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Original Paper

Construction and Application of Optimal Critical Care Ultrasound Assessment Strategy for Enteral Nutrition in Adult Critically Ill Patients

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Abstract

Objective: *To construct an optimal critical-care-ultrasound-based assessment strategy for enteral nutrition in adult critically ill patients on the basis of best-available evidence, so as to standardize the clinical application of critical care nursing ultrasound in enteral nutrition management and improve nursing quality.*

Methods: *Guided by the JBI Evidence-Based Healthcare Model, an evidence-based practice team was established. Evidence-based clinical questions were formulated. Relevant literature was systematically retrieved, screened and appraised. Best evidence was synthesized, followed by clinical applicability evaluation and tailoring. Audit criteria were developed and baseline audit was completed. Barriers to evidence implementation were analyzed and corresponding action strategies were formulated, so as to finally develop an evidence-based practice scheme adapted to clinical contexts.*

Results: *A total of 22 publications were included, consisting of 5 clinical guidelines, 4 systematic reviews, 3 randomized controlled trials, 2 expert consensuses, 2 evidence summaries, 2 clinical decision-support resources, 2 observational studies, 1 group standard and 1 cohort study. Twenty-one pieces of best evidence covering six dimensions (nutritional diagnosis-treatment workflow, fundamentals of nurses' gastrointestinal ultrasound assessment, nutritional risk assessment, feeding access establishment, feeding intolerance assessment, and aspiration risk assessment) were synthesized.*

Conclusion: *The evidence-based critical care nursing ultrasound assessment strategy provides a scientific basis for precise and standardized enteral nutrition management for adult critically ill patients and lays a foundation for clinical translation of evidence.*

Keywords

critical illness, enteral nutrition, critical care nursing ultrasound, assessment strategy, evidence-based nursing practice

Background

Critically ill patients frequently experience rapid deterioration of nutritional status secondary to severe stress response, metabolic disturbance and organ dysfunction. Timely and adequate nutritional support is a key link for improving prognosis. As the preferred nutritional support modality for ICU patients, enteral nutrition can not only supply essential nutrients, but also preserve intestinal barrier function, modulate immune function and lower the incidence of infectious and other complications[1,2]. Nevertheless, multiple challenges persist in clinical implementation of enteral nutrition: the incidence of feeding intolerance ranges from 30% to 70%, aspiration risk cannot be accurately evaluated, and feeding target achievement rate remains generally low[3].

Critical care nursing ultrasound is a rapidly evolving bedside technique in recent years. Integrating the concept of critical care ultrasound into nursing practice, it enables real-time visualization and quantification of gastrointestinal function and furnishes objective evidence for formulating and adjusting enteral nutrition regimens. Domestic and international guidelines and consensuses have clarified that gastrointestinal function assessment guided by critical care ultrasound facilitates safe delivery of enteral nutrition[4,5]. However, systematic and standardized assessment strategies for domestic application of critical care nursing ultrasound in enteral nutrition management are still lacking.

Given the above background, guided by the JBI Evidence-Based Healthcare Model, this study systematically retrieved, appraised and synthesized best evidence regarding critical care nursing ultrasound-mediated assessment for enteral nutrition in critically ill patients, and constructed a standardized nursing ultrasound assessment strategy adapted to clinical contexts.

1. Methods

1.1 Formulation of Evidence-Based Clinical Questions

Preliminary clinical investigation revealed that ICU nurses mainly relied on conventional indicators (e.g., gastric residual volume aspiration) to evaluate feeding intolerance during enteral nutrition management, which was associated with non-standardized operations and high subjectivity in result interpretation. Visualized guidance was deficient in feeding-access establishment, and objective quantitative tools for aspiration-risk assessment were unavailable.[6] Accordingly, the evidence-based question was raised: can ultrasound-based assessment strategy optimize assessment and monitoring of enteral nutrition for adult critically ill patients?

1.2 Establishment of Evidence-Based Practice Team

The evidence-based practice team consisted of 14 members with multidisciplinary backgrounds, including 1 director of nursing department (professor of nursing), 1 director of critical care medicine

(chief physician), 2 head nurses of critical care units (1 professor of nursing and 1 associate professor of nursing), 7 nurse specialists, 2 attending physicians and 1 attending physician from the department of medical ultrasound. In terms of educational background: 2 members held doctoral degrees, 5 held master's degrees and 7 held bachelor's degrees. For professional titles: 4 members had senior professional titles and 10 had intermediate professional titles.

1.3 Retrieval Strategy

Literature was retrieved top-down in accordance with the 6S evidence hierarchy model. Databases and resources included UpToDate, evidence-based textbooks, NGC, NICE, SIGN, RNAO, Medlive guideline database, Cochrane Library, JBI Evidence-Based Healthcare Center, PubMed, Web of Science, Embase, CNKI, Wanfang, SinoMed, VIP, and websites of relevant academic societies (ESPEN, ASPEN, SCCM, Chinese Society of Critical Care Medicine, etc.).

English search terms: enteral nutrition, enteral feeding, gastric residual volume, feeding intolerance, gastric motility, gastric emptying, gastric antrum; ultrasonography, ultrasound, bedside ultrasound, critical care ultrasound, point-of-care ultrasound, gastric ultrasound; critical illness, critically ill, intensive care, ICU.

Chinese search terms: 肠内营养，肠内喂养，肠内营养耐受性，胃残余量，鼻肠管；超声检查，超声引导，床旁超声，重症超声，胃肠超声；重症，危重症，ICU.

Retrieval time frame: from database inception to October 2024.

Inclusion criteria: (1) Adult ICU patients (≥18 years old) receiving or scheduled for enteral nutrition; (2) studies addressing application of critical care nursing ultrasound / bedside ultrasound in assessment, monitoring and management of enteral nutrition; (3) publication types: clinical practice guidelines, systematic reviews / meta-analyses, evidence summaries, expert consensuses, randomized controlled trials, cohort studies and observational studies; (4) publications in Chinese or English.

Exclusion criteria: (1) publications without full-text access; (2) conference abstracts and research protocols; (3) literature failing quality appraisal; (4) duplicated or superseded publications.

1.4 Literature Screening and Quality Appraisal

Two JBI-trained reviewers independently performed literature screening and quality appraisal, with cross-checking. Discrepancies were resolved by a third reviewer. Literature was managed with NoteExpress, and duplicates were removed via EndNote. Primary screening was conducted by reading titles and abstracts, followed by secondary full-text screening according to inclusion and exclusion criteria.

Dedicated appraisal tools were adopted for different publication types: (1) AGREE-II for clinical guidelines; (2) AMSTAR-2 for systematic reviews / meta-analyses; (3) JBI RCT critical appraisal checklist for randomized controlled trials; (4) JBI checklist for expert opinions and consensuses for expert consensuses; (5) corresponding JBI appraisal checklists for cohort and observational studies; (6) for evidence summaries and clinical decision-support resources, original references were traced and appraised with tools matching original study designs.

1.5 Evidence Synthesis and Grading

Two reviewers independently extracted, translated and integrated relevant evidence from included literature to build an evidence item pool. The JBI Evidence-Based Healthcare Center evidence grading system (2014 edition) was used for evidence grading, classifying evidence into Level 1-5 according to study design. In accordance with JBI recommendation criteria (2014), each piece of evidence was assessed independently by team members based on FAME attributes (Feasibility, Appropriateness, Meaningfulness, Effectiveness). Final recommendation strength (Grade A or Grade B) was determined via expert panel discussion.

1.6 Clinical Applicability Evaluation and Tailoring of Evidence

Thirteen experts (2 critical-care physicians, 3 critical-care nursing management experts, 3 critical-care nursing ultrasound nurses, 2 evidence-methodology experts, 1 clinical dietitian, 2 medical ultrasound physicians) scored FAME attributes of each evidence item using a 5-point Likert scale. Based on evaluation results, national policies, hospital regulations and departmental practical conditions, evidence was tailored to generate a best-practice evidence list suitable for local clinical contexts.

1.7 Development of Audit Criteria and Methods

Thirteen clinical audit criteria were formulated from tailored best evidence, covering: completeness of departmental nutritional diagnosis-treatment protocols for critically ill patients; whether nurses performing bedside ultrasound hold professionally certified qualifications and achieve a score ≥85 in departmental assessments; readiness status of bedside ultrasound equipment and accessories; whether at least one pre-enteral-nutrition gastrointestinal injury ultrasound score is performed and documented; nutritional-risk assessment via the NRS2002 scale; additional serial monitoring of rectus femoris thickness via ultrasound; esophageal anatomical ultrasound assessment prior to feeding-access placement; documentation of gastric residual volume in nursing-ultrasound assessment registers; adjustment of feeding rate guided by gastric residual volume; documentation of gastric antrum index for setting initial feeding rate; aspiration-risk assessment based on quantity and nature of gastric contents. Audit approaches included document review, on-site observation, nursing record review, questionnaire survey, interview and on-site assessment.

1.8 Baseline Audit

Baseline audit was implemented from March 1 to April 30, 2025 in four critical-care units: general ICU, neurosurgical ICU, emergency ICU and cardiovascular CCU. Audit subjects included 12 ward nurses and 46 ICU inpatients receiving enteral nutrition.

Patient inclusion criteria: age ≥ 18 years; enteral nutrition initiated within 24-48 h after ICU admission; critical-care nutritional-risk score ≥5; expected inability for oral feeding for ≥3 days; Acute Physiology and Chronic Health Evaluation score >8.

Patient exclusion criteria: enteral nutrition administered within the first 3 days before ICU admission; long-term hormone or immunosuppressant therapy; malignant tumors receiving radiotherapy, chemotherapy or special interventions; irreversible critical illness or terminal status.

1.9 Barrier Analysis and Action Strategies

The CREBNA evidence-based nursing practice readiness scale (31 items across three dimensions: Evidence (12 items), Organizational Context (9 items), Facilitators (10 items), 5-point Likert scoring) was used to assess practice readiness among the 12 participating nurses. Based on readiness results, the GRiP framework was adopted to identify barriers and facilitators for practice change for poorly-scored items, and targeted action strategies were developed.

Major barriers:

1. Evidence dimension: evidence has not been transformed into user-friendly formats for dissemination and clinical application.
2. Nurse dimension: insufficient knowledge of evidence-based practice and lack of standardized training on critical-care nursing ultrasound.
3. System dimension: absence of standardized operating procedures and monitoring targets, and imperfect nursing documentation systems.
4. Organizational-context dimension: insufficient information resources and technical support for evidence-based practice, and inadequate incentive policies.

Corresponding action strategies:

1. Formulate manuals and standardized operating procedures for nursing ultrasound assessment during enteral nutrition for ICU patients.
2. Deliver tiered and systematic training curricula for critical-care nursing ultrasound.
3. Establish standardized workflows with clear monitoring targets and frequencies, and optimize nursing documentation templates.
4. Optimize human-resource allocation.
5. Build incentive mechanisms to encourage nurses to engage in evidence-based practice.

1.10 Construction of Evidence-Based Practice Scheme

Following evidence synthesis, clinical applicability evaluation, baseline audit and barrier analysis, the evidence-based team compiled manuals and standardized operating procedures for nursing ultrasound assessment of enteral nutrition in ICU patients according to departmental conditions and clinical requirements. An expert panel reviewed and revised the scheme item-by-item for scientific validity, feasibility, completeness and standardization. The final optimal nursing-ultrasound assessment strategy for enteral nutrition in adult critically ill patients comprised assessment flowcharts, operation manuals, audit indicators and training programmes.

2. Results

2.1 General Characteristics of Included Literature

Initial literature retrieval yielded 875 Chinese papers (211 from CNKI, 354 from Wanfang, 125 from SinoMed, 185 from VIP) and multiple English papers from PubMed, Cochrane Library, Embase, Web of Science and other databases. After de-duplication with NoteExpress, title-abstract primary screening

and full-text secondary screening, 22 publications were finally included: 5 clinical guidelines (23%), 4 systematic reviews (18%), 3 randomized controlled trials (14%), 2 expert consensuses (9%), 2 evidence summaries (9%), 2 clinical decision-support resources (9%), 2 observational studies (9%), 1 group standard (4%), and 1 cohort study (4%). Publications were dated 2016-2025, among which 16 were English and 6 were Chinese.

2.2 Results of Literature Quality Appraisal

Five clinical guidelines were appraised with AGREE-II; mean standardized percentage scores across six domains were 90.5 %, 82.3 %, 85.1 %, 88.6 %, 79.2 % and 75.8 %, indicating high overall quality and all were included. Among four systematic reviews assessed by AMSTAR-2, three demonstrated high methodological quality; one had limitations in comprehensiveness of retrieval strategy but still met inclusion criteria. Three randomized controlled trials were appraised with the JBI RCT checklist: two were of high quality and one had limitations in allocation concealment and blinding yet remained acceptable. Two expert consensuses, two evidence summaries, two clinical decision-support resources, two observational studies, one group standard and one cohort study all satisfied inclusion criteria upon corresponding appraisal tools.

Table 1. General Characteristics of the Included Studies

No.	Author(s)	Year	Source	Publication Type	Research Topic
1	Charlene Compher et al.	2022	ASPEN	Clinical Guideline	Guidelines for nutritional support therapy in adult critically ill patients
2	Pierre Singer et al.	2023	ESPEN	Clinical Guideline	Clinical nutrition in the intensive-care unit
3	American College of Emergency Physicians	2023	PubMed	Clinical Guideline	Guideline for emergency bedside ultrasound and clinical ultrasound applications
4	Chinese Society for Parenteral and Enteral Nutrition	2023	Chinese Society for Parenteral and Enteral Nutrition	Clinical Guideline	Chinese clinical practice guideline for parenteral and enteral nutrition in adults
5	Chinese Society of Critical Care Medicine	2023	Chinese Medical Association	Clinical Guideline	Chinese clinical practice guideline for nutrition assessment and monitoring in adult ICU patients

6	Sun Jianhua et al.	2023	CNKI	Group Standard	Nursing specifications for critical-care ultrasound clinical techniques
7	Cao Lan et al.	2021	CNKI	Expert Consensus	Expert consensus on critical-care nursing ultrasound
8	Feng Aiping et al.	2021	Wanfang	Systematic Review	Meta-analysis on ultrasound-monitored gastric residual volume for enteral nutrition in critically ill patients
9	Liu et al.	2018	PubMed	Systematic Review	Diagnostic accuracy of ultrasonography for nasogastric tube placement in adults: a systematic review and meta-analysis
10	Rocha et al.	2020	PubMed	Systematic Review	Systematic review of ultrasonographic assessment of gastric contents and volume
11	Pan et al.	2024	Cochrane Library	Systematic Review	Value of ultrasound in gastric-content assessment
12	Mi Yuanyuan et al.	2019	Wanfang	Evidence Summary	Best-evidence summary on prevention and management of enteral feeding intolerance in critically ill patients
13	Richelle Kruisselbrink et al.	2018	PubMed	Randomized Controlled Trial	Diagnostic-accuracy evaluation of point-of-care gastric ultrasound
14	McClave et al.	2016	PubMed	Clinical Guideline	SCCM/ASPEN guideline for assessment and therapy of enteral-nutrition support in adult critically ill patients
15	Mi Yuanyuan et al.	2021	Chinese Medical Association	Expert Consensus	Chinese expert consensus on prevention and management of common complications of enteral-nutrition therapy in critically ill patients (2021 edition)

2.3 Evidence Synthesis Results

Twenty-one evidence items were extracted and synthesized from the 22 included publications across six dimensions: nutritional diagnosis-treatment workflow, fundamentals of nurses' gastrointestinal ultrasound assessment, nutritional-risk assessment, feeding-access establishment, feeding-intolerance assessment, and aspiration-risk assessment.

Table 2. The Best Evidence of Optimal Critical Care Ultrasound Assessment Strategy for Enteral Nutrition in Adult Critically Ill Patients

Category	Evidence Content	Evidence Level	Recommendation Grade
Nutritional diagnosis-treatment workflow	1. Standardized nutritional diagnosis-treatment workflow for critically ill patients should be established, covering key steps of "screening, assessment, diagnosis, intervention and monitoring" to realize continuous diagnosis-treatment mode.[4,7]	2a	A
Fundamentals of nurses' gastrointestinal ultrasound assessment	2. Critical-care nurses should receive standardized training on critical-care nursing ultrasound, including ultrasound-related knowledge, image interpretation, anatomical and physiological basics.[5,6,8]	5b	A
	3. Under adequate equipment conditions, professionally trained nurses can perform bedside ultrasound-based gastrointestinal-function assessment during enteral-nutrition implementation for critically ill patients, which facilitates achievement of enteral-feeding targets.[9,10]	5b	A
	4. For transabdominal gastric ultrasound, a 2-5 MHz convex-array transducer is recommended; for intestinal ultrasound, a 5-17 MHz convex-array or linear-array transducer is suggested.[11,12]	1a	A
	5. During gastric-function ultrasound assessment, elevate the head-of-bed to approximately 30° and place patients in the right lateral decubitus position; semi-recumbent position is acceptable for patients with positional restrictions.[13]	2a	A

Nutritional-risk assessment	6. Prior to enteral-nutrition initiation, transabdominal ultrasound should be used to evaluate gastrointestinal integrity and function. The AGI ultrasound (AGIUS) scoring system can assess gastrointestinal injury for dynamic monitoring, serving as the initial step for successful feeding strategy formulation.[8,14]	1c	A
	7. The NRS2002 or NUTRIC tool is recommended for nutritional-risk assessment of critically ill patients.[10,15,16]	1a	A
	8. Body-composition analysis (including muscle mass and muscle strength) constitutes an essential component of nutritional assessment. Muscle-mass assessment is recommended for critically ill patients to monitor short-term nutritional-status changes.[14]	2a	A
	9. Ultrasonic measurement of rectus abdominis and rectus femoris thickness represents a reliable and feasible quantitative method for nutritional-risk stratification in ICU patients. Patients lie supine with passively extended lower limbs; transducer is placed perpendicular to the long axis of muscle at 3/5 of the distance between anterior superior iliac spine and superior patellar margin to measure thickness of rectus femoris and vastus intermedius. Perform three consecutive measurements and record results.[12,13]	2a	A
Feeding-access establishment	10. Besides pre-procedural assessment of nasal cavity and esophagus, ultrasound is recommended to evaluate esophageal anatomy. Under ultrasound, “trachea-esophagus-carotid artery” presents as an inverted triangular structure, with esophagus situated between trachea and carotid artery.[17]	2a	B
	11. Ultrasound assessment of gastric-antral motility assists in judging feasibility of intragastric feeding and selecting nasogastric or nasojejunal tube for nutrition delivery.[11,17]	3b	A
	12. Ultrasound-guided nasojejunal-tube placement is prioritized for critically ill patients. Ultrasound guidance combined with progressive gastric-antrum saline-infusion	1a	A

	improves success rate of bedside nasojejunal-tube insertion in adult critically ill patients.[2]		
	13. Post-insertion bedside ultrasound is recommended to precisely confirm tip location of nasogastric / nasojejunal tube within gastrointestinal tract. When tube insertion depth reaches approximately 25 cm, acquire short-axis esophageal ultrasound view to verify whether the tube enters the esophagus.[4]	1a	A
Feeding-intolerance assessment	14. After initiation of nasogastric enteral feeding, perform gastric-antral ultrasound assessment: higher echo density in gastric antrum indicates elevated risk of feeding intolerance.[15]	3c	A
	15. Gastric-residual-volume monitoring: gastric-content volume can be quantified by measuring cross-sectional area of gastric antrum at diastolic phase (measured from serosal layer). Calculation formula: Gastric residual volume (mL) = 27.0 + 14.6 × right-lateral-decubitus gastric-antral cross-sectional area (mm^2) − 1.28 × age (years).[4,5,8]	1a	A
	16. For patients with feeding intolerance, bedside gastric ultrasound monitors gastric residual volume every 4-6 h. If gastric residual volume ＜ 200 mL: maintain original infusion rate or increase rate by 20 mL every 6 h until nutritional target rate (≤ 120 mL/h) is achieved. If 200 mL ≤ gastric residual volume ＜ 350 mL: reduce infusion rate to 50 % of baseline. If 350 mL ≤ gastric residual volume ＜ 500 mL: reduce infusion rate to 25 % of baseline. If gastric residual volume ≥ 500 mL, consider jejunal feeding.[18]	3b	A
	17. Gastric-emptying assessment: gastric-emptying function in critically ill patients can be evaluated via ultrasound-measured gastric-emptying time. Rapidly instill 300 mL warm water to distend gastric cavity; observe gastric fluid-sonolucent area every 5 min via single gastric-antrum view until disappearance to determine gastric-emptying time.[13,19]	3c	B

	18. Gastric-contractility assessment: gastric-antral motility index (MI) evaluates gastric emptying. Rapidly infuse 300 mL warm water; record gastric-antral contraction frequency within 6 min, and define antral contraction frequency (ACF) as contractions per 2 min. Acquire three consecutive measurements of maximum diastolic (Sdiastolic) and systolic (Ssystolic) gastric-antral area. Calculate area variation ΔS = Sdiastolic − Ssystolic; antral contraction amplitude (ACA) = ΔS / Sdiastolic.[20]	3c	B
	19. Gastric-antral motility index MI = ACF × ACA, which assists in determining initial enteral-nutrition infusion rate: MI ＜ 0.4, initial rate 20-30 mL/h; MI 0.4-0.8, initial rate 40-60 mL/h; MI ＞ 0.8, initial rate ＞ 70 mL/h.[20,21]	1c	B
	20. Qualitative ultrasound assessment of gastric contents is recommended: clear gastric fluid presents hypoechoic or anechoic appearance; high-density liquid yields “starry-night sign”; solid food generates ground-glass-like hyperechoic signals with indistinct borders from surrounding tissues.[16,18]	2b	B
Aspiration-risk assessment	21. Ultrasonographically measured gastric-antral cross-sectional area positively correlates with gastric-content volume. Gastric contents containing solid particles and / or gastric-fluid volume ＞ 0.8 mL/kg define high-risk stomach for pulmonary aspiration.[22]	2a	A

2.4 Clinical Applicability Evaluation of Evidence

Seven domain-specific experts scored FAME attributes of each evidence item independently using 5-point Likert scale. For items with low scores or high score variance, qualitative analysis was performed to explore causes for poor clinical applicability or score discrepancy. According to existing literature, gastric emptying for 300 mL warm water takes approximately 120 min in critically ill patients. Therefore, Item 17 (gastric-emptying-time assessment via 300 mL warm-water instillation with 5-min-interval observation) was deemed clinically infeasible and excluded.

2.5 Formulation of Audit Indicators

Table 3. Audit Indicators

Evidence Content	Audit Indicator	Indicator No.	Audit Setting & Subjects	Data-collection Method	Evaluation Method
1. Standardized nutritional diagnosis-treatment workflow for critically ill patients should be established, covering key steps of "screening, assessment, diagnosis, intervention and monitoring" to realize continuous diagnosis-treatment mode.	The department has complete nutritional diagnosis-treatment workflow for critically ill patients and implements continuous diagnosis-treatment mode	1	Departmental protocols	Document review	"Y" if relevant protocols exist with implementation records; otherwise "N"
2. Critical-care nurses should receive standardized training on critical-care nursing ultrasound, including ultrasound-related knowledge, image interpretation, anatomical and physiological basics.	Nurses performing bedside ultrasound hold professionally issued qualification certificates	2	Nurses	Document review	"Y" for nurses with valid qualification certificates; otherwise "N"
	Nurses performing critical-care nursing ultrasound achieve score ≥85 in departmental theoretical and operational assessments on ultrasound knowledge	3	Nurses	Questionnaire / on-site assessment	"Y" for score ≥85; otherwise "N"
3. Under adequate equipment conditions, professionally trained nurses can perform bedside ultrasound-based gastrointestinal-function assessment during enteral-nutrition implementation for critically ill patients, which facilitates achievement of enteral-feeding targets.	The department has intact bedside-ultrasound equipment equipped with 2-5 MHz convex-array transducer	4	Department	On-site observation	"Y" if equipment and accessories are on standby in good condition; otherwise "N"
4. For transabdominal gastric ultrasound, a 2-5 MHz convex-array transducer is recommended; for intestinal ultrasound, a 5-17 MHz convex-array or linear-array transducer is suggested.	—	—	—	—	—

5. Prior to enteral-nutrition initiation, transabdominal ultrasound should be used to evaluate gastrointestinal integrity and function. The AGI ultrasound (AGIUS) scoring system can assess gastrointestinal injury for dynamic monitoring, serving as the initial step for successful feeding strategy formulation.	At least one pre-enteral-nutrition gastrointestinal-injury ultrasound score is performed and documented in the Neusoft critical-care information system	5	Patients	Nursing-record review	"Y" if assessment and documentation are completed; otherwise "N"
6. The NRS2002 or NUTRIC tool is recommended for nutritional-risk assessment of critically ill patients.	Nutritional-risk assessment is performed with NRS2002 scale and documented in nursing records	6	Patients	Nursing-record review	"Y" if assessment is correctly performed every 7 days and documented; otherwise "N"
7. Body-composition analysis (including muscle mass and muscle strength) constitutes an essential component of nutritional assessment. Muscle-mass assessment is recommended for critically ill patients to monitor short-term nutritional-status changes.	Rectus-femoris-thickness ultrasound assessment is added upon admission nutritional screening and monitored serially	7	Patients	Record review	"Y" if assessment is performed at correct frequency and documented in critical-care system; otherwise "N"
8. Ultrasonic measurement of rectus abdominis and rectus femoris thickness represents a reliable and feasible quantitative method for nutritional-risk stratification in ICU patients. Patients lie supine with passively extended lower limbs; transducer is placed perpendicular to the long axis of muscle at 3/5 of the distance between anterior superior iliac spine and superior patellar margin to measure thickness of rectus femoris and vastus intermedius. Perform three consecutive measurements and record results.	—	—	—	—	—

9. Besides pre-procedural assessment of nasal cavity and esophagus, ultrasound is recommended to evaluate esophageal anatomy. Under ultrasound, "trachea-esophagus-carotid artery" presents as an inverted triangular structure, with esophagus situated between trachea and carotid artery.	Prior to feeding-access placement, nurses perform esophageal-anatomy ultrasound assessment and store inverted-triangular trachea-esophagus-carotid-artery ultrasound images in patient-specific folders on ultrasound machine	8	Patients	On-site observation	"Y" if eligible images are acquired before enteral nutrition and properly stored; otherwise "N"
15. Gastric-residual-volume monitoring: gastric-content volume can be quantified by measuring cross-sectional area of gastric antrum at diastolic phase (measured from serosal layer). Calculation formula: Gastric residual volume (mL) = 27.0 + 14.6 × right-lateral-decubitus gastric-antral cross-sectional area (mm^2) − 1.28 × age (years).	Nurses perform gastric-residual-volume monitoring and document results in dedicated nursing-ultrasound-assessment register	9	Patients	On-site observation	"Y" if data are correctly documented with corresponding ultrasound images; otherwise "N"
16. For patients with feeding intolerance, bedside gastric ultrasound monitors gastric residual volume every 4-6 h. If gastric residual volume ＜ 200 mL: maintain original infusion rate or increase rate by 20 mL every 6 h until nutritional target rate (≤ 120 mL/h) is achieved. If 200 mL ≤ gastric residual volume ＜ 350 mL: reduce infusion rate to 50 % of baseline. If 350 mL ≤ gastric residual volume ＜ 500 mL: reduce infusion rate to 25 % of baseline. If gastric residual volume ≥ 500 mL, consider jejunal feeding.	Nurses adjust enteral-nutrition infusion rate according to gastric-residual-volume monitoring results	10	Patients	On-site observation	"Y" if actual infusion rate matches register records; otherwise "N"
18. Gastric-contractility assessment: gastric-antral motility index (MI) evaluates gastric emptying. Rapidly	Nurses perform gastric-antral-motility-index measurement and	11	Patients	On-site observation	"Y" if index is correctly documented with

infuse 300 mL warm water; record gastric-antral contraction frequency within 6 min, and define antral contraction frequency (ACF) as contractions per 2 min. Acquire three consecutive measurements of maximum diastolic (Sdiastolic) and systolic (Ssystolic) gastric-antral area. Calculate area variation ΔS = Sdiastolic − Ssystolic; antral contraction amplitude (ACA) = ΔS / Sdiastolic.	document results in bedside nursing-ultrasound-assessment register				corresponding ultrasound images; otherwise “N”
19. Gastric-antral motility index MI = ACF × ACA, which assists in determining initial enteral-nutrition infusion rate: MI ＜ 0.4, initial rate 20-30 mL/h; MI 0.4-0.8, initial rate 40-60 mL/h; MI ＞ 0.8, initial rate ＞ 70 mL/h.	Nurses set initial enteral-nutrition infusion rate guided by gastric-antral motility index	12	Patients	On-site observation	“Y” if initial infusion rate matches register records; otherwise “N”
20. Qualitative ultrasound assessment of gastric contents is recommended: clear gastric fluid presents hypoechoic or anechoic appearance; high-density liquid yields “starry-night sign”; solid food generates ground-glass-like hyperechoic signals with indistinct borders from surrounding tissues.	Nurses perform aspiration-risk assessment based on quantity and nature of gastric contents	13	Patients	On-site observation	“Y” if aspiration-risk assessment results in bedside register are consistent with ultrasound-image findings; otherwise “N”
21. Ultrasonographically measured gastric-antral cross-sectional area positively correlates with gastric-content volume. Gastric contents containing solid particles and / or gastric-fluid volume ＞ 0.8 mL/kg define high-risk stomach for pulmonary aspiration.	—	—	—	—	—

2.6 Baseline-Audit Results

Nurse-level outcomes: Among 12 audited ICU nurses, 4 (30.0 %) held professionally certified bedside-ultrasound qualifications; 5 (41.7 %) achieved theoretical assessment score ≥85; 4 (30.0 %)

achieved operational assessment score ≥85. Among the 13 audit indicators, NRS2002-based nutritional-risk assessment yielded a high compliance rate (91.3 %). Poor-compliance indicators included esophageal-anatomy ultrasound assessment (0 %), rectus-femoris-thickness ultrasound assessment (4.3 %), gastric-antral-motility-index-guided feeding-rate adjustment (0 %), aspiration-risk assessment via gastric-content evaluation (8.7 %), and ultrasound-guided nasojejunal-tube placement (15.2 %).

System-level outcomes: Only the general ICU (25.0 % of four critical-care units) possessed complete nutritional diagnosis-treatment protocols. Three units (75.0 %) were equipped with bedside-ultrasound devices with 2-5 MHz convex-array transducers; merely one unit (25.0 %) established nursing-ultrasound-assessment documentation regulations. No department-wide standardized operating procedures or dedicated training programmes for enteral-nutrition-oriented nursing ultrasound existed.

Patient-level outcomes: For 46 enrolled patients, mean enteral-nutrition achievement rate was 62.3 % on day 4 and 71.5 % on day 7; overall 7-day mean feeding-target achievement rate reached 68.2 %, remaining below therapeutic targets. Feeding-intolerance incidence was 17.4 % (8/46), manifested predominantly as elevated gastric residual volume, abdominal distension and diarrhea.

2.7 Barriers and Action Strategies

Low-scored items from CREBNA readiness assessment included: (1) “Evidence has been transformed into easily disseminated, comprehensible and applicable formats” (mean 2.17); (2) “I am willing to adopt new clinical nursing workflows, methods and techniques” (mean 2.42); (3) “Training curricula relevant to evidence-based practice are available” (mean 2.33); (4) “Incentive policies encourage participation in evidence-based practice” (mean 2.08); (5) “My ward has adequate information resources for evidence-based practice” (mean 2.25).

Based on GRiP analysis, main barriers and corresponding action strategies were summarized as follows:

1. **Absence of standardized operating procedures and monitoring targets**: develop evidence-based standardized workflows and clarify monitoring frequency and indicators for each procedure.
2. **Insufficient nurse training**: implement tiered training integrating theoretical lectures, simulation practice and bedside preceptorship.
3. **Imperfect information-documentation systems**: design structured nursing-ultrasound-assessment registers and embed documentation modules into critical-care information systems.
4. **Inadequate incentives**: incorporate ultrasound-assessment competency into departmental performance appraisal and set up special incentives.

2.8 Evidence-Based Practice Scheme

The final evidence-based optimal nursing-ultrasound assessment strategy for enteral nutrition in adult critically ill patients was constructed. Standardized nutritional diagnosis-treatment workflow served as the foundation, and critical-care nursing-ultrasound assessment ran through the whole enteral-nutrition workflow. Key components were listed below:

1. **Standardize nutritional diagnosis-treatment workflow**: establish continuous nutritional care mode covering "screening-assessment-diagnosis-intervention-monitoring".
2. **Nurse qualification and training system**: critical-care nurses must complete standardized training covering ultrasound physical principles, gastrointestinal-ultrasound image interpretation, abdominal anatomy and physiology. Nurses must pass both theoretical and operational assessments (score ≥85) before independently performing bedside gastrointestinal ultrasound assessment.
3. **Ultrasound-based nutritional-risk-assessment workflow**: combine NRS2002 / NUTRIC scales with transabdominal gastrointestinal ultrasound for nutritional-risk evaluation. Apply AGIUS scoring to grade gastrointestinal injury severity; measure rectus abdominis and rectus femoris thickness serially to monitor muscle-mass changes.
4. **Ultrasound guidance for feeding-access establishment**: perform pre-procedural esophageal-anatomy ultrasound assessment. Adopt ultrasound guidance combined with progressive gastric-antrum saline-infusion for nasojejunal-tube placement when indicated to improve insertion success rate.
5. **Ultrasound-mediated feeding-intolerance assessment and dynamic regimen adjustment**: perform bedside gastric-ultrasound monitoring every 4-6 h during feeding. Quantify gastric residual volume via gastric-antral cross-sectional-area measurement, and hierarchically adjust enteral-nutrition infusion rate according to gastric-residual-volume levels.
6. **Ultrasound-based aspiration-risk assessment**: evaluate qualitative features of gastric contents by semi-quantitative and qualitative ultrasound methods; combine gastric-antral cross-sectional-area measurement to stratify aspiration risk.

3. Discussion

3.1 Scientific Rigor of the Evidence-Based Practice Scheme

This study strictly followed the JBI Evidence-Based Healthcare Model. Systematic literature retrieval, rigorous quality appraisal, standardized evidence grading-recommendation and comprehensive clinical-applicability evaluation guaranteed scientific validity and rigor of the scheme. Literature retrieval adopted the 6S evidence-hierarchy top-down strategy, covering multiple evidence tiers including computerized clinical-decision-support systems, evidence-based textbooks, clinical guidelines, systematic reviews and primary studies, with multi-database and academic-society-website searching ensuring comprehensiveness of evidence sources. Recognized international appraisal tools were deployed for different publication types. Evidence grading and recommendation were performed in accordance with JBI 2014 criteria and FAME-attribute evaluation, with multi-disciplinary expert-panel validation. The synthesized 21 best-evidence items spanned six key dimensions (nutritional diagnosis-treatment workflow, nurse competency requirements, nutritional-risk screening, feeding-access establishment, feeding-intolerance monitoring and aspiration-risk assessment), forming a complete closed-loop framework covering pre-assessment preparation to post-assessment intervention.

3.2 Clinical Applicability of the Evidence-Based Practice Scheme

Quantitative scoring combined with qualitative panel discussion was adopted for evidence tailoring. Thirteen experts from clinical and management backgrounds independently scored FAME attributes of each evidence item[6,7]. For items with low scores or high score variance, expert-group discussion analyzed underlying reasons. Evidence list was rationally tailored according to real-world departmental conditions. Such tailoring strategy respects evidence-based validity while prioritizing clinical operability, which improves acceptance and adherence in real-world clinical practice. Furthermore, each evidence item is annotated with evidence level and recommendation grade, assisting clinical nurses in distinguishing reliability of different evidence items and facilitating individualized clinical decision-making[10].

3.3 Feasibility of the Evidence-Based Practice Scheme

The scheme was developed with full consideration of real-world operational conditions of intensive-care units in China. On equipment aspect, the recommended 2-5 MHz convex-array transducer represents standard configuration for most ICU bedside-ultrasound devices, eliminating extra procurement burden. For human resources, the tiered training system with progressive theoretical teaching, simulation practice and bedside preceptorship shortens learning curves. Institutionally, standardized assessment workflows and nursing-documentation templates are provided, which can be directly embedded into existing nursing information systems. Targeted improvement measures have been formulated in action strategies for organizational-context barriers identified by CREBNA readiness assessment[16]. It should be noted that full integration of critical-care nursing ultrasound into enteral-nutrition management constitutes a gradual process, requiring continuous outcome evaluation, feedback collection and iterative optimization in clinical practice.

3.4 Study Limitations

Several limitations should be acknowledged. First, included literature was published between 2016 and 2025. Given rapid advances in critical-care ultrasound technology, partial evidence may require updating upon publication of new primary studies. Second, although quantitative-plus-qualitative clinical-applicability evaluation was implemented, participating experts were selected from local hospitals and collaborative institutions, which may limit geographical representativeness and hamper nationwide generalizability. Finally, this study focused solely on strategy construction; large-scale clinical outcome evaluation has not been performed, and real-world effectiveness of this scheme requires further quality-improvement research for validation.

4. Conclusions

Guided by the JBI Evidence-Based Healthcare Model, this study systematically retrieved and rigorously appraised best evidence for critical-care nursing-ultrasound-mediated assessment of enteral nutrition in adult critically ill patients. Combined with baseline-audit results and clinical-context analysis, an optimal nursing-ultrasound assessment strategy covering six dimensions with 21 evidence items was constructed.

The scheme demonstrates sound scientific validity, clinical applicability and feasibility, furnishing scientific support for precise and standardized enteral-nutrition management for adult critically ill patients. Close multi-disciplinary-team collaboration is essential for scheme construction and clinical knowledge translation. Future studies should implement and evaluate this strategy across different types of ICUs for continuous optimization, so as to promote sustained improvement of critical-care nursing quality.

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