An introduction to aviation cardiology

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ABSTRACT
The management of cardiovascular disease (CVD) has evolved significantly in the last 20 years; however, the last major publication to address a consensus on the management of CVD in aircrew was published in 1999, following the second European Society of Cardiology conference of aviation cardiology experts. This article outlines an introduction to aviation cardiology and focuses on the broad aviation medicine considerations that are required to manage aircrew appropriately and optimally (both pilots and non-pilot aviation professionals). This and the other articles in this series are born out of a 3 year collaborative working group between international military aviation cardiologists and aviation medicine specialists, many of whom also work with and advise civil aviation authorities, as part of a North Atlantic Treaty Organization (NATO) led initiative to address the occupational ramifications of CVD in aircrew (HFM-251). This article describes the types of aircrew employed in the civil and military aviation profession in the 21st century; the types of aircraft and aviation environment that must be understood when managing aircrew with CVD; the regulatory bodies involved in aircrew licensing and the risk assessment processes that are used in aviation medicine to determine the suitability of aircrew to fly with medical (and specifically cardiovascular) disease; and the ethical, occupational and clinical tensions that exist when managing patients with CVD who are also professional aircrew.

INTRODUCTION
Fortunately, cardiovascular disease (CVD) is a relatively infrequent cause of sudden incapacitation in aircrew, but it accounts for 50% of all pilot licences declined or withdrawn for medical reasons in Western Europe.[1–3] Aircrew (both pilots and non-pilot aircrew) are responsible for both flight safety and reliable flight operations, and while the need for cardiac intervention is relatively uncommon among both active pilots and the wider aircrew population, when CVD is discovered, appropriate (and often lengthy and in-depth) investigations and clinical management are required to ensure flight safety is not compromised. Aircrew are medically screened more intensively than many other professions; however, despite this, cardiovascular conditions such as acute coronary syndromes remain a causative factor in commercial aircraft accidents and fatalities.[4 5] In both the civil and military domains, aircrew retirement age is increasing (up to age 65 years) and the burden of subclinical but potentially significant pathology, such as coronary atherosclerosis and valvular heart disease, is unknown in qualified pilots above the age of 40.[6–9] The risk of aeromedically important cardiovascular medical complications increase with age and include acute ischaemic pain, thromboembolic events and rhythm disturbances, due to their potential for both distraction and sudden incapacitation. Largely because of this, the French Air Force retire their single-seat military fighter aircraft aircrew at the age of 40 years old.[i]

The last major publication that addressed a consensus on the management of CVD in aircrew was published in 1999 following the second European Society of Cardiology conference of aviation cardiology experts.[1] Significant developments in cardiovascular medicine and aviation have occurred since this was published, and these advances must be considered in contemporary practice of aviation cardiology/medicine. Modern fast jet military aircraft place significantly greater strain on the cardiovascular system than in the late 1990s. This manuscript describes the current medical regulatory framework for aircrew; aircrew roles in the civil and military aviation profession; the types of aircraft and aviation environment that must be understood when managing aircrew with CVD; the regulatory bodies involved in aircrew licensing and the risk assessment processes that are used in aviation medicine to determine the suitability of aircrew to fly with medical (and specifically cardiovascular) disease; and the ethical, occupational and

[i]Evidence-based cardiovascular risk assessment in aircrew poses significant challenges in the aviation environment as data to support decision making at the low level of tolerable risk in aviation are rarely available from the published literature. As a result, there are discrepancies between aviation authorities' recommendations in different countries, and even between licensing organisations within single countries. The North Atlantic Treaty Organization (NATO) HFM-251 Occupational Cardiology in Military Aircrew working group comprises full-time aviation medicine and aviation cardiology experts who advise both their military and civil aviation organisations including, but not limited to, the US Federal Aviation Administration (FAA), the UK Civil Aviation Authority (CAA), the European Aviation Safety Agency (EASA) and the National Aeronautics and Space Administration (NASA). The recommendations of this group are a result of a 3 year working group that considered best clinical cardiovascular practice guidelines within the context of aviation medicine and risk principles. This work was conducted independently of existing national and transnational regulators, both military and civilian, but considered all available policies, in an attempt to determine best evidence-based practice in this field. The recommendations presented in this document, and associated articles, is based on expert consensus opinion of the NATO group. This body of work has been produced to develop the evidence base for military aviation cardiology and to continue to update the relevant civilian aviation cardiology advice following the 1998 European Society of Cardiology aviation cardiology meeting.

clinical tensions that exist when managing patients with CVD who are also professional aircrew. It serves as an introduction to the subsequent papers on risk assessment of aircrew,[10] screening of aircrew[11] and specific articles that address coronary artery disease (both pre- and post-intervention),[12 13] electrical abnormalities of the heart,[14] valvular disease,[15] heart muscle disease,[16] congenital heart disease[17] and cardiac intervention[18] in aircrew. This article does not address cabin crew or passengers.

REGULATION OF MEDICAL CONDITIONS IN AIRCREW

The determination of an individual's suitability for flying falls under the field of aviation medicine, a recognised sub-specialty of medicine[19] and one, from a clinical perspective, which requires a detailed understanding of occupational roles, commercial and recreation aviation activities, environmental physiology and specific risk assessment. Different medical regulations apply for aircrew (that are statutory) and for passengers (non-statutory), and while guidance on the fitness to fly for passengers with CVD is relatively contemporaneous,[20] the last consensus guidelines for aircrew require updating.

United Nations countries are signatories to the International Civil Aviation Organisation (ICAO) which provides high level governance to international civilian air operations in the form of International Standards and Recommended Practices (ISARPS). Medical requirements are codified in Article 1 of the ICAO convention and Annex 1 contains brief medical statements that are interpreted by national regulators. At the national level, air operations are governed by aeronautics legislation that license all aircraft operations, both military and civilian, within their jurisdictions. Some countries may have separate acts for military air operations. Civilian aircrew are certified under the relevant aeronautics acts for specific aircrew privileges—that is, professional/private pilot, air traffic controllers (ATCO), etc. For aircrew, a medical certificate is required to exercise the privileges of their specific licence—that is, single or multicrew operations, aircraft weight limits and allowable numbers of passengers. In the civilian world, aviation medical certificates are usually issued by designated aeromedical examiners (AME). In military operations, aircrew are similarly authorised for specific aircrew functions (pilot, navigator, air controller, etc), and medical examination is performed by flight surgeons or similarly trained military aviation medical specialists before authorisation of aircrew privileges.

The assessment of aircrew requires specific aviation medicine training (such as the Diploma in Aviation Medicine (DAvMed)), accredited specialist training programmes for aerospace medicine, and certification from both the national and supranational aviation agencies (eg, Civil Aviation Authority (CAA) in the UK, Federal Aviation Administration (FAA) in the USA, and European Aviation Safety Agency (EASA) for the European continent, to name but a few). A licensed AME is the primary medical person who assesses aircrew,[2 21 22]although nowadays some jurisdictions (such as the CAA) allow general practitioners to assess (non-commercial) light aircraft pilots.[23] The AME, as a general aviation medicine specialist, is a valuable resource who may assist cardiologists, both when determining the most appropriate clinical management of aircrew, and when determining the post-intervention or surgical time-scale for patients to fly, both as both passengers and aircrew.

There are several levels of licence covering commercial, private and recreational privileges,[24 25] in addition to air traffic control[26] and engineer licences.[27] In broad terms, professional pilots, private pilots, and air controllers (ATCO) hold different classes of licences with differing medical standards; professional pilots hold class I licences, private pilots class II, and ATCO class III, all with differing medical standards required to be met to be eligible. In the civil environment restrictions on licences, for those with known medical conditions, may require a multicrew limitation and mandate a second pilot, suitably qualified on type, to be present and able to take control, in the event of acute incapacitation, with non-pilot aircrew having similar restrictions to ensure flight safety.[23]

Military aircrew clearance is usually significantly more restrictive than civil regulations as military aircrew are also likely to be exposed to significant additional demands when conducting their duties, whether due to environmental factors associated with flying high performance aircraft (eg, hypoxia, sustained acceleration (G forces)),[28] undertaking their activity in a hostile operational environment (from flying over enemy territory to being engaged in air combat manoeuvres), or merely operating from base environments that are not conducive to the usual maintenance of circadian rhythm or sleep patterns.[29] All of these factors may generate additional psychological and physical stressors that must be considered in military flight operations. The concept of being 'mission critical' (where incapacitation would lead to failure to complete the mission) must also be considered for any member of aircrew, alongside the baseline consideration of whether an individual is 'flight critical' (where incapacitation would lead to loss of the aircraft). Military employment standards need to meet the regulatory requirements of the Military Aviation Authority as well as those of general military employment, whereas the civil authority is only concerned as a regulator, not an employer. Consequently, military standards tend to be higher due to the operating environment and general employment considerations.

Finally, aircrew standards usually differ for applicants versus trained aircrew, both in the commercial and military sectors. This is predominantly for economic reasons and reflects the fact that investment in aircrew training often runs into many hundreds of thousands, if not millions, of pounds.[30] There is an understandable reluctance to accept additional risk at the outset of flying training or aircrew licensing; however, in trained aircrew, an ability to protect the substantial investment made in individuals, by restricting the role of trained aircrew, while maintaining flight safety, results in differing standards for applicants and those already licensed.

AIRCREW AND AIRCRAFT TYPES

Aircrew are defined differently in civil and military aviation. In the civilian sector aircrew are categorised as flight crew (pilots)/technical crew members and cabin crew,[31] with separate regulation for air traffic controllers (ATCO). The military have a far broader definition, with aircrew more loosely defined as 'persons having duties concerned with the flying or operation of the air system, or with passengers or cargo when in flight'[32] (see table 1).

In addition to understanding the occupational roles of aircrew, it is also important to have at least a basic understanding of aircraft types and the potential operating envelope that may impact on cardiovascular physiology. Aircraft are often categorised as fixed or rotary wing (helicopters). Fixed wing aircraft may be further classified as high performance (fast jet, or high-powered propeller-driven aircraft) that allow sustained acceleration (high, and rapidly changing, G forces) and high air manoeuvrability, or low performance (heavy commercial turbojet passenger aircraft,

Table 1 Aircrew categories and types

Category	Aircrew roles
Pilots and navigators	Civil pilots—commercial, airline transport or rotary wing (helicopter) pilots Recreational pilots—including private pilot licence holders, light aircraft, helicopter, glider and balloon pilots Military pilots—fixed wing or rotary wing (helicopters), high performance, fast jet, single seat or multi-crew operators, instructors Navigators—duties may include Air Combat Systems Officers in fast jet air operations
Rear crew	Airborne Combat Systems Operators, Flight Engineers, Airborne Electronic Sensor Operators, Mission Specialists, Flight Test Engineers, Loadmasters, Aerospace Control Operators, Aeromedical Training Officers, Aeromedical Technicians, Search and Rescue technicians, boom operators, observers, etc
Controlling ground crew	Air traffic controllers (civil and military), Battle space managers, Remotely Piloted Aircraft Systems (RPAS) pilots
Others	Aeromedical staff including Flight Surgeons, Flight Nurses, Flight Medical Technicians. Flight Attendants, Flight Stewards, Airborne Warning and Control System (AWACS) technicians, RPAS payload operators, etc

military air transport), smaller turboprop aircraft, and piston aircraft that are comparatively less demanding on the cardiovascular system.

Aircrew flying in high performance aircraft may require positive pressure suits ('G suits') to maintain cardiac output and negate the effects of high $+G_z$ on the circulation (table 2). Fixed wing aircraft may be operated as either single seat or multi-seat platforms, and the acceptable medical risk is significantly lower in single seat flying operations, including instructional duties in a multicrew platform, if the second pilot is not qualified on the aircraft type (and thus not qualified to land the aircraft safely in the event of incapacitation of the first pilot). Rotary platforms may also be single seat or multi-seat; however, a significant proportion are flown as single pilot platforms and, because of the inherent instability of helicopters, and (usually) closer proximity to the ground, medical standards for rotary wing operations may be more exacting than for fixed wing aircraft.

All platforms may operate at altitudes that require supplemental oxygenation to mitigate the effects of the hypoxic (>10 000 feet) and hypobaric environment (>18 000 feet) and potentially require positive pressure breathing to mitigate the hypoxia (if flying above 40 000 feet). The latter will further impact on the cardiovascular system.[33] Some military aircraft fly at extreme altitudes with an associated risk for decompression sickness, requiring aircrew to wear full pressure suits.

The evolution of remotely piloted aircraft systems (RPAS) has also required the development of appropriate medical standards

Table 2 Effect of mild increase in sustained acceleration ($+G_z$) on heart rate, stroke volume and cardiac output. Adapted from DeHart and Davis[39]

Parameter	$+2\ G_z$	$+3\ G_z$	$+4\ G_z$
Heart rate (beats/min)	+14	+35	+56
Stroke Index (mL/m^2)	−24	−37	−49
Cardiac output (% change)	−7	−18	−22

and, if undertaking cardiovascular risk assessment, for this cohort it is essential to understand the size of the aircraft system, the role it undertakes (offensive weapon system vs purely surveillance vs hybrid), and where RPAS operators will be operating from (ie, home base or austere location remote from sophisticated medical care).

AVIATION ENVIRONMENT

The flight deck is a unique and exacting working environment, especially in high-performance military aircraft and in those platforms that allow for recreational aircrew to undertake aerobatics. In addition to the high inherent cognitive demand placed on aircrew (and particularly pilots), one must also consider additional factors that may degrade physical performance such as hypoxia, acceleration forces in high-performance flight, operational pressure, and enemy action and circadian disruption in the military environment. Most fixed-wing commercial pilots who carry passengers will work in a multicrew environment, in a dry, contained environment, pressurised at 6–8000 feet, but with little exposure to significant sustained acceleration (high G force). Recreational pilots performing regular aerobatics, or military fast jet pilots, may need to perform under intense physiological pressure (both from sustained acceleration and a potentially hypoxic environment[33]).

Acceleration (or G) is a centrifugal gravitational force that, in flight, is usually applied to the vertical axis of the body (the 'z' axis). If it is experienced from head to foot (positive G_z), it is termed $+G_z$. Aircrew may be exposed to high levels of $+G_z$ in manoeuvres such as pulling out of a dive or into an inside loop.[34] Certain aircraft manoeuvres—for example, an 'outside' loop or 'bunt' (pushing forward on the stick or control column)—result in rapid foot-to-head G loading and is termed $-G_z$ (minus G_z). Rapid transitions from plus to minus G or vice versa can cause large sudden perturbations of the sympathetic system as a substrate for arrhythmias, and a deleterious effect on the $+G_z$ tolerance. Exposure to high $+G_z$ places a significant physiological burden on aircrew that requires thoughtful consideration in all cardiac pathology. To perform competently in this demanding environment requires high cardiac output, optimal coronary flow and near-normal transvalvular gradients with laminar flow pattern at rest. In military aviation and aerobatics, exposure to significant $+G_z$ results in an exceptional strain on the cardiovascular system to maintain vital cerebral and coronary perfusion under unusual attitudes (figure 1).[35] As examples, we know that valve stenosis, even if mild, can restrict and even prevent the required cardiac output in high $+G_z$ environments, while negatively chronotropic agents will suppress the physiological tachycardia that is also required to maintain cardiac output. The effect of even modest $+G_z$ environments on the heart is shown in table 2. Those dealing with military aircrew should also be aware of push-pull manoeuvres (such as air combat, tactical flight, including rotatory wing and aerobatics) where aircrew are subjected to rapid shifts between $-G_z$ and $+G_z$.

At altitude, the effects of both hypoxia and hypobaria must also be considered. Most commercial aircraft are pressurised at a cabin altitude of 5–8000 feet, allowing a tolerable degree of hypoxia. In unpressurised aircraft, supplemental oxygen alone will be insufficient to prevent hypoxia above 33 000 feet (due to the lack of atmospheric pressure) and positive pressure breathing (PPB, akin to continuous positive airway pressure (CPAP) systems) is also required to maintain adequate oxygenation. Clearly any cardiovascular condition that is associated with hypoxia at sea level, or where the effects of PPB may affect

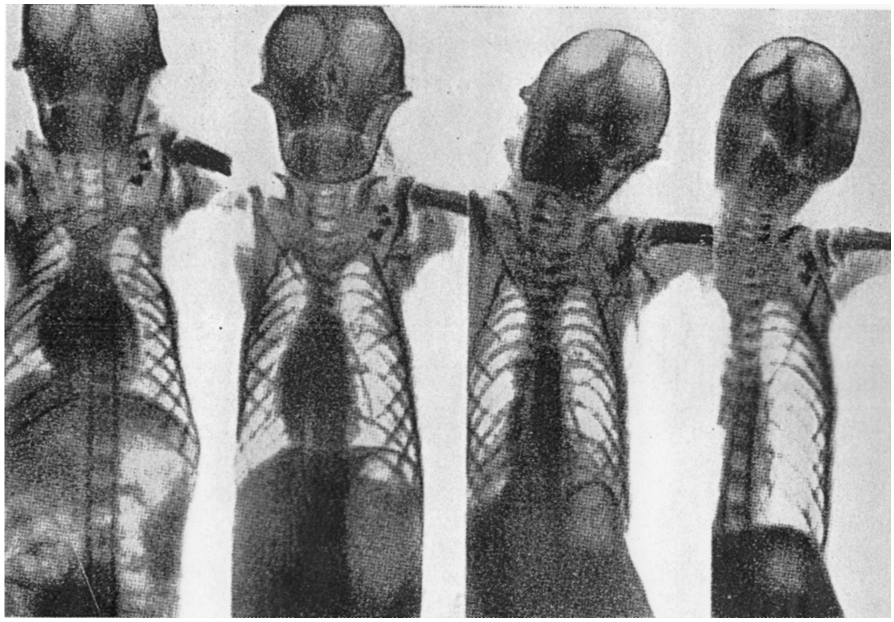

Figure 1 Chest x-rays of a chimpanzee undergoing centrifuge testing at +1 G_z, +2 G_z, +4 G_z and +6 G_z. Mediastinal elongation with topographic changes.[35]

cardiovascular physiology at extreme altitude, needs to be carefully considered.

Rotary wing (helicopter) flying is often performed as a single seat operation, including flying at low level, while military flying often involves high performance fast-jet flying, or is undertaken in hostile environments. Aircraft controlling requires intense concentration, but again will differ between the role undertaken in an air traffic control tower on an airfield, working with complex systems at a National Air Traffic Control Service (NATS), and coordinating military aircraft undertaking air combat manoeuvres in a military operational setting. These roles and scenarios require differing levels of risk management and understanding of both risk and consequence in the event of incapacitation or distraction because of CVD.

Finally, flying is often an exhilarating and adrenaline provoking pursuit, and this must be borne in mind when assessing cardiovascular conditions that involve vagal stimulation or suppression, or which may be exacerbated by catecholamine surges. Many aircrew, particularly military aircrew, are very fit individuals, with low resting heart rates and a myriad of mild, but acceptable, ECG variants; these include (but are not limited to) resting bradycardias (40–50 beats/min), incomplete right bundle branch block, Mobitz type I (Wenkebach) atrioventricular block, and trace/mild valvular regurgitation. If aircrew can mount an appropriate physiological response to stress (as demonstrated on an exercise stress test), these conditions (unless extreme) are usually regarded as acceptable in a high adrenaline flying environment, and the critical phases of flight. Again, the use of pharmacological agents that suppress appropriate adrenergic drive should be avoided in aircrew, wherever possible.

RISK ASSESSMENT

The medical, and cardiovascular, risk assessment of aircrew extends well beyond the usual clinical risk assessment. In addition to the usual care provided to all patients, an AME or specialist aviation medicine clinician will consider the occupational and flight safety ramifications of both the disease and its treatment. The aviation medicine specialist must determine whether the human 'system' has a failure risk that is acceptable, in the same way that the engineer must determine a suitable threshold for failure of the other aircraft systems. In aviation, the current consensus risk threshold for an acceptable level of controlled risk of acute incapacitation is 1% per annum (for dual pilot operations), a percentage calculated using engineering principles to ensure the incidence of a fatal air accident due to any pilot subsystem (ie, 1/100 of the overall 1 per 10^7 hours of flying risk) is no greater than 1 per 10^9 flying hours. This is known as the '1% rule'[2 21] (box 1).

However, the 1% rule is not without limitations. It was derived for short duration, commercial, dual pilot operations. Events other than death can cause acute incapacitation and the model does not acknowledge more subtle effects such as distraction, that may also result in system failure. It must be appreciated that this rule has been developed for a civil multicrew environment, with enough time for handover of the command of the aircraft in case the pilot is acutely incapacitated. These assumptions may not be valid, and the ability to predict risk at this clinically low level (event rates of 1% per annum) is extremely challenging, given clinical literature is usually not this specific.

Box 1 Derivation of the 1% rule

- 1 year ≈ 10 000 hours
- A 1% cardiovascular mortality of 1%/annum is ≈ 1 in 10 000 hours x 0.01=1 event in 10^6 hours
- However, in dual crew operations the risk is only critical in take -off and landing phases (≈ 10% of total flight time)—an event rate of $1\times10^6\times10=1\times10^7$ hours
- Simulator data suggest that the second co-pilot successfully takes control 99 times out of 100, therefore the probability of a fatal accident at a critical point is $1\times10^7\times100=10^9$ hours

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Table 3 Cardiovascular investigations in aircrew

Anatomical investigations	Cardiac CT, cardiac MR or invasive coronary angiography, transthoracic and transoesophageal echocardiography
Physiological investigations	Myocardial perfusion imaging, including perfusion MRI, myocardial perfusion scintigraphy (MPS, both single photon emission CT (SPECT) and positron emission tomography (PET)), stress echocardiogram (with either physiological or pharmacological stress) and fractional flow reserve (FFR)
Clinical investigations (to further allow first line risk stratification)	Exercise stress ECG test* (METS, symptoms), coronary artery calcium scoring

*Exercise stress ECG test is not recommended as a solely investigative tool for assessment of significant coronary artery disease in aircrew.[10]

It is also clear that since the 1980s both the aviation and medical worlds have changed; in aviation, this includes the development of automated flight systems and longer average flight times (the initial model was based on a mean flight time of 1 hour), meaning the 'flight critical' take-off and landing phases are now less than the 10% used in the original model. Medically, the quoted age-adjusted annual mortality rate has fallen dramatically (especially in CVD) and therefore, depending on the type of aircraft, kind of flight operation or mission, and the aircrew role (flight or mission criticality), one could consider accepting a higher level of risk, for instance 2%.[36] At the other end of the spectrum, a lower risk may be appropriate for single seat high performance aircraft, for instance, that equivalent to peers (ie, no disease that increases incapacitation risk). Along with the whole field of risk management, the process of aeromedical risk assessment has evolved to consider not only the probability of an event, but also the consequences through various aircrew roles. This area is complex and hotly debated and is addressed in detail in the associated paper on cardiovascular risk assessment in aircrew.[10]

TERMINOLOGY

Within aviation cardiology it is important that terminology is clearly understood, as the usual clinical use of a term such as functional test may be generally assumed to mean a test to determine the level of myocardial perfusion; however, in an aviation cardiology context this may relate to the adequate suppression of ventricular ectopy or adequate myocardial oxygen consumption (MVO_2) on exercise ECG testing or cardiopulmonary exercise testing. We recommend the terminology listed in table 3 is used as far as possible for aircrew.

AEROMEDICAL SIGNIFICANCE VERSUS CLINICAL SIGNIFICANCE IN TERRESTRIAL ENVIRONMENTS

The aeromedical significance of CVD and its management differ to that in a standard clinical setting for most conditions, due to the acceptable aviation risk limits. Examples of this include the negative side-effects of common pharmacological agents on G_z tolerance (ie, β-blockers) or a risk of postural hypotension (α-blockers), while anticoagulation remains a disqualifying condition for many pilots (due to the residual thromboembolic and haemorrhagic risk), and partial revascularisation (leaving lesions untreated that clinically would not warrant intervention but are significant aeromedically) would often also lead to a loss of flight licence in many countries. 'Benign' ECG findings, such as ventricular ectopy or idioventricular rhythms in single seat pilots, may precipitate a withdrawal or restriction of flying privileges, while up to 30 s of sustained broad complex tachycardia would be deemed non-sustained ventricular tachycardia (NSVT) under current European guidelines,[37] and this level of broad complex tachycardia would not be acceptable in aircrew.[14] Stenotic valve disease, if more than mild, is of significant concern in aircrew, whereas mild regurgitant lesions may be slightly better tolerated,[15] while for coronary artery disease, stenosis that would be considered of little concern in a terrestrial environment may be deemed significant in an aeromedical context.[12]

It is possible to return to flying after a diagnosis of CVD, although this may be in a limited occupational role, and special attention to the pharmacological management, intervention or perioperative planning is essential. The choice of procedure (eg, percutaneous coronary intervention (PCI) with stenting vs full revascularisation with coronary artery bypass grafting (CABG))[13] or consideration of the prosthetic material (eg, stentless bioprosthesis) used for a valve replacement[18] are often critical in the determination of licence renewal, but intervention should always be driven by the clinical need, not the occupational one.

Restrictions on aircrew licences often apply following cardiovascular intervention and follow-up usually requires additional investigations at specific time points. The cardiologist and the cardiac surgeon should always consider liaising with the pilot's AME/and or regulatory authority before intervention or surgery, if there is a genuine clinical choice of procedure. They should also aim to understand the ramifications of various courses of action, and the need for certain clinical investigations to allow the AME to determine their suitability to return to their flying career or recreation. However, the overriding principle remains that every individual should be treated as a patient first, and aircrew second—that is, the optimal management of any condition should not be compromised to try and maintain full flying privileges.

The requirement for additional investigations and the cut-off values for aeromedical significance versus clinical significance can lead to some difficult ethical challenges. A single stenosis of >50% may preclude pilots from flying in some jurisdictions but is below the standard threshold for intervention. However, if the pilot has an intervention that results in no residual stenosis the licensing authorities would consider a return to flying. The threshold for ablation or the requirement for repeat angiography post-PCI may also be influenced by the aircrew's need to fulfil regulatory aviation medical requirements, and this can pose significant challenges to cardiologists.

LACK OF EVIDENCE BASE IN AVIATION CARDIOLOGY

Given the often younger age of aircrew (particularly military aircrew) and the requirement to achieve an aeromedically acceptable risk, there is little or no strong evidence to support decision making in aviation cardiology. This is one reason for the development of the NATO aviation cardiology working group (HFM-251) including a cardiac surgeon, general internal medicine physicians, flight surgeons and cardiologists, and the publication of this article and those related to it.[10–18] In this context, expert consensus is likely to be the best that can be achieved at present (given the numbers likely to be required for any other type of evidence to be produced); however, it is hoped that further research in this area will be forthcoming, such as that on the role of CT coronary angiography (CTCA) versus coronary artery calcium score (CACS) in the assessment of aircrew with suspected coronary artery disease.[38] While these studies have small cohorts, they still inform the decision-making process and policies that in turn ensure that aircrew can be returned to flying where possible or grounded if this is appropriate. A lack of evidence of risk does not mean an absence of risk, and any endeavour to build an evidence base in aviation cardiology is likely to be of significant individual, occupational and societal value.

CONCLUSION

Aviation cardiology is a specialist field that requires a detailed and deep understanding of occupational roles, commercial and recreation aviation activities, environmental physiology and specific risk assessment. Absence of evidence in this population does not equal evidence of absence of risk. The NATO working group has had access to data from various air forces that are often not shared with the public. These have informed the expert consensus statements in all the papers produced. However, there are still many areas not covered by any data, and therefore many recommendations are also based on expert opinion.

All medical staff (cardiologists, cardiac surgeons, general physicians, AME, etc) should have some understanding of the broad ramifications of CVD for this cohort of patients. As a general principle, the authors recommend that the most appropriate evidence-based management of any cardiovascular condition should always be offered, while ensuring that aircrew are aware of the ramifications of the suggested course of action on their professional role. If unacceptable, however, the cardiologist should be willing to offer aircrew alternative options (that may differ from usual practice). These should still be clinically appropriate but allow these professionals the opportunity to continue with their professional careers (although potentially in a limited capacity). Aircrew should be aware of the additional risks that might be associated with these alternative courses of action, but if an informed decision is agreed between the surgeon and pilot, informed consent is maintained.

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