Observational Study

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Impact of FMEA-based nursing intervention combined with early rehabilitation training on the prognosis of mechanically ventilated patients in cardiac intensive care units

Qin Chen, MM[a,*], Siyu Chen, MM[a], Lian Zhang, MM[a]

Abstract

This study aimed to assess the effects of failure mode and effect analysis (FMEA)-based nursing intervention combined with early rehabilitation training on the outcomes of mechanically ventilated patients in the cardiac intensive care unit (CICU). A retrospective cohort design included 100 patients who underwent tracheal intubation and mechanical ventilation in the CICU from January 2023 to June 2024. The observation group (n = 50) received FMEA-based nursing intervention alongside early rehabilitation training, while the control group (n = 50) received standard nursing care with early rehabilitation training. Results demonstrated that the observation group had significantly better muscle strength levels, lower incidence of ICU-acquired weakness, fewer tracheal intubation-related complications, shorter durations of mechanical ventilation, and reduced hospital stays compared to the control group ($P < .05$). Additionally, nursing satisfaction was significantly higher in the observation group ($P = .027$). In conclusion, the combination of FMEA-based nursing intervention and early rehabilitation training notably improves the prognosis of mechanically ventilated patients in the CICU, minimizes complications, and enhances patient satisfaction with nursing care.

Abbreviations: CICU = cardiac intensive care unit, FMEA = failure mode and effect analysis, ICU-AW = ICU-acquired weakness.

Keywords: early rehabilitation training, FMEA nursing intervention, ICU-acquired weakness, tracheal intubation

1. Introduction

The cardiac intensive care unit (CICU) offers life-sustaining support and specialized care for critically ill cardiac patients who often require tracheal intubation and mechanical ventilation due to severe conditions such as acute heart disease, heart failure, and respiratory failure.[1,2] While these interventions are crucial for prolonging life, they are frequently associated with complications like tracheal intubation-related issues, ventilator-associated pneumonia, and ICU-acquired weakness (ICU-AW).[3,4] These complications not only extend hospital stays but also significantly impede patient recovery and reduce quality of life.[5,6] Consequently, preventing and minimizing these complications has become a key focus in critical care nursing research in recent years.

Failure mode and effect analysis (FMEA) is a systematic risk management tool that has been implemented across various clinical nursing processes.[7–9] By identifying potential failure modes within medical procedures and evaluating their impact on patient safety, FMEA allows healthcare providers to implement preventive measures proactively, thereby reducing nursing errors and the occurrence of complications.[10,11] In the context of critical patient care, FMEA has proven effective in enhancing nursing quality, particularly in ventilator management and tracheal intubation procedures, leading to a decrease in adverse events.[12]

Early rehabilitation training is an essential intervention for promoting functional recovery in patients. Numerous studies have demonstrated its benefits in increasing muscle strength, improving respiratory function, and lowering the incidence of ICU-AW.[13,14] Early rehabilitation not only helps prevent muscle atrophy but also reduces the duration of mechanical ventilation and accelerates the overall recovery process.[15] Although both FMEA-based nursing interventions and early rehabilitation training are individually recognized for improving the prognosis of critically ill patients, the combined effect of these 2 approaches has not been extensively evaluated. Specifically, in mechanically ventilated patients within the CICU, the impact of integrating FMEA-based nursing intervention with early rehabilitation training on outcomes such as muscle strength recovery, prevention of ICU-AW, duration of mechanical ventilation, and length of hospital stay remains unclear.

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Therefore, this retrospective cohort study aims to assess the combined effects of FMEA-based nursing intervention and early rehabilitation training on the prognosis of mechanically ventilated patients in the CICU. The study focuses on key clinical indicators, including muscle strength levels, incidence of ICU-AW, duration of mechanical ventilation, length of hospital stay, and nursing satisfaction, to provide scientific evidence for critical care nursing practices and promote the clinical application of integrated intervention models.

2. Materials and methods

2.1. General information

This study was approved by the Ethics Committee of West China Hospital. This retrospective cohort study included patients who underwent tracheal intubation and mechanical ventilation in the CICU from January 2023 to June 2024. Patients were divided into 2 groups based on the nursing protocol: the observation group (n = 50) received FMEA-based nursing intervention combined with early rehabilitation training, while the control group (n = 50) received standard nursing care alongside early rehabilitation training. All data were extracted from the hospital's electronic health record system, ensuring anonymity to protect patient privacy and data security. As the study was retrospective, informed consent forms were archived in the hospital database, and no additional consent was required.

2.2. Inclusion and exclusion criteria

2.2.1. Inclusion criteria. Critically ill patients diagnosed with cardiac diseases confirmed by echocardiography, coronary angiography, or other cardiac imaging techniques. Patients requiring tracheal intubation and mechanical ventilation upon admission, with a ventilation duration of ≥ 24 hours. Patients with clear clinical symptoms and medical history, capable of basic communication, and willing to participate in the study. Adults aged 18 years and above with a strong social support system, able to adhere to the treatment plan.

2.2.2. Exclusion criteria. Patients with severe cognitive impairment, mental disorders, dementia, hearing loss, or communication barriers that impede participation in assessments and communication. Patients with multiple organ dysfunction (e.g., renal failure, liver failure) or other terminal illnesses. Patients with limb motor dysfunction caused by non-cardiac conditions (e.g., trauma, stroke) or those with neurological disorders. Patients with immunodeficiency or those recently undergoing immunosuppressive therapy. Pregnant women or those with pregnancy-related complications. Patients with contraindications to the medications or treatments used in the study.

2.3. Nursing models

2.3.1. Control group. Patients in the control group received standard nursing care combined with early progressive rehabilitation training. Rehabilitation commenced within 24 hours of CICU admission and was tailored by respiratory and rehabilitation therapists to develop individualized plans. The training included the following stages:

Pulmonary rehabilitation: Assess lung function using imaging data, perform timely airway management, adjust ventilator settings, and conduct sputum clearance.

Passive exercise: For patients with reduced consciousness or muscle strength, joint mobility and muscle strength training were conducted twice daily, each session lasting one hour.

Active exercise: Encourage patients with better consciousness to engage in active limb training, gradually increasing activity levels.

Bedside and out-of-bed activities: As patients regain mobility, they were encouraged to perform bedside activities and progressively transition to out-of-bed activities. All training was administered by specialized rehabilitation therapists, with adjustments made based on patient recovery progress.

2.3.2. Observation group. The observation group implemented an FMEA-based nursing intervention model combined with early progressive rehabilitation training. An FMEA nursing team was established, consisting of the CICU head nurse and 6 nursing staff members. All team members received standardized training in FMEA nursing principles and conducted thorough analyses of potential failure modes in the care process of mechanically ventilated patients, covering areas such as ventilation management, sputum suction, analgesia, oral care, psychological care, and exercise intervention. Based on the analysis, targeted nursing intervention measures were developed.

2.3.2.1. Implementation of FMEA process. Ventilation care: Continuously monitor patients' vital signs during mechanical ventilation and adjust ventilator settings in real-time to maintain stable oxygenation.

Sputum suction care: Ensure timely sputum suction and perform airway humidification to prevent airway blockage and infection.

Analgesia care: Regularly assess pain levels, promptly adjust analgesic medications, and utilize non-pharmacological methods such as music therapy for patients with mild pain.

Oral care: Conduct oral cleaning twice daily to prevent oral infections.

Psychological care: Play soothing music to alleviate anxiety, guide patients in meditation and relaxation, and boost their confidence in recovery.

2.3.2.2. Early progressive rehabilitation training. Initiated within 24 hours of CICU admission, personalized rehabilitation plans were developed and implemented in stages:

Pulmonary rehabilitation: Enhance lung function through airway humidification and ventilator setting adjustments.

Passive exercise: Conduct joint mobility training for patients with impaired consciousness or muscle strength, once daily for 1 hour.

Active exercise: Encourage autonomous joint activity training, gradually increasing activity levels.

Bedside and out-of-bed activities: Transition to standing at the bedside and short-duration gait training based on patient recovery, enhancing activity tolerance.

2.3.2.3. Dynamic assessment and adjustment. All interventions were continuously assessed during implementation to monitor changes in patients' conditions, adjust training intensity, and modify nursing plans as necessary to ensure effective and safe rehabilitation within the patient's capacity.

2.4. Observation indicators

The primary observation indicators of this study included:

2.4.1. Muscle strength levels. Assessed using standardized muscle strength evaluation scales on days 3, 6, and 9 post-intervention to evaluate muscle strength recovery at different time points.

2.4.2. Incidence of ICU-AW. Evaluated through regular assessment of clinical symptoms and physical condition, comparing incidence rates on days 3, 6, and 9 between the 2 groups.

Table 1

Baseline data [mean ± SD, n (%)].

	Observation group (n = 50)	Control group (n = 50)	t/χ^2	*P* value
Age (yr)	61.24 ± 5.46	62.15 ± 4.59	$t = -0.931$	.352
Gender			$\chi^2 = 0.040$	.841
Male	27 (54.00)	28 (56.00)		
Female	23 (46.00)	22 (44.00)		
BMI (kg/m²)	22.36 ± 3.53	21.58 ± 4.57	$t = 0.956$	.341
Marital status			$\chi^2 = 0.421$	.810
Spinsterhood	5 (10.00)	8 (16.00)		
Married	33 (66.00)	29 (58.00)		
Divorced/widowed	12 (24.00)	13 (26.00)		
Education level			$\chi^2 = 0.060$	.805
Primary education	24 (48.00)	25 (50.00)		
Secondary education	22 (44.00)	20 (40.00)		
Higher education	4 (8.00)	5 (10.00)		
Comorbidities			$\chi^2 = 0.067$	.796
Hypertension	25 (50.00)	26 (52.00)		
Diabetes	22 (44.00)	24 (48.00)		
COPD	6 (12.00)	5 (10.00)		
NYHA functional classification			$\chi^2 = 0.060$	.806
Class II	11 (22.00)	13 (26.00)		
Class III	27 (54.00)	26 (52.00)		
Class IV	12 (24.00)	11 (22.00)		

COPD = chronic obstructive pulmonary disease, SD = standard deviation.

2.4.3. Duration of mechanical ventilation and length of hospital stay. Recorded the duration of mechanical ventilation and ICU hospitalization to compare the 2 groups.

2.4.4. Incidence of tracheal intubation-related complications. Documented occurrences of unplanned extubation, catheter slippage, airway obstruction, and oxygen supply interruption during the study period.

2.4.5. Nursing satisfaction. Assessed using a self-designed nursing satisfaction questionnaire at the end of the intervention, covering aspects such as nursing quality, communication, and intervention effectiveness.

2.5. Data collection

Data were collected using a combination of electronic medical records and questionnaire surveys. Researchers extracted basic information from patients' hospitalization records, including age, gender, and primary disease type. For the primary observation indicators (muscle strength levels, incidence of ICU-AW, duration of mechanical ventilation and hospital stay, incidence of tracheal intubation-related complications, and nursing satisfaction), data were gathered through clinical examinations, regular assessments, and medical records. Nursing satisfaction was evaluated using a self-designed questionnaire completed by patients at the end of the intervention. All data were collected and recorded by research team members according to standardized protocols. To ensure data accuracy and consistency, the research team underwent training and established detailed data collection procedures.

2.6. Statistical methods

Data analysis was performed using SPSS 22.0 statistical software. Continuous data were expressed as mean ± standard deviation ($x \pm s$) and compared between groups using independent samples t tests. Categorical data were presented as frequencies and percentages and compared using chi-square tests (χ^2 tests). The significance level for all statistical tests was set at $P < .05$. For continuous variables such as duration of mechanical ventilation, ICU hospitalization time, and muscle strength levels, independent samples t tests were used to compare differences between the observation and control groups. For categorical variables such as the incidence of ICU-AW, tracheal intubation-related complications, and nursing satisfaction, chi-square tests were employed for intergroup comparisons. All data were analyzed at different time points before and after the intervention to assess the impact of different intervention methods on patients. Bonferroni correction was applied for multiple comparisons to reduce Type I errors.

3. Results

3.1. Baseline characteristics

In this study, there were no significant differences in baseline demographic and clinical characteristics between the observation and control groups, indicating that the 2 groups were comparable prior to the intervention. No statistically significant differences were observed in age ($P = .352$), gender ($P = .841$), BMI ($P = .341$), marital status ($P = .810$), education level ($P = .805$), and comorbidities ($P = .796$). Additionally, there were no significant differences in the distribution of NYHA functional classification ($P = .806$). These findings suggest that the clinical characteristics of the 2 groups were similar at baseline, minimizing the potential impact of baseline differences on the study results (see Table 1).

3.2. Muscle strength comparison

The muscle strength levels in the observation group were significantly higher than those in the control group at all time points ($P < .001$). On day 3, the muscle strength level in the observation group was 59.48 ± 5.47, significantly higher than the 52.32 ± 7.21 in the control group ($t = 5.600$, $P < .001$). On day 6, the muscle strength in the observation group was 52.73 ± 6.53, still significantly higher than the 44.53 ± 6.13 in the control group ($t = 6.470$, $P < .001$). On day 9, the muscle strength level in the observation group was 45.25 ± 6.56, noticeably higher than the 36.82 ± 8.33 in the control group

($t = 5.610$, $P < .001$). These results demonstrate that the observation group maintained better muscle strength recovery at different time points (see Table 2, Fig. 1).

3.3. Incidence of ICU-AW in cardiac intensive care unit

The incidence of ICU-AW in the observation group was significantly lower than in the control group at different time points. On day 3, the incidence of ICU-AW in the observation group was 14.00%, compared to 26.00% in the control group, with no significant difference ($P = .179$). On day 6, the incidence in the observation group was 18.00%, significantly lower than 40.00% in the control group ($\chi^2 = 8.340$, $P = .015$). On day 9, the incidence in the observation group was 36.00%, compared to 56.00% in the control group, with a statistically significant difference ($\chi^2 = 4.340$, $P = .037$). These findings indicate that the intervention in the observation group significantly reduced the incidence of ICU-AW (see Table 3).

Table 2

Comparison of muscle strength between 2 groups at different times (mean ± SD).

	n	3d	6d	9d
Observation group	50	59.48 ± 5.47	52.73 ± 6.53	45.25 ± 6.56
Control group	50	52.32 ± 7.21	44.53 ± 6.13	36.82 ± 8.33
t		5.600	6.470	5.610
P value		<.001	<.001	<.001

SD = standard deviation.

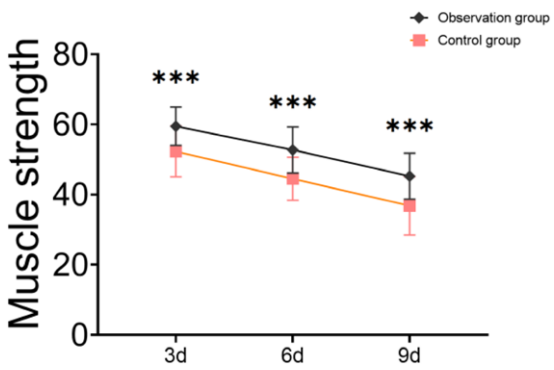

Figure 1. Comparison of muscle strength; *** represents $P < .001$.

Table 3

Comparison of the incidence of ICU-AW between the 2 groups at different times (n/%).

	n	3d	6d	9d
Observation group	50	7 (14.00)	9 (18.00)	18 (36.00)
Control group	50	13 (26.00)	20 (40.00)	28 (56.00)
χ^2		1.800	8.340	4.340
P value		.179	.015	.037

ICU-AW = Intensive Care Unit-acquired weakness.

3.4. Comparison of tracheal intubation-related complications

The incidence of complications related to tracheal intubation, such as unplanned extubation, catheter dislodgement, airway obstruction, and oxygen supply interruption, was significantly lower in the observation group compared to the control group. The incidence of unplanned extubation in the observation group was 2.00%, significantly lower than the 12.00% in the control group ($P = .059$), with the difference approaching significance. The rates of catheter dislodgement, airway obstruction, and oxygen supply interruption were significantly lower in the observation group, with P values of .034, .014, and .008, respectively (see Table 4). These results suggest that the nursing intervention in the observation group significantly reduced the occurrence of tracheal intubation-related complications.

3.5. Mechanical ventilation time and length of hospital stay

The mechanical ventilation time in the observation group (5.24 ± 1.53 days) was significantly shorter than the 6.63 ± 2.43 days in the control group ($t = -3.42$, $P = .001$). In terms of length of hospital stay, the observation group had a mean stay of 7.52 ± 1.35 days, significantly shorter than the 9.76 ± 2.25 days in the control group ($t = -6.03$, $P < .001$). These results indicate that the intervention in the observation group significantly reduced both mechanical ventilation time and length of hospital stay (see Table 5, Fig. 2).

3.6. Nursing satisfaction comparison

The nursing satisfaction in the observation group was significantly higher than in the control group. In the observation group, 96.00% of patients reported being very satisfied or satisfied, while 80.00% of patients in the control group expressed satisfaction ($\chi^2 = 7.220$, $P = .027$). Specifically, 52.00% of patients in the observation group reported being "very satisfied," 42.00% were "satisfied," and only 6.00% were "dissatisfied." In contrast, 20.00% of patients in the control group were "dissatisfied." These results indicate that the nursing intervention in the observation group significantly improved patient satisfaction (see Table 6).

4. Discussion

This study, through a retrospective cohort design, evaluated the impact of FMEA-based nursing interventions combined with early rehabilitation training on the prognosis of patients undergoing tracheal intubation in the CICU. The results showed that

Table 4

Comparison of the incidence of tracheal intubation related complications between the 2 groups (n/%).

	n	Unplanned extubation	Catheter slippage	Airway obstruction	Oxygen supply interruption
Observation group	50	1 (2.00)	1 (2.00)	0	0
Control group	50	6 (12.00)	7 (14.00)	6 (12.00)	7 (14.00)
χ^2		3.571	4.500	6.000	7.000
P value		.059	.034	.014	.008

the observation group outperformed the control group in several key outcome measures, including muscle strength, incidence of ICU-AW, tracheal intubation-related complications, mechanical ventilation duration, length of hospital stay, and nursing satisfaction. These findings support the effectiveness of combining FMEA-based nursing interventions with early rehabilitation training.

FMEA, as a systematic risk management tool, has been applied in various clinical nursing settings and has been shown to effectively reduce nursing errors and complications.[16,17] The results of this study are consistent with those of Kuo et al[10] indicating that FMEA's application in critical care nursing significantly reduces the incidence of adverse events. Additionally, the beneficial effects of early rehabilitation training on improving muscle strength and reducing ICU-AW are consistent with previous research.[18,19] which demonstrates that early rehabilitation can effectively prevent muscle atrophy and accelerate functional recovery. However, the combined effect of FMEA-based nursing interventions and early rehabilitation training has not been fully evaluated in CICU patients with tracheal intubation, and this study fills this gap by further confirming the synergistic effects of these 2 interventions.

The significant improvement in muscle strength in the observation group can likely be attributed to the customized rehabilitation plan and early intervention embedded in the FMEA nursing protocol. FMEA, by systematically identifying and preventing potential nursing failure modes, ensures the safety and effectiveness of rehabilitation training, thereby reducing complications caused by improper care and creating favorable conditions for muscle strength recovery. These findings align with previous studies.[20] Early rehabilitation training further promotes muscle activity and functional recovery, preventing muscle atrophy and loss of function, thereby enhancing muscle strength. Moreover, interventions within the FMEA nursing protocol, such as ventilation management, suction care, and pain management, helped optimize mechanical ventilation parameters, reduce tracheal intubation-related complications, and shorten both mechanical ventilation duration and hospital stay.

However, this study has several limitations. First, as a retrospective cohort study, there may be selection bias and information bias that could affect the accuracy and reliability of the results. Second, since this is a single-center study, the generalizability of the findings is limited, and validation in a multi-center setting is needed. Additionally, the nursing satisfaction assessment was based on a self-designed questionnaire, which may introduce subjective bias and affect the objectivity of the results. Future research should adopt a prospective randomized controlled design to minimize bias and enhance the credibility of the findings.

We acknowledge the limitations of this study, including its retrospective design and single-center data, which may impact the generalizability of the findings. To address these limitations. Future studies adopt a multi-center, prospective randomized controlled trial design. This approach would help reduce bias and enhance the reliability and external validity of the results. In addition, incorporating a broader range of clinical variables, such as patients' social support networks or psychological states, would further strengthen the generalizability and clinical relevance of future research. Exploring the specific impact of different FMEA-based nursing interventions and their combination with other nursing measures will provide valuable insights for optimizing nursing protocols and improving critical care practices.

Table 5

Mechanical ventilation time and hospital stay of the 2 groups (mean ± SD).

	n	Mechanical ventilation time (d)	Hospital stay (d)
Observation group	50	5.24 ± 1.53	7.52 ± 1.35
Control group	50	6.63 ± 2.43	9.76 ± 2.25
t		−3.42	−6.03
P value		.001	<.001

SD = standard deviation.

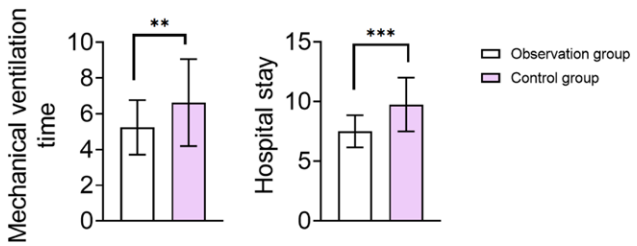

Figure 2. Comparison of mechanical ventilation time and hospital stay; ** represents $P = .001$, *** represents $P < .001$.

5. Conclusion

This study highlights that the combination of FMEA nursing intervention and early rehabilitation training significantly improved muscle strength recovery, reduced the occurrence of ICU-AW and endotracheal intubation-related complications, shortened mechanical ventilation duration and hospital stay, and increased nursing satisfaction in CICU patients. These findings suggest substantial clinical value. It is recommended that this nursing approach be adopted in clinical settings, and further multi-center, prospective randomized controlled trials should be conducted to confirm its effectiveness and refine nursing protocols, ultimately enhancing critical care quality and patient outcomes.

Author contributions

Conceptualization: Qin Chen, Siyu Chen, Lian Zhang.
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Investigation: Qin Chen.
Methodology: Qin Chen.
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Writing – review & editing: Qin Chen.

Table 6

Nursing satisfaction (n/%).

	n	Not satisfied	Satisfied	Very satisfied	Total satisfaction
Observation group	50	2 (6.00)	21 (42.00)	27 (52.00)	48 (96.00)
Control group	50	10 (20.00)	13 (26.00)	27 (54.00)	40 (80.00)
χ^2					7.220
P value					.027

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