Commercial Air Travel for Passengers With Cardiovascular Disease: Recommendations for Common Conditions

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Abstract: The exponential growth of commercial flights has resulted in an explosion of air travelers over the last few decades, including passengers with a wide range of cardiovascular conditions. Notwithstanding the ongoing COVID-19 pandemic that had set back the aviation industry for the next 1-2 years, air travel is expected to rebound fully by 2024. Guidelines and evidence-based recommendations for safe air travel in this group vary, and physicians often encounter situations where opinions and assessments on fitness for flights are sought. This article aims to provide an updated suite of recommendations for the aeromedical disposition of passenger with common cardiovascular conditions, such as ischemic heart disease, congestive heart failure, valvular heart disease, cardiomyopathies, and common arrhythmias. (Curr Probl Cardiol 2021;46:100768.)

Introduction

The first part of this series introduced[1] the key aerospace principles and evidence relevant for the attending physician to develop an understanding of the various factors that impact cardiovascular health for the commercial passenger. Building on this, part 2 of the

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review focuses on practical recommendations for specific cardiovascular conditions.

The following sections detail the author's recommended approach to evaluate fitness-for-flight for common cardiovascular ailments and procedures. In general, such circumstances subject the affected individual to a heightened risk of recurrent events or complications, which tapers over time. The more hazardous the initial cardiac injury or intervention, the more critical the early phase of convalescence, and sufficient interval should lapse before the patient can participate in activities that predispose them to an increased likelihood of relapse or aggravation. The factors affecting recovery or recurrences are protean and challenging to predict, and medical advice on fitness to fly provided to the air traveler is often based on clinical judgment after a comprehensive assessment to identify and address all mitigatable risks.[2-6]

Medical Clearance Requirements

The International Aviation Transport Association states the following general criteria[6] for airlines to ensure a passenger obtains the requisite medical clearance for flight if he/she:

1. suffers from any disease which is believed to be actively contagious and communicable; or
2. is likely to be a hazard or cause discomfort to other passengers because of the physical or behavioral condition; or
3. is a potential risk to the safety or punctuality of the flight, including the possibility of flight diversion or an unscheduled landing; or
4. is incapable of caring for himself/herself and requires special assistance; or
5. has a medical condition which may be adversely affected by the flight environment.

In general, passengers with cardiovascular conditions, either acute or chronic, fall under the categories described above in points 4 and 5. From various guidelines and consensus documents, the following absolute cardiovascular contraindications for commercial flights are extracted and highlighted in Table 1.[3,4,7-9] This list is not exhaustive, and clinicians need to assess the passengers on a case-by-case basis to determine their fitness for flight.

Table 1. Absolute cardiovascular contraindications for commercial flights

Absolute cardiovascular contraindications for commercial flights[3,4,7-10]	
Uncomplicated myocardial infarction within 2 weeks	Coronary artery bypass graft surgery within 2 weeks*
Complicated myocardial infarction within 6 weeks	Acute decompensated cyanotic heart disease (including Eisenmenger Syndrome)
Unstable angina	Uncontrolled hypertension
Acute decompensated heart failure	Unrepaired Stanford Type A aortic dissection‡
Severe symptomatic valvular heart disease†	Resuscitated cardiac arrest secondary to arrhythmic collapse, without an implanted ICD and with left ventricular ejection fraction (EF) persistently <35% or without a reversible/ correctable cause, within 6 months‡
Uncontrolled ventricular or supraventricular arrhythmias	

*This includes other open-heart surgeries such as valvular repair/replacement, pericardial and thoracic aorta operations etc.
†To assess in tandem under heart failure category if ejection fraction <40%.
‡Author's suggestions.

As the first step of evaluation, once a passenger is assessed to have any of the above contraindications, air travel must be deferred, and the extant clinical condition addressed in a timely manner by the attending specialist.

Ischemic Heart Disease

Ischemic heart disease (IHD) is one of the commonest cardiovascular conditions among air travelers. The risk of in-flight medical emergencies arising from the underlying disease, potentially provoked by the stress of flight,[11] remain the topmost concern for airlines, physicians, and passengers.

Chronic Coronary Syndromes

Chronic coronary syndromes (CCS), previously known as stable IHD or stable coronary artery disease,[12,13] represent the largest subset amongst the various manifestations of IHD, but prevailing evidence suggests that anginal episodes are rarely triggered or worsened purely from the flying environment.[7-9] This is significantly contributed by the relative sedentariness during flying, mitigating any crossing of activity thresholds that would otherwise precipitate ischemia.

Guidelines from major cardiovascular societies (American College of Cardiology, European Society of Cardiology) do not specifically recommend routine pre-flight stress testing in patients with CCS.[12,14] However, any recent worsening or development of new ischemic symptoms despite

Table 2. Aeromedical recommendations for CCS

Condition	Elaboration	Aeromedical recommendation(s)
Chronic coronary syndrome on medical therapy (including remote history of angioplasty / bypass graft surgery >6 months, or prior myocardial infarction >6 months)	CCS I – II*	Unrestricted for flight
	CCS III	Consider airport assistance and in-flight supplemental oxygen
	CCS IV	Unfit for flight
Chronic coronary syndrome post elective angioplasty (uncomplicated)	Complex angioplasty – left main stenting, bifurcation stenting, multiple stents, use of intra-aortic balloon counter pulsation pump during procedure	Fit for flight after 5 days to 1 week
	Simple angioplasty	Fit for flight after 48-72 h
Chronic coronary syndrome post elective angioplasty (complicated)	Complications from angioplasty – dissection, perforation, vascular access problems (bleeding/haematoma etc.)	Unfit for flight Consult cardiologist and aviation medicine specialist
Chronic coronary syndrome post elective coronary artery bypass graft (CABG) surgery	Presence of all of the following: - Asymptomatic or minimal symptoms - Haemodynamically stable - Electrically stable† - Good wound healing	Fly after 10-14 days

*Canadian cardiovascular society grading of angina pectoris.[17]
†No uncontrolled dysrhthmias such as atrial fibrillation with rapid ventricular rate, frequent non-sustained ventricular tachycardia, sustained ventricular tachycardia, high grade conduction defects, or pauses etc

adherence to medications should prompt further cardiac evaluation, and any travel plans must be suspended until the patient is properly assessed.[15]

Table 2 summarizes the aeromedical recommendations for the various CCS conditions[4,6,7,16,26] regarding fitness for commercial passenger flights, and does not apply to dedicated aeromedical evacuation sorties.

Acute Coronary Syndromes

Acute coronary syndromes (ACS) encompass the spectrum of unstable angina pectoris (UAP), non-ST elevation myocardial infarction (NSTEMI), and ST-elevation myocardial infarction (STEMI).[18-21] Given the acute and damaging nature of the cardiac insult, and the potential to

develop post infarct complications, this population constitutes a heightened risk group for air travel especially in the ab initio window following the cardiac event.[22,23]

Various documents have attempted to organize and sense-make the heterogeneous literature and data on cardiovascular safety of air travel following ACS, but quality studies adequately powered to assess outcomes are practically nonexistent. Therefore, existing aeromedical recommendations are understandably inferred from theoretical mechanistic insights of in-flight stressors on passengers,[24] coupled with the more prevalent knowledge of clinical outcomes post ACS. Given how tenuous such recommendations on fitness-to-fly are reached, in subsequent updates of the NSTEMI guidelines,[18] the American College of Cardiology removed the statements on air travel post-NSTEMI,* previously included in an earlier version.[25] Evolving risk appetites of patients, physicians, airlines, regulatory authorities, and professional bodies have also led to more compressed time windows post-ACS to allow passengers to fly.[7,9,26,27] This is supported by emerging evidence that a significant portion of patients revascularized early and invasively (predominantly via angioplasty) has nominal risk of adverse events after day 2 of ACS.[28]

As the clinical predictors of patient outcomes with ACS are multifaceted and sometimes dynamic (including age, resting heart rate, residual ventricular function, extent of coronary disease, and the degree of revascularization performed[29-34]), applying selected nonmodifiable elements combined with appropriate risk calculators (such as the Zwolle risk score[35]), for further risk stratification to determine flying fitness post-ACS appears to be a reasonable and prudent strategy.[7,24] Table 3 summarizes the aeromedical recommendations for ACS with regards to fitness for conventional commercial air travel, assimilated from various guidelines, studies and expert opinion pieces.[4,6,7,16,24,26,36-40]

Heart Failure and Cardiomyopathies

In general, the presence of heart failure does not necessarily lead to a no-fly status, especially if the patient is functionally stable (NYHA I and II inclusive) in the preceding 4-6 weeks prior to air travel.[7] This extends to even those with significant left ventricular systolic impairment, who

* *"Air travel within the first 2 weeks of MI should be undertaken only if a patient has no angina, dyspnea, or hypoxemia at rest or fear of flying, flies with a companion, carries NTG, and avoids rushing and increased physical demands of travel. Low-risk patients with UA/ NSTEMI who are revascularized and otherwise stable may accelerate their return to work, driving, flying, and other normal activities (often, within a few days)."* Extracted from the ACC/AHA 2007 guidelines for the management of patients with unstable angina/non ST-elevation myocardial infarction. This statement was not included in the 2014 guidelines.

Table 3. Aeromedical recommendations post-ACS

Condition	Elaboration	Aeromedical recommendation(s)
Post-ACS (uncomplicated)	Presence of ALL of the following: - Asymptomatic or minimal symptoms - EF ≥50% - Age ≤65 years - Electrically stable* - No mechanical complications	Fly after 1 week (thrombolysis or medical therapy only) + consider predischarge stress test in consultation with cardiologist Fly after 3 days (post angioplasty)
Post-ACS (mild complications)	Presence of ANY of the following: - Mild symptoms (CCS I-II, NYHA I-II) - EF 40-50%	Fly after 10-14 days
Post-ACS (intermediate complications)	Presence of ANY of the following: - Moderate symptoms (CCS III-IV, NYHA III-IV) - EF <40%	Fly only if medically necessary (e.g. transfer to tertiary level medical facilities) after 4-6 weeks + consider airport assistance, medical escort,[39] and/or in-flight supplemental oxygen
Post-ACS (severe complications)	Presence of any unresolved complications: - Mechanical complications (ventricular septal/papillary muscle/free wall rupture) - Electrical complications (recurrent VT/VF, atrial fibrillation with rapid ventricular rate, high grade conduction defects or pauses)	Unfit for flight Consult cardiologist and aviation medicine specialist
Post CABG (emergent/ semiemergent after ACS)	Presence of ALL of the following: - Asymptomatic or minimal symptoms - Haemodynamically stable - Electrically stable* - Good wound healing	Fly after 10-14 days
	Any complications or instability	Unfit for flight Consult surgeon, cardiologist and aviation medicine specialist
	Presence of ANY of the following post-op or post discharge: - Moderate symptoms (NYHA III-IV) - EF <40%	Fly only if necessary after 4-6 weeks + consider airport assistance, medical escort, and/or in-flight supplemental oxygen

*No uncontrolled dysrhthmias such as atrial fibrillation with rapid ventricular rate, frequent non-sustained ventricular tachycardia, sustained ventricular tachycardia, high grade conduction defects or pauses etc.

were shown to be able to tolerate mild levels of hypoxia in the aircraft cabin environment.[41-43] Acute decompensation or recent hospitalization poses the highest risk group,[44] and careful assessment and optimization of their cardiac status must be made before prescribing fitness for flight. Broadly, valvular heart disease and the array of cardiomyopathies (infiltrative, restrictive, hypertrophic, toxins related, Takotsubo, peripartum, postinfectious etc.)[45,46] adhere to the same principles of functional evaluation for clinical stability before air travel,[36] and can be considered under the heart failure paradigm.

During an episode of acute decompensation, it is critical for all correctable derangements (such as electrolyte imbalances, endocrine disorders, medications noncompliance, uncontrolled hypertension, fluid and salt indiscretion, dehydration, acute viral illnesses etc) to be addressed, with a period of observation to ensure clinical stability.[47-50] Equally important is the appropriate institution of primary or secondary preventive measures via insertion of implantable cardioverter defibrillator devices (ICDs) when the situations demand for them: (1) persistently depressed EF meeting ICD criteria, or (2) resuscitated cardiac arrest without a correctable or reversible cause.[46,47,50,51]

Special mention is made of mechanical circulatory support equipment such as the left ventricular assist device (LVAD) as destination or bridging therapy,[52-54] in view of the growing number of patients with such implanted hardware.[26] Generally, despite the troubling appearance of the device, passengers with LVADs and stable clinically are considered safe to fly, and no interactions or interference between LVADs and security screening devices or in-flight avionics have been reported.[55-57]

Table 4 summarizes the aeromedical recommendations for heart failure with regards to fitness for conventional commercial air travel.[4,6,7,16,26,36,37,48,58]

Arrhythmias, Cardiac Implantable Electronic Devices, and Invasive Electrophysiological Procedures

Prevailing guidelines on air travel safety focus predominantly on patients shortly after cardiac implantable electronic devices (CIEDs) procedures,[4,6,7,26,36] and detailed advisories on active dysrhythmias or post invasive electrophysiological interventions are usually summarily recommended fit to fly so long as “stable” or “uncomplicated.” This is currently inadequate as an assortment of clinical scenarios and severity spectrum may be encountered for different patients, and a more comprehensive matrix is required to guide the attending physician for better

Table 4. Aeromedical recommendations for heart failure

Condition	Elaboration	Aeromedical Recommendation(s)
Acute decompensated heart failure (ADHF)	NYHA IV	Unfit for flight (does not apply to dedicated aeromedevac flights that are ICU-equipped) Allow 6-8 weeks of recovery post discharge before re-evaluation
Stable chronic heart failure (mild)	NYHA I-II	Unrestricted for flight
Stable chronic heart failure (moderate)	NYHA III	Consider airport assistance and in-flight supplemental oxygen
Stable chronic heart failure (severe)	NYHA IVa (ambulatory class IV)	Defer nonessential travel Consult cardiologist and aviation medicine specialist Strongly advise airport assistance and in-flight supplemental oxygen
Left ventricular assistance device (LVAD)	Recently implanted	Defer nonessential travel until at least 8 weeks postoperative Consult heart failure cardiologist and aviation medicine specialist Strongly advise airport assistance, medical escort, and/or in-flight supplemental oxygen
	After 3-6 months	Defer non-essential travel Consider airport assistance and not to travel alone Consult heart failure cardiologist and aviation medicine specialist
	General advice	Bring along LVAD card, medical memos and reports for security clearance at immigration and security checks Check INR at least 24-48 h preflight Maintain hydration, avoid caffeinated beverages Carry on-board extra LVAD batteries (fully charged)[59] Call ahead and liaise with LVAD experienced centre(s) at destination

decision making. A preflight 12-lead electrocardiogram should preferably be performed as a routine during the clinical evaluation for flight fitness.

Post CIED Pneumothorax

The insertion of permanent pacemakers and implantable cardioverter defibrillators invariably involve central venous access, with pneumothorax being a recognized complication from this approach.[60,61] Chest X-rays are routine after CIEDs implantations, and besides ensuring proper lead positions, clinicians must also examine the images carefully to detect

small pneumothoraces, due to the inherent risk of gas expansion at altitude that may compromise respiratory function,[62] or in rare occurrences, develop into a life-threatening tension pneumothorax. Any active pneumothorax is a contraindication for flight. However, there is consensus amongst guidelines and professional bodies that it is safe to undertake commercial air travel 2 weeks following the resolution of a pneumothorax.[4,6,7,26,63,64]

Environmental CIED Interactions

Electromagnetic interference (EMI) from airport security scanners are known to potentially cause inhibition of pacing,[65,66] which would be disastrous for a patient who is pacing dependent. However, such occurrences are rare and larger studies refute any significant EMI on CIEDs for either handheld or walk-through metal detectors of airport security systems.[67-69] It must be noted that exposures to such EMI are usually brief, and passengers with CIEDs must be cautioned to inform security personnel of their devices to avoid prolonged contact with the security equipment,[8,70] and to avoid unnecessary stress from the inadvertent alarm trigger when the security devices detect the metallic CIEDs.[8,66,71]

Invasive Electrophysiological Study and Ablation

The performance of invasive electrophysiological studies and/or ablation carry the risk of increased thrombogenicity due to the long in-dwell time of catheters in the central venous/arterial systems, and major complications include femoral vein thrombi or pulmonary embolism.[72-75] Significantly, patients undergoing left sided procedures in the left atrium/pulmonary veins/ventricle represent a higher risk group as any potential thrombi, formed either from the catheters or from endocardial lesions produced post-ablation, may embolize systematically.[76,77] As a result, current cardiovascular guidelines[77] strongly recommends coverage with short term anticoagulation for such patients if they were not already on such medications. In light of the additional postprocedure thromboembolic risk (on top of traditional venous thromboembolic risk associated with air travel), the first week constitutes the most hazardous window for clot formation and patients should be advised to delay nonurgent air travel during that period.[7]

Oral Anticoagulants

There is a rising number of passengers on oral vitamin K antagonists (warfarin) for thromboembolic risk reduction for atrial fibrillation/atrial

flutter. However, the risk of flight has more to do with the proneness for increased thrombogenicity,[3,7,8,10,26,36,78-80] which warfarin counteracts. The hazard of flying while on anticoagulants thus pertains more to bleeding probability, which unfortunately cannot be referenced against any trials, either in-vivo or ex-vivo, specifically looking at air travel safety while on blood thinning medications, due to a paucity of such studies. Any fitness-to-fly recommendations must thus be inferred from terrestrial studies on clinical scenarios related to anticoagulant related bleeding risk, which in itself is a continuum. In a landmark study to determine the safety of uninterrupted warfarin for CIED surgery, it was observed that it was safe to maintain the anticoagulant perioperatively without an increased incidence of device pocket hematoma (preoperative INR interquartile range 2.0-2.6).[81] Extrapolating from this, and broadly assuming that a conventional aeroplane ride is at least 50% less risky than a CIED surgery, a safety limit of INR $\leq$4 can be safely derived. This is also supported by other studies suggesting an increase in spontaneous bleeding events when INR exceeds 4.[82,83]

Due to the difficulty in monitoring the activity of direct oral anticoagulants (dabigatran, rivaroxaban, apixaban etc.),[84] clinical evaluation to ensure the patient is not experiencing any ongoing bleeding complications is paramount before clearance for flight.

Table 5 summarizes the aeromedical recommendations for arrhythmias, post-CIEDs implantations, and invasive electrophysiological procedures, with regards to fitness for conventional commercial air travel.[4,6,7,16,26,36,37,48,64,66,85]

Post Cardiac Surgery

Following open thoracotomy, trapped air within pockets of the thoracic cavity pose the risk of volumetric changes from altitudinal elevation and an accompanying drop in cabin pressures during commercial flights, with resultant compressive effect on structures adjacent to the expanded gas contained space.[60-62] The persistence of any pneumopericardium, pneumothorax, or pneumomediastinum postoperatively may potentially cause hemodynamic embarrassment in-flight, and adequate time should elapse during the recovery phase to allow complete resorption of the air. Generally, most guidelines recommend safety to fly after 10-14 days following open-heart surgeries, including coronary artery bypass grafting, valvular repair/replacement, or aortic root operations,[4,6,7,9,16,26,58] although some guidelines caveat that hemoglobin must be replete before flying.[16]

Table 5. Aeromedical recommendations for arrhythmias, post-CIEDs implantations, and invasive electrophysiological procedures

Condition	Elaboration	Aeromedical recommendation(s)
Tachyarrhythmia (atrial fibrillation with rapid ventricular rate, atrial tachycardia, supraventricular tachycardias)	Symptomatic and recurrent episodes	Defer nonessential air travel Consult electrophysiology cardiologist and aviation medicine specialist
	Taking vitamin K antagonist (VKA) for thromboembolic risk reduction from atrial fibrillation (AF)/atrial flutter (AFL)	Check INR 24-48 h preflight: - INR $>4 \rightarrow$ defer air travel and manage accordingly - INR ≤ 4 but with severe bleeding manifestations (hematuria, melaena, anemia) - INR ≤ 4 without significant bleeding manifestations $\rightarrow$ fit for flight, consider omitting next 1-2 doses of VKA and recheck INR after arrival at destination
	Taking direct oral anticoagulants (eg, dabigatran, rivaroxaban, apixaban, edoxaban) for thromboembolic risk reduction from AF/AFL	Evaluate for active bleeding: - Active significant bleeding $\rightarrow$ defer air travel and manage accordingly - No significant bleeding $\rightarrow$ fit for flight
	Paroxysmal AF	Unrestricted for flight Carry pill-in-the-pocket medications (flecainide/propafenone etc) on board and within easy reach
	Resuscitated cardiac arrest secondary to arrhythmic collapse (VT/VF/Torsades de pointes), without an implanted ICD and with left ventricular ejection fraction (EF) persistently $<35\%$ or without a reversible/correctable cause	Unfit for flight Consult electrophysiology cardiologist and aviation medicine specialist Strongly consider ICD or wearable defibrillator vest before future travel plans
Bradyarrhythmia (sick sinus syndrome, high grade atrioventricular blocks)	Symptomatic and meets indication for pacemaker	Unfit for flight until pacemaker implantation

(*continued on next page*)

Table 5. (*continued*)

Condition	Elaboration	Aeromedical recommendation(s)
	Pathologic severe bradyarrhythmia (resting heart rate <40 bpm)	Defer nonessential air travel Consult electrophysiology cardiologist and aviation medicine specialist
Post pacemaker implantation	No pneumothorax Normal device function Post-op pain well controlled	Fly after post-op day 2 Hand carry device identification card
	Presence of pneumothorax	Defer air travel until 2 weeks post resolution of pneumothorax
	Abnormal device function	Defer air travel until malfunction corrected
	Poorly controlled post-op pain	Defer air travel until pain adequately controlled
Post ICD implantation (transvenous system)	No pneumothorax Normal device function Post-op pain well controlled	Fly after post-op day 2
	Presence of pneumothorax	Defer air travel until 2 weeks post resolution of pneumothorax
	Abnormal device function	Defer air travel until malfunction corrected
	Poorly controlled post-op pain	Defer air travel until pain adequately controlled
	ICD therapy/shock delivered	Defer air travel Consult electrophysiology cardiologist and aviation medicine specialist
	Recurrent VT/NSVT below ICD therapy threshold	Defer air travel Consult electrophysiology cardiologist and aviation medicine specialist
Post ICD implantation (subcutaneous system)	Normal device function Post-op pain well controlled	Unrestricted for flight
Post implantable loop recorder (ILR) implantation (subcutaneous)	Normal device function Post-op pain well controlled	Unrestricted for flight

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Table 5. (*continued*)

Condition	Elaboration	Aeromedical recommendation(s)
Post CIED Implantation (PPM, ICD, ILR)	General advice for CIEDs[9]	Liaise ahead with CIED management capable clinic and manufacturer representative at travel destination Hand carry device identification card and medical memos/reports Inform security personnel to avoid placing handheld metal detectors over CIEDs Minimize dwell time near metal detectors Provide latest copy of 12-lead ECG with and without pacing Airport and in-flight assistance with luggage, especially during stowing and unloading from overhead cabins
Electrophysiological studies ± ablation	Uncomplicated procedure (no access site bleeding/haematoma, pericardial effusion, stroke, thromboembolism, valvular/ myocardial injury etc)	Fly after post-op day 2 if urgent air travel indicated, otherwise delay flight until after post-op day 7 to minimize thromboembolic risk[85] Antithrombotics for left sided ablations[77]
	Post procedure complications	Defer air travel until complications resolve/stabilize Consult electrophysiology cardiologist and aviation medicine specialist

Heart transplant recipients have been shown in one study to tolerate commercial air travel, but the shortest interval between the transplant and flight was 3 years,[86] and there is no data currently available to guide fitness for flight within the first few months of transplant. It follows that post heart transplant, the fitness to fly should then align to those of other open-heart surgeries. As cardiac transplant patients are under chronic immunosuppression, due diligence must be exercised to prepare and adequately prophylax the passenger prior to any long-haul travel.[87]

Less is known of the safety to fly shortly after percutaneous structural heart interventions, such as device closure for atrial/ventricular septal defects, percutaneous mitral or tricuspid valve edge-to-edge repair (eg, MitraClipTM), or transcatheter aortic valve replacement. Fitness to fly postoperatively after such procedures should take into account procedural success, presence or absence of any ensuing complications, and hemodynamic stability post hospital discharge. Beyond these considerations, it is likely that

Table 6. . Aeromedical recommendations after open-heart surgeries or minimally invasive percutaneous structural heart interventions

Condition	Elaboration	Aeromedical recommendation(s)
Open-heart surgeries (CABG, heart transplant, valvular or aortic operations)	Presence of all of the following: - Asymptomatic or minimal symptoms - Hemodynamically stable - Electrically stable* - Good wound healing	Fly after 10-14 days
	Any complications or instability	Unfit for flight Consult surgeon, cardiologist and aviation medicine specialist
Percutaneous structural heart interventions (edge-to-edge mitral/tricuspid valve repair, ASD/VSD device closure)	Presence of ALL of the following: - Asymptomatic or minimal symptoms - Hemodynamically stable - Electrically stable* - No immediate complications	Fly after 1 week
	Any complications or instability	Unfit for flight Consult interventional cardiologist and aviation medicine specialist

*No uncontrolled dysrhthmias such as atrial fibrillation with rapid ventricular rate, frequent nonsustained ventricular tachycardia, sustained ventricular tachycardia, high grade conduction defects, or pauses etc.

the in-flight environment poses little or no additional risk to the cardiovascular status of these patients.

Table 6 lists the aeromedical recommendations for flying fitness following open-heart surgeries or minimally invasive percutaneous structural heart interventions.[4,6,7,9,16,26,58]

Conclusion

Ischemic heart disease, heart failure, arrhythmias, CIED implantations, and other forms of open-heart surgeries constitute the commonest cardiovascular conditions encountered in the assessment of the cardiac patient for safety of commercial flying. Careful assessment, with a keen understanding of factors implicating aeromedical fitness, especially in the early postoperative or post-discharge period, is critical to ensure all identified risks are mitigated to the lowest levels prior to air travel.

REFERENCES

1. Koh CH. Commercial Air Travel for Passengers with Cardiovascular Disease: Stressors of Flight and Aeromedical Impact. *Curr Probl Cardiol* 2020:100746. https://doi.org/10.1016/j.cpcardiol.2020.100746. Epub ahead of print. PMID: 33213942.
2. Assessing Fitness to Fly: Guidance to Health Professionals. UK Civil Aviation Authority; 2015. Published Accessed 25 Jun 2020 https://www.caa.co.uk/passengers/before-you-fly/am-i-fit-to-fly/guidance-for-health-professionals/assessing-fitness-to-fly/.
3. Bettes TN, McKenas DK. Medical advice for commercial air travellers. *Am Fam Physician* 1999;60:801−810.
4. Aerospace Medical Association (AsMA). Medical guidelines task force medical guidelines for airline travel, 2nd edition. *Aviat Space Environ Med* 2003;74:A1–A19.
5. Thibeault C, Evans AD, Dowdall NP. AsMA medical guidelines for air travel: fitness to fly and medical clearances. *Aerosp Med Hum Perform* 2015;86:656. https://doi.org/10.3357/AMHP.4222.2015.
6. International Air Transport Association (IATA). International Air Transport Association Medical Manual. Montreal, QC: International Air Transport Association; 2018 11th ed.
7. Smith D, Toff W, Joy M, et al. Fitness to fly for passengers with cardiovascular disease. *Heart* 2010;96(Suppl 2):ii1−ii16. https://doi.org/10.1136/hrt.2010.203091.
8. Possick SE, Barry M. Evaluation and management of the cardiovascular patient embarking on air travel. *Ann Intern Med* 2004;141:148−154. https://doi.org/10.7326/0003-4819-141-2-200407200-00014.
9. Possick SE, Barry M. Air travel and cardiovascular disease. *J Travel Med* 2004;11:243–8. https://doi.org/10.2310/7060.2004.19009.
10. Silverman D, Gendreau M. Medical issues associated with commercial flights. *Lancet* 2009;373:2067−2077. https://doi.org/10.1016/S0140-6736(09)60209-9.

11. Al-Janabi F, Mammen R, Karamasis G, et al. In-flight angina pectoris; an unusual presentation. *BMC Cardiovasc Disord* 2018;18:61 https://doi.org/10.1186/s12872-018-0797-1.
12. Knuuti J, Wijns W, Saraste A, et al. ESC guidelines for the diagnosis and management of chronic coronary syndromes. *Eur Heart J* 2019;41:407–77. https://doi.org/10.1093/eurheartj/ehz425. 2020.
13. Silber S. ESC-Leitlinie 2019 zum chronischen Koronarsyndrom (CCS, vormals "stabile KHK"): Was ist neu? Was ist besonders wichtig? [ESC guidelines 2019 on chronic coronary syndrome (CCS, previously "stable coronary artery disease"): what is new? What is particularly important?]. *Herz* 2019;44:676–83. https://doi.org/10.1007/s00059-019-04862-6.
14. Fihn SD, Gardin JM, Abrams J, et al. ACCF/AHA/ACP/AATS/PCNA/SCAI/STS Guideline for the diagnosis and management of patients with stable ischemic heart disease: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines, and the American College of Physicians, American Association for Thoracic Surgery, Preventive Cardiovascular Nurses Association, Society for Cardiovascular Angiography and Interventions, and Society of Thoracic Surgeons. *J Am Coll Cardiol* 2012;60:e44–e164. https://doi.org/10.1016/j.jacc.2012.07.013. 2012.
15. Ohman EM. Clinical practice. Chronic stable angina. *N Engl J Med* 2016;374:1167–76. https://doi.org/10.1056/NEJMcp1502240.
16. Simpson C, Dorian P, Gupta A, et al. Assessment of the cardiac patient for fitness to drive and fly: fly subgroup executive summary. *Can J Cardiol* 2004;20:1314–20.
17. Campeau L. Letter: Grading of angina pectoris. *Circulation* 1976;54:522–3.
18. Amsterdam EA, Wenger NK, Brindis RG, et al. AHA/ACC Guideline for the Management of Patients with Non-ST-Elevation Acute Coronary Syndromes: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines [published correction appears in J Am Coll Cardiol 2014 Dec 23;64(24):2713-4. Dosage error in article text]. *J Am Coll Cardiol* 2014;64:e139–228. https://doi.org/10.1016/j.jacc.2014.09.017. 2014.
19. O'Gara PT, Kushner FG, Ascheim DD, et al. ACCF/AHA guideline for the management of ST-elevation myocardial infarction: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines [published correction appears in Circulation. 2013 Dec 24;128(25):e481]. *Circulation* 2013;127:e362–425. https://doi.org/10.1161/CIR.0b013e3182742cf6. 2013.
20. Ibanez B, James S, Agewall S, et al. ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: The Task Force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European Society of Cardiology (ESC). *Eur Heart J* 2017;39:119–77. https://doi.org/10.1093/eurheartj/ehx393. 2018.
21. Roffi M, Patrono C, Collet JP, et al. ESC Guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation: Task Force for the Management of Acute Coronary Syndromes in Patients Presenting

without Persistent ST-Segment Elevation of the European Society of Cardiology (ESC). *Eur Heart J* 2016;37:267–315. https://doi.org/10.1093/eurheartj/ehv320.
22. DeHart RL. Health issues of air travel. *Annu Rev Public Health* 2003;24:133−151. https://doi.org/10.1146/annurev.publhealth.24.100901.140853.
23. O'Rourke MF, Donaldson E, Geddes JS. An airline cardiac arrest program. *Circulation* 1997;96:2849–53. https://doi.org/10.1161/01.cir.96.9.2849.
24. Wang W, Brady WJ, O'Connor RE, et al. Non-urgent commercial air travel after acute myocardial infarction: a review of the literature and commentary on the recommendations. *Air Med J* 2012;31:231−237. https://doi.org/10.1016/j.amj.2012.01.002.
25. Anderson JL, Adams CD, Antman EM, et al. ACC/AHA 2007 guidelines for the management of patients with unstable angina/non ST-elevation myocardial infarction: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 2002 Guidelines for the Management of Patients With Unstable Angina/Non ST-Elevation Myocardial Infarction): developed in collaboration with the American College of Emergency Physicians, the Society for Cardiovascular Angiography and Interventions, and the Society of Thoracic Surgeons: endorsed by the American Association of Cardiovascular and Pulmonary Rehabilitation and the Society for Academic Emergency Medicine [published correction appears in Circulation. 2008 Mar 4;117(9):e180]. *Circulation* 2007;116:e148–304. https://doi.org/10.1161/CIRCULATIONAHA.107.181940.
26. Hammadah M, Kindya BR, Allard-Ratick MP, et al. Navigating air travel and cardiovascular concerns: Is the sky the limit? *Clin Cardiol* 2017;40:660−666. https://doi.org/10.1002/clc.22741.
27. Medical aspects of transportation aboard commercial aircraft. AMA commission on emergency medical services. *JAMA* 1982;247:1007–11.
28. Sezer M, Cimen AO, Aslanger EK, et al. Infarct remodeling process during long-term follow-up after reperfused acute myocardial infarction. *Am J Med Sci* 2009;338:465–9. https://doi.org/10.1097/MAJ.0b013e3181b911a2.
29. Boersma E, Pieper KS, Steyerberg EW, et al. Predictors of outcome in patients with acute coronary syndromes without persistent ST-segment elevation. Results from an international trial of 9461 patients. The PURSUIT Investigators. *Circulation* 2000;101:2557–67. https://doi.org/10.1161/01.cir.101.22.2557.
30. Califf RM, Pieper KS, Lee KL, et al. Prediction of 1-year survival after thrombolysis for acute myocardial infarction in the global utilization of streptokinase and TPA for occluded coronary arteries trial. *Circulation* 2000;101:2231–8. https://doi.org/10.1161/01.cir.101.19.2231.
31. Granger CB, Goldberg RJ, Dabbous O, et al. Predictors of hospital mortality in the global registry of acute coronary events. *Arch Intern Med* 2003;163:2345e53.
32. Morrow DA, Antman EM, Giugliano RP, et al. A simple risk index for rapid initial triage of patients with ST-elevation myocardial infarction: an InTIME II substudy. *Lancet* 2001;358:1571e5.
33. Dorsch MF, Lawrance RA, Sapsford RJ, et al. A simple benchmark for evaluating quality of care of patients following acute myocardial infarction. *Heart* 2001;86:150e4.

34. Kurz DJ, Bernstein A, Hunt K, et al. Simple point-of-care risk stratification in acute coronary syndromes: the AMIS model. *Heart* 2009;95:662e8.
35. De Luca G, Suryapranata H, van 't Hof AW, et al. Prognostic assessment of patients with acute myocardial infarction treated with primary angioplasty: implications for early discharge. *Circulation* 2004;109:2737–43. https://doi.org/10.1161/01.CIR.0000131765.73959.87.
36. Joy M. Cardiovascular disease and airline travel. *Heart* 2007;93:1507–9. https://doi.org/10.1136/hrt.2007.134247.
37. Naouri D, Lapostolle F, Rondet C, Ganansia O, Pateron D, Yordanov Y. Prevention of medical events during air travel: a narrative review. *Am J Med* 2016;129. https://doi.org/10.1016/j.amjmed.2016.05.013. 1000.e1-1000.e10006.
38. Zahger D, Leibowitz D, Tabb IK, Weiss AT. Long-distance air travel soon after an acute coronary syndrome: a prospective evaluation of a triage protocol. *Am Heart J* 2000;140:241–2. https://doi.org/10.1067/mhj.2000.107998.
39. Cox GR, Peterson J, Bouchel L, Delmas JJ. Safety of commercial air travel following myocardial infarction. *Aviat Space Environ Med* 1996;67:976−982.
40. Thomas MD, Hinds R, Walker C, Morgan F, Mason P, Hildick-Smith D. Safety of aeromedical repatriation after myocardial infarction: a retrospective study. *Heart* 2006;92:1864−1865. https://doi.org/10.1136/hrt.2006.094607.
41. Hobkirk JP, Damy T, Walters M, et al. Effects of reducing inspired oxygen concentration for one hour in patients with chronic heart failure: implications for air travel. *Eur J Heart Fail* 2013;15:505–10. https://doi.org/10.1093/eurjhf/hft003.
42. Agostoni P, Cattadori G, Guazzi M, et al. Effects of simulated altitude-induced hypoxia on exercise capacity in patients with chronic heart failure. *Am J Med* 2000;109:450–5. https://doi.org/10.1016/s0002-9343(00)00532-5.
43. Ideal Cabin Environment Project. European Commission; 2010. Published 29 http://www.bre.co.uk/filelibrary/BFA/ICE_Final_Publishable_report.pdf.
44. Lewis EF, Velazquez EJ, Solomon SD, et al. Predictors of the first heart failure hospitalization in patients who are stable survivors of myocardial infarction complicated by pulmonary congestion and/or left ventricular dysfunction: a VALIANT study. *Eur Heart J* 2008;29:748–56. https://doi.org/10.1093/eurheartj/ehn062.
45. Bozkurt B, Colvin M, Cook J, et al. Current diagnostic and treatment strategies for specific dilated cardiomyopathies: a scientific statement from the American Heart Association [published correction appears in Circulation. 2016 Dec 6;134(23):e652]. *Circulation* 2016;134(2):e579–646. https://doi.org/10.1161/CIR.0000000000000455.
46. Authors/Task Force members, PM Elliott, Anastasakis A, et al. 2014 ESC Guidelines on diagnosis and management of hypertrophic cardiomyopathy: the Task Force for the Diagnosis and Management of Hypertrophic Cardiomyopathy of the European Society of Cardiology (ESC). *Eur Heart J* 2014;35:2733–79. https://doi.org/10.1093/eurheartj/ehu284.
47. Ponikowski P, Voors AA, Anker SD, et al. 2016 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure: The Task Force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC)Developed with the special contribution of the Heart Failure Association

(HFA) of the ESC [published correction appears in Eur Heart J. 2016 Dec 30;:]. *Eur Heart J* 2016;37:2129–200. https://doi.org/10.1093/eurheartj/ehw128.
48. Izadi M, Alemzadeh-Ansari MJ, Kazemisaleh D, Moshkani-Farahani M. Air travel considerations for the patients with heart failure. *Iran Red Crescent Med J* 2014;16: e17213. https://doi.org/10.5812/ircmj.17213.
49. Yancy CW, Jessup M, Bozkurt B, et al. 2017 ACC/AHA/HFSA Focused Update of the 2013 ACCF/AHA Guideline for the Management of Heart Failure: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines and the Heart Failure Society of America. *J Card Fail* 2017;23:628–51. https://doi.org/10.1016/j.cardfail.2017.04.014.
50. Writing Committee Members, Yancy CW, Jessup M, et al. 2013 ACCF/AHA guideline for the management of heart failure: a report of the American College of Cardiology Foundation/American Heart Association Task Force on practice guidelines. *Circulation* 2013;128:e240–327. https://doi.org/10.1161/CIR.0b013e31829e8776.
51. Epstein AE, DiMarco JP, Ellenbogen KA, et al. 2012 ACCF/AHA/HRS focused update incorporated into the ACCF/AHA/HRS 2008 guidelines for device-based therapy of cardiac rhythm abnormalities: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines and the Heart Rhythm Society. *J Am Coll Cardiol* 2013;61:e6–e75. https://doi.org/10.1016/j.jacc.2012.11.007.
52. Miller LW, Guglin M. Patient selection for ventricular assist devices: a moving target. *J Am Coll Cardiol* 2013;61:1209–21. https://doi.org/10.1016/j.jacc.2012.08.1029.
53. Boruah P, Saqib N, Barooah J, Baruah D, Sharma P. Left ventricular assist device: what the internist needs to know. A review of the literature. *Cureus* 2019;11:e4399. https://doi.org/10.7759/cureus.4399. Published 2019 Apr 5.
54. Eisen HJ. Left Ventricular Assist Devices (LVADS): history, clinical application and complications. *Korean Circ J* 2019;49:568–85. https://doi.org/10.4070/kcj.2019.0161.
55. Potapov EV, Merkle F, Güttel A, et al. Transcontinental transport of a patient with an AbioMed BVS 5000 BVAD. *Ann Thorac Surg* 2004;77:1428–30. https://doi.org/10.1016/S0003-4975(03)01310-9.
56. Haddad M, Masters RG, Hendry PJ, et al. Intercontinental LVAS patient transport. *Ann Thorac Surg* 2004;78:1818–20. https://doi.org/10.1016/j.athoracsur.2003.09.018.
57. Tissot C, Buchholz H, Mitchell MB, et al. First pediatric transatlantic air ambulance transportation on a Berlin Heart EXCOR left ventricular assist device as a bridge to transplantation. *Pediatr Crit Care Med* 2010;11:e24–5. https://doi.org/10.1097/PCC.0b013e3181bc5974.
58. UK Civil Aviation Authority Guidance for Health Professionals. Cardiovascular disease. Published 2015. Accessed 25 Jun 2020 https://www.caa.co.uk/Passengers/Before-you-fly/Am-I-fit-to-fly/Guidance-for-health-professionals/Cardiovascular-disease/
59. Matsuwaka R, Matsuda H, Kaneko M, et al. Overseas transport of a patient with an extracorporeal left ventricular assist device. *Ann Thorac Surg* 1995;59:522–3. https://doi.org/10.1016/0003-4975(94)00583-s.

60. Aggarwal RK, Connelly DT, Ray SG, Ball J, Charles RG. Early complications of permanent pacemaker implantation: no difference between dual and single chamber systems. *Br Heart J* 1995;73:571–5. https://doi.org/10.1136/hrt.73.6.571.
61. Chauhan A, Grace AA, Newell SA, et al. Early complications after dual chamber versus single chamber pacemaker implantation. *Pacing Clin Electrophysiol* 1994;17(11 Pt 2):2012–5. https://doi.org/10.1111/j.1540-8159.1994.tb03791.x.
62. Boye's Law. Encyclopedia Britannica. Published 20 Nov 2019. Accessed 25 Jun 2020. https://www.britannica.com/science/Boyles-law
63. Nicholson TT, Sznajder JI. Fitness to fly in patients with lung disease. *Ann Am Thorac Soc* 2014;11:1614−1622. https://doi.org/10.1513/AnnalsATS.201406-234PS.
64. Tam A, Singh P, Ensor JE, et al. Air travel after biopsy-related pneumothorax: is it safe to fly? *J Vasc Interv Radiol* 2011;22:595–602. https://doi.org/10.1016/j.jvir.2011.01.436.
65. Santucci PA, Haw J, Trohman RG, Pinski SL. Interference with an implantable defibrillator by an electronic antitheft-surveillance device. *N Engl J Med* 1998;339:1371–4. https://doi.org/10.1056/NEJM199811053391905.
66. Dyrda K, Khairy P. Implantable rhythm devices and electromagnetic interference: myth or reality? *Expert Rev Cardiovasc Ther* 2008;6:823–32. https://doi.org/10.1586/14779072.6.6.823.
67. Copperman Y, Zarfati D, Laniado S. The effect of metal detector gates on implanted permanent pacemakers. *Pacing Clin Electrophysiol* 1988;11:1386–7. https://doi.org/10.1111/j.1540-8159.1988.tb04985.x.
68. Kolb C, Schmieder S, Lehmann G, et al. Do airport metal detectors interfere with implantable pacemakers or cardioverter-defibrillators? *J Am Coll Cardiol* 2003;41:2054–9. https://doi.org/10.1016/s0735-1097(03)00424-8.
69. Jilek C, Tzeis S, Vrazic H, et al. Safety of screening procedures with hand-held metal detectors among patients with implanted cardiac rhythm devices: a cross-sectional analysis. *Ann Intern Med* 2011;155:587–92. https://doi.org/10.7326/0003-4819-155-9-201111010-00005.
70. Yerra L, Reddy PC. Effects of electromagnetic interference on implanted cardiac devices and their management. *Cardiol Rev* 2007;15:304–9. https://doi.org/10.1097/CRD.0b013e31813e0ba9.
71. Passenger Health FAQs: At the Airport. *UK Civil Aviation Authority* 2015. Published Accessed 25 Jun 2020 https://www.caa.co.uk/Passengers/Before-you-fly/Am-I-fit-to-fly/Health-information-for-passengers/Passenger-health-FAQs−At-the-airport/.
72. Scheinman MM, Huang S. The 1998 NASPE prospective catheter ablation registry. *Pacing Clin Electrophysiol* 2000;23:1020–8. https://doi.org/10.1111/j.1540-8159.2000.tb00891.x.
73. Greene TO, Huang SK, Wagshal AB, et al. Cardiovascular complications after radiofrequency catheter ablation of supraventricular tachyarrhythmias. *Am J Cardiol* 1994;74:615–7. https://doi.org/10.1016/0002-9149(94)90756-0.
74. Hindricks G. The Multicentre European Radiofrequency Survey (MERFS): complications of radiofrequency catheter ablation of arrhythmias. The Multicentre European Radiofrequency Survey (MERFS) investigators of the Working Group on

Arrhythmias of the European Society of Cardiology. *Eur Heart J* 1993;14:1644–53. https://doi.org/10.1093/eurheartj/14.12.1644.
75. Saunderson C, Hickman S, Wilkinson E, Tayebjee M. Current venous thromboembolism prevention practices following endovascular electrophysiological procedures in the UK: a retrospective study. *Sultan Qaboos Univ Med J* 2018;18:e374–8. https://doi.org/10.18295/squmj.2018.18.03.018.
76. Deneke T, Jais P, Scaglione M, et al. Silent cerebral events/lesions related to atrial fibrillation ablation: a clinical review. *J Cardiovasc Electrophysiol* 2015;26:455–63. https://doi.org/10.1111/jce.12608.
77. Sticherling C, Marin F, Birnie D, et al. Antithrombotic management in patients undergoing electrophysiological procedures: a European Heart Rhythm Association (EHRA) position document endorsed by the ESC Working Group Thrombosis, Heart Rhythm Society (HRS), and Asia Pacific Heart Rhythm Society (APHRS). *Europace* 2015;17:1197–214. https://doi.org/10.1093/europace/euv190.
78. European Aviation Safety Agency (EASA). Doc CS25 amendment 2 para 25.841
79. Mannucci PM, Gringeri A, Peyvandi F, Di Paolantonio T, Mariani G. Short-term exposure to high altitude causes coagulation activation and inhibits fibrinolysis. *Thromb Haemost* 2002;87:342–3.
80. Le Roux G, Larmignat P, Marchal M, Richalet JP. Haemostasis at high altitude. *Int J Sports Med* 1992;13(Suppl 1):S49–51. https://doi.org/10.1055/s-2007-1024592.
81. Birnie DH, Healey JS, Wells GA, et al. Pacemaker or defibrillator surgery without interruption of anticoagulation. *N Engl J Med* 2013;368:2084–93. https://doi.org/10.1056/NEJMoa1302946.
82. Makris M, van Veen JJ, Maclean R. Warfarin anticoagulation reversal: management of the asymptomatic and bleeding patient. *J Thromb Thrombolysis* 2010;29:171–81. https://doi.org/10.1007/s11239-009-0412-5.
83. Pagano MB, Chandler WL. Bleeding risks and response to therapy in patients with INR higher than 9. *Am J Clin Pathol* 2012;138:546–50. https://doi.org/10.1309/AJCPJ2GMDS7BXLEO.
84. Baron TH, Kamath PS, McBane RD. Management of antithrombotic therapy in patients undergoing invasive procedures. *N Engl J Med* 2013;368:2113–24. https://doi.org/10.1056/NEJMra1206531.
85. Ablation for Atrial Fibrillation. AF Association. Endorsed by UK Department of Health. Published July 2015. Accessed 25 Jun 2020. https://www.heartrhythmalliance.org/resources/view/304/pdf
86. Kofidis T, Pethig K, Rüther G, et al. Traveling after heart transplantation. *Clin Transpl* 2002;16:280–4. https://doi.org/10.1034/j.1399-0012.2002.01144.x.
87. Guide to Safe Travel after Transplant. American society of transplantation. Published July 2018. Accessed 25 Jun 2020. https://transplantfirst.org/wp-content/uploads/2019/02/AST.Guide-To-Save-Travel.pdf