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Research Advances on Multidisciplinary Team Collaboration Model for Prevention Ventilator-Associated Pneumonia in ECMO Patients

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Abstract: *Ventilator-associated pneumonia (VAP) is a common and severe complication among patients receiving extracorporeal membrane oxygenation (ECMO) support, increasing the mortality risk and healthcare costs. Traditional single-department management models are inadequate in addressing its complex risk factors. The multidisciplinary team (MDT) collaboration model integrates expertise from critical care medicine, respiratory therapy, nursing, pharmacy, infection control, and rehabilitation to establish a systematic and structured prevention and control system, and is recognized as a key strategy for improving patient outcomes. This article reviews the latest advancements in the application of multidisciplinary team collaboration for the prevention of ventilator-associated pneumonia (VAP) in ECMO patients, based on the epidemiological characteristics of VAP in this population. It analyzes the specific roles and collaborative logic of members from various disciplines within the team and outlines the application of multidisciplinary teams (MDTs) in VAP prevention. The aim is to provide standardized guidelines for clinical practice and to clarify the central role of nursing staff within the team.*

Keywords: *Multidisciplinary team collaboration; Extracorporeal membrane oxygenation; Ventilator-associated pneumonia; Literature review*

1. Introduction

With continuous advances in medical technology, extracorporeal membrane oxygenation (ECMO), as a specialized life-support technology, is playing an increasingly critical role in the treatment of critically ill patients. The rapid initiation and immediate cardiac support provided by ECMO have led to its widespread adoption in the emergency management of patients with severe cardiac conditions, such as cardiogenic shock, refractory arrhythmias, and cardiac dysfunction following myocardial infarction, thereby securing valuable time for resuscitation[1-2]. However, various serious complications may arise during ECMO use. Hospital-acquired infections are a common complication, with ventilator-associated pneumonia (VAP) being the most prevalent type[3]. Due to the absence of a unified diagnostic standard for VAP during ECMO treatment, along with regional and population variations, reported incidence rates vary significantly. Currently, the incidence of VAP during ECMO therapy averages 24.4 cases per 1,000 ECMO days, and patients with concurrent infections face a 38% to 63% increased risk of mortality[4]. Once VAP develops, it can result in prolonged hospital stays and mechanical ventilation, elevated mortality rates, and higher treatment costs[5]. To effectively prevent VAP, a multidisciplinary team collaboration model is increasingly emphasized in the care of ECMO patients. This model underscores cooperation and communication among professionals from diverse disciplines, facilitating the integration of their respective expertise and skills to deliver more comprehensive patient care[6]. Through multidisciplinary collaboration, individualized care plans can be implemented in the management of ECMO patients, optimizing ventilator use and reducing the incidence of VAP, thereby improving clinical outcomes. This article aims to explore the application of the multidisciplinary team model in VAP prevention for ECMO patients, focusing on their unique characteristics, and to conduct an in-depth analysis of the pivotal role of nursing staff within the team, thereby providing a basis for clinical nursing practice.

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2. Epidemiology and Pathological Mechanisms of Ventilator-Associated Pneumonia in ECMO Patient

Ventilator-associated pneumonia (VAP) is the most common complication in patients undergoing invasive mechanical ventilation. It is defined as pneumonia that develops in patients with endotracheal intubation or tracheostomy more than 48 hours after the initiation of mechanical ventilation; pneumonia occurring within 48 hours after weaning from mechanical ventilation or extubation is also classified as ventilator-associated pneumonia[7]. A systematic review reported an overall incidence of VAP of 26.4% in adult ECMO patients, with an incidence rate of 28.3 cases per 1,000 ECMO days[8]. Grasselli et al.'s study[9] of 92 ECMO-treated patients found a VAP incidence as high as 31.0 cases per 1,000 ECMO days, which significantly increased mortality and prolonged the duration of mechanical ventilation, ICU stay, and ECMO support.

However, ECMO therapy itself introduces pathophysiological processes that increase the risk of VAP. First, there is ECMO-associated immunosuppression. When blood comes into contact with the extracorporeal circuit, it triggers a strong systemic inflammatory response, leading to acquired immunosuppression characterized by lymphocytopenia and impaired function, which weakens the patient's ability to clear pathogens[10]. Second, endothelial damage and vascular leakage also contribute to the risk of VAP. Non-physiological blood flow shear stress and a storm of inflammatory cytokines can damage the vascular endothelium, increasing pulmonary capillary permeability. The protein-rich fluid from pulmonary edema provides an ideal \"culture medium\" for bacterial colonization and proliferation [11]. Finally, this is associated with pulmonary \"inactivity\" and impaired secretion clearance. In \"hyperprotective ventilation\" or \"lung rest\" strategies under VV-ECMO support, the extremely low tidal volumes and respiratory rates employed to reduce ventilator-associated lung injury severely inhibit physiological clearance mechanisms such as ciliary beating and the cough reflex, leading to airway secretion retention and an increased risk of infection[12]. The combination of these mechanisms makes the onset of VAP in ECMO patients more insidious, its progression faster, and the disease more severe.

3. Definition of the Multidisciplinary Team Collaboration Model and Mechanism of Action for Preventing Ventilator-Associated Pneumonia

3.1 Definition of the Multidisciplinary Team Collaboration Model

The multidisciplinary team (MDT) collaboration model refers to a form of collaboration in which a core team, composed of permanent members from two or more distinct disciplines, addresses complex medical issues affecting a specific patient population. Through regular, structured meetings and communication, the team jointly develops and implements integrated treatment plans[13]. Currently, extracorporeal membrane oxygenation (ECMO) is primarily performed in intensive care units (ICUs), and the multidisciplinary team may include physical therapists, respiratory therapists, ICU nurses, ICU physicians, and ECMO specialist nurses. Each member assumes a specific role within the team, contributing their professional expertise to ensure patients receive optimal treatment and care. For example, critical care physicians are responsible for developing treatment plans[14–15]; respiratory therapists manage ventilator parameter adjustments, airway management, and the implementation of pulmonary rehabilitation techniques; ECMO specialist nurses oversee circuit safety maintenance, direct execution of bundled care protocols, and continuous monitoring of the patient's condition; clinical pharmacists focus on the rational use and dose optimization of antimicrobial agents under ECMO conditions; hospital infection control specialists supervise aseptic techniques, monitor infection data, and enforce infection control protocols; and physical therapists lead the assessment and implementation of safe, early rehabilitation activities. Additionally, dietitians, clinical microbiologists, and other specialists are often included as needed. In recent years, the MDT model has evolved from a 'simple aggregation of specialties' to a 'deeply integrated systems engineering' approach, with its core no longer merely the assembly of personnel, but rather collaborative action based on a shared mental model and the establishment of a systematic safety culture[16].

3.2 Mechanisms Underlying the Role of Multidisciplinary Team Collaboration in Preventing Ventilator-Associated Pneumonia

At the multidisciplinary team (MDT) level, team members must undergo specialized ECMO training relevant to their professional fields to ensure they possess the expertise required to implement early interventions. The MDT facilitates the integration of knowledge and systematic prevention and control

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by consolidating fragmented knowledge from various specialties—such as infection control, respiratory care, pharmacy, and rehabilitation—into a comprehensive prevention and control network that addresses all risk factors. Second, by establishing and collectively adhering to standardized operating procedures (e.g., bundled care protocols), the MDT ensures uniformity and high-quality execution of interventions. Furthermore, daily multidisciplinary rounds enable real-time, dynamic assessment of patients' ventilator-associated pneumonia (VAP) risk, facilitating early detection of signs and rapid mobilization of resources to respond. Nurses, as the first to detect changes in a patient's condition, play a crucial early-warning role in this process. Finally, the MDT fosters a culture of system safety, encouraging non-punitive root-cause analysis of adverse events. Nursing staff actively participate in such analyses, proposing systemic improvement recommendations regarding nursing procedures, handover protocols, and other processes, thereby driving the continuous optimization of prevention protocols[17].

4. Use of MDT Approaches in the Prevention of VAP

The effectiveness of MDT collaboration in VAP prevention depends on the clear division of roles and responsibilities among team members. Each discipline brings unique expertise to the prevention system, and their coordinated actions ensure that preventive measures are implemented comprehensively and consistently. Table 1 summarizes the core responsibilities of each MDT member in VAP prevention for ECMO patients.

Table 1. Roles and responsibilities of MDT members in VAP prevention for ECMO patients

MDT Member	Core Responsibilities in VAP Prevention
ICU physician	Develop ventilation strategy; prescribe and adjust antibiotics based on microbiological results
Respiratory therapist	Adjust ventilator settings; perform airway suctioning
ECMO nurse	Monitor circuit safety; execute bundled care; assess patient response; coordinate team communication
Infection control specialist	Supervise aseptic technique; monitor infection data
Clinical pharmacist	Optimize antimicrobial dosing under ECMO conditions
Physical therapist	Implement early mobilization safely

4.1 Implementation of the Bundled Care Program

Within the Multidisciplinary Team (MDT) framework, the implementation of Ventilator-Associated Pneumonia (VAP) prevention bundles—such as elevating the head of the bed, daily sedation interruption, oral care, and stress ulcer prophylaxis—has transitioned from a list of discrete measures to a dynamic, individualized, and continuous care process. For instance, while oral care typically employs 0.12% chlorhexidine solution, the specific frequency, technique, and need for adjustments must be determined through the MDT's daily joint assessment of the patient's oral mucosal condition, bleeding risk, and likelihood of reintubation. As shown in Table 1, ECMO nurses are responsible for executing bundled care protocols; they function not only as implementers but also as providers of assessment results and active participants in protocol adjustments[18]. In position management, head-of-bed elevation must be implemented on an individualized basis following a joint assessment by physicians, nurses, and respiratory therapists of the patient's hemodynamics, intracranial pressure, and Extracorporeal Membrane Oxygenation (ECMO) circuit safety[19]. Sedation and analgesia target \"light sedation.\" Through the standardized implementation of daily scheduled arousal (SAT) and spontaneous breathing trials (SBT), physicians determine sedation depth, nurses conduct detailed assessments, and respiratory therapists monitor respiratory drive, collaborating to enable patients to cooperate with treatment and rehabilitation as early as possible[20].

4.2 Ventilator and Airway Management

With extracorporeal membrane oxygenation (ECMO) providing ex vivo gas exchange support, the team can implement a more stringent 'hyperprotective ventilation' strategy. Under physician guidance, respiratory therapists strictly limit tidal volume to less than 4 ml/kg of ideal body weight and collaboratively determine the optimal positive end-expiratory pressure (PEEP), with the aim of minimizing ventilator-associated lung injury[21]. Regarding airway secretion management, for patients using subglottic suction catheters, the multidisciplinary team (MDT) stipulates continuous or intermittent

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subglottic suction every 1–2 hours, with secretion characteristics recorded. As outlined in Table 1, respiratory therapists perform airway suctioning, while ECMO nurses monitor circuit safety throughout the procedure. Respiratory therapists prepare and perform the procedure, while nurses ensure appropriate patient sedation and secure tube fixation, and closely monitor vital signs and check for bleeding post-procedure. Strict aseptic techniques must be followed throughout the procedure under the supervision of an infection control nurse or specialist[22].

4.3 Safe Integration of Early Rehabilitation

Early mobilization promotes lung re-expansion and secretion clearance and is a key measure for preventing ventilator-associated pneumonia (VAP); however, its implementation carries higher risks in extracorporeal membrane oxygenation (ECMO) patients. The multidisciplinary team (MDT) model ensures the safety and effectiveness of rehabilitation interventions. Prior to rehabilitation intervention, physicians, physical therapists, and ECMO nurses must conduct a rigorous safety screening to assess consciousness, hemodynamics, coagulation function, and circuit safety[23]. Consistent with their roles in Table 1, physical therapists guide movements, ECMO nurses secure the ECMO tubing and ventilator lines throughout the process, and respiratory therapists dynamically monitor SpO_2 and respiratory mechanics, forming a seamless safety monitoring network. The rehabilitation process is staged, progressing from passive joint movements in bed and sitting up in bed to sitting at the bedside and marching in place; each step requires re-evaluation by the MDT.

4.4 Goal-Oriented Infection Control

Clinical pharmacists participate in daily rounds, guiding the precise use of antimicrobial agents and step-down therapy based on microbiological surveillance results and changes in pharmacokinetics under ECMO conditions, thereby preventing antimicrobial resistance caused by overuse[24]. As detailed in Table 1, infection control specialists integrate a culture of prevention into daily operations by supervising hand hygiene and aseptic techniques and analyzing infection data. The team regularly conducts root cause analyses of VAP cases to continuously improve prevention and control measures related to policies, procedures, and staff training.

5. Implementation Results, Challenges, and Outlook

Although large-scale randomized controlled trials are currently lacking, several observational studies have demonstrated that structured multidisciplinary team (MDT) collaboration can effectively reduce the incidence of ventilator-associated pneumonia (VAP) in extracorporeal membrane oxygenation (ECMO) patients. These studies have shown that the implementation of a daily multidisciplinary rounds model significantly reduces VAP incidence, while also shortening the duration of ECMO support, mechanical ventilation, and intensive care unit (ICU) stay[22]. MDTs further enhance adherence to and the quality of implementation of core preventive measures by clarifying roles and standardizing communication.

However, the implementation of MDTs still faces challenges. Frequent meetings and communication requirements consume significant time and human resources. Role ambiguity or conflicts regarding decision-making authority among specialties may impede efficiency. Additionally, the absence of universally accepted, standardized quality metrics for evaluating ECMO-MDT-based VAP prevention complicates the comparison and improvement of practices across institutions[25]. The rapidly changing clinical conditions of ECMO patients also impose extremely high demands on the MDT's responsiveness and flexibility.

To promote the scientific and standardized development of multidisciplinary team (MDT) collaboration models in the prevention of ventilator-associated pneumonia (VAP) among ECMO patients, future research and practice should focus on multiple dimensions. First, rigorously designed, large-scale, multicenter prospective studies should be conducted to clarify the impact of the MDT model on VAP incidence, survival rates, and long-term outcomes . Second, the research methodology of 'team science' should be adopted to investigate the role of team dynamics—such as team cohesion, communication quality, perceived psychological safety, and leadership style—in the effectiveness of VAP prevention[26]. Finally, the role of nurses within the MDT should be strengthened by developing VAP risk assessment tools tailored to ECMO patients, as well as quality indicators to evaluate the nursing-sensitive aspects of the VAP prevention process.

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6. Conclusion

The multidisciplinary team (MDT) collaboration model transforms ventilator-associated pneumonia (VAP) prevention from the implementation of isolated, passive measures into a systematic, proactive, and dynamic risk management process by integrating resources across multiple specialties. It serves as a key strategy for reducing VAP incidence in extracorporeal membrane oxygenation (ECMO) patients and improving their prognosis. Within this model, nursing staff leverage their unique advantages—including close patient contact, continuous observation, and hands-on implementation throughout the care process—to assume a central role in early warning of disease progression, treatment plan implementation, team communication, and quality improvement. In the future, it will be necessary to further refine the standardized operational mechanisms and effectiveness evaluation systems of the MDT, while strengthening the leadership and professional autonomy of nursing staff within the team, to continuously improve the quality of care for ECMO patients.

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