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Review article

Medical Maydays at 35,000 Feet: *Navigating In-Flight Medical Emergencies*-from Turbulence to Differential Diagnosis and Treatment

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Abstract

In-flight medical emergencies (IMEs) are unforeseen acute medical events, though rare demand prompt recognition and effective treatment intervention due to their unpredictable nature and high risk of dismal prognosis if not appropriately manage promptly. These emergencies pose significant challenges for cabin crew and any medical professionals mid-air due to limited medical resources onboard. These events present diversely, from syncope and seizures to dyspnea, chest pain, traumatic injuries and sudden death, often causing fear and distress among everyone onboard. Misdiagnosis can lead to inappropriate treatment intervention, poor outcomes, and costly flight diversions. Consequently, a thorough understanding of IMEs is crucial for both cabin crew and medical professionals. This requires sound theoretical knowledge, focused history-taking, a high index of suspicion, clinical skills, competencies, meticulous physical examination, clinical reasoning, investigation with point of care devices, well-defined management strategies and treatment protocols, comprehensive cabin crew training and retraining, effective use of telemedicine and technological applications, and research specific to IMEs. With growing air travel volume, an aging global population, and a rising prevalence of cardiometabolic diseases, IMEs are expected to become more frequent. This necessitates optimizing emergency responses and preparedness measures, to enhance passenger safety and reduce flight disruptions. This review explores various aspects of IMEs, including their aetiologies, pathophysiology, clinical presentation, differential diagnosis, management, and the vital roles of cabin crew and any medical professionals present, along with the pressing need for integrating training program and curricula on IMEs in medical, allied health and flight attendant institutions worldwide. Furthermore, the review underscores the importance of in-flight clinical vigilance, the supportive role of telemedicine, and the impact of onboard automated external defibrillators in improving passenger outcomes. Ultimately, strong and continuous collaboration between the medical and aviation sectors is essential for a safer travel experience for everyone.

Keywords: In-Flight Medical Emergencies, Medical Maydays, Vasovagal Syncope, Differential Diagnosis, Telemedicine.

INTRODUCTION

Serenity shattered. A commercial plane, cruising steadily at 35,000 feet with a cloudscape below mimicking a majestic mountain range, was plunged into chaos. A loud noise echoed through the cabin, followed by a sickening thud. A man collapsed in the aisle, gasping for breath and writhing in pain. Panic erupted in the cabin as flight attendants rushed to his side. This was no ordinary turbulence; it was a medical emergency unfolding at 35,000 feet, where life and death hung precariously in the balance, testing the courage and determination of the flight crew and medical professionals onboard.

In-flight medical emergencies (IMEs) do occur and require prompt recognition and treatment intervention to avert dismal prognosis which may be associated with devastating psychological trauma to the affected passenger's family, the fellow passengers, and cabin crew. The prevalence of IMEs is increasing globally, driven by the growth of commercial air travel, an aging passenger’s population, environmental stressors, rising prevalence of cardiometabolic comorbidities, insufficient preparedness for medical emergencies, and increased reporting and awareness [1-3]. These emergencies pose unique challenges to both cabin crew and clinicians onboard as a result of limited medical resources, and cabin space [3, 4], and probable lack of adequate clinical knowledge, skills and competency regarding IMEs among flight crew and clinicians onboard [5], all compound the complexities, variability and unpredictability of IMEs.

There are an estimated 4 billion air travellers per year [6]. Of these, there are an estimated 44,000 in-flight medical emergencies (IMEs) per year [7-9]. This is one IME per 604 flights or 24 to 130 IMEs per million passengers [4-9]. In 75% of these cases a medical professional is already on board to assist [7, 8]. The incidence of life-threatening in-flight emergencies is estimated at 1 per 10-40,000 passengers and the mortality between 1 in 3.5 million passengers [10].

Challenges of medical management of IMEs are exacerbated at cruising altitudes 30-35,000 feet, where providing adequate medical care is complex. Passengers, flight crew, and clinicians should be aware that underlying medical conditions may worsen with or precipitated by air travel. Though airlines are required to equip aircraft with first-aid kits and essential medical supplies as well as automated external defibrillators (AEDs) [3-11], though the materials are typically available on international and domestic airlines from developed nations, the same cannot hold for the airlines of low and middle-income countries (LMICs), and therefore stand to jeopardize safety standards. Even-though flight attendants receive basic training for medical emergencies, airlines also rely on ground-based medical consultancy services to support them during IMEs.

The most frequent inflight medical emergencies seen during air travel include vasovagal syncope, gastrointestinal upset, and respiratory distress, while chest pain and cardiovascular event such as (myocardial infarction, stroke), in addition to seizures disorders, and psychiatric conditions are responsible for flight diversion most a times [1-7].

Management of inflight medical emergencies is complex and requires sound clinical knowledge, skills and competencies, clinical reasoning and judgment, of the most frequent inflight medical emergencies. Beside a sound clinical knowledge of IMEs, there is need for familiarity with on-board emergency medical kits, and close coordination with well train flight crew and remote ground medical services, and provision of care within one's scope of practice [1]. Nonetheless, responding to inflight medical emergencies is not straightforward, even for experienced clinician [10].

While current knowledge offers insights into in-flight medical emergencies (IMEs) [1-10], significant research gaps hinder advancements in safety and response. Key areas needing more research include standardized data collection and epidemiological studies to better understand IME prevalence and patterns. Evaluating the effectiveness of current response protocols and the impact of the unique cabin environment on medical events are also crucial. Longitudinal studies can track long-term outcomes, while research into training effectiveness and the influence of psychological factors and cultural differences will further refine crew preparedness. Addressing these gaps is essential for improving passenger safety and clinical outcomes during IMEs.

Effective management of IMEs, often critical life-or-death situations, relies heavily on the sound clinical knowledge, skills, competence, and research-driven approach of both flight crews and any onboard clinicians. These emergencies are shaped by a complex interplay of factors, including clinical observations, passengers' pre-existing disease conditions, the inflight environment, onboard medical resources, socioeconomic and technological shifts, and ongoing research. A passenger's medical history is also a vital factor influencing care.

Alarmingly, a significant knowledge gap exists regarding IMEs across healthcare professionals, the general public, airlines, policymakers, researchers, funders, and travellers especially those with underlying medical conditions. This is compounded by inadequate preparedness among, airlines, flight crews and clinicians. Enhancing the quality of care and passenger outcomes demands a concerted effort to improve IMEs awareness and understanding. This requires cultivating a larger group of cabin crew and medical professionals equipped with strong clinical knowledge, skills and competencies on IMEs and operations, and a commitment to IMEs research.

To address the challenges of IMEs, there is need for integrating high-fidelity training program and IMEs curricula in undergraduate and post graduate medical, allied health and flight attendant training institutions globally through the use of demo flight cabin a bid to simulate real inflight clinical emergency scenarios [4]. This approach has shown promising results else where in increasing self-assessed competency and medical knowledge among emergency medicine residents [4]. While inflight medical volunteers play a vital role in successful outcomes, it is important to note that the medico-legal liability risk for these volunteers is extremely small, with various laws and industry indemnity practices offering additional protection [10].

This review article offers a comprehensive overview of IMEs, covering their basics, pathophysiology, clinical presentation, differential diagnosis, diagnosis and treatment challenges. It aims to improve the clinical knowledge, skills and competencies of flight crew and clinicians on IMEs. The article advocates for structured training programs and curricula of IMEs in flight attendant, medical and allied health institutions globally to enhance knowledge and clinical outcomes of IMEs and reduce costly flight diversions.

METHODS

A comprehensive literature search was conducted on IMEs from the data bases of Google Scholar, PubMed, Medline and Scopus. The use of search terms inflight medical emergencies, air medical preparedness, physiological changes in high altitude, telemedicine, air crew training, spectrum of inflight medical emergencies, and inflight sudden death were all looked up and relevant information obtained. Apart from that, abstracts, power-point presentation, full text of published papers, and bibliographies of selected pertinent studies in inflight medical emergencies were also reviewed in detail and relevant information extracted.

Review

Physiological Effects of Altitude during Air Travel

High-altitude air travel triggers a range of physiological changes due to reduced cabin and atmospheric pressure, limited oxygen, and the aircraft environment. Key stresses include cabin pressurization, hypoxia, decompression sickness, and the potential worsening of underlying cardiopulmonary and neurological diseases [12-14]. Commercial flights typically maintain cabin pressure equivalent to 1,524 to 2,438 meters (5,000 to 8,000 feet), causing a decrease in arterial oxygen partial pressure (PaO2) that can worsen underlying cardiopulmonary diseases. Consequently, passengers may experience acute mountain sickness symptoms like fatigue, headache, and nausea, with severity often increasing with flight duration and altitude [13, 14].

Hypoxia, the primary high-altitude stressor, results from lower atmospheric oxygen, leading to reduced blood and tissue oxygen saturation [14, 15]. This triggers immediate physiological responses such as increased ventilation (hyperventilation) to improve oxygen uptake (potentially causing respiratory alkalosis) and elevated heart rate, cardiac output, and blood pressure [16]. Pathological responses can manifest as high-altitude illnesses like high-altitude pulmonary edema (HAPE) and high-altitude cerebral edema (HACE), with symptoms ranging from mild discomfort to life-threatening emergencies requiring prompt recognition and treatment intervention [17].

Decompression sickness (DCS) can occur when dissolved gases, mainly nitrogen, form bubbles in blood and tissues [18]. This typically happens during rapid ascents to high altitudes after scuba diving followed by immediate air travel, or during rapid descent. These nitrogen bubbles can obstruct blood flow and trigger ischemia and inflammation, leading to symptoms such as joint pain, muscle aches, fatigue, neurological issues (numbness, tingling), and respiratory dysfunction [19]. Risk factors for DCS include rapid altitude changes, high altitude, obesity, dehydration, and underlying cardiopulmonary diseases.

Passengers with underlying cardiopulmonary diseases face a higher risk of complications at high altitudes. Hypoxia-induced increases in heart rate and blood pressure can worsen cardiovascular diseases like arrhythmias, angina and heart failure. Similarly, respiratory diseases such as asthma and COPD can be exacerbated by insufficient oxygen, often requiring supplemental oxygen or medication adjustments [12]. Understanding these physiological impacts is crucial for these travellers to take necessary precautions, ensuring a safer and more comfortable flight.

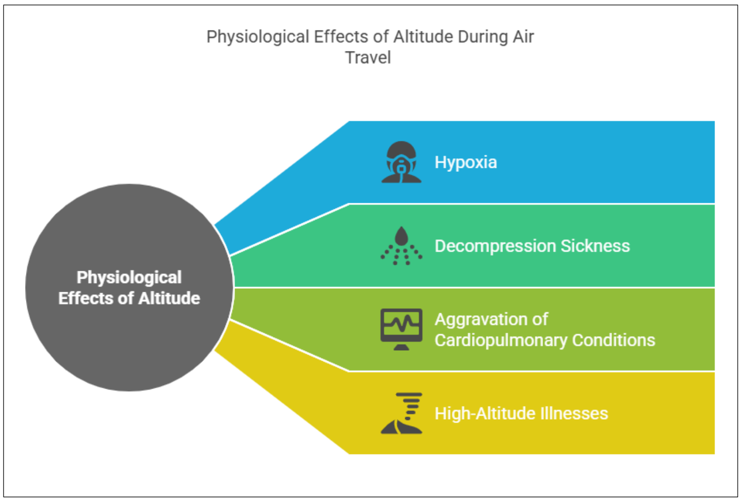

Figure 1: Showing physiological effect of altitude on passenger during air travel

Unique Challenges of In-Flight Medical Emergencies

Providing effective medical care during in-flight emergencies (IMEs) is significantly challenging due to the confine aircraft environment and limited onboard medical resources, creating a difficult high-altitude medical setting [3]. Passengers with underlying cardiopulmonary diseases are especially vulnerable at high altitudes (30,000-35,000 feet), where physiological changes can worsen cardiovascular and respiratory symptoms due to reduced oxygen [12].

Further complicating matters is the reliance on volunteer medical professionals and the potential need for remote consultation (e.g., Med-Aire). Flight diversions, which may become necessary, also carry substantial financial and logistical burdens. The combination of these resource, procedural, and environmental factors creates a challenging situation for managing medical emergencies at high altitude.

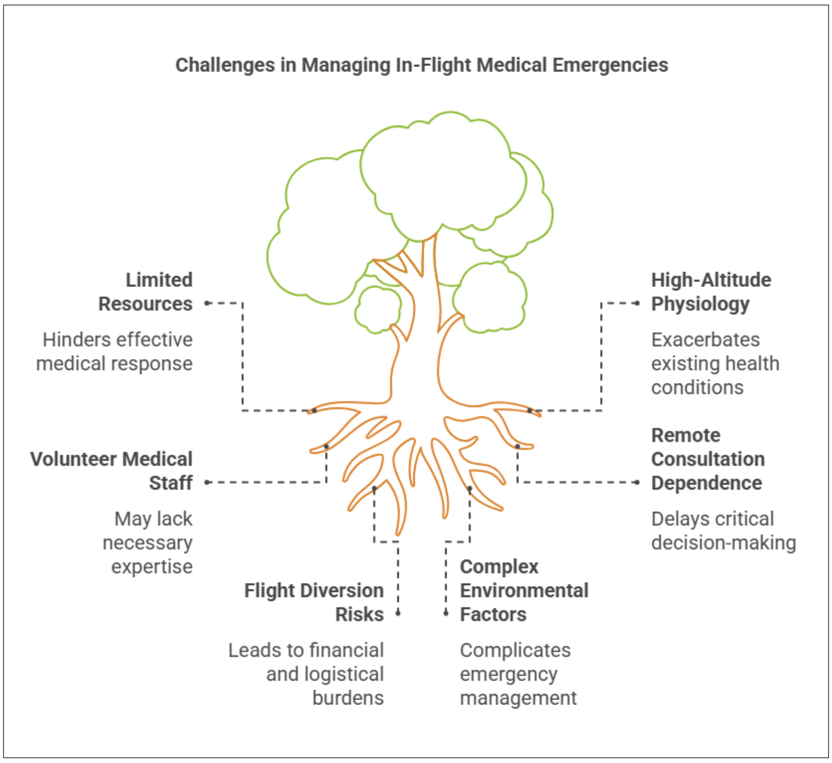

Figure 2: Showing unique challenges of in-flight medical emergencies

In-Flight Medical Emergencies

Inflight medical emergencies are unexpected clinical incidents that occurs inflight requiring prompt recognition and rapid institution of appropriate treatment intervention by cabin crew or clinicians onboard. Although, there is no universally accepted classification of IMEs, but these emergencies can be broadly classified into: (1) Common medical emergencies (Vasovagal syncope, respiratory distress, myocardial infarction, stroke, seizure disorders, hypoglycaemia, gastrointestinal disorders, bronchial asthma attack, Cardiac emergencies and allergic reactions); (2) infrequent but critical situations (e.g., seizures, myocardial infarction, trauma, altitude-related decompression sickness, cerebral air embolism); (3) Psychological/psychiatric emergencies (e.g., anxiety, panic attacks, mania, substance withdrawal); (4) Obstetrics emergencies; (5) Traumatic emergencies. On the other hand, inflight medical emergencies may also be classified base on the affected system into:

Inflight Neurological Emergencies:
Syncope

Syncope account for 37.4% of in-flight medical emergencies (IMEs) [7], a benign clinical condition characterized by transient loss of consciousness and postural tone as a result of decreased cerebral blood flow [20]. The transient loss of consciousness usually resolves spontaneously within a matter of minutes, but when prolonged leads to convulsions, referred to as convulsive syncope. Various syncope's were reported in clinical practice including vasovagal, vasodepressor, carotid sinus, hypoxic, postural orthostatic tachycardia syndrome (POTS), neurally mediated, situational (e.g., tussive, excretory), post-exertional, gelastic, deglutition [21, 22], and pseudo-syncope. But the most common syncope inflight is vasovagal syncope, also known as reflex or neurocardiogenic syncope [23]. Occurring in the upright position, it can often be alleviated by recumbency. It is characterized by pooling of blood in capacitance vessels leading to decreased preload and vagal-mediated bradycardia, resulting in hypotension. In contrast, to vasodepressor syncope which involves decreased peripheral vascular resistance and hypotension without bradycardia.

Symptoms of vasovagal syncope include light-headedness, nausea, yawning, anxiety, epigastric discomfort, weakness, warmth, blurred or tunnel vision, and altered consciousness, which may last seconds to 30 minutes in some cases. Patients typically experience a dramatic recovery upon regaining consciousness, except when kept upright for prolonged periods, as a result of significant cerebral hypoperfusion [24]. Signs observed in this syncope include, a slow weak pulse, dilated pupils, muscle jerks, shortness of breath, and pallor in Caucasians.

Common triggers of syncope include abrupt standing from sitting or supine position, prolonged standing, heat exposure, severe pain, emotional stress, extreme weakness, fear of injury, sleep deprivation, phobias (especially hemophobia), and sometimes no identifiable cause. Treatment typically involves avoidance of triggers and simple manoeuvres like lying the patient down with elevated legs, along with oxygen administration [7-25]. In rare cases, medications like fludrocortisone acetate and selective serotonin reuptake inhibitors are needed. In-flight vasovagal syncope is commonly challenging to diagnose, even for medical professionals on board. However, it typically requires supportive care rather than medication.

Seizures/Convulsions:

In-flight medical emergencies involving seizures/convulsions account for about 6% of IMEs [7]. Convulsions can stem from various medical conditions, including epileptic seizures, syncope, transient ischemic attacks (TIAs), stroke, metabolic disturbances (hypoglycaemia and hyperglycaemia), infections, post-traumatic head injuries, and disruptions in circadian rhythms caused by travel. Convulsion can also result severe hypoxia or altitude-related decompression sickness. Inflight epileptic seizures typically present with distinct features, such as an aura and rhythmic jerking movements (tonic-clonic, clonic, tonic, or myoclonic) in the extremities, followed by loss of consciousness. While myoclonic jerks of convulsive syncope, however, occurs after loss of consciousness and are typically non-rhythmic and synchronous [26]. Signs of epileptic seizures include upward rolling or lateral deviation of the eyes, foamy saliva, tongue biting (especially on the lateral sides), is highly specific to epilepsy [26], as oppose to vasovagal syncope that usually occurs at the middle of the tongue), facial cyanosis, and faecal or urinary incontinence, are more common during epileptic seizures than convulsive syncope. Additionally, post-ictal symptoms like sleep, confusion, automatism, and lateral head deviation are more common in epileptic seizures than in convulsive syncope [26]. Syncope typically presents with facial pallor and shorter loss of consciousness. Urinary incontinence and jaw clenching can occur in both but more common in epilepsy. Loss of consciousness is typically longer in epileptic seizures, which do not typically have clear precipitating factors, and hence is more unpredictable. Rarely, a patient may experience both seizures and syncope. It has been noted that epileptic activity in certain brain regions can disrupt the central autonomic network, potentially leading to arrhythmias and syncope [27].

Stroke

In-flight stroke, while rare, presents significant diagnostic and treatment challenges due to the confined environment, limited medical resources, and unavailability of certain stroke medications. Reliable incidence data is scarce due to limited studies, reporting inconsistencies, and difficulties in recognizing and diagnosing stroke mid-flight [28]. Several underlying cardiometabolic diseases, such as hypertension, metabolic syndrome, diabetes, obesity, atrial fibrillation, and prior stroke/TIA, are primary risk factors [29]. These conditions elevate the risk of venous and arterial thromboembolic events, potentially worsened by air travel's physiological changes. Dehydration, common during flights, further increases blood viscosity and thrombosis risk [30]. Reduced cabin pressure may also subtly affect cerebral blood flow, potentially increasing ischemic stroke susceptibility [31].

Early recognition of typical stroke symptoms using tools like CPSS and atypical stroke symptoms is crucial for prompt supportive care [32]. However, the lack of immediate neuroimaging and neurologist prevents administering acute stroke therapies like thrombolysis, which are typically not onboard. Thus, in-flight stroke management focuses on basic life support and vital sign monitoring. Communication with ground-based medical professionals is vital for assessing flight diversion needs and arranging immediate care upon landing [33].

With increasing air travel, an aging population, and rising cardiometabolic diseases prevalence, airlines must enhance preparedness for in-flight stroke. Improved cabin crew training for recognizing stroke symptoms and providing basic life support is essential [34]. Standardized communication protocols with ground experts and diversion decision-making are also needed. Airlines should explore equipping aircraft with remote neurological assessment tools and telemedicine. Collaboration with medical societies is crucial for developing evidence-based guidelines for in-flight stroke management. Further research is necessary to better understand incidence and risk factors, to develop more effective inflight management strategies, and explore the feasibility of administering acute stroke therapies mid-flight.

Motion Sickness

In-flight motion sickness, a common and typically benign condition, arises from a sensory mismatch between the vestibular system's detection of airplane motion and the visual system's perception of a static cabin environment [35, 36]. This conflict can trigger symptoms like nausea, vomiting, dizziness, and pallor [35, 36]. Predisposing factors include a history of motion sickness, anxiety, and certain medications [35, 36]. Management ranges from simple visual fixation upon a point or eye closure to pharmacological interventions using antihistamines or anticholinergics [35, 36]. Cabin crew can assist with airsickness bags and supportive care. Although usually harmless, severe or prolonged motion sickness can significantly reduce passenger comfort and potentially lead to dehydration in rare cases of persistent vomiting [35, 36].

Cerebral Air Embolism (CAE)

In-flight cerebral air embolism (CAE) is a rare but potentially fatal condition where air bubbles obstruct brain blood flow, possibly causing ischemic infarction [37]. CAE is categorized as cerebral venous air embolism (CVAE) or cerebral arterial air embolism (CAAE), also known as cerebral arterial gas embolism (CAGE). CVAE involves air entering the venous system, often retrogradely via jugular veins, while CAAE occurs when air enters the arterial system, typically during medical procedures. Both can lead to brain infarction, edema, and increased intracranial pressure, and neurological dysfunction.

The primary in-flight causes of CAE are decompression sickness (DCS) and non-DCS-related factors. DCS poses a risk to passengers with history of recent scuba diving due to nitrogen bubble formation during rapid ascent, potentially leading to CVAE. Although commercial cabins are pressurized, the equivalent of 5,000-8,000 feet can still cause hidden nitrogen bubbles to expand in susceptible individuals. Rarely, paradoxical air embolism, where bubbles cross from the venous to the arterial circulation through a cardiac shunt like patent foramen ovale (PFO), may occasionally be found in the brain in susceptible passengers [38].

Beyond decompression sickness, non-DCS-related causes of in-flight cerebral air embolism (CAE) include lung barotrauma from rapid altitude changes in passengers with pre-existing pulmonary diseases [37]. Several factors elevate the risk of CAE during flight, such as underlying lung diseases like bullous emphysema [39], patent foramen ovale (PFO) facilitating paradoxical embolism [40], older age (increasing susceptibility to brain ischemia), obesity (potentially altering gas exchange and DCS risk), dehydration (increasing blood viscosity) [30], and recent scuba diving, particularly without adhering to recommended surface intervals [41].

In-flight CAE symptoms vary depending on the embolus location and size. Common neurological signs include severe headache, sudden focal deficits (numbness/weakness), slurred speech, visual disturbances, coordination abnormality, confusion, loss of consciousness, and seizures. Physical examination might reveal coma, a mill-wheel murmur, signs of pulmonary edema/respiratory failure, hypotension, or underlying disease, though it can also be normal. In-flight CAE can mimic stroke and seizures, complicating diagnosis due to limited onboard resources and lack of specialists. Diagnosis relies on high clinical suspicion based on symptoms, thorough but focused history-taking, and meticulous physical examination. Post-landing, brain MRI, CT angiography, and transesophageal echocardiography (for PFO assessment) are crucial [32].

Immediate in-flight management of suspected CAE focuses on stabilization: maintaining airway, administering oxygen, closely monitoring vital signs, and promptly consulting ground-based medical teams for advice and immediate post-landing care. Hospital treatment for CAE involves hyperbaric oxygen therapy (HBOT), the standard treatment that reduces air bubble size and improves brain blood flow [42]. Other treatments include intravenous fluids and management of seizures and cerebral edema.

Preventing in-flight CAE involves educating passengers about air travel risks, especially advising those with risk factors like lung disease, obesity, PFO, recent scuba diving to consult their doctor before flying. Adequate hydration during air travel is also recommended. Further research is needed to better understand the incidence and risk factors of in-flight CAE, particularly non-diving-related causes. Developing standardized management protocols for suspected cases and improving timely access to post-landing diagnostic and therapeutic interventions are also important areas for future research.

Inflight Respiratory Emergencies

In-flight medical emergencies related to shortness of breath account for approximately 12% of incidents [7], carry significant risks for travellers. Cabin environment, is characterized by lower pressure and humidity, has been found to exacerbate underlying cardiopulmonary diseases such as COPD, asthma, and heart disease, leading to symptoms like dyspnea and hypoxia [43-46]. In-flight respiratory emergencies encompass.

Acute Bronchial Asthma Attacks

In-flight acute asthma attack is a critical medical emergency marked by a sudden worsening of symptoms like dyspnea, wheezing, cough, and chest tightness [47]. These attacks are frequently triggered by the reduced cabin pressure and lower oxygen levels at high altitudes. Less common triggers during flights include stress, anxiety, cold air, allergens, irritants, and respiratory infections. Physical examination may reveal tachypnea, cyanosis, use of accessory muscle of respiration, anxiety, fear, widespread polyphonic rhonchi, and difficulty in completing full sentences. Severe cases might present with a silent chest, hypotension, and altered mental status, potentially requiring immediate flight diversion.

Passengers with asthma should proactively manage their condition by carrying their medications and taking preventative measures. Managing an acute asthma attack in-flight poses unique challenges for both cabin crew and clinicians due to the confined space and limited onboard medical resources. Therefore, airlines must be adequately prepared with appropriate medical kits containing nebulizers, inhalers, beta-2 agonists, corticosteroids (such as hydrocortisone or prednisolone), ipratropium bromide, magnesium sulphate, oxygen therapy equipment, and well-defined emergency protocols.

Pulmonary Embolism

In-flight pulmonary embolism (PE) is a rare but critical medical emergency posing diagnostic and treatment challenges for cabin crew and onboard clinicians [2-48]. While studies highlight the broader risk of venous thromboembolism (VTE) with air travel [2-51], specific data on in-flight PE is limited due to its low incidence, emphasizing the need for greater awareness.

In-flight PE often arises from a combination of travel-related and underlying VTE risk factors. Prolonged immobility during long flights leads to venous stasis and potential deep vein thrombosis (DVT) [50], a primary source of PE. Dehydration from dry cabin air and limited fluid intake further increases blood viscosity and DVT risk [30]. While cabin pressure and oxygen level changes might theoretically contribute, their exact role is unclear. Pre-existing conditions like prior VTE, recent surgery, obesity, diabetes, metabolic syndrome, hypertension, cancer, oral contraceptive use, pregnancy, postpartum period, and inherited thrombophilias significantly elevate the risk.

Classic presenting symptoms of PE in-flight include sudden onset of dyspnea often with tachypnea, pleuritic chest pain, cough occasionally productive of blood-stained sputum. The triad of dyspnea, chest pain, and tachypnea, when present, is highly specific for PE, and its absence makes PE less likely. While atypical masquerading presentation of PE include syncope, recurrent syncope or convulsive syncope [52], or mimicking pneumonia, acute MI, acute heart failure and de novo PE [53], which diagnosis can be quit challenging especially in-flight. Given limited onboard resources, a high index of suspicion is crucial for passengers with sudden onset of dyspnea, chest pain, and tachypnea or syncope with dyspnea, or dyspnea with low oxygen saturation that failed to improve despite adequate oxygen therapy onboard in any passenger with identifiable risk factors for VTE. Physical examination findings of PE include tachypnea, crepitation and tachycardia while less common examinations findings include loud P2, S3 or S4, pleural friction rub, Hoffman sign, bradycardia and in rare occasion physical examination findings in keeping with pulmonary edema.

Onboard management focuses on stabilization and arranging urgent medical care post-landing. Ground diagnosis involves CT pulmonary angiography, D-dimer testing, echocardiography and Doppler ultrasound.

Prevention is key, especially for high-risk individuals, through regular cabin walking and frequent calf muscle exercises, maintaining adequate hydration by drinking water and avoiding excessive caffeine or alcohol intake, the use of compression stockings, and potentially thromboprophylaxis in selected high-risk passengers after physician consultation.

Acute Respiratory Distress Syndrome

In-flight acute respiratory distress syndrome (ARDS) is a rare yet critical respiratory emergency with potentially fatal outcomes [54, 55]. Due to limited research specific to this context, our understanding relies heavily on case studies and general ARDS literature. Consequently, the true incidence, underlying mechanisms, and specific in-flight triggers remain unclear, emphasizing the urgent need for further investigation into its epidemiology, pathophysiology, and risk factors.

Several factors are hypothesized to contribute to in-flight ARDS. These include pre-existing pulmonary conditions that may decompensate at high-altitude due to reduced cabin oxygen, in-flight transmission of respiratory infections like COVID-19, severe acute respiratory syndrome (SARS), middle east respiratory syndrome-Coronavirus (MERS-CoV) and influenza facilitated by the confined space and close proximity of passengers, which, though less common, can trigger ARDS, particularly in susceptible passengers. Other contributing factors to inflight ARDs include aspiration pneumonitis resulting from gastric content aspiration during turbulence, inflight medical emergencies involving coma, and recent surgery or trauma in passengers with underlying respiratory diseases. The diagnosis and management of in-flight ARDS present significant challenges, including limited onboard medical equipment, dry cabin air and reduced oxygen availability complicating treatment, and the logistical complexities of potential flight diversion.

Ultimately, in-flight ARDS is a life-threatening medical emergency demanding a high index of suspicion in at-risk individuals, prompt recognition and implementation of appropriate treatment and stabilization measures by cabin crew and any medical professionals onboard. Crucially, communication with ground-based medical consultation services for guidance and potential flight diversion to the nearest suitable airport is paramount. Prioritizing passenger stabilization and supportive treatment is essential in these critical situations.

High-Altitude Pulmonary Edema (HAPE)

In-flight high altitude pulmonary edema (HAPE) is a rare but critical emergency that can affect susceptible air travellers, particularly on partially or unpressurized high-altitude flights. While most commercial flights maintain cabin pressure equivalent to 5,000-8,000 feet, certain flights operate at higher altitudes, elevating the risk. Even on commercial flights, individuals with pre-existing cardiorespiratory conditions face increased susceptibility.

The primary trigger for HAPE is the reduced oxygen partial pressure at altitude, leading to hypobaric hypoxia, increased pulmonary vasoconstriction, elevated capillary pressure, and fluid leakage into the alveoli [56, 57]. A history of HAPE, pulmonary hypertension, or other cardiopulmonary diseases, along with rapid ascent are also significant risk factors in susceptible individuals [57, 58].

In-flight HAPE manifests as dyspnea on exertion, potentially progressing to dyspnea at rest, a cough productive of frothy (whitish or pinkish) sputum, fatigue, headache, and in severe cases, confusion, cyanosis, and respiratory distress [57, 59]. Diagnosis can be challenging due to limited onboard resources, but a high index of suspicion based on symptoms, risk factors, and low pulse oximetry is crucial. Portable chest X-ray findings of pulmonary edema can aid diagnosis.

The immediate treatment involves supplemental oxygen. Descent to a lower cabin altitude is the definitive solution. Nifedipine may be used to reduce pulmonary arterial hypertension if not contraindicated. Ground-based medical consultation is essential for treatment guidance and potential flight diversion [15]. Challenges in managing in-flight HAPE include limited diagnostic and therapeutic tools, communication difficulties with ground control, and the logistical complexities of flight diversion.

Preventive measures include pre-flight assessment for at-risk passengers [60], considering supplemental oxygen for high-altitude flights in those with a history of HAPE or significant cardiopulmonary disease [60], and ensuring awareness of HAPE among cabin crew, medical professionals, and airlines [60]. Research specifically on in-flight HAPE is limited, with current understanding largely based on terrestrial altitude studies. Further research is needed to better define the incidence, risk factors, and optimal management of this in-flight emergency.

Pneumothorax

In-flight pneumothorax, is a rare life-threatening emergency with high risk of sudden death if not promptly recognized and manage appropriately. The presence of air in the pleural space of passenger, poses a significant risk due to the changes in aircraft's cabin pressure. Reduced atmospheric pressure at high-altitude will result in trapped air to expand, potentially worsening the pneumothorax and compromising respiratory function especially in passengers with underlying pulmonary diseases, recent thoracic surgery, or a previous history of spontaneous pneumothorax [61]. Clinical presentation includes sudden chest onset of chest pain, dyspnea, and tachypnea. Inflight diagnosis can be challenging, reliant on clinical assessment and portable ultrasound if available could be helpful in establishing the diagnosis [62]. Management includes oxygen administration and, in severe cases needle decompression could be perform if a tension pneumothorax is suspected. Prevention involves screening high-risk passengers and advising against air travel for those with recent pneumothorax or significant pulmonary disease [43, 44].

Inflight Gastrointestinal Emergencies

While, inflight gastrointestinal (GI) emergencies account for (34%) of IMEs [46]. A number of factors are accountable for these inflight events, including gastroenteritis as a result of prior or in-flight food and beverage consumption, motion sickness, the impact of cabin pressure changes on gastrointestinal tract gas, travel-related stress and anxiety on GI tract, and underlying gastrointestinal conditions such as exacerbated acid peptic disease or irritable bowel syndrome. The management of these emergencies presents with unique challenges, due to space constraints, limited medical resource, and the varying medical expertise of clinicians onboard. A factor in effective management is the implementation of clear protocols for common inflight gastrointestinal disorders and recognizing the impact of cabin pressure changes, which can exacerbate these disorders due to gas expansion within the body. Complex cases often necessitate ground-based medical support. In summary, although inflight gastrointestinal emergencies can be disruptive, most are manageable with proper preparedness and well-defined management protocols tailored to the unique cabin environment.

Inflight Cardiac Emergencies

In-Flight Cardiac Arrest

In-flight cardiac arrest (IFCA) is a rare but critical medical emergency that presents unique challenges to cabin crew and clinicians onboard due to the confine aircraft environment and limited medical resources onboard. While precise incidence is hard to determine, estimates range from 0.3 to 1.7 cases per million passengers [63, 64]. Majority IFCA events are reported in adults with underlying cardiac diseases and older age [65, 66]. Other rare causes of IFCA but more so in the in-flight environment include vasovagal syncope, and pulmonary embolism especially on long flights [64]. Hypoxia, dehydration and electrolyte imbalances though less common potentially exacerbated by air travel, can also play a role in IFCA.

Managing IFCA is difficult due to limited space and medical resources, hindering resuscitation efforts. The availability of trained medical personnel onboard varies, and communication with ground control can be challenging. Current guidelines emphasize rapid recognition, CPR initiation, and AED use, which are increasingly available [67]. Early communication with ground support is vital for guidance and post-landing care. Onboard medical kits should be utilized under the direction of trained personnel or ground support.

Preventative strategies involve optimizing passenger health before travel, including hydration and managing pre-existing conditions. Further research is needed to improve our understanding of IFCA, including data collection and analysis to determine true incidence and risk factors for IFCA. Enhancing in-flight medical equipment availability, training, and communication protocols are crucial for improving outcomes. Standardized IFCA management protocols are also essential.

Inflight Myocardial infarction

In-flight myocardial infarction (MI) is a rare but critical emergency during air travel, complicated by the unique cabin environment. While recorded traditional risk factors for inflight MI are identical with those observed on the ground [68, 69], air travel stressors like hypoxia and psychological and physical stress, potentially heighten risk of developing inflight MI whereas limited medical resources onboard, complicate it management. Key risk factors for inflight MI include underlying coronary artery disease, hypertension, diabetes, and a history of smoking, air travel-stressors, circadian rhythm disruption, crowded environments, and fatigue, all of which contribute to increased cardiovascular strain. The reduced partial pressure of oxygen in aircraft cabins, which can exacerbate myocardial ischemia in vulnerable passengers, while prolonged immobility during long-haul flights heightens the risk of venous thromboembolism, consequently contributing to the overall cardiovascular disease burden inflight. Common symptoms are chest pain, dyspnea, diaphoresis and feeling of impending doom, but atypical presentations can occur.

Managing in-flight MI is challenging due to confined space, limited medical resources, diagnostic challenges, and the inability to perform advanced interventions like PCI. This necessitates swift flight diversion for appropriate care. Thorough pre-flight risk assessments for at-risk passengers are crucial. Efforts are underway to improve in-flight medical protocols and resources for cardiac emergencies.

Inflight Allergic Reactions

Allergic reactions account for 1.6% of in-flight medical emergencies, most commonly induced by food such as peanuts or tree nuts, environmental allergens exposure, and travelling pets [25]. Inflight allergic reactions can present as minor reactions (localized hives) with itching to life-threatening anaphylaxis, angioedema or shock. Inflight medical kits carried onboard usually contain antiallergic medications including prednisolone, hydrocortisone, antihistamines (oral or injectable), epinephrine and intravenous fluid for the treatment of different in-flight allergic reactions. In addition to preventive measures including removal or avoidance of offending allergens.

Inflight Obstetrics Emergencies

In-flight obstetric emergencies, while accounting for a small percentage of in-flight medical events (0.7%), pose significant and unpredictable challenges for cabin crew and medical professionals [70]. Despite their low frequency, they are a notable cause of flight diversions and hospitalizations [7-25], underscoring the need for preparedness. Risk factors include a history of obstetric complications, and airline restrictions based on gestational age. Common emergencies include preterm labor, pre-partum hemorrhage, active labor at term, spontaneous abortion, abruptio placenta, and preeclampsia/eclampsia [25].

Flight diversion is recommended for moderate to severe vaginal bleeding and severe abdominal pain, with intravenous fluids therapy advised to prevent shock [3]. Although air travel is generally considered safe during pregnancy, documented in-flight deliveries highlight the reality of such events.

Managing these emergencies is complex due to limited onboard medical resources [70], spatial constraints, and potential turbulence. Variable medical expertise among medical volunteers and communication challenges with ground-based support further complicate care. Mitigation strategies include thorough pre-flight screening of pregnant passengers, standardized emergency protocols, comprehensive cabin crew training focusing on basic life support, child delivery assistance, and the management of pre-partum, and intra haemorrhage, and effective communication with ground-based medical professionals for guidance and flight diversion. Successful management relies on diligent pre-flight precautions, clear protocols, and seamless telemedicine support.

Inflight Traumatic Injuries

In-flight medical emergencies (IMEs) involving traumatic injuries constitute 4% of all IMEs [25]. Understanding these incidents requires knowledge of crash mechanics, injury patterns during flight, and the impact of high altitude on trauma. In-flight traumatic injuries vary widely in severity and frequency.

Common injuries include head injuries from turbulence, leading to neck strain and concussions. Less common injuries include bruises, twisted ankles, bone fractures, concussions, facial lacerations, collarbone injuries, and scalding burns. Contributing factors include age, anticoagulant use [71], sudden altitude changes, falling objects, spills, and falls within the cabin. Immediate treatment focuses on stabilization, including bleeding control, splinting, neurological assessments, and intervention for unconscious passengers [71].

For severe trauma, understanding crash dynamics is vital for improving aircraft safety through better airframe design, safety regulations and successful inflight trauma control. Research correlates injury types with aircraft factors, identifying common severe injuries like spinal and head trauma, burns, and fractures. Altitude effects, such as hypoxia, can worsen these injuries, emphasizing the need for prompt oxygen administration. Future research should address logistical challenges of in-flight trauma care and the impact of pre-hospital care and rapid evacuation. Effective management requires collaboration between cabin crew and medical professionals.

Inflight Psychiatric Emergencies

In-flight psychiatric emergencies, accounting for 3-3.5% of IMEs [3-72], present unique challenges in the confined aircraft environment. Acute anxiety and panic attacks are most common [72], followed by agitation, psychosis, and disruptive behaviour.

Contributing factors include fear of flying, long check-in, delay flight, strict security measures, cramped cabins, claustrophobia, disruptions of flight routines, substance misuse/withdrawal, PTSD, alcohol, and physiological effects of altitude [3-71]. The increasing global prevalence of psychiatric disorders also contributes.

Managing these emergencies is complicated by limited space, availability of trained personnel and medications, and the safety risks posed by disruptive behaviour. Airlines should have clear protocols and train cabin crew to recognize and respond to psychological distress. As has suggested there should be consideration of adding a rapid-onset anxiolytic agent [72], in the onboard medical kit may be beneficial and integrating telemedicine support and ground-based medical support should be actively pursued to enhance the management of such emergencies.

Differential Diagnosis of Inflight Medical Emergencies

In-flight medical emergencies are challenging due to overlapping symptoms, limited space, and resources, making differential diagnosis is crucial. This systematic approach helps cabin crew and any onboard clinicians consider two or more clinical conditions with similar symptoms and signs, enabling accurate and timely diagnoses. This leads to appropriate and prompt treatment, reduces misdiagnosis risks, and guides focused assessments and treatment both in-flight and after landing. Ultimately, this framework prioritizes patient safety by ensuring thorough evaluation and facilitating optimal care in the demanding in-flight setting, including vital decisions about potential flight diversions for advanced medical attention.

Differential Diagnosis of Passenger Presenting with Seizures and Loss of Consciousness Inflight

In-flight differential diagnosis of loss of consciousness with seizures include vasovagal syncope, epileptic or cardiogenic syncope, acute diabetic emergencies (hypoglycaemia, diabetic ketoacidosis or hyperosmolar hyperglycemic state), substance-related disorders (intoxication or withdrawal), psychogenic seizures, cardiac events, cerebral air embolism, decompression sickness, and head injuries. A focused approach is key, involving detailed medical history, thorough physical examination, and focused investigations inflight or after landing. Key distinguishing factors include event duration, postictal state, eyewitness accounts, auras, foamy salivation, upward rolling of eye balls, medical history, examination findings, and associated symptoms like chest pain or dyspnea.

Differential Diagnosis of Passenger Presenting with Dysnea and Chest Pain Inflight

Evaluating in-flight shortness of breath and chest pain requires considering many differential diagnoses like myocardial infarction, pulmonary embolism, acute bronchial asthma, anxiety and panic, acute exacerbation acid peptic disease, pneumothorax, acute exacerbated COPD. A focused medical history and meticulous physical exam are key essentials for mid-flight assessment. Consulting ground-based medical experts can help some time reach a definitive diagnosis.

Differential Diagnosis of Passenger Presenting with Sudden Death Syndrome Inflight

In-flight sudden death syndrome (ISDS), though rare, is a psychologically devastating medical emergency requiring differential diagnosis. It can stem from serious conditions like coronary artery disease, malignant arrhythmias, myocardial infarction, massive pulmonary embolism, or severe respiratory distress. Other causes include haemorrhagic stroke, seizures with post ictal apnea, tension pneumothorax, anaphylaxis, aortic dissection, and pre-boarding drug overdoses. Prompt treatment intervention, including rapid assessment and CPR, is critical in managing inflight cardiac arrest. The availability and use of AEDs are vital. Consulting ground-based medical experts and reviewing the passenger's medical history, if possible, are also strongly advised.

Figure 3: Showing spectrum of in-flight medical emergencies

Differential Diagnosis of Passenger Presenting with Abdominal Pain Inflight

In-flight abdominal pain varies greatly in severity, creating diagnostic and treatment challenges for cabin crew and any onboard clinician due to limited resources and flight-related physiological stressors. Differential diagnosis of inflight abdominal pain includes gastroenteritis and constipation (worsened by immobility and dehydration) to intestinal obstruction (possibly affected by cabin pressure) and exacerbated acid peptic disease. Renal colic (aggravated by dehydration) and anxiety can also manifest as abdominal pain. In female passengers, labor, pregnancy complications, menstruation, and ectopic pregnancy are possibilities. Accurate diagnosis relies on medical history, meticulous physical examination, and prompt assessment of vital signs. While onboard kits offer some relief, ground consultation is often needed, and severe cases may require flight diversion for specialized care.

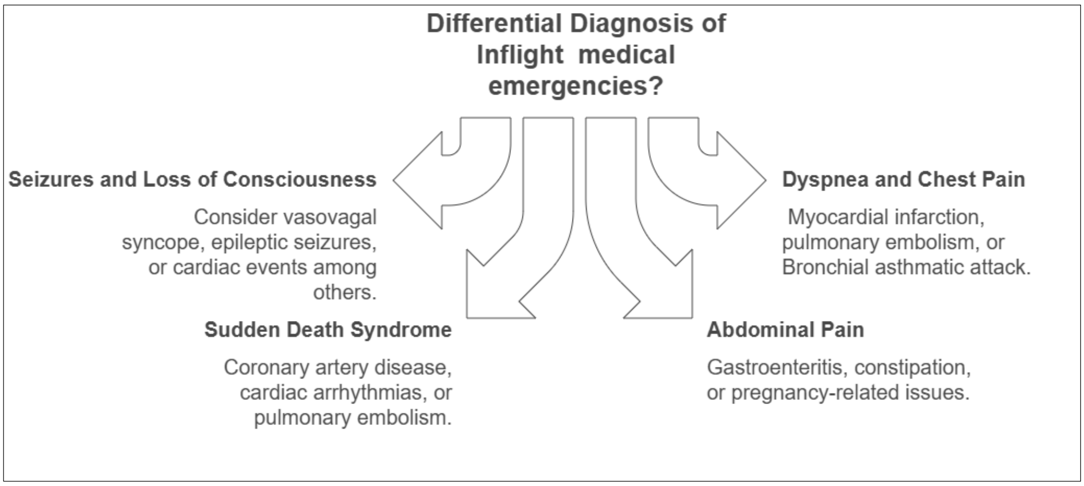

Figure 4: Showing differential diagnosis of inflight medical emergencies

Factors Predisposing Passengers to In-Flight Medical Emergencies

Inflight medical emergencies are spectrum of life-threatening medical emergencies with a variety of contributing factors that include:

Environmental Factors

The cabin of aircraft is pressurized to an altitude equivalent of 5,000 to 8,000 feet above sea level. This can lead to reduced oxygenation, especially for those passengers with underlying cardiopulmonary diseases [73]. Very low humidity of cabin air was also documented to contribute to dehydration that exacerbate certain medical conditions [1]. Prolonged sitting with limited mobility during long flight can lead to impairment of circulation, and this increase the risk of venous and arterial thrombosis and other cardiovascular events [1].

Passenger-Related Factors

Air travellers with underlying chronic cardiopulmonary and metabolic diseases like heart failure, ischemic heart disease, asthma, COPD, ILD, diabetes mellitus and obesity are at higher risk of developing inflight emergencies [3]. Older passengers are found to be more susceptible to the physiological changes associated with air travel [1], which may heighten their risk of inflight medical emergencies. Moreover, air travel can be a source of physical and emotional stress/anxiety for some passengers, potentially triggering panic attacks or exacerbating underlying mental health illness [74]. Excessive alcohol or caffeine intake inflight may predispose passengers to dehydration, and fatigue triggering in-flight medical emergencies [74].

Flight-Related Factors

Longer flights were found to increase the risk of inflight medical emergencies [1]. Similarly, severe turbulence was documented to cause injuries or exacerbate underlying medical conditions [74].

Other Factors

In-flight medical emergencies can arise due to passengers forgetting to take their prescribed medication or lacking access to it. Food poisoning, is rare but has the potential to cause outbreak of gastroenteritis onboard. Contagious diseases like the viral flu, corona virus infections (SIRS, MERS or COVID-19) can spread between inflight passengers [74].

In conclusion, although in-flight medical emergencies are relatively uncommon, airlines are prepared with protocols and trained cabin crew. Air travellers can take active role in reducing their own risk by staying hydrated, limiting alcohol and caffeine consumption, and carefully managing any underlying health conditions.

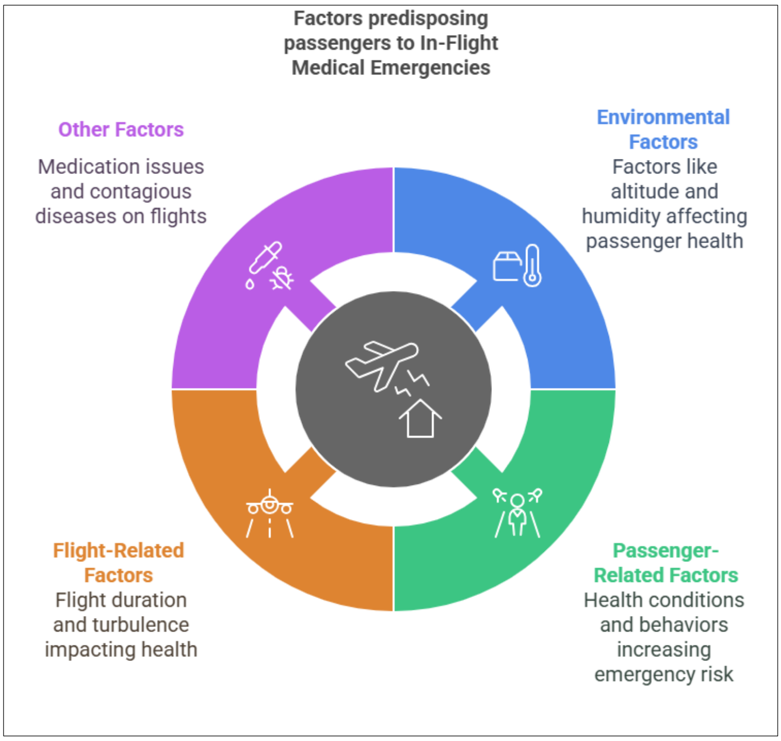

Figure 5: Showing factors predisposing passengers to in-flight medical emergencies

Protocols and Procedures for Handling Inflight Medical Emergencies and the Challenges

Inflight medical emergencies (IMEs), though infrequent, necessitate robust protocols for effective management, shaped by airlines, medical professionals, and international organizations. Prompt identification, assessment (including focused history, physical exam, and onboard tests like RBS, ECG, handheld echo, and ultrasound), and treatment is crucial. Airlines equip aircraft with medical kits and may seek aid from medical professionals onboard [75]. The in-flight environment presents unique challenges, such as ambient noise affecting use of stethoscope and blood pressure measurement, requiring alternative methods like palpatory method for measuring systolic pressure can be adopted [23].

Effective communication between flight crew, onboard clinicians, and ground-based medical support is vital, often involving radio consultation. Aircraft carry basic medical kits, with some having more comprehensive emergency kits, the contents of which are regulated [75]. Airlines often request assistance from medical professionals, who are offered legal protection in some regions, like the US Aviation Medical Assistance Act [76]. The captain ultimately decides on flight diversion based on the medical condition's severity, onboard resources, and nearby airports [77]. Seamless coordination with ground medical services for patient transfer and information sharing is essential upon arrival.

Despite these established procedures, challenges persist, including the confined aircraft space, limited advanced medical equipment, variability in training among cabin crew and clinicians, and liability concerns. Crucially, improved data collection on IMEs is needed to refine protocols and identify trends. Nevertheless, IME management has evolved due to advancements in aviation medicine, communication technology, and understanding the physiological impact of air travel. Continuous research and collaboration are key to further enhancing these protocols and ensuring passenger safety and health.

Availability of Trained Medical Personnel among Inflight Passengers

Studies show that clinicians are frequently present on commercial flights, with physicians found on nearly half of flights with medical emergencies, the presence of nurses and other healthcare providers were also noted among passengers [78, 79]. Their presence significantly influences the management of these emergencies, as they are more likely to perform advanced interventions compared to flight attendants [80], potentially improving clinical outcomes for critical emergencies like cardiac arrest.

However, relying on volunteer clinicians has challenges. These include varying levels of training and experience, limited on-board medical resources, and potential liability concerns, despite some legal protections like the Aviation Medical Assistance Act [81].

In conclusion, while drawbacks exist, the presence of volunteer medical professionals can be immensely valuable during in-flight medical emergencies. Further research is needed to understand the impact of clinicians on commercial flights, and to develop strategies that optimize their role in in-flight medical care.

Use of Telemedicine (Technology) in Inflight Medical Emergency Care

Telemedicine has proven effective in addressing in-flight medical emergencies [82, 83]. This technology connects passengers and crew with ground-based experts for real-time diagnosis and treatment guidance and informed decision-making during in-flight medical emergency [84]. Key components include aircraft equipped with satellite communication for voice and data transmission to ground-based medical experts, enriched on-board essential medical supplies, diagnostic tools, monitoring and medications delivery systems, and airline partnerships with aviation medicine specialists. Benefits include timely care, better clinical decision-making regarding treatment options and potential flight diversions, reduced costly and unnecessary flight diversions, and increased passenger confidence, assurance of prompt and effective medical care should a IME arise [2,85,86].

Despite its promise, telemedicine faces challenges like poor connectivity in remote areas, high implementation costs for airlines, and varying international regulations. However, with technological advancements and decreasing costs, telemedicine is expected to play a larger role in ensuring passenger safety during flights.

Prevention and Preparedness of Inflight Medical Emergencies

Pre-flight medical assessments are crucial for ensuring the safety of high-risk air travellers by addressing potential in-flight medical emergencies (IMEs) [87, 88]. These evaluations offer significant advantages, including identifying at-risk passengers (e.g., those with underlying cardiopulmonary and neurological diseases or recent surgeries) for risk stratification. This allows for personalized recommendations like medication adjustments or oxygen, and early detection of conditions that could lead to IMEs, thereby reducing their occurrence. Passengers with known health conditions gain confidence knowing their health has been considered, and overall airline safety improves by minimizing costly flight diversions [88, 89].

However, challenges exist. The absence of standardized protocols leads to inconsistent evaluations, and the reliance on self-reported history can be subjective. Comprehensive assessments can be resource-intensive, and their cost can be a barrier [87], especially for frequent travellers.

Improvements can be made through standardized, evidence-based tools. Telemedicine and wearable devices can enable remote monitoring. Better collaboration between healthcare providers and airlines can streamline the process and information flow. Educating passengers and providers about the importance of these assessments can also encourage proactive health management.

In conclusion, while challenges remain, pre-flight medical assessments are vital for safeguarding high-risk passengers. Ongoing advancements hold the promise of making air travel safer and more comfortable for everyone.

Comprehensive Cabin Crew Training on Inflight Medical Emergencies

Flight crews are crucial first responders during in-flight medical emergencies (IMEs), necessitating comprehensive initial and recurrent training. Effective programs should cover the identification, diagnosis, management, and stabilization of common IMEs, including first aid, CPR, and the use of onboard equipment. Crews need to understand differential diagnoses, assess IME severity for timely decisions, and communicate effectively with ground-based medical experts.

Training must include the use of onboard medical kits like AEDs, foster strong communication within the crew and with passengers, and address the management of anxious individuals. Understanding how flight conditions can worsen certain medical issues is also vital. Hands-on simulations are key to reinforcing knowledge and skills.

These evidence-based programs should align with current medical guidelines and global best practices. Regular refresher training is essential to maintain competence and incorporate updates. Integrating crew resource management (CRM) principles enhances teamwork and decision-making. Collaboration with medical professionals is needed for complex case.

While regulations exist, standardized training across airlines is important. Exploring technologies like virtual reality and telemedicine can improve training. Ultimately, robust training equips crews to effectively manage IMEs, enhancing passenger safety. Further research is needed to assess the long-term impact on crew performance and patient outcomes.

Research on In-Flight Medical Emergencies

Research into IMEs is crucial for passenger safety and well-being. Identifying common IME types, incidence, and outcomes through comprehensive research enables the development of effective onboard medical management protocols and guidelines. Analysing IME trends enhances cabin crew training, ensuring preparedness for diverse emergencies. Furthermore, research optimizes onboard medical resources, aligning kit composition with prevalent emergencies and informing strategic stocking of medications and equipment based on likelihood of occurrence.

IME research also improves telemedicine support by determining effective communication methods and appropriate remote medical assistance, enhancing coordination between cabin crew and ground support. Data from IMEs can influence aviation health policies, leading to standardized global protocols. Identifying IME causes facilitates preventative strategies, boosting public confidence in air travel. Additionally, IMEs research addresses critical legal and ethical questions and enriches travel medicine, providing insights into air travel's health impacts. Finally, this research fosters medical technology innovation for advanced onboard diagnostics and interventions, ultimately increasing passenger safety, improving IMEs care, and ensuring comprehensive preparedness in the aviation industry.

Concept: Inflight Clinical Vigilance (ICV)

Inflight Clinical Vigilance (ICV) is a proactive and systematic approach to passenger health during air travel, primarily focused on the early identification and management of inflight medical emergencies (IMEs). This strategy integrates vigilant cabin crew monitoring for passengers exhibiting potential health issues, strict adherence to established protocols, and comprehensive analysis of relevant passenger data to enhance safety and well-being.

Key components of ICV include training cabin crew to recognize passengers displaying visible signs of distress or those falling under high-risk category (elderly or those with pre-existing health conditions). Airlines should also provide confidential channels for passengers to voluntarily disclose health information, respecting privacy regulations. Crew awareness of cabin environmental factors like pressure changes, dry air, and turbulence, which can worsen existing conditions, is also crucial.

Proactive surveillance, involving regular cabin walk-throughs, especially on long flights, and training to identify subtle physiological and behavioural cues, foreshadowing potential emergencies is vital. Direct passenger interaction aids in discreet observation. In emergencies, swift assessment, clear communication with flight deck and ground support, and skilled use of onboard medical equipment/medication are essential.

Post-flight, detailed documentation and trend analysis of IMEs facilitate the identification of patterns and areas for procedural enhancement. Regular audits of medical kits and continuous evaluation of crew training ensure preparedness and adherence to best practices. Ultimately, ICV aims to reduce the occurrence and severity of IMEs, ensure rapid responses, improve crew skills, and contribute to the advancement of airline medical protocols, thereby significantly improving passenger safety and care within the unique challenges of air travel.

Medical Equipment and Resources on Board

Modern in-flight medical kits have undergone significant improvement, reflecting advancements in medical technology and better understanding of in-flight medical emergencies (IMEs) [90]. They now include AEDs, vital signs monitor, oxygen delivery systems, and medications for cardiac events, allergies, respiratory distress, and pain [90,3]. Advanced tools like point of care ultrasound devices, and glucometer are increasingly included. This continuous evolution is driven by the need to adhere to evolving medical guidelines [74]. Additionally, telemedicine integration enable real-time consultation with ground-based medical professionals, serves to further optimize the effectiveness of on-board medical resources [91].

The Federal Aviation Administration FAA and International Civil Aviation Organization ICAO mandate standardized medical kits on commercial airlines [25]. These include basic first-aid and comprehensive emergency kits with AEDs and infectious disease agent handling kits. The specific contents of these medical kits are tailored to fit the anticipated medical needs in flight, and may vary depending on flight duration and flight capacity [92, 93].

Table 1: In-flight Medical Emergencies Clinical evaluation, relevant medical resource, Treatment interventions and Decision for potential flight diversion

In-flight medical emergencies	Relevant clinical /physical examination findings	Relevant Equipment/devices	Treatment intervention	Decision for flight diversion
Vasovagal syncope	Altered level of consciousness, bradycardia, Small volume pulse, pallor, hypotension, myoclonic jerks, dyspnea	Stethoscope Sphygmomanometer (digital or aneroid) Portable ECG device	Oxygen therapy, supine positioning of patient, raising the legs, Intravenous fluid therapy, fludrocortisone acetate, selective serotonin reuptake inhibitors,	Flight diversion less likely

In-flight medical emergencies	Relevant clinical /physical examination findings	Relevant Equipment/devices	Treatment intervention	Decision for flight diversion
Epileptic seizure	Convulsion, altered level of consciousness, upward rolling of eyeball, foamy salivation, Urinary or faecal incontinence	Stethoscope Sphygmomanometer (digital or aneroid), oropharyngeal airway devices,	oxygen therapy, secure IV access, Inj. diazepam, lorazepam, midazolam, phenytoin, Dextrose 50%,	Potential flight diversion in case of status epilepticus
Stroke	Coordination and gait abnormality, sudden loss of vision or blurred, Facial asymmetry, arm limbs weakness, aphasia or slurred speech, limbs weakness, altered level of consciousness, Convulsion,	Stethoscope, Sphygmomanometer (digital), oropharyngeal airways devices, pen torch, fundoscope	IV fluid normal saline, mannitol,	Potential flight diversion
Motion sickness	Vomiting, drowsy. Salivation, sweating,		Focusing on a stable horizon, reducing head movement, restraining movement, IV fluid therapy, Antiemetics, anti histamine, scopolamine, phenothiazine, cinnarizine	Flight diversion less likely
Cerebral air embolism	Features suggestive of stroke, altered level of consciousness, Convulsion, mill-wheel murmur, PFO murmur		IV fluid therapy, anticonvulsant, cerebral decongestant, Hyperbaric oxygen therapy upon arrival,	Potential flight diversion
Acute bronchial asthmatic attack	Dyspnea, tachypnea, wheezing, rhonchi's, failure to complete sentence, tachycardia, bradycardia, hypotension, cyanosis,	Oxygen delivery system, nebulizer, inhaler	Oxygen therapy, Beta-2 agonists, corticosteroids (e.g., hydrocortisone or prednisolone), IV fluid, ipratropium bromate, magnesium sulphate	Potential flight diversion if acute severe or life-threatening asthma
Pulmonary embolism	Dyspnea, tachypnea, chest pain, cyanosis, crepitations, pleural effusion, loud P2, hypotension, shock, right-sided S3 gallop, unilateral limb swelling and tenderness, pitting pedal edema	Oxygen delivery devices, pulse oximeter, portable hand held or hand carry-on doppler USS, and Echocardiography	Oxygen therapy, heparin, warfarin, fibrinolytics	Potential flight diversion if no remarkable improvement
ARDs	Dyspnea, tachypnea, fever, cyanosis, crepitations,	Oxygen delivery devices, sphygmomanometer, thermometer, Pulse oximeter	Oxygen therapy, corticosteroids	Potential flight diversion if severe

In-flight medical emergencies	Relevant clinical /physical examination findings	Relevant Equipment/devices	Treatment intervention	Decision for flight diversion
HAPE	Dyspnea, tachypnea, cyanosis, crepitations, Altered level of consciousness	Oxygen delivery devices, diuretics, Pulse oximeter	Supplemental oxygen therapy, moving to lower altitude diuretics,	Potential flight diversion if severe
Pneumothorax	Sudden onset of dyspnea, tachypnea, chest pain, cyanosis, crepitations, Hyperresonance percussion note,	Oxygen delivery devices, Pulse oximeter	Oxygen therapy, Needle decompression if spontaneous pneumothorax	Potential flight diversion if no remarkable improvement
In-flight gastrointestinal emergencies	Abdominal examination, tenderness, increase or decrease bowel sound	Portable ultrasound machine, stethoscope sphygmomanometer, thermometer	IV fluid, anti-emetics, antibiotics, analgesics	Flight diversion less likely
In-flight cardiac arrest	Sudden collapse, loss of consciousness, dyspnea, cessation of breathing pulseless, hypotension, shock	Ambu bag Oxygen delivery devices, defibrillator, CPR masks for paediatric and adult sizes), Pulse oximeter	BLS, CPR, ALS, nor-adrenaline, atropine, antiarrhythmic medications, calcium gluconate, sodium bicarbonate	Potential flight diversion
In-flight MI	Sudden onset of chest pain, dyspnea, diaphoresis, feeling of impending doom, hypotension, shock, cardiac arrest	Oxygen delivery devices, ECG machine, point of care troponin detector, defibrillator, Pulse oximeter	IV access, oxygen therapy, dual antiplatelet, nitro-glycerine tablets and spray, morphine, vasopressors like (Epinephrine e.t.c) heparin, fibrinolytics, statins, beta-blockers, ACEIs	Potential flight diversion
In-flight allergic reactions	Whale and plagues, urticaria, hypotension, shock, angioedema	Oxygen delivery devices, stethoscope, sphygmomanometer,	IV access in anaphylaxis, anti-allergic medications prednisolone, hydrocortisone, antihistamines (oral or injectable) oxygen, epinephrine, IV fluid	flight diversion less likely
In-flight obstetrics emergencies	Abdominal pain, palpable gravid uterus, foetal part, PV bleeding	Oxygen delivery devices, stethoscope, sphygmomanometer	IV access, IV fluid normal saline, analgesics, Medication for pre and postpartum bleeding	Potential flight diversion
In-flight traumatic injuries	Bruise, laceration, tenderness, fracture	Oxygen delivery devices, stethoscope, sphygmomanometer	IV access, IV fluid, analgesics	Flight diversion depends on severity of the traumatic injury
In-flight psychiatric emergencies	Restlessness, disruptive, behaviour, agitation,		IV access, sedative, hypnotics, antipsychotics	Potential flight diversion if disruptive
Additional medical resources: intravenous catheters, antiseptic wipes, urethral catheter, syringe, needle, venous tourniquet, sponge gauze, surgical masks, disposable gloves, non-mercury thermometer, adhesive tape, flashlight and batteries, sponge gauze, sharps disposal box				

Clinician Approach to Managing In-Flight Medical Emergencies

Basically, if a cabin crew request for medical help, here's the guiding rules for any volunteer medical professional. So, in a nutshell, if you step up during an in-flight medical emergency, make sure you identify yourself, try to treat the passenger where they are or use aisle blocks mobility of cabin crew, document your clinical examination findings and treatment administered, work as a team with the crew and ground support, practice within the jurisdiction of your expertise, request for access to the medical kit, and use a translator if needed.

DISCUSSION

This critical review examines the growing issue of in-flight medical emergencies (IMEs) and their complexities. Their unpredictable and potentially life-threatening nature demands swift action to avoid dismal outcomes and costly diversions. The confined cabin, limited resources, and diagnostic difficulties pose challenges for both crew and any onboard medical professionals.

High-altitude physiological effects like reduced pressure and hypoxia can worsen existing conditions or trigger new IMEs. The rise in IMEs is linked to increased air travel, an aging population, environmental factors, more cardiometabolic diseases, and better reporting. While vasovagal syncope is frequent, serious events like myocardial infarction, cardiac arrest, respiratory emergencies, seizures and strokes present major treatment challenges and are key causes of in-flight deaths.

Inflight medical emergencies (IMEs) present unique diagnostic and management challenges due to limited resources and the aircraft environment [1]. A differential diagnosis approach is crucial given the overlap in IMEs symptoms for conditions like chest pain (acute coronary syndrome vs. PE vs. anxiety vs exacerbated acid peptic disease), while loss of consciousness differential diagnosis include syncope vs. stroke vs. epileptic seizure vs. cerebral air embolism vs. hypoglycemia/hyperglycemia, and differential diagnosis of respiratory distress could stem from acute severe/life-threatening asthma, acute respiratory distress syndrome, acute exacerbated COPD, myocardial infarction, panic attacks, and pneumothorax. Abdominal pain differential diagnosis can range from gastroenteritis to surgical/obstetric emergencies. Accurate diagnosis requires a focused history-taking, meticulous physical examination within aircraft constraints, and interpretation of physical examination findings and vital signs [74]. Effective management relies on clinical knowledge, examination skills, competencies, clinical reasoning, and familiarity with onboard kits. Enhanced training for cabin crew and clinicians, integrated into medical programs, is essential for improved passenger safety.

In-flight medical emergencies (IMEs) result from complex interplay of environmental and passengers' susceptibility factors [1]. Lower oxygen levels, dry air, and pressure changes can worsen cardiopulmonary diseases [94]. Prolonged immobility increases DVT risk. Passenger factors like age, chronic diseases, and lifestyle choices (dehydration from excessive caffeine/alcohol) heighten risk of IMEs. Additionally, air travel related stress may exacerbate underlying medical conditions, and recent surgical procedures may predispose passenger to complications due to cabin pressure variations [13].

IME protocols prioritize passenger safety through situation assessment, seeking onboard medical help, utilizing medical kits, and communicating with ground support [74]. Airlines often employ a "physician-on-board" call, or seeking volunteer medical personnel. Nevertheless, challenges arise from limited equipment, varying volunteer expertise, and aircraft constraints [3]. Communication difficulties and legal concerns can complicate responses. Standardized protocols and adequate cabin crew training are vital for effective IME management.

Prevention involves proactive measures by passengers and airlines [95]. Passengers should consult doctors, stay hydrated [90], carry medications, and avoid excessive alcohol/caffeine intake while onboard. Airlines should provide well-stocked kits, train crew in life support and emergency procedures, and establish robust communication with ground support [74]. Pre-flight health screenings and clear guidelines for passengers with medical needs further enhance preparedness. A collaborative effort between passengers and airlines is needed to mitigate IMEs.

Clinical evidence reveals a significant knowledge gap in managing in-flight medical emergencies (IMEs) among cabin crew, medical professionals, and the general public, particularly in low- and middle-income countries (LMICs). Well-trained cabin crew and medical professionals are vital for improving patient outcomes during IMEs globally. Their expertise allows for thorough yet focused passenger assessments, including detailed histories, physical exams, and targeted investigations. This comprehensive approach enables personalized, evidence-based treatment. Therefore, proficiency in IME diagnosis, treatment, and diversion decisions is essential. To bridge this gap, targeted training, retraining, integrating IMEs into medical curricula, and further research are strongly recommended.

Pilot studies and research highlight the effectiveness of telemedicine in managing IMEs. Thus, pre-flight medical checks, thorough preparedness, and the strategic use of telemedicine are crucial for passenger health. Integrating these approaches with enhanced training is vital for reducing IME-related risks and promoting air traveller well-being. This comprehensive review of IMEs offers significant potential for advancing in-flight medical care. It serves as an educational resource for cabin crew, pilots, and medical professionals, providing essential knowledge. By analysing the frequency and nature of IMEs, it can guide the stocking of appropriate medical kits. Its emphasis on differential diagnosis enables prompt and accurate evaluation, crucial for timely interventions and improved outcomes. Incorporating best practices informs effective treatment strategies, reducing morbidity and mortality.

Furthermore, the review underscores the importance of understanding altitude-related physiological changes, facilitating risk mitigation for vulnerable passengers. It can also drive regulatory innovations in airline protocols for medical kits, training, and communication, potentially fostering international collaboration for standardized care and clarifying legal obligations. By highlighting research gaps, including telemedicine integration and enhanced education, this review can ultimately improve the quality and safety of in-flight medical care, benefiting airlines, medical professionals, passengers, and regulatory bodies alike.

CONCLUSIONS

As the skies grow increasingly congested with both young and older passengers, the prevalence of IMEs is bound to rise. Furthermore, the aircraft cabin complex environment necessitates collaborative approach in order to effectively handle in-flight medical emergencies. Better communication and collaboration of expertise among cabin crew, medical professionals onboard to ground-based support, is necessary to enhance collaborative action in ensuring the health and well-being of passengers. Although, inflight medical emergencies pose some exceptional challenges, but continued research, crew and clinicians training and retraining on IMEs, inflight clinical vigilance and technological innovations are paving the way for an ever-safer flight in future. By embracing innovation in telemedicine, portable handheld or carry-on diagnostics equipment, and enriched medical kits, we can transform the inflight environment into a space where medical emergencies are met with prompt and effective treatment interventions. In the realm of aviation, where every flight is a journey into the unknown, preparedness for medical emergencies is one of necessity and not choice. By prioritizing training and retraining of cabin crew and clinicians, integration of IMEs curricula in medical training institutes, collaboration and enriched medical resources, we can ensure every passenger flight with the assurance of care and safety. Finally, this review underscores the urgent need for more innovations for onboard medical equipment, improved cabin crew and medical professionals training on IMEs, and better ground support. By prioritizing preparedness, we can ensure that when medical maydays (emergencies) occur at 30-35,000 feet, we are prepared to respond with unwavering confidence.

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Abbreviations

IMEs: Inflight medical emergencies **LMICs:** Low-middle income countries, **VTE:** Venous thromboembolism,

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