

Multicausal factors underlying post-hajj oxygen desaturation: a case-based analysis from two elderly pilgrims at the 2025 surabaya debarkation

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ABSTRACT

Oxygen desaturation is a significant clinical concern among Hajj pilgrims, particularly in older adults with comorbidities such as lower respiratory tract infections. Prolonged travel, exposure to extreme environmental conditions, and immune decline during pilgrimage substantially contribute to respiratory compromise. This report describes two elderly pilgrims who developed oxygen desaturation upon arrival at the Surabaya debarkation site in 2025. The first patient, an 88-year-old woman, presented with desaturation following the pilgrimage and was diagnosed with community-acquired pneumonia after hospitalization at King Abdul Aziz Hospital, Mecca. The second patient, a 75-year-old woman with no prior comorbidities, developed mild desaturation suspected to be due to bronchopneumonia following high-risk environmental exposure during the pilgrimage. Contributing factors included advanced age, prolonged air travel, exposure to extreme temperatures, post-hospital immobility, and dehydration. These cases highlight that post-Hajj desaturation is multifactorial and predominantly affects elderly pilgrims. Early identification, comprehensive pre-departure health screening, continuous monitoring during and after pilgrimage, and implementation of early detection systems at debarkation sites are essential to prevent severe complications and reduce morbidity among returning pilgrims.

Key words: Debarkation, elderly, Hajj pilgrims, oxygen desaturation, pneumonia.



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INTRODUCTION

The annual Hajj pilgrimage brings millions of Muslims into a densely crowded, high-mobility setting, creating a substantial burden for public health systems globally (Alandijany, 2024). Older adults returning from Hajj face particularly elevated risks of respiratory complications, including community-acquired pneumonia, which may precipitate significant oxygen desaturation. Recent Indonesian data show that among elderly pilgrims aged 60 and over, the prevalence of pneumonia in the 2023 season reached 37.1 %, with chronic obstructive pulmonary disease identified as a

major risk factor (Fitrianti *et al.*, 2025). Mass-gathering conditions such as crowding, shared accommodation, extensive travel, and extreme climate contribute to the high transmission of airborne pathogens during Hajj (Mahdi *et al.*, 2023). Viral respiratory infections remain a major concern in the post-Hajj period, with surveillance studies during recent seasons documenting diverse viral agents and the need for continuous monitoring (Alandijany, 2024).

Advanced age is accompanied by progressive immunosenescence, a coordinated decline in innate and adaptive immune functions that reduces pathogen clearance and increases susceptibility to lower respiratory tract infections (Liu *et al.*, 2023). Age-related immune alterations include thymic involution, reduced naive T-cell output, impaired neutrophil chemotaxis and phagocytosis, and a chronic low-grade pro-inflammatory state (“inflammaging”), all of which accelerate pulmonary injury and compromise gas-exchange when infections occur (Goyani, Christodoulou and Vassiliou, 2024). Concurrently, dehydration and environmental heat stress conditions frequently encountered during Hajj perturb cardiorespiratory physiology by increasing metabolic rate and ventilatory demand, reducing circulating plasma volume, and impairing pulmonary perfusion, thereby raising the risk of ventilation–perfusion mismatch and arterial oxygen desaturation in vulnerable individuals (Périard, Eijsvogels and Daanen, 2021). Experimental and clinical studies additionally show that heat exposure independently degrades dynamic oxygen delivery and aerobic capacity, findings that plausibly link pilgrimage-related heat and exertion to faster development of hypoxaemia during lower respiratory tract infection (Geng *et al.*, 2023). While there is limited direct data linking heat stress to desaturation in Hajj pilgrims, studies of mass gatherings indicate that environmental stressors intensify respiratory disease risk (Narimani, Nouri and Khoshmirsafa, 2025).

On returning from Hajj, pilgrims with underlying comorbidities (such as diabetes, cardiovascular disease or chronic lung disease) are more likely to develop serious outcomes including hypoxemia, and oxygen saturation decline serves not only as a marker of severity but also as a prognostic indicator (Mahomed, Jaffer and Parker, 2024). Considering the interplay of host vulnerability (older age, comorbidity, immunosenescence) with pathogen exposure (viral, bacterial) and environmental stressors (crowding, heat, travel fatigue), a systems-oriented analysis is required to identify risk determinants for post-Hajj oxygen desaturation (Noviari and Santi, 2025). The objective of this study therefore is to explore the multifactorial risk factors for oxygen desaturation among elderly pilgrims with pneumonia following the Hajj, and to inform strategies for screening, monitoring and preventive intervention (Lee and Yoon, 2024).

MATERIALS AND METHODS

Recognizing the complex interaction between physiological aging, environmental stress, and infectious exposure during the Hajj, this study employed a descriptive case study framework to investigate episodes of post-pilgrimage oxygen desaturation among elderly Indonesian pilgrims returning through the Surabaya Debarkation in 2025.

This report employed a descriptive case study design focusing on post-Hajj pilgrims presenting with oxygen desaturation upon arrival at the Surabaya debarkation site in 2025. Clinical data were collected from official post-arrival medical records and structured interviews with attending physicians.

Two elderly female pilgrims were purposively selected based on documented oxygen desaturation ($\text{SpO}_2 < 94\%$ on room air) following the completion of the Hajj pilgrimage. Data were analyzed using a descriptive qualitative approach. Clinical findings, environmental exposures, and comorbidity profiles were compared narratively to identify shared and distinct determinants of post-Hajj oxygen desaturation.

CASE DESCRIPTION

Case I

An 88-year-old Indonesian female pilgrim (Ny. M) from Malang, East Java, returned from the 2025 Hajj with a clinical presentation of acute respiratory compromise on arrival at Debarkasi Surabaya. Initial examination revealed SpO_2 88% on room air, tachypnoea (28 breaths min^{-1}), and fine bilateral crackles. The patient had a history of community-acquired pneumonia treated at King Abdul Aziz Hospital, Mecca, where she received intravenous ceftriaxone and supportive oxygen therapy. On assessment, she reported exertional dyspnoea, low-grade fever (37.8°C), and fatigue, without chest pain or productive cough. Physical examination showed decreased vesicular breath sounds bilaterally, consistent with residual lower-respiratory infection. The patient had well-controlled hypertension managed with amlodipine 5 mg daily but no history of chronic pulmonary or cardiac disease. Laboratory and imaging data from the referring hospital supported a diagnosis of community-acquired pneumonia with post-infective hypoxaemia. Oxygen therapy via nasal cannula (2–3 L min^{-1}), nebulized bronchodilator, and empirical ciprofloxacin were administered. Nutritional support and semi-Fowler positioning were recommended to improve ventilation–perfusion matching. Following initial stabilization, the patient was referred for further evaluation and chest radiography at her local hospital.

Case II

A 75-year-old female Hajj pilgrim (Ny. R) from Tulungagung, East Java, arrived in Surabaya via Saudia Airlines flight SV-5704 as part of the second pilgrimage cohort. On disembarkation, she appeared clinically stable and was transferred to the Debarkasi Hajj Health Post for screening. Upon arrival at the reception hall, the medical team noted signs of respiratory distress with an oxygen saturation of 84% on room air, respiratory rate 30/min, and bilateral fine crackles on auscultation. The patient denied any history of chronic respiratory or cardiac disease, diabetes, or hypertension. There was no significant family history of pulmonary or cardiovascular illness.

At the Balai Besar Kekarantinaan Kesehatan (BBKK) polyclinic, she was administered supplemental oxygen via nasal cannula (2–3 L/min), nebulized with farbivent 1 ampoule, and received intravenous fluids (Ringer's lactate 20 tpm) and paracetamol 1 g. Physical examination

revealed a body temperature of 37.5°C, pulse 110/min, blood pressure 128/78 mmHg, and warm, well-perfused extremities. Chest auscultation confirmed bilateral rhonchi with diminished vesicular breath sounds at the lower lung fields. The patient was diagnosed with community-acquired pneumonia complicated by hypoxemia. She was subsequently referred to her local hospital for radiologic evaluation and further management.

The case illustrates post-Hajj desaturation secondary to acute lower respiratory infection in an elderly pilgrim without prior comorbidity, suggesting the combined effect of environmental exposure, travel-induced fatigue, and impaired mucociliary clearance contributing to pulmonary compromise.

RESULT AND DISCUSSION

The occurrence of oxygen desaturation observed in returning elderly Hajj pilgrims underscore how ageing, infection and extreme environmental exposures converge to overwhelm physiological respiratory reserve. Advanced age brings immunosenescence, including thymic involution, reduced naive T-cell output, diminished neutrophil function, and a state of chronic low-grade inflammation that markedly increases vulnerability to respiratory infection in older individuals. (Liu *et al.*, 2023). Older adults also manifest structural and functional pulmonary changes: decreased elastic recoil, impaired mucociliary clearance and reduced inspiratory and expiratory muscle strength, which lower the margin for gas-exchange compensation when challenged by infection or hypoxia (Wrona *et al.*, 2024).

In both cases discussed, prior or concurrent lower respiratory tract infections played a pivotal role as a proximal agent of alveolar damage and ventilation–perfusion mismatch, thereby precipitating hypoxaemia despite treatment. The inflammatory exudate within alveolar spaces, along with airway obstruction and loss of functional lung units, increases physiological shunt and reduces effective diffusion surface area (Murdaca *et al.*, 2023). In older subjects, the capacity to restore gas-exchange homeostasis is compromised by decreased pulmonary reserve and impaired immune-mediated resolution of inflammation, accelerating progression to oxygen desaturation (Alfano *et al.*, 2024).

Environmental and travel-related stressors further amplify the risk of desaturation in this context. Older adults exhibit markedly reduced thermoregulatory and cardiovascular compensation when exposed to heat stress: sweating and skin vasodilation responses are blunted, autonomic adjustments are impaired, and the threshold for uncompensable heat stress is lower compared with younger individuals (Tony Wolf *et al.*, 2023). In mass-gathering environments such as the Hajj pilgrimage, characterized by prolonged air travel, high ambient temperatures, dense crowding and sustained physical exertion or immobility, the cumulative burden of heat stress, dehydration and increased respiratory demand may precipitate or exacerbate hypoxaemia (Tony Wolf *et al.*, 2023). Epidemiological evidence furthermore indicates that older adults are disproportionately affected by respiratory morbidity and hospitalisation during episodes of extreme heat, reinforcing the vulnerability of ageing populations under environmental stress (Fastl *et al.*, 2024).

In the specific context of elderly Hajj pilgrims, multiple mechanisms likely interact synergistically to precipitate oxygen desaturation: age-related declines in immunological and pulmonary reserve mean older individuals have a diminished capacity to compensate for acute insults structural changes in the ageing lung further reduce ventilatory and diffusive reserve (Quiros-Roldan *et al.*, 2024). Infection imposes an acute burden on gas-exchange by causing alveolar inflammation, increased shunt, and ventilation–perfusion mismatch, which older hosts tolerate less effectively and which accelerate hypoxaemia (Putot *et al.*, 2025). Environmental extremes including high ambient temperature, humidity, crowding and travel fatigue, further impair effective oxygen delivery and perfusion by inducing dehydration, increasing metabolic oxygen demand and reducing cardiovascular and thermoregulatory reserve (Tony Wolf *et al.*, 2023). The net result in such a triple-hit scenario is oxygen desaturation that may manifest rapidly, even in the absence of classic comorbidities. Importantly, this multifactorial model implies prevention must be equally multi-pronged: pre-departure screening should stratify by age, baseline pulmonary status and nutrition; in-flight and post-arrival protocols should include early pulse-oximetry, hydration and heat-exposure mitigation; and return-debrief health services should integrate serial oxygen-saturation monitoring and early intervention for respiratory symptoms. While our small case series is descriptive and limited in scope, the broader literature supports these targeted strategies for older adults in pilgrimage or mass-gathering settings and argues for prospective cohort studies to quantify relative risk contributions and develop predictive models of post-mass-gathering desaturation risk in ageing populations (Ndlovu and Chungag, 2024).

CONCLUSION

Post-Hajj oxygen desaturation in elderly pilgrims represents a multifactorial clinical phenomenon arising from the convergence of physiological ageing, infectious disease burden, and environmental stress. Advanced age and the accompanying immunosenescence markedly impair pulmonary defense mechanisms and reduce compensatory capacity during acute infections. Lower respiratory tract infections such as pneumonia remain the most prominent proximate cause of hypoxaemia, while environmental challenges including prolonged air travel, dehydration, and exposure to extreme heat, further exacerbate respiratory compromise. The cumulative interaction of these factors results in rapid and sometimes severe desaturation even among individuals without chronic comorbidities. Effective prevention therefore requires an integrated, systems-based strategy encompassing pre-departure risk stratification, vigilant in-flight and post-arrival monitoring using pulse oximetry, and early clinical intervention for respiratory symptoms. Comprehensive health education, hydration management, and thermal protection measures should be prioritized within Hajj health protocols to mitigate morbidity among older pilgrims. Future studies should employ longitudinal and predictive modeling approaches to better quantify desaturation risk and guide evidence-based interventions tailored for ageing populations participating in mass gatherings such as the Hajj.

ACKNOWLEDGEMENT

The author gratefully acknowledges Dr. Tias Pramesti Griana, M.Biomed for her invaluable guidance, constructive feedback, and supervision throughout the completion of this study. Sincere

appreciation is also extended to the Maulana Malik Ibrahim Islamic State University of Malang, for providing academic support and research facilities, as well as to the Balai Besar Kekejarantinaan Kesehatan Surabaya for granting access to clinical data and assisting in field coordination. This research received no specific grant or financial support from any funding agency in the public, commercial, or not-for-profit sectors.

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