Am J Cancer Res 2025;15(5):2427-2438
www.ajcr.us /ISSN:2156-6976/ajcr0162727

Original Article

Multidisciplinary collaborative approach to cardiopulmonary rehabilitation in cancer patients with intensive care unit-acquired weakness: a clinical efficacy and safety analysis

Ming Yao[1*], Li Zhang[2*], Meng Ai[1], Haiyan Chen[1], Lu Zhang[3], Yanshun Wei[4], Dandan Wang[5], Yajie Jia[6]

[1]Department of Respiratory Medicine, Wuhan University of Science and Technology Affiliated Geriatric Hospital, Wuhan 430000, Hubei, China; [2]Department of Intensive Care Medicine, Hubei Cancer Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan 430079, Hubei, China; [3]Department of Integrated Traditional Chinese and Western Medicine, Wuhan University of Science and Technology Affiliated Geriatric Hospital, Wuhan 430000, Hubei, China; [4]Department of Laboratory Medicine, Puren Hospital Affiliated to Wuhan University of Science and Technology, Wuhan 430081, Hubei, China; [5]Department of Critical Care Medicine, Wuhan University of Science and Technology Affiliated Geriatric Hospital, Wuhan 430000, Hubei, China; [6]Department of Critical Care Medicine, Puren Hospital Affiliated to Wuhan University of Science and Technology, Wuhan 430081, Hubei, China. [*]Co-first author.

Received December 17, 2024; Accepted April 21, 2025; Epub May 25, 2025; Published May 30, 2025

Abstract: Objectives: To evaluate the efficacy and safety of a multidisciplinary team (MDT)-based cardiopulmonary rehabilitation model in patients with intensive care unit-acquired weakness (ICU-AW). Methods: Between January 2020 and June 2023, 80 ICU patients were enrolled: 40 received standard cardiopulmonary rehabilitation (control group), and 40 underwent MDT-based rehabilitation (observation group). Outcome measures included ICU-AW incidence, muscle strength Medical Research Council (MRC) scores, upper/lower limb strength, Barthel Index Sequential Organ Failure Assessment (SOFA) Acute Physiology and Chronic Health Evaluation (APACHE) II scores, duration of ICU and hospital stay, mechanical ventilation time, complications, and patient satisfaction. Predictive variables for ICU-AW were also analyzed. Results: On days 4 and 7 post-intervention, ICU-AW incidence was significantly lower in the observation group (both $P < 0.05$). MRC scores, limb muscle strength, Barthel Index, and satisfaction were significantly higher in the observation group (all $P < 0.05$), while SOFA, APACHE II scores, ICU stay, hospital stay, and ventilation duration were significantly lower (all $P < 0.05$). SOFA scores declined from day 5, with lower values in the observation group ($P < 0.05$). The risk of ICU-AW in the observation group was a significant reduction in risk than in the control group (OR = 0.067, 95% CI: 0.005-0.606, $P = 0.017$). No significant differences in complications were observed ($P > 0.05$). Conclusions: MDT-based cardiopulmonary rehabilitation significantly improves muscle strength, functional status, and patient satisfaction, while reducing ICU-AW incidence, ICU and hospital stay, and ventilation duration. These findings support its broader clinical application in ICU-AW management.

Keywords: Multidisciplinary collaboration, cardiopulmonary rehabilitation, efficacy observation

Introduction

Intensive Care Unit-Acquired Weakness (ICU-AW) refers to muscle weakness and functional deterioration that develops during ICU hospitalization, particularly affecting cancer patients. Prolonged mechanical ventilation and bed rest - common in this population - contribute to muscle atrophy and further decline in functional capacity [1]. ICU-AW not only increases mortality risk but also extends hospital stays, raises healthcare costs, and significantly impairs patients' quality of life [2].

Cancer patients are especially vulnerable to ICU-AW due to the nature of their disease and the adverse effects of treatments such as chemotherapy and radiotherapy. Chemotherapy-related fatigue, nausea, and vomiting, along with potential muscle and nerve damage

https://doi.org/10.62347/UVQC5990

caused by radiotherapy, compound the risk of weakness and immobility [3].

With advances in critical care, the focus has shifted from merely reducing mortality to improving long-term quality of life for survivors [4]. As a result, ICU-AW has received growing academic attention, leading to both theoretical advancements and practical applications.

Cardiopulmonary rehabilitation aims to enhance cardiopulmonary function, increase exercise tolerance, and improve overall quality of life [5]. For cancer patients with ICU-AW, it plays a crucial role in restoring muscle strength and physical function, minimizing complications, shortening hospitalization, and improving survival outcomes [6]. However, many rehabilitation programs lack individualized guidance and fail to fully address patients' comprehensive needs, including psychological support and nutritional care. Furthermore, the compartmentalization of medical disciplines often hinders the development of standardized, holistic treatment strategies, resulting in variable outcomes [7, 8].

A multidisciplinary team (MDT) approach helps bridge these gaps by facilitating communication across specialties and delivering personalized, integrated care. This model enables the design of comprehensive rehabilitation programs that better address the complex needs of patients, ultimately improving therapeutic outcomes and quality of life [9].

Studies have shown that early rehabilitation guided by MDTs in critically ill patients can enhance organ function and reduce hospital-acquired infections, supporting its feasibility and safety. Therefore, in this study, MDT interventions were initiated within 24 hours of mechanical ventilation in the ICU, based on physician evaluation, with early cardiopulmonary rehabilitation provided to eligible patients [10, 11].

This study aims to provide evidence for clinical practice by evaluating the efficacy and safety of a multidisciplinary cardiopulmonary rehabilitation model in cancer patients with ICU-AW. The objective is to optimize rehabilitation strategies and improve both outcomes and quality of life in this vulnerable patient population.

Materials and methods

Sample size calculation

This study was designed as a prospective clinical trial. An initial sample size of 36 patients per group was calculated based on $\alpha = 0.05$, $\beta = 0.20$ (two-tailed), δ (p1-p2) = 0.21, and an estimated incidence of ICU-AW of p1 = 0.23, derived from previous data collected at Wuhan University of Science and Technology Affiliated Geriatric Hospital and relevant literature [12]. To account for a potential 10% loss due to dropout or refusal to participate, the final minimum sample size was adjusted to 40 patients per group.

Study design

A total of 80 patients diagnosed with ICU-AW were enrolled between January 2020 and June 2023 from the Intensive Care Units of the Geriatric Hospital Affiliated with Wuhan University of Science and Technology and Wuhan Puren Hospital. Randomization was performed using the sealed-envelope method to ensure single-blind allocation. Both participants and investigators were unaware of group assignments, with a 1:1 allocation ratio. The random sequence was generated by an independent statistician using computerized software. After applying the inclusion and exclusion criteria and accounting for refusals and confounding factors, 40 patients were assigned to the control group and 40 to the observation group.

Inclusion criteria: (1) All participants were diagnosed with cancer; (2) All met the diagnostic criteria for ICU-AW, including ICU admission for > 24 hours, mechanical ventilation, and an MRC score assessment. Patients performed movements such as neck flexion, neck extension, and shoulder abduction based on their physical condition. The MRC scoring system ranges from 0 (complete paralysis) to 5 (normal strength) per muscle group, with a total maximum score of 60. A total MRC score < 48 was considered diagnostic for ICU-AW; (3) Patients who could not be weaned from the ventilator within 24 hours; (4) Informed consent was obtained from patients or their legal representatives.

Exclusion criteria: (1) Patients with unstable conditions, including those at risk of cardiac

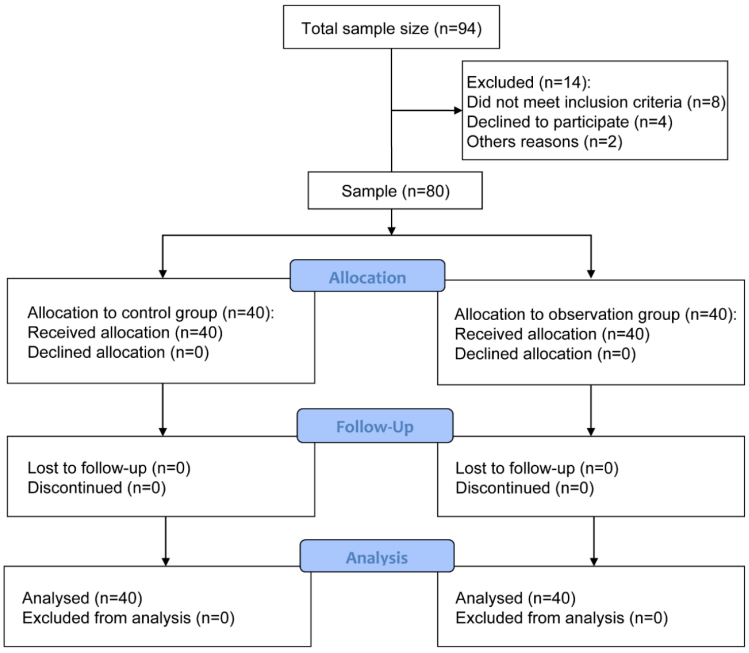

Figure 1. The recruitment diagram of the subjects.

arrest, respiratory failure, or multiple organ dysfunction; (2) Patients with pre-existing movement disorders, unstable limb fractures, spinal injuries (cervical/thoracic), deep vein thrombosis, or pulmonary embolism, which contraindicated positional changes; (3) Patients who failed to comply with medical treatment or could not cooperate with the clinical team; (4) Patients who had previously withdrawn, were discharged prematurely, or were excluded at the request of family members.

The trial protocol was reviewed and approved by the Ethics Committee of the Wuhan University of Science and Technology Affiliated Geriatric Hospital (Approval No. 20241206001). Informed consent was obtained from all participants and/or their family members, with signed consent forms collected. Participant recruitment and group allocation were illustrated in a CONSORT flow diagram (**Figure 1**).

Interventions

Control group: The control group received standard ICU rehabilitation and nutritional support, including the following components:

(1) Psychological support: Patients were guided in managing negative emotions through environmental modifications, psychological counseling, and family engagement, aiming to improve emotional well-being and compliance.

(2) Physical exercise: Exercise regimens were customized and gradually intensified based on the patient's condition, incorporating both passive and active movements.

(3) Respiratory training: Breathing exercises focused primarily on pursed-lip and diaphragmatic techniques to enhance pulmonary function.

(4) Airway clearance: Methods included postural drainage, chest oscillation, and assisted coughing to facilitate mucus clearance and improve ventilation.

Observation group: In addition to the interventions provided to the control group, the observation group received structured cardiopulmonary rehabilitation under a MDT framework.

(1) Multidisciplinary team formation [13]: The MDT was composed of professionals from multiple specialties, with specific responsibilities outlined in **Table 1**.

(2) MDT member training [14]: Upon team formation, a structured one-month training program was launched to promote interdisciplinary collaboration and skill acquisition.

Week 1: The training began with theoretical instruction. Leading experts delivered lectures on the history, principles, and recent advancements in multidisciplinary collaboration. These sessions aimed to enhance participants' understanding of the value of interdisciplinary teamwork and clarify their individual roles.

Week 2: The Department of Rehabilitation Medicine organized two targeted courses for ICU physicians and nurses. Delivered using a centralized teaching model, the sessions focused on the theoretical underpinnings and technical aspects of cardiopulmonary rehabilitation, equipping ICU staff to address common clinical challenges during rehabilitation.

Table 1. Personnel allocation in the DMT group

Members of the group	Division of responsibility
Director of intensive care Unit	General manager responsible for the overall execution of the project.
Intensive care unit nurses	Charged with establishing and overseeing the WeChat group for the MDT, this role involves coordinating communication among staff from different departments, organizing training sessions, convening meetings, facilitating discussions, and disseminating pertinent information.
Deputy chief of rehabilitation Department	Accountable for the consultation, risk assessment, and formulation of individualized rehabilitation plans for patients undergoing cardiopulmonary rehabilitation.
Deputy Director of intensive care Unit	To proficiently diagnose ICU-AW in patients and preliminarily assess the feasibility of cardiopulmonary rehabilitation, while also engaging with family members to ascertain their willingness to participate in actual cardiopulmonary resuscitation (CPR) protocols. Concurrently, the efficacy and safety of cardiopulmonary function recovery were monitored throughout the rehabilitation process.
Intensive Care Nurses	Cardiopulmonary recovery was performed.
Respiratory physicians	Patient respiratory function was closely monitored, and a comprehensive assessment of the indications and risks associated with mechanical ventilation, respiratory therapy, weaning, and extubation was performed.
Rehabilitation physician	Comprehensive training and guidance were provided to intensive care unit (ICU) nursing staff in cardiopulmonary rehabilitation, ensuring that they possessed the requisite knowledge and skills for delivering high-quality patient care.
Psychological counseling consultant	To evaluate and intervene the psychological status of patients with ICU-AW.
Nutritionist	Patient nutritional status was comprehensively assessed, followed by the implementation of targeted nutritional interventions.

Note: ICU-AW: ICU-acquired weakness; MDT: multidisciplinary diagnosis and treatment.

Weeks 3-4: ICU nurses underwent hands-on operational training three times per week, supervised by rehabilitation physicians. These sessions emphasized skill refinement in key nursing procedures essential for ICU-based cardiopulmonary rehabilitation.

Final evaluation: The training concluded with a competency assessment conducted by the rehabilitation department. Nurses who passed the evaluation received hospital certification, authorizing them to carry out ICU responsibilities.

Monthly training sessions continued thereafter, progressively enhancing the practical competencies of MDT members.

(3) Implementation of MDT [15]: The intensivist used clinical judgment to initiate MDT consultations after discussions with the patient's family and obtaining informed consent. The MDT convened promptly to conduct a comprehensive assessment of the patient's condition and determine the optimal timing and strategy for intervention.

Respiratory physicians managed all aspects of respiratory care, including ventilator setting adjustments, evaluation of weaning readiness, and implementation of the weaning protocol.

Rehabilitation physicians and nursing staff collaboratively designed and implemented a phased rehabilitation program in coordination with the attending physicians. Each rehabilitation plan was tailored to the patient's evolving condition:

Phase I: Respiratory and pulmonary rehabilitation included airway suctioning and sputum evaluation. Multi-frequency vibration therapy was applied three times daily for 20 minutes per session to aid sputum clearance. Patients underwent weaning training, extubation preparation, and active respiratory muscle exercises.

Passive exercises involved elevating the head of the bed to 30° and placing patients in a comfortable lateral position for turning and assisted percussion (10 minutes per session, 3-4 times daily). Passive joint range-of-motion exercises - flexion, extension, adduction, abduction, pronation, and supination - were performed on all limbs twice daily, with at least 8 repetitions per movement. Neuromuscular electrical stimulation (NMES) targeting major lower limb muscles (e.g., quadriceps, tibialis anterior) was administered once daily for up to 30 minutes. Pneumatic compression therapy was also applied to the lower limbs three times daily, 15 minutes per session.

Active exercises emphasized joint mobility against gravity, active bed turning, and activities of daily living (ADLs) training, such as main-

taining bed posture, oral care, face washing, feeding, and dressing.

Phase II: Patients sat on the edge of the bed with legs suspended for up to 30 minutes per session, twice daily.

Phase III: Patients performed bed-to-chair transfers at least 15 times daily. Ambulation training with a walker was conducted for a minimum of 30 minutes per session, twice daily, until successful weaning from mechanical ventilation.

Nursing staff assisted with rehabilitation exercises, monitored vital signs, administered medications, and performed essential care tasks, including oral hygiene, skin care, and ventilator tube maintenance.

Psychological counselors engaged in daily sessions with patients to assess mental status, alleviate anxiety, fear, and treatment resistance, and foster motivation. They also facilitated bedside family visits to enhance emotional well-being.

Dietitians developed individualized meal plans based on patient preferences, emphasizing a diet low in fat and sodium but rich in calcium and essential nutrients.

Throughout the rehabilitation process, the MDT conducted ongoing evaluations of patient status and treatment efficacy to adjust the intensity and duration of interventions accordingly. MDT-based care was discontinued if the patient's condition changed significantly or at the time of discharge.

Outcome measures

The primary outcome of this study was the incidence of ICU-AW, assessed on post-intervention days 1, 4, and 7. Secondary outcomes included:

The total Medical Research Council (MRC) score, evaluated at baseline, during, and after the intervention, along with separate assessments of upper and lower limb muscle strength before and after the intervention [12].

Functional independence, measured using the Barthel Index throughout the intervention period [16].

Organ failure, assessed using the Sequential Organ Failure Assessment (SOFA) score at baseline, during, and after the intervention [17].

Acute and chronic health status, evaluated via the Acute Physiology and Chronic Health Evaluation II (APACHE II) score before and after the intervention [18].

Other outcomes included ICU length of stay, total hospital stay, duration of mechanical ventilation, incidence of complications (e.g., ventilator-associated pneumonia), and patient satisfaction at discharge.

The MRC sum score [12] evaluates muscle strength across six bilateral muscle groups, ranging from 0 (quadriplegia) to 60 (normal strength), with scores < 48 commonly used to diagnose ICU-AW. Although widely regarded as the gold standard, MRC assessment is subject to inter-rater variability due to its subjective nature.

The Barthel Index [16] assesses 10 basic ADLs; higher scores reflect greater independence and self-care capacity.

The SOFA score [17] evaluates six organ systems, including hematologic, respiratory, and circulatory functions, with a maximum score of 24. Higher scores indicate greater severity of illness.

The APACHE II score [18] includes 12 physiological parameters, with a maximum of 71 points. A score ≥ 15 indicates critical illness.

Patient satisfaction was measured using a self-developed questionnaire from our department, completed by patients prior to discharge. The questionnaire included 20 items covering diagnostic services, disease condition, nursing services, psychological needs, and accompanying symptoms. Each item was rated on a 5-point Likert scale (1 = very dissatisfied to 5 = very satisfied), for a total possible score of 100.

All outcome measures used in this study have demonstrated validity and reliability in ICU/acute care settings. Baseline assessments were conducted by recruiting nurses. Functional outcomes (MRC sum score, Barthel Index) during and after ICU stay were independently evaluated by two physiotherapists. All other

clinical outcomes were recorded by research personnel.

Quality control

All interventions were administered by senior specialists with over 10 years of clinical experience. Data used for statistical analysis were reviewed and verified by the MDT leader to ensure accuracy and reliability.

Statistical analysis

Statistical analysis was performed by an independent statistician using SPSS version 27.0 and GraphPad Prism version 9.1.1. The Shapiro-Wilk test and Levene's test were used to assess normality and homogeneity of variance, respectively.

Data conforming to normal distribution were presented as mean ± standard deviation ($\bar{x}$ ± s). Between-group comparisons were performed using one-way ANCOVA, and within-group comparisons used paired t-tests. Non-normally distributed data were expressed as median and interquartile range, and compared using the Wilcoxon test. Categorical data, expressed as frequencies (n) and percentages (%), were analyzed using Chi-Square Test. The measurements at different time points were measured by repeated measure ANOVA and posthoc pair comparison (LSD).

A logistic regression model was applied to assess the effect of the observation group on ICU-AW incidence, adjusting for covariates such as APACHE II and MRC scores. Covariate selection followed the change-in-estimate approach: covariates producing < 10% change in the odds ratio (OR) upon removal were excluded from the final model. Statistical significance was set at $P < 0.05$.

Results

Comparison of patient characteristics

The demographic and baseline clinical characteristics of participants were well balanced between the control and observation groups. No statistically significant differences were observed in age, sex, BMI, education level, cancer type, APACHE II score, $PaCO_2$, PaO_2/FiO_2 ratio, or mean arterial pressure (MAP) (all $P > 0.05$; **Table 2**).

Comparison of ICU-AW incidence

On day 1 of treatment, there was no significant difference in the incidence of ICU-AW between the two groups ($P > 0.05$). However, by days 4 and 7, the incidence of ICU-AW was significantly lower in the observation group compared to the control group (both $P < 0.05$; **Table 3**).

Comparison of muscle strength assessment indicators

Prior to the intervention, no significant differences were found between groups in MRC scores, upper limb strength, or lower limb strength (all $P > 0.05$). Post-intervention, both groups showed significant improvements in all three indicators (all $P < 0.05$). Moreover, the observation group demonstrated significantly higher post-intervention scores in MRC, upper limb, and lower limb strength compared to the control group (all $P < 0.05$; **Figure 2**).

Comparison of daily MRC score, Barthel index and SOFA score (days 0-7)

From day 0 to day 7, both groups exhibited a progressive increase in MRC scores starting from day 4, with the observation group consistently showing higher scores than the control group ($P < 0.05$; **Figure 3A**). The Barthel Index also improved significantly in both groups ($P < 0.05$), following a pattern similar to that of MRC score changes (**Figure 3B**). SOFA scores declined in both groups beginning on day 5, with the observation group exhibiting significantly lower scores compared to the control group ($P < 0.05$; **Figure 3C**).

Comparison of treatment duration parameters

Patients in the observation group had significantly shorter ICU stays, total hospital stays, and durations of mechanical ventilation than those in the control group (all $P < 0.05$; **Figure 4**).

Comparison of SOFA and APACHE II scores post-intervention and complications during treatment

Post-intervention, both SOFA and APACHE II scores were significantly lower in the observation group compared to the control group (both

Table 2. Patient characteristics

Parameter	Control (n = 40)	Observation (n = 40)	t/χ^2	*P*
Age (years, mean ± SD)	51.71 ± 15.53	52.06 ± 15.11	0.102	0.919
Sex (n%)			0.058	0.809
Male	27 (67.50)	28 (70.00)		
Female	13 (32.50)	12 (30.00)		
BMI (kg/m^2, mean ± SD)	24.23 ± 4.02	23.98 ± 3.86	0.284	0.777
Education level			1.736	0.629
Primary school or less	11 (27.50)	11 (27.50)		
Middle school	17 (42.50)	12 (30.00)		
High school	8 (20.00)	11 (27.50)		
College or above	4 (10.00)	6 (15.00)		
Types of cancer (n%)			2.293	0.807
Lung cancer	8 (20.00)	9 (22.50)		
Gastric cancer	8 (20.00)	8 (20.00)		
Colorectal cancer	7 (17.50)	8 (20.00)		
Breast cancer	6 (15.00)	7 (17.50)		
Prostate cancer	5 (12.50)	6 (15.00)		
Others	6 (15.00)	2 (5.00)		
Comorbidities (n%)			1.077	0.956
Renal failure	6 (15.00)	5 (12.50)		
Gastrointestinal/Liver diseases	4 (10.00)	6 (15.00)		
Respiratory diseases	3 (7.50)	4 (10.00)		
Acute pancreatitis	4 (10.00)	3 (7.50)		
Heart diseases	2 (5.00)	3 (7.50)		
Others	21 (52.50)	19 (47.50)		
APACHA II score (score, mean ± SD)	15.41 ± 2.11	15.42 ± 2.08	0.021	0.983
$PaCO_2$ (muHg, mean ± SD)	50.16 ± 7.13	50.54 ± 7.87	0.226	0.822
$PxOFiO_2$ (mmHg, mean ± SD)	138.79 ± 8.11	137.17 ± 5.02	1.074	0.286
MAP (mmHg, mean ± SD)	94.66 ± 6.52	95.85 ± 7.23	0.773	0.442

Note: $PaCO_2$: Partial Pressure of Carbon Dioxide in Arterial Blood; PxO_2/FiO_2: Ratio of Partial Pressure of Oxygen in Arterial Blood to Fraction of Inspired Oxygen; MAP: Mean Arterial Pressure; BMI: Body Mass Index; APACHE II: Acute Physiology and Chronic Health Evaluation II.

Table 3. Comparison of ICU-AW incidence between the two groups (n%)

Group	Day 1	Day 4	Day 7
Control (n = 40)	2 (5.00)	6 (15.00)[a]	8 (20.00)[a,b]
Observation (n = 40)	1 (2.50)	1 (2.50)[a]	2 (5.00)[a,b]
t	0.346	3.914	4.114
P	0.556	0.048	0.043

Note: Compared to day 1, [a]$P < 0.05$; compared to Day 4, [b]$P > 0.05$.

Analysis of predictive variables for ICU-AW

The risk of developing ICU-AW in the observation group was a significant reduction in risk than in the control group (OR = 0.067, 95% CI: 0.005-0.606, P = 0.017; **Table 5**).

Comparison of patient satisfaction

P < 0.05). One case of ventilator-associated pneumonia occurred in the control group, while no such cases were reported in the observation group. However, this difference in complication rates was not statistically significant (P > 0.05; **Table 4**).

Scores for diagnostic and treatment services, disease condition, nursing care, psychological support, accompanying symptoms, and overall satisfaction were all significantly higher in the observation group than in the control group (all P < 0.05; **Table 6**).

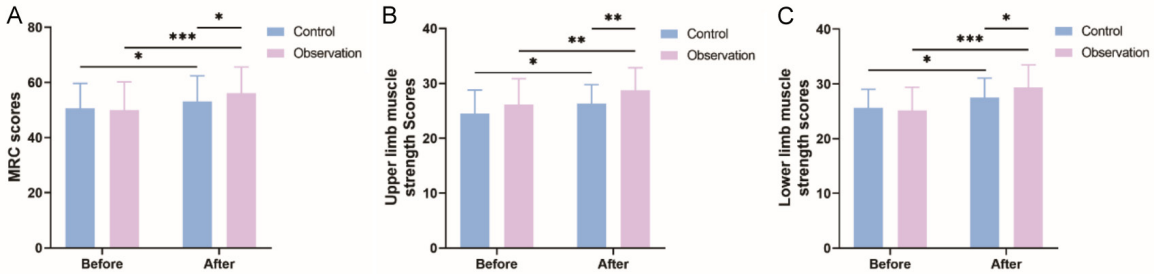

Figure 2. Comparison of muscle strength assessment indicators between two groups. Note: A: MRC scores; B: Upper limb muscle strength scores; C: Lower limb muscle strength scores; MRC, Medical Research Council; *: $P < 0.05$; **: $P < 0.01$; ***: $P < 0.001$.

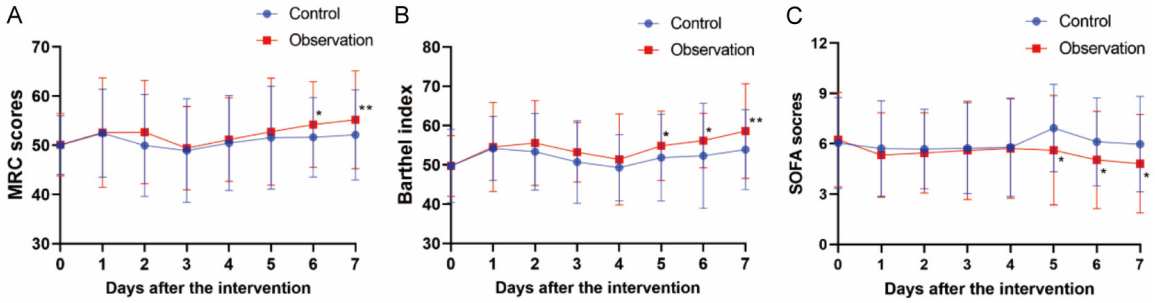

Figure 3. Comparison of mean daily MRC score, Barthel index and SOFA score per trial day 0-7 for the two groups. Note: A: MRC scores; B: Barthel index; C: SOFA scores; MRC, Medical Research Council; SOFA, Sequential Organ Failure Assessment; *: $P < 0.05$; **: $P < 0.01$.

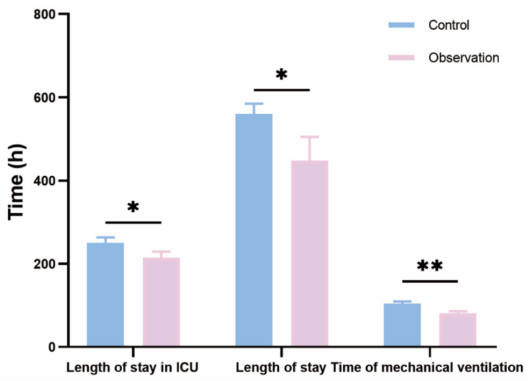

Figure 4. Comparison of treatment duration parameters between the two groups. Note: *: $P < 0.05$; **: $P < 0.01$.

Discussion

The findings of this study demonstrate that, compared to conventional rehabilitation therapy, MDT-based cardiopulmonary rehabilitation significantly improves the prevention of ICU-AW, muscle strength, functional independence, organ function, ICU stay duration, total hospitalization time, mechanical ventilation duration, and patient satisfaction. During the intervention period, one case of ventilator-associated pneumonia occurred in the control group, whereas no such cases were reported in the observation group; however, the difference in complication rates was not statistically significant.

The results also indicated a gradual increase in ICU-AW incidence with prolonged mechanical ventilation in both groups, particularly between days 4 and 7 post-intervention - an observation consistent with the findings of Sinha et al. [19]. No significant difference in ICU-AW incidence was found between the two groups on the first day of intervention. However, by days 4 and 7, the incidence was significantly lower in the observation group, suggesting that MDT-based cardiopulmonary rehabilitation effectively prevents ICU-AW, aligning with the results reported by Anekwe et al. [20].

Anekwe's study emphasized the importance of early, comprehensive rehabilitation in counteracting physiological changes associated with ICU-AW, including muscle mass preservation

Table 4. Comparison of the SOFA and APACHE II scores after the intervention and complications during the intervention period between the two groups

Group	SOFA (scores, mean ± SD)	APACHE II (scores, mean ± SD)	Complication (pneumonia) (n%)
Control (n = 40)	5.23 ± 2.11	17.12 ± 4.66	1 (2.5%)
Observation (n = 40)	4.16 ± 2.44	14.23 ± 6.46	0 (0.00%)
t/χ^2	2.098	2.295	1.013
P	0.039	0.024	0.314

Note: SOFA: Sequential Organ Failure Assessment; APACHE II: Acute Physiology and Chronic Health Evaluation II.

Table 5. Impact of interventions on ICU-AW during ICU stay adjusted for covariates

Variables	OR (95% CI)	*P*
MRC score	1.269 (1.025-1.571)	0.029
APACHE II score	1.222 (1.072-1.392)	0.003
Study group		
Control	Referent	0.026
Observation	0.067 (0.005-0.606)	0.017

Note: MRC: Medical Research Council; APACHE II: Acute Physiology and Chronic Health Evaluation II; ICU-AW: intensive care unit-acquired weakness.

and neuromuscular function recovery. Similarly, a meta-analysis by Huang et al. [21] consolidated evidence from multiple studies, concluding that early mobility and rehabilitation programs significantly reduce ICU-AW risk. Proposed mechanisms include reduction of systemic inflammation, prevention of muscle atrophy, and maintenance of neuromuscular connectivity. These mechanisms are consistent with our study's findings and support the hypothesis that MDT-based rehabilitation may exert protective effects via similar physiological pathways.

The MRC score remains a key indicator in evaluating the prognosis of ICU-AW patients [22]. In the present study, both groups exhibited post-intervention improvements in MRC scores, upper limb, and lower limb muscle strength, with the observation group showing significantly greater gains. These findings are supported by Zhou et al. [12], who reported that early activity-based nursing interventions reduced ICU-AW incidence and improved MRC scores compared to routine care.

Our study further supports the notion that early MDT-guided cardiopulmonary rehabilitation promotes muscle fiber contraction and stretch, which may be particularly effective in preserving or enhancing lower limb muscle strength [23]. This benefit may stem from the physical stimulation provided by early mobilization, as well as the MDT's ability to tailor rehabilitation programs based on individual patient needs. By addressing physiological, psychological, and nutritional dimensions, the MDT approach enables personalized, precise rehabilitation, thereby improving overall treatment outcomes.

The SOFA score is widely used to assess and monitor organ dysfunction in critically ill patients. It allows for the repeated quantification of individual or multiple organ dysfunctions over time, thereby characterizing the progression or resolution of organ failure [19]. The Barthel Index reflects a patient's level of functional independence and is useful for evaluating disability and changes in functional status over time [25].

To capture changes in muscle strength, functional independence, and organ function during the intervention period, this study assessed MRC scores, Barthel Index, and SOFA scores for both groups over a 7-day period. Results showed that from day 0 to day 7, MRC scores gradually increased in both groups starting from day 4, with consistently higher scores in the observation group. The Barthel Index also improved significantly in both groups, mirroring the trend seen in MRC scores. SOFA scores began to decline from day 5, with significantly lower scores observed in the observation group.

These findings are consistent with a study by Othman et al. [2], in which early mobilization significantly reduced the incidence of ICU-AW on days 4, 7, and 10. The experimental group in their study also demonstrated higher MRC scores compared to the control group, indicating better muscle strength. Similarly, our results suggest that early MDT-based cardiopulmonary rehabilitation improves muscle strength, functional independence, and organ function.

Table 6. Comparison of patient satisfaction between the two groups (scores, mean ± SD)

Group	Diagnostic and treatment services	Disease condition	Nursing care	Psychological support	Accompanying symptoms	Total score
Control (n = 40)	15.51 ± 5.41	15.56 ± 5.71	17.53 ± 4.57	18.20 ± 4.61	16.24 ± 2.04	85.50 ± 8.24
Observation (n = 40)	12.53 ± 4.81	10.70 ± 4.97	11.02 ± 5.25	10.31 ± 5.08	14.26 ± 4.21	70.51 ± 7.61
t	2.604	4.060	5.915	7.274	2.677	8.685
P	0.011	< 0.001	< 0.001	< 0.001	0.009	< 0.001

The potential mechanisms underlying these improvements include prevention of muscle atrophy through early mobilization, enhanced maintenance of muscle mass and strength, and improved cardiopulmonary function, which in turn supports organ perfusion and oxygenation. Moreover, the MDT model enables comprehensive, individualized treatment plans tailored to patients' specific conditions and comorbidities, further enhancing recovery outcomes.

Difficulties in weaning from mechanical ventilation are a major contributor to prolonged ICU stays, increased healthcare costs, and resource strain [26]. In this study, the ICU stay, total hospital stay, and mechanical ventilation duration were significantly shorter in the observation group than in the control group. This benefit is likely attributable to the early implementation of MDT-led cardiopulmonary rehabilitation, which allows patients to safely participate in targeted physical and respiratory exercises, thereby accelerating ventilator weaning and recovery [27].

Post-intervention SOFA and APACHE II scores were significantly lower in the observation group, further confirming the effectiveness of early multidisciplinary rehabilitation. Only one case of ventilator-associated pneumonia occurred during the study, in the control group, with no statistically significant difference in complication rates. After adjusting for covariates, the risk of ICU-AW in the observation group was a significant reduction in risk than in the control group, indicating that both conventional and MDT-based interventions are safe and well-tolerated.

Patient satisfaction was also significantly higher in the observation group. This may be due to the involvement of a psychological counselor, who provided individualized mental health support and coordinated bedside visits with family members. Additionally, dietitians offered customized nutrition plans to improve patients' nutritional status. These supportive interventions likely contributed to increased patient confidence and enhanced recovery outcomes [28, 29].

This study employed a multidisciplinary collaborative model for cardiopulmonary rehabilitation in cancer patients with ICU-AW. Results confirmed that the model effectively reduced the incidence of ICU-AW, shortened mechanical ventilation and hospital duration, and improved muscle strength, functional recovery, and patient satisfaction. These findings provide valuable insights into ICU-AW management and underscore the pivotal role of multidisciplinary teams in critical care rehabilitation.

However, this study has limitations. The relatively short follow-up period may have restricted the evaluation of long-term or stage-specific outcomes, and the increased workload for healthcare professionals under the MDT model may limit its scalability in resource-constrained settings.

In conclusion, MDT-based cardiopulmonary rehabilitation is a safe and effective strategy for improving outcomes in critically ill cancer patients with ICU-AW. It significantly reduces the incidence of ICU-AW, shortens the duration of mechanical ventilation and hospital stay, enhances muscle strength and functional independence, and increases patient satisfaction, with a high level of safety.

Disclosure of conflict of interest

None.

Address correspondence to: Yajie Jia, Department of Critical Care Medicine, Puren Hospital Affiliated to Wuhan University of Science and Technology, No. 1, Benxi Street, Qingshan District, Wuhan 430081, Hubei, China. E-mail: 15997482094@163.com

References

[1] Wu TT, Chen QL, Lin XX, Xu ML, Chen XX, Luo CJ, Zhuang YN, Wei YQ, Wu JB, Xiong J, Chen LL and Li H. Effects of a multilevel intervention of resistance training with or without beta-hydroxy-beta-methylbutyrate in medical ICU patients during entire hospitalisation: a four-arm multicentre randomised controlled trial. Crit Care 2023; 27: 493.

[2] Othman SY, Elbiaa MA, Mansour ER, El-Menshawy AM and Elsayed SM. Effect of neuromuscular electrical stimulation and early physical activity on ICU-acquired weakness in mechanically ventilated patients: a randomized controlled trial. Nurs Crit Care 2024; 29: 584-596.

[3] Wei M, Huang M, Duan Y, Wang D, Xing X, Quan R, Zhang G, Liu K, Zhu B, Ye Y, Zhou D, Zhao J, Ma G, Jiang Z, Huang B, Xu S, Xiao Y, Zhang L, Wang H, Lin R, Ma S, Qiu Y, Wang C, Zheng Z, Sun N, Xian L, Li J, Zhang M, Guo Z, Tao Y, Zhang L, Zhou X, Chen W, Wang D and Chi J. Prognostic and risk factor analysis of cancer patients after unplanned ICU admission: a real-world multicenter study. Sci Rep 2023; 13: 22340.

[4] TEAM Study Investigators and the ANZICS Clinical Trials Group, Hodgson CL, Bailey M, Bellomo R, Brickell K, Broadley T, Buhr H, Gabbe BJ, Gould DW, Harrold M, Higgins AM, Hurford S, Iwashyna TJ, Serpa Neto A, Nichol AD, Presneill JJ, Schaller SJ, Sivasuthan J, Tipping CJ, Webb S and Young PJ. Early active mobilization during mechanical ventilation in the ICU. N Engl J Med 2022; 387: 1747-1758.

[5] Fabero-Garrido R, Del Corral T, Plaza-Manzano G, Sanz-Ayan P, Izquierdo-García J and López-de-Uralde-Villanueva I. Effects of respiratory muscle training on exercise capacity, quality of life, and respiratory and pulmonary function in people with ischemic heart disease: systematic review and meta-analysis. Phys Ther 2024; 104: pzad164.

[6] Fabero-Garrido R, Del Corral T, Angulo-Díaz-Parreño S, Plaza-Manzano G, Martín-Casas P, Cleland JA, Fernández-de-Las-Peñas C and López-de-Uralde-Villanueva I. Respiratory muscle training improves exercise tolerance and respiratory muscle function/structure post-stroke at short term: a systematic review and meta-analysis. Ann Phys Rehabil Med 2022; 65: 101596.

[7] Moisey LL, Merriweather JL and Drover JW. The role of nutrition rehabilitation in the recovery of survivors of critical illness: underrecognized and underappreciated. Crit Care 2022; 26: 270.

[8] Lamper C, Beckers L, Kroese M, Verbunt J and Huijnen I. Interdisciplinary care networks in rehabilitation care for patients with chronic musculoskeletal pain: a systematic review. J Clin Med 2021; 10: 2041.

[9] Vernooij JEM, Boerlage RM, Doggen CJM, Preckel B, Dirksen CD, van Leeuwen BL, Spruit RJ, Festen S, van der Wal-Huisman H, van Basten JP, Kalkman CJ and Koning NJ; PREPARATION study investigators. Is a preoperative multidisciplinary team meeting (cost)effective to improve outcome for high-risk adult patients undergoing noncardiac surgery: the PREPARATION study-a multicenter stepped-wedge cluster randomized trial. Trials 2023; 24: 660.

[10] Dong Z, Liu Y, Gai Y, Meng P, Lin H, Zhao Y and Xing J. Early rehabilitation relieves diaphragm dysfunction induced by prolonged mechanical ventilation: a randomised control study. BMC Pulm Med 2021; 21: 106.

[11] Unoki T, Hayashida K, Kawai Y, Taito S, Ando M, Iida Y, Kasai F, Kawasaki T, Kozu R, Kondo Y, Saitoh M, Sakuramoto H, Sasaki N, Saura R, Nakamura K, Ouchi A, Okamoto S, Okamura M, Kuribara T, Kuriyama A, Matsuishi Y, Yamamoto N, Yoshihiro S, Yasaka T, Abe R, Iitsuka T, Inoue H, Uchiyama Y, Endo S, Okura K, Ota K, Otsuka T, Okada D, Obata K, Katayama Y, Kaneda N, Kitayama M, Kina S, Kusaba R, Kuwabara M, Sasanuma N, Takahashi M, Takayama C, Tashiro N, Tatsuno J, Tamura T, Tamoto M, Tsuchiya A, Tsutsumi Y, Nagato T, Narita C, Nawa T, Nonoyama T, Hanada M, Hirakawa K, Makino A, Masaki H, Matsuki R, Matsushima S, Matsuda W, Miyagishima S, Moromizato M, Yanagi N, Yamauchi K, Yamashita Y, Yamamoto N, Liu K, Wakabayashi Y, Watanabe S, Yonekura H, Nakanishi N, Takahashi T and Nishida O; Committee for the Clinical Practice Guidelines of Early Mobilization and Rehabilitation in Intensive Care of the Japanese Society of Intensive Care Medicine. Japanese clinical practice guidelines for rehabilitation in critically ill patients 2023 (J-ReCIP 2023). J Intensive Care 2023; 11: 47.

[12] Zhou W, Yu L, Fan Y, Shi B, Wang X, Chen T, Yu H, Liu J, Wang X, Liu C and Zheng H. Effect of early mobilization combined with early nutrition on acquired weakness in critically ill patients (EMAS): a dual-center, randomized controlled trial. PLoS One 2022; 17: e0268599.

[13] Donelan K, DesRoches CM, Guzikowski S, Dittus RS and Buerhaus P. Physician and nurse practitioner roles in emergency, trauma, critical, and intensive care. Nurs Outlook 2020; 68: 591-600.

[14] Sharshar T, Grimaldi-Bensouda L, Siami S, Cariou A, Salah AB, Kalfon P, Sonneville R, Meunier-Beillard N, Quenot JP, Megarbane B,

Gaudry S, Oueslati H, Robin-Lagandre S, Schwebel C, Mazeraud A, Annane D, Nkam L and Friedman D; Suivi-Rea Investigators. A randomized clinical trial to evaluate the effect of post-intensive care multidisciplinary consultations on mortality and the quality of life at 1 year. Intensive Care Med 2024; 50: 665-677.

[15] Shimabukuro-Vornhagen A. Intensive care unit organization and interdisciplinary care for critically Ill patients with cancer. Crit Care Clin 2021; 37: 19-28.

[16] Mahoney FI and Barthel DW. Functional evaluation: the barthel index. Md State Med J 1965; 14: 61-65.

[17] Liu H, Zhang L, Xu F, Li S, Wang Z, Han D, Zhang F, Lyu J and Yin H. Establishment of a prognostic model for patients with sepsis based on SOFA: a retrospective cohort study. J Int Med Res 2021; 49: 3000605211044892.

[18] Wunderink RG, Matsunaga Y, Ariyasu M, Clevenbergh P, Echols R, Kaye KS, Kollef M, Menon A, Pogue JM, Shorr AF, Timsit JF, Zeitlinger M and Nagata TD. Cefiderocol versus high-dose, extended-infusion meropenem for the treatment of Gram-negative nosocomial pneumonia (APEKS-NP): a randomised, double-blind, phase 3, non-inferiority trial. Lancet Infect Dis 2021; 21: 213-225.

[19] Sinha RK, Sinha S, Nishant P and Morya AK. Intensive care unit-acquired weakness and mechanical ventilation: a reciprocal relationship. World J Clin Cases 2024; 12: 3644-3647.

[20] Anekwe DE, Biswas S, Bussières A and Spahija J. Early rehabilitation reduces the likelihood of developing intensive care unit-acquired weakness: a systematic review and meta-analysis. Physiotherapy 2020; 107: 1-10.

[21] Huang D, Zhao W, Chen Y, Shen B, Wang Y, Guan H and Luo W. Effect of mechanical ventilation and pulmonary rehabilitation in patients with ICU-acquired weakness: a systematic review and meta-analysis. Ann Palliat Med 2021; 10: 9594-9606.

[22] Latronico N and Gosselink R. A guided approach to diagnose severe muscle weakness in the intensive care unit. Rev Bras Ter Intensiva 2015; 27: 199-201.

[23] Chew STH, Kayambu G, Lew CCH, Ng TP, Ong F, Tan J, Tan NC and Tham SL. Singapore multidisciplinary consensus recommendations on muscle health in older adults: assessment and multimodal targeted intervention across the continuum of care. BMC Geriatr 2021; 21: 314.

[24] Lambden S, Laterre PF, Levy MM and Francois B. The SOFA score-development, utility and challenges of accurate assessment in clinical trials. Crit Care 2019; 23: 374.

[25] Dos Reis NF, Figueiredo FCXS, Biscaro RRM, Lunardelli EB and Maurici R. Psychometric properties of the barthel index used at intensive care unit discharge. Am J Crit Care 2022; 31: 65-72.

[26] Ambrosino N and Vitacca M. The patient needing prolonged mechanical ventilation: a narrative review. Multidiscip Respir Med 2018; 13: 6.

[27] Blackwood B, Alderdice F, Burns K, Cardwell C, Lavery G and O'Halloran P. Use of weaning protocols for reducing duration of mechanical ventilation in critically ill adult patients: cochrane systematic review and meta-analysis. BMJ 2011; 342: c7237.

[28] Lammila-Escalera E, Greenfield G, Barber S, Nicholls D, Majeed A and Hayhoe BWJ. A systematic review of interventions that use multidisciplinary team meetings to manage multimorbidity in primary care. Int J Integr Care 2022; 22: 6.

[29] Wischmeyer PE, Bear DE, Berger MM, De Waele E, Gunst J, McClave SA, Prado CM, Puthucheary Z, Ridley EJ, Van den Berghe G and van Zanten ARH. Personalized nutrition therapy in critical care: 10 expert recommendations. Crit Care 2023; 27: 261.