Respiratory syncytial virus hospitalization were respiratory syncytial virus-associated bronchiolitis and viral pneumonia | Total respiratory syncytial virus-associated hospitalization was 2.1% (0-1 year of age) and 0.38% (1-2 year) and mortality rate was 1.9%  Total viral lower respiratory infection hospitalization was 8.6% (0-1 year of age) and 2.1% (1-2 year) and mortality rate 0.6%  Respiratory syncytial virus-associated hospitalization was higher in the cyanotic group than in hemodynamically significant acyanotic and non-hemodynamically significant acyanotic groups both before 1 year of age (4.8% versus 2.1% versus 1.5%, p<0.001) and between 1 and 2 years of age (0.9% versus 0.56% versus 0.14%, p=0.003) |  |
| Granbom et al., 2016[5](#_ENREF_5) | Sweden | Retrospective cohort  Population-based study used Swedish inpatient registry | Children aged <2 years with CHD and non-CHD,  n = 1102310 | Pre operative infection | Respiratory syncytial virus infection hospitalization | Hospitalization due to respiratory infection was 276/9064 (3%) in CHD and 3158/1093246 (0.28%) in non CHD  The relative risk of hospitalization for respiratory syncytial virus infection and respiratory tract infection was increased for all CHD subgroups, and there was a greater increase in risk in summer for the most severe CHD (RR 10.26, 95%CI 9.09–11.58, p<0.0001) |  |
| Resch et al., 2016[11](#_ENREF_11) | Austria | Retrospective cohort | Children aged <2 years,  n = 602 | Pre operative infection | Respiratory syncytial virus hospitalization was defined as hospitalization associated with lower respiratory tract infection and a positive respiratory syncytial virus test result | Respiratory syncytial virus-related hospitalization was 9.6% (58/602), no difference between hemodynamically significant CHD and non-hemodynamically significant CHD (7.3% versus 10.4%, p=0.258)  Patients with hemodynamically significant CHD and early surgery were significantly less often hospitalized due to respiratory syncytial virus compared to those with delayed surgery (1.3% versus 14.3%, p=0.003) |  |
| Jaworski et al., 2016[7](#_ENREF_7) | Poland | Retrospective cohort | Children aged <18 years,  n = 1540 | Post operative infection | Invasive fungal disease was if blood, tissue or bone aspirate samples were positive for microbiological culture | 6/1540 (0.4%) had fungal infection  None of the patients died due to infection in the early postoperative period |  |
| Gupta et al., 2016[24](#_ENREF_24) | USA | Retrospective cohort study | Children aged <19 years,  n = 3840 | Pre operative infection | Infective endocarditis was defined using Duke’s criteria | Incidence of infective endocarditis was 0.43/100000 children  30.2% of cases were culture-negative  Overall mortality was 2.8% | Staphylococcus species were in 43.1%, Streptococcus species in 39.5%. Viridans Streptococcus group was most common in those with heart disease (32.7%) and *Staphylococcus aureus* was common in non-heart disease (46.9%) |
| Chu et al., 2017[20](#_ENREF_20) | USA | Cohort retrospective | Children aged <2 years,  n = 549265 | Pre operative infection | Respiratory syncytial virus hospitalizations were hospitalizations with bronchiolitis, pneumonia, or respiratory syncytial virus infection | Respiratory syncytial virus hospitalization in children with hemodynamically significant CHD was 2518/549265 (0.5%)  Incidence of respiratory syncytial virus hospitalization decreased by 36% when comparing pre and post-palivizumab eras versus an 8% decline in children non significant CHD (p<0.001)  Children with hemodynamically significant CHD had higher rates of respiratory syncytial virus-associated mortality (4.9 versus 0.1%, p<0.001) and morbidity (31.5 versus 3.5%, p<0.001) and longer hospital length of stay (17.9 versus 3.9 days, p<0.001) compared with children without significant CHD |  |
| Sochet et al., 2017[31](#_ENREF_31) | USA | Retrospective matched cohort study | Children aged <18 years,  n = 981 | Post operative infection | Surgical site infection was defined using National Healthcare Safety Network criteria | Surgical site infection was 12/981 (1.2%)  Children with surgical site infection had longer median cardiac ICU stay (9 versus 3 days, p<0.01), hospital stay (18 versus 8.5 days, p<0.01), and duration of ventilator (2 versus 1 day, p<0.01) and vasoactive use (4.5 versus 1 day, p<0.01) |  |
| Moynihan et al., 2017[36](#_ENREF_36) | Australia | Retrospective cohort | Children aged <18 years,  n = 1737 | Post operative infection | Viral respiratory infection | Respiratory virus polymerase chain reaction was positive in 73/1737 (4.2%) included rhino/enterovirus (48%), adenovirus (32%), parainfluenza virus (10%), and respiratory syncytial virus (3%)  Virus positive patients were more likely to require pediatric ICU admission >4 days (OR 3.5; 95%CI 1.9–6.2) and intubation >48 hours (OR 2.5; 95%CI 1.4–4.7), but no difference in mortality |  |
| Delgado-Corcoran et al., 2017[23](#_ENREF_23) | USA | Before and after study  Pre-operative: preoperative patients had a regular bath and mupirocin ointment  Operative: chlorhexidine and perioperative antibiotics every 3 hours  Post operative: antibiotics for 48 hours and dressing removal at 48 hours  Development of surveillance: readmission data, cardioaccess, antibiotic use > 72 hours after chest closure | Children,  n = 1747  Preintervention: children aged 40 (7–131) days (n = 847)  Postintervention: children aged 130 (6-1387) days (n=900) | Post operative infection | Wound infections were defined using National Healthcare Safety Network criteria as superficial, organ space, or nonsurgical site | Preintervention: 32 patients (3.8%) developed sternal wound infection  Postintervention: 19 (2.1%) developed sternal wound infection (p=0.04)  Patients with delayed sternal closure had significantly lower post intervention infection (10.6% versus 3.9%; p=0.02) |  |

CHD=congenital heart disease; OR=odds ratio

**Table 2.** **Perioperative infection in children with heart disease in low- to middle-income countries**

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| Authors | Country | Design | Type and number of subjects | Classification of infection | Type and definition of infections | Frequency | Type of organism |
| Tan et al., 2004[44](#_ENREF_44) | China | Retrospective cohort | Infants aged 8 days to 12 months,  n = 311 | Post operative infection | Nosocomial pneumonia was defined using National Nosocomial Infections Surveillance criteria  Early-onset nosocomial pneumonia: onset of pneumonia <5 days Late-onset pneumonia: ≥5 days after ICU admission | 67/311 (21.5%) patients had nosocomial pneumonia who was more frequently associated with complex CHD compared to simple CHD (43% versus 15.9%, p<0.0001)  Proportion of late-onset nosocomial pneumonia was higher in patients with complex CHD (p=0.014) | Gram-negative bacilli was 68 (86.1%), fungi was 6 (7.6%) and Gram-positive cocci was 5 isolates (6.3%)  The main Gram-negative bacilli: *Acinetobacter baumanii* (11 isolates, 13.9%), *Pseudomonas aeruginosa* (10 isolates, 12.7%), *Flavobacterium meningosepticum* (7 isolates, 8.9%), *Klebsiella pneumoniae* (7 isolates, 8.9%), *Escherichia coli* (6 isolates, 7.6%), *Xanthomonas maltophilia* (5 isolates, 6.2%)  The most common Gram-positive cocci: *Staphylococcus aureus* (2 isolates, 2.5%), *Staphylococcus epidermidis* (2 isolates, 2.5%)  Fungi: *Candida albicans* (5 isolates, 6.3%)  There were one case of methicillin-resistant *Staphylococcus aureus* and 1 case of methicillin-resistant *Streptococcus epidermidis* |
| Bakshi et al., 2007[47](#_ENREF_47) | India | Retrospective cohort | Neonates aged <30 days,  n = 330 | Post operative infection | Post operative bloodstream infection:  a positive blood culture  Superficial wound infection was if the sternum was stable and deep if there was bony involvement and sternal instability | 17 (21.2%) patients had bloodstream infection, and 55 (12.7%) patients had surgical site infection |  |
| Vida et al., 2007[60](#_ENREF_60) | Guatemala | Retrospective cohort | Children aged 2 to 131 months,  n = 535 | Post operative infection | Mediastinitis | 18/535 (3.3%) developed mediastinitis |  |
| Rosanova et al., 2009[56](#_ENREF_56) | Argentina | Retrospective cohort | Children aged <18 years,  n = 350 | Post operative infection | Definition of post operative infections used National Healthcare Safety Network criteria | 38/350 (11%) had post operative infection  4/350 (1%) were superficial wound infections, 5 (1.5%) were deep infections, 3 (1%) had mediastinitis and 26 (7.5%) had sepsis | Surgical site infection:  *Staphylococcus aureus* (5),coagulase-negative Staphylococcus(1), *Pseudomonas aeruginosa* (1), Salmonella spp(1), and negative cultures (4)  Gram negatives bacilli was found in non surgical infections |
| Abou Elella et al., 2010[54](#_ENREF_54) | Saudi Arabia | Prospective cohort | Children,  n = 311 | Post operative infection | Bloodstream infection was defined using National Healthcare Safety Network criteria | 27/311 (8.6%) developed bloodstream infection and incidence rate was 25.8/1000 central line-days  Risk factors of bloodstream infection: lower weight (p=0.005), high surgical complexity score (p<0.05), open sternum (p<0.05), longer duration of central lines (p<0.0001), and prolonged pediatric cardiac ICU and hospital stay (p<0.0001) | Gram-negative was 67% of bloodstream infection, Pseudomonas spp was 28% and Enterobacter spp was 22% |
| Hadzimuratovic et al., 2010[57](#_ENREF_57) | Bosnia Herzegovina | Retrospective cohort | Premature infants with gestational age of 24 to 36 weeks,  n = 80 | Pre operative infection | Late sepsis syndrome: sepsis acquired from caregiving environment | Late sepsis syndrome was 14/80 (17.5%)  Culture proven sepsis was 4/14 (28.6%) | *Staphylococcus aureus*, Klebsiella spp, Serratia spp |
| Senthilkumar et al., 2010[50](#_ENREF_50) | India | Retrospective cohort | Children and adults aged 11 to 20 years old,  n = 116 | Pre operative infection | Infective endocarditis was defined using Duke’s criteria | Definite endocarditis was 99/116 (81.8%)  “Probable” endocarditis was 17/116 (14.1%)  Underlying disease of rheumatic heart disease was 81/116 (69.8%), CHD was 24/116 (20.7%) and idiopatic was 11/116 (9.5%) | Culture negative was 89/116 (76.7%)  Culture positive was 27/116 (23.3%)  Viridans group streptococci was 5/27 (55.5%) Staphylococcus spp. was 4/27 (14.8%) Pseudomonasspp was 2/27 (7.4%) *Corynebacterium diphtheria* was 1/27 (3.7%) *Acinetobacter baumannii* was 1/27 (3.7%)  *Salmonella enterica serovar Typhi* was 1/27 (3.7%) *Granulicatella adiacens* was 1/27 (3.7%) |
| Jacomo et al., 2011[53](#_ENREF_53) | Brazil | Randomized controlled trial  Oral hygiene with 0.12% chlorhexidine gluconate or placebo preoperatively and twice a day postoperatively until pediatric ICU discharge or death | Children,  n = 160 | Post operative infection | Nosocomial pneumonia and ventilator-associated pneumonia was defined using National Nosocomial Infections Surveillance System criteria | Nosocomial pneumonia was 29.8% versus 24.6% (p=0.46) and the incidence of ventilator-associated pneumonia was 18.3% versus 15% (p=0.57) in the chlorhexidine and the control group, respectively |  |
| Wang et al., 2014[45](#_ENREF_45) | China | Retrospective cohort  Group A: In 2000-2011  Group B: In 1964-1999 | Children aged 1 month to 16 years old,  n = 106 | Pre operative infection | Infective endocarditis was defined using Duke’s criteria | Group A:  CHD related endocarditis was 27/34 (79.4%) and  rheumatic heart disease related endocarditis was 2/34 (5.9%)  Group B:  CHD related endocarditis was in 40/72 (55.6%) and rheumatic heart disease related endocarditis was 14/72 (11.4%) | Group A:  Culture positive was 12/30 (40%) included *Staphylococcus aureus, Streptococcus viridians, Enterobacter faecium, Streptococcus agalactiae, and Staphylococcus sciuri*  Group B:  Culture positive was 25/67 (37.3%) and the microorganisms were similar to those in group A |
| Zhang et al., 2014[46](#_ENREF_46) | China | Cross sectional | Children aged from 3 to 9 years old,  n = 300 | Post operative infection | Infection rate:  children were tested as positive by sputum culture | Infection was 120/300 (40%) patients  Risk factors for infection: hospitalization stay length, combined use of antibiotics, systemic use of hormones, mechanical ventilation and catheter indwelling | Of the 150 isolated pathogenic microbial strains, 100/150 (66.6%) were Gram-positive, 40/150 (26.7%) Gram-negative bacteria and 10/150 (6.7%) fungi  The most common pathogens: *Streptococcus epidermidis, Staphylococcus aureus,* Enterococcus spp, *Pseudomonas aeruginosa,* *Candida albicans* |
| Shaath et al., 2014[55](#_ENREF_55) | Saudi Arabia | Prospective cohort | Children aged <14 years,  n = 137 | Post operative infection | Ventilator-associated pneumonia was defined according to National Healthcare Safety Network criteria | Ventilator-associated pneumonia occurred in 9/137 (6.6 %) patients  Ventilator-associated pneumonia density rate was 29/1000 ventilator-days  Risk factors for ventilator-associated pneumonia: prolonged cardiopulmonary bypass time, use of total parenteral nutrition, and prolonged ICU stay (p<0.002 for all)  Mortality in ventilator-associated pneumonia was 11 % | 33% ventilator-associated pneumonia had Gram-negative bacilli |
| Sheng et al., 2014[43](#_ENREF_43) | China | Retrospective cohort | Children and adults aged from 3 years to 87 years,  n = 1688 | Post operative infection | Diagnosis of ventilator-associated pneumonia were based on the new guidelines of the American Thoracic Society and the Infectious Diseases Society of America | Ventilator-associated pneumonia was 105/1688 (6.2%) and mortality was 27/105 (25.7%)  Risk factors for ventilator-associated pneumonia: age >70 (p<0.01), emergent surgery (p<0.01), perioperative blood transfusions (p<0.01), reintubation (p<0.01) and days of mechanical ventilation (p<0.01) | 198 pathogen strains were isolated, Gram negative bacteria yielded 137/198 (69.2%), Gram positive bacteria 55/198 (27.8%), and fungi 6/198 (3%)  The main pathogens: *Pseudomonas aeruginosa, Klebsiellae pneumoniae, Staphylococcus aureus,* and *Acinetobacter baumannii* |
| Faria et al., 2014[52](#_ENREF_52) | Brazil | Prospective cohort | Children aged 6-48 months with Down syndrome,  n = 127 | Pre operative infection | Severe infections as sepsis and pneumonia were classified according to the Brazilian guidelines for treatment of severe sepsis | Pneumonia was 23.6% and sepsis was 5.5%  Of the cases of pneumonia, 70% had CHD (p=0.001) and of those with sepsis, 85% presented CHD (p=0.001) |  |
| Jenkins et al., 2014[62](#_ENREF_62) | India, Pakistan, Colombia, Rusia, China, Dominican Republic, Brazil, Argentina, El Savador, Ukraine, Peru, Mexico, Belarus, Vietnam, Uganda, Guatemala, Bangladesh | Before and after study  Intervention: Webinars targeted 3 key drivers: safe perioperative practice, infection reduction, and team-based practice and registry data were audited annually | Children aged <18 years,  n = 15049 | Post operative infections | In-hospital mortality, 30-day mortality, surgical site infection, and bacterial sepsis  Any major infection was defined as surgical site infection and/or bacterial sepsis based on National Healthcare Safety Network criteria | Unadjusted mortality was 6.3% and any major infection was 7%  Overall standardized mortality ratios were 0.71 (95%CI 0.62–0.81) in 2011 and 0.76 (95%CI 0.69–0.83) in 2012, compared with 2010 baseline  Standardized mortality ratio among 7 sites participating in all 3 years were 0.85 (95%CI 0.71–1.00) in 2011 and 0.80 (95%CI 0.66–0.96) in 2012; among 14 sites participating in 2011 and 2012, the mortality was 0.80 (95%CI 0.70–0.91) in 2012 |  |
| Patwary et al., 2015[48](#_ENREF_48) | India | Prospective cohort | Children aged 27 days to 7 years,  n = 84 | Pre and post operative infection | Pre operative infection  Post operative septicemia | Pre operative infection was 28/84 (33.3%)  Pre operative infection associated with increased mortality (OR 4.1, 95%CI 1.2– 13.9), p=0.02)  Postoperative septicemia was associated with early mortality |  |
| Moges et al., 2015[59](#_ENREF_59) | Ethiopia | Retrospective cohort | Children aged <18 years,  n = 40 | Pre operative infection | Infective endocarditis was defined using  Duke’s criteria | 41 episodes of infective endocarditis with underlying risk factors were rheumatic heart disease in 49% and CHD in 51% of cases |  |
| Kabbani et al., 2016[63](#_ENREF_63) | Saudi Arabia | Retrospective cohort | Children aged <14 years,  n = 413 | Post operative infection | Nosocomial urinary tract infection | Catheter-associated urinary tract infection were 29/413 (7%)  Incidence density was 18/1000 catheter-days (1578 urinary catheter-days)  Risk factors for catheter-associated urinary tract infection: duration of urinary catheter placement (p<0.001), presence of congenital abnormalities of kidney and urinary tract (p<0.0041) and the presence of syndromes (Down, William, and Noonan) (p<0.02) | Gram-negative bacteria were 63% of the catheter-associated urinary tract infection  Klebsiellae spp was 27%, Candida spp was 24% and *Escherichia coli* was 21%  Resistant organisms were 34% of catheter-associated urinary tract infection |
| Mirzaei et al., 2016[58](#_ENREF_58) | Iran | Cross sectional study | Children aged 7 days to 18 years,  n = 203 | Post operative infection | Definition of infection was not available | 7.8% patients had infection |  |
| Sahu et al., 2016[49](#_ENREF_49) | India | Retrospective cohort | Children and adults,  n = 6864 | Post operative infection | Nosocomial infections were infections developed within 48 hours  Lower respiratory tract infections included bronchitis, pneumonitis, and pneumonia  Surgical site infection included nonhealing wound with or without discharge involving the sternal wound and/or leg or arm and culture proven pathogens from the discharge  Bloodstream infection was bloodstream infection‐culture proven pathogens in blood, sampled from one central, and one peripheral site  Urinary tract infection was >105 colony forming bacterial units on culture | 319/6864 patients (4.6%) developed nosocomial infection  Lower respiratory tract infections were 44.2%  Surgical site infection was 11.6%  Bloodstream infection was 7.5%  Urinary tract infection was 6.9%  Infections from combined sources were 29.8% |  |
| de Araujo Motta et al., 2016[51](#_ENREF_51) | Brazil | A matched case control study | Children aged <18 years,  n = 30 | Post operative infection | Candidemia | 0.7/1000 patient-days had candidemia  Risk factors of candidemia: Risk Adjustment for Congenital Heart surgery-1 category of ≥3 (OR 3.165, 95%CI 1.377–8.467), acid suppression therapy (OR 1.9, 95%CI 0.949–3.979), thrombocytopenia (OR 2.2, 95%CI 1.2–4.2) |  |
| Mohamed Ali et al., 2017[61](#_ENREF_61) | Sudan | Cross sectional study | Children aged 3 to 12 years,  n = 160 (80 CHD and 80 controls) | Pre operative infection | Caries and gingivitis  The definition used decayed, missing, filled teeth index criteria | CHD cases had a significantly higher caries (decayed, missing, filled teeth index=4.1 versus 2.3, p<0.05; decayed, missing, filled teeth index=1.4 versus 0.7, p<0.05) and a higher mean number of examined teeth with gingivitis (4.2 versus 2.0; p<0.05) compared with controls | *Streptococcus mutans* counts were significantly higher among the CHD cases (p<0.05) |

CHD=congenital heart disease; OR=odds ratio