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ORIGINAL ARTICLE
Cardiac Rehabilitation

Exercise Training for Patients With Severe Aortic Stenosis in a Convalescent Rehabilitation Ward

— A Retrospective Cohort Study —

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Background: Exercise loading is contraindicated for patients with severe aortic stenosis (AS); however, everyday activities mandate the inclusion of a light load. The aim of this study was to investigate the efficacy and safety of exercise training for patients with severe AS who were admitted to a rehabilitation ward because of physical disability.

Methods and Results: This historical cohort study was conducted at a single rehabilitation center in Japan. Patients admitted for rehabilitation of physical disability and those who met the definition of severe AS were analyzed. An exercise training program was implemented for patients with disability and severe AS. Cardiovascular symptoms during hospitalization were evaluated. Improvements in the performance of activities of daily living were assessed using the Functional Independence Measure (FIM). Eighteen patients undertook an exercise training program. The median patient age was 87 years (range 76–95 years). Of these patients, 3 died and another 3 were transferred to another hospital due to causes other than the exercise training program. None of the other patients experienced cardiovascular symptoms, and the FIM scores of 12 patients were significantly improved (median [range] scores at admission and discharge of 63 [32–88] and 87 [51–104], respectively; P<0.001).

Conclusions: An exercise training program could be applied to patients with severe AS who were admitted for convalescent rehabilitation, because it can improve FIM scores.

Key Words: Disuse syndrome; Motor disorder; Neurological disease; Rehabilitation; Severe aortic stenosis

The incidence of aortic stenosis (AS) is increasing as the mean age of the population increases; AS affects up to 5% of the elderly population.[1] Severe AS is defined by Doppler echocardiography as a peak aortic jet velocity (AV-Vel) >4.0 m/s, a mean transvalvular pressure gradient >40 mmHg, and a continuity equation valve area <1.0 cm^2 or a valve area index <0.6 cm^2 and is fatal if left untreated.[1] There have been considerable advances in treatments for AS, including transcatheter aortic valve implantation (TAVI), which was recently introduced for patients who cannot undergo surgical aortic valve replacement (SAVR).[2] With regard to mortality, SAVR and TAVI result in good outcomes among older patients.[3] In contrast, some patients with AS are inoperable because of their clinical status or comorbidities,[1] and up to 40% of patients with severe AS still do not undergo SAVR or TAVI.[4] These patients may experience stroke, bone fractures resulting from falls, and disuse syndrome. Disuse syndrome is a pathophysiological condition or symptom that affects body systems, such as the musculoskeletal, circulatory, and respiratory systems, and occurs after prescribed or unavoidable inactivity;[5] hence, there is a deterioration in the performance of activities of daily living (ADLs). The mortality rate is higher among patients with severe AS who are also diagnosed with frailty, including slow gait speed or low physical activity.[6] Although rehabilitation is needed for such patients with disability, exercise loading is contraindicated for patients with severe AS indicated for surgery.[7]

Only 1 case report has presented rehabilitation data for a patient with severe AS and New York Heart Association (NYHA) functional class III.[8] In addition, the efficacy and safety of rehabilitation or exercise training in patients with severe AS admitted to a convalescent rehabilitation ward are uncertain. Thus, the aim of the present historical cohort study was to describe the clinical course of patients

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Table 1. Exercise Training Program

	Intensity and strength	Duration of 1 session	Frequency
Aerobic exercise	*K*: 0.3–0.4	5–10 min	1–3 sessions/day
	RPE (Borg scale): 10–11		7 days/week
Resistance training	10–20% of 1RM	–	5–10 repetitions/set
	RPE (Borg scale): 10–11		1–3 sets/day
			7 days/week

The percentage of 1 repetition maximum (1RM) was calculated from actual measured values in individuals. *K*, Karvonen value; RPE, ratings of perceived exertion.

with severe AS who undertook an exercise training program in a convalescent rehabilitation ward.

Methods

Study Design and Participants

A historical cohort study (April 2015–July 2020) was performed at Toyonaka Heisei Hospital. Of the patients admitted to the convalescent rehabilitation ward due to neurological diseases, motor disorders, or disuse syndrome, those who met the definition of severe AS (i.e., AV-Vel >4.0 m/s and/or aortic valve area [AVA] <1.0 cm^2) on echocardiography were included in the present study. Echocardiography was performed in patients who were diagnosed with AS in previous medical facilities or had physical signs on admission indicative of AS.

Informed Consent

Informed consent to take part in exercise training was obtained from all patients and their family members after explaining that exercise loading was contraindicated, but that rehabilitation was necessary and would be conducted without excessive loading.

Rehabilitation

Convalescent Rehabilitation The rehabilitation for each patient was planned in line with the medical insurance system in Japan.[9] Patients with motor disorder received three 20-min sessions of physical therapy and occupational therapy (for a total of 9 sessions per day).[9] Patients with neurological disease received three 20-min sessions of physical therapy, occupational therapy, and speech language therapy (for a total of 9 sessions per day).[9] Patients with disuse syndrome received three 20-min sessions of physical therapy, occupational therapy, and speech language therapy (for a total of 6 sessions per day).[9] The highest of length of stay in the convalescent rehabilitation ward for patients with neurological disease, motor disorder, and disuse syndrome was 180, 150, and 90 days, respectively.[9]

Exercise Training Programs No guidelines have been established for rehabilitation in patients with severe AS, and exercise loading was contraindicated for this population. Consequently, we referred to the Guidelines for Rehabilitation in Patients with Cardiovascular Disease published by the Japanese Circulation Society and a report regarding rehabilitation for a patient with severe AS.[7,8]

The exercise training programs consisted of warm-up exercises, the main exercise, and cool-down exercises.[7] Warm-up exercises included massage therapy for pain management, stretching, and range-of-motion exercises (ROMEs).[7] The main exercise consisted of upper and lower limb resistance training and aerobic exercise,[7] including walking between 2 parallel bars, walking with a walking-assistance device, and training for independent walking. Cool-down exercises included massage and stretching.[7] In addition, sitting training, standing training, upper extremity functional training, training in ADLs (e.g., grooming, changing clothes, using the toilet, transferring between a bed and a wheelchair, wheelchair operation, and taking a shower), rehabilitation for higher brain dysfunction, and dysphagia rehabilitation were conducted.[8]

The exercise load was adjusted based on vital signs, target heart rate, and target rate of perceived exertion as indices during rehabilitation.[7] For patients who were not receiving β-blockers, the target heart rate was calculated using the Karvonen formula (i.e., [maximum heart rate-resting heart rate]$\times K$+resting heart rate, where K is the Karvonen value and was set at 0.3–0.4; **Table 1**).[7] For patients taking β-blockers, the target heart rate was calculated using the simple formula resting heart rate+20.[7] The target rate of perceived exertion was set at 10–11 on the Borg scale (fairly light).[7] The strength of resistance training was 10–20% of 1 repetition maximum. The strength of resistance training was set at 10–11 on the Borg scale for patients in whom 1 repetition maximum could not be measured (**Table 1**).[7] Because we assumed that the exercise intensity necessary for our patients to perform ADLs, such as sitting and conversation (1.5 metabolic equivalent [METs]), brushing their teeth, hand washing, taking a shower, having a meal and conversing, walking slowly at home (2.0 METs), walking at standard speed, and cleaning a house (3.0 METs),[7] would be ≤3.0 METs in all patients, rehabilitation was conducted at an intensity of ≤3.0 METs. In patients with femoral fracture leading to the adoption of conservative treatment because of their poor cardiac function, an attending physician and an orthopedist decided on the degree of loading on the affected leg, with the load increased in a step-wise manner.

If the exercise capacity of the patients improved, the walk distance was gradually increased up to 100 m per set and up to 300 m per day. Patients climbed up and down stairs (>4.5 METs)[7] after a survey of individual patient's houses before potential discharge. The protocol for climbing up and down stairs included 3 stages. At the start of the program, patients performed 2–3 repetitions of climbing up and down a staircase with 2 steps per set, for 1–3 sets per day. In the second stage, patients performed 2–3 repetitions of climbing up and down a staircase with 5 steps per set, for 1–3 sets per day. In the final stage, patients performed 2–3 repetitions of climbing up and down a staircase with 10 steps per set, for 1–3 sets per day.

Conversely, exercise intensity was reduced in patients with worsened chronic heart failure, because the Guidelines for Rehabilitation in Patients with Cardiovascular Disease

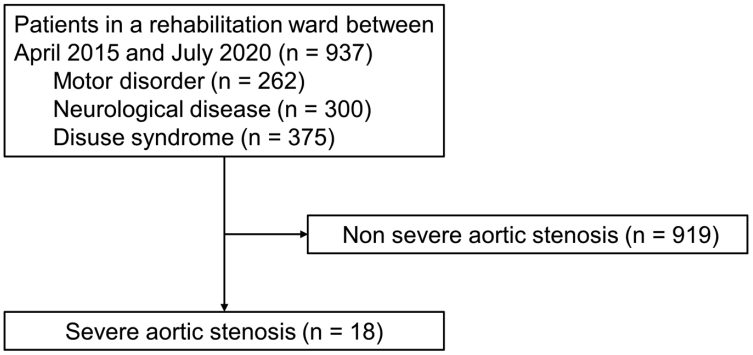

Figure 1. Flow diagram.

Table 2. Characteristics of Patients With Disability and Severe Aortic Stenosis

Patient no.	Age (years)	Sex	Target disease for rehabilitation	NYHA class	EuroSCORE II (%)	CTR (%)	AVA (cm^2)	AV-Vel (m/s)	LVEF (%)	NT-proBNP (pg/mL)
1	93	Female	Femoral neck fracture	I	7.4	47.6	0.9	3.2	40.0	3,872
2	94	Female	Femoral neck fracture	I	5.6	50.8	0.5	4.3	65.6	1,386
3	93	Female	Femoral neck fracture	II	16.5	76.0	0.4	4.5	59.0	9,430
4	88	Male	Femoral trochanteric fracture	I	2.3	50.0	0.4	NA	61.0	739
5	91	Female	Femoral trochanteric fracture	I	2.6	70.4	NA	3.8	70.0	626
6	76	Female	Femoral trochanteric fracture	I	2.0	61.1	0.3	5.6	68.0	9,149
7	83	Female	Periprosthetic fracture around the femoral stem	I	9.8	46.9	0.4	3.8	66.2	431
8	84	Female	Hip osteoarthritis	I	2.5	53.3	0.6	3.7	85.0	87
9	87	Female	Cerebral infarction	I	4.7	72.5	NA	4.1	51.0	4,020
10	82	Male	Cerebral infarction	II	3.7	62.9	NA	4.0	84.0	7,517
11	84	Female	Cervical spondylotic myelopathy	I	2.5	53.1	0.6	3.7	72.0	46
12	86	Female	Disuse syndrome	I	4.3	46.0	0.2	4.1	73.1	265
13	86	Female	Disuse syndrome	I	3.6	57.2	0.7	3.2	74.7	656
14	87	Male	Disuse syndrome	I	6.0	74.9	0.6	4.0	38.6	7,555
15	95	Female	Disuse syndrome	II	6.4	49.6	0.3	4.0	68.0	5,160
16	87	Female	Disuse syndrome	II	4.9	59.4	0.3	4.7	77.6	1,376
17	84	Male	Disuse syndrome	III	11.0	67.8	0.4	3.4	13.0	23,954
18	94	Female	Disuse syndrome	III	7.4	63.9	1.0	4.1	55.0	3,166

AV-Vel, peak aortic jet velocity; AVA, aortic valve area; CTR, cardiothoracic ratio; EuroSCORE II, European System for Cardiac Operative Risk Evaluation; LVEF, left ventricular ejection fraction; NA, not assessed; NT-proBNP, N-terminal pro B-type natriuretic peptide; NYHA, New York Heart Association.

published by the Japanese Circulation Society suggest that no activity is recommended until a patient's condition improves.[7] Respiratory rehabilitation and ROMEs were conducted at the bedside. If a patient's general condition deteriorated because of infections or pain in an affected body part, the exercise intensity was reduced. Rehabilitation, including ROMEs, and sitting training were primarily conducted at the bedside to prevent disuse syndrome.

One session of aerobic exercise that included walking and climbing up and down stairs lasted 5–10 min.[7] Aerobic exercises were performed in 1–3 sessions per day.[7] For resistance training, patients performed 5–10 repetitions per set and 1–3 sets per day.[7] All patients received rehabilitation every day (**Table 1**).

Vital signs, weight, and pedal edema were assessed before rehabilitation. Monitoring devices for electrocardiography, percutaneous arterial oxygen saturation, and blood pressure were used during rehabilitation.[7] The standards for discontinuing rehabilitation from the Japanese Circulation Society were followed.[7] Gait training and climbing up and down stairs were only conducted if the patient was asymptomatic on symptom inquiry. During the main exercise session, patients were frequently assessed for the presence of symptoms. After rehabilitation, the patients were carefully observed for changes in vital signs and any physical changes. Heart failure was monitored through changes in subjective symptoms (e.g., general fatigue and dyspnea on effort), weight gain (increase

Table 3. Diagnosis of Severe AS, Treatments for Severe AS, Past History, Comorbidities, Medications, and Laboratory Data of Patients With Severe AS (n=18)

Diagnosis of severe AS prior to admission to the convalescent rehabilitation ward	14 (78)
Treatments for severe AS	
Balloon aortic valvuloplasty	1 (6)
Conservative therapy	13 (72)
Past history	
Heart failure	4 (22)
Coronary artery disease	3 (17)
Cerebrovascular disease	2 (11)
Comorbidities	
Valvular heart disease other than AS	13 (72)
Atrial fibrillation	6 (33)
Hypertension	11 (61)
Diabetes	6 (33)
Hyperlipidemia	1 (6)
Anemia	12 (67)
Chronic kidney disease	3 (17)
Chronic liver disease	5 (28)
Motor function disorder	5 (28)
Hypothyroidism	3 (17)
Cervical spondylotic myelopathy	1 (6)
Dementia	11 (61)
Medications	
Angiotensin-converting enzyme inhibitor	3 (17)
Angiotensin II receptor blocker	3 (17)
β-blocker	3 (17)
Spironolactone	6 (33)
Furosemide	2 (11)
Tolvaptan	3 (17)
Digoxin	1 (6)
Aspirin	2 (11)
Clopidogrel	2 (11)
Apixaban	2 (11)
Rivaroxaban	2 (11)
Edoxaban	1 (6)
Laboratory data	
Hemoglobin (g/dL)	10.6 [8.0–13.5]
Creatinine (mg/dL)	0.8 [0.4–1.4]
Blood urea nitrogen (mg/dL)	18.1 [9.4–45.4]
Serum protein (g/dL)	6.3 [5.3–7.9]
Serum albumin (g/dL)	3.6 [2.2–4.0]

Data are presented as the median [range] or n (%). AS, aortic stenosis.

Table 4. Clinical Outcome of Patients With Severe Aortic Stenosis

Patient no.	Clinical outcome
1	Discharge to a long-term care facility
2	Discharge home
3	Discharge home
4	Discharge home
5	Discharge home
6	Discharge to a long-term care facility
7	Discharge home
8	Discharge home
9	Transfer to another hospital due to stroke
10	Transfer to another hospital due to anemia
11	Discharge home
12	Discharge home
13	Died due to pneumonia
14	Died due to pneumonia
15	Discharge to a long-term care facility
16	Discharge home
17	Died due to heart failure
18	Transfer to another hospital due to heart failure

≥2kg/week), increased heart rate, and N-terminal pro B-type natriuretic peptide (NT-proBNP) concentrations.[7]

Measurements

The following clinical characteristics were evaluated at baseline: age, sex, body mass index, Revised Hasegawa's Dementia Scale, target disease of rehabilitation, NYHA classification, the European System for Cardiac Operative Risk Evaluation (EuroSCORE II; a well-established cardiac surgery risk scoring tool for estimating operative mortality),[10] the cardiothoracic ratio (CTR), AVA, AV-Vel, left ventricular ejection fraction (LVEF), NT-proBNP, number of patients diagnosed with severe AS prior to admission to the convalescent rehabilitation ward, treatments for AS, past history, comorbidities, medications, and laboratory data.

Dementia was defined as ≤20 points on the Revised Hasegawa's Dementia Scale.[11] Laboratory data included hemoglobin, creatinine, blood urea nitrogen, serum total protein, and serum albumin. Anemia was defined as hemoglobin levels <13.0 g/dL in men and <12.0 g/dL in women according to the World Health Organization.[12] Safety parameters included cardiac death, exacerbation of chronic heart failure, chest pain, arrhythmia events, and syncope due to rehabilitation during the stay in a convalescent rehabilitation ward.

Improvements in ADLs were assessed using the Functional Independence Measure (FIM) to represent the effectiveness of rehabilitation. The FIM is a tool for the collection and comparison of rehabilitation outcomes, measurement of patients' progress, and planning treatment protocols.[13] ADLs include self-care, eating, grooming, bathing, dressing, toileting, swallowing, sphincter control, mobility, transfer, and locomotion.[13] The FIM contains 18 items, 13 of which are in the physical domains and 5 of which are related to cognition.[13] Motor items measure self-care, sphincter control, locomotion, and transfer.[13] Cognitive items evaluate a subject's communication and social cognition.[13] Based on the level of independence, each item is scored on a scale from 1 (total dependence) to 7 (complete independence).[13] Possible total scores range from 18 to 126, with higher scores meaning more independence in performing ADLs.[13] The FIM score is indicative of a patient's level of disability and the burden of their care.[13]

Statistical Analysis

Categorical variables are expressed as numbers and percentages, whereas continuous variables are presented as the median and range. Changes in FIM and NT-proBNP concentrations from admission to discharge were assessed using the Wilcoxon signed-rank test. Two-tailed $P<0.05$

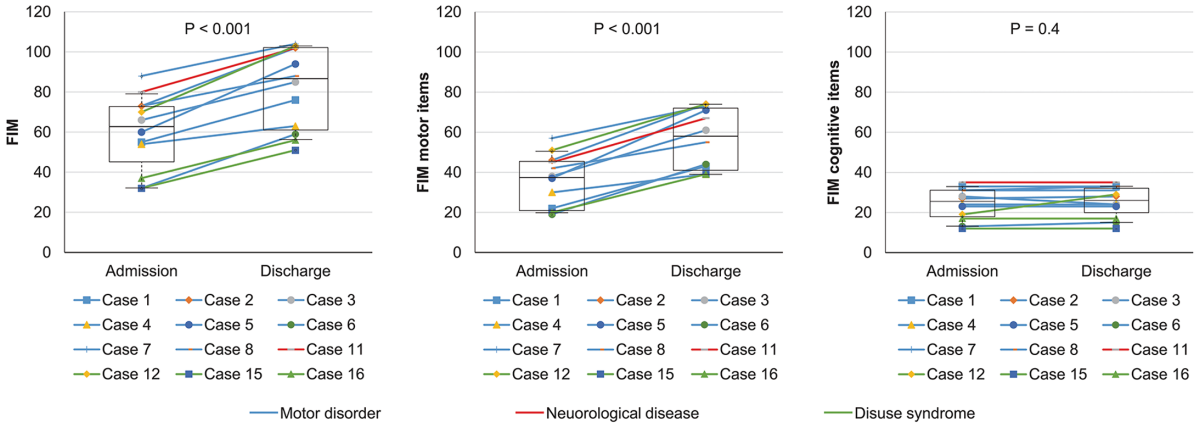

Figure 2. Comparison of time courses of Functional Independence Measure (FIM) scores from admission to discharge in the 12 patients who completed convalescent rehabilitation.

was considered statistically significant. All statistical analyses were performed using JMP 14.0 (SAS Institute Inc., Cary, NC, USA).

Results

Of the 937 patients who were admitted to the convalescent rehabilitation ward during the study period, 18 (4 men; median age 87 years [range 76–95 years]) had severe AS (**Figure 1**; **Table 2**). The median body mass index was 17.2 kg/m^2 (range 13.4–23.2 kg/m^2) and the median Revised Hasegawa's Dementia Scale score was 16 (range 0–29). The reasons for convalescent rehabilitation were motor disorder (n=8), neurological disease (n=3), and disuse syndrome (n=7; **Table 2**). In 2 patients with femoral neck fracture (Patients 1 and 3 in **Table 2**) and in 2 patients with femoral trochanteric fracture (Patients 5 and 6 in **Table 2**), conservative treatment was adopted. The causes of disuse syndrome were congestive heart failure (n=2), pulmonary tuberculosis (n=1), urinary tract infection (n=1), and a composite of infection and congestive heart failure (n=3).

In the present study, 12, 4, and 2 patients were classified as NYHA Class I, II, and III, respectively. The median EuroSCORE II was 4.8% (range 2.0–16.5%). Chest radiography showed median CTR of 58.3% (range 46.0–74.9%). Echocardiography revealed a median AVA of 0.4 cm^2 (range 0.2–1.0 cm^2) with a median AV-Vel of 4.0 m/s (range 3.2–5.6 m/s) and a median LVEF of 67.1% (range 13.0–77.6%). The median NT-proBNP concentration was 2,276 pg/mL (range 46–23,954 pg/mL; **Table 2**). Of the 18 patients included in this study, 14 were diagnosed with severe AS prior to hospital admission. One of these 14 patients underwent balloon aortic valvuloplasty, and another received conservative therapy. The comorbidity with the highest prevalence was valvular heart disease other than AS (n=13; **Table 3**).

Fourteen patients underwent gait training (Patients 1–9, 11, 12, 14, 15, and 16 in **Table 2**). Four patients climbed up and down stairs (Patients 2, 7, 11, and 12 in **Table 2**). One patient died of congestive heart failure on Day 41 after admission (Patient 17 in **Tables 2**,**4**). In this patient, respiratory rehabilitation and ROMEs were only conducted at the bedside because of severe general fatigue. Two patients died of pneumonia (Patients 13 and 14 in **Tables 2**,**4**). Three of the 18 patients withdrew from the program because of new onset of stroke, exacerbation of anemia, and congestive heart failure (Patients 9, 10, and 18, respectively, in **Tables 2**,**4**). Because Patient 18 had developed congestive heart failure prior to admission to hospital, only respiratory rehabilitation and ROMEs were performed. This patient was subsequently transferred to another hospital the following day. No other patients experienced chest pain, arrhythmia events, or syncope.

Except for the 6 patients who died or were transferred to another hospital, the median FIM scores at admission and discharge were 63 (range 32–88) and 87 (range 51–104), respectively (P<0.001). On the FIM, the median scores at admission and discharge were 38 (range 19–57) and 58 (range 39–74), respectively (P<0.001) for motor items, and 26 (range 12–35) and 26 (range 15–35), respectively (P=0.2), for cognitive items (**Figure 2**). In 18 patients, the median NT-proBNP concentration at a time near discharge was 2,680 pg/mL (range 76–29,860 pg/mL; P=0.2), and the median length of the hospital stay was 63 days (range 2–105 days).

Discussion

In this study we evaluated the clinical course of 18 patients with severe AS who were admitted to a convalescent rehabilitation ward and undertook an exercise training program. Of these 18 patients, 3 died and another 3 were transferred to another hospital due to causes other than the exercise training program. In the remaining 12 patients, the FIM scores improved significantly without apparent adverse events.

In this study, rehabilitation was conducted with utmost care and attention. Although 2 of the 18 patients died or were transferred to another hospital due to congestive heart failure, they had severe heart failure symptoms and NYHA Class III at admission. The prognosis for symptomatic AS is typically poor.[14] The cumulative 1-year incidence of aortic valve-related death and heart failure is significantly higher in patients with than without symp-

toms (13.4% vs. 6.6%, respectively).[15] Because respiratory rehabilitation and ROMEs were only performed for Patient 17, we conclude that his death can be attributed to natural causes rather than an excessive exercise load. There is no doubt that the cause of congestive heart failure in Patient 18 was not attributed to our exercise program because the same rehabilitation program was applied to Patient 17. In addition, our exercise program did not affect Patients 9, 10, 13, and 14 in that the cause of their death or transfer to another hospital was not cardiac disease.

A previous study has reported the use of rehabilitation exercises, such as sitting training, standing training, walking, and ADL training, for a patient with severe AS;[8] therefore, the participants in the present study received this type of rehabilitation. Subsequently, improvements FIM were observed in 12 of 18 patients (the exceptions being the 6 patients who died or were transferred to another hospital). Although no improvements were observed in FIM cognitive items, we noted improvements in FIM motor items (**Figure 2**). The prevalence of mild cognitive impairment in patients with heart failure ranges from 50% to 80%.[16] One randomized controlled trial of an intervention strategy to help heart failure patients with mild cognitive impairment or dementia found no significant improvement in cognitive function.[16] The rehabilitation may have demonstrated effectiveness by improving patients' physical function.

In the present study, 8 of the 18 patients had motor disorder. Among various multimorbidities, motor disorders are crucial for physical health.[17] Musculoskeletal comorbidities, such as arthritis, osteoporosis, rheumatism, and chronic back pain, impair the ability of patients with heart failure to walk.[18] Because slow gait speed was associated with mortality in severe AS,[6] gait training is necessary. Rehabilitation, including gait training, was conducted in 8 patients, and improvements in FIM scores were observed without worsening cardiac function.

Two of the 18 patients had experienced cerebral infarction. Physical health significantly decreases when cerebral stroke complicates heart failure.[17] In addition, patients with cerebral stroke require 1.5- to 2-fold the amount of oxygen used by healthy individuals when walking and climbing up and down stairs.[19] Therefore, rehabilitation is required for such patients.

Seven of the 18 patients in the present study had disuse syndrome. The decreased lower extremity muscle mass in patients with heart failure can cause abnormal ventilation, worsening exercise tolerance capacity.[20,21] A significant improvement in the functional capacity of patients with mild chronic heart failure can be obtained with low-intensity exercise training at 40% of peak oxygen uptake.[22] The mechanism responsible for this effect is most likely an increase in the oxidative capacity of the trained skeletal muscles.[22] Therefore, a combination of aerobic exercise and resistance training is critical.[23]

Study Limitations

This study has several limitations. First, the sample size was small because therapeutic exercise is generally contraindicated for patients with severe AS. Second, this study followed an observational design and did not compare patients who did and did not undertake the exercise training program. In addition, selection bias was inherent because those who appeared to tolerate the exercise training program received the program and were therefore included in the study. Finally, cardiopulmonary exercise testing was not conducted to set a target heart rate. However, despite these limitations, this study is the first to describe the clinical course of patients with severe AS who undertook an exercise training program in a convalescent rehabilitation ward. Further studies with more patients are needed to determine the efficacy and safety of the exercise training program to provide more reliable and generalizable knowledge regarding this topic.

Conclusions

This study presents an exercise training program conducted in older patients with disability and severe AS. Despite the absolute contraindication of therapeutic exercises for patients with severe AS, an exercise training program in such patients can be conducted on a case-by-case basis. In particular, gait training should be implemented for patients with severe AS whenever possible.

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Disclosures

The authors report no conflict of interests in this work.

IRB Information

This study was approved by the Research Ethics Committee of Toyonaka Heisei Hospital (No. 202001).

Data Availability

All individual deidentified participant data that support the findings of this study will be shared upon reasonable request to the corresponding author. The study protocol and statistical analysis plan will become available immediately following publication and will be available indefinitely.

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