BICUSPID AORTIC Valve IN SPECIAL CAREERS

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[La valvola aortica bicuspidi nelle occupazioni speciali]

ABSTRACT

Athletes, firefighters and pilots are often in intense working stress. They are prone to have heart attack, especially in the condition of a bicuspid aortic valve. Aortic regurgitation and aortic wall weakness are often complicated with bicuspid aortic valve, thereby placing these professionals in a more dangerous circumstance. An appropriate screening strategy and further annual cardiovascular work-up are indispensable in order to disqualify the professionals who are at risk, to prevent sudden cardiac death and to assure a safe working environment. Therefore, athletes, firefighters and pilots with a bicuspid aortic valve warrant regular follow-up with at least annual echocardiographic assessment. Waiver guidelines have to be strictly followed in order to avoid unnecessary losses.

Key words: Bicuspid aortic valve; firefighters; sports.

Received February 25, 2013; Accepted March 19, 2013

Introduction

Bicuspid aortic valve (BAV) is the most common congenital heart defect accounting for 1-2% of the population\(^{(1)}\). Patients with a BAV tend to develop aortic dilation, aneurysmal formation or dissection due to the weakened aortic wall. A BAV has therefore been taken as an entity of both the aortic valve and the aorta rather than a pure aortic valvular malformation\(^{(1)}\). BAVs are often associated with many cardiovascular complications: aortic stenosis, aortic regurgitation (AR) and infective endocarditis\(^{(2)}\). In the condition of physical stress, a disordered aortic valve may easily deteriorate and the ascending aorta may dilate\(^{(3)}\). Accordingly, disruption of the valvular apparatus, or of the valve itself, may predispose sudden cardiac death under extreme physical activity\(^{(4)}\). Besides, various cardiovascular disorders that involve the myocardium, coronary arteries, aortic walls and conduction system represent the most common causes of sudden cardiac death in young athletes\(^{(5)}\).

Athletes, firefighters and pilots are in intense working stress in a hazardous environment similar with athletes. BAV has not been sufficiently described in regard to these special careers. The aim of the present article is to review the key literature and discuss the potential hazards of a BAV in these careers.

Special occupations

Athletes

Sports activities are classified into two main categories: dynamic and static, and sport intensity is roughly divided into three: low, moderate and high\(^{(6)}\). Athletic exercise is associated with cardiac morphology changes including increase of volume, wall thickness and mass index of the left ventricle (LV)\(^{(7)}\). Long-term cardiovascular adaptation to dynamic exercise may impact volume load on the LV through increased cardiac output and increased maximal oxygen uptake\(^{(8)}\). Strength-trained athletes may have increased wall thickness, LV circumferential end-sys-
to diastolic stress and relative wall thickness and larger aortic root diameters; whereas endurance-trained athletes had greater LV stroke volume and LV end-diastolic diameter\(^8\). Body surface area, type and duration of training and LV circumferential end-systolic stress were proved to be the independent predictors of aortic root diameter\(^8\). A comparison made between children, adolescents and young athletes revealed that LV mass was apparently increased in childhood, approached near maximal values in adolescents and remained maximal in young adults\(^9\).

The prevalence of BAV was 0.89-2.5% in athletes in diverse series\(^10-12\), with a male predilection account for 78%\(^10\). Prevalence of normally functioning BAVs in athletes varied between 15.5-50%\(^10-12\). Athletes with a normally functioning BAV may exacerbate the pre-existing pathological adaptation and those with a regurgitant BAV may accelerate valve deterioration and progressive aortic dilation with sustained sport activities\(^10\). The natural course of BAV in the young was AR rather than aortic stenosis, followed by aortic root dilation\(^10\). Valvular dysfunction in athletes with a BAV was predominantly AR\(^12-13\). About 80% of the competitive athletes had only mild to moderate AR, but aortic stenosis was merely an occasional perception of the preparticipation screening\(^11-14\). The valvular disorder may progress with a long-term and intensive physical exercise in young athletes\(^15\).

Athletes with a BAV may have a normal LV performance\(^15\). However, sport activity may influence the LV performance of asymptomatic BAV athletes even though their LV structures were somehow normal\(^16\). These athletes may have lower strains than healthy subjects in LV basal segments\(^15\). LV end-systolic diameters were larger at rest in the BAV than in athletes with a tricuspid aortic valve, and aortic peak flow velocity and LV ejection fraction showed a significant increase after physical effort in both BAV and tricuspid aortic valve groups\(^17\).

Clinical observations revealed that the aortic root dimensions were significantly larger in athletes with a BAV than in those with a tricuspid aortic valve, but aortic dilation did not correlate with age, body surface area, aortic regurgitation or duration of training\(^12\). Aortic root enlargement (>40 mm in males and >34 mm in females) was particularly uncommon in highly trained athletes. Enlarged aortas in male athletes showed further dimensional increases, thereby outstanding the importance of echocardiography in the annual athletic follow-up\(^15\). A BAV with aortic dilation may increase blood pressure and predispose to an aortic rupture during intensive and competitive exercise\(^9\).

The risk for sudden cardiac death was 1:72,500 in high school athletes\(^19\). Male athletes were at higher risk of sports-related sudden death than females with a male-to-female ratio of 10:1, due to the fact that males had higher participation rate of competitive sports, more intensive training load and higher athletic achievement targets\(^20\). Anomalous origin of the left main coronary artery from the right sinus of Valsalva, stenosed BAV and myocarditis have been found to be cardiovascular causes of sudden deaths in competitive athletes\(^20\).

The possible negative or positive impacts of regular physical activity and intense training on BAVs have not been assured. The eligibility for participation of athletes with a BAV in sports should be individualized depending on age, severity of lesions and type of sport\(^17\). Athletes with a BAV should undergo a thorough evaluation of the aortic valve and serial cardiac surveillance. Antibiotic prophylaxis for endocarditis is necessary\(^21,22\). Athlete participants with a suspicion of cardiovascular disease by preparticipation screening should be disqualified from competitive sports\(^20\). After a surgical procedure, the eligibility for participation in sports has to be based on the type of intervention, the anatomy of the prosthetic valve and the LV recovery rate from volume or pressure overload as well as ascending aortic and arch dimensions. Ross procedure is an exception of heart surgery to be readmitted to competitive sports as it is free of mechanical prosthetic and postoperative anticoagulant therapy\(^23\). The limitations for the athletic competitive sports were summarized in Table 1.

**Firefighters**

Firefighting is one of the most strenuous and hazardous civilian occupations\(^24\). It often requires firefighters to work at near maximal heart rates for long periods as a result of the insulated protective clothing they wear in a thermoneutral environment\(^29\). The increase in heart rate may start with responding to the initial alarm and persist throughout the course of fire suppression\(^30-33\). Heavy physical exertion may trigger the onset of cardiovascular events during periods of alarm response of fire suppression\(^34-35\). The high physical and psychological stresses made the firefighters be with numerous metabolic abnormalities and at an increased cardiovascular risk\(^36\). The prevalence of metabolic syndrome in the firefighters was 15%\(^36\). Cardiorespiratory fitness declines with aging were an independent predictor of cardiovascular...
lar mortality among firefighters dependent on the maximal oxygen consumption\(^{(37)}\). An inverse relationship has been found between cardiorespiratory fitness and the number of metabolic abnormalities\(^{(36)}\). Firefighters seemed to be healthier if they remained actively in their career than those who switched to sedentary working positions in their later decades. A young male firefighter was reported to be suddenly collapsed while working, who was evidenced to have a BAV, which ensured aortic

Table 1: Sport limitations for athletes.

<table>
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<th>Limitation</th>
<th>Cardiovascular disorder</th>
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| No limitation | ![List of cardiovascular disorders](image)
| Moderate static or low/moderate dynamic sports | ![List of cardiovascular disorders](image)
| Low-intensity competitive sports | ![List of cardiovascular disorders](image)
| Disqualified from competitive sports | ![List of cardiovascular disorders](image)
valve disorder a risk factor responsible for the sudden death\textsuperscript{29}. Therefore, annual physical performance evaluation for firefighters is essential for the examination of the capability of firefighting\textsuperscript{29}.

**Pilots**

Aortic stenosis is still unusual in military aviators with a BAV. In the US, any degree of aortic stenosis is disqualifying for army pilots of all aviation classes, and any AR greater than trace is disqualifying for all flying classes. Aortic disease or any valvular disease is disqualifying for Space and Missile Operations Duty (SMOD) personnel. Aeromedical Consult Service re-evaluations are performed at 1-3 year intervals, depending on the degree of AR and LV performance and dimensions. Angiotensin-converting-enzyme inhibitors and calcium channel antagonists have been acceptable for afterload reduction in aviators with asymptomatic moderate or severe AR. Waiver may be considered after surgery\textsuperscript{38}. Pilots with heart valve replacements, rhythm disturbances, pacemakers and heart failure are granted waivers. According to Virtual Flight Surgeons, only 0.1% of medical applications to the Federal Aviation Administration received a final denial\textsuperscript{39}.

Civilian pilots with AR are generally followed with annual echocardiographic evaluation. When they become symptomatic or with progressive cardiac chamber enlargement, then their cases may be assessed by a Federal Aviation Administration cardiology consultant. Review of Aeromedical Information Management and Waiver Tracking System revealed 144 cases of BAVs. Of the 16 disqualified BAV cases, eight were disqualified for a BAV with associated cardiac conditions (e.g. moderate to severe AR, dilated aortic root, and post aortic valve replacement due to AR), three for additional cardiac conditions (e.g. coronary artery disease, and exercise-induced syncope) and the remaining five for other medical conditions\textsuperscript{40}. Lü et al.\textsuperscript{40} did not find any hemodynamic changes or indications for medical intervention or operation for BAV in two asymptomatic civilian pilots. Both showed good endurance after taking a flying task for 13 and three months respectively and no flying accident or accident proneness occurred. Accordingly, civilian pilots with a BAV should undergo a medical work-up following the principles of individual evaluation, risk assessment and caution care. Special qualification would be issued on the base of pilot’s self-awareness, flight surgeon’s supervision and regular consultation. BAV may fit for civil navigation if no other aortic abnormality was demonstrated\textsuperscript{41}.

**Discussion**

Some people are attracted to type of work typically engaged in adventurous, daring, or risky activities, such as skydiving, racing, mountain climbing and flying. Under these circumstances, they require physical and mental attributes, such as balance, strength and endurance\textsuperscript{42}. Athletics is characterized by a strong interest in athletic pursuits. Successful people in this career are usually competitive. They are usually involved in competing activities while displaying athletic skills, participating with a team, training in physical fitness, or teaching, coaching or instructing. As mentioned above, normally functioning BAV usually does not represent a limit for physical stress. Impact of exercise stress on an abnormal aortic valve may predispose its early deterioration and accelerate the development of complications.

Firefighters face extreme danger every day. Some of the major risks are burn injuries, suffocation due to oxygen deprivation, dangerous smoke inhalation, toxic gases and falling or collapses of building materials. To protect from the hazards, firefighters wear heavy-duty safety equipment. Routine firefighters also face risks due to exposure to asbestos and many other hazardous materials like carcinogens\textsuperscript{43}. While working with the special equipment, the firefighter is exposed to high noise environment, changing thermal conditions and hazardous breathing atmospheres. In addition, their protective equipments that would reduce injury, disability and even death can be limitations to their movements, efficiency and performance\textsuperscript{44}. The risk of heart attack is high when firefighters are working at a fire scene with 10-100 times the normal risk of heart attack. Although firefighters spend only 1-5% of their time putting out fires, 32% of firefighter deaths from heart attacks occur at fire scenes. Firefighters may have increased death risk during fire suppression due to strenuous exertion and the underlying coronary heart disease. In addition, many firefighters are overweight and lack adequate physical fitness, which may constitute risk factors\textsuperscript{45}.

Pilot’s +Gz tolerance can be affected by the Push-Pull phenomenon, which is characterized by the rapid and significant decrease of blood pressure with a slower recovery to normal\textsuperscript{46}. The bottom line is that
G tolerance for each individual aviator may fluctuate and lead to disastrous consequences in flight so that military pilots do a “G warm-up” maneuver prior to flying\footnote{47}. During +Gz accelerations, pressure breathing may maintain cerebral perfusion by raising the systemic arterial pressure. The G tolerance level can be enhanced by the use of anti-G suits and seat tiltback angles alone\footnote{48}. Aortic valve surgery in active flight duty showed a particularly high rate of BAV. According to European legislation, pilots can return to flight duty six months after the operation with reasonable limitations including a good cardiac function and no cardioactive medication requirements for bioprostheses. However, mechanical prostheses may hinder their recruitment due to anticoagulation requirements. Pericardial and stentless valves can be the preferable bioprostheses of choices due to their better flow characteristics under high output volume conditions\footnote{49}.

Military life is more stressful, while physical activity is an effective way to reduce stress. Besides, mental health including biofeedback, assisted relaxation and stress management may be helpful to relieve the stress disorders. Preparticipation evaluation including genetic screening is to detect and disqualify athletes at risk and to reassure the healthy, unaffected individuals\footnote{50}. In the US, Aeromedical Examiner is responsible for determining the flight duty of pilots\footnote{49}. Repetitive cardiological controls are mandatory for early assessment of structural valve disease and rhythm disturbances\footnote{49}.

In conclusion, stressful occupations including athletes, firefighters and pilots are prone to have heart attack, especially in the condition of a BAV. AR and aortic wall weakness are often complicated with BAV, thereby placing these professionals in a more dangerous circumstance. An appropriate screening strategy and further annual cardiovascular work-up are indispensable in order to disqualify the professionals who are at risk, to prevent sudden cardiac death and to assure a safe working environment. Therefore, athletes, firefighters and pilots with a BAV warrant regular follow-up with at least annual echocardiographic assessment. Waiver guidelines have to be strictly followed in order to avoid unnecessary losses.

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