



Acute Pulmonary Hemorrhage: Multidisciplinary Perspectives in Respiratory, Anesthesia, and Emergency Care

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Abstract

Background: Pulmonary hemorrhage is a life-threatening condition characterized by bleeding from the lower respiratory tract, most often presenting as hemoptysis. Its severity ranges from minor, self-limited episodes to massive hemorrhage causing airway obstruction, respiratory failure, and hemodynamic collapse. The bronchial arterial circulation accounts for the majority of clinically significant cases, and etiologies vary globally, including tuberculosis, bronchiectasis, malignancy, and infectious or inflammatory lung diseases.

Aim: This review aims to provide a multidisciplinary overview of the etiology, epidemiology, pathophysiology, evaluation, and management of pulmonary hemorrhage, emphasizing contemporary evidence-based clinical practices.

Methods: The manuscript synthesizes findings from major cohort studies, prospective analyses, and current clinical guidelines. It integrates data on causes, regional variations, diagnostic strategies, interventional options, and outcomes to present a comprehensive overview for respiratory, anesthesia, and emergency care teams.

Results: Evidence shows that massive hemoptysis comprises a small proportion of total cases but carries high mortality if not promptly managed. CT imaging provides superior diagnostic accuracy compared to chest radiography and often surpasses bronchoscopy for localization. Modern bronchial artery embolization achieves initial hemostasis in up to 90% of patients, though rebleeding occurs in approximately 30%. Airway stabilization, bronchoscopic interventions, anticoagulation reversal, and adjunctive therapies such as tranexamic acid are effective components of acute management.

Conclusion: Pulmonary hemorrhage requires rapid diagnosis, airway protection, multidisciplinary coordination, and timely interventional therapy. Advances in imaging, bronchoscopy, and embolization have significantly reduced mortality, but recurrence and complications remain substantial concerns.

Keywords: Pulmonary hemorrhage, hemoptysis, bronchial artery embolization, bronchoscopy, airway management, emergency care

Introduction

Pulmonary hemorrhage represents a severe and potentially fatal condition within respiratory and emergency medicine, characterized by bleeding originating from the lower respiratory tract and commonly presenting as hemoptysis. Hemoptysis is defined as the expectoration of blood, either pure or mixed with sputum, arising from airways distal to the vocal cords. It is associated with a broad range of

pulmonary and systemic disorders, including bronchiectasis, primary and metastatic lung tumors, pulmonary tuberculosis, aspergilloma, and cystic fibrosis. The clinical presentation varies substantially, from minor self-limited bleeding to massive hemorrhage that threatens airway patency and cardiovascular stability, with death resulting from asphyxiation or hypovolemic shock in severe cases [1]. The underlying pathophysiology of pulmonary

hemorrhage most frequently involves disruption of the pulmonary or bronchial vasculature. In the majority of cases, bleeding originates from the bronchial arterial system, which operates under systemic pressure and is therefore more prone to high-volume hemorrhage compared to the low-pressure pulmonary circulation [2]. Historically, pulmonary hemorrhage was classified according to the estimated volume of blood expectorated, a method that is inherently unreliable due to inaccuracies in patient reporting and difficulty in objective measurement [2]. Contemporary clinical practice increasingly favors classification based on the magnitude of bleeding and its physiological impact, such as airway compromise, respiratory failure, or hemodynamic instability, as this approach more directly informs urgent management decisions [2].

Pulmonary hemorrhage is associated with significant morbidity and mortality, particularly when not promptly recognized and managed. Prior to the widespread adoption of bronchial artery embolization, mortality rates approached 70% in cases of massive hemoptysis [2]. Although advances in interventional radiology and critical care have improved outcomes, pulmonary hemorrhage remains a medical emergency requiring rapid, coordinated intervention. Immediate priorities include airway protection, maintenance of adequate oxygenation and ventilation, and circulatory stabilization. Concurrently, clinicians must initiate diagnostic evaluation to localize the source of bleeding through imaging and endoscopic techniques, enabling definitive therapeutic intervention [2][3]. Given its acute onset, complex etiology, and high risk of rapid deterioration, pulmonary hemorrhage demands a multidisciplinary approach involving respiratory physicians, anesthesiologists, emergency clinicians, and interventional specialists. Early recognition and structured management are essential to reduce mortality and prevent irreversible complications.

Etiology

Pulmonary hemorrhage most commonly originates from the bronchial vasculature, a high pressure arterial system that accounts for the majority of clinically significant bleeding episodes. This system is responsible for up to 90% of cases of massive hemoptysis, reflecting both its systemic pressure and its tendency to undergo hypertrophy and neovascularization in chronic inflammatory lung diseases [2]. In contrast, bleeding from the pulmonary arterial circulation, which operates under lower pressure, accounts for a much smaller proportion of cases, estimated at approximately 5%. Additional uncommon but clinically important sources include aortobronchial fistulas, ruptured thoracic aneurysms, and other nonbronchial systemic vessels, which together contribute to a minority of presentations but are associated with particularly high mortality due to sudden and uncontrollable bleeding. The underlying etiologies of massive pulmonary hemorrhage vary according to geographic region, disease prevalence,

and population characteristics. A large retrospective cohort study conducted at a tertiary care center in France involving 1087 patients identified tuberculosis as the single most common cause, accounting for 25% of cases. Within this group, active tuberculosis was responsible for 12% of cases, while post-tuberculous sequelae such as cavitation and bronchial artery hypertrophy accounted for 13%. Bronchiectasis was the second most frequent cause at 20%, reflecting chronic airway inflammation and vascular remodeling. Cryptogenic hemoptysis, in which no definitive cause is identified despite thorough evaluation, represented 18% of cases. Bronchogenic carcinomas accounted for 17%, underscoring the importance of malignancy as a major etiology in adults. Mycetomas, particularly aspergillomas within pre-existing lung cavities, contributed to 6% of cases, while trauma and iatrogenic causes represented additional less common sources [4][1].

More recent prospective data from an Italian multicenter study of 606 patients demonstrated a shift in etiologic patterns. In this cohort, lung cancer emerged as the most common cause at 19.1%, followed closely by pneumonia and lung abscesses at 18.6%. Bronchiectasis remained a significant contributor at 14.9%, while acute bronchitis accounted for 13.7%. Tuberculosis was less prevalent in this population, responsible for only 5% of cases, with active disease accounting for 3.3% and post-infectious sequelae for 1.7% [5]. These findings highlight the influence of regional disease burden and public health control measures on the etiologic spectrum of pulmonary hemorrhage. Supporting these observations, a Greek study focusing on moderate-to-severe pulmonary hemorrhage identified bronchiectasis and pulmonary neoplasms as the leading causes, reinforcing the central role of chronic structural lung disease and malignancy in the pathogenesis of clinically significant bleeding [6]. Collectively, these studies emphasize that pulmonary hemorrhage is a heterogeneous condition with multifactorial etiologies, necessitating individualized diagnostic evaluation based on clinical context, epidemiology, and risk factors.

Epidemiology

Hemoptysis, defined as the expectoration of blood originating from the lower respiratory tract, represents a clinical manifestation with highly variable epidemiological characteristics that depend on underlying disease patterns, population demographics, and regional health determinants. As a symptom rather than an independent disease entity, hemoptysis reflects a wide range of pulmonary and systemic disorders, most commonly respiratory infections, chronic inflammatory lung diseases, and thoracic malignancies. In the majority of cases, hemoptysis is mild and self-limited, typically involving small volumes of blood, often less than 100 mL over a 24-hour period, and is frequently associated with infectious or inflammatory processes affecting the

airways. Massive hemoptysis, although relatively uncommon, constitutes a medical emergency due to its association with significant morbidity and mortality. Epidemiological data suggest that massive hemoptysis accounts for approximately 5% to 15% of all hemoptysis cases. Despite its low frequency, it carries a disproportionate risk of adverse outcomes, primarily due to airway obstruction, hypoxemia, and hemodynamic compromise. One of the challenges in epidemiological reporting is the lack of a universally accepted definition for massive hemoptysis. Earlier descriptions in the literature have defined it based on estimated blood volume loss, with thresholds ranging from greater than 200 mL to more than 1000 mL within 24 hours [7]. More recent approaches emphasize the clinical impact of bleeding, particularly its effect on gas exchange and airway patency, rather than strict volumetric measurements.

The incidence and prevalence of hemoptysis vary significantly across geographic regions, largely reflecting differences in disease prevalence and healthcare infrastructure. In regions with a high burden of tuberculosis, hemoptysis remains a common presenting symptom, particularly among younger adults with active infection or residual structural lung disease following treatment. In contrast, in high-income countries, where tuberculosis is less prevalent, chronic bronchitis, bronchiectasis, and lung malignancies constitute the predominant causes. This geographic variability contributes to a bimodal age distribution, with younger patients more frequently affected by infectious etiologies and older patients more commonly presenting with hemoptysis secondary to neoplastic disease. Sex and smoking history also play important roles in the epidemiology of hemoptysis. Multiple studies have demonstrated a male predominance, which is often attributed to higher rates of smoking and occupational exposures among men. A single-center French study reported a median patient age of 54 years, with men accounting for 71% of cases and a smoking history present in 71% of patients. Similarly, the study by Mondoni et al documented a higher median age of 67 years, with 66.7% of patients being male and 54% reporting a history of smoking [5]. These findings underscore the strong association between hemoptysis, advancing age, male sex, and tobacco exposure. Overall, the epidemiology of hemoptysis reflects complex interactions between demographic factors, environmental exposures, and regional disease patterns, highlighting the need for context-specific diagnostic and management strategies.

Pathophysiology

Pulmonary hemorrhage arises from disruption or injury to the pulmonary or bronchial vasculature, leading to bleeding into the airways. The underlying mechanisms vary according to etiology and involve both structural and inflammatory processes affecting the bronchial and pulmonary vessels. In tuberculosis, hemoptysis can result from

active infection with ulceration and necrosis of the bronchial wall, causing direct vessel injury [8]. In patients with prior TB, residual structural changes, including calcified lymph nodes, bronchiectasis, or cavity formation, can predispose to erosion into adjacent vessels or the airway, occasionally involving a Rasmussen aneurysm arising from the pulmonary artery circulation [9][10]. Chronic vascular remodeling and localized inflammation create tortuous, fragile vessels, increasing susceptibility to rupture. In bronchiectasis, repeated inflammation and infection lead to hypertrophy of bronchial arteries and expansion of peribronchial and submucosal vascular networks. These abnormal vessels are prone to rupture under increased hemodynamic stress, contributing to recurrent or massive hemoptysis. Mycetomas, most commonly caused by *Aspergillus fumigatus*, induce localized vascular injury and parenchymal changes within pre-existing cavities, further predisposing to vascular erosion and hemorrhage [8]. In cryptogenic cases, particularly in patients with a history of smoking, diffuse microvascular injury and chronic inflammation are believed to play a primary role in spontaneous bleeding [11][12]. Carcinomas, especially centrally located squamous cell carcinomas, can either serve as direct sources of bleeding due to inherent tumor vascularity or induce vascular erosion into adjacent bronchial or pulmonary vessels [2].

In infectious etiologies such as pneumonia and *Staphylococcus aureus*, including strains producing Panton-Valentine Leukocidin (PVL) toxin, can cause pulmonary hemorrhage. PVL toxin enhances virulence by binding to G protein-coupled receptors on endothelial cells, promoting neutrophil adhesion, capillary dilation, leukocyte migration, and vascular necrosis [13]. This sequence of events disrupts vessel integrity and facilitates hemorrhage, particularly in severe or necrotizing infections. Overall, the pathophysiology of pulmonary hemorrhage reflects a combination of vascular fragility, inflammatory injury, structural lung alterations, and direct tissue invasion, with specific mechanisms varying according to the underlying disease. The resultant bleeding may be intermittent or massive, depending on the vascular source, hemodynamic pressures, and extent of tissue involvement.

History and Physical

Accurate differentiation between pulmonary and gastrointestinal sources of bleeding is a critical initial step in evaluating hemoptysis. Patients should be asked whether the blood is expectorated with cough or associated with emesis, as this can help distinguish pulmonary from gastric bleeding. A detailed history should document the onset, volume, and frequency of bleeding, along with systemic symptoms such as fever, night sweats, weight loss, and signs of infection. Past medical history is essential, including prior tuberculosis exposure or travel to endemic regions, chronic lung disease, malignancy, smoking history,

and use of anticoagulant or antiplatelet medications. Functional status and exercise tolerance, such as the ability to climb stairs or walk significant distances, are particularly relevant when assessing suitability for surgical interventions like lobectomy [14]. The physical examination should follow a structured approach beginning with airway, breathing, and circulation assessment. Evaluation of airway patency and inspection of the oropharynx helps exclude proximal sources of bleeding. Vital signs, capillary refill, and skin perfusion provide early indicators of hemodynamic instability and the potential need for emergent blood transfusion. Pulmonary examination should focus on breath sounds, wheezing presence, crackles, or asymmetric findings that may localize the source of bleeding to one lung. Peripheral oxygen saturation and breathing work help gauge severity. Quantifying blood loss in hemoptysis is challenging, with estimates ranging from 100 to 200 mL for significant bleeding. Given that adult anatomical dead space approximately 200 mL, even moderate hemoptysis can result in hypoxia and respiratory distress. Clinical indicators—tachypnea, hypoxia, hemodynamic compromise—should guide immediate resuscitation and stabilization rather than attempting precise measurement of expectorated blood. The combination of thorough history and systematic examination informs the urgency of intervention and the selection of definitive diagnostic or therapeutic procedures.

Evaluation

The initial evaluation of a patient with pulmonary hemorrhage requires both laboratory and imaging studies to guide diagnosis and management. Laboratory assessment should include a complete blood count with differential to evaluate hemoglobin and hematocrit levels and detect any thrombocytopenia. A basic metabolic panel is indicated to assess renal function and electrolyte status. Blood type and crossmatch should be prepared in anticipation of potential transfusions, while arterial blood gas analysis provides information on oxygenation, ventilation, and acid-base balance. A coagulation panel is essential to identify coagulopathies that may exacerbate bleeding or influence management decisions [15]. Imaging plays a central role in localizing the source of bleeding. A frontal chest radiograph should be obtained early, as it can identify a unilateral source in approximately 45% to 65% of patients and suggest the etiology in 25% to 35% of cases. Radiographs may demonstrate localized consolidation, cavitation, mass lesions, or signs of chronic lung disease, all of which help narrow the differential diagnosis. For stable patients, computed tomography (CT) of the chest is often considered a more sensitive modality than bronchoscopy, providing high-resolution detail of the airways, parenchyma, and vasculature. CT can better delineate the source and underlying cause, including tumors, bronchiectasis, or vascular anomalies, and may identify lesions not

apparent on plain radiographs. Some guidelines recommend CT as the first-line diagnostic imaging for hemoptysis when patient stability allows [16][17][18][19][20]. Together, laboratory evaluation and imaging provide the foundation for risk stratification, determine the urgency of intervention, and guide subsequent procedures such as bronchoscopy or bronchial artery embolization. This systematic approach ensures that management decisions are evidence-based and targeted to the underlying etiology.

Treatment / Management

Management of pulmonary hemorrhage requires a systematic, multidisciplinary approach aimed at rapid stabilization, airway protection, hemostasis, and definitive control of bleeding. Initial strategies focus on lung isolation, airway management, and resuscitation, progressing to interventional and surgical procedures depending on the severity and source of bleeding. If the source of bleeding is unilateral or localized based on radiographic or clinical assessment, positioning the affected lung down can help isolate the hemorrhage and protect the contralateral lung [15][21]. Additional maneuvers, such as Trendelenburg or reverse Trendelenburg positioning, may enhance isolation, reduce contamination and optimize ventilation. Proper positioning is especially critical in massive hemoptysis, as aspiration of blood into the unaffected lung is associated with rapid respiratory compromise and hypoxia. Endotracheal intubation is indicated for airway protection in patients with significant hemorrhage, respiratory distress, or inability to maintain oxygenation. An 8 mm or larger ETT is preferred to allow subsequent bronchoscopy and bronchial blocker placement. Direct laryngoscopy is often favored over video laryngoscopy to optimize visualization when bleeding obscures the airway. Meconium aspirators attached to the ETT may facilitate clearance of blood, while right mainstem intubation can isolate the affected lung if bleeding is uncontrolled. In cases of left-sided bleeding without bronchoscopic support, right-lateral decubitus positioning may aid in mediastinal shift and lung protection. Cadaver studies have demonstrated that rotational ETT techniques can selectively ventilate the desired lung, achieving success rates up to 94% for right-sided intubation [22]. Suction-assisted laryngoscopy and double suction techniques (SALAD) are valuable for managing a soiled airway during emergency intubation [23].

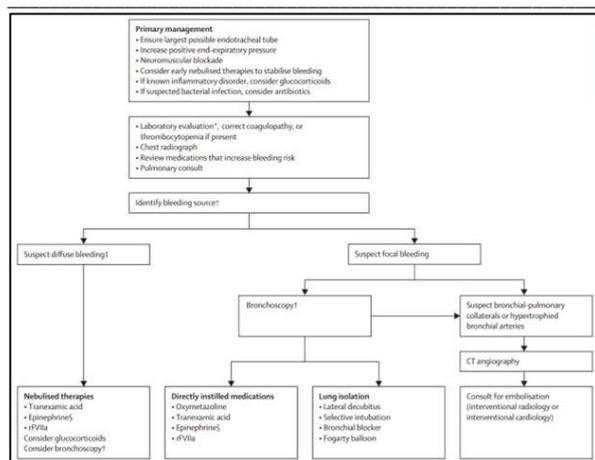


Fig. 1: Management of Acute pulmonary hemorrhage.

Patients on anticoagulants require prompt reversal to achieve hemostasis. Specific reversal agents should be administered according to the type of anticoagulant, whether vitamin K antagonists, direct oral anticoagulants, or heparin derivatives. Timely reversal is critical to prevent ongoing hemorrhage and reduce morbidity. Tranexamic acid (TXA) has been utilized as an adjunctive therapy in pulmonary hemorrhage, extrapolating from successful use in trauma (CRASH-2) and postpartum hemorrhage (WOMAN trial). Both intravenous and nebulized formulations have demonstrated efficacy in small case series and randomized trials. One trial showed 96% resolution of hemoptysis within five days using inhaled TXA 500 mg three times daily, compared with 50% in the placebo group [24]. Patients with massive hemoptysis or hemodynamic instability were excluded, limiting generalizability, but TXA offers a low-risk adjunct in selected cases. Double-lumen ETTs are generally not recommended in acute massive hemoptysis due to limitations in suction capacity, difficulty in placement, inability to perform therapeutic bronchoscopy, and lack of proximal airway evaluation [14]. Placement is technically demanding, time-consuming, and may not be feasible during emergent scenarios. Bronchoscopy plays a central role in diagnosis and management. Fiberoptic bronchoscopy allows visualization of the bleeding source, clearance of clots, and potential placement of bronchial blockers. It can facilitate intubation of the nonbleeding lung and temporary tamponade of the hemorrhagic site. Rigid bronchoscopy is particularly advantageous when simultaneous airway evaluation, suctioning, and therapeutic intervention are required. Its larger channels accommodate suction catheters and therapeutic instruments for intrabronchial interventions.

Bronchial blockers enable selective lung isolation, allowing ventilation of the unaffected lung while tamponading the bleeding bronchus. They are typically inserted under fiberoptic guidance through an ETT, with the cuffed catheter positioned in the mainstem or intermediate bronchus. Temporary

hemostasis is achieved, providing a bridge to definitive therapy [25]. When commercial devices are unavailable, Fogarty catheters can serve a similar purpose. Local measures can assist in controlling bleeding through a bronchoscope, including cold saline lavage, epinephrine injection, spigots, cellulose mesh, and antidiuretic hormone derivatives. If the source is accessible, electrocautery, cryotherapy, laser, or argon plasma coagulation may achieve definitive hemostasis [14]. Bronchial artery embolization (BAE) is the first-line definitive treatment for massive pulmonary hemorrhage arising from the bronchial circulation, responsible for approximately 90% of cases. Embolization is guided by radiographic findings, including tortuous, hypertrophied vessels, aneurysms, or arteriovenous malformations, as active extravasation is only seen in 10%–15% of patients [26][27][29]. Success rates for initial embolization reach 90%, though rebleeding occurs in about 30% within 30 days. Embolization materials include microspheres, gelatin sponges, or coils, and advances have reduced the risk of anterior spinal artery injury to less than 1% [15].

Surgical resection is reserved for cases in which embolization is unsuccessful or unsuitable, given the higher associated mortality rates. Emergent resections carry a mortality rate of up to 35%, whereas elective resections after hemostasis have a mortality of 4% or lower, and planned resections after discharge may approach 0% [30]. Whenever possible, achieving temporary hemostasis with airway management, bronchoscopy, or BAE allows stabilization and optimization before definitive surgery, reducing operative risk. Management of pulmonary hemorrhage requires rapid recognition, airway protection, and stabilization. Lung isolation, intubation strategies, anticoagulation reversal, and adjunctive TXA use provide initial control. Bronchoscopy, bronchial blockers, intrabronchial interventions, and BAE allow temporizing and definitive hemostasis. Surgery remains a last-resort option reserved for patients who fail less invasive measures. Multidisciplinary coordination among emergency medicine, pulmonology, interventional radiology, anesthesia, and critical care is essential to optimize outcomes, minimize morbidity, and improve survival in this high-risk population. Each intervention should be tailored to the patient's hemodynamic status, source of bleeding, and underlying etiology, ensuring that both acute and long-term management are addressed comprehensively. This integrated approach prioritizes stabilization, rapid source control, and minimization of complications, reflecting contemporary evidence and clinical best practices in the management of massive pulmonary hemorrhage [15].

Differential Diagnosis

Pulmonary hemorrhage presents with hemoptysis, which may arise from multiple underlying pathologies. Accurate differential diagnosis is essential to guide timely intervention and

prevent morbidity and mortality. Aspergilloma, or fungal ball formation within preexisting lung cavities, is a common source of recurrent or massive hemoptysis, typically associated with prior tuberculosis or chronic lung disease. Alveolar hemorrhage syndromes, including idiopathic pulmonary hemosiderosis, vasculitides such as granulomatosis with polyangiitis, and systemic autoimmune disorders, can cause diffuse bleeding with bilateral radiographic findings. Pulmonary arteriovenous malformations are congenital or acquired vascular anomalies that may rupture spontaneously, resulting in hemoptysis. Infectious causes such as acute bronchitis, pneumonia, or lung abscesses can produce localized inflammation and erosion of vasculature. Bronchiectasis, often secondary to chronic infections or cystic fibrosis, causes hypertrophied bronchial arteries prone to rupture. Coagulopathies, whether congenital (e.g., hemophilia) or acquired (e.g., anticoagulant therapy), increase bleeding risk even with minor insults. Pulmonary embolism may lead to infarction and hemorrhage, particularly when anticoagulation is withheld. Cardiac causes, such as mitral stenosis, can result in elevated pulmonary venous pressures and hemoptysis. Tuberculosis remains a major etiology globally, especially in endemic regions, causing cavity formation and vascular erosion. Finally, primary or metastatic tumors can directly invade vasculature or erode adjacent structures, producing hemorrhage. A systematic evaluation of clinical history, imaging, and laboratory findings is essential to differentiate these causes and tailor management appropriately [14][15].

Prognosis

The prognosis of pulmonary hemorrhage is highly dependent on etiology, severity, and timeliness of intervention. For mild to moderate hemoptysis, prognosis is generally favorable, especially when underlying causes such as bronchiectasis, tuberculosis, or fungal infections are appropriately treated. Early intervention can prevent progression to life-threatening hemorrhage, and many patients recover without long-term sequelae. Massive hemoptysis, defined variably in the literature but often exceeding 200–600 mL in 24 hours, carries a high risk of mortality. Historically, mortality rates reached 70% before advanced interventions such as bronchial artery embolization (BAE). Modern interventional techniques have improved survival significantly, with BAE achieving immediate hemostasis in up to 90% of cases. However, rebleeding remains a concern, occurring in approximately 30% of patients within 30 days, particularly in those with underlying structural lung disease or malignancy. Prognosis is also influenced by patient comorbidities, including cardiovascular disease, chronic lung disease, and coagulation abnormalities, as well as the availability of interprofessional care. Optimal outcomes are achieved through rapid recognition, airway protection, resuscitation, and definitive hemostatic interventions.

Continuous monitoring, follow-up imaging, and patient education on symptom recognition are essential to reduce recurrence and improve long-term survival. Comprehensive care through an interprofessional team ensures early intervention, appropriate resource allocation, and enhanced patient outcomes.

Complications

Pulmonary hemorrhage is associated with a range of complications that can significantly impact morbidity and mortality. Respiratory failure is the most immediate and severe complication, arising from airway obstruction by blood, leading to hypoxia, hypercapnia, and, in severe cases, acute respiratory distress syndrome. Hemodynamic instability is common in massive hemorrhage, as acute blood loss can precipitate hypovolemic shock requiring rapid fluid resuscitation and blood product transfusion. Infection represents a secondary complication; retained blood within airways provides a medium for bacterial growth, increasing the risk of pneumonia, particularly in patients requiring prolonged mechanical ventilation. Rebleeding is a frequent concern, often related to underlying vascular abnormalities such as bronchiectasis or arteriovenous malformations. Airway interventions, including intubation and bronchoscopy, carry risks such as mucosal injury, bronchospasm, and airway trauma; improper positioning of endotracheal tubes or bronchial blockers can exacerbate bleeding. Interventional procedures like bronchial artery embolization, though generally safe, carry rare but serious risks, including non-target embolization leading to spinal cord ischemia. Cardiovascular complications may occur due to increased pulmonary vascular resistance, potentially causing right ventricular strain or failure. Neurological sequelae, including hypoxic brain injury, may result from prolonged hypoxemia during massive hemorrhage. Mortality remains significant in massive hemoptysis, with rates around 38%, particularly in patients with malignancy or coagulopathy, emphasizing the need for a coordinated multidisciplinary approach to reduce adverse outcomes [31].

Patient Education

Prevention and patient education are critical components in managing pulmonary hemorrhage, particularly for high-risk populations. Proactive strategies include rigorous monitoring and management of chronic respiratory conditions such as bronchiectasis, cystic fibrosis, chronic bronchitis, and tuberculosis to reduce the risk of hemorrhagic episodes. Smoking cessation is a fundamental preventative measure, as tobacco use is associated with increased vascular fragility and pulmonary pathology. Vaccination against respiratory infections, including influenza and pneumococcus, can mitigate infection-related hemoptysis. Patients with known risk factors should be educated on early recognition of symptoms, including minor hemoptysis, and

instructed to seek immediate medical care to prevent progression. Education also involves informing patients about the importance of adherence to prescribed treatments for underlying conditions, the necessity of follow-up appointments, and strategies to minimize additional risk, such as avoiding anticoagulant misuse or exposure to respiratory irritants. Symptomatic reassurance is essential, as hemoptysis often causes anxiety for patients and caregivers. Guidance on airway safety, recognition of massive bleeding, and when to activate emergency services can significantly improve outcomes. Lifestyle modifications, including regular exercise, nutritional optimization, and avoidance of high-risk activities that may exacerbate pulmonary conditions, support overall lung health. Empowering patients through education ensures timely intervention, reduces the likelihood of severe episodes, and enhances quality of life [15].

Enhancing Healthcare Team Outcomes

Optimal management of pulmonary hemorrhage requires a multidisciplinary, coordinated approach to enhance patient outcomes, safety, and quality of care. Physicians, advanced practice providers, nurses, pharmacists, and ancillary staff must collaborate effectively, leveraging each team member's expertise. Clinicians are responsible for rapid assessment, decision-making, and initiation of stabilization, including airway protection and hemostatic interventions such as bronchial artery embolization. Nurses provide continuous bedside monitoring, administer medications, and assist with procedural preparation, ensuring patient safety and timely response to changes in condition. Pharmacists ensure appropriate selection, dosing, and availability of medications, including anticoagulant reversal agents, sedatives, and adjunctive therapies, while monitoring for potential drug interactions. Effective interprofessional communication and care coordination are essential; standardized protocols, checklists, and clear channels for rapid information sharing improve response efficiency. Utilization of electronic health records facilitates timely access to patient data across disciplines, ensuring continuity of care during handoffs. Regular team education, simulation exercises, and debriefing sessions support skill maintenance and crisis preparedness. A collaborative approach allows precise stratification of patient risk, timely intervention, and optimal allocation of resources. By fostering interprofessional collaboration, teams reduce complications, enhance patient safety, and improve outcomes in cases of pulmonary hemorrhage, ensuring both acute management and long-term care are addressed comprehensively.

Conclusion:

Pulmonary hemorrhage remains a critical emergency with significant morbidity and mortality, demanding rapid recognition and coordinated intervention. The article highlights that outcomes depend heavily on early stabilization—particularly

airway protection and prevention of aspiration into the unaffected lung. As most life-threatening cases arise from the bronchial circulation, prompt imaging with CT and early bronchoscopy are instrumental in identifying the bleeding source and facilitating targeted therapy. Modern bronchial artery embolization has transformed prognosis, offered high initial success rates and reduced the historical mortality associated with massive hemoptysis. Nevertheless, recurrence rates remain considerable, especially in patients with chronic lung disease, malignancy, or underlying structural abnormalities. Management also requires careful attention to reversible factors, such as anticoagulant use, hemodynamic instability, and infectious triggers. Adjunctive therapies—including inhaled or systemic tranexamic acid—provide additional options in selected patients. Despite advancements, the complexity of pulmonary hemorrhage necessitates collaboration among pulmonologists, emergency physicians, anesthesiologists, interventional radiologists, and critical care specialists. Long-term outcomes are optimized when acute management is coupled with treatment of underlying etiologies and patient education regarding symptom recognition and prevention. Ultimately, a systematic, evidence-driven approach is essential to improving survival, reducing complications, and ensuring comprehensive care for this high-risk condition.

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