

Partial Mediation by Self-Efficacy of the Association Between Information-Motivation-Behavioral Skills Nursing and Quality of Life After Lung Cancer Cryoablation: A Retrospective Cohort Study With Propensity Score Matching

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Abstract

Background

The Information Motivation Behavioral Skills (IMB) model posits that behavioral skills, with self-efficacy as a core component, serve as the proximal mechanism through which information and motivation influence health outcomes. However, whether self-efficacy mediates the relationship between IMB-based perioperative nursing interventions and quality of life (QoL) in patients undergoing lung cancer cryoablation remains unexplored.

Methods

This single-center retrospective cohort study included 552 patients (268 IMB-based nursing, 284 routine care) treated between June 2023 and April 2025. One-to-one propensity score matching on 11 baseline covariates yielded 264 matched pairs (N = 528). Mediation analysis with 1,000 pair-level bootstrap resamples tested self-efficacy (Strategies Used by People to Promote Health [SUPPH] total at 3 months) as a mediator of the association between IMB nursing and QoL (Functional Assessment of Cancer Therapy–Lung [FACT-L] total at 3 months).

Results

The total effect of IMB nursing on QoL at 3 months was 5.13 points (95% CI, 3.33 to 6.87; $P < 0.001$). The indirect effect through self-efficacy (average causal mediation effect [ACME]) was 0.63 points (95% CI, 0.07 to 1.21; $P = 0.020$), 12.2% of the total effect, with a direct effect of 4.50 points. Self-efficacy was higher in the IMB group (a-path, 2.01 points; $P = 0.028$) and strongly associated with QoL (b-path, 0.31; $P < 0.001$). Indirect effects were significant across all five FACT-L subscales, although two showed inconsistent mediation (non-significant total effects). IMB nursing was associated with shorter length of stay (incidence rate ratio 0.77; $P < 0.001$). E-values for the ACME point estimate and its lower CI limit were 1.28 and 1.08. In a change-score-based sensitivity analysis, the ACME point estimate was of similar magnitude (0.54 points) but its 95% CI included zero ($P = 0.086$).

Conclusions

Self-efficacy at 3 months was a statistically significant but fragile partial mediator of the association between IMB-based perioperative nursing and QoL, although most of the association ($\approx 88\%$) was not attributable to differential self-efficacy. Because the mediator and the outcome were measured concurrently, temporal precedence cannot be established; the findings are consistent with—but do not prove—the IMB model's prediction that self-efficacy functions as a proximal mediator.

1. Introduction

Lung cancer remains the leading cause of cancer-related mortality worldwide, with an estimated 2.2 million new cases in 2020.¹ For patients who are medically inoperable because of cardiopulmonary comorbidity, advanced age, or multifocal disease, CT-guided argon–helium cryoablation provides a minimally invasive local treatment option.^{2,3} Recovery after cryoablation depends not only on technical procedural success but also on symptom monitoring, early recognition of postoperative complications, and patient engagement in rehabilitation—domains that are central to perioperative oncology nursing.

The IMB model, originally developed by Fisher and Fisher for HIV prevention⁴ and subsequently extended to chronic disease management⁵, provides a theoretically grounded framework for designing health behavior interventions. The model posits that health behavior change requires three interconnected components: accurate and personally relevant information, personal and social motivation to act on that information, and behavioral skills to execute the recommended actions effectively.⁶ A central prediction of the model is that behavioral skills—of which perceived self-efficacy, as conceptualized by Bandura, is a key constituent⁷—should function as the proximal mediator through which information and motivation exert their effects on health outcomes. The IMB model has been applied in diabetes self-management^{8,9} and cardiovascular rehabilitation¹⁰, and its components align with self-management and self-efficacy approaches in cancer care.^{11,12}

Despite the theoretical appeal of IMB-based nursing interventions, a critical gap remains: most IMB-based nursing studies have reported whether the intervention improves outcomes, but few have formally tested the model's mediation chain, so the question of how such programs work has largely been left unanswered. It is unclear to what extent self-efficacy functions as the mediating mechanism through which IMB-based perioperative nursing is associated with better QoL, and to what extent the benefit operates through other pathways. This distinction is clinically consequential: if self-efficacy is the primary mechanism, nursing resources should be concentrated on self-efficacy-building strategies (mastery experiences, vicarious learning, verbal persuasion); if it is only one of several mechanisms, programs should invest in the other components as well. Quantifying the mediated share therefore has direct implications for the design and resource allocation of perioperative nursing protocols.

The present study aimed to address this gap by empirically testing the mediation hypothesis derived from the IMB model in the context of lung cancer cryoablation recovery. Our objectives were: (1) to test whether self-efficacy, measured at 3 months post-procedure, mediates the association between IMB-based perioperative nursing and QoL at 3 months; (2) to examine whether the mediation differs across QoL subdomains (physical, social/family, emotional, and functional well-being, and lung cancer–specific symptoms); and (3) to analyze the association of IMB nursing with length of hospital stay as a health-service outcome. We employed propensity score matching (PSM) to strengthen confounding control and mediation analysis within a counterfactual framework. Based on the IMB model's theoretical logic, we hypothesized that self-efficacy would significantly mediate the association between IMB nursing and

QoL, particularly in the functional and emotional well-being domains. We did not make directional hypotheses for the remaining QoL subdomains.

2. Methods

2.1 Study Design and Setting

This single-center retrospective cohort study was conducted in the Department of Thoracic Surgery of the Second Affiliated Hospital of Army Medical University (Xinqiao Hospital, Chongqing, China). The 552 included patients underwent cryoablation between June 2023 and April 2025. Data were obtained from the electronic medical record system and a prospectively maintained nursing assessment questionnaire database.

The IMB-based perioperative nursing pathway was implemented in Thoracic Surgery Ward 1 from July 2023 onward; during the same period, Thoracic Surgery Ward 2 continued to provide routine perioperative care. Patients admitted to Ward 1 therefore received IMB-based nursing, and patients admitted to Ward 2 received routine care. Group assignment thus followed the ward of admission, which was determined by ward bed availability at the time of admission rather than by patient characteristics or randomization; both wards admitted patients from the same thoracic surgery service, and both protocols were delivered by the same nursing team, which limits provider-level confounding to some extent.

The descriptive rehabilitation outcomes of this pathway have been reported previously¹³, and the present cohort partially overlaps with that report. That earlier report presented unadjusted descriptive rehabilitation outcomes derived from group labels attached to the questionnaire database; the present analysis corrects the group assignment to the primary clinical database (ward-based group assignment), uses a propensity-matched design, and adds a formal causal mediation analysis that was not included in the previous report. A correction to the previous report has been prepared by the authors. This study is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.

2.2 Participants

The source cohort comprised 552 patients who underwent CT-guided argon–helium cryoablation for lung tumors and received either IMB-based (n = 268) or routine (n = 284) perioperative nursing. Inclusion criteria were: (1) age 18–80 years; (2) meeting clinical indications for percutaneous cryoablation of lung tumors; (3) ability to participate in perioperative nursing and follow-up assessments; and (4) availability of complete baseline and 3-month follow-up questionnaire data (a criterion that may introduce selection bias by excluding patients unable to complete the questionnaires; see Limitations). Exclusion criteria were: (1) active systemic infection at the time of the procedure; (2) severe organ dysfunction (e.g., hepatic or renal failure); (3) severe chronic obstructive pulmonary disease (Global Initiative for Chronic Obstructive Lung Disease [GOLD] stage III–IV); (4) coagulopathy contraindicating percutaneous

puncture; and (5) severe cognitive impairment or psychiatric disorder precluding participation in nursing activities.

2.3 IMB-Based Perioperative Nursing Intervention

The IMB-based pathway was delivered in three phases: preoperative (2–3 days before cryoablation), intraoperative (day of procedure), and postoperative (from the procedure day through discharge and follow-up). Information component: structured, individualized education covering the principles and procedural steps of cryoablation, expected postoperative symptoms and their normal trajectory, warning signs requiring immediate medical attention, and self-care strategies for wound management, activity resumption, and respiratory exercises, delivered through a printed illustrated patient handbook, bedside one-on-one teaching sessions (approximately 20 minutes each), and a short video demonstration of postoperative respiratory exercises. Motivation component: collaborative goal-setting between the patient and the primary nurse, positive reinforcement through verbal encouragement during each nursing encounter, sharing of recovery narratives from previous patients who had undergone cryoablation (with consent), and involvement of family members in goal-setting and encouragement. Behavioral skills component: supervised practice in deep breathing and effective coughing for pulmonary hygiene, use of a 0–10 numeric rating scale for pain self-reporting, gradual activity progression planning, and wound-care self-inspection, taught with a demonstrate–practice–feedback cycle in which the nurse modeled the skill, observed the patient performing it, and provided corrective feedback.

The control group received routine perioperative nursing, including standard preoperative orientation, postoperative monitoring of vital signs and the puncture site, as-needed pain management, and discharge instructions, without the structured education, motivational, or supervised behavioral skills practice components of the IMB program.

The intervention and the comparator are described following the items of the TIDieR (Template for Intervention Description and Replication) checklist where applicable.¹⁴ Because the pathway was delivered as routine clinical care, fidelity assessment (TIDieR item 11) was limited to routine clinical execution records, and no quantitative adherence score was prospectively collected for either group.

2.4 Variables and Measurements

2.4.1 Primary Outcome: Quality of Life

QoL was assessed with the Chinese version of the Functional Assessment of Cancer Therapy–Lung (FACT-L, version 4.0).^{15,16} The analytic dataset comprised 36 scored items across five subscales: Physical Well-Being (PWB, 7 items), Social/Family Well-Being (SWB, 7 items), Emotional Well-Being (EWB, 6 items), Functional Well-Being (FWB, 7 items), and the Lung Cancer Subscale (LCS, 9 items). Each item is rated 0–4, giving a total score range of 0–144, with higher scores indicating better QoL. The FACT-L was administered at hospital admission (baseline) and at 3 months post-cryoablation (primary endpoint). Out-of-range item values in the analytic dataset (seven cells at follow-up and one at baseline)

were treated as data-entry errors and truncated at the scale maximum of 4 before summing. Reverse-worded items were verified to have been scored in the standard direction at data entry. Internal consistency (Cronbach's alpha) at 3 months was 0.92; at baseline, responses exhibited restricted variability, and alpha could not be meaningfully estimated (near-zero and negative average inter-item covariance), consistent with uniform responding at admission—possibly reflecting completion under admission-related stress rather than true pre-procedural differences in QoL.

2.4.2 Hypothesized Mediator: Self-Efficacy

Self-efficacy was measured with the Chinese version of the Strategies Used by People to Promote Health (SUPPH) scale¹⁷, a 28-item instrument assessing confidence in performing self-care behaviors. Each item is rated 1–5 (1 = very little confidence, 5 = quite a lot of confidence), giving a total score range of 28–140, with higher scores indicating greater self-efficacy. Given that the published original scale supports 1–5 scoring and the raw data contained responses of 5, these values were retained rather than recoded or discarded to avoid arbitrary data manipulation. The SUPPH was administered at baseline and at 3 months post-cryoablation. Cronbach's alpha at 3 months was 0.80; as for the FACT-L, baseline responses exhibited restricted variability and baseline internal consistency could not be meaningfully estimated.

2.4.3 Secondary Outcome: Length of Stay

Length of stay (LOS) was defined as the number of days from hospital admission to discharge, extracted from the electronic medical record system.

2.4.4 Covariates

The following baseline covariates were extracted for PSM and adjusted analyses: age (years, continuous); sex; TNM (tumor–node–metastasis) stage (I–IV, ordinal); maximal tumor diameter (mm, continuous); lesion side (left/right); admission year (2023, 2024, 2025); history of prior lung surgery (yes/no); history of hypertension (yes/no); history of diabetes (yes/no); smoking history (ever/never); and histologic type (adenocarcinoma, squamous, other). These covariates were selected because they are plausibly associated with both treatment assignment and the outcomes of interest.

2.5 Sample Size

All eligible patients treated during the study period were included (n = 552). Because this retrospective analysis used a complete clinical database, no a priori sample-size calculation was performed. Post-hoc power was not formally computed for the mediation endpoints; we relied on multiple sensitivity analyses to assess the robustness of estimated effects.

2.6 Statistical Analysis

Analyses were performed with Python 3.12 (pandas, NumPy, SciPy, statsmodels). Continuous variables are reported as mean $\pm$ SD; categorical variables as counts with percentages. Continuous variables were

compared with Welch-adjusted two-sample t tests. Two-sided $P < 0.05$ was considered statistically significant.

2.6.1 Propensity Score Matching

One-to-one propensity score matching without replacement was performed with greedy nearest-neighbor matching within a caliper of $0.1 \times \text{SD}$ of the logit of the propensity score. The propensity score was estimated by logistic regression with the treatment group as the dependent variable and 11 covariates as predictors: age, sex, TNM stage (ordinal), tumor diameter, lesion side, prior lung surgery, hypertension, diabetes, smoking history, admission year (dummy-coded), and histologic type (dummy-coded). Among prespecified candidate specifications (calipers of 0.1 and $0.2 \times \text{SD}$ of the logit of the propensity score; treated units processed in ascending or descending propensity-score order; with and without exact matching on admission year and TNM stage), we selected the specification that minimized the maximum standardized mean difference (SMD) across the propensity-score model covariates, with ties broken in favor of more matched pairs. Crucially, model specifications were pre-specified before examining outcome data to avoid outcome-driven selection of matching parameters. Covariate balance was assessed with SMDs, with $\text{SMD} < 0.10$ considered adequate.¹⁸ The propensity score model discriminated group assignment with a C-statistic of 0.59, indicating modest discrimination; a C-statistic close to 0.5 reflects prediction near random chance, consistent with allocation driven primarily by ward bed availability rather than by measured patient characteristics. The matched cohort served as the primary analysis sample. Because treatment was allocated by ward, patients within a ward may be correlated beyond the measured covariates. Standard cluster-robust inference requires many more clusters than the two wards available here; clustering was therefore addressed by disclosure, covariate balance checks, and E-value sensitivity analyses rather than by cluster-robust variance estimation.

2.6.2 Mediation Analysis (Primary Analysis)

Mediation was analyzed within the counterfactual framework using the product-of-coefficients approach.¹⁹ The treatment variable was group assignment ($\text{IMB} = 1$, control = 0); the mediator was the SUPPH total score at 3 months; and the outcome was the FACT-L total score at 3 months. The mediator model regressed the SUPPH score at 3 months on group, baseline SUPPH, and baseline FACT-L; the outcome model regressed the FACT-L score at 3 months on group, the SUPPH score at 3 months, baseline SUPPH, and baseline FACT-L. The a-path is the group coefficient in the mediator model; the b-path is the SUPPH coefficient in the outcome model; the average causal mediation effect (ACME, the indirect effect) equals $a \times b$; the direct effect (c') is the group coefficient in the outcome model; the total effect equals $\text{ACME} + c'$; and the proportion mediated equals ACME/total . Because the mediator and the outcome were measured concurrently at the 3-month follow-up, the estimates cannot establish temporal precedence; the causal interpretation rests on the IMB model's theoretical assumption that self-efficacy precedes QoL. Because 1:1 matching creates correlated pairs, 95% confidence intervals and two-sided P values were obtained from 1,000 nonparametric bootstrap resamples drawn at the pair level (whole

matched pairs resampled as units), using percentile confidence intervals; analytic P values are reported for path coefficients. A subject-level bootstrap (resampling individual patients rather than matched pairs) was additionally performed as a sensitivity check. Separate models with the same specification were fitted for each FACT-L subscale (500 bootstrap resamples). Sensitivity analyses comprised: (1) the same models in the full, unmatched cohort (n = 552); (2) a fully adjusted model in the full cohort (all baseline covariates plus TNM stage and histology dummies); (3) exclusion of the matched pairs involving stage IV disease (a structural imbalance); (4) omission of baseline covariates from the mediator and outcome models; (5) a change-score analysis in which both the mediator and the outcome were analyzed as 3-month minus baseline differences (matched cohort, 1,000 pair-level bootstrap resamples); and (6) a random-forest propensity score specification (out-of-bag probabilities; 1:1 nearest-neighbour matching with the same caliper; Supplementary Table S5). In the change-score analysis, the mediator and outcome were computed as 3-month minus baseline differences and analyzed without further adjustment for baseline values, because the baseline is inherently accounted for in the difference score. Detailed results of these analyses are provided in the supplementary material (Tables S1–S5).

Interpretation of the ACME as an indirect effect rests on four assumptions^{20,21}: (i) no unmeasured exposure–mediator or exposure–outcome confounding, addressed by propensity score matching on 11 prespecified covariates, with residual ward-level confounding acknowledged in Section 4.5; (ii) no unmeasured mediator–outcome confounding, quantified by the E-values reported in Section 3.5; (iii) no exposure–mediator interaction, empirically supported in the matched cohort (group × self-efficacy interaction, -0.06 points per SUPPH point; 95% CI, -0.24 to 0.12; P = 0.51); and (iv) correct model specification and temporally ordered measurement. Because the mediator and the outcome were measured concurrently, assumption (iv) rests on the IMB model's theoretical premise that self-efficacy precedes QoL, as discussed in Section 4.5.

2.6.3 E-Values for Unmeasured Confounding

E-values were calculated for the ACME, the direct effect, and the total effect, standardized by the SD of the FACT-L total score at 3 months in the matched cohort (11.86 points). For a standardized effect d, the risk-ratio scale conversion is $RR = \exp(0.91 \times d)$, and the E-value is $RR + \sqrt{RR \times (RR - 1)}$.

2.6.4 Length of Stay

LOS was analyzed with negative binomial regression, with the dispersion parameter estimated by maximum likelihood; results are expressed as incidence rate ratios (IRRs) with 95% CIs. In the full cohort, the model adjusted for group, age, sex, TNM stage (ordinal), tumor diameter, lesion side, and admission year; in the matched cohort, it adjusted for group, age, sex, and admission year.

3. Results

3.1 Study Population and Propensity Score Matching

Of 552 patients with complete baseline and 3-month questionnaire data, 268 received IMB-based perioperative nursing and 284 received routine care. No patients were excluded for incomplete data after cohort entry, because complete questionnaires were an eligibility requirement; patients without such data were never represented in the source cohort, and the total number of patients screened before the eligibility assessment is not known (Fig. 1). Before matching, the groups were largely comparable on measured baseline characteristics, with the largest pre-match SMDs being 0.196 (admission year 2023) and 0.125 (tumor diameter) (Table 1). After 1:1 PSM, 264 matched pairs were retained (N = 528; 98.5% of IMB patients). The maximum SMD across the propensity-score model covariates was 0.104 (tumor diameter), which marginally exceeded the conventional 0.10 threshold (a between-group difference of 0.36 mm); the sensitivity analyses in Section 3.7, including full covariate adjustment for tumor diameter and exclusion of the stage IV pairs, yielded similar mediation estimates, suggesting that this small imbalance did not materially affect the results. In the expanded Table 1, individual category rows showed residual SMDs of 0.108 for TNM stage II and 0.151 for stage IV; the stage IV imbalance is structural (no stage IV patients in the IMB group vs three in the control group), and all other covariates had SMDs $\leq$ 0.095 (Table 1, Fig. 2). No stage-IV patients in the IMB arm limits inference for advanced-stage patients.

Figure 1. Participant flow. The flow diagram begins at the source-cohort level (n = 552) because the study used an existing clinical database; the total number of patients screened before the application of the eligibility criteria could not be determined. Patients without complete baseline and 3-month questionnaire data were ineligible and are therefore not represented in the source cohort; consequently, no patients were excluded for missing data after cohort entry. Of 552 patients with complete data (268 Ward 1 IMB-based nursing, 284 Ward 2 routine care; June 2023 to April 2025), propensity score matching retained 264 pairs (N = 528); 24 patients were unmatched (4 IMB, 20 routine care).

Table 1
Baseline characteristics before and after propensity score matching.

Variable	IMB Pre (n = 268)	Ctrl Pre (n = 284)	SMD	IMB Post (n = 264)	Ctrl Post (n = 264)	SMD
Age, years	59.19 (9.76)	59.16 (9.70)	0.003	59.17 (9.81)	59.30 (9.82)	0.013
Sex, male	113 (42.2%)	129 (45.4%)	0.066	110 (41.7%)	119 (45.1%)	0.069
TNM stage I	190 (70.9%)	214 (75.4%)	0.101	189 (71.6%)	198 (75.0%)	0.077
TNM stage II	54 (20.1%)	45 (15.8%)	0.112	53 (20.1%)	42 (15.9%)	0.108
TNM stage III	23 (8.6%)	22 (7.7%)	0.031	21 (8.0%)	21 (8.0%)	0.000
TNM stage IV [†]	0 (0.0%)	3 (1.1%)	0.144	0 (0.0%)	3 (1.1%)	0.151
Tumor diameter, mm	12.78 (3.98)	12.34 (2.94)	0.125	12.73 (3.98)	12.37 (2.97)	0.104
Lesion side, right	162 (60.4%)	181 (63.7%)	0.068	161 (61.0%)	164 (62.1%)	0.023
Histology, adenocarcinoma	245 (91.4%)	253 (89.1%)	0.079	241 (91.3%)	238 (90.2%)	0.039
Histology, squamous	14 (5.2%)	22 (7.7%)	0.102	14 (5.3%)	17 (6.4%)	0.048
Histology, other	9 (3.4%)	9 (3.2%)	0.011	9 (3.4%)	9 (3.4%)	0.000
Admission year 2023	48 (17.9%)	74 (26.1%)	0.196	48 (18.2%)	58 (22.0%)	0.095
Admission year 2024	158 (59.0%)	148 (52.1%)	0.138	154 (58.3%)	144 (54.5%)	0.076
Admission year 2025	62 (23.1%)	62 (21.8%)	0.031	62 (23.5%)	62 (23.5%)	0.000
Prior lung surgery	31 (11.6%)	36 (12.7%)	0.034	31 (11.7%)	35 (13.3%)	0.046
Hypertension	50 (18.7%)	60 (21.1%)	0.062	50 (18.9%)	57 (21.6%)	0.066
Diabetes	19 (7.1%)	17 (6.0%)	0.045	17 (6.4%)	15 (5.7%)	0.032
Smoking history	45 (16.8%)	39 (13.7%)	0.085	42 (15.9%)	35 (13.3%)	0.075

Values are mean (SD) for continuous variables and n (%) for categorical variables. Abbreviations: IMB, Information-Motivation-Behavioral Skills; SMD, standardized mean difference; SD, standard deviation; Ctrl, control. SMD < 0.10 indicates adequate covariate balance. Matching: 1:1 greedy nearest-neighbor without replacement, caliper $0.1 \times$ SD of the logit of the propensity score; propensity score from logistic regression on 11 covariates (age, sex, TNM stage, tumor diameter, lesion side, prior lung surgery, hypertension, diabetes, smoking history, admission year, histologic type). The maximum SMD across the

propensity-score model covariates after matching was 0.104 (tumor diameter); the stage IV SMD (0.151) reflects a structural imbalance (0 vs 3 patients). Slight residual imbalance in tumor diameter (SMD, 0.104) was addressed in the fully adjusted model (Supplementary Table S1), which adjusts for all baseline covariates including tumor diameter, and in the sensitivity analyses of Section 3.7. †Sensitivity analyses excluding the three affected pairs are reported in Supplementary Table S2.

Figure 2. Standardized mean differences (SMDs) before and after propensity score matching. Dashed line: SMD = 0.10. †TNM stage IV: a structural imbalance after matching (0 IMB vs 3 control patients; SMD 0.151), addressed in sensitivity analyses excluding the three affected pairs (Supplementary Table S2).

3.2 Self-Efficacy and Quality-of-Life Outcomes

At baseline, there were no statistically significant differences between groups in SUPPH or FACT-L total scores or any subscale in the matched cohort (all $P > 0.05$; Table 2). At 3 months, the IMB group scored higher than the control group on the SUPPH (96.67 ± 10.48 vs 94.67 ± 10.46 ; $P = 0.028$) and on the FACT-L total (100.50 ± 11.98 vs 95.58 ± 11.24 ; $P < 0.001$). Subscale differences were significant for EWB (17.18 ± 1.78 vs 15.91 ± 2.36 ; $P < 0.001$), FWB (19.95 ± 2.74 vs 18.22 ± 2.45 ; $P < 0.001$), and LCS (25.50 ± 3.17 vs 23.46 ± 2.78 ; $P < 0.001$), but not for PWB ($P = 0.339$) or SWB ($P = 0.572$). Within-group changes from baseline to 3 months were larger in the IMB group for the FACT-L (19.25 ± 12.24 vs 14.12 ± 12.38 ; $P < 0.001$); the difference in SUPPH change scores was not statistically significant (17.54 ± 11.20 vs 15.94 ± 11.28 ; $P = 0.102$). Although within-group SUPPH improvements were seen in both arms, the between-group difference in change-score did not reach statistical significance.

Table 2
Self-efficacy and quality-of-life scores in the matched cohort (N = 528).

Measure	IMB (n = 264)	Control (n = 264)	P value
SUPPH total, baseline	79.13 ± 4.24	78.73 ± 4.01	P = 0.264
SUPPH total, 3 months	96.67 ± 10.48	94.67 ± 10.46	P = 0.028
SUPPH change (3 months – baseline)	17.54 ± 11.20	15.94 ± 11.28	P = 0.102
FACT – L total, baseline	81.25 ± 4.06	81.46 ± 4.32	P = 0.554
FACT – L total, 3 months	100.50 ± 11.98	95.58 ± 11.24	P < 0.001
FACT – L change (3 months – baseline)	19.25 ± 12.24	14.12 ± 12.38	P < 0.001
FACT – L PWB, baseline	16.27 ± 2.70	16.31 ± 2.62	P = 0.870
FACT – L PWB, 3 months	18.95 ± 3.33	19.23 ± 3.58	P = 0.339
FACT – L SWB, baseline	15.07 ± 2.54	15.11 ± 2.73	P = 0.869
FACT – L SWB, 3 months	18.92 ± 3.16	18.76 ± 3.30	P = 0.572
FACT – L EWB, baseline	14.43 ± 2.13	14.62 ± 2.28	P = 0.314
FACT – L EWB, 3 months	17.18 ± 1.78	15.91 ± 2.36	P < 0.001
FACT – L FWB, baseline	15.69 ± 2.20	15.45 ± 2.35	P = 0.244
FACT – L FWB, 3 months	19.95 ± 2.74	18.22 ± 2.45	P < 0.001
FACT – L LCS, baseline	19.80 ± 2.77	19.97 ± 2.59	P = 0.446
FACT – L LCS, 3 months	25.50 ± 3.17	23.46 ± 2.78	P < 0.001

Values are mean ± SD. P values from Welch-adjusted two-sample t tests. Abbreviations: SUPPH, Strategies Used by People to Promote Health; FACT-L, Functional Assessment of Cancer Therapy–Lung; PWB, Physical Well-Being; SWB, Social/Family Well-Being; EWB, Emotional Well-Being; FWB, Functional Well-Being; LCS, Lung Cancer Subscale.

3.3 Primary Mediation Analysis

In the matched cohort, the a-path (group → SUPPH at 3 months, adjusted for baseline SUPPH and FACT-L) was 2.01 (95% CI, 0.25 to 3.70; P = 0.028), indicating significantly higher self-efficacy at 3 months in the IMB group. The b-path (SUPPH at 3 months → FACT-L at 3 months) was strong: 0.31 (95% CI, 0.23 to 0.40; P < 0.001). The direct effect (c') was 4.50 (95% CI, 2.75 to 6.31; P < 0.001), the total effect was 5.13 (95% CI, 3.33 to 6.87; P < 0.001), and the ACME (a × b) was 0.63 (95% CI, 0.07 to 1.21; P = 0.020), accounting for 12.2% of the total effect (Table 3, Fig. 3). With subject-level bootstrap resampling (resampling patients rather than pairs), the results were similar: ACME 0.63 (95% CI, 0.04 to 1.26; P =

0.044). Given concurrent measurement of mediator and outcome, these estimates should be interpreted as associational only (see Section 2.6.2).

Table 3
Mediation analysis of the association between IMB nursing and the FACT-L total score at 3 months through self-efficacy (SUPPH at 3 months), matched cohort (N = 528).

Path	Estimate (95% CI)	P value
a-path (IMB → SUPPH at 3 months)	2.01 (0.25 to 3.70)	P = 0.028
b-path (SUPPH at 3 months → FACT - L at 3 months)	0.31 (0.23 to 0.40)	P < 0.001
Direct effect c'	4.50 (2.75 to 6.31)	P < 0.001
ACME (indirect effect, $a \times b$)	0.63 (0.07 to 1.21)	P = 0.020
Total effect	5.13 (3.33 to 6.87)	P < 0.001
Proportion mediated	12.2%	—

Models adjusted for baseline SUPPH and baseline FACT-L. 95% CIs from 1,000 pair-level nonparametric bootstrap resamples (percentile method); two-sided bootstrap P values for the ACME and total effect, analytic P values for path coefficients. Abbreviations: ACME, average causal mediation effect; CI, confidence interval.

Figure 3. Path diagram of the mediation model for the FACT-L total score at 3 months (matched cohort, N = 528; 264 pairs). ACME ($a \times b$) = 0.63 points (95% CI, 0.07 to 1.21; P = 0.020); total effect = 5.13 points (95% CI, 3.33 to 6.87; P < 0.001); proportion mediated = 12.2%. Models adjusted for baseline SUPPH and baseline FACT-L; 95% CIs from 1,000 pair-level bootstrap resamples; two-sided bootstrap P values for the ACME and total effect, analytic P values for path coefficients. Note: The mediator (SUPPH at 3 months) and the outcome (FACT-L at 3 months) were measured at the same time point; temporal precedence cannot be empirically established, and the estimates should be interpreted as associational rather than as definitive causal effects.

3.4 Mediation Across FACT-L Subscales

All five subscales showed statistically significant indirect effects through self-efficacy: PWB 0.12 (95% CI, 0.02 to 0.25; P = 0.024), SWB 0.14 (95% CI, 0.02 to 0.28; P = 0.016), EWB 0.10 (95% CI, 0.01 to 0.21; P = 0.024), FWB 0.13 (95% CI, 0.01 to 0.25; P = 0.024), and LCS 0.13 (95% CI, 0.01 to 0.25; P = 0.020) (Table 4). Direct effects were significant for EWB (1.21; 95% CI, 0.88 to 1.54), FWB (1.63; 95% CI, 1.23 to 2.03), and LCS (1.95; 95% CI, 1.46 to 2.52) (all P < 0.001), but not for PWB (− 0.36; P = 0.217) or SWB (0.06; P = 0.820). The total effect was not statistically significant for PWB (− 0.24; P = 0.432) or SWB (0.20; P = 0.440); the significant indirect effects in these two domains should therefore be interpreted cautiously (inconsistent mediation), and the proportion mediated is numerically unstable when the total effect is near zero. Inconsistent mediation of this kind can arise when the indirect pathway is offset by

an opposite-signed direct pathway, and it does not by itself indicate a meaningful benefit of IMB nursing in the PWB and SWB domains.

Table 4
Mediation analysis for the five FACT-L subscales at 3 months, matched cohort (N = 528).

Subscale	ACME (95% CI)	P	Direct effect (95% CI)	P	Total effect (95% CI)	P	Prop. med.
PWB	0.12 (0.02 to 0.25)	P = 0.024	-0.36 (- 0.96 to 0.20)	P = 0.217	-0.24 (- 0.83 to 0.31)	P = 0.432	—*
SWB	0.14 (0.02 to 0.28)	P = 0.016	0.06 (- 0.46 to 0.58)	P = 0.820	0.20 (- 0.34 to 0.73)	P = 0.440	—*
EWB	0.10 (0.01 to 0.21)	P = 0.024	1.21 (0.88 to 1.54)	P < 0.001	1.31 (0.97 to 1.65)	P < 0.001	7.7%
FWB	0.13 (0.01 to 0.25)	P = 0.024	1.63 (1.23 to 2.03)	P < 0.001	1.76 (1.33 to 2.20)	P < 0.001	7.2%
LCS	0.13 (0.01 to 0.25)	P = 0.020	1.95 (1.46 to 2.52)	P < 0.001	2.08 (1.56 to 2.69)	P < 0.001	6.1%

Models adjusted for baseline SUPPH and the corresponding baseline subscale; 500 pair-level bootstrap resamples; two-sided bootstrap P values for the ACME and total effect, analytic P values for path coefficients. Abbreviations: ACME, average causal mediation effect; CI, confidence interval; PWB, Physical Well-Being; SWB, Social/Family Well-Being; EWB, Emotional Well-Being; FWB, Functional Well-Being; LCS, Lung Cancer Subscale. *The total effects for these subscales were not statistically significant (inconsistent mediation); the indirect-effect estimates for these subscales should not be interpreted as evidence of IMB-nursing benefit.

3.5 Sensitivity Analysis: E-Values

The E-value for the ACME point estimate was 1.28, and the E-value for the lower 95% CI limit was 1.08; the E-value for the total effect was 2.33 (Table 5). An unmeasured confounder associated with both the mediator and the outcome by a risk ratio of at least 1.28 (above and beyond the measured covariates) would be required to explain away the ACME point estimate. The CI-limit E-value of 1.08 is low relative to the strength that plausible confounders—such as ward-level factors, health literacy, or baseline psychological distress—could have, indicating that the statistical significance of the indirect effect is fragile to unmeasured confounding; the total effect is comparatively more robust (E-value 2.33). For the direct effect (4.50 points), the corresponding E-values were 2.18 (point estimate) and 1.77 (lower 95% CI limit), indicating that the overall IMB-QoL association is considerably less sensitive to unmeasured confounding than the mediated pathway.

Table 5
E-values for unmeasured confounding
(matched cohort).

Quantity	E-value
ACME (0.63 points)	1.28
ACME, lower 95% CI limit	1.08
Direct effect (4.50 points)	2.18
Direct effect, lower 95% CI limit	1.77
Total effect (5.13 points)	2.33

E-values computed from effects standardized by the SD of the FACT-L total score at 3 months in the matched cohort (11.86 points): for standardized effect d , $RR = \exp(0.91 \times d)$ and $E = RR + \sqrt{RR \times (RR - 1)}$ ²¹. The E-value is the minimum strength of association (risk-ratio scale) that an unmeasured confounder would need with both the mediator and the outcome to explain away the observed effect, conditional on the measured covariates.

3.6 Length of Stay

In the matched cohort, the mean LOS was 1.70 ± 1.57 days in the IMB group and 2.21 ± 2.05 days in the control group ($P = 0.001$). Negative binomial regression (dispersion estimated by maximum likelihood; dispersion parameter $\alpha = 0.22$, adjusted for group, age, sex, and admission year) yielded an IRR of 0.77 (95% CI, 0.66 to 0.89; $P < 0.001$), corresponding to an approximately 23% reduction in expected LOS. In the full cohort, the estimate was similar: IRR 0.77 (95% CI, 0.67 to 0.89; $P < 0.001$; $\alpha = 0.21$) (Table 6). Because cryoablation is minimally invasive and the mean LOS was below 2.5 days in both groups, this relative reduction corresponds to a modest absolute saving per patient (0.51 days in the matched cohort). To assess potential secular changes, we added group $\times$ admission-year interaction terms to the full-cohort model; the interactions were not statistically significant ($P = 0.57$ for 2024 and $P = 0.44$ for 2025; joint $P = 0.73$), providing no evidence that the LOS association changed across the study period.

Table 6
Length of hospital stay by group.

Cohort	IMB mean (SD), days	Control mean (SD), days	IRR (95% CI)	P value
Matched (n = 264 per group)	1.70 ± 1.57	2.21 ± 2.05	0.77 (0.66 to 0.89)	$P < 0.001$
Full (n = 268 / 284)	1.69 ± 1.56	2.22 ± 2.07	0.77 (0.67 to 0.89)	$P < 0.001$

IRR, incidence rate ratio from negative binomial regression (dispersion estimated by maximum likelihood; dispersion parameter $\alpha = 0.22$ [matched cohort] and 0.21 [full cohort]). Matched cohort model

adjusted for group, age, sex, and admission year; full-cohort model adjusted for group, age, sex, TNM stage, tumor diameter, lesion side, and admission year. IRR < 1 indicates shorter LOS in the IMB group.

3.7 Sensitivity Analyses of the Mediation Model

Sensitivity analyses of the mediation model were consistent with the primary analysis (Fig. 4). In the full, unmatched cohort (n = 552; Supplementary Table S1), in a fully adjusted model in the full cohort (Supplementary Table S1), in a model excluding the three matched pairs involving stage IV disease (261 pairs; Supplementary Table S2), in a model omitting baseline covariates (Supplementary Table S3), and in a model in which the propensity score was estimated by a random forest instead of logistic regression (out-of-bag probabilities; 250 pairs; Supplementary Table S5), the ACME ranged from 0.58 to 0.86 points and remained statistically significant in every specification ($P \leq 0.046$). In the random-forest specification, covariate balance was somewhat poorer than in the primary logistic specification (maximum SMD, 0.28 vs 0.10), and the indirect effect was larger (ACME, 0.86 points; 95% CI, 0.28 to 1.48; $P = 0.004$). In the change-score analysis (mediator and outcome analyzed as 3-month minus baseline differences; Supplementary Table S4), the ACME point estimate was similar (0.54 points) but the 95% CI included zero (-0.08 to 1.19; $P = 0.086$), underscoring the fragility of the indirect effect already indicated by the E-values.

Figure 4. Forest plot of the average causal mediation effect (ACME) across the primary analysis and the sensitivity analyses. Squares represent point estimates and horizontal lines 95% percentile-bootstrap confidence intervals; the dashed vertical line marks the null (ACME = 0). Primary specification: matched cohort (264 pairs); random-forest propensity score specification: 250 pairs; full-cohort specifications: N = 552; excluding-stage-IV specification: 261 pair.

4. Discussion

4.1 Summary of Principal Findings

In this propensity-matched retrospective cohort of 528 patients undergoing lung cancer cryoablation, self-efficacy measured at 3 months was a statistically significant partial mediator of the observed association between IMB-based perioperative nursing and QoL: the indirect effect (ACME) was 0.63 points, accounting for 12.2% of the estimated total effect of 5.13 points. The IMB program was associated with higher self-efficacy after baseline adjustment (a-path, 2.01 points), self-efficacy was strongly associated with QoL (b-path, 0.31), and a substantial direct estimate ($c' = 4.50$ points) remained. Indirect-effect estimates were statistically significant in all five QoL subscales; however, for PWB and SWB the corresponding total effects were not significant (inconsistent mediation), and those two estimates should be interpreted cautiously. IMB nursing was also associated with an approximately 23% shorter expected length of stay (IRR 0.77). Because the mediator and the outcome were measured concurrently, the mediation interpretation rests on the IMB model's theoretical ordering rather than on observed temporal precedence.

4.2 Interpretation and Mechanisms

Conditional on the identifying assumptions of the mediation model (no unmeasured mediator–outcome confounding and no reverse causation), these results provide empirical support for a core mechanistic prediction of the IMB model: the behavioral skills component, indexed by self-efficacy, appears to carry part of the program's benefit to QoL. At the same time, most of the association ($\approx 88\%$) operated through pathways other than differential self-efficacy enhancement. Candidate direct pathways—plausible but untested—include structured information that reduces uncertainty and anxiety about the procedure and recovery trajectory, systematic postoperative symptom monitoring that enables earlier detection and management of complications, standardized care processes that reduce variability in care quality, and a stronger therapeutic alliance between patient and nurse. We cannot quantify the relative contribution of these individual direct pathways in the present dataset. The direct effect was considerably more robust to unmeasured confounding than the mediated pathway (E-value, 2.18; E-value for the lower 95% CI limit, 1.77), indicating that the overall IMB–QoL association does not rest on the mediation chain alone. The modest size of the a-path is consistent with both groups receiving high-quality nursing in a tertiary center; the strong b-path confirms that self-efficacy is a robust correlate of QoL in this population, consistent with the broader cancer self-efficacy literature.^{12,17}

4.3 Comparison With Existing Literature

Our group previously reported the descriptive rehabilitation outcomes of this nursing pathway¹³; the present analysis corrects the group assignment to the primary clinical database and adds a formal counterfactual mediation analysis. IMB-based interventions have improved self-management outcomes in diabetes^{8,9} and in patients undergoing coronary artery bypass grafting¹⁰, but formal tests of the model's mediation chain in oncology nursing remain scarce. Mediation analyses are susceptible to selective reporting, and significant indirect effects in the literature should be interpreted in light of publication bias toward positive findings²²; we therefore report both the point estimate and the proportion mediated together with their confidence intervals and E-values. The LOS reduction is directionally consistent with the broader literature on structured perioperative care and enhanced recovery pathways^{23,24}, although the absolute LOS values in this cohort are shorter because cryoablation is minimally invasive.

The modest mediated share (12.2%) also merits discussion in relation to the IMB model itself. The model positions behavioral skills as the proximal determinant of health behavior change, so a larger mediated component might have been anticipated. One reading is that the mediation chain is less prominent in a perioperative, provider-delivered setting, in which the information and motivation components can act directly on symptom experience and emotional well-being without first producing durable behavioral-skills gains. An alternative reading is that self-efficacy, as measured by the SUPPH, captures only part of the behavioral-skills construct, so the 12.2% figure may underestimate the true mediated share. Both readings are compatible with the data, and both imply that future IMB-based

programs in this setting should retain the information and motivation components rather than concentrate resources on behavioral-skills training alone.

4.4 Implications for Nursing Practice

These findings have direct implications for program design. Self-efficacy-building components (supervised skills practice, goal-setting, positive reinforcement) deserve retention in IMB programs because self-efficacy carries a measurable share of the QoL association. However, the structured information, symptom monitoring, and care standardization components accounted for most of the observed association and should not be traded away in favor of exclusively psychological components. The LOS finding suggests efficiency gains: illustratively, for a unit performing 200 cryoablations per year, the observed mean difference of 0.51 days per patient would free approximately 102 bed-days per year. This bed-day projection assumes consistent patient case-mix and adherence to the IMB nursing protocol across time.

In absolute terms, the estimated total effect of 5.13 points corresponds to a Cohen's d of 0.43, standardized by the SD of the FACT-L total score at 3 months in the matched cohort (11.86 points). This moderate standardized difference is of a similar order of magnitude to the 2–3-point (LCS) and 5–7-point (TOI) changes proposed as upper limits for clinically meaningful change on the FACT-L.²⁵ By contrast, the mediated component (0.63 points; Cohen's d = 0.05) is far below those thresholds and should be regarded as statistically, but not necessarily clinically, meaningful on its own; the practical importance of the indirect pathway lies in identifying self-efficacy as one mechanism among several rather than as the dominant mechanism.

4.5 Limitations

Several limitations warrant consideration. First, the retrospective, non-randomized design and ward-based allocation leave open the possibility of ward-level confounding (e.g., staffing, ward environment, and correlated care processes within a ward). With only two wards, cluster-robust variance estimation is not feasible, so this source of uncertainty could not be quantified statistically, and the reported confidence intervals may therefore be slightly too narrow. Detailed ward-level staffing data were not available for analysis. The low C-statistic of the propensity score model (0.59) could also reflect unmeasured selection factors, such as patient or family preferences for a particular ward, or misspecification of the propensity score model, rather than bed-availability allocation alone. PSM cannot remove ward-level confounding, and residual confounding by unmeasured variables such as health literacy, social support, personality, and baseline psychological distress remains possible. Second, the mediator and the outcome were both measured at the same 3-month time point, so temporal precedence of self-efficacy over QoL cannot be established; the causal interpretation rests entirely on the IMB model's theoretical assumption that self-efficacy precedes QoL, and reverse or reciprocal causation cannot be excluded. Third, the E-value for the ACME point estimate (1.28) is moderate, and the E-value for the lower CI limit (1.08) is low, indicating that the statistical significance of the indirect effect is relatively sensitive to unmeasured confounding. Fourth, complete baseline and 3-month questionnaire

data were an eligibility criterion. To the extent that patients who were lost to follow-up or unable to complete the questionnaires were thereby not represented in the source cohort, this may introduce selection bias; we cannot quantify the magnitude of this selection bias using the available dataset. The direction of the bias is also unknown: if excluded patients had poorer health and lower QoL, the estimated between-group differences could be biased toward or away from the null depending on how the exclusions were distributed across wards. Because the IMB pathway was implemented from July 2023, after the study period began, differential loss to follow-up between wards cannot be ruled out. Only two admissions in the database (both to Ward 2) preceded the IMB implementation date, so a formal pre-implementation comparison of ward-level baseline outcomes was not possible. Fifth, no quantitative adherence or fidelity metric was prospectively collected, precluding dose–response analyses, so we could not examine whether higher exposure to IMB components corresponded to better patient outcomes. Sixth, the study tested a single mediator; multiple-mediator designs are needed to characterize the remaining direct pathways. Seventh, the single-center setting with a high baseline standard of routine care limits generalizability; in centers with less comprehensive routine care, the mediated share might be larger. Eighth, follow-up was limited to 3 months, and longer-term trajectories were not examined. Ninth, baseline questionnaire responses exhibited restricted variability with low baseline–follow-up correlations ($r \approx 0.01$), which limits the value of baseline adjustment and may reflect how patients responded at admission rather than measurement failure; if the restricted variability instead reflects measurement error, baseline adjustment would be incomplete. Internal consistency at follow-up was adequate (SUPPH alpha 0.80; FACT-L alpha 0.92). Sensitivity analyses that omitted baseline covariates (Supplementary Table S3) and that used change-scores for both mediator and outcome (Supplementary Table S4) yielded similar point estimates, indicating that the primary results were not driven by baseline adjustment. However, in the change-score analysis, the ACME 95% CI included zero ($P = 0.086$), consistent with the fragility already indicated by the E-values.

4.6 Future Research

Prospective cohort studies or randomized trials with repeated measurement of the hypothesized mediator at intermediate time points are needed to establish temporal precedence. Future work should incorporate multiple candidate mediators (health literacy, patient activation, treatment satisfaction, social support, illness perception), extend follow-up to 6, 12, and 24 months, and include multiple centers with varying standards of routine nursing care. Future work should also collect intervention fidelity metrics to support dose–response evaluation.

5. Conclusion

In this propensity-matched retrospective cohort of 528 patients undergoing lung cancer cryoablation, self-efficacy measured at 3 months emerged as a statistically significant but fragile partial mediator of the association between IMB based perioperative nursing and QoL, accounting for 12.2% of the estimated total effect. A substantial direct effect and an approximately 23% reduction in expected length of stay were also observed. These associational findings are consistent with the IMB model's prediction

that self-efficacy functions as a proximal mediator, though they do not establish causality, and underscore the importance of the program's components beyond self-efficacy.

Declarations

Ethics approval and consent to participate:

This retrospective study was approved by the Ethics Committee of the Second Affiliated Hospital of Army Medical University (Xinqiao Hospital) in 2026 (approval number: 2026-226-02). The study was conducted in accordance with the Declaration of Helsinki. Given the retrospective design and the use of de-identified clinical data, the requirement for written informed consent was waived by the aforementioned ethics committee. All patient data were anonymized prior to analysis, and patient confidentiality was strictly protected throughout the study.

Competing interests:

The authors declare that they have no competing interests.

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Author Contribution

H.P., L. T. conceived the study, collected data, and drafted the manuscript. Z. D., J.W., M. Y., and M.H. contributed to data collection, nursing intervention implementation, and manuscript revision. Q.L. and M. C. designed the study, supervised the clinical program, performed statistical analyses, and critically revised the manuscript. All authors read and approved the final manuscript.

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Data Availability

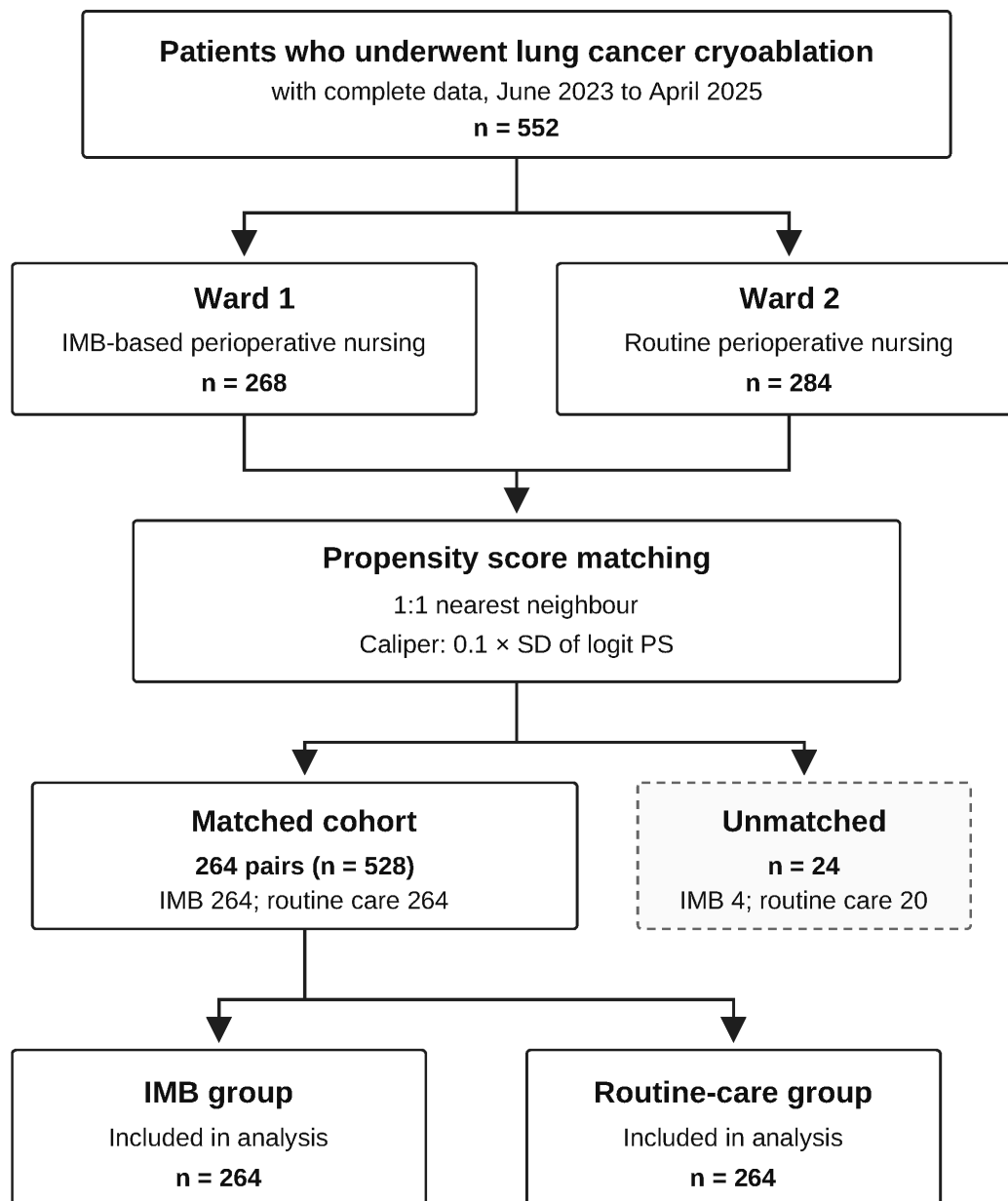
The datasets generated and analyzed during the current study are not publicly available due to institutional data protection policies but are available from the corresponding author on reasonable request, subject to institutional approval.

References

1. Sung H, et al. Global Cancer Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers in 185 Countries. *CA Cancer J Clin*. 2021;71:209–49. <https://doi.org/10.3322/caac.21660>.
2. de Baere T, et al. Evaluating Cryoablation of Metastatic Lung Tumors in Patients–Safety and Efficacy: The ECLIPSE Trial–Interim Analysis at 1 Year. *J Thorac Oncol*. 2015;10:1468–74. <https://doi.org/10.1097/JTO.0000000000000632>.
3. Yamauchi Y, et al. Percutaneous cryoablation for the treatment of medically inoperable stage I non-small cell lung cancer. *PLoS ONE*. 2012;7:e33223. <https://doi.org/10.1371/journal.pone.0033223>.
4. Fisher JD, Fisher WA. Changing AIDS-risk behavior. *Psychol Bull*. 1992;111:455–74. <https://doi.org/10.1037/0033-2909.111.3.455>.
5. Xu H, Wang J. An information-motivation-behavioral skills model-based intervention for patients with epilepsy. *Epilepsy Behav*. 2023;147:109408. <https://doi.org/10.1016/j.yebeh.2023.109408>.
6. Rongkavilit C, et al. Applying the information-motivation-behavioral skills model in medication adherence among Thai youth living with HIV: a qualitative study. *AIDS Patient Care STDS*. 2010;24:787–94. <https://doi.org/10.1089/apc.2010.0069>.
7. Bandura A. Self-efficacy: toward a unifying theory of behavioral change. *Psychol Rev*. 1977;84:191–215. <https://doi.org/10.1037//0033-295x.84.2.191>.
8. Gao J, et al. Effects of self-care, self-efficacy, social support on glycemic control in adults with type 2 diabetes. *BMC Fam Pract*. 2013;14:66. <https://doi.org/10.1186/1471-2296-14-66>.
9. Nelson LA, et al. Assessing barriers to diabetes medication adherence using the Information-Motivation-Behavioral skills model. *Diabetes Res Clin Pract*. 2018;142:374–84. <https://doi.org/10.1016/j.diabres.2018.05.046>.
10. Zarani F, Besharat MA, Sadeghian S, Sarami G. The effectiveness of the information-motivation-behavioral skills model in promoting adherence in CABG patients. *J Health Psychol*. 2010;15:828–37. <https://doi.org/10.1177/1359105309357092>.
11. Lorig KR, Holman H. Self-management education: history, definition, outcomes, and mechanisms. *Ann Behav Med*. 2003;26:1–7. https://doi.org/10.1207/S15324796ABM2601_01.
12. Merluzzi TV, et al. Interventions to enhance self-efficacy in cancer patients: A meta-analysis of randomized controlled trials. *Psychooncology*. 2019;28:1781–90. <https://doi.org/10.1002/pon.5148>.
13. Peng H, et al. A retrospective study on the rehabilitation effects of IMB nursing intervention for lung cancer patients after cryoablation. *Discov Oncol*. 2026. <https://doi.org/10.1007/s12672-026-05606-9>.

14. Hoffmann TC, et al. Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. *BMJ*. 2014;348:g1687. <https://doi.org/10.1136/bmj.g1687>.
15. Cella DF, et al. Reliability and validity of the Functional Assessment of Cancer Therapy-Lung (FACT-L) quality of life instrument. *Lung Cancer*. 1995;12:199–220. [https://doi.org/10.1016/0169-5002\(95\)00450-f](https://doi.org/10.1016/0169-5002(95)00450-f).
16. Wan C, et al. Psychometric properties of the Chinese version of the FACT-L for measuring quality of life in patients with lung cancer. *Lung Cancer*. 2007;56:415–21. <https://doi.org/10.1016/j.lungcan.2007.01.004>.
17. Yuan C, et al. Factorial structure of a scale: Strategies Used by People to Promote Health–Chinese version. *Cancer Nurs*. 2015;38:E13–20. <https://doi.org/10.1097/NCC.0000000000000151>.
18. Austin PC. An Introduction to Propensity Score Methods for Reducing the Effects of Confounding in Observational Studies. *Multivar Behav Res*. 2011;46:399–424. <https://doi.org/10.1080/00273171.2011.568786>.
19. Imai K, Keele L, Tingley D. A general approach to causal mediation analysis. *Psychol Methods*. 2010;15:309–34. <https://doi.org/10.1037/a0020761>.
20. VanderWeele TJ, Ding P. Sensitivity Analysis in Observational Research: Introducing the E-Value. *Ann Intern Med*. 2017;167:268–74. <https://doi.org/10.7326/M16-2607>.
21. Mishel MH. Uncertainty in illness. *Image J Nurs Sch*. 1988;20:225–32. <https://doi.org/10.1111/j.1547-5069.1988.tb00082.x>.
22. MacKinnon DP, Fairchild AJ, Fritz MS. Mediation analysis. *Annu Rev Psychol*. 2007;58:593–614. <https://doi.org/10.1146/annurev.psych.58.110405.085542>.
23. Kehlet H. Enhanced Recovery After Surgery (ERAS): good for now, but what about the future? *Can J Anaesth*. 2015;62:99–104. <https://doi.org/10.1007/s12630-014-0261-3>.
24. Batchelor TJP, et al. Guidelines for enhanced recovery after lung surgery: recommendations of the Enhanced Recovery After Surgery (ERAS(R)) Society and the European Society of Thoracic Surgeons (ESTS). *Eur J Cardiothorac Surg*. 2019;55:91–115. <https://doi.org/10.1093/ejcts/ezy301>.
25. Cella D, et al. What is a clinically meaningful change on the Functional Assessment of Cancer Therapy-Lung (FACT-L) Questionnaire? Results from Eastern Cooperative Oncology Group (ECOG) Study 5592. *J Clin Epidemiol*. 2002;55:285–95. [https://doi.org/10.1016/s0895-4356\(01\)00477-2](https://doi.org/10.1016/s0895-4356(01)00477-2).

Figures



IMB, information–motivation–behavioral skills; PS, propensity score; SD, standard deviation.

Figure 1

Participant flow. The flow diagram begins at the source-cohort level (n = 552) because the study used an existing clinical database; the total number of patients screened before the application of the eligibility criteria could not be determined. Patients without complete baseline and 3-month questionnaire data were ineligible and are therefore not represented in the source cohort; consequently, no patients were excluded for missing data after cohort entry. Of 552 patients with complete data (268 Ward 1 IMB-based

nursing, 284 Ward 2 routine care; June 2023 to April 2025), propensity score matching retained 264 pairs (N = 528); 24 patients were unmatched (4 IMB, 20 routine care).

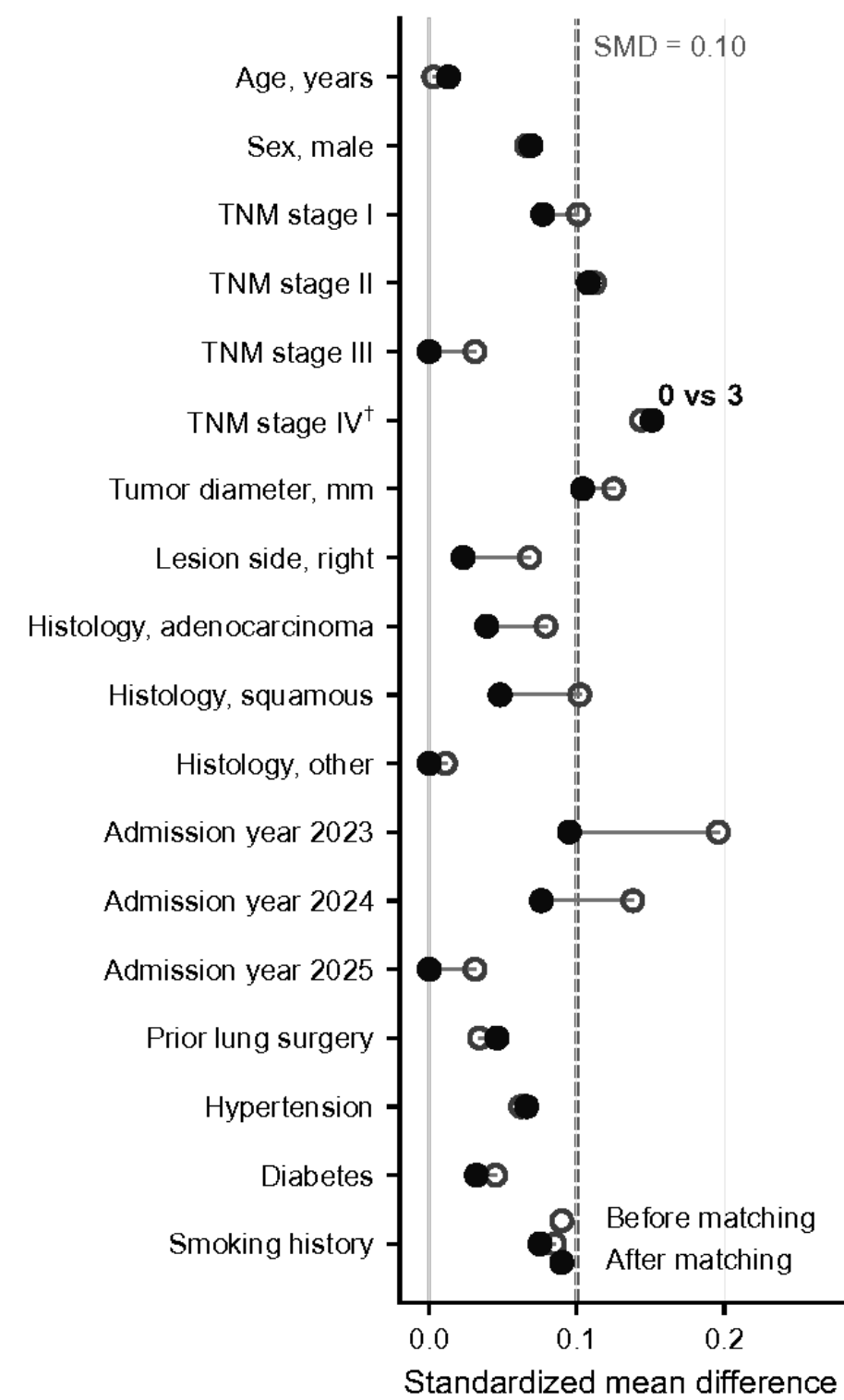
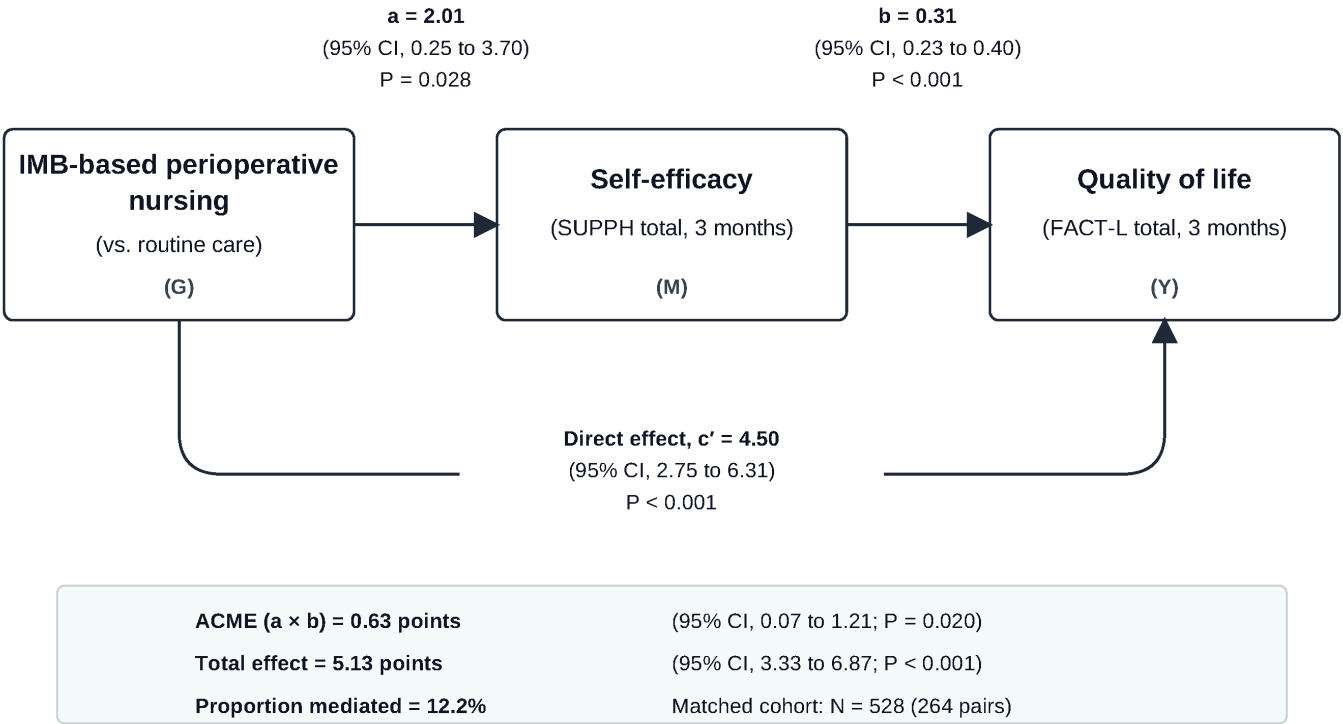


Figure 2

Standardized mean differences (SMDs) before and after propensity score matching. Dashed line: SMD = 0.10. †TNM stage IV: a structural imbalance after matching (0 IMB vs 3 control patients; SMD 0.151),

addressed in sensitivity analyses excluding the three affected pairs (Supplementary Table S2).



Models adjusted for baseline SUPPH and baseline FACT-L.

Figure 3

Path diagram of the mediation model for the FACT-L total score at 3 months (matched cohort, N = 528; 264 pairs). ACME (a × b) = 0.63 points (95% CI, 0.07 to 1.21; P = 0.020); total effect = 5.13 points (95% CI, 3.33 to 6.87; P < 0.001); proportion mediated = 12.2%. Models adjusted for baseline SUPPH and baseline FACT-L; 95% CIs from 1,000 pair-level bootstrap resamples; two-sided bootstrap P values for the ACME and total effect, analytic P values for path coefficients. Note: The mediator (SUPPH at 3 months) and the outcome (FACT-L at 3 months) were measured at the same time point; temporal precedence cannot be empirically established, and the estimates should be interpreted as associational rather than as definitive causal effects.

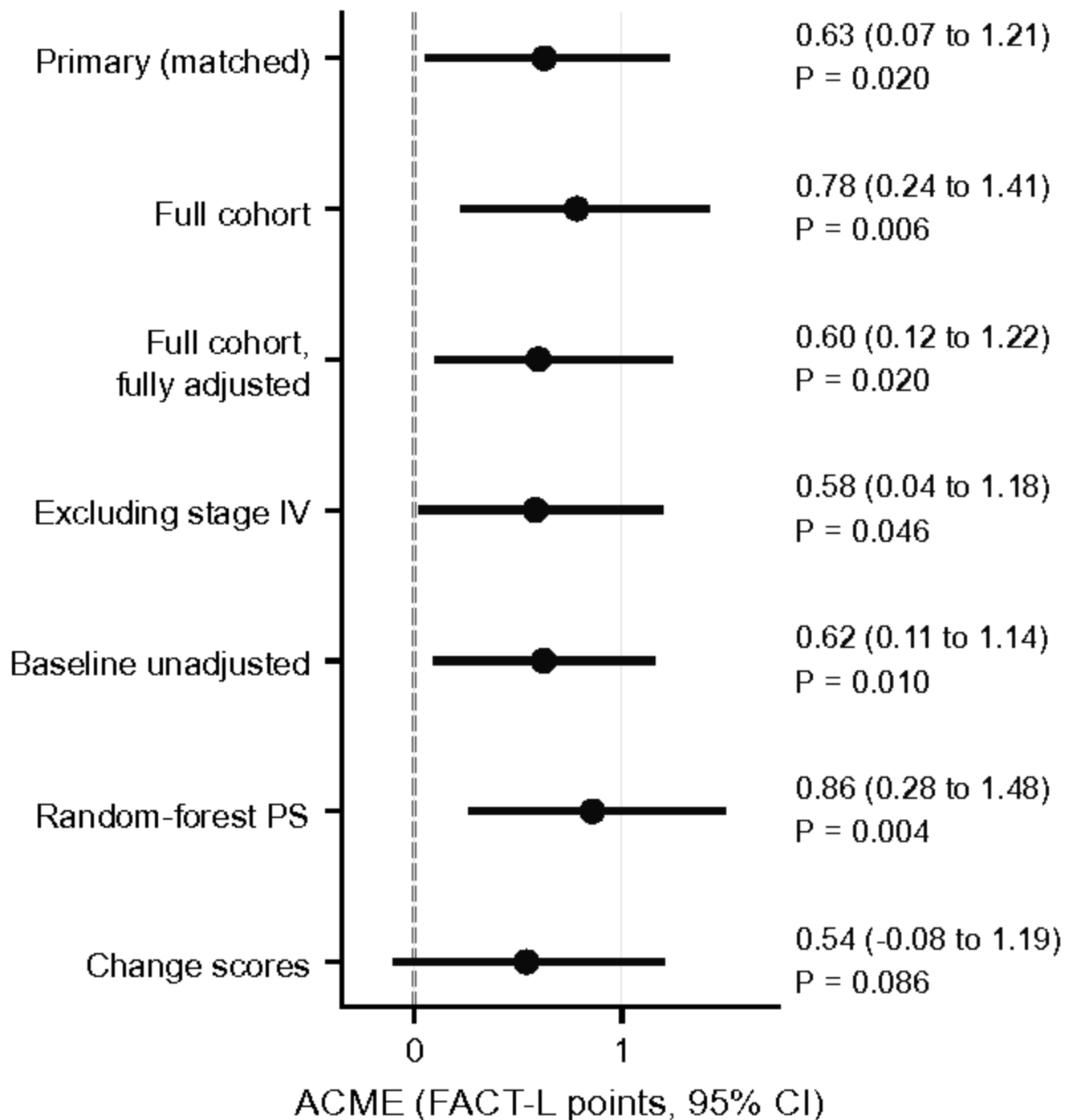


Figure 4

Forest plot of the average causal mediation effect (ACME) across the primary analysis and the sensitivity analyses. Squares represent point estimates and horizontal lines 95% percentile-bootstrap confidence intervals; the dashed vertical line marks the null (ACME = 0). Primary specification: matched cohort (264 pairs); random-forest propensity score specification: 250 pairs; full-cohort specifications: N = 552; excluding-stage-IV specification: 261 pair.