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Cardiac rehabilitation and acute aortic dissection: understanding and addressing the evidence GAP a systematic review

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ABSTRACT

Despite guideline recommendations, strategies for implementing cardiac rehabilitation (CR) in patients with acute aortic dissection (AAD) are not well established with little evidence to risk stratify prudent and effective guidelines for the many required variables. We conducted a systematic review of studies (2004-2023) reporting CR following type A (TA) and type B (TB) AAD. Our review is limited to open surgical repair for TA and medical treatment for TB. A total of 5 studies were included (4 TA-AAD and 1 TB-AAD) in the qualitative analysis. In general, observational data included 311 patients who had an overall favorable effect of CR in AAD consisting of a modestly improved exercise capacity and work load during cycle cardiopulmonary exercise test (TB-AAD), and improved quality of life (QoL). No adverse events were reported during symptom limited pre-CR treadmill or cycle exercise VO_2 max or CR. Given the overall potential in this high risk population without adequate evidence for important variables such as safe time from post-op to CR, intensity of training, duration and frequency of sessions and followup it is time for a moderate sized well designed safe trial for patients' post-op surgery for TA-AAD and medically treated TB-AAD who are treated with standardized evidence based medical therapy and

Abbreviation: AAD, Acute aortic dissection; ACC, American College of Cardiology; ADL, Activity of daily living; AHA, American Heart Association; AVR, Aortic valve surgery; BP, Blood pressure; CPET, Cardiopulmonary exercise testing; CR, Cardiac rehabilitation; CVD, Cardiovascular disease; dBP, Diastolic blood pressure; HR, Heart rate; ICU, Intensive care unit; NOS, Newcastle–Ottawa quality assessment Scale; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines; QoL, Quality of life; sBP, Systolic blood pressure; SF-36, Short form 36; TA-AAD, Type A acute aortic dissection; TB-AAD, Type B acute aortic dissection; VO_2 max, Maximal oxygen uptake.

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physical therapy from discharge randomized to CR versus usual care. **PROSPERO registry ID:** CRD42023392896.

Introduction

Cardiac rehabilitation (CR) is a guideline-recommended, multidisciplinary program of exercise training, risk factor management, and psychosocial counseling for patients with cardiovascular disease including thoracic aortic dissection.[1-3] The earliest comprehensive guideline for managing aortic dissection was published in 2006 then regularly updated through 2023 by the Japanese Circulation Society including 3 phases of comprehensive gradual CR (intensive care unit and total hospitalization), 1-2 months post type A acute aortic dissection (TA-AAD) and 2-3 months post TA-AAD,[3] an approach to improve short and long term outcome for this very high risk group.[4]

Despite recommendation for CR by guidelines based upon clinical experience and experts, other than the safety and value of cardiopulmonary exercise testing[5–7] few evidence based recommendations are available after initial treatment of AAD. This is particularly important because of the fear and anxiety of exercise which further reduces functional capacity and quality of life (QoL) in survivors of AAD.[8–13] Among the concerns in patients with a history of aortic aneurysms and AAD is that competitive sports and isometric weightlifting increase aortic wall shear stress due to sudden rises in aortic blood pressure have been considered triggers.[12] In 2022 the American College of Cardiology/American Heart Association guidelines highlight the evidence gap for an optimal exercise program following AAD, but still recommended CR following AAD therapeutic interventions in part because of the demonstration that high intensity exercise testing following TA-AAD surgery with and without aortic valve surgery (AVR) could be done safely.[14] Remarkably, post-surgical treatment of TA-AAD without aortic valve intervention is not covered by 3rd party insurance carriers in the United States.

The purpose of this systematic review is to investigate the existing evidence regarding CR utilization and strategies in AAD survivors.

Materials and methods

A systematic review and meta-analysis of literature were conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (PRISMA).[15]

(PROSPERO registry ID: CRD42023392896).

Study selection and eligibility criteria

Inclusion criteria: 1) studies of patients participating in a hospital or out-patient center based supervised and/or hybrid or home-based CR protocol after surgery for TA-AAD or medical therapy for TB-AAD.

Exclusion criteria were: (1) endovascular surgery, (2) review/commentary articles without original data and conference abstracts; (3) studies not in English language.

Search strategy and data sources

Electronic databases: MEDLINE, Embase, Web of Science databases for relevant articles published between February 1, 2004, and July 30, 2023. Our study goal is to assess benefit and risk of CR by assessing 30day and 1 year complications and mortality, long term survival, QoL, workability, and exercise capacity. Data would include known risk factors for AAD (e.g. hypertension, atherosclerosis, genetics, rheumatologic diseases). Grey literature was screened through research from institutional repository or online platforms. Search filters applied: data of publication, document type, language, publication stage (Supplementary Table 1).

Data collection

Studies were first evaluated by title and abstract by 4 independent reviewers (NL, BR, AC, and CS). All disagreements at the title and abstract review stage were selected for assessment at the full text stage. Studies selected for full-text review were reviewed by 2 independent reviewers (AC and CS), with all discrepancies mediated by a third reviewer (NL).

Data extraction and outcome measures

Data extraction was conducted by 2 independent reviewers (AC and CS). Extracted data were compiled and manually checked by 2 independent reviewers (NL and BR).

Outcome variables sought include number of study participants active and control, symptoms and time from initial presentation, type of surgery for dissection and AVR, and time from discharge to participation in CR; duration and content of CR program (aerobic, resistance, combined, center supervised/home-based), frequency (weekly activity level), and intensity of content. Functional outcomes determined pre and post CR included exercise VO_2 maximum workload, mean peak oxygen uptake, functional capacity, QoL and workability. We documented available data on malperfusion, risk factors and comorbidities, in-hospital/30 days and long-term

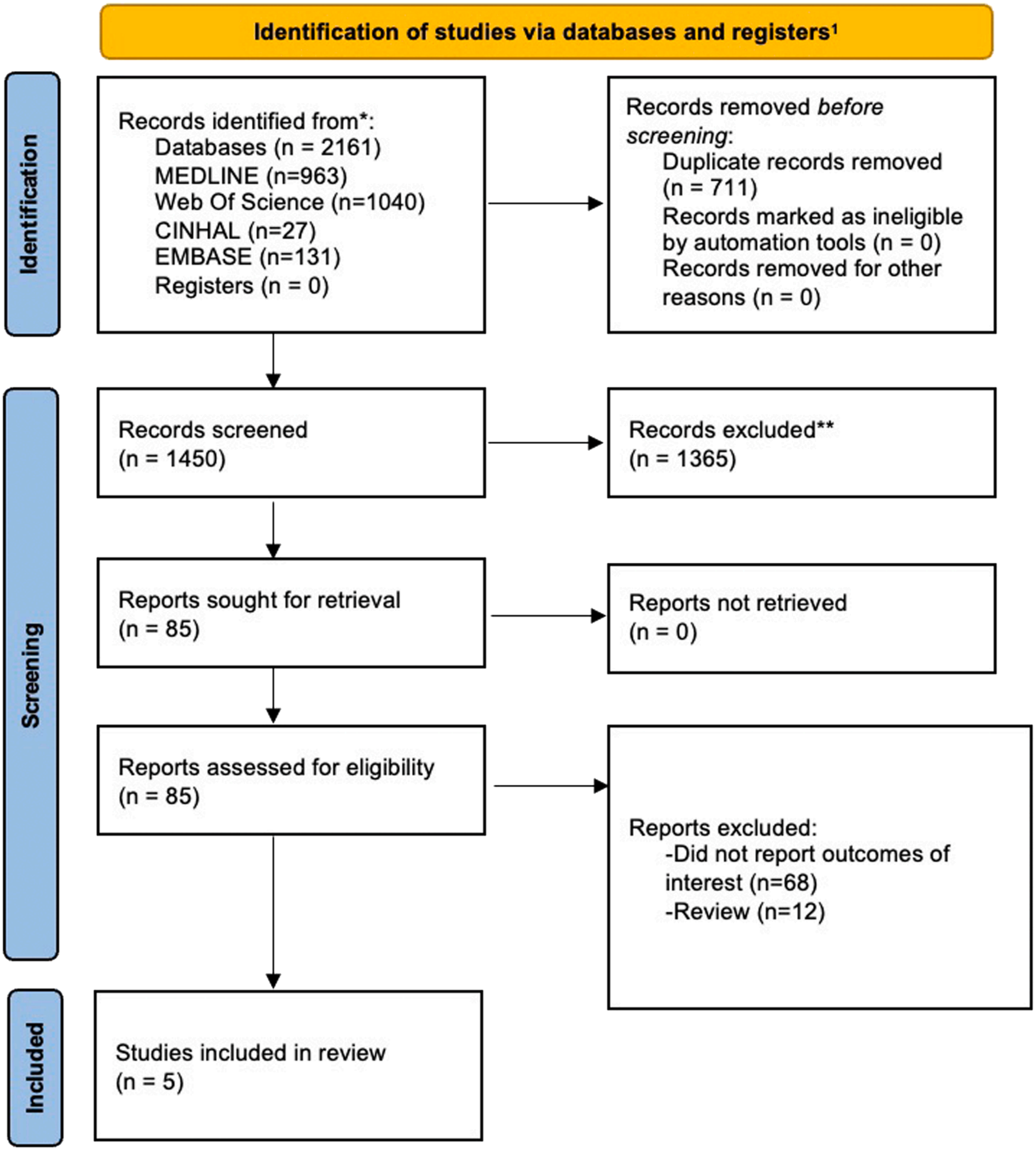

Fig. 1. PRISMA Flow Diagram for Study Selection and Screening.

outcomes (complications and mortality).

Due to high study heterogeneity in methodology and reporting of outcomes, statistical analysis was not performed for CR outcomes.

Certainty assessment

The Newcastle–Ottawa quality assessment Scale (NOS) for assessing bias in non-randomized studies was used to score the quality of the studies included in our analysis.[16]

Results

A total of 2181 entries were retrieved from the databases and manual searches. After removal of the duplicates, the pool of articles was screened upon title/abstract and a final sample of 85 articles with full text were analyzed. From this sample, 5 studies fulfilled all the eligibility criteria and were therefore included in the qualitative analysis [17–21] (Fig. 1). Two additional studies were initially

Table 1
Main characteristics of included studies, patient's clinical history and clinical presentation.

First author, year	Study design Region	Enrollment period	AAD, n Compared groups, n	Men n (%)	Age (years), mean±SD	BMI (kg/ m2), mean ±SD	Hypertension, n (%)	Smoking, n (%)	Marfan, n (%)	Neurological deficits, n(%)	Hypotension/ Shock, n (%)
TYPE A AAD											
Corone S, 2009	Prospective Multicenter France	2004 –2005	33 -	25 (78)	55.1 ± 9.3	-	-.	-	-	-	-
Fuglsang S, 2017	Retrospective Single center Denmark	2010 –2014	29 CR+CPET =10 CR = 9 Control=10	19 (65) 6 (66) 6 (66) 7 (70)	59.3± 9.3 56±7 64±13 58±8	26.4±5.9 26.8±3.6 26.9±2.6	22 (76) 8 (80) 6 (67) 8 (80)	4 (14) 3 (30) 1 (11)	3 (10) 3 (30) 0 (0) 0 (0)	-	-
Tashima Y, 2021	Retrospective Single center Japan	2009 -2019	103 AAD<70 years=51 AAD≥70 years=52	46 (45) 35 (68) 11 (22)	70±6.3 61±6.3 78±3	24.1±2.3 25.6±2.3 23.1±2.6	69 (67) 35 (66) 34 (67)	-	-	6 (6) 3 (6) 3 6()	19 (18) 8 (16) 11 (21)
Zhou N, 2022	Retrospective Single center France	2015-2021	73 -	57 (90) -	62.2±12.7	23.9±4.4	40 (55)	21 (29)	-	-	-
TYPE B AAD											
Kato T, 2020	Retrospective Single center Japan	2009 - 2017	73 Conventional[a] CR= 39 Fast-track [a]CR= 34	47 (64) 28 (72) 19 (56)	67.1±11.6 66.2±12.8 68.0±10.4	-	-	-	-.	-	-

AAD= acute aortic dissection; BMI= body mass index; CPET= Cardiopulmonary exercise testing; CR=Cardiac Rehabilitation; SD= standard deviation.

[a] Conventional CR= strict bed rest until day 4 after the onset, sitting position from day 5, standing by the bed from day 7 and walking in the ward from day 9; the fast-track rehabilitation program consisted of the following: oral intake from day 1 after onset, sitting position from day 2, standing by the bed and usage of a portable water closet from day 3, walking in the room from day 5, and discharge from day 16 if all goes smoothly.

Table 2
In-hospital treatment and outcomes.

First author, year	Surgical, n (%)	Medical, n (%)	Aortic valve replacement, n(%)	Neurological deficit, n(%)	Post-op hemodialysis, n (%)	Malperfusion, n (%)	Reintervention for bleeding, n (%)	LOS, (days), mean±SD	ICU stay, (days), mean±SD	In-hospital/30-day mortality, n (%)		Notes
										Overall[a]	Cardiac	
TYPE A AAD												
Corone S, 2009	33 (100)	0 (0)	14 (42)	3 (9)	3 (9)	9 (27)	4 (12)	-	-	-	-	Deaths for: Sepsis (n=7) MI (n=1)
Fuglsang S, 2017	29 (100)	0 (0)	0 (0)	-	-	-		-	-	-	-	
Tashima Y, 2021	103 (100)	0 (0) **<70** **70 or >**	7 (6.8) 4 (6.8) 3 (5.8) p.NS	103 (100)	12 (11.7) Total 10 (19.6) <70 yr 2 (3.8) **p 0.015**	1 (1) 0 (0) 1 (1) p NS	5 (5) 1 (2) 4 (8) p NS	24±5 22±6 **29±7 p. 045**	7±1 7±2 8±2 p.NS	8 (8) 6 (12) 2 (4) p NS	-	
Zhou N, 2022	73 (100)	0 (0)	19 (26)	-	-	-	-	-.	-	-	-	
TYPE B AAD												
Kato T, 2020	0 (0)	73 (100)	-	4 (5) 4 (5) 0 (0)	-	-	1 (1.3) 1 (1.3) 0 (0)	20±4.6 21.9±7.4 18.1±1.9	-. -	1 (1.3) 1 (1.3) 0(0)	1 (1.3) 1 (1.3) 0(0)	

LOS= length of stay; ICU=intensive care unit; MI= myocardial infarction.
[a] no studies specified surgical vs non-surgical mortality.

deemed to be suitable for inclusion, but finally were not analyzed. The first included patients presenting with an acute neurologic syndrome requiring stroke rehab following TA-AAD surgery,[22] and the other demonstrated the safety and normal blood pressure (BP) response to an afternoon of resistance training.[23]

Characteristics of the included articles, patient's clinical history and presentation

The articles included were 5 single-center retrospective studies of which one was a retrospective registry of four groups.[17–20] No randomized controlled trials were identified. The study by Tashima was designed to assess capacity to perform physical activities in the first 30 days post-op and surgical outcomes and late mortality in the elderly (≥70 yrs compared to <70yrs) who underwent surgery for TA-AAD.[20] In a retrospective pilot study of the Danish experience, Fuglsang et.al. enrolled 4 groups to assess the relative risk and value of CR following surgery for TA-AAD.[17] Primary endpoint was systolic BP during maximal cycle exercise pre and post-CR and secondary endpoints change in VO_2 max and QoL. Group I (n = 10) TA-AAD without AVR who underwent formal testing, Group II (n = 9) TA-AAD enrolled in CR without testing, Group III (n-10) TA-AAD neither tested or referred to CR, and Group IV (n = 32) post-op AVR for aortic valve stenosis. Group I, II, and IV entered a 12-week exercise based CR program at 12 weeks' post-op with QoL assessment at 6 weeks for Group I and II, and maximal incremental exercise VO_2 max in Groups I and IV 12-weeks post-op just prior to CR and 4 weeks after CR.

On the Modified NOS for studies included in a systemic review, of the 8 questions (one of which is often not done) the Kato[19] study scored (7), Fuglsang[17] (6), Corone[18] (5), Tashima[20] (5) and Zhou[21] (1). (Supplementary table 2).

The final pool of five articles included a total of 311 patients (men n = 194); two studies were conducted in France,[18,21] one Denmark,[17] and two in Japan.[19,20] Enrollment period was between 2004 and 2021. The main characteristics of included studies are reported in Table 1.

Four studies reported patients with TA-AAD,[17,18,20,21] and the Kato study was limited to uncomplicated TB-AAD.[19] The studies of Fuglsang et al.[17] and Corone et al.[18] reported the prevalence of patients affected by Marfan's syndrome, while no studies included information about the prevalence of genetic etiologies or vasculopathies. Data focusing on cardiovascular risk factors was reported in two studies.[19,21] Hypertension ranged from 55–76 % and smoking 29 to 100 %.

In-hospital treatment and clinical outcomes

All patients with diagnosis of TA-AAD were treated surgically and AVR ranged from 6.8 % to 42 %.[17,18,21] Data regarding in-hospital outcomes was variably reported by the different authors[17–21] for TA-AAD. The mean hospital stay was 23±5 days for TA-AAD, and thirty-days mortality, when reported, ranged from 4 to 8 % [9,16,20]; re-interventions for bleeding were observed between 1 and 12 % and neurological complications appeared in 5 to 30 % of patients.[18–20]

The Kato et al.[19] study was limited to patients with uncomplicated TB-AAD medically treated with the intension of lowering post-operatory complications from long term bed rest. They compared outcome in two 4year time periods, 39 patients from April 2009 through July 2013 after which 34 patients were included in a novel fast–track rehabilitation program through February 2017. The fast-track began in post-operatory day 1 and continued to discharge. The results included highly significant shorter hospital stay and lower expense in the fast-track CR compared to the conventional group ($p = 0.005$), no difference for in-hospital mortality or late adverse aortic events within 12 months after onset. There was significantly more rapid mobilization, less pneumonia, and more rapid weaning from oxygen and intravenous anti-hypertensive agents. (Table 2).

CR and functional outcomes

In two studies[19,20] patients received in-hospital phase 1 CR, starting the day after surgery or after the day 1 of TB-AAD onset. In the other studies, CR was conducted inside the hospital and started between two to twelve weeks after the surgical procedure.[17,18,21]

The studies were heterogynous for the type of CR interventions: three programs included walking sessions that gradually lengthened,[18,20] and two used stationary cycles.[18,21] In relation to muscle training, three sites incorporated strengthening exercises with calisthenics or single-muscle contraction[17,18,21] for upper and lower limbs. Finally, two groups mentioned the employment of conventional physiotherapy[19,20] and Corone et al[18] specified use of respiratory muscle training.

Regarding frequency, intensity, time, type (F.I.T.T.) parameters of the training, all but that of Fuglsang et al.[17] scheduled a daily program, with a mean duration of the sessions ranging from 30 to 60 min. Limited information was available in relation to exercise intensity, that was labelled as light by Corone et al.[18] and Zhou et al.,[21] while the other authors did not report. Finally, the entire CR program lasted from 3 to 4 weeks [18,21] for all included studies, except for Fuglsang et al. [17] who performed a 12-week program.

Adherence to intervention and CR-associated complications were not reported. Outcome were collected at the end of CR program for all studies, and at a long-term follow up by Fuglsang et al..[17] Three studies reported the variations of maximal workload during a cycle cardiopulmonary exercise testing (CPET) with a mean improvement of approximately 31.1 W.[17,18,21]

Four studies reported[17,18,20,21] BP before and after CR and/or at rest and at peak during training in TA-AAD patients. In particular, Tashima et al.[20] reported systolic and diastolic BP in TA-AAD patients, showing no significant differences pre and post CR and by age between <70 and ≥70 years old. Zhou et al.[21] didn't compare the changes in BP before and after CR. The short CR duration was not sufficient to observe benefits of exercise on resting BP, especially considering exercise training was performed at a very low intensity. Fuglsang et al.[17] showed a normal and linear increase in BP response to exercise in TA-AAD patients compared to another group of cardiovascular patients (aortic stenosis surgically treated).

Corone et al.[18] reported the mean diameter of the thoracic descending aorta had increased from 36.1±5.9 mm (initial) to 36.8 ±7.5mm at 6 month ($p = 0.005$) and to 37.6±7.0mm at 12 months after CR ($p = 0.07$vs. 6 month and $P = 0.002$ vs. initial). Kato et al[19] described, in patients with uncomplicated TB-AAD, the maximum diameter at discharge of the dissected aorta was similar between the standard CR and fast-track CR group (36.4 ± 4.4 and 36.5 ± 5.6 mm, respectively). During the 12 months of follow-up after the onset, in the standard CR group, there were 3 (7.6 %) patients with slow dilatation of the aorta requiring aortic intervention, 1 (2.5 %) with re-dissection requiring hospitalization, and 1 (2.5 %) with rupture. In contrast, there were five patients (14.7 %) with dilatation requiring aortic intervention in fast-track CR group.[19]

In TA-AAD patients, QoL was limited to the study by Fuglsang et al.[17] who observed an improvement in the physical component summary score of the short form-36 Health Survey (SF-36) questionnaire ranging from 5 to 8 points, and of 0 to 10 points for the mental component summary score; the authors observed also greater QoL values when comparing the CR group to a non-treated control group. Average age was late 50′s, and majority were males and hypertensive. While groups were small there was no significant difference in incremental change in the marked increase in resting or peak systolic BP, diastolic BP, or heart rate following CR between TA-AAD and aortic stenosis with AVR. Mean peak oxygen uptake in group I (uncomplicated TA-AAD with CR) increased from 23.5 ± 7.9 ml/min/kg before CR to 28.6 ± 8.4 ml/min/kg after CR, $p = .001$ with a comparable increase in mean maximal workload. All group I patients had an individual increase in peak oxygen uptake and maximal workload with mean increases of 22 % and 26 %, respectively. The baseline 12 weeks post-operatory VO_2 max is significantly greater than found in large cohorts from the University of Michigan (Ann Arbor, U.S) in whom patients about 12 weeks post-surgery for TA-AAD were compared to those operated for a TA-aneurysm (TAA) with bicuspid or tricuspid aortic valve. Patients ($n = 128$) completed a maximal effort treadmill stress test. The median VO_{2max} was 36 % below normative values in the TA-AAD group (at 19.2 mL/min/kg $P < 0.0001$) which was significantly lower than the TAA groups without AAD and much lower than found post-op in Group I of the Fuglsang study (23.5 ± 7.9 ml/min/kg). Systolic BP response was normal and did not differ between groups. Similar results were reported in a French group by Delsart et al who found 12week post-operatory TA-AAD cycle peak VO_2 was significantly reduced as was peak O_2 pulse (peak VO_2 divided by peak HR) each of which helped stratify risks of new aortic events and major events not directly related to aortic events post TA-AAD. Conclusion was that CR appears to be essential following aortic dissection.[7]

In uncomplicated TB-AAD patients, Kato et al[19] found no significant differences in worsening of activities of daily life (ADL) or delirium between standard and fast-track CR groups. Tashima et al[20] reported the TA-AAD elderly group (≥70 years) had significantly worsening of ADL (by Barthal Index) than the <70 years ($p = 0.032$). Only Corone et al[18] reported that 52.6 % of TA-AAD patients of working age were able to return to work.

Long-term outcomes

Data regarding long term outcomes were not uniformly reported in the studies with some having no data.[18–20] At one year follow-up in the French registry Corone et al[18] reported re-hospitalization rate for major central complication and peripheral ischemic injuries of 33 % after TA-AAD. After TA-AAD, survival rate at 1, 3, and 5 years from initial surgical repair was 89.7 %, 80.6 % and 76.4 %, respectively, for patients with postoperative walking difficulty vs 98.2 %, 98.2 %, and 98.2 % respectively, for patients without postoperative walking difficulty.[20]

Discussion

While limited and fragmented, the present report provides information about the safety and the beneficial effect of CR in AAD survivors that can be used to assist in designing a randomized clinical trial. In general, an overall favourable effect of CR in AAD patients was observed, considered as an improvement of exercise capacity during CPET,[17,18,21] QoL[17] and/or ADL.[19,20] Interestingly, in TA-AAD there was a normal and linear increase in BP response to exercise.[20] Post-operative walking difficulty appeared to be an independent predictor of mortality.[20] Amongst the most important study was in patients with uncomplicated TB-AAD, a fast-track from ICU to discharge CR is associated with lower costs and shorter hospital stay[19] with no adverse effects. It should be highlighted, except for uncomplicated TB-AAD,[19] no adverse events were reported during CR.[17–21]

There is minimal data to help decide the most appropriate exercise protocols post AAD for CR but there is good expert opinion. The 2022 ACC/AHA guidelines recommend a patient-tailored CR program characterized by an intensity of 3 to 5 metabolic equivalents of task, and avoiding strenuous lifting, lifting to the point of exhaustion, and other activities that entail maximal exertion.[14]

Van Iterson et al.[24] wrote an excellent review from the Cleveland Clinic including rationale for CR and protocols for an individual exercise prescription following AAD. They recommend exercise testing of heart rate and blood pressure responses to provide key information for developing an exercise prescription; an exercise prescription that is reflective of medical history, medications, and cardiorespiratory fitness optimizes patient safety and yields improvements in blood pressure control and cardiorespiratory fitness, among other benefits. They emphasize avoiding the quick, impulsive, and high-intensity exercise mechanical stressors that need to be intentionally avoided among individuals who in the weeks-to-months prior experienced a life-threatening AAD, but to improve prognosis also suggested not to delay enrollment in CR after hospital discharge. Content of CR should include aerobic or cardio exercise at a workload intensity ranging from 50 to 70 % of maximal/peak exercise oxygen uptake aiming at reaching at least 150 min/weekly of aerobic exercises, to be progressed to 300 min weekly over all days of a week if tolerated.[24–26] In addition, strengthening exercises may be performed at a low intensity, and generally speaking the patients must never train to exhaustion or at an intensity causing a rise of blood pressure higher than 150/90 mmHg.[24–26]

Although the previous suggestions can be broadly supported, they mirror the general recommendations for physical activity[26–33]

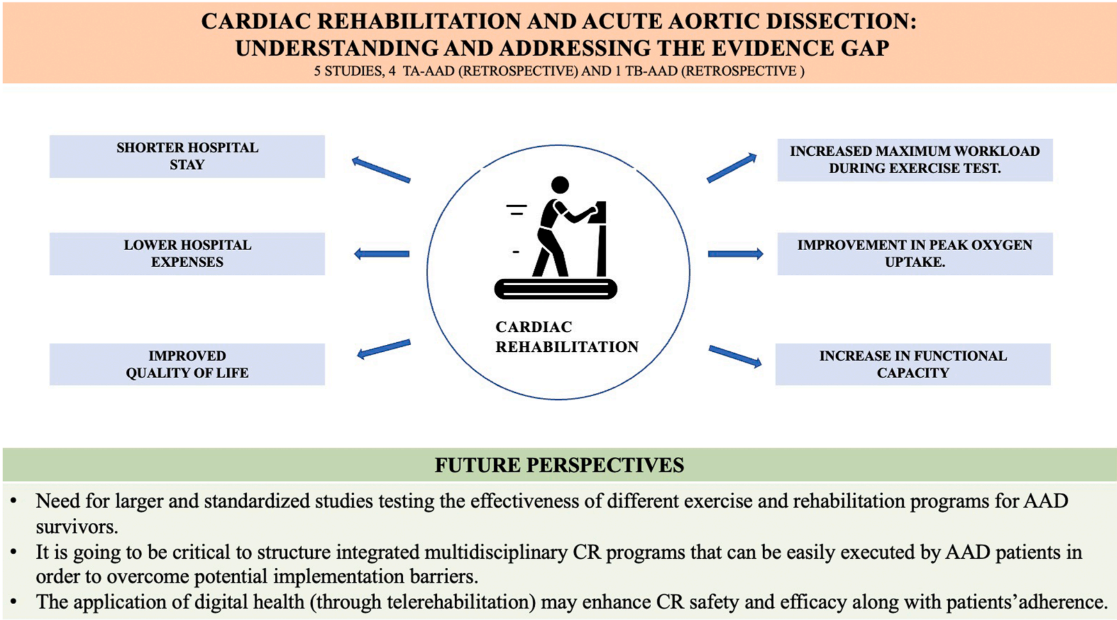

Fig. 2. Tailored cardio-respiratory rehabilitation program integrated multidisciplinary team.

and did not take into account critical aspects of patients' requiring CR after aortic surgery: 1) the stage of CR according to the patients' symptoms (CHF, orthopedic mobility, cognitive function, organ damage; 2) control of sBP and dBP with drugs as recommended in guidelines; 3) availability of CPET pre CR and post CR, 4) availability of CR programs with equipment and staff for high risk patients, and patients' adherence to medical treatment recommendations.

The risk of cardiopulmonary complications and hemodynamic status post-op surgery for type TA-AAD and TB-AAD are quite different with the former much high risk. Thus the importance of designing protocols for each facet of care including mobility as has been performed and reported in the Japanese literature.[3] Additionally, protocols for in-patient CR that transition to out-patient hospital or out-of-hospital rehabilitation phase, with graded increase in intensity as determined by physiologic testing of strength, BP response, mobility and fatigue to adjust the training intensity and duration, and to monitor the heart rate and BP response.[21] In relation to the training parameters, the available literature recommends the execution of a CPET, that is the gold standard for assessing functional capacity,[12,24] but that requires specific instruments and skilled personnel for its execution. In this regard, it should be noted in patients with heart failure the 6-minute walking test proved to be a low-cost, low fatiguing and reliable instrument to assess patients' exercise capacity and short-term prognosis, when analyzed against the CPET.[31] Secondly, the availability of CR programs is worldwide low (only 38.8 % of countries),[32] as well the adherence by the patients, that is reported to be low despite their effectiveness, and that is influenced by age, sex and retirement.[34] In addition, the lack of referral by physicians, associated illness, specific cardiac diagnoses, reimbursement, self-efficacy, perceived benefits of CR, distance and transportation, self-concept, self-motivation, family composition and occupation need to be taken into account.[35]

Limitations

First, the included studies were characterized by retrospective design resulting in an overall moderate-low quality of the evidence. Furthermore, a high heterogeneity was observed which may have influenced the results. Second, different CR protocols and related functional outcomes were implemented which were often not comparable. Third, the effects of CR on BP and aortic diameters remains to be fully investigated. Finally, data about CR adherence were not reported.

Conclusions and future perspectives

CR performed after AAD therapeutic interventions in those relatively low risk is associated with improvements in exercise capacity and QoL. However, there is an urgent need for centers of excellence in aortic disease to have standardized in-hospital protocols with phase I CR integrated with post-operative care protocols in the patients' local community delivered by staff trained in care of AAD. Randomized controlled trials are needed to test the effectiveness and duration of CR protocols for AAD survivors. Most importantly, patients' adherence remains a major issue. Thus, it is going to be critical to structure integrated multidisciplinary CR programs that can be easily executed by AAD survivors in order to overcome potential implementation barriers.[36–39]

We recommend a moderate sized well designed safe trial for post- AAD therapeutic interventions (surgical, endovascular and/or medical) patients randomized at the time of hospital discharge to CR (center based, hybrid, and/or home-based depending on

Table 3
Cardiac Rehabilitation (CR), functional outcome and quality of life.

First author, year	Time after surgery to CR	CR interventions (n)	Frequency (times/ week)	Time per session (min)	Intensity	Duration	Functional outcomes	Aortic diameters variations (mm), mean±SD	Blood pressure (mmHg), mean ±SD	Quality of lifeADL, IADLs
TYPE A AAD										
Corone S, 2009	27 ± 21 days	Walk, relaxations and respiratory physiotherapy (7) Cycle ergometer training (21) Calisthenics + isolated segmental dynamic exercise session (16) Calisthenics only (n= ?) Walking training (33)	- 3-5 5 5 3 -5	- 40 30 -45 30 -45 30	- Light Light Light -	18±10 days	Maximum workload (Watt) Pre 62.7 ± 11.8 Post 91.6 ± 16.5	Pre 36.1 ± 5.9 mm Post 36.8 ± 7.5 mm	-	-
Fuglsang S, 2017	6 to 12 weeks	Fitness, muscle strength training, stretching	3	60	Individually adjusted	12 weeks	Vo2peak (ml/ kg/min) CR+CPET Pre 23.5±7.9 Post 28.6±8.4 Maximum Workload (Watt) Pre143±80 W Post 178±97 W	-	CR+CPET Pre SBP 143±16 post 200±32 Pre DBP 80±12 post 95±22 At end of program: SBP (140±10 at rest; 207±33 at maximum effort) DPB (83±13 at rest to 99±21 at maximum effort)	PCS in CR+CPET Pre 37.5±87.5 Post 45.1 ± 15.0 MCS Pre 40.1±14.5 Post 51.1±6.0 CR PCS Pre 35.6±8.4 Post 40.0± 9.0 MCS Pre 42.7±13.1 Post 41.7±6.7 Control group PCS 30.0±11.3 MCS 32.5±13.3
Tashima Y, 2021	1 day	Physical rehabilitation carried out in a seated position including foot stepping, standing by bedside and then walking 50m, with walking distance gradually increasing	-	-	-	-	-	-	Pre SBP 116.5 (106-128) Pre DBP 69.5 (60–74.3) Post SBP 121.5 (110–134) Post DBP 72 (64-80.5)	Barthel Index at discharge: 96.9 ± 6.7
Zhou N, 2022	26.±17 days	Moderate intensity continuous training on a bike and muscle strengthening exercises of upper and lower limbs	5	60	Moderate	30±11 days	Maximal workload (Watt): Pre 63.5±28.6 Post 93.0 ±35.6 MET (Kcal/kg/ h): Pre 3.67±0.96 Post 4.94 ±1.21	-	Maximal SBP during exercise test: pre CR 142 ±29 post CR 170 ±39 Maximal DBP during exercise test: pre CR 75 ±19 post CR 96 ±30	-
TYPE B AAD										
Kato T, 2020	1 day	Conventional CR[a] Fast-track CR[b]	7	-	-	16 -22 days	-	At discharge: Conventional CR: 36.4±4.4 Fast track: 36.5 ±5.6	-	No differences in ADL between conventional and fast track CR.

ADL= Activity of daily living; CPET=Cardiopulmonary exercise testing; CR=Cardiac Rehabilitation; DBP=Diastolic blood pressure; IADLs=Instrumental activities of daily living; MCS=Mental component score; MET=Metabolic Equivalent of Task; PCS=Physical component score; SBP=Systolic blood pressure; Vo2peak=Peak oxygen consumption; W=Watt.

[a] bed rest until day 4, seating day 5, standing day 7, walking 50m from day 9.

[b] seating day 2, standing day 3, walking 50 m day 7 to 300 m day 9.

Table 4
Follow-up and Long-term survival.

First author	Follow-up, mean	1-year survival, %	5-year survival, %	Rehospitalization, n (%)
TYPE A AAD				
Corone S, 2009	12 months	-	-	FU over 12 months: Re-intervention for major central complication= 3 (9.1) Peripheral ischemia complication= 3 (9.1)
Fuglsang S, 2017	-	-	-	-
Tashima Y, 2021	49 months	<70 years: 97.8 % ≥70 years: 92 %	<70 years: 94 % ≥70 years: 85 %	-
Zhou N, 2022	-	-	-	-
TYPE B AAD				
Kato T, 2020	12 months	-	-	Aortic events within 1 year after discharge: Conventional CR n=5 (12.8) Fast-track CR n=5 (14.7) Late aortic events (3-year) including dilatation >5mm or dissection: Conventional CR =13 (38.2) Fast-track =11 (40.7)

CR=Cardiac Rehabilitation; FU=Follow-up

comorbidities) versus usual care. The study would aim to assess the value of out-patient CR in reducing 1 year (and long term) complications and survival as well as in enhancing QoL, workability, and exercise capacity along with a cost/benefit analysis. Fig. 2, Table 3,Table 4

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Authors' Contributions

AC (Vanvitelli University), NL draft the work. CS, BR, GC and RP collected the data. AC (University Vanvitelli), NL, RI, AMM, GE RM and FM analyzed data; ST, AC (Federico II), MR and EB revised the manuscript.

All authors have read and agreed to the published version of the manuscript.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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