Circulation Journal
Circ J 2025; 89: 946–956
doi:10.1253/circj.CJ-24-0843

ORIGINAL ARTICLE
ACHD

Clinical Characteristics and Outcomes of Cardiac Surgery and Transcatheter Procedures in Patients With Adult Congenital Heart Disease

— Insights From Japanese Registry Data —

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Background: Adult congenital heart disease (ACHD) patients often require additional interventions or surgeries in adulthood, presenting new clinical challenges. However, clinical research on the current status and outcomes of cardiac procedures in ACHD patients remains limited.

Methods and Results: We analyzed the Japanese Registry of All Cardiac and Vascular Diseases-Diagnosis Procedure Combination (JROAD-DPC) database between April 2013 and March 2021. Patients with ACHD (aged >15 years) who underwent major cardiac surgery and transcatheter procedures were included. We assessed clinical background, treatment, length of hospital stay, and in-hospital mortality. In all, 22,490 patients with ACHD (median age 56 years [interquartile range 36–69 years], 51.1% female) were enrolled. Emergency hospitalizations and in-hospital deaths were observed in 3.7% and 1.1% of cases, respectively. Congenital heart operations with high in-hospital mortality (>5.0%) included aortic arch repair, systemic-to-pulmonary artery shunts, cardiac tumor resection, coronary artery bypass grafting, 3-valve replacement, and ventricular assist device implantation. Although stent graft procedures had the highest in-hospital mortality rate (2.6%), other transcatheter procedures, such as transcatheter patent ductus arteriosus closure, atrial septal defect closure, and catheter ablation, had in-hospital mortality rates of <1.0%.

Conclusions: This study provides fundamental insights into the current clinical characteristics and outcomes associated with procedures in patients with ACHD. The in-hospital mortality rates for both cardiac surgery and transcatheter procedures in Japanese ACHD patients were low, demonstrating acceptable outcomes.

Key Words: Adult congenital heart disease; Cardiac surgery; Congenital heart disease; Japanese Registry of All Cardiac and Vascular Diseases-Diagnosis Procedure Combination (JROAD-DPC); Percutaneous interventions

The number of patients with adult congenital heart disease (ACHD) has increased significantly over the past several decades due to advances in therapies for pediatric congenital heart disease (CHD).[1,2] The shift towards surgical correction and repair alternatives to palliative repair has increased the number of patients with ACHD.[3] Consequently, ACHD has become an important aspect of cardiovascular disease practice globally. The number of adult patients with complex CHD after cardiac surgery is also increasing, with patients with moderate or severe CHD accounting for 32% of all cases of ACHD.[4] In patients with ACHD, cardiac surgery for CHD in childhood is not always curative; complications, residual disease, and sequelae different from those in childhood are common. Therefore, patients with ACHD may require cardiac intervention or surgery. In addition, some adult patients are first diagnosed with CHD and may need interventional procedures in adulthood.

Recently, significant advances have been made in transcatheter procedures for structural heart diseases and

Received October 23, 2024; revised manuscript received February 23, 2025; accepted March 10, 2025; J-STAGE Advance Publication released online May 25, 2025 Time for primary review: 28 days

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ISSN-1346-9843

arrhythmias. Procedures such as transcatheter aortic valve implantation (TAVI), mitral valve transcatheter edge-to-edge repair (M-TEER), percutaneous patent foramen ovale (PFO) closure, percutaneous atrial septal defect (ASD) closure, and patent ductus arteriosus (PDA) closure have become well established.[5–9] These less invasive treatments are suitable for high-risk surgical patients, including those who have undergone multiple surgeries. Moreover, patients with ACHD often experience atrial and fatal ventricular arrhythmias, and catheter ablation for these arrhythmias has become increasingly common.[8,9]

Despite these advances, little clinical research has assessed outcomes after cardiac procedures in patients with ACHD. The overall perioperative mortality rate after CHD surgery in patients with ACHD is approximately 2–3%.[10–12] Previous analyses evaluating outcomes of congenital heart operations in adults focused on in-hospital mortality per type of cardiac surgery.[11,12] However, these studies did not discuss in-hospital mortality related to transcatheter interventions. Using current data to understand the present status of surgical and catheter procedures and in-hospital outcomes for ACHD patients will help clinicians assess the risk–benefit ratio, thereby facilitating informed patient explanations and optimizing treatment choices.

The aim of this study was to clarify the clinical outcomes of cardiac procedures, including surgical and catheter interventions, in patients with ACHD using the large-scale nationwide claims-based Japanese Registry of All Cardiac and Vascular Disease-Diagnostic Procedure Combination (JROAD-DPC) dataset.

Table 1. Baseline Clinical Characteristics of ACHD (n=22,490)

Clinical characteristics	
Age (years)	56 [36–69]
Female sex	11,487 (51.1)
BMI (kg/m²)	22.0 [19.7–24.5]
Emergency hospitalization	843 (3.7)
Length of ICU hospitalization (days)	2 [1–4]
Length of hospitalization (days)	12 [6–22]
Hospital characteristics and inpatient departments	
Bed count	656 [462–864]
JSACHD-certified hospital	9,863 (43.9)
Department of pediatrics	1,946 (8.7)
Department of cardiology	7,993 (35.5)
Department of cardiovascular surgery	8,797 (39.1)
Comorbidities	
Hypertension	6,567 (29.2)
Diabetes	2,379 (10.6)
Hyperlipidemia	3,007 (13.4)
Renal disease	687 (3.1)
Liver disease	530 (2.4)
Cerebrovascular disease	1,365 (6.1)
Peripheral vascular disease	1,678 (7.5)
Chronic pulmonary disease	643 (2.9)
Cancer	382 (1.7)
Dementia	80 (0.4)
Atrial fibrillation	1,009 (4.5)
Endocarditis	328 (1.5)
Therapy	
Dialysis	355 (1.6)
IABP	263 (1.2)
VA-ECMO	140 (0.6)
All-cause death	
24-h death	6 (0.03)
30-day death	130 (0.6)
In-hospital death	243 (1.1)

Data are given as the median [interquartile range] or n (%). ACHD, adult congenital heart disease; BMI, body mass index; IABP, intra-aortic balloon pumping; ICU, intensive care unit; JSACHD, Japanese Society for Adult Congenial Heart Disease; VA-ECMO, veno-arterial extracorporeal membrane oxygenation.

Methods

The data used in this article are provided by the Japanese Circulation Society for research purposes. It cannot be shared publicly without the permission of the Japanese Circulation Society.

Data Source

This study was conducted using the JROAD-DPC database, which combines data from the JROAD nationwide survey by the Japanese Circulation Society, aimed at evaluating clinical activities in Japanese hospitals, and DPC data, maintained by the Ministry of Health, Labour and Welfare of Japan, based on the diagnosis-related group classification of inpatients. The JROAD-DPC database includes the following clinical information: age, sex, height, weight, diagnosis/comorbidities based on the International Classification of Diseases (ICD)-10 diagnosis codes, treatment contents, hospital length of stay, and admission and discharge status. Procedural details for patients with ACHD are derived from healthcare claims, which are requests for payments submitted by healthcare providers to insurance companies after treatment. Some patients underwent multiple invasive procedures. Our group has previously conducted studies using the same database.[13,14]

Study Design and Population

Inpatient data for patients with ACHD was collected for the period April 2013 to March 2021. The identification of ACHD hospitalizations was based on ICD-10 diagnosis codes (ACHD: Q200–269). We included patients with ACHD aged >15 years who underwent cardiac surgery or transcatheter procedures. Patients were excluded if they were aged <15 years, did not undergo major cardiac surgery or catheter interventions, and had insufficient data. Major cardiac surgeries and catheter interventions are listed in **Table 1**. Heart transplants were not considered in this analysis due to the lack of available data. In the DPC system, multiple procedures performed during a single operation are typically registered with their corresponding K-codes in order of importance or based on medical fee points. The JROAD-DPC database allows for the extraction of surgical or catheter procedure names from "Operation Name 1" to "Operation Name 10." However, procedures listed later in this order are less likely to be directly related to the patient's primary medical condition. In the present study, to more accurately analyze the relationship between surgical procedures particularly related to the primary pathology and clinical outcomes, we extracted only procedures corresponding to "Operation Name 1" and "Operation Name 2".

We assessed clinical characteristics and mortality rates, including 24-h, 30-day, and in-hospital mortality, all mea-

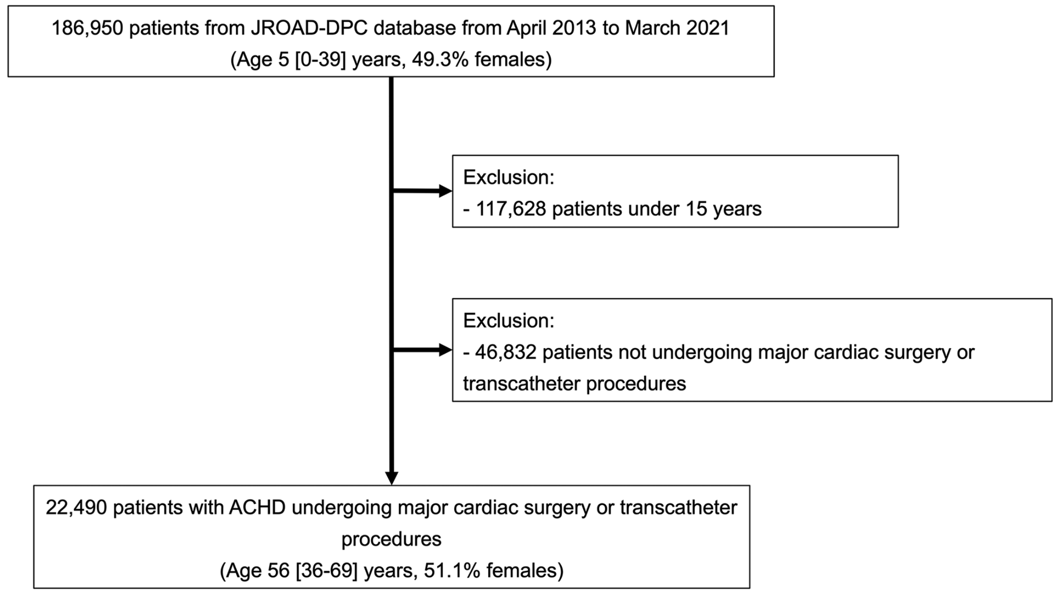

Figure 1. Patient flowchart. ACHD, adult congenital heart disease; DPC, diagnostic procedure combination; IQR, interquartile range; JROAD, Japanese Registry of All Cardiac and Vascular Diseases.

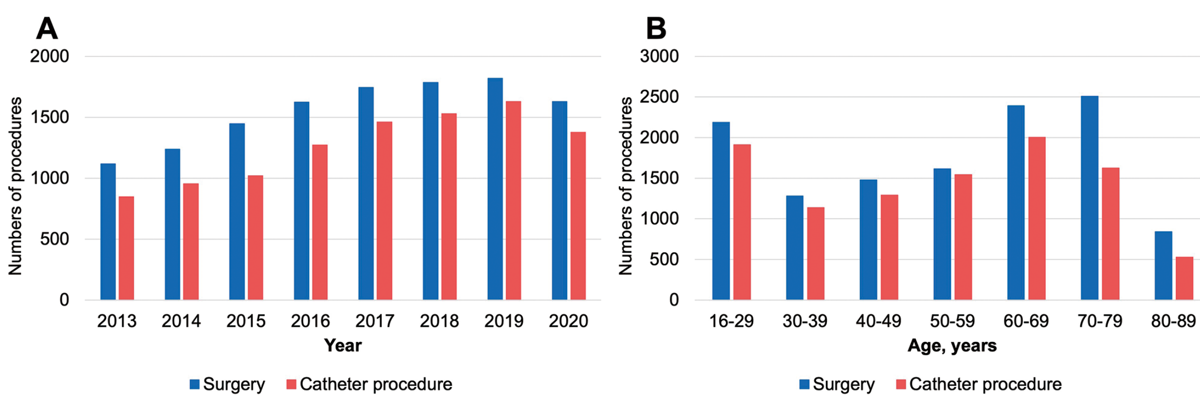

Figure 2. Number of surgical and transcatheter procedures by (**A**) year and (**B**) age group. Invasive interventions for patients with adult congenital heart disease were almost evenly split between cardiac surgery and transcatheter procedures every year (**A**). Cardiac surgery and percutaneous interventions were performed in all age groups, with higher frequencies observed in the 16–29- and 60–79-year age groups (**B**).

sured from the time of admission rather than after any procedure. The demographic and clinical information of patients with ACHD were analyzed, including age, sex, body mass index (BMI), emergency admission (ambulance), hospital bed count, hypertension, diabetes, hyperlipidemia, liver disease, renal disease, chronic pulmonary disease, cancer, length of intensive care unit stay, and in-hospital length of stay. Emergency hospitalization was defined as hospitalization with emergency medical services. In this study, the year was defined in a fiscal year format, beginning in April and ending in March the following year. We also evaluated patient background and clinical outcomes in Japanese Society for Adult Congenital Heart Disease (JSACHD)-certified and non-certified hospitals. JSACHD-certified hospitals were defined as facilities with cardiologists, pediatric cardiologists, and cardiovascular surgeons, all certified as ACHD specialists by the JSACHD. In addition, the facilities must have a multidisciplinary care system for ACHD, including collaboration with obstetrics, radiology, psychiatry, and genetic counseling departments.

After evaluating the clinical characteristics and outcomes of surgical or transcatheter interventions, we further assessed the current therapeutic status of ASD and PDA, which have both surgical and percutaneous closure options.

Ethics Statement

This study was conducted in accordance with the principles of the Declaration of Helsinki. The study was designed by the authors and approved by the Institutional Review Board of the University of Tsukuba (Approval no. 1543). No information that could identify individual patients or hospitals was available, and the requirement for informed consent was waived owing to the anonymous nature of the database. Each hospital anonymized patient identification using code change equations made by individual hospitals in the original DPC data. The National Cerebral and Cardiovascular Center managed the database.

Statistical Analysis

Continuous variables are presented as median values with the interquartile range (IQR) and were compared between groups using Student's t-test. Categorical data are presented as absolute numbers and percentages and were compared using Chi-squared tests. The Cochran-Armitage test was used to analyze trends in the proportions of surgical and transcatheter procedures over time. Statistical significance was set at $P<0.05$. All analyses were performed using Stata 17.0 statistical software (StataCorp, College Station, TX, USA).

Results

Study Population and Patients' Clinical Characteristics

Figure 1 shows the patient flow diagram for this study. Of the 186,950 patients with CHD (median age 5 years [IQR 0–39 years], 49.3% female) in the JROAD-DPC database between April 2013 and March 2021, 117,628 patients aged <15 years and 46,832 patients with ACHD who did not undergo major cardiac surgery or transcatheter interventions were excluded. Thus, 22,490 patients with ACHD who underwent major cardiac surgery or percutaneous intervention (median age 56 years [IQR 36–69 years], 51.1% female) were enrolled in the present study. **Table 1** presents the clinical characteristics of the included patients. Emergency hospitalizations were observed in 3.7% of cases. Common comorbidities included hypertension (n=6,567; 29.2%), diabetes (n=2,379; 10.6%), hyperlipidemia (n=3,007; 13.4%), and cerebrovascular disease (n=1,365; 6.1%). The incidence of intra-aortic balloon pumping or veno-arterial extracorporeal membrane oxygenation during hospitalization was approximately 1%. The in-hospital mortality rate was 1.1%.

Figure 2A shows trends in the number of surgical and catheter-based procedures over time. As shown in **Figure 2A**, invasive interventions for patients with ACHD were almost evenly split between cardiac operations and transcatheter procedures each year and there was a slight increase in the ratio of catheter procedures over time (P for trend<0.001). Cardiac surgery and percutaneous interventions were performed in all age groups, with higher frequencies observed in the 16–29- and 60–79-year age groups (**Figure 2B**).

The background and clinical outcomes between specialized and non-specialized hospitals are presented in the **Supplementary Table**. Certified hospitals for ACHD had younger patients with a lower prevalence of lifestyle-related diseases. More than half the patients admitted to certified hospitals underwent transcatheter procedures and had shorter hospital stays. The in-hospital mortality rates for certified and non-certified hospitals were 0.6% and 1.4%, respectively.

Clinical Outcomes of Cardiovascular Surgery

Table 2 presents clinical characteristics and mortality by procedural group. Emergency hospitalization via ambulance (>5.0%) was more common among patients undergoing surgical treatment of subvalvular aortic stenosis, anomalous coronary repair, pacemaker implantation, implantation of an automatic implantable cardioverter defibrillator, surgical procedures for sinus of Valsalva aneurysm, surgical interventions for right ventricle aneurysm, aortic arch repair, surgery for aortic aneurysm, non-valve-sparing aortic root replacement, cardiac tumor resection, coronary artery bypass grafting (CABG), multiple valve replacement, and aortic valve surgery/ascending aorta replacement.

Cardiac surgeries with (<1.0%) low in-hospital mortality rates included surgical ASD closure, partial anomalous pulmonary venous connection repair, pacemaker implantation/procedure, explantation of a pacing system, vascular ring repair, Ebstein's repair, pulmonic valvuloplasty, surgical procedures for supravalvular aortic stenosis, surgery for a right ventricle aneurysm, surgical interventions for double-chamber right ventricle, repair of incomplete atrioventricular septal defect, systemic venous stenosis repair, tetralogy of Fallot repair, Ross procedure, coarctation repair, and ASD creation or enlargement. Conversely, procedures with high (>5.0%) in-hospital mortality rates included aortic arch repair, systemic-to-pulmonary shunting, cardiac tumor resection, CABG, 3-valve replacement, and ventricular assist device implantation.

Clinical Outcomes of Cardiovascular Catheter Intervention

Table 3 presents the clinical characteristics of the cardiovascular percutaneous procedures. Emergency hospitalization occurred for patients undergoing TAVI or M-TEER. The length of hospital stay was longer for patients who underwent TAVI, M-TEER, and stent graft procedures. Stent graft implantation had the highest in-hospital mortality rate at 2.6%. TAVI, percutaneous PDA closures, percutaneous pulmonic valvuloplasty, balloon pulmonary angioplasty, percutaneous ASD closures, percutaneous PFO closures, percutaneous transvenous mitral commissurotomy, M-TEER, and catheter ablation all had in-hospital mortality rates of ≤1.0%.

For patients undergoing TAVI, the ICD-10 codes Q230 (congenital aortic valve stenosis), Q231 (congenital aortic valve regurgitation, bicuspid aortic stenosis), and Q253 (Williams syndrome, supravalvular aortic stenosis, aortic stenosis) had been registered. For patients who underwent M-TEER, Q211 (ASD) and Q213 (tetralogy of Fallot) were listed as disease names in addition to I340 (mitral regurgitation).

Clinical Outcomes of Percutaneous and Surgical ASD Closures

Supplementary Figure 1A shows the number of surgery and transcatheter ASD procedures by year, indicating a slight increase in the ratio of percutaneous ASD closures over time (P for trend<0.001). **Supplementary Figure 1B** shows that percutaneous ASD closures were more prevalent across all ages, with the number of both treatments showing a bimodal distribution, with higher prevalence in the 16–29- and 60–69-year age groups. **Table 4** presents the clinical characteristics of patients undergoing surgical and percutaneous ASD closure. In the percutaneous group, there was a high proportion of females, and few patients had hypertension, diabetes, and atrial fibrillation. Surgical

Table 2. Clinical Backgrounds and Outcomes of ACHDs Following Cardiac Surgery

Procedural group	No. patients	Age (years)	Female sex	BMI (kg/m²)	Emergency admission	Bed count (n)	Hypertension	Diabetes
One-valve replacement	2,526	60 [37–73]	1,133 (44.9)	22.3 [19.8–25.0]	113 (4.5)	612 [400–812]	1,012 (40.1)	374 (14.8)
One-valve repair	1,910	61 [49–70]	992 (51.9)	21.9 [19.6–24.2]	53 (2.8)	612 [419–812]	650 (34.0)	251 (13.1)
Surgical ASD closure	1,678	55 [38–67]	972 (57.9)	22.2 [19.8–24.8]	26 (1.6)	612 [450–800]	540 (32.2)	242 (14.4)
Pacemaker implantation	1,344	66 [42–77]	724 (53.9)	21.7 [19.4–24.0]	158 (11.8)	603 [396–812]	428 (31.8)	193 (14.4)
CABG	850	70 [61–77]	282 (33.2)	23.2 [20.8–25.4]	83 (9.8)	602 [400–717]	359 (42.2)	228 (26.8)
Two-valve replacement	817	64 [41–75]	400 (49.0)	21.5 [19.1–24.0]	45 (5.5)	643 [434–852]	222 (27.2)	121 (14.8)
Pacemaker procedure	781	41 [27–68]	421 (53.9)	21.0 [19.0–23.7]	2 (0.3)	632 [405–915]	140 (17.9)	55 (7.0)
Two-valve repair	658	67 [58–74]	327 (49.7)	21.5 [19.4–23.7]	24 (3.7)	611 [405–778]	204 (31.0)	83 (12.6)
Surgical repair of VSD	503	38 [22–55]	212 (42.2)	21.6 [19.3–24.3]	10 (2.0)	644 [500–815]	127 (25.3)	45 (9.0)
Valve-sparing aortic root replacement	317	51 [38–63]	53 (16.7)	23.1 [20.7–25.5]	10 (3.2)	614 [405–862]	153 (48.3)	27 (8.5)
Implantation of automatic ICD	296	48 [34–61]	89 (30.1)	21.7 [19.1–24.3]	79 (26.7)	714 [575–953]	81 (27.4)	32 (10.8)
Aortic valve surgery/ascending aorta replacement	237	66 [51–73]	88 (37.1)	23.3 [20.7–25.6]	28 (11.8)	594 [405–743]	121 (51.1)	23 (9.7)
Repair of sinus of Valsalva aneurysm	188	54 [42–67]	54 (28.7)	22.2 [20.4–24.5]	31 (16.5)	650 [482–844]	85 (45.4)	29 (15.4)
PA reconstruction	178	26 [17–37]	75 (42.1)	20.4 [18.6–23.3]	1 (0.6)	700 [575–956]	23 (12.9)	7 (3.9)
Partial anomalous pulmonary venous connection repair	174	39 [20–59]	95 (54.6)	21.8 [19.5–24.2]	0 (0)	708 [600–1,000]	20 (11.5)	16 (9.1)
Three-valve replacement	172	70 [58–77]	81 (47.1)	23.1 [19.0–23.1]	15 (8.7)	623 [481–789]	44 (25.6)	25 (14.5)
Repair of aortic aneurysm	159	65 [51–74]	46 (28.9)	23.1 [20.6–24.9]	15 (9.4)	482 [391–743]	88 (55.4)	20 (12.6)
Fontan procedure	138	25 [20–30]	63 (45.7)	20.5 [17.9–23.0]	1 (0.7)	855 [550–1,228]	12 (8.7)	6 (4.4)
Repair of double-chamber RV	116	46 [31–63]	72 (62.1)	20.9 [19.2–24.2]	2 (1.7)	685 [602–855]	16 (13.8)	5 (4.3)
Aortic root replacement, non-valve-sparing	102	64 [52–71]	30 (29.4)	25.2 [20.0–25.2]	13 (12.8)	605 [409–749]	45 (44.1)	10 (9.8)
Repair of subvalvular aortic stenosis	100	67 [37–77]	68 (68.0)	20.9 [19.5–24.7]	8 (8.0)	640 [401–933]	41 (41.0)	7 (7.0)
Aortic arch repair	92	66 [54–75]	35 (38.0)	22.3 [20.5–24.4]	16 (17.4)	588 [398–776]	54 (58.7)	9 (9.8)
Konno procedure	91	53 [28–71]	55 (60.4)	22.3 [19.8–25.0]	9 (9.9)	654 [404–934]	31 (34.1)	8 (8.8)
Common AV canal repair	80	51 [32–64]	47 (58.8)	22.1 [19.5–23.8]	0 (0)	663 [424–847]	25 (31.3)	5 (6.3)
Automatic ICD procedure	77	45 [34–59]	25 (32.5)	22.7 [20.7–24.5]	1 (1.3)	663 [434–1,076]	16 (20.8)	12 (15.6)
VAD implantation	75	42 [34–47]	38 (50.7)	19.8 [18.8–21.2]	7 (9.3)	1,086 [658–1,225]	9 (12.0)	6 (8.0)
Three-valve repair	73	53 [34–65]	44 (60.3)	22.4 [19.8–24.1]	1 (1.4)	666 [494–849]	20 (27.4)	5 (6.9)
Conduit RV to PA	65	25 [18–32]	32 (49.2)	20.6 [17.7–23.5]	0 (0)	743 [527–849]	5 (7.7)	3 (4.6)
Ebstein's repair	57	43 [24–63]	38 (66.7)	21.9 [19.5–24.1]	0 (0)	800 [600–1,033]	10 (17.5)	4 (7.0)
Anomalous coronary repair	45	49 [39–67]	20 (44.4)	22.8 [20.3–25.4]	4 (8.9)	613 [369–904]	19 (42.2)	2 (4.4)
Cardiac tumor resection	40	69 [55–76]	21 (52.5)	23.0 [20.6–26.5]	3 (7.5)	602 [453–808]	12 (30.0)	3 (7.5)
Surgical PDA closure	39	49 [32–66]	27 (69.2)	23.4 [17.6–23.4]	1 (2.6)	610 [481–931]	11 (28.2)	2 (5.1)
Coarctation repair	33	25 [17–35]	14 (42.4)	21.2 [18.2–23.8]	0 (0)	700 [608–855]	19 (57.6)	1 (3.0)
Tetralogy of Fallot repair	28	36 [28–51]	18 (64.3)	19.8 [18.2–22.2]	0 (0)	815 [706–852]	6 (21.4)	2 (7.1)
Explantation of pacing system	24	48 [36–64]	10 (41.7)	22.6 [20.6–24.4]	0 (0)	777 [643–1,149]	5 (20.1)	2 (8.3)
Surgical ablation of ventricular arrhythmia	20	41 [27–45]	12 (60.0)	21.3 [17.9–23.5]	0 (0)	665 [654–900]	2 (10.0)	2 (10.0)
Repair of supravalvular aortic stenosis	16	20 [18–41]	8 (50.0)	21.4 [19.1–24.5]	0 (0)	607 [486–756]	6 (37.5)	1 (6.3)
Systemic-to-pulmonary shunts	13	20 [18–28]	9 (69.2)	18.4 [16.8–21.2]	0 (0)	700 [575–849]	0 (0)	0 (0)
Repair of RV aneurysm	10	33 [23–67]	3 (30.0)	20.0 [18.8–24.2]	2 (20.0)	663 [518–1,086]	4 (40.0)	3 (30.0)
Ross procedure	7	17 [16–18]	5 (71.4)	21.2 [18.9–24.7]	0 (0)	612 [316–934]	1 (14.3)	0 (0)
Vascular ring repair	5	27 [19–42]	3 (60.0)	25.8 [18.5–25.8]	0 (0)	613 [575–963]	1 (20.0)	0 (0)
Systemic venous stenosis repair	4	16 [16–17]	1 (25.0)	18.7 [18.0–21.4]	0 (0)	869 [710–1,079]	1 (25.0)	0 (0)
Pulmonic valvuloplasty	3	47 [32–48]	2 (66.7)	24.5 [21.4–27.6]	0 (0)	612 [199–697]	1 (33.3)	1 (33.3)
ASD creation or enlargement*	1							

(**Table 2** continued the next page.)

Procedural group	Hyperlipidemia	Liver disease	Renal disease	ICU stay (days)	Hospitalization (days)	Mortality		
						24 h	30 day	In-hospital
One-valve replacement	492 (19.5)	91 (3.6)	125 (5.0)	3 [2–4]	22 [17–32]	0 (0)	25 (1.0)	53 (2.1)
One-valve repair	250 (13.1)	54 (2.8)	68 (3.6)	2 [2–4]	20 [15–28]	0 (0)	14 (0.7)	23 (1.2)
Surgical ASD closure	227 (13.5)	22 (1.3)	31 (1.9)	2 [1–3]	17 [13–24]	0 (0)	4 (0.2)	10 (0.6)
Pacemaker implantation	166 (12.4)	49 (3.6)	67 (5.0)	3 [2–5]	16 [10–28]	0 (0)	4 (0.3)	13 (1.0)
CABG	259 (30.5)	17 (2.0)	95 (11.2)	4 [2–6]	25 [19–36]	1 (0.1)	29 (3.4)	51 (6.0)
Two-valve replacement	72 (8.8)	34 (4.2)	56 (6.9)	4 [2–6]	27 [21–40]	1 (0.1)	12 (1.5)	28 (3.4)
Pacemaker procedure	50 (6.4)	23 (2.9)	17 (2.2)	1 [1–4]	8 [5–10]	0 (0)	0 (0)	0 (0)
Two-valve repair	65 (9.9)	12 (1.8)	26 (4.0)	3 [2–4]	23 [18–32]	0 (0)	4 (0.6)	8 (1.2)
Surgical repair of VSD	61 (12.1)	12 (2.4)	8 (1.6)	2 [1–3]	16 [13–24]	0 (0)	4 (0.8)	7 (1.4)
Valve-sparing aortic root replacement	51 (16.1)	5 (1.6)	15 (4.7)	3 [2–4]	21 [17–31]	1 (0.3)	6 (1.9)	8 (2.5)
Implantation of automatic ICD	29 (9.8)	7 (2.4)	7 (2.4)	4 [2–9]	21 [12–35]	0 (0)	0 (0)	5 (1.7)
Aortic valve surgery/ascending aorta replacement	46 (19.4)	8 (3.4)	9 (3.8)	4 [2–6]	26 [19–38]	1 (0.4)	10 (4.2)	12 (5.1)
Repair of sinus of Valsalva aneurysm	26 (13.8)	4 (2.1)	6 (3.2)	2 [2–4]	20 [15–27]	0 (0)	2 (1.1)	2 (1.1)
PA reconstruction	4 (2.3)	3 (1.7)	1 (0.6)	2 [1–3]	21.5 [17–29]	0 (0)	0 (0)	5 (2.8)
Partial anomalous pulmonary venous connection repair	10 (5.7)	4 (2.3)	0 (0)	2 [1–3]	18 [15–24]	0 (0)	0 (0)	0 (0)
Three-valve replacement	25 (14.5)	78 (4.1)	18 (10.5)	4 [2–6]	28 [22–46]	0 (0)	6 (3.5)	13 (7.6)
Repair of aortic aneurysm	27 (17.0)	3 (1.9)	11 (6.9)	3 [2–5]	20 [16–29]	0 (0)	4 (2.5)	6 (3.8)
Fontan procedure	1 (0.7)	8 (5.8)	2 (1.5)	4 [2–6]	30 [23–43]	0 (0)	2 (1.5)	2 (1.5)
Repair of double-chamber RV	1 (0.9)	7 (6.0)	3 (2.6)	2 [1–3]	18 [14–25]	0 (0)	0 (0)	1 (0.9)
Aortic root replacement, non-valve-sparing	16 (15.7)	3 (2.9)	3 (2.9)	3 [2–5]	25 [18–35]	0 (0)	4 (3.9)	5 (4.9)
Repair of subvalvular aortic stenosis	17 (17.0)	3 (3.0)	3 (3.0)	3 [2–4]	24 [19–37]	0 (0)	1 (1.0)	4 (4.0)
Aortic arch repair	13 (14.1)	3 (3.3)	1 (1.1)	3 [2–5]	26 [17–38]	1 (1.1)	5 (5.4)	6 (6.5)
Konno procedure	13 (14.3)	3 (3.3)	3 (3.3)	3 [2–7]	25 [20–42]	0 (0)	1 (1.1)	2 (2.2)
Common AV canal repair	11 (13.8)	2 (2.5)	0 (0)	2 [2–4]	17 [15–23]	0 (0)	0 (0)	0 (0)
Automatic ICD procedure	10 (13)	3 (3.9)	4 (5.2)	8 [3–14]	8 [7–10]	0 (0)	0 (0)	1 (1.3)
VAD implantation	2 (2.7)	2 (2.7)	5 (6.7)	11 [7–14]	34 [9–111]	0 (0)	0 (0)	7 (9.3)
Three-valve repair	9 (12.3)	2 (2.7)	1 (1.4)	3 [2–5]	19 [15–25]	0 (0)	1 (1.4)	1 (1.4)
Conduit RV to PA	1 (1.5)	2 (3.1)	1 (1.5)	3 [2–5]	23 [18–36]	0 (0)	1 (1.5)	2 (3.1)
Ebstein's repair	2 (3.5)	1 (1.8)	3 (5.3)	3 [2–5]	22 [19–28]	0 (0)	0 (0)	0 (0)
Anomalous coronary repair	15 (34.1)	0 (0)	0 (0)	2 [2–3]	24 [17–33]	0 (0)	1 (2.2)	2 (4.4)
Cardiac tumor resection	4 (10.0)	1 (2.5)	4 (10.0)	2 [2–3]	21 [17–28]	0 (0)	2 (5.0)	3 (7.5)
Surgical PDA closure	4 (10.3)	1 (2.6)	0 (0)	2 [1–4]	20 [14–30]	0 (0)	0 (0)	1 (2.6)
Coarctation repair	2 (6.1)	1 (3.0)	0 (0)	3 [2–4]	17 [14–24]	0 (0)	0 (0)	0 (0)
Tetralogy of Fallot repair	0 (0)	2 (7.1)	0 (0)	3 [2–5]	22 [19–26]	0 (0)	0 (0)	0 (0)
Explantation of pacing system	3 (12.5)	0 (0)	0 (0)	1 [1–2]	14 [10–37]	0 (0)	0 (0)	0 (0)
Surgical ablation of ventricular arrhythmia	2 (10.0)	1 (5.0)	0 (0)	3 [3–5]	25 [18–31]	0 (0)	1 (5.0)	1 (5.0)
Repair of supravalvular aortic stenosis	3 (18.8)	0 (0)	1 (6.3)	2 [2–3]	21 [16–23]	0 (0)	0 (0)	0 (0)
Systemic-to-pulmonary shunts	0 (0)	0 (0)	0 (0)	7 [5–9]	33 [24–50]	0 (0)	0 (0)	1 (7.7)
Repair of RV aneurysm	1 (10.0)	0 (0)	0 (0)	4 [3–5]	26 [17–44]	0 (0)	0 (0)	0 (0)
Ross procedure	0 (0)	0 (0)	0 (0)	2 [2–4]	31 [24–43]	0 (0)	0 (0)	0 (0)
Vascular ring repair	0 (0)	0 (0)	0 (0)	1 [1–1]	15 [14–19]	0 (0)	0 (0)	0 (0)
Systemic venous stenosis repair	0 (0)	0 (0)	0 (0)	3 [2–4]	21 [15–38]	0 (0)	0 (0)	0 (0)
Pulmonic valvuloplasty	1 (33.3)	0 (0)	0 (0)	3 [1–3]	22 [15–30]	0 (0)	0 (0)	0 (0)
ASD creation or enlargement*								

Unless indicated otherwise, data are given as the median [interquartile range] or n (%). *Data are not disclosed for this procedure due to ethical considerations, as the number of patients is n=1 and there is a risk of personal identification. ACHD, adult congenital heart disease; ASD, atrial septal defect; AV, atrioventricular; BMI, body mass index; CABG, coronary artery bypass grafting; ICD, implantable cardioverter defibrillator; ICU, intensive care unit; PA, pulmonary artery; PDA, patent ductus arteriosus; RV, right ventricle; VAD, ventricular assist device; VSD, ventricular septal defect.

Table 3. Clinical Background and Outcomes of ACHDs Following Transcatheter Procedures

Procedural group	No. patients	Age (years)	Female sex	BMI (kg/m²)	Emergency admission	Bed count (n)	Hyperten-sion	Diabetes
Percutaneous ASD closure	4,433	55 [36–68]	2,788 (62.9)	22.0 [20.0–24.5]	37 (0.8)	750 [612–950]	894 (20.2)	332 (7.5)
Catheter ablation	3,527	55 [39–67]	1,597 (45.3)	22.5 [20.1–24.9]	99 (2.8)	663 [500–944]	1,003 (28.4)	336 (9.5)
Balloon pulmonary angioplasty	862	31 [20–51]	449 (52.1)	20.6 [18.4–23.1]	10 (1.2)	654 [609–1,033]	123 (14.4)	26 (3.0)
Percutaneous PDA closure	539	58 [38–69]	423 (78.5)	21.9 [19.9–24.7]	4 (0.7)	689 [590–934]	134 (24.9)	28 (5.2)
Stent graft implantation	348	70 [58–77]	111 (31.9)	22.9 [20.8–25.3]	41 (11.8)	586 [400–736]	190 (54.6)	39 (11.2)
Percutaneous PFO closure	182	54 [45–64]	73 (40.1)	23.2 [20.8–25.5]	5 (2.8)	750 [409–855]	35 (19.2)	11 (6.0)
Percutaneous pulmonic valvuloplasty	107	21 [17–38]	44 (41.1)	20.8 [18.2–24.7]	2 (1.9)	654 [575–985]	13 (12.2)	1 (0.9)
TAVI	87	84 [80–87]	57 (65.5)	21.6 [20.0–23.9]	7 (8.1)	608 [405–877]	43 (49.4)	13 (14.9)
M-TEER	12	81 [72–84]	6 (50.0)	20.3 [18.5–21.9]	6 (50.0)	663 [405–1,065]	4 (33.3)	1 (8.3)
Percutaneous transvenous mitral commissurotomy	7	77 [70–78]	6 (85.7)	20.7 [18.8–25.5]	1 (14.3)	460 [405–654]	3 (42.9)	1 (14.3)

Procedural group	Hyperlipidemia	Liver disease	Renal disease	ICU stay (days)	Hospitalization (days)	Mortality		
						24 h	30 day	In-hospital
Percutaneous ASD closure	588 (13.3)	59 (1.3)	74 (1.7)	1 [1–1]	6 [5–8]	0 (0)	1 (0.02)	3 (0.07)
Catheter ablation	443 (12.6)	78 (2.2)	55 (1.6)	1 [1–4]	5 [4–8]	0 (0)	4 (0.1)	8 (0.2)
Balloon pulmonary angioplasty	58 (6.7)	10 (1.2)	21 (2.4)	1 [1–3]	5 [4–9]	1 (0.1)	4 (0.5)	4 (0.5)
Percutaneous PDA closure	61 (11.3)	6 (1.1)	14 (2.6)	1 [1–2]	6 [4–7]	0 (0)	0 (0)	0 (0)
Stent graft implantation	77 (22.1)	15 (4.3)	17 (4.9)	2 [1–5]	16 [11–29]	0 (0)	4 (1.2)	9 (2.6)
Percutaneous PFO closure	35 (19.2)	2 (1.1)	2 (1.1)	1 [1–2]	5 [4–6]	0 (0)	0 (0)	0 (0)
Percutaneous pulmonic valvuloplasty	1 (0.9)	2 (1.9)	1 (0.9)	1 [1–2]	5 [4–7]	0 (0)	1 (0.9)	1 (0.9)
TAVI	21 (24.1)	3 (3.5)	7 (8.1)	1 [1–1]	15 [11–27]	0 (0)	0 (0)	0 (0)
M-TEER	2 (16.7)	0 (0)	4 (33.3)	1 [1–1]	18 [13–27]	0 (0)	0 (0)	0 (0)
Percutaneous transvenous mitral commissurotomy	2 (28.6)	0 (0)	1 (14.3)	11 [10–12]	8 [4–49]	0 (0)	0 (0)	0 (0)

Unless indicated otherwise, data are given as the median [interquartile range] or n (%). M-TEER, mitral valve transcatheter edge-to-edge repair; PFO, patent foramen ovale; TAVI, transcatheter aortic valve implantation. Other abbreviations as in Table 2.

closure was associated with extended hospitalization and intensive care unit stays. The in-hospital mortality rates for the surgical and percutaneous closure groups were 0.6% and 0.07%, respectively.

Clinical Outcomes of PDA Closures Percutaneous and Surgery

Supplementary Figure 2A shows the number of surgery and transcatheter PDA procedures over time, with an increasing trend in the proportion of percutaneous PDA closures and a decreasing trend in surgical procedures over time (P for trend=0.003). Percutaneous PDA closure was performed across all ages (**Supplementary Figure 2B**). **Table 5** presents the clinical characteristics of patients undergoing surgical and percutaneous PDA closures. Patients who underwent surgical closures experienced extended hospitalization stays. The in-hospital mortality rate was 2.6% for the surgical group and 0% for the percutaneous group.

Discussion

Using large-scale nationwide registry data from Japan, this study provides detailed information regarding the clinical characteristics and outcomes of cardiac operations and transcatheter procedures in patients with ACHD. During the study period, invasive interventions for patients with ACHD were performed in approximately equal proportions of surgical and transcatheter procedures each year. Although the in-hospital mortality of patients with ACHD after surgical and percutaneous interventions was generally low, it was higher for aortic arch repair, systemic-to-pulmonary artery shunt, cardiac tumor resection, CABG, 3-valve replacement, ventricular assist device implantation, and stent graft implantation.

Transitions With Time and Age in Patients With ACHD Undergoing Cardiac Procedures

The number of annual transcatheter interventions or transcatheter interventions within each age group still does not exceed that of surgical procedures in ACHD patients despite the widespread adoption and significant benefits of minimally invasive treatments, such as TAVI and M-TEER, in general.[15,16] This disparity may arise from the inherent complexity of certain cases of ACHD, both anatomically and hemodynamically, making catheter intervention challenging. Despite current advances in catheter interventions, these procedures are not a complete replacement for surgery in patients with ACHD. The findings of this study suggest that both surgical and catheter-based interventions remain essential in managing ACHD, even in contempo-

Table 4. Clinical Characteristics of Patients With ASD Undergoing Surgical and Percutaneous Procedures

	ASD closure	
	Surgical (n=1,678)	Percutaneous (n=4,433)
Clinical characteristics		
Age (years)	55 [38–67]	55 [36–68]
Female sex	972 (57.9)	2,788 (62.9)
BMI (kg/m²)	22.2 [19.8–24.8]	22.0 [20.0–24.5]
Emergency hospitalization	26 (1.6)	37 (0.8)
ICU stay (days)	2 [1–3]	1 [1–1]
Hospitalization duration (days)	17 [13–24]	6 [5–8]
Hospital characteristics and inpatient departments		
Bed count	612 [450–800]	750 [612–950]
JSACHD-certified hospital	518 (30.9)	2,927 (66.0)
Department of pediatrics	40 (2.4)	687 (15.5)
Department of cardiology	61 (3.6)	2,830 (63.8)
Department of cardiovascular surgery	1,347 (80.3)	93 (2.1)
Comorbidities		
Hypertension	540 (32.2)	894 (20.2)
Diabetes	242 (14.4)	332 (7.5)
Hyperlipidemia	27 (13.5)	588 (13.3)
Renal disease	31 (1.9)	74 (1.7)
Liver disease	22 (1.3)	59 (1.3)
Cerebrovascular disease	120 (7.2)	530 (12.0)
Peripheral vascular disease	47 (2.8)	62 (1.4)
Chronic pulmonary disease	65 (3.9)	90 (2.0)
Cancer	20 (1.2)	50 (1.1)
Dementia	2 (0.1)	15 (0.3)
Atrial fibrillation	44 (2.6)	13 (0.3)
Endocarditis	6 (0.4)	2 (0.1)
Therapy		
Dialysis	20 (1.2)	26 (0.6)
IABP	14 (0.8)	3 (0.07)
VA-ECMO	8 (0.5)	0 (0)
All-cause death		
24-hour death	0 (0)	0 (0)
30-day death	4 (0.2)	1 (0.02)
In-hospital death	10 (0.6)	3 (0.07)

Data are given as the median [interquartile range] or n (%). JSACHD, Japanese Society for Adult Congenital Heart Disease. Other abbreviations as in Tables 1,2.

rary practice.

The use of percutaneous ASD closure has been increasing. A previous study showed that the number of transcatheter ASD closures has grown over time, except in 2020.[17] The drop in 2020 is likely due to the COVID-19 pandemic. The overall rise in transcatheter ASD closures is driven by technological progress and social factors. Transcatheter ASD closure is less invasive, and new devices continue to be developed. In Japan, significant milestones include the introduction of the Amplatzer Septal Occluder in 2005, the Figulla Flex II in 2016, and the GORE Cardioform ASD Occluder in 2021, reflecting the continuous evolution of closure technologies.[18–20] This trend in percutaneous ASD closure may also be influenced by changes in the indications given in guidelines. Traditionally, a ratio of pulmonary blood flow to systemic blood flow (Qp/Qs) of 1.5–2.0 or higher was seen as an indication for performing ASD closure. However, the current guidelines now recommend considering ASD closure if there is right ventricular enlargement, atrial arrhythmia, paradoxical embolism, or platypnea-orthodeoxia syndrome.[8,9,21]

Clinical Outcomes of Cardiac Procedures

Our findings regarding high mortality rates for CABG, Fontan surgery, and cardiac tumor resection are consistent with previous research on in-hospital mortality in patients with ACHD undergoing cardiac operations, as indicated by the adult congenital heart surgery (ACHS) mortality score study.[11] For transcatheter procedures, the overall mortality rate was considerably lower, except for stent graft implantation (2.6%). Generally, outcomes following stent grafting are influenced by various factors, such as the urgency of the intervention, presenting symptoms, and treatment site. In-hospital mortality rates for stent grafting for ruptured acute type B aortic dissection range from 0% to 61%,[22,23] whereas in uncomplicated cases, the rate was previously reported to be 7.1%.[24] Considering that the present study included some emergency cases, the in-hospital

Table 5. Clinical Characteristics of Patients With PDA Undergoing Surgical and Percutaneous Procedures

	PDA closure	
	Surgical (n=39)	Percutaneous (n=539)
Clinical characteristics		
Age (years)	49 [32–66]	58 [38–69]
Female sex	27 (69.2)	423 (78.5)
BMI (kg/m²)	20.7 [17.6–23.4]	21.9 [19.9–24.7]
Emergency hospitalization	1 (2.6)	4 (0.7)
ICU stay (days)	2 [1–4]	1 [1–2]
Hospitalization duration (days)	20 [14–30]	6 [4–7]
Hospital characteristics and inpatient departments		
Bed count	610 [481–931]	689 [590–934]
JSACHD-certified hospital	12 (30.8)	362 (67.2)
Department of pediatrics	0 (0)	120 (22.3)
Department of cardiology	2 (5.1)	292 (54.2)
Department of cardiovascular surgery	32 (82.1)	12 (2.2)
Comorbidities		
Hypertension	11 (28.2)	134 (24.9)
Diabetes	2 (5.1)	28 (5.2)
Hyperlipidemia	4 (10.3)	61 (11.3)
Renal disease	0 (0)	14 (2.6)
Liver disease	1 (2.6)	6 (1.1)
Cerebrovascular disease	1 (2.6)	10 (1.9)
Peripheral vascular disease	4 (10.3)	5 (0.9)
Chronic pulmonary disease	2 (5.1)	8 (1.5)
Cancer	0 (0)	6 (1.1)
Dementia	0 (0)	3 (0.6)
Atrial fibrillation	0 (0)	2 (0.4)
Endocarditis	1 (2.6)	0 (0)
Therapy		
Dialysis	0 (0)	4 (0.7)
IABP	1 (2.6)	0 (0)
VA-ECMO	1 (2.6)	0 (0)
All-cause death		
24-hour death	0 (0)	0 (0)
30-day death	0 (0)	0 (0)
In-hospital death	1 (2.6)	0 (0)

Data are given as the median [interquartile range] or n (%). BJSACHD, Japanese Society for Adult Congenital Heart Disease. Other abbreviations as in Tables 1,2.

outcome is reasonable.

Except for high-risk surgeries, the in-hospital mortality rate was generally acceptable. Based on these outcomes, surgical interventions should be prioritized for ACHD patients who are in favorable preoperative condition and anatomically operable, because they can more effectively address all hemodynamic abnormalities compared with catheter-based procedures.

In this study, patients with ACHD who underwent invasive treatment had a higher incidence of lifestyle-related diseases, with hypertension present in 30% and diabetes in 10%. A German study also reported that approximately 60% of patients with ACHD had acquired comorbidities, and that the number of complications increased with age.[25] As the number of patients with ACHD with comorbidities increases in an aging society, minimally invasive treatments with a lower risk are preferable. Demonstrating the comprehensive clinical outcomes of the percutaneous procedures in this study may be meaningful.

Clinical Outcomes of Surgical and Percutaneous ASD Closures

In the present study, patients who underwent surgical ASD closures had a higher prevalence of diabetes, hyperlipidemia, and atrial fibrillation, and these factors may have influenced the outcome of surgical treatment. Nevertheless, the in-hospital mortality was low for both percutaneous and surgical ASD closures. As indicated in the present study, percutaneous ASD closure generally shortens hospitalization and intensive care unit length of stay. Moreover, transcatheter ASD closure improves heart failure symptoms in patients aged ≥75 years, with long-term prognoses comparable to those of younger patients.[26] These pieces of evidence potentially lead to a more proactive adoption of this procedure in older patients. Our results, consistent with previous studies, underscore that in the absence of anatomical problems or other structural cardiac anomalies, percutaneous closure may essentially be the first treatment option because of its less invasive nature in adults of all ages with ASD.[27,28]

Hospitals limited to performing ASD surgeries alone should consider referring patients to facilities capable of providing both percutaneous and surgical ASD closure options.

Clinical Outcomes of Surgical and Percutaneous PDA Closures

The risks of aortic injury due to ligation or amputation of the calcified aorta highlight the preference for percutaneous PDA closure as the initial choice unless anatomical issues dictate otherwise.[29,30] However, few studies have compared surgical treatment with percutaneous PDA closure in adults with PDA. We showed that percutaneous PDA closures were significantly associated with shorter hospital stays and lower in-hospital mortality rates in adults with PDA. The percentage of transcatheter PDA closures in Japan has increased steadily since the introduction of the technique in 2008. Percutaneous PDA closure is expected to become a major therapeutic strategy in the future.

JSACHD-Certified Hospitals

JSACHD-certified hospitals must include physicians from multiple medical departments, such as pediatrics, cardiology, and cardiovascular surgery, with expertise in ACHD. These hospitals require multidisciplinary support and emphasize research and clinical experience in ACHD. As indicated in the **Supplementary Table**, pediatric doctors were more prevalent in JSACHD-certified hospitals. Transcatheter procedures were performed more frequently at JSACHD-certified hospitals, whereas cardiac surgeries were more common in non-certified hospitals. In this study, transcatheter ASD and PDA closures were also higher at JSACHD-certified hospitals. Various factors, including anatomy, disease severity, and underlying comorbidities, influence the choice between transcatheter or surgical treatment. Therefore, it is challenging to state definitively which approach is superior. Previous reports indicate that the involvement of ACHD specialists leads to more appropriate management and improved patient outcomes.[31,32] The importance of receiving proper treatment within an ACHD team cannot be overstated.

Study Limitations

This study has several limitations. First, the DPC database was not sourced directly from medical records, potentially leading to inaccuracies in comorbidities or diagnoses. Second, key data such as anatomical information, history of median sternotomy, hemoglobin levels, and echocardiographic and catheter data, including left ventricular ejection fraction, which are known to impact postoperative outcomes in patients with ACHD,[10,33,34] were lacking because of the limitations of the DPC database. Third, details regarding specific valve intervention details, crucial for prognosis in valvuloplasty or valve replacement,[11] were lacking. Fourth, data on heart transplantation and transcatheter pulmonary valve implantation were insufficient. Heart transplantation is not as common in Japan as in other countries,[35] and transcatheter pulmonary valve implantation was excluded from this analysis because it has only been available in Japan from 2023 onwards. Fifth, because this study was based on practice data from Japanese hospitals, factors such as patient race, previous treatment history, available medical devices, and healthcare system may have influenced the results. Sixth, given the potential for selection bias between the surgical and transcatheter groups, we avoided direct comparisons between the 2 treatment modalities. Further research using cohorts after propensity score matching is required to compare the outcomes between these groups. Seventh, it was not possible to determine from this database whether patients were admitted to adult hospitals or children's hospitals.

Finally, this study using the JROAD-DPC database may not fully reflect actual clinical practice and could differ from data in the Japanese Cardiovascular Surgery Database (JCVSD).[36,37] The JCVSD, based on direct surgical registrations, may provide more accurate information on surgical procedures in Japan. The JROAD-DPC database does not include information from hospitals not participating in JROAD or the DPC system. Furthermore, in this study, we focused on "Operation Name 1" and "Operation Name 2" in the DPC data, because these are more directly related to the primary pathology, and omitted data related to concomitant procedures with less impact on the primary pathology. This approach likely allowed for a more accurate analysis of the association between each procedure and in-hospital outcomes. However, it may have resulted in the underreporting of secondary surgical procedures that were less likely to influence outcomes. In addition, the number of percutaneous ASD closures reported by Cardiovascular Intervention and Therapeutics[17] is lower than that in the JROAD-DPC database. This discrepancy could be attributed to percutaneous PFO closures being registered as percutaneous ASD closures in the DPC system prior to the introduction of insurance coverage for PFO closures in 2019, potentially leading to an overestimation of percutaneous ASD closures in the JROAD-DPC data. These limitations may account for some discrepancies between JROAD-DPC and other databases compiled by medical professionals. Nevertheless, a key strength of the JROAD-DPC database is its capacity to facilitate joint analyses of surgical and transcatheter treatments, providing a comprehensive perspective of treatment patterns and trends.

Conclusions

The in-hospital mortality rates for cardiac surgery and percutaneous procedures in Japanese patients with ACHD remained low, except for CABG, 3-valve replacement, aortic arch repair, ventricular assist device implantation, and tumor resection. This study provides fundamental insights into the risk of postoperative mortality for individual surgical and catheter-based procedures in patients with ACHD.

Acknowledgment

The authors thank Editage (www.editage.jp) for English language editing.

Sources of Funding

None.

Disclosures

M.S. has received lecture fees from Medtronic, Abbott Medical, and Daiichi Sankyo. The remaining authors declare no conflicts of interest.

IRB Information

This study was approved by the Institutional Review Board of the University of Tsukuba (Approval no. 1543).

Data Availability

The data used in this article is provided by the Japanese Circulation Society for research purposes. It cannot be publicly shared without permission from the Japanese Circulation Society.

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Supplementary Files

Please find supplementary file(s);
https://doi.org/10.1253/circj.CJ-24-0843