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ORIGINAL ARTICLE
ACHD

Trends in Unplanned Admissions of Patients With Adult Congenital Heart Disease Based on the Japanese Registry of All Cardiac and Vascular Diseases-Diagnosis Procedure Combination Study

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Background: The prevalence of adult congenital heart disease (ACHD) is increasing rapidly and in particular, patients who underwent complicated surgeries are reaching their youth and middle age. Therefore, the need for ACHD treatment will increase, but the current medical situation is unknown. In this study we assessed trends in unplanned admissions in patients with ACHD in Japan.

Methods and Results: From the Japanese Registry of All Cardiac and Vascular Diseases-Diagnosis Procedure Combination, a nationwide claim-based database, we selected patients aged >15 years with CHD defined by the International Classification of Diseases, 10th Revision codes. We identified 39,676 admissions between April 2012 and March 2018; 10,444 (26.3%) were unplanned. Main diagnoses were categorized into 3 degrees of complexity (severe, moderate, and mild) and other. Among unplanned admissions, the proportion of the severe group increased with time. Patients in the mild group were significantly older than those in the moderate and severe groups (median age: 70.0, 39.0, and 32.0 years, respectively). There were 765 deaths during hospitalization (overall mortality rate, 7.3%). The odds ratio of death during admission was significantly higher in patients aged >50 years, especially in the moderate group.

Conclusions: Patients with moderate or severe ACHD tended to experience unplanned admissions at a younger age. In anticipation of greater numbers of new, severe patients, we need to prepare for their increasing medical demands.

Key Words: Adult congenital heart disease; Congenital heart disease; JROAD-DPC; Unplanned admissions

Currently, most children born with congenital heart disease (CHD) will survive and reach adulthood. CHD includes various anatomical and physiological characteristics, even in the same diagnosis. The population of adults with CHD (ACHD) has dramatically increased with surgical improvements and in addition to the variations in CHD, ACHD status is determined by surgical status such as unrepair, repair or palliation. This heterogeneity makes it difficult to completely understand ACHD as a whole. Furthermore, surgical repair in childhood does not mean a complete cure; hence, many patients with ACHD may have varied, often unrecognized, complications.[1]

With the growing importance of ACHD, relatively large clinical reports have been published.[2–4] According to these, the frequency of admission due to heart failure and other problems is high, even in the young population and in patients with mild forms of CHD. The distribution of severity and complexity may keep changing with age and medical advances. In the past 50 years, there have been considerable improvements and innovations in both diagnosis and treatment of CHD, but most occurred in the past 30–40 years, especially for severe CHD, such as that affecting a single ventricle (SV). Therefore, at present, more of the patients with severe CHD are surviving into adulthood.

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In this study, we aimed to determine the trends in

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Table 1. Hierarchy of Diagnosis and Classification of Complexity

Complexity	CHD	ICD-10 code	No. of admissions	No. of unplanned admissions
Severe	SV	Q204, 224, 226, 232, 234, 248	2,982 (7.5%)	1,048 (10.0%)
	PA-IVS	Q220, 255	66 (0.2%)	21 (0.2%)
	PTA	Q200	248 (0.6%)	69 (0.7%)
	TGA	Q203	1,070 (2.7%)	259 (2.5%)
	cTGA	Q205	978 (2.5%)	331 (3.2%)
Moderate	PA-VSD	Q213	440 (1.1%)	123 (1.2%)
	TOF	Q213	3,288 (8.3%)	1,037 (9.9%)
	TAPVR	Q262	179 (0.5%)	36 (0.3%)
	AVSD	Q212	901 (2.3%)	312 (3.0%)
	Ebstein	Q225	578 (1.5%)	180 (1.7%)
	CoA	Q251	492 (1.2%)	91 (0.9%)
	DORV	Q201	746 (1.9%)	275 (2.6%)
Mild	VSD	Q210	4,411 (11.1%)	1,344 (12.9%)
	ASD	Q211	14,765 (37.2%)	3,063 (29.3%)
	PDA	Q250	1,089 (2.7%)	272 (2.6%)
Other	PS	Q221, 256	661 (1.7%)	84 (0.8%)
	AS	Q230	450 (1.1%)	114 (1.1%)
	BAV	Q231	1,482 (3.7%)	252 (2.4%)
	MV disease	Q232, 233, 238	219 (0.6%)	105 (1.0%)
	PFO	Q211	1,437 (3.6%)	590 (5.6%)
	Other	Other than those listed above	3,194 (8.1%)	838 (8.0%)

AS, aortic stenosis; ASD, atrial septal defect; AVSD, atrioventricular septal defect; BAV, bicuspid aortic valve; CHD, congenital heart disease; CoA, coarctation of the aorta; cTGA, corrected transposition of the great artery; DORV, double-outlet right ventricle; ICD-10, International Classification of Diseases, 10th Revision; MV, mitral valve; PA-IVS, pulmonary atresia with intact ventricular septum; PA-VSD, pulmonary atresia with ventricular septal defect; PDA, patent ductus arteriosus; PS, pulmonary stenosis; PTA, persistent truncus arteriosus; PFO, patent foramen ovale; SV, single ventricle; TAPVR, total anomalous pulmonary venous return; TGA, complete transposition of the great arteries; TOF, tetralogy of Fallot; VSD, ventricular septal defect.

unplanned admissions among ACHD patients, which is considered one of the major adverse cardiovascular events in cardiac disease research.[5]

Methods

Ethical Approval

The present study complied with the Declaration of Helsinki and was approved by the Institutional Review Board of Tsukuba University (No. 1543). The need for informed consent was waived because information specific to individuals was not included.

Study Population

This retrospective, observational cohort study was based on the Japanese Registry of All Cardiac and Vascular Diseases-Diagnosis Procedure Combination (JROAD-DPC) database, details of which have been described previously.[6,7] Briefly, the JROAD-DPC is a nationwide registry of information on admissions and discharges for cardiovascular diseases, clinical examination and treatment status, patient status, and hospital overviews. A validation study showed an acceptable concordance rate between registry and clinical data.[8]

We obtained the data of patients who were admitted and discharged between 1 April 2012 and 31 March 2018 through identification based on the diagnosis codes of the International Classification of Diseases, 10th Revision (ICD-10). Patients aged >15 years who had ICD-10 codes associated with CHD (Q200–269) as the main diagnosis, the admission-precipitating diagnosis, most resource-consuming diagnosis, and second most resource-consuming diagnosis were identified. We excluded patients who represented the normal variant and appeared to be mistaken for having acquired heart disease; to do so, we used the ICD-10 codes as well as detailed diagnosis information written in Japanese. Admissions were categorized as planned or unplanned.

Diagnostic Criteria and Definitions

We determined 19 main diagnoses referring to the registration system of Japanese ACHD. Each main diagnosis contains multiple allied diseases, so we finally decided the main diagnosis of each admission using the detailed Japanese disease name (**Table 1**). We assigned each patient 1 main diagnosis, and if there were >2 diagnoses at readmission, the main diagnosis was determined based on the doctor's confirmation. All analyses were conducted using a record-base, even if a patient was admitted multiple times. Comorbidities and pharmacological therapy were defined based on the medication intake and procedures that each patient underwent during admission. We categorized the 19 disease groups into 3 degrees of complexity (severe, moderate, and mild) and others. The others group contained multiple diseases with difficult to determine severity because of their rarity and high variety.

Statistical Analysis

Data on the diagnosis and complexity, as well as other categorical data, are shown as frequencies and percentages and were compared using the chi-square test or Fisher's exact test, as appropriate. Continuous data are expressed as the median and interquartile range (IQR) and were compared

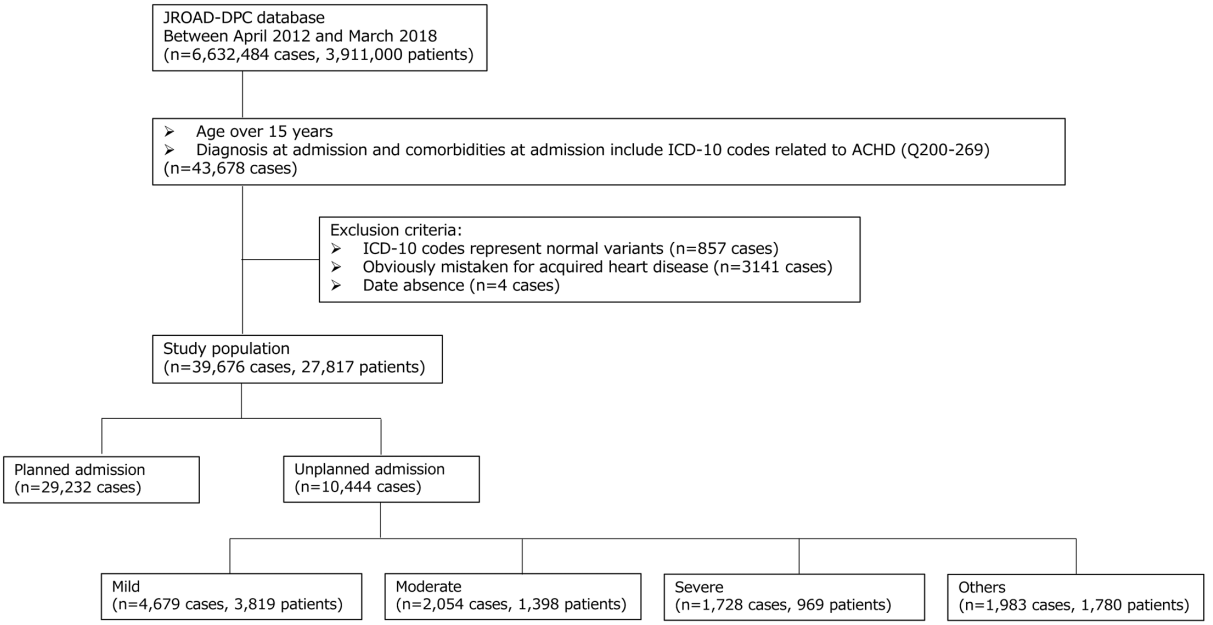

Figure 1. Flow diagram of the selection process for the study population. ACHD, adult congenital heart disease; ICD-10, International Classification of Diseases, 10th Revision; JROAD-DPC, Japanese Registry of All Cardiac and Vascular Diseases-Diagnosis Procedure Combination.

using the Student's t-test or Mann-Whitney U test. Multiple comparison tests were performed using Dunnett's test for continuous variables and the chi-square test for categorical variables. The Cochran-Armitage trend test was also performed to evaluate yearly changes in the number of admissions. Multilevel univariate and multivariate mixed-effect logistic regression analyses with the institute as a random intercept were used to assess the risk of death during unplanned admissions. Statistical significance was set at $P<0.05$. All analyses were conducted using STATA 16.1 (STATA Corp., College Station, TX, USA).

Results

We identified 43,678 admissions of patients aged >15 years with ACHD associated with the ICD-10 codes Q200–269 between April 2012 and March 2018 (**Figure 1**). Patients with ICD-10 codes representing normal variants, such as a persistent left superior vena cava (Q261), or were obviously mistaken to have acquired heart disease or had wrongly inputted data were excluded. Finally, 39,676 admissions (27,817 patients) were included in this study.

The JROAD-DPC database expanded during the study period; as a result, the number of hospitals and admissions increased. Therefore, the accurate number of admissions was unclear. The mean ratio of ACHD-related admission to all JROAD-DPC admissions for each year was 0.60%, and there was no significant yearly trend. Of the total of 39,676 admissions, 10,444 (26.3%) were unplanned and this ratio did not change significantly during the study period.

The classification of diagnosis and complexity is shown in **Table 1**. The average number of unplanned admissions per person was 1.22 in the mild group, 1.47 in the moderate group, and 1.78 in the severe group. The percentage of

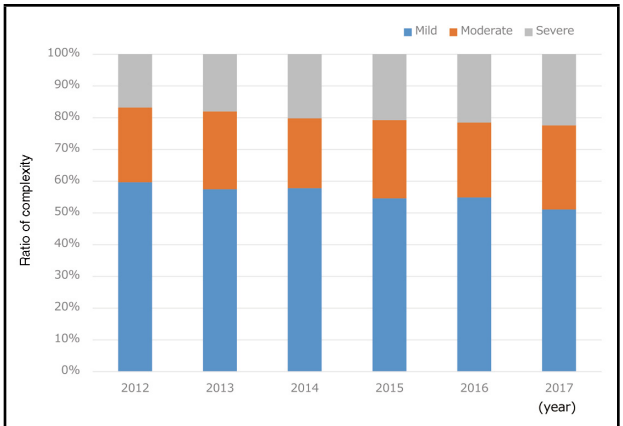

Figure 2. Trends in the complexity distribution from 2012 to 2017.

cases in the severe group significantly increased from 16.8% in 2012 to 22.4% in 2017 ($P<0.001$) (**Figure 2**). There were different peaks of admissions in each age group. The severe group peaked in their 20s, the moderate group in their 30s, and the mild group in their 80 s (**Figure 3A**). The ratio of deaths during unplanned admissions was high in the moderate group among patients aged >60 years (**Figure 3B**).

The characteristics of patients with unplanned admissions are shown in **Table 2**. The median age was 57.0 years (34.0–75.0 years), and 50.8% were male. Patients in the mild group were significantly older than those in the moderate and severe groups. There were no difference in length of hospital stay in each group. Heart failure and arrhyth-

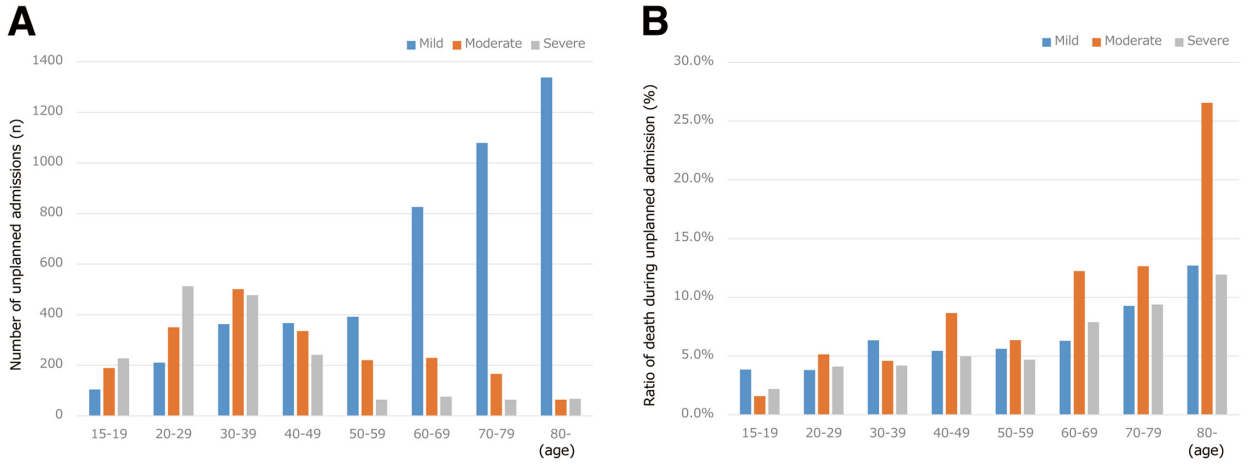

Figure 3. Trends in the age distribution by complexity group. (**A**) Number of unplanned admissions, (**B**) rate of death during unplanned admissions.

mia were the common comorbidities; the former was relatively more commonly observed in patients with mild disease and the latter in those with moderate and severe disease.

There were 765 deaths (7.3%) during admission. The number and percentage of deaths were 399 (8.5%), 153 (7.5%), and 81 (4.7%) in the mild, moderate, and severe groups, respectively. Among patients aged >50 years, the percentage of deaths was 9.5% in the mild group, 11.8% in the moderate group, and 8.5% in the severe group. Multilevel mixed-effect logistic regression analysis showed that, compared with patients in the mild group aged <50 years, the odds ratio of death during admission was significantly higher in patients aged >50 years in each group, especially those in the moderate group (**Table 3**). In addition to age and severity, New York Heart Association scores of III and IV, heart failure, hemorrhage, cerebrovascular, sepsis, and aortic dissection were associated with poor prognosis.

Discussion

This is the first study to assess the trends in ACHD treatment by disease complexity and age in Japan. The ratio of admission for the moderate and severe groups increased; from now on, patients with complicated conditions may experience unplanned admissions at a young age.

The relationship between age distribution and disease complexity showed obvious association with medical history, especially in patients with moderate and severe CHD. Among various ACHDs, the SV physiology is one of the most complicated types of CHD. Fontan and Baudet first described the Fontan procedure in 1971.[9] Since then, several modifications and adaptations, such as the extracardiac total cavopulmonary connection in 1990,[10] have been introduced, and surgical outcomes have improved. In addition to the SV physiology, other severe and moderate CHDs have recently begun to benefit from surgical innovations. At this time, the prevalence of heart failure in ACHD is 6.4%, but higher in patients with cyanotic CHD (41%), Fontan circulation (30%), and a systemic right ventricle (25%).[11] More severe CHD patients are reaching their youth and middle age, and the problems that may occur in the future with aging remain unclear.

In the mild group, there was a rapid increase in unplanned admissions after 60 years of age in this study. The detailed reasons for admission might be related to their CHD or other cardiovascular disorders particular to the elderly, but unfortunately it was not possible to distinguish this is the current research. However, it is obvious that elderly patients with mild CHD need medical treatment for diseases common in their age just like everyone else. On the other hand, recent study from Denmark showed that patients with simple CHD had increased risks of all comorbidities and even in patients with surgically repaired ventricular septal defect had a high late hazard of heart failure.[12,13] We might need to pay more attention to mild severity CHD than we ever thought. We could not obtain enough data to assess this issue, so further consideration in detail for each disease and group will be required for greater understanding.

In this study, the overall mortality rate of patients with ACHD during unplanned admission was 7.3%. In another study that used the JROAD-DPC to assess patients with heart failure, the in-hospital mortality rate was 7.7% in patients with a mean age of 78 years.[14] The mortality rate of patients with ACHD was as high as that of elderly patients with heart failure. There are several possible reasons for the age distribution trends identified in this study. The high percentage of deaths among the elderly with mild CHD may relate to both CHD and aging. Although the mortality rate in the severe group was not so high, they were younger age at the time of death, which is likely related to the CHD. The number of hospitalizations per person was significantly high for patients with severe CHD, which could lead to underestimation of the mortality rate during total hospitalization.

Other factors associated with poor prognosis, such as hemorrhage, cerebrovascular, sepsis, and aortic dissection, were not clearly correlated with CHD at the time of this study. For example, aortic dissection is possibly triggered by the aortic dilatation commonly observed in patients with tetralogy of Fallot and aortic coarctation associated with bicuspid aortic valve. These diseases are classified as moderate

Table 2. Characteristics of Patients (Unplanned Admissions)

Characteristic	All	Mild	Moderate	Severe	Others	P value
No. of admissions	10,444	4,679 (44.8%)	2,054 (19.7%)	1,728 (16.5%)	1,983 (19.0%)	
Median age (years, IQR)	57.0 (34.0–75.0)	70.0 (53.0–81.0)	39.0 (29.0–57.0)*	32.0 (23.0–42.0)*	62.0 (43.0–76.0)*	<0.001
Age ≥50 years	5,919 (56.7%)	3,635 (77.7%)	679 (33.1%)*	271 (15.7%)*	1,334 (67.3%)*	<0.001
Age <50 years	4,525 (43.3%)	1,044 (22.3%)	1,375 (66.9%)*	1,457 (84.3%)*	649 (32.7%)*	<0.001
Male	5,304 (50.8%)	2,002 (42.8%)	1,004 (48.9%)*	970 (56.1%)*	1,128 (56.9%)*	<0.001
NYHA III or IV	3,129 (7.9%)	1,189 (25.4%)	423 (20.6%)*	292 (16.9%)*	242 (12.2%)*	<0.001
Length of hospital stay	14 (7–25)	16 (9–27)	11 (5–22)	10 (4–19)	15 (8–27)	<0.001
Death during hospitalization	765 (7.3%)	399 (8.5%)	153 (7.5%)	81 (4.7%)*	132 (6.7%)*	<0.001
Age at death (years, IQR)	69.0 (45.0–80.0)	77.0 (65.0–84.0)	53.0 (38.0–69.0)*	37.0 (27.0–59.0)*	70.5 (47.0–80.5)*	<0.001
Comorbidities						
Heart failure	4,095 (39.2%)	2,267 (48.5%)	800 (39.0%)*	543 (31.4%)*	485 (24.5%)*	<0.001
Arrhythmia	2,472 (23.7%)	673 (14.4%)	487 (23.7%)*	428 (24.8%)*	884 (44.6%)*	<0.001
Hemorrhage	918 (8.8%)	351 (7.5%)	217 (10.6%)*	220 (12.7%)*	130 (6.6%)	<0.001
Cerebrovascular	918 (8.8%)	338 (7.2%)	48 (2.3%)*	61 (3.5%)*	471 (23.8%)*	<0.001
Pulmonary hypertension	753 (7.2%)	376 (8.0%)	136 (6.6%)*	162 (9.4%)	79 (4.0%)*	<0.001
Hepatic failure	605 (5.8%)	306 (6.5%)	125 (6.1%)	90 (5.2%)*	84 (4.2%)*	0.002
Renal disease	541 (5.2%)	284 (6.1%)	105 (5.1%)	73 (4.2%)*	79 (4.0%)*	<0.001
Cancer	430 (4.1%)	223 (5.0%)	49 (2.4%)*	50 (2.9%)*	108 (5.4%)	<0.001
Endocarditis	357 (3.4%)	153 (3.3%)	71 (3.5%)	36 (2.1%)*	97 (4.9%)*	<0.001
Sepsis	184 (1.8%)	82 (1.8%)	42 (2.0%)	23 (1.3%)	37 (1.9%)	0.40
Acute coronary syndrome	281 (2.7%)	171 (3.7%)	9 (0.4%)*	10 (0.6%)*	91 (4.59%)	<0.001
Aortic dissection	145 (1.4%)	48 (1.0%)	9 (0.4%)*	3 (0.2%)*	85 (4.3%)*	<0.001
Non-pharmacological therapy						
Ventilation management	1,822 (17.5%)	817 (17.46%)	325 (15.82%)	209 (12.09%)	471 (23.75%)	<0.001
Hemodialysis	183 (1.8%)	90 (1.92%)	32 (1.56%)	17 (0.9%)	44 (2.22%)	0.021
Cardiac surgery	906 (8.67%)	386 (8.25%)	74 (3.60%)*	49 (2.84%)*	397 (20.02%)*	<0.001
Intervention	324 (3.10%)	152 (3.25%)	70 (3.41%)	36 (2.08%)*	66 (3.33%)	0.064
Ablation	181 (1.73%)	68 (1.45%)	64 (3.12%)*	34 (1.97%)	15 (0.76%)*	<0.001
PMI/ICD/CRT	292 (2.80%)	149 (3.18%)	60 (2.92%)	41 (2.37%)	42 (2.12%)*	0.066
PCPS	89 (0.85%)	24 (0.51%)	16 (0.78%)	14 (0.81%)	35 (1.77%)*	<0.001
IABP	119 (1.10%)	47 (1.00%)	17 (0.83%)	9 (0.52%)	46 (2.32%)	<0.001
VAD	1 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	1 (0.05%)	0.23
Transplantation	1 (0.00%)	0 (0.00%)	0 (0.00%)	1 (0.06%)	0 (0.00%)	0.17
Pharmacological therapy (intravenous)						
Catecholamine	2,221 (21.3%)	1,026 (21.93%)	374 (18.21%)	257 (14.87%)	564 (28.44%)	<0.001
Antiarrhythmic	2,022 (19.4%)	895 (19.13%)	342 (16.65%)	244 (14.12%)	541 (27.28%)	<0.001
Diuretics	4,198 (40.2%)	2,161 (46.19%)	703 (34.23%)	593 (34.32%)	741 (37.37%)	<0.001
Pharmacological therapy (oral)						
Antiarrhythmic	3,811 (36.50%)	1,643 (35.11%)	819 (39.87%)	716 (41.44%)	633 (31.92%)	<0.001
ACEi/ARB	3,702 (35.45%)	1,659 (35.46%)	633 (30.82%)*	717 (41.49%)*	693 (34.95%)	<0.001
β-blocker	4,147 (39.71%)	1,796 (38.38%)	807 (39.29%)	770 (44.56%)*	774 (39.03%)	<0.001
MRA	2,872 (27.50%)	1,307 (27.93%)	587 (28.58%)	540 (31.25%)*	438 (22.09%)*	<0.001
Loop diuretic	6,098 (58.39%)	2,908 (62.15%)	1,181 (57.50%)*	1,045 (60.47%)	964 (48.61%)*	<0.001

*P<0.05 vs. mild severity group. ACEi, angiotensin-converting enzyme inhibitor; ARB, angiotensin II receptor blocker; CRT, cardiac resynchronization therapy; IABP, intra-aortic balloon pumping; ICD, implantable cardioverter defibrillator; IQR, interquartile range; MRA, mineralocorticoid-receptor antagonist; NYHA, New York Heart Association; PCPS, percutaneous cardiopulmonary support; PMI, pacemaker implantation; VAD, ventricular assist device.

and did not match the age distribution of aortic dissection in this study. Aortic dissection in elderly patients is mainly related to aging, but we should note the potential for an increase in this disease at a young age with moderate CHD.

The most common comorbidity in this study was heart failure. Patients with ACHD are more likely to experience heart failure at a younger age than the general population, and the risk factors are age, sex, CHD severity, recent hospitalization, and the number of comorbidities.[2,15] One of the difficulties in ACHD treatment is that in many cases ACHD-related heart failure the symptoms are typical, and few predictors have been studied to help with detection, monitoring, and prevention.[16] Improving the detection and prevention of heart failure in patients with ACHD may help to improve their future health. Many causes of death in ACHD are attributed to CHD or other cardiovascular disorders; however, coexisting congenital malformations, respiratory diseases, infections, and neoplasms can also

Table 3. Multilevel Mixed-Effect Logistic Regression Model for Assessing Death During Unplanned Hospitalization

Variable	Univariate		Multivariate	
	OR (95% CI)	P value	OR (95% CI)	P value
Mild with age <50	1.00		1.00	
Mild with age ≥50	1.82 (1.35, 2.46)	<0.001	1.62 (1.17, 2.25)	0.004
Moderate with age <50	1.15 (0.79, 1.66)	0.471	1.07 (0.72, 1.58)	0.738
Moderate with age ≥50	2.56 (1.77, 3.72)	<0.001	2.06 (1.38, 3.07)	<0.001
Severe with age <50	0.86 (0.58, 1.28)	0.464	0.72 (0.48, 1.09)	0.124
Severe with age ≥50	1.76 (1.04, 2.96)	0.035	1.59 (0.92, 2.75)	0.099
Sex	0.96 (0.81, 1.13)	0.615	0.91 (0.76, 1.08)	0.271
NYHA III or IV	1.92 (1.60, 2.30)	<0.001	1.57 (1.27, 1.94)	<0.001
Length of hospital stay	1.00 (0.99, 1.01)	0.239	0.99 (0.98, 0.99)	<0.001
Heart failure	1.71 (1.44, 2.03)	<0.001	1.48 (1.19, 1.84)	<0.001
Arrhythmia	0.79 (0.63, 1.00)	0.053	1.16 (0.90, 1.49)	0.258
Hemorrhage	5.34 (4.30, 6.62)	<0.001	5.35 (4.24, 6.76)	<0.001
Cerebrovascular	1.05 (0.74, 1.49)	0.788	1.62 (1.11, 2.36)	0.012
Pulmonary hypertension	1.23 (0.91, 1.65)	0.174	1.25 (0.90, 1.72)	0.177
Hepatic failure	2.62 (2.00, 3.42)	<0.001	1.59 (0.71, 3.53)	0.258
Renal disease	2.54 (1.92, 3.37)	<0.001	1.21 (0.52, 2.79)	0.662
Cancer	1.16 (0.78, 1.74)	0.461	0.88 (0.57, 1.35)	0.552
Endocarditis	0.59 (0.32, 1.06)	0.079	0.77 (0.39, 1.52)	0.453
Sepsis	4.85 (3.23, 7.28)	<0.001	5.61 (3.50, 8.99)	<0.001
Acute coronary syndrome	1.10 (0.65, 1.86)	0.715	1.37 (0.79, 2.39)	0.268
Aortic dissection	2.37 (1.15, 4.89)	0.019	3.55 (1.65, 7.62)	0.001

CI, confidence interval; NYHA, New York Heart Association; OR, odds ratio.

cause death.[17] Patients with severe CHD must cope with disease severity as well as a high prevalence of non-cardiovascular comorbidities.[4] Since birth, patients with ACHD are exposed to hemodynamic consequences and undergo repeated interventions that affect the heart as well as other organs. Therefore, clinicians should take all organs into consideration when treating patients with ACHD.

On detailed analysis of guidelines, it is apparent that the classification of severity and complexity is inconsistent. Heterogeneity with high causative variance relative to the low frequency of specific CHD phenotypes makes disease classification difficult.[18] Furthermore, most guidelines consider whether surgery is performed and the type of surgery. In this study, we could not obtain such data, and we classified patients based only on the diagnosis. The 2018 ACHD guidelines do not include patent foramen ovale (PFO) or bicuspid aortic valve (BAV), but they mention overlap of severity, especially with valve disease.[1] We designed our simple classification to reflect the severity as accurately as possible, keeping PFO, BAV, and other valve disease in a separate group. Most recommendations associated with ACHD are largely the result of expert consensus based on retrospective and prospective observational studies and registries because of the lack of evidence-based data.[19] Development of a registration system and large clinical research studies using simple and unified disease definitions are warranted.

Because ACHD is a group of diseases that requires specialization, more specialists and specialized facilities are required. Several reports have described the value of specialized care, especially its positive impact on mortality rates, and major complications.[20,21] The 2020 European Society of Cardiology guidelines stratified patients into 3 categories: (1) require care exclusively in a specialist center, (2) shared care can be established with appropriate general adult services, and (3) can be managed in non-specialist clinics (with access to specialized care if required).[19] Although patients with ACHD have better outcomes under specialized care, other medical providers often need to manage and to treat them because of the increasing number of such patients. The guidelines were intended to provide specialized care instructions for specialists, as well as primary care or other healthcare providers.[1] One report describes the management of ACHD patients encountered in emergency outpatient departments with pathological conditions such as arrhythmia, syncope, chest pain, and cyanosis.[22] Continuous efforts must be made to encourage both specialist and primary care.

Importantly, in the ACHD population, the prevalence of cardiovascular risk factors, such as obesity and metabolic syndrome, is higher than in the general population. Having to avoid exercise during school age is common among ACHD patients, and an ongoing restriction in physical activity.[23] Thus, patients with ACHD are exposed to not only CHD-related complications but also standard cardiovascular risk factors such as aging.[24] Guidance on daily life is required from childhood. The most important aspect of patient education is avoiding interruptions in care; a cohort study revealed that 26.1% of patients experienced interruptions.[25] Factors contributing to the lack of consistent cardiology care for ACHD are patient barriers, financial barriers, system barriers, and geographic barriers.[26] Enhancement of the social system is obviously warranted. Furthermore, a medical transition system from pediatrics to adult, and coaching health behavior programs for the patients themselves are needed.

Study Limitations

This study has some limitations owing to the restrictions on information obtained from the JROAD-DPC database. The number of registered hospitals and admissions increased during the study period; thus, the data included in the analysis were not exhaustive. As a result, we could not confirm the correct number and changes of ACHD-related admissions. Important factors for prognosis prediction, such as the surgical method, presence of cyanosis, pulmonary hypertension, Eisenmenger syndrome and the relationship between comorbidity and CHD could not be assessed. Further, because this was a limited-time survey, so follow-up evaluation was not possible.

Conclusions

Patients with ACHD have risks related to their health since birth, and age-related changes become apparent from a young age, especially in patients with severe CHD. Considering the history of progress in CHD treatment, we can easily imagine an even more dramatic increase in the number of patients with ACHD as well as an increase in the severity of CHD among patients in the near future. Therefore, we should prepare for the medical demands in terms of both medical resources and patient education.

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Disclosures

M.I. is a member of *Circulation Journal*'s Editorial Team.

IRB Information

The Institutional Review Board of Tsukuba University approved the study protocol (No. 1543).

Data Availability

The deidentified participant data will not be shared.

References

1. Stout KK, Daniels CJ, Aboulhosn JA, Bozkurt B, Broberg CS, Colman JM, et al. 2018 AHA/ACC guideline for the management of adult with congenital heart disease. *Circulation* 2019; **139:** e698–e800.
2. Cohen S, Liu A, Wang F, Guo L, Brophy JM, Abrahamowicz M, et al. Risk prediction models for heart failure admissions in adults with congenital heart disease. *Int J Cardiol* 2021; **322:** 149–157.
3. Spector LG, Menk JS, Knight JH, McCracken C, Thomas AS, Vinocur JM, et al. Trends in long-term mortality after congenital heart surgery. *J Am Coll Cardiol* 2018; **71:** 2434–2446.
4. Agarwal A, Thombley R, Broberg CS, Harris IS, Foster E, Mahadevan VS, et al. Age- and lesion-related comorbidity burden among US adults with congenital heart disease: A population-based study. *J Am Heart Assoc* 2019; **8:** e013450.
5. Kunimoto M, Yokoyama M, Shimada K, Matsubara T, Aikawa T, Ouchi S, et al. Relationship between skin autofluorescence levels and clinical events in patients with heart failure undergoing cardiac rehabilitation. *Cardiovasc Diabetol* 2021; **20:** 208.
6. Kaku H, Funakoshi K, Ide T, Fujino T, Matsushima S, Ohtani K, et al. Impact of hospital practice factors on mortality in patients hospitalized for heart failure in Japan: An analysis of a large number of health record from a nationwide claims-based database, the JROAD-DPC. *Circ J* 2020; **84:** 742–753.
7. Yasuda S, Miyamoto Y, Ogawa H. Current status of cardiovascular medicine in the aging society of Japan. *Circulation* 2018; **138:** 965–967.
8. Nakai M, Iwanaga Y, Sumita Y, Kanaoka K, Kawakami R, Ishii M, et al. Validation of acute myocardial infarction and heart failure diagnoses in hospitalized patients with the nationwide claim-based JROAD-DPC database. *Circ Rep* 2021; **3:** 131–136.
9. Fontan F, Baudet E. Surgical repair of tricuspid atresia. *Thorax* 1971; **26:** 240–248.
10. Marcelletti C, Corno A, Giannico S, Marino B. Inferior vena cava-pulmonary artery extracardiac conduit: A new form of right heart bypass. *J Thorac Cardiovasc Surg* 1990; **100:** 228–232.
11. Arnaert S, De Meester P, Troost E, Droogne W, Van Aelst L, Van Cleemput J, et al. Heart failure related to adult congenital heart disease: Prevalence, outcome and risk factors. *ESC Heart Fail* 2021; **8:** 2940–2950.
12. El-Chouli M, Meddis A, Christensen DM, Gerds TA, Sahested T, Malmborg M, et al. Lifetime risk of comorbidity in patients with simple congenital heart disease: A Danish nationwide study. *Eur Heart J* 2023; **44:** 741–748.
13. Eckerstrom F, Nyboe C, Redington A, Hjortdal VE. Lifetime burden of morbidity in patients with isolated congenital ventricular septal defect. *J Am Heart Assoc* 2023; **12:** e027477.
14. Kusunose K, Okushi Y, Okayama Y, Zheng R, Nakai M, Sumita Y, et al. Use of echocardiography and heart failure in-hospital mortality from registry date in Japan. *J Cardiovasc Dev Dis* 2021; **8:** 124.
15. Burstein DS, Rossano JW, Griffis H, Zhang X, Fowler R, Frischertz B, et al. Greater admissions, mortality and cost of heart failure in adults with congenital heart disease. *Heart* 2021; **107:** 807–813.
16. Ladouceur M. Heart failure in adults with congenital heart disease: A call for action. *Heart* 2021; **107:** 774–775.
17. McCracken C, Spector LG, Menk JS, Knight JH, Vinocur JM, Thomas AS, et al. Mortality following pediatric congenital heart surgery: An analysis of the causes of death derived from the national death index. *J Am Heart Assoc* 2018; **7:** e010624.
18. Diller GP, Arvanitaki A, Opotowsky AR, Jenkins K, Moons P, Kempny A, et al. Lifespan perspective on congenital heart disease research: JACC state-of-the-art review. *J Am Coll Cardiol* 2021; **77:** 2219–2235.
19. Baumgartner H, De Backer J, Babu-Narayan SV, Budts W, Chessa M, Diller GP, et al. 2020 ESC guidelines for the management of adult congenital heart disease. *Eur Heart J* 2021; **42:** 563–645.
20. Mizuno A, Niwa K, Ochiai R, Shiraishi I, Sumita Y, Daida H, et al. Impact of facilities accredited by both adult and pediatric cardiology society on the outcome of patients with adult congenital heart disease. *J Cardiol* 2020; **75:** 105–109.
21. Diller GP, Orwat S, Lammers AE, Radke RM, De-Torres-Alba F, Schmidt R, et al. Lack of specialist care is associated with increased morbidity and mortality in adult congenital heart disease: A population-based study. *Eur Heart J* 2021; **42:** 4241–4248.
22. Chessa M, Brida M, Gatzoulis MA, Diller GP, Roos-Hesselink JW, Dimopoulos K, et al. Emergency department management of patients with adult congenital heart disease: A consensus paper from the ESC Working Group on Adult Congenital Heart Disease, the European Society for Emergency Medicine (EUSEM), the European Association for Cardio-Thoracic Surgery (EACTS), and the Association for Acute Cardiovascular Care (ACVC). *Eur Heart J* 2021; **42:** 2527–2535.
23. Niwa K. Metabolic syndrome and coronary artery disease in adults with congenital heart disease. *Cardiovasc Diagn Ther* 2021; **11:** 563–576.
24. Troost E, Roggen L, Goossens E, Moons P, De Meester P, Van De Bruaene A, et al. Advanced care planning in adult congenital heart disease: Transitioning from repair to palliation and end-of-life care. *Int J Cardiol* 2019; **279:** 57–61.
25. Moons P, Bratt EL, De Backer J, Goossens E, Hornung T, Tutarel O, et al. Transition to adulthood and transfer to adult care of adolescents with congenital heart disease: A global consensus statement of the ESC Association of Cardiovascular Nursing and Allied Professions (ACNAP), the ESC Working Group on Adult Congenital Heart Disease (WG ACHD), the Association for European Paediatric and Congenital Cardiology (AEPC), the Pan-African Society of Cardiology (PASCAR), the Asia-Pacific Paediatric Cardiac Society (APPCS), the Inter-American Society of Cardiology (IASC), the Cardiac Society of Australia and New Zealand (CSANZ), the International Society for Adult Congenital Heart Disease (ISACHD), the World Heart Federation (WHF), the European Congenital Heart Disease Organization (ECHDO), and the Global Alliance for Rheumatic and Congenital Hearts (Global ARCH). *Eur Heart J* 2021; **42:** 4213–4223.
26. Khan AD, Valente AM. Don't be alarmed: The need for enhanced partnerships between medical communities to improve outcomes for adults living with congenital heart disease. *Eur Heart J* 2021; **42:** 4249–4251.